THE UNIVERSITY OF ASTON IN BIRMINGHAM

The use of a computer model to assess telephony performance

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Summary

This thesis describes the formation of a computer model which can be used to aid the planning of, and future developments in, telephone speech transmission networks. The model is named TCAM (Telephone Connection Assessment Model). It is comprised of 6 stages. Stages 1 and 2 form the main body of the model and are described fully in this thesis. Stages 3 to 6 form the subjective parts and are implemented by D.L. Richards. These are described elsewhere.

The system is of modular construction and is run on a microcomputer. It is implemented in BASIC computer language.

Also described is an investigation into the suitability of the modulation transfer function (MTF) method for objectively assessing the quality of a telephone channel. The method was however, found to be unsuitable in this particular case.

A study into the preferred listening level (p.l.l.) of speech was made, concentrating on the effects of p.l.l. on speech bandwidth and the type of noise present with the speech.

Relationships between random (Gaussian) noise and speech-correlated noise (as found in PCM systems) were found. The results from these investigations can now be incorporated into Stage 5 of the model.

Keywords: Speech Transmission Computer Model

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CONTENTS

LIST OF TABLES AND FIGURES — PAGE NO.

GLOSSARY OF SYMBOLS USED

e.r.p.	ear reference point
m.r.p.	mouth reference point
JW	Junction interface at west end of connection
JE	Junction interface at east end of connection
IW	International interface (west end)
IE	International interface (east end)
TW	Interface for west telephone set
TE	Interface for east telephone set
$x_{TJ(W)}$	Insertion loss between tel. and JW at west end
x_{JJ}	Insertion loss between junctions JW and JE
$x_{TI(W)}$	Insertion loss between tel and IW at west end
x_{II}	Insertion loss between interfaces IW and IE
$x_{IT(E)}$	Insertion loss between IE and tel at east end
$x_{JT(E)}$	Insertion loss between JE and tel at east end
x_{TT}	Insertion loss between telephones at west and east ends
SUMJ(W) SUMJ(E)	Sending sensitivity from m.r.p. to junction
SUJe(W) SUJe(E)	Receiving sensitivity from junction to e.r.p.
SUMI(W) SUMI(E)	Sending sensitivity from m.r.p. to International
SUIe(W) SUIe(E)	Receiving sensitivity from International to e.r.p.

---e-	referred to artificial ear
---E-	referred to real ear
ZL(W) ZL(E)	Impedance of the line seen by a telephone set
LUMe(W-E) LUMe(E-W)	Overall loss from m.r.p. to e.r.p. (end to end) in direction shown
-U------	referred to 'unknown' connection
-R------	referred to 'reference' connection
x_{imp}(W-E) x_{imp}(E-W)	Impairment loss in direction shown
x_L	Nominal loss of all elements between JW and JE
LMeST(W) LMeST(E)	Sidetone path loss from m.r.p. to e.r.p. (local end)
S_S	Matched sending sensitivity of a telephone set
S_R	Matched receiving sensitivity of tel. set
Z_C	Impedance looking in to line terminal of a tel. set
Z_{SO}	Impedance across the terminals for zero sidetone
SLR	Send loudness rating (to JW)
RLR	Receive loudness rating (from JE)
JLR	Junction loudness rating
SLR(N)	Send loudness rating (to IW)
RLR(N)	Receive loudness rating (from IE)
ILR	International loudness rating
STLR	Sidetone loudness rating (without human masking)
STMR	Sidetown loudness rating (with human masking)
V_L	Speech voltage at junction
pll	Preferred listening level
SPL	Sound Pressure Level

Note

Impedances are denoted by Z

Sensitivities by S

Electrical losses by x

Acoustical losses by L

TCAM assumes that all connections are reciprocal.

CHAPTER 1

INTRODUCTION TO T.C.A.M.

CHAPTER 1

INTRODUCTION TO TCAM

1. BACKGROUND

When telephone engineers plan a telephone system, they must ensure that the customers using it can converse with others without difficulty. In other words, its transmission performance should be within a set of limits such that no matter what type of connection is involved, these limits are not exceeded. Since only the telephone sets and the lines to the local exchange are fixed for each customer, a wide variety of connections can occur as a customer chooses to converse with various other customers.

In order to check that the transmission plan falls within these limits, a small number of connections can be chosen to represent the whole of the system, and an examination made of their transmission performance. These are known as "hypothetical reference connections".

In the past, it has been usual to use tables or graphs to obtain a measure of the degree of customer satisfaction (a figure of merit) from approximate values of overall transmission loss and circuit noise, etc. for a particular connection. To investigate the connection more deeply would have involved many tedious calculations.

The planning of modern telephone systems has become increasingly complicated due to the introduction of new facilities like digital transmission. Also, a wider variety of different types of telephone sets require consideration. Long distance and international calls are also becoming increasingly more important.

Coinciding with this has been the development and also steady reduction in size and cost of digital computers. Computers can provide a comprehensive basis for investigating connections and estimating customer satisfaction. They can be used to make an "assessment model" which is contained within a set of computer programs. The model can simulate the characteristics of telephone sets and the frequency dependant transmission elements making up the connection, and provide a figure of merit for it. (The figure of merit commonly used is "percentage Good or Excellent", or "percentage Difficult"). Thus, it is possible to model existing connections and even connections for the future and to investigate their suitability for conversational purposes.

2. THE PURPOSE OF TCAM

Telephone engineers have for a long time, used measuring systems and calculation procedures based on theoretical models, to quantify the transmission losses of speech paths from the point of view of loudness of the received speech. It is now feasible (by use of suitable computer programs) to model the physical transmission characteristics[3] of telephone connections by the use of ABCD parameters considered at various frequency points.

A comprehensive model combining physical and subjective models has been assembled by the British Post Office and is named CATPASS.[4] (Computer-aided telephony performance assessment system). It was developed to run on a fairly large time-sharing computer system. Other telephone transmission computer models have been developed by various telephone organisations and the matter is being studied by CCITT study group XII.

As a result of the work taking place in the communications section at Aston University, there is a need for a means of estimating the customer satisfaction of telephone connections containing various transmission elements that are undergoing study. TCAM was developed as a research tool that fulfills this requirement. It has been implemented on a small computing system comprising a 16K PET microcomputer with back up storage from a dual drive floppy disk unit, and a printer for obtaining permanent copies of results from a run. Because the complete set of programs making up TCAM[5,6] is modular in construction, it is possible to examine a connection in various ways.

Basically, the particulars of a telephone connection are entered (its objective characteristics) and an estimate of its "satisfactoriness" is produced. (From subsequently derived subjective characteristics).

To enter the connection description, each of the successive transmission elements is named from one telephone set to the other. The position of the planning interfaces is then given after which the types of telephone set used are identified. The mouth-to-ear transmission losses of the principal and sidetone paths are then derived as functions of frequency from previously stored data and calculation procedures. This information can be used as input to a 'subjective' model of hearing and perception from which loudness ratings[13,14] can be calculated. By combining these results with particulars concerning noise, estimates of listening opinion score may be calculated. Further modelling makes it possible to finish up with estimates of conversation opinion scores and percentage "difficult" conversations.

3. THE STRUCTURE OF TCAM

As previously mentioned, TCAM is built-up of program modules. These modules give great flexibility in that in obtaining the final results, any intermediate process may be easily modified by making suitable alterations to the respective program module.

The complete system of calculation procedures embodied in TCAM has been broken down into six stages.

Stages 1 and 2 are the objective parts (and the main bulk) of the model, and make use of complex ABCD parameters at 20 frequency points for describing the transmission characteristics of each electrical element in the connection, and for the subsequent cascading of these to determine the overall characteristics of the electrical sections. The characteristics of the telephone sets are described by their fundamental transmission parameters. These are then combined with the overall characteristics of the electrical sections to give acoustical/acoustical and Electrical/acoustical transmission losses and sensitivities. These results provide the input to the subjective parts of the model. (Stages 3-6)[6]. The subjective parts comprise a method for calculating loudness ratings, a model for estimating listening effort opinion scores, and models for relating conversation scores to listening scores and allowance for changes in talking behaviour.

4. APPLICATION OF TCAM

The introduction of digital devices into the telephone network is now becoming extensive. These devices however, produce non-linear distortions that have not been experienced previously, but are likely to have less effect on customer satisfaction than the degradations experienced in ordinary analogue circuits. In the long term, all-digital connections will also have much smaller variations in loudness since attenuation due to cable loss etc., has no effect on the amplitude of the speech signal which has been digitally encoded.

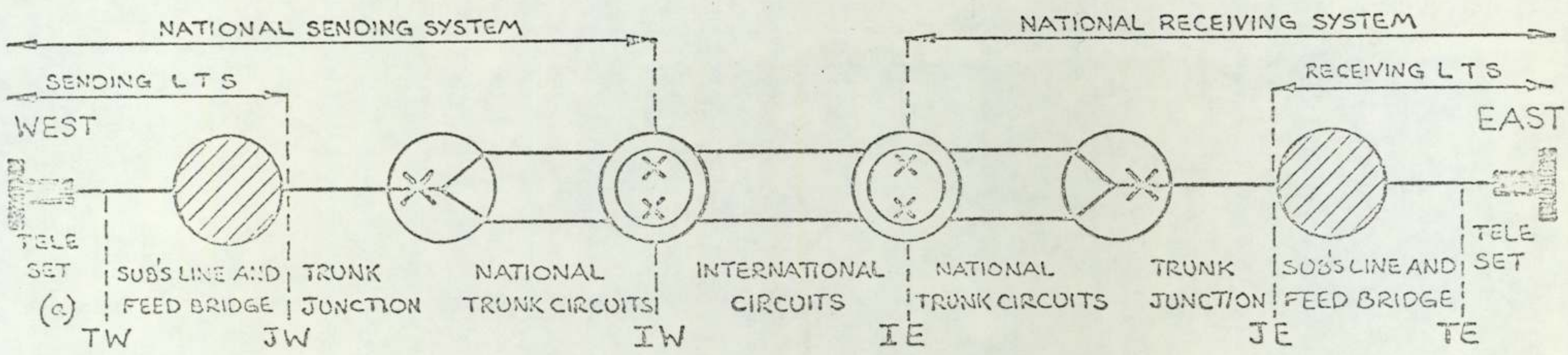
In the shorter term, while new digital and old analogue facilities have to interwork, some difficult problems must be solved to avoid any temporary degradation in performance of some connections until the old facilities are replaced. Hypothetical connections[7] representing mixed analogue and digital situations can be set up with the aid of TCAM and the best way of avoiding such troubles can be studied.

5. SUB-DIVISION OF A TELEPHONE CONNECTION

A telephone network may be sub-divided into local telephone systems and junction and trunk circuits. An internationally planned connection can be treated as being composed of a national system and an international circuit. The interfaces between these sub-divisions are used as part of the description of the connection for the computer model. Fig. 1.1 shows an example of the sub-division of a connection. To describe the interfaces, two letters are used. The first may be T, J or I, meaning telephone junction or international. The second gives the position about the centre - i.e. W or E meaning west or east.

Interfaces TW and TE are considered when calculating the sidetone performance of each telephone set. The section between TW and TE is considered when calculating the overall loss LMe (the mouth to (artificial) ear transmission loss). Other calculations are made considering the junction and international interfaces to determine sending and receiving sensitivities up to and from these interfaces with respect to TW and TE. These transmission quantities are determined in stages 1 and 2.

Note. Interfaces are considered as 600Ω terminations in the calculation for transmission losses.



X ≡ Switching point

—— ≡ 2 wire working (analogue)

═══ ≡ 4 wire working (digital or FDM)

≡ Local Telephone Exchange

≡ Group Switching Centre (2wire to 4 wire)

≡ International Switching Centre (4 wire)

TW ≡ Telephone Set (WEST station)
TE ≡ Telephone Set (EAST station)
JW ≡ Junction West
JE ≡ Junction East
IW ≡ International West
IE ≡ International East

FIG. 1.1

Telephone systems however, do not usually present 600Ω at these sections and so the overall mouth to ear loss LMe does not exactly equal the sum of the losses between the sub-divisions. This is taken into account by a quantity known as "impairment loss" (ximp).

6. ACHIEVEMENTS MADE WITH THE AID OF TCAM

TCAM has been used in the study of hypothetical connections reqpresenting various stages in the evolution of an all-digital telephone network [7]. Prior to this, the characteristics desirable of a digital telephone set were determined by setting-up a special connection. This connection comprised a "reference standard telephone set" (RSTAN1) [2] having characteristics representative of a set operating under average conditions in the network, together with an attenuator and a channel filter representing the codec necessary for digitised speech. The attenuator was altered until the required reference equivalents (CCITT recommended) were obtained and the characteristics were obtained from the composite results.

A comparison between Loudness Ratings and Reference Equivalents has also been made with the aid of TCAM. (See Appendix 5).

Parts of the model have been extended and other related programs created as part of an investigation into the preferred listening level of speech in the presence of random noise and correlated noise. (See Chapter 3).

7. Extension of TCAM to include the effects of preferred listening level

When a listener hears speech under noisy conditions, he will prefer the speech to be louder than that under quieter conditions. Two types of circuit noise are used in listening tests, these being random (or "white") noise, found in everyday analogue telephone channels, and a new type of digitally produced noise which is speech correlated in its amplitude. This noise arises from the quantising of speech into discrete levels for which a corresponding binary number is obtained from an analogue-to-digital converter. As the speech level increases, so does the quantising error according to the quantising law[8] used in the encoder. This is typical of what occurs in a PCM[8] system. A convenient way of generating this type of noise for use in listening tests, is with the use of a "modulated noise reference unit" (MNRU)[9].

Telephone administrations have found it desirable to be able to relate ordinary signal to injected circuit noise ratios (S/ICN) with the subjectively equivalent signal to quantising noise ratio, Q (as proposed by D.L. Richards)[10] and at present use a relationship based on one listening level of speech only. This gives a limited result as the complete answer must involve the speech being presented at the preferred listening level (PLL) corresponding to the particular S/N ratio present.

Various experiments based on preferred listening level have been performed (described in chapter 3 of this thesis) and include the S/ICN vs Q relationship based on the preferred listening level of speech, and also the effects of the reduction of speech bandwidth.

These results are used in stage 5 of the TCAM model where the preferred listening level is one of the parameters used in the determination of listening effort and mean opinion score.

Stages 1 and 2 form the objective and main part of the TCAM model, and have been implemented by the author. This work, along with the preferred listening level experiments, forms the body of the thesis. Stages 3 to 6 form the subjective parts of the model and have been implemented by my colleague and supervisor, Professor D.L. Richards.

Note: The programs making up TCAM are identified by file numbers rather than filenames. This is a spin-off from the earlier versions that ran on a Tektronix 4051 computer. When the PET computer was acquired, the operating structure of TCAM was as far as possible directly transferred over to save time. If time became available, the organisation of the programs within the structure would be clarified by using filenames as permitted by the version of the BASIC language used in the PET computer.

CHAPTER 2

THE STRUCTURE OF THE PROGRAM MODULES.

Note

Before proceeding to Chapter 2, the reader who is unfamiliar with the operation of T.C.A.M. is advised to briefly look through the user instructions given in Appendix I.

INTRODUCTION AND TECHNICAL BACKGROUND

The use of ABCD matrices. (chain matrices)

ABCD parameters may be used to completely describe the electrical characteristics of a 2 port network. (See Fig. 1.2). All the elements making up a connection (apart from the telephone sets) are described in this way. These elements are all linear and time invariant and appear as a set of four complex numbers at twenty frequency points. (The ISO recommended range).

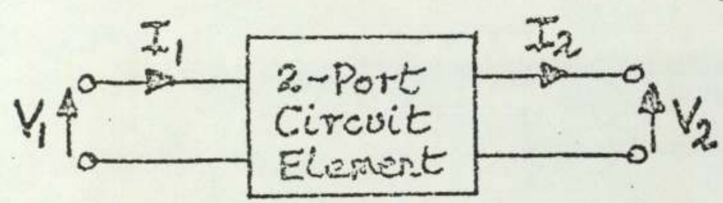
ABCD parameters lend themselves to the cascading of 2 port networks.

By cascading all the elements in a connection overall and between the interfaces (representing junction and trunk circuits) a set of parameters will be obtained from which required losses and impedances can be computed. (See Fig. 2.2)

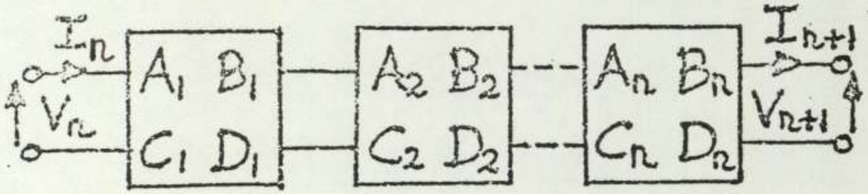
After finding the insertion loss between the various sections, the next step is to compute the respective transmission losses. These are obtained by combining the various losses and impedances with the characteristics of the telephone sets. This is discussed more fully in the following sections.

Telephone Sets

The transmission characteristics of a 2-wire telephone set can be fundamentally described in terms of two frequency dependant impedances and the sending and receiving frequency

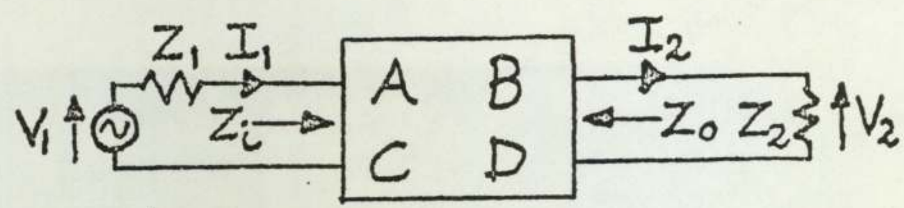


$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_2 \\ I_2 \end{vmatrix}$$



$$\begin{vmatrix} V_n \\ I_n \end{vmatrix} = \begin{vmatrix} A_1 & B_1 \\ C_1 & D_1 \end{vmatrix} \begin{vmatrix} A_2 & B_2 \\ C_2 & D_2 \end{vmatrix} \cdots \begin{vmatrix} A_n & B_n \\ C_n & D_n \end{vmatrix} \begin{vmatrix} V_{n+1} \\ I_{n+1} \end{vmatrix}$$

$$= \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_{n+1} \\ I_{n+1} \end{vmatrix}$$



Input Impedance $Z_i = \dfrac{AZ_2 + B}{CZ_2 + D}$

Output Impedance $Z_o = \dfrac{DZ_1 + B}{CZ_1 + A}$

Insertion Loss

$$X = 20 \log \frac{|AZ_2 + B + CZ_1Z_2 + DZ_1|}{|Z_1 + Z_2|}$$

FIG. 2.2

FIG. 1.3

responses. These are as follows:

(i) The matched sending sensitivity (S_S) which relates the emf at the line terminals to the pressure at the mouth reference point (m.r.p.)

(ii) The matched receiving sensitivity (S_R) which relates the pressure at the ear reference point (e.r.p.) to the voltage at the line terminals.

(iii) The impedance of the telephone (Z_C) measured at the line terminals.

(iv) The impedance that causes zero sidetone (Z_{SO}) when connected across the line terminals.

Local Telephone Circuit

This comprises the telephone set, subscribers line and exchange feeding bridge. The symbol S_{MJ} is used to denote the sensitivity of the local telephone circuit from m.r.p. to the 600Ω junction and is given by

$$S_{MJ} = S_S - x_{TJ} + 20 \log \frac{2 \times 600}{|Z_C + 600|}$$

where x_{TJ} is the insertion loss of the subscribers line plus feeding bridge.

S_{Je} is used to denote the sensitivity from the 600Ω junction to the e.r.p. (artificial ear). If a real ear is used, the loss due to an imperfect seal between the ear and the earcap must be taken into account,

$$S_{Je} = S_R - x_{JT} + 20 \log \frac{2|Z_C|}{|Z_C+600|}$$

For reciprocal networks (those considered in TCAM)

$$x_{JT} = x_{TJ}.$$

Note, the 600Ω junction is an internationally agreed convention.

The impedance looking into the line from the telephone set is denoted Z_L and is calculated from the ABCD parameters as explained previously.

The sidetone path loss (L_{MeST}) is given by:

$$L_{MeST} = -(S_S+S_R) + 20 \log \frac{|Z_L+Z_C||Z_C+Z_{SO}|}{2|Z_C||Z_L-Z_{SO}|}$$

Junction and Trunk Circuits

The insertion loss between the 600Ω junctions is denoted x_{JJ}.

Note, 'junction' applies to the complete circuit between any two local exchanges.

'International' applies to the circuit between international switching centres, and its insertion loss is denoted x_{II}.

Complete Connections

The overall loss from m.r.p. to e.r.p. (artificial ear) is denoted L_{Me}. Fig. 3.2 gives a representation of the parameters used so far in relationship to the connection.

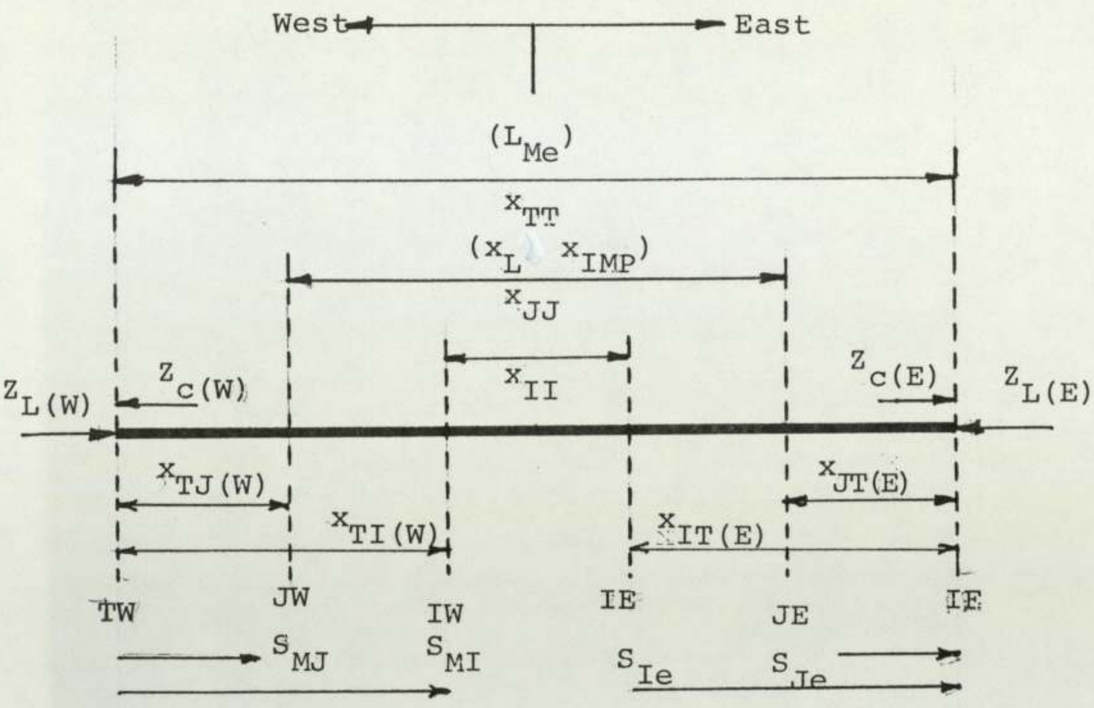


FIG. 3.2

In order to distinguish between the 'near' end and 'far' end, in both directions, 'east' and 'west' are used to completely define the sending and receiving conditions for each telephone.

Although 600Ω impedances are stipulated in the definitions for sensitivities, local telephone systems rarely present 600Ω to the junctions, and so L_{me} is not exactly equal to the sum $-S_{MJ}-S_{Je}+x_{JJ}$. Allowance for this is given by the 'impairement loss' denoted ximp.

In the planning of telephone networks it is common practice to characterize the total transmission losses of junctions and trunks by a 'nominal loss' denoted x_L, which is given by the sum of their image attenuations at say, 1000 Hz. Clearly this number ignores attentuation/ frequency distortion and impedance mismatches. X_{imp} is determined in such a way that these items can be taken into account, and is obtained by combining the sensitivities of the local telephone circuits with the nominal losses and subtracting from the true overall mouth-ear loss. Thus, $x_{imp} = L_{Me} - (-S_{MJ} - S_{Je} + x_L)$.

IMPLEMENTATION OF TCAM

TCAM is implemented on a PET 2001 (16N) computer, which is self contained and may be described as a small 'desk-top computer'.

An extended form of BASIC is used for the programming language. It is cheap to use as there is no expense on computer time, but it has limited dynamic memory capacity. (Approx. 16K useable). This is overcome by adopting a modular approach in the construction of the total programming requirements. (Obviously, this causes a reduced speed of operation compared to a large computer capable of storing the complete set of programs as a whole).

Storage of the suite of programs making up TCAM is provided by the use of 'Floppy Disks'. Five disks are used (each having a duplicate spare with cassette tape back-up). Disk 1 contains all the programs necessary to obtain the overall objective characteristics of the telephone connection. Disk 2 contains data and programs relating to different types of telephone set. Disk 3 contains the programs required for the computation of the subjective characteristics of the connection. A fourth disk contains auxiliary programs which are not normally used when running TCAM. (These are diagnostic and special printing out programs). The fifth disk is an 'archives' disk and is used to store the objective results obtained from previous runs.

INTERWORKING OF PROGRAMS

This is accomplished by using data files to link the programs together, i.e. the computer runs through a program, stores the results from that program in a data file, and then loads the next program into memory. This program then reads the data from the data file and uses it accordingly as it runs through. Upon reaching the end of its run, the new data is stored, ready to be used as input for the next program ...., and so on.

The data files have been designated into 'fixed' and 'variable' categories. Fixed data files relate to data describing electrical elements which always have fixed characteristics in any connection. E.g. feeding bridges and channel filters.

Variable data files relate to data describing:

(a) Electrical elements which vary according to the individual connection, and so their parameters can take on any value. E.g. transmission lines, attenuators, transformers, etc.

(b) Data providing links for program interworking. These will be results derived at various stages in the computation of the overall characteristics.

(c) Datum numbers giving interface positions, element types and positions, number of variable data files, etc.. Also character strings giving parametric values of the elements inputted.

INTERWORKING OF PROGRAMS AND DATA FILES WHEN SETTING-UP A CONNECTION. (REFER TO FIG.4.2

CONNECTION SET-UP PROGRAM

Upon running this program, the computer asks the user to input the title of the connection and the date of set-up (input as T$) and then asks for the number of electrical elements making up the connection, (input as N). It then sets a counter (T) to zero. As each element is inputted, the key (K array) and description (D array) are formed.

When a variable data element is chosen, after setting it up, T is incremented by 1. Thus, T gives the number of variable data files.

After all the elements have been described, N, K and D are stored in data file D 25 and T, T$ are stored in D 26. Control is then passed on to the interface positions program.

INTERFACE POSITIONS PROGRAM (Refer to Fig.5.2

Here, the P array is formed as the user describes the position of the junction and international interfaces in the connection. After this, the nominal loss (X_L) is inputted and control is then passed on to the telephone options program.

TELEPHONE OPTIONS PROGRAM

At this point, the user chooses which type of telephone he wishes to use with the connection. Information on the types chosen for the west and east ends is retrieved from Disk 2 and stored on Disk 1 in data files D 23 (west) and D 24 (east). Control then passes on to the cascading program.

CASCADING PROGRAM

This program sets a counter (C) to zero and then proceeds to cascade between the positions given by the P array. P is also used to decide whether or not international interfaces are being used. (If P(2)*P(3) = Ø then only junction interfaces are being used. If international has been chosen, it does the necessary extra cascadings (incrementing C at each cascading) and then cascades all the elements together to form an overall product array. Whilst forming the product arrays for each section, it uses Q+C (where Q = T + 27) to find the data file into which it writes the product array. C is then incremented by 1. After the cascading operations are complete, TØ, X, P and Q are stored in D 26. Control then passes on to the program for calculation of transmission losses.

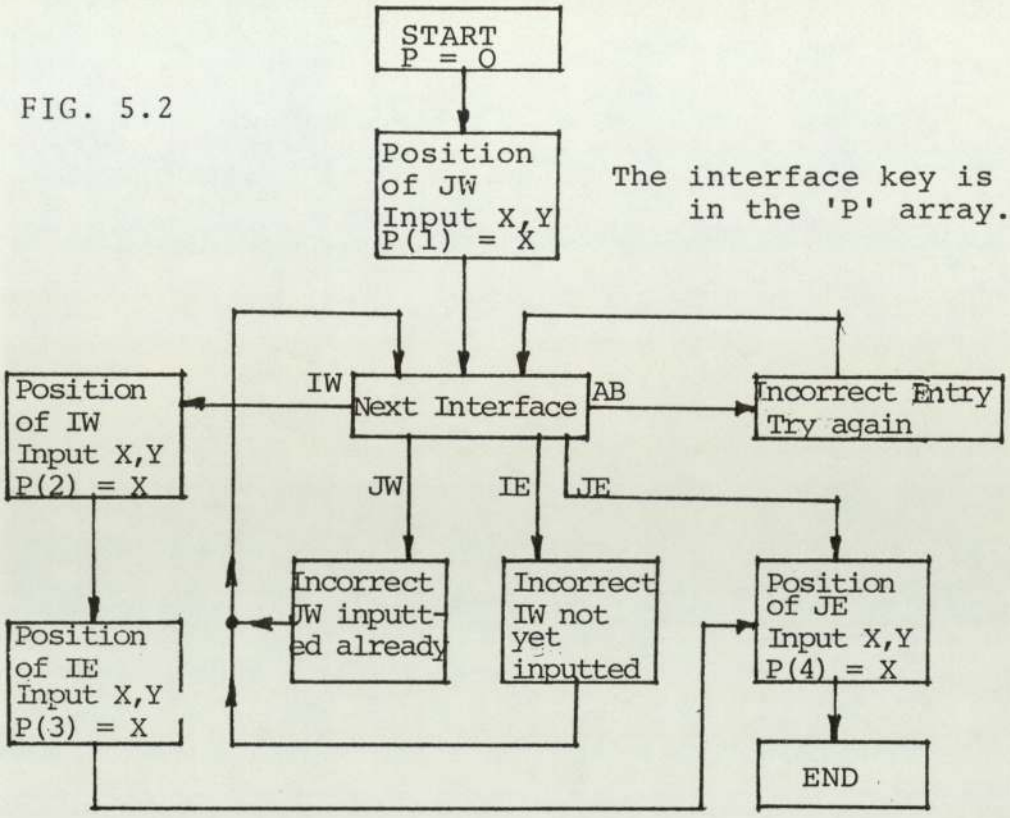
INSERTION AND TRANSMISSION LOSS PROGRAM

Upon running this program, TØ, P, X and Q are read from D26. P is then used to determine whether or not international has been used. If junction only, it puts G=4, if junction and international, then G=7. (G is equal to the number of product arrays and also insertion losses for the connection). A counter C was initially set to zero. As each insertion loss is calculated, C is incremented by 1. It then finds data file number Q+C and writes the insertion loss data into this file. After calculating all the insertion losses, control passes on to the transmission loss section of the program.

The various transmission losses to be contained in the U-files are now calculated. Counter C is incremented as before, and used to find the correct data file for data storage. After all the calculations are complete the user is returned to the information program.

FLOWCHART FOR THE INTERFACE POSITIONS PROGRAM

FIG. 5.2



The interface key is stored in the 'P' array.

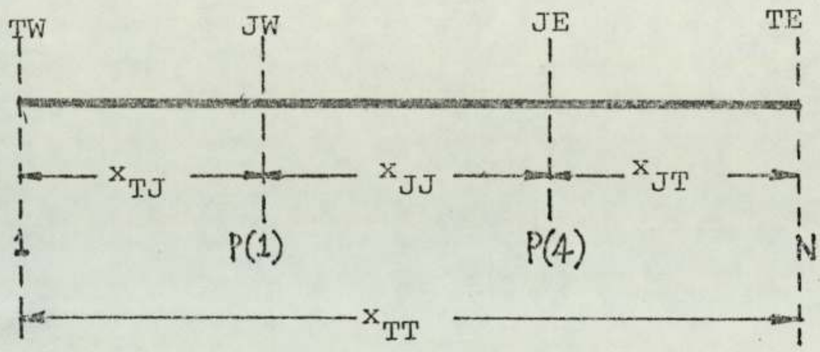
Initially, P(4) is dimensioned in the program, and its value set to zero. The corresponding element numbers to the interface positions are then overwritten into the P array.

Thus, P(1), P(2), P(3), and P(4) give the position of JW, IW, IE, and JE respectively.

CASCADING BETWEEN SECTIONS

In order to arrive at the insertion loss between sections, all the elements making up a particular section must be cascaded together to form an overall set of ABCD parameters for that particular section.

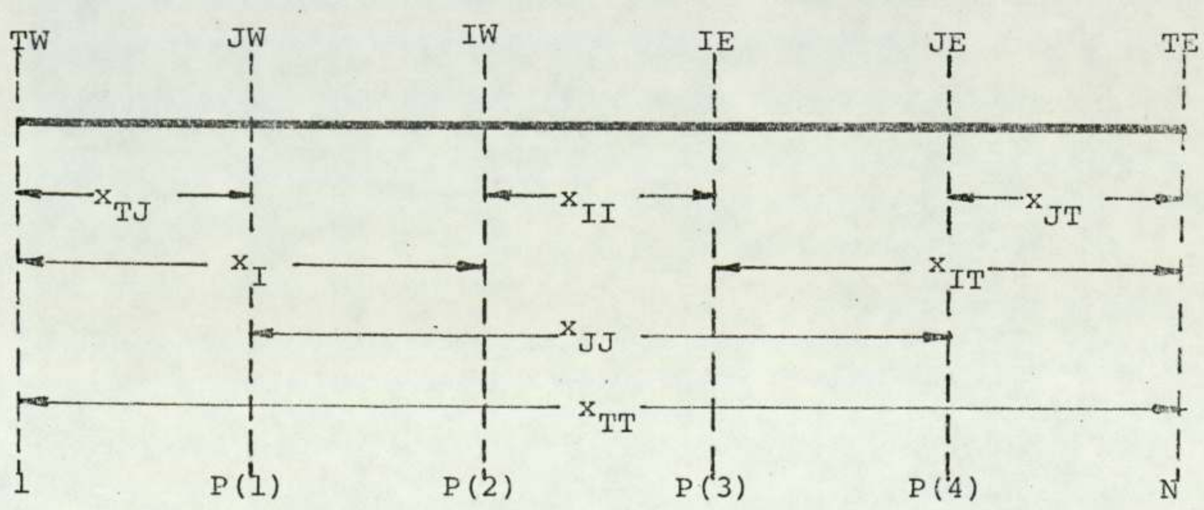
Consider the junction-only case:



The sections to cascade will be:

1 to P(1)
P(1) + 1 to P(4)
P(4) + 1 to N
1 to N

For the case when international interfaces are present:



The sections to cascade will be:

1 to P(1)	1 to P(2)
P(1) + 1 to P(4)	P(2) + 1 to P(3)
P(4) + 1 to N	P(3) + 1 to N
	1 to N

ORGANISATION OF DISKS 1 AND 2

DISK 1

Programs

Information & Conn. Set-up	1
Bridges & channel filter set-up	2
LCJ Set-up	3
Options for Conn. Elements	4
Interface Positions	5
Telephone Options	6
Cascadings	7
Insertion & Transmission losses	8
File location	9
Conn. Description Recall	10
Print-out losses	11
Transfer to Archives	12

Data

SFB	15	
HFB	16	
IFB	17	
CHF	18	
LCJ (0.6)	19	
LCJ (0.9)	20	
AAL	21	
Spare	22	
W$, W data	23	
E$, E data	24	
N, K, D,	25	
T$, X, P, Q	26	*
Variable data	27	
Variable data		
Array Products	Q	∓
Array Products	Q	
Array Products	Q	
Insertion Losses	Q + G	
Insertion Losses		
Insertion Losses		
U-Files	Q + 2 G	
U-Files		

DISK 2

Programs

RSN1 Set up	
New Telephone Set up	1
Old Telephone Set up	2
Print-out Tel. Set Parameters	3
PTF	
Checktel	
Disktran	
Transtel	
Teltrans	
Datum	

Data

STD
Option
RSN1
746Z
746L
DIG1
DIG2
WE5Z
WE5A
WE5L
DLS1
746A

*(initially T, T$) from P1

∓ Q = T + 27

FIG. 4.2

NOTE: Referring to Fig. 4.2,

P = Program file (eg P7)

D = Data file (eg D28)

Q is a datum point

T = No. of variable data files

G = No. of product arrays (and hence insertion losses)

G = 4 for junction only

G = 7 for junction and international

FURTHER NOTES ON SETTING-UP THE CONNECTION

As mentioned previously, the K array describes the data files representing the elements chosen in a particular connection. The key is formed by ascribing a value to K(I) (where I is the element number) in a for-next loop. e.g. SFB is stored in file No.15 and if it is the second element in the connection, then K(2) = 15.

Thus, for a typical connection having say, 8 elements, the following may occur:

I	1	2	3	4	5	6	7	8	
K(I)	27	15	28	29	18	30	16	31	N = 8
	TXL	SFB	TXL	ATT	CHF	TXL	HFB	ULC	

This information is then used in conjunction with the P array by the cascading program to form product arrays of the elements between the interfaces.

LUMPED COMPONENTS (LCO)

These may be R, L or C or a combination (Z) either in series (SE) or shunt (SH).

The ABCD parameters are:

For series

$$\begin{vmatrix} 1 & Z \\ 0 & 1 \end{vmatrix}$$

i.e. 1 0 RL Im 0 0 1 0

For parallel

$$\begin{vmatrix} 1 & 0 \\ 1/Z & 1 \end{vmatrix}$$

1 0 0 0 RL Im 1 0

Thus, the basic array for each component will be:

RSE	1	0	R	0	0	0	1	0	RSH	1	0	0	1/R	0	1	0	
LSE	1	0	0	ωL	0	0	1	0	LSH	1	0	0	0	0	$\frac{-1}{\omega L}$	1	0
CSE	1	0	0	$\frac{-1}{\omega C}$	0	0	1	0	CSH	1	0	0	0	0	ωC	1	0
ZSE	1	0	R	X	0	0	1	0	ZSH	1	0	0	0	$\frac{R}{S}$	$\frac{-X}{S}$	1	0

where $X = L - \frac{1}{\omega C}$, $S = R^2+X^2$

CONNECTION DESCRIPTION RECALL (Refer to Fig. 6.2)

A necessary facility is the ability to refer back to the initial connection description and to print it out as a hard copy to accompany data print-outs. In order to achieve this, an array is set-up along with the 'key' to represent the character strings relating to the elements chosen.

Basically, the arrays defining the connection are:

The Key . (K-array)

K(I) gives the position of the data file containing the data for element (I).

The Description. (D-array)

D(I) generally describes which type element (I) is. Supplementary information on a particular element follows the ABCD parameters of that element in its data file.

Thus, in the connection set-up program, as each element is inputted, K and D and the supplementary information are all set-up together.

The position of the interfaces is also required to be known. This is supplied by the P-array. In order to determine whether or not international is used, the product P(2)*P(3) is calculated, and if this is zero, then only junction interfaces have been used. P(1) and P(1)+1 then give the position of JW. P(4) and P(4)+1 give the position of JE. Similarly, P(2) and P(2)+1, P(3) and P(3) +1 give IW and IE when they exist.

The types of telephone set chosen for the west and east ends are contained in data files D23 and D24, represented by strings S$\not{S}$ and R$\not{S}$.

The D-array is used to recall the description in the following way:

A character string A$\not{S}$ is set-up which contains all the element types available. Thus, each element is represented by its substring B$\not{S}$ within A$\not{S}$.

D(I) represents the position of B$\not{S}$ within A$\not{S}$.

By use of the MID statement, B$\not{S}$ may be extracted.

i.e.

```
A$ = "RSE LSE CSE RSH LSH CSH TFR SFB, etc.
      1   4   7   10  13  16  19  22
```

B$\not{S}$ = MID$\not{S}$(A$\not{S}$, D(I), 3).

Note, A$\not{S}$ is allowed to be up to 256 characters in length.

The relationship between K and D is shown in Table 1.2

Supplementary information is contained in the character strings C$\not{S}$, D$\not{S}$ and E$\not{S}$. (i.e. three parameters).

In the case of less than three parameters, the unused string appears as " - - -".

E.g. Element 4 : Length = 5.9 km

Gauge = 0.5 mm

If an element has greater than three parameters concatenation may be used to reduce down to three strings.

ELEMENT (I)	K(I)	D(I)
RSE	T + 27	1
LSE	T + 27	4
CSE	T + 27	7
RSH	T + 27	10
LSH	T + 27	13
CSH	T + 27	16
TFR	T + 27	19
SFB	15	22
HFB	16	25
IFB	17	28
CHF	18	31
LCJ (0.6 mm)	19	34
LCJ (0.9 mm)	20	34
ATT	T + 27	37
ULC	T + 27	40
TXL	T + 27	43
LAT	T + 27	46
MCC	T + 27	49
AAL	21	52
ZSE	T + 27	55
ZSH	T + 27	58

TABLE 1.2

The relationship between arrays K and D.

FLOWCHART FOR THE PRINT-OUT OF THE CONNECTION DESCRIPTION ELEMENTS

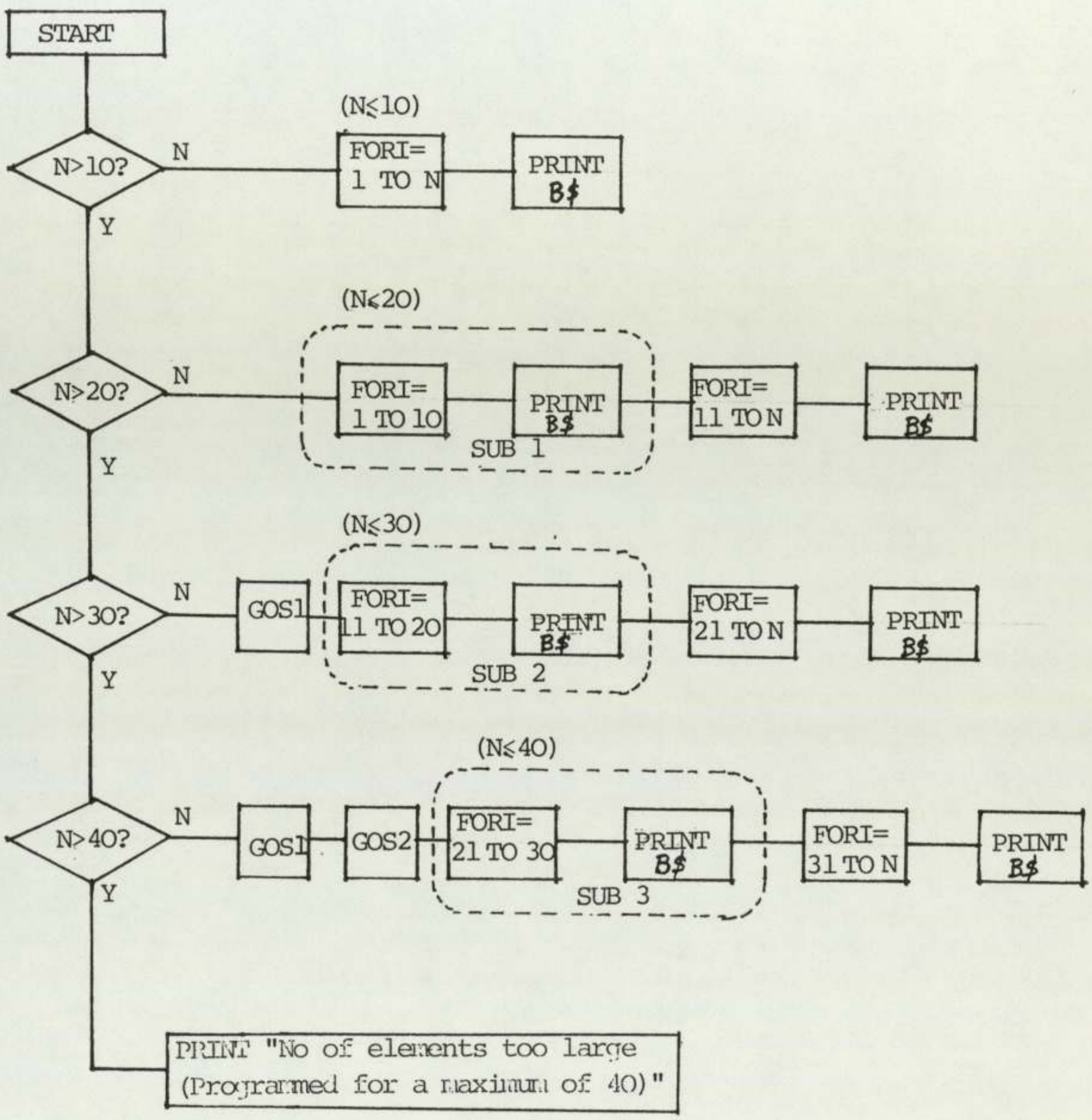


FIG. 6.2

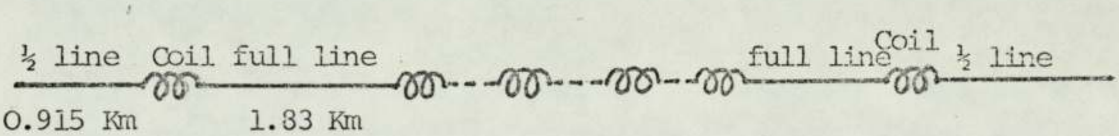
LOADED CABLE JUNCTION (LCJ)

Provision has been made (as a 'fixed' data file) for 10lb/mile (0.6mm) and 20lb/mile (0.9mm) loaded cable with an 88 mH, 3Ω resistance loading coil placed at 1.83 Km intervals. The nominal loss of LCJ at 800 Hz is 4.5 dB.

Consider 0.6 mm gauge:

Four full sections of 1.83Km line with a half section at each end give the 4.5 dB loss. The primary constants for the line are, R = 109Ω/Km and C = 41nF/Km.

i.e.



For the 0.9 mm gauge, ten full sections are required. The primary constants are, R = 55Ω/Km, C = 41nF/Km.

Let F ≡ Full line

F/2 ≡ Half line

C ≡ loading coil

Then, for 0.6 mm gauge, this can be represented as

$$\frac{F}{2} * 4(C*F)*C*\frac{F}{2}$$

and for 0.9 mm gauge,

$$\frac{F}{2}*10(C*F)*C*\frac{F}{2}$$

These expressions are set-up on the computer according to the sequence diagram shown on the following page.

SEQUENCE [illegible] FOR SET-UP OF LCJ

Let X = 4 represent 0.6 mm gauge

X = 10 represent 0.9 mm gauge.

This gives a general expression:-

$$\frac{F}{2}*X(C*F)*C*\frac{F}{2}$$

Let A1 ≡ C, A2 ≡ F, A3 ≡ F/2

To cascade X(C*F) use a subroutine of the form:- M2 = M1*M2

By putting A1 into M1 and A2 into M2, this gives:-

M2 = C*F. Put this into M1.

A for-next loop is now used. The number of loops being equal to X. i.e. For V = 1 to X.

Initially, when V = 1,

M2 = 1, M1 = C*F

then M2 = C*F

V = 2,

M2 = C*F, M1 = C*F

then M2 = =(C*F)

V = 3, M2 = 2(C*F), M1 = C*F

then M2 = 3(C*F)

etc.

For F/2*X(C*F):-

Put M1 = A3, already have M2 = X(C*F)

then M2 = F/2*X(C*F)

For F/2*X(C*F)*C:-

Put M1 = M2, already have A1 ≡ C ∴ put M2 = A1

then M2 = F/2*X(C*F)*C

To complete

Put M1 = M2, already have A3 ≡ F/2 ∴ put M2 = A3

then <u>M2 = F/2*X(C*F)*C*F/2</u>

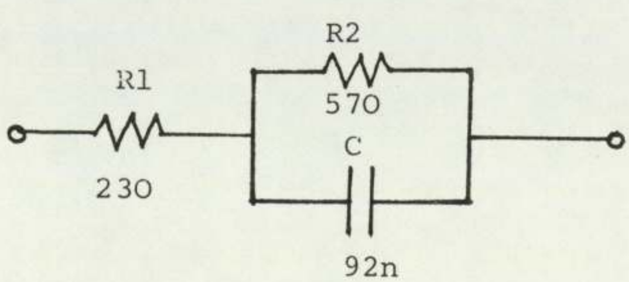
SETTING-UP THE TELEPHONE FILES

There are three main programs on Disk 2 (namely P1, P2 and P3) which deal with the setting-up of information relating to the four parameters used to define a telephone set. The parameters are S_S (or S_S600), S_R (or S_R600), Z_C and Z_{SO}. P1 is used to set-up a new telephone data file, P2 is used to modify an old (previously set-up) data file. P3 will then give a print-out as a hard copy, the data that has been entered into the computer whilst setting-up the telephone set.

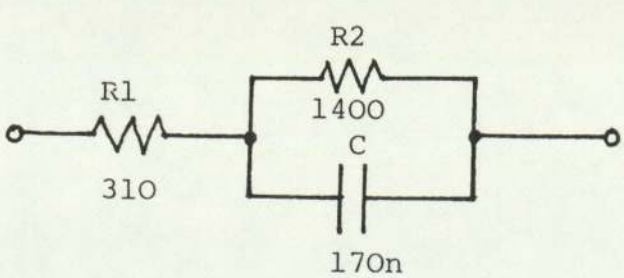
Programs P1 and P2 contain a correction routine where incorrectly inputted data may be corrected before it is saved in the data file. A dedicated program exists called "RSN1 SET-UP" which sets-up RSN1 using data contained within the program. (P1 and P2 require the user to type in all the data to be stored).

SETTING-UP RSN1

From Memo 12[2] the following equivalent circuits can be obtained for the Z_C and Z_{SO}.



(Used in the insertion loss calculations)



(Used in the sidetone loss calculations)

For each circuit,

$$Z = R1 + \frac{R2/j\omega C}{R2+1/j\omega C} = R1 + \frac{R2}{1+j\omega CR2}$$

$$= R1 + \frac{R2(1-j\omega CR2)}{1+\omega^2 C^2 R2^2}$$

i.e. $$\underline{Z = R1 + \frac{R2}{1+(\omega CR2)^2} - j\,\frac{WCR2^2}{1+(\omega CR2)^2}}$$

This may be written into the program as:-

```
READ R1, R2, C
FOR J = 1 TO 20 : ω = 2*π*F(J)
A(J,1)=R1+R2/(1+ω*C*R2)↑2)
A(J,2) = -ω*C*R2↑2/(1+(ω*C*R2)↑2)
NEXT J
DATA 230, 570, 92E-9  (For Z_C)
```

Data is available for S_S600 and S_R600 at the twenty ISO frequencies. By using this in conjunction with Z_C, S_S and S_R may be found as follows:-

$$S_S = S_S600 + 20 \log_{10} \frac{|Z_C+600|}{2*600}$$

$$S_R = S_R600 + 20 \log_{10} \frac{|Z_C+600|}{2*|Z_C|}$$

Let $M = 20 \log_{10}|Z_C+600|$

then,

$$\underline{S_S = S_S600 + M - 20 \log_{10}1200}$$

$$\underline{S_R = S_R600 + M - 20 \log_{10}(2*|Z_C|)}$$

These expressions may now be written into the computer program as follows:-

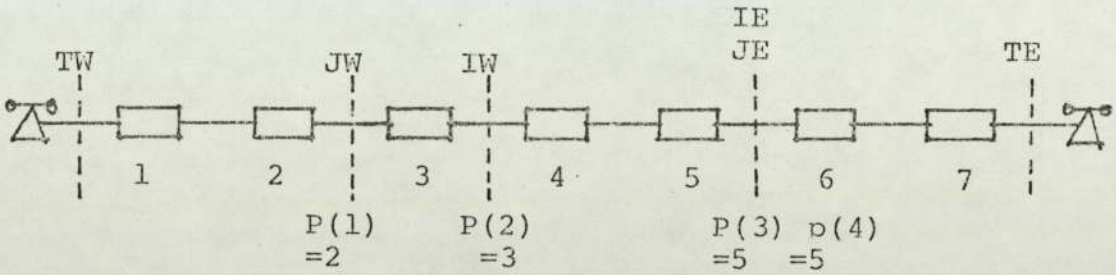
```
FOR J = 1 TO 20 : D = LOG(10)
M = 20*LOG(SQR((A1(J,1)+600)↑2+A1(J,2)↑2))/D
A3(J)=A3(J)+M-20*LOG(1200)/D
A4(J)=A4(J)+M-20*LOG(2*SQR(A1(J,1)↑2+A1(J,2)↑2))/D
NEXT J
```

Note, D is used to convert LOG ($\log_e$) into $\log_{10}$.

USE OF THE IDEAL FEEDING BRIDGE (I.F.B.)

1. As a separator where international and junction interfaces coincide.

E.G.



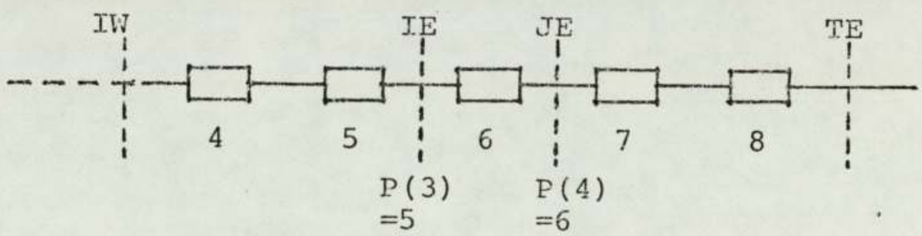
In the cascading program this will produce:-

For I = p(3) + 1 to p(4)

i.e. I = 6 to 5 which is an invalid instruction.

To overcome this, use IFB as follows:-

i.e.

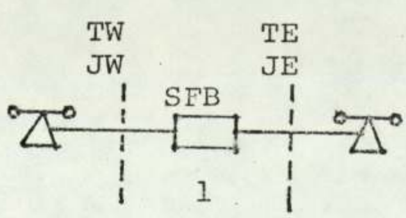


This now produces:

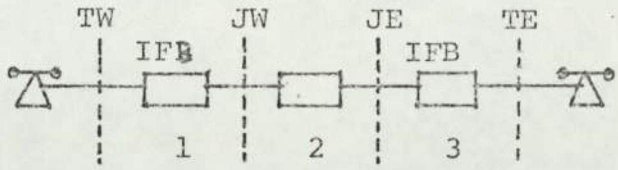
For I = p(3) + 1 to p(4)

i.e. I = 6 to 6 (Simply goes round the loop once).

2. Own exchange call with zero line.



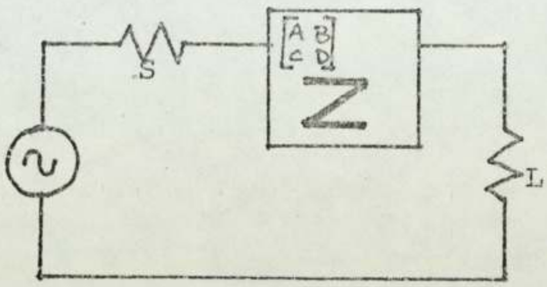
By using IFB, this can be represented as:



(Without IFB, JW & JE cannot be defined as they do not occur between two elements).

INSERTION AND TRANSMISSION LOSSES

Consider a section Z, inserted between source and load impedances as shown below.



The insertion loss of the above section Z, = 20 log R

where, $R = \dfrac{AL + DS + CSL + B}{S + L}$

This is in complex form,

i.e. $R1 + jR2 = \dfrac{(a+jA)(L1+jL2)+(d+jD)(S1+jS2)+(c+jC)(S1+jS2)(L1+jL2)+(b+jB}{S1+jS2+L1+jL2}$

Let $P1+jP2 = (C+jC)(S1+jS2)(L1+jL2)+(b+jB)$

$= (cS1-CS2+j(CS1+cS2))(L1+jL2)+(b+jB)$

$= L1(cS1-CS2) + jL1(CS1+cS2)$

$+ jL2(cS1-CS2) - L2(CS1+cS2) + b + jB$

i.e $P1 = L1(cS1-CS2) - L2(CS1+cS2) + b$

$P2 = L1(CS1 + cS2) + L2(cS1 - CS2) + B$

Let $Y1 = cS1 - CS2$, $Y2 = CS1 + cS2$

Then $\underline{P1 = L1.Y1 - L2.Y2 + b}$

$\underline{P2 = L1.Y2 + L2.Y1 + B}$

Let $U1 + jU2 = S1 + jS2 + L1 + jL2$

i.e. $\underline{U1 = S1 + L1}$

$\underline{U2 = S2 + L2}$

$$\text{Let } V1 + jV2 = (a + jA)(L1 + jL2) + (d + jD)(S1 + jS2)$$

$$= aL1 - AL2 + j(AL1 + aL2) + dS1 - DS2 + j(DS1 + dS2)$$

i.e. $V1 = aL1 - AL2 + dS1 - DS2$

$V2 = aL1 + aL2 + DS1 + dS2$

Thus, $R1 + R2 = \dfrac{V1 + jV2 + P1 + jP2}{U1 + jU2}$

Let $W1 = V1 + P1$

$W2 = V2 + P2$

then

$$R1 + jR2 = \frac{W1 + jW2}{U1 + jU2}$$

i.e. $R1 + jR2 = \dfrac{(W1 + jW2)(U1 - jU2)}{(U1)^2 + (U2)^2}$

$$= \frac{W1.U1 + W2.U2 + j(W2.U1 - W1.U2)}{(U1)^2 + (U2)^2}$$

$$\therefore \quad R1 = \frac{W1.U1 + W2.U2}{(U1)^2 + (U2)^2}$$

$$R2 = \frac{W2.U1 - W1.U2}{(U1)^2 + (U2)^2}$$

But only the modulus of R1 and R2 is required and so computing time can be saved by working out:

$T1 = W1.U1 + W2.U2$ i.e. $R1 = \dfrac{T1}{U1^2 + U2^2}$

$T2 = W2.U1 - W1.U2$ $R1 = \dfrac{T2}{U1^2 + U2^2}$

Thus $R = \frac{\sqrt{(T1) + (T2)}}{(U1)^2 + (U2)^2}$

In the program, this will be a subroutine to find the insertion loss of various sections. The final result will be:

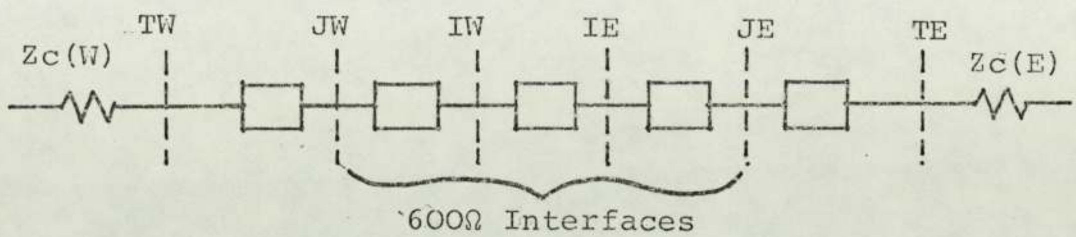
$X = 20 \log_{10}(R)$, the insertion loss for that section.

This can be written into the program as follows:

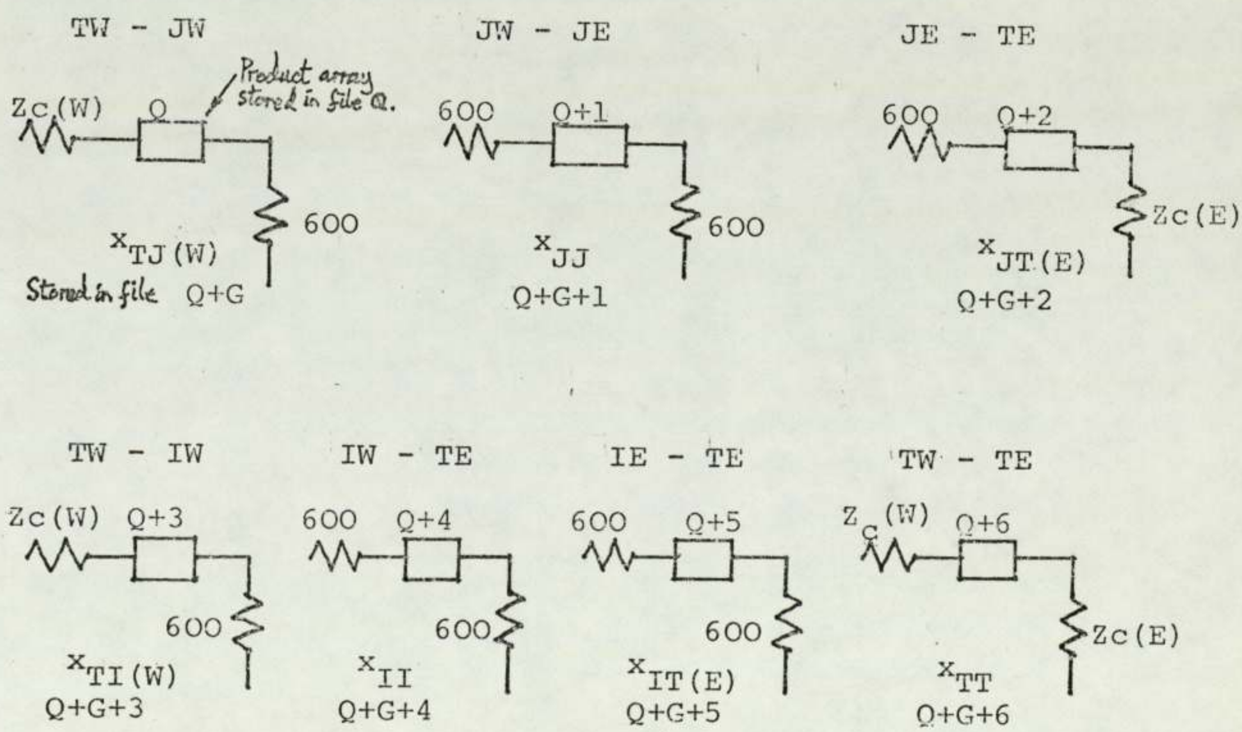
```
Y1 = A(J,5)*S1(J) - A(J,6)*S2(J)
Y2 = A(J,6)*S1(J) + A(J,5)*S2(J)
P1 = L1(J)*Y1 - L2(J)*Y2 + A(J,3)
P2 = L1(J)*Y2 + L2(J)*Y1 + A(J,4)
U1 = S1(J) + L1(J)
U2 = S2(J) + L2(J)
V1 = A(J,1)*L1(J) - A(J,2)*L2(J) + A(J,7)*S1(J) - A(J,8)*S2(
V2 = A(J,2)*L1(J) + A(J,1)*L2(J) + A(J,8)*S1(J) + A(J,7)*S2(
W1 = U1 + P1
W2 = U2 + P2
T1 = W1*U1 + W2*U2
T2 = W2*U1 - W1*U2
R = SQR(T1↑2 + T2↑2)/(U1↑2 + U2↑2)
X(J) = 20*LOG(R)/LOG(1Ø)
```

INSERTION LOSS BETWEEN SECTIONS

Since only reciprocal networks are being dealt with, the insertion loss will be the same in both directions. Consider the case where both junction and international interfaces exist:



The insertion losses for each section are considered as follows:



Note, the calculation procedures for $x_{TI(W)}$, x_{II} and $x_{IT(E)}$ are simply skipped over when junction only is present, the overall product array then being stored in file Q + 3.

After the insertion losses have been calculated, the following parameters are required for the U-files:

U1-file	U2-file	U3-file
SUMJ(W) SUMJ(E)	ZL(W) ZL(E)	LMeST(W) LMeST(E)
SUJE(W) SUJe(E)	x_{TT}	x_{imp} x_L
SUMI(W) SUMI(E)	LUMe(W) LUMe(E)	
SUIe(W) SUIe(E)		
x_{JJ} x_{II}		

These quantities are calculated from the previous results as follows:

$$S_{UMJ(W)} = S_{s(W)} - x_{TJ(W)} + 20 \log_{10} \frac{2 \times 600}{|Z_{c(W)} + 600|}$$

$$S_{UJe(W)} = S_{R(W)} - x_{JT(W)} + 20 \log \frac{2|Z_{c(W)}|}{|Z_{c(W)} + 600|}$$

$$S_{UMJ(E)} = S_{S(E)} - x_{TJ(E)} + 20 \log \frac{2 \times 600}{|Z_{c(E)} + 600|}$$

$$S_{UJe(E)} = S_{R(E)} - x_{JT(E)} + 20 \log \frac{2|Z_c(E)|}{|Z_{c(E)} + 600|}$$

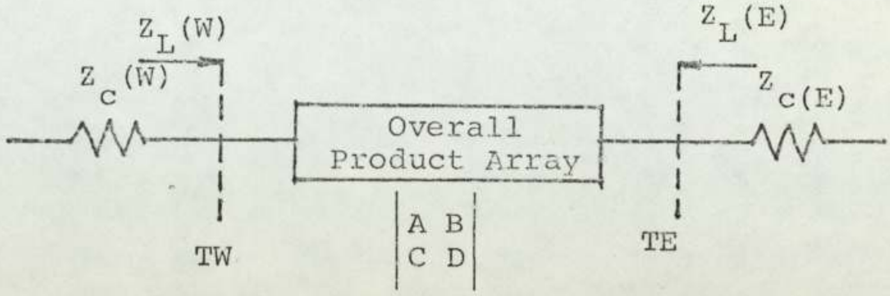
$$S_{UMI(W)} = S_{S(W)} - x_{TI(W)} + 20 \log \frac{2 \times 600}{|Z_{c(W)} + 600|}$$

$$S_{UIe(W)} = S_{R(W)} - x_{IT(W)} + 20 \log \frac{2|Z_{c(W)}|}{|Z_{c(W)} + 600|}$$

$$S_{UMI(E)} = S_{S(E)} - x_{TI(E)} + 20 \log \frac{2 \times 600}{|Z_{c(E)} + 600|}$$

$$S_{UIe(E)} = S_{R(E)} - x_{IT(E)} + 20 \log \frac{2|Z_{c(E)}|}{|Z_c(E) + 600|}$$

Consider Z_L. (Used in the calculation of side-tone path loss, L_{MeST}).



$$Z_{L(W)} = \frac{AZ_{c(E)}+B}{CZ_{c(E)}+D} \qquad Z_{L(E)} = \frac{B+DZ_{c(W)}}{A+CZ_{c(W)}}$$

These are complex expressions and so require to be converted into separate real and imaginary components.

Consider the expression $\frac{U'Z'+V'}{W'Z'+Y'}$

where U'V'W'Y'Z' are all complex.

In Cartesian form, this becomes,

$$\frac{(u+jU)(z+jZ)+(v+jV)}{(w+jW)(z+jZ)+(y+jY)}$$

Small letters ≡ Real components
Large letters ≡ Imaginary components

$$= \frac{uz-UZ+j(Uz+uZ)+v+jV}{wz-WZ+j(Wz+wZ)+y+jY}$$

$$= \frac{(Uz-UZ+v)+j(Uz+uZ+V)}{(wz-WZ+y)+j(Wz+wZ+Y)} = \frac{E+jF}{G+jH}$$

$$\frac{E+jF}{G+jH} = \frac{(E+jF)(G-jH)}{G^2+H^2} = \frac{EG+FH}{G^2+H^2} + j\frac{FG-HE}{G^2+H^2}$$

Let $D = G^2+H^2$

then $\frac{U'Z'+V'}{W'Z'+Y'} = \frac{EG+FH}{D} + j\frac{FG-HE}{D}$

where,

$$E = uz - UZ + v$$

$$F = Uz + uZ + V$$

$$G = wz - WZ + y$$

$$H = Wz + wZ + Y$$

$$D = G^2 + H^2$$

Now, $Z_{L(W)} = \dfrac{AZ_{c(E)} + B}{CZ_{c(E)} + D}$ Let array M1 contain $Z_{c(E)}$

$$= \frac{(a + jA)(M1(J,1) + jM1(J,2)) + (b + jB)}{(C + jC)(M1(J,1) + jM1(J,2)) + (d + jD)}$$

$$= \frac{\overset{u}{\{A(J,1)} + j\overset{U}{A(J,2)}\}\{\overset{z}{M1(J,1)} + j\overset{Z}{Mi(J,2)}\} + \{\overset{v}{A(J,3)} + j\overset{V}{A(J,A)}\}}{\underset{w}{\{A(J,5)} + j\underset{W}{A(J,6)}\}\{\underset{z}{M1(J,1)} + j\underset{Z}{M1(J,2)}\} + \{\underset{y}{A(J,7)} + j\underset{Y}{A(J8)}\}}$$

This will therefore be represented in the program as:

```
FOR J = 1 to 20
E = A(J,1)*M1(J,1)-A(J,2)*M1(J,2)+A(J,3)
F = A(J,2)*M1(J,1)+A(J,1)*M1(J,2)+A(J,4)
G = A(J,5)*M1(J,1)-A(J,6)*M1(J,2)+A(J,7)
H = A(J,6)*M1(J,1)+A(J,5)*M1(J,2)+A(J,8)
D = G↑2 + H↑2
Z(J,1) = (E*G+F*H)/D
Z(J,2) = (F*G - H*E)/D
Next J
```

<u>For $Z_{L(E)}$</u>

$$Z_{L(E)} = \frac{DZ_{C(W)} + B}{CZ_{C(W)} + A} \quad \text{Let array A1 contain } Z_{C(W)}$$

$$= \frac{(d+jD)(A1(J,1) + jA1(J,2)) + (b+jB)}{(c+jC)(A1(J,1)+jA1(J,2)) + (a+jA)}$$

$$= \frac{\overset{u}{\{A(J,7)} + \overset{U}{jA(J,8)\}}\{\overset{z}{A1(J,1)} + \overset{Z}{jA1(J,2)}\} + \{\overset{v}{A(J,3)} + \overset{V}{jA(J,4)}\}}{\underset{w}{\{A(J,5)} + \underset{W}{jA(J,6)\}}\{\underset{z}{A1(J,1)} + \underset{Z}{jA1(J,2)}\} + \{\underset{y}{A(J,1)} + \underset{Y}{jA(J,2)}\}}$$

This will be represented in the program as:

```
For J = 1 to 20
E  =  A(J,7)*A1(J,1) - A(J,8)*A1(J,2) + A(J,3)
F  =  A(J,8)*A1(J,1) + A(J,7)*A1(J,2) + A(J,4)
G  =  A(J,5)*A1(J,1) - A(J,6)*A1(J,2) + A(J,1)
H  =  A(J,6)*A1(J,1) + A(J,5)*A1(J,2) + A(J,2)
D  =  G↑2 + H↑2
Z(J,1)  =  (E*G + F*H)/D
Z(J,2)  =  (F*G - H*E)/D
Next J
```

<u>For LUMe</u>

$$L_{UMe(W-E)} = x_{TT} - S_{s(W)} - S_{R(E)} + 20 \log_{10} \frac{|Z_{C(W)} + Z_{C(E)}|}{2|Z_{C(E)}|}$$

$$L_{UMe(E-W)} = x_{TT} - S_{S(E)} - S_{R(W)} + 20 \log_{10} \frac{|Z_{C(E)} + Z_{C(W)}|}{2|Z_{C(W)}|}$$

Let S1 contain $|Z_{C(W)} + Z_{C(E)}|$

S2 contain $|Z_{C(W)}|$

S3 contain $|Z_{C(E)}|$

The arrays may be assigned as follows:

$X1 = x_{TT}$	Then update to give:
$A3 = S_{S(W)}$	$A3 = L_{UMe(W-E)}$
$A4 = S_{R(W)}$	$A4 = L_{UMe(E-W)}$
$M3 = S_{S(E)}$	
$M4 = S_{R(E)}$	
$A1 = Z_{C(W)}$	
$A2 = Z_{C(E)}$	

For x_{imp}

$$x_{imp(W-E)} = L_{UMe(W-E)} + S_{UMJ(W)} + S_{UJe} - x_L$$

$$x_{imp(E-W)} = L_{UMe(E-W)} + S_{UMJ(E)} + S_{UJe(W)} - x_L$$

x_{imp} is obtained directly from the parameters previously calculated in the program.

For L_{MeST}

$$L_{MeST(W)} = -S_{S(W)} - S_{R(W)} + 20 \log_{10} \frac{|Z_{L(W)} + Z_{C(W)}||Z_{C(W)} + Z_{SO(W)}|}{2|Z_{C(W)}||Z_{L(W)} - Z_{SO(W)}|}$$

$$L_{MeST(E)} = -S_{S(E)} - S_{R(E)} + 20 \log_{10} \frac{|Z_{L(E)} + Z_{C(E)}||Z_{C(E)} + Z_{SO(E)}|}{2|Z_{C(E)}||Z_{L(E)} - Z_{SO(E)}|}$$

- again calculated from parameters previously obtained.

THE U-FILES

These are stored on Disk 1 in the following order:

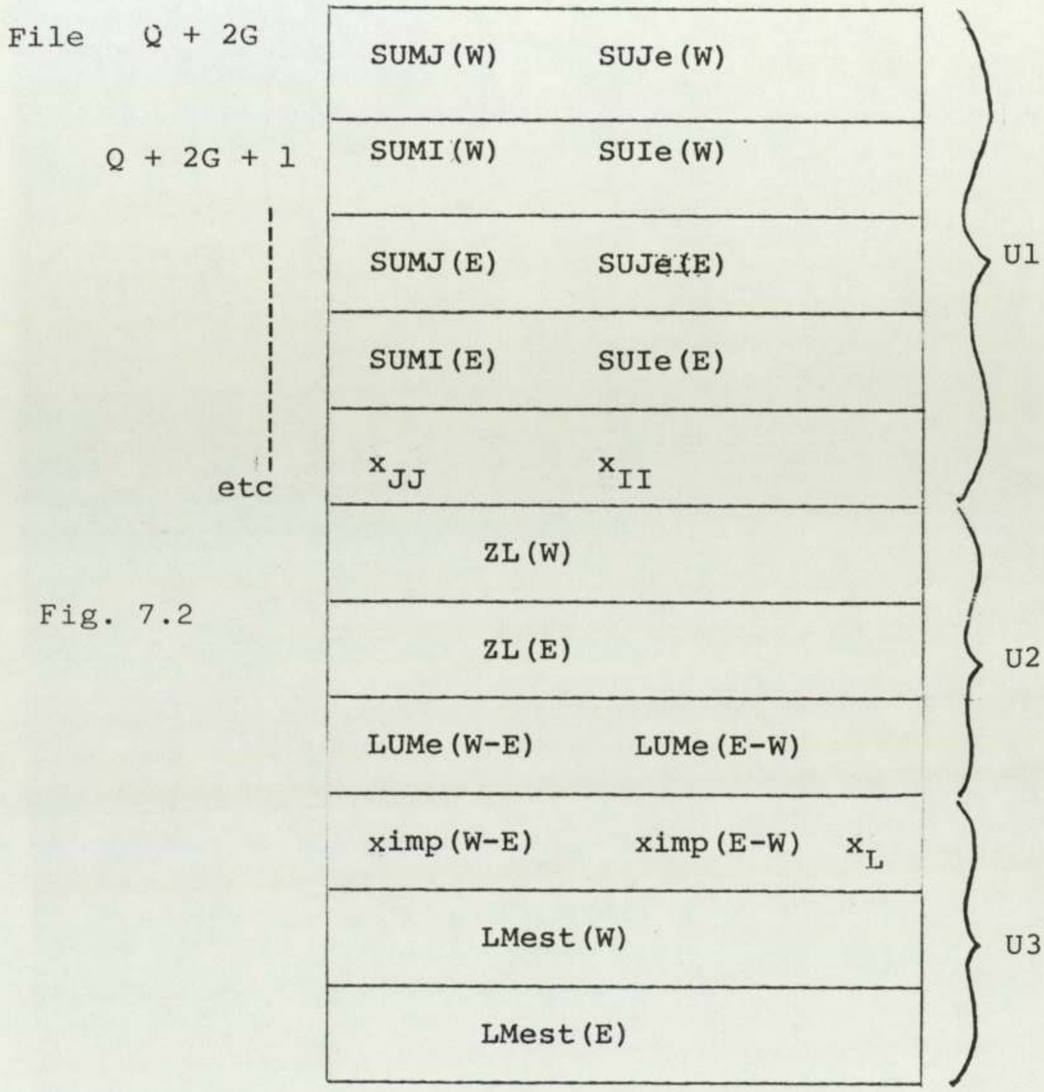


Fig. 7.2

The U-Files are split-up into U1, U2 and U3. If an array reserved for international is not used (ie only junction interfaces are present), its value is set to zero.

TRANSFERRING THE U-FILES TO DISK 3 (See Fig. 8.2)

It is convenient to change the order of the U-files to a form more convenient to the calculation of the loudness ratings for various sections. This is done during the transfer to disk 3.

DISK 3 ORGANIZATION

U-File Recovery	P7
Ul (W-E)	D 16
U3 (W-E)	D 17
Ul (E-W)	D 18
U3 (E-W)	D·19
G, T$, S$, R$	D 20
Calculation of L.R. & V_L	P 35
R (W-E), V_L (W)	D 39
R (E-W), V_L (E)	D 40
Print-out L.R. & V_L	P 45

Fig. 8.2

The U-Files are read from disk 1 in the following sequence (and are read into an array A(K,J) where K represents the particular transmission loss at a frequency F(J)). Note, U2 is no longer required as it was used only to construct U3.

SUMJ(W)	SUJe(W)	SUMI(W)	SUIe(E)	SUMJ(E)	SUJe(E)
K=1	K=2	3	4	5	6

SUMI(E)	SUIe(E)	x_{JJ}	x_{II}	ZL(W) Real	ZL(W) Imaginary
7	8	9	10	11	12

ZL(E) Real	ZL(E) Imaginary	LUMe(W-E)	LUMe(E-W)
13	14	15	16

ximp(W-E)	ximp(E-W)
17	18

x_L	LMesT(W)	LMesT(E)
19	20	21

ORDER OF THE U-FILES REQUIRED FOR STORAGE ON DISK 3

U1 (W-E) (Stored in data-file D16)

SUMJ(W)	SUJe(E)	x_{JJ}	SUMI(W)	SUIe(E)	XII
K=1	K=6	9	3	8	10

U3 (W-E) (D17)

x_L	ximp(W-E)	LMesT(W)
19	17	20

U1 (E-W) (D18)

SUMJ(E)	SUJe(W)	x_{JJ}	SUMI(E)	SUIe(W)	x_{II}
5	2	9	7	4	10

U3 (E-W) (D19)

x_L	ximp(E-W)	LMesT(E)
19	18	21

Data file D20 is used to store G(4 or 7), T$ (the title of the connection), S$ (the west telephone name) and R$ (the east telephone name).

TRANSFERENCE OF THE CONNECTION DESCRIPTION AND U-FILES TO THE ARCHIVES DISK (See Fig. 9.2)

The data required to transfer is as follows:

T$	Title of the connection and date of set-up.
N	Number of elements making up the connection.
D	Positions and descriptions of the elements.
P	Planning interface positions.
S$	Sending telephone type.
R$	Receiving telephone type.
X	Nominal loss between the junctions.
Q	Datum number for variable data file locations.
A1	10 x 20 array containing U1 data.
A2	5 x 20 array containing U3 data.

DATUM FOR THE START OF DATA STORAGE

Running the "datum" program will put a value (C) = 9 into data file number 4. This then causes the connection data to be stored in data file 10 on the first transfer. There-after, C is automatically updated by 1 for each transfer from Disk 1.

CONNECTION LOCATION

The connection location program prints a list of the titles of the connections stored and their respective file number containing the data. The user then chooses the required set of data he wishes to transfer to Disk 3, by selecting the respective file number.

ARCHIVES DISK ORGANIZATION

Connection Location	P2
Transfer from Disk 1	P3
C,F	D4
Print-out Connection Description	P6
Print-out U-Files	P7
Transfer to Disk 3	P8
T$, R$, S$, N, P, D, X, Q, A1, A2	D 10
T$, R$, S$, N, P, D, X, Q, A1, A2	D 11
T$, R$, S$, N, P, D, X, Q, A1, A2	D 12
T$, R$, S$, N, P, D, X, Q, A1, A2	D 13

Stored Connections

Fig. 9.2

CHAPTER 3. SECTION 1.

THE USE OF HEADPHONES IN SUBJECTIVE TESTING.

CHAPTER 3

SECTION 1

THE USE OF HEADPHONES IN SUBJECTIVE TESTING

1. CHOICE OF HEADPHONES

In telephony, subjective tests very often involve subjects making judgements in a listening only mode. In this, the listener may use a telephone handset and be seated in a special soundproof room. High quality headphones are now available at modest cost and offer a convenient way of obtaining fairly quiet listening conditions without the need to resort to a special enclosure.

The main features of the headphones should be:

(a) Flat frequency response from 100 Hz to 8 kHz

(b) Good sound insulation, (therefore circum-aural)

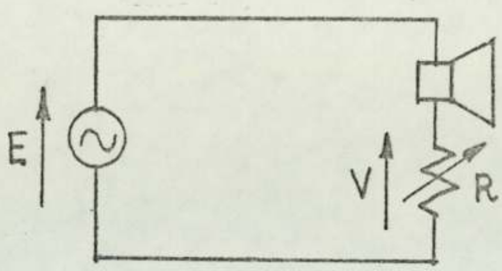
(c) Fairly high impedance (ideally 600Ω).

Bearing these factors in mind, it was decided to purchase a pair of Beyer DT100 headphones. Various test procedures were then undertaken in order to calibrate the headphones.

2. TEST PROCEDURES

2.1 Impedance measurement

Referring to the diagram shown, the generator frequency was set to 1 kHz. Variable resistor R was then adjusted until voltage V was equal to E/2. This was found to correspond to 420Ω for each headphone. (This agrees with the manufacturers quoted value and was fairly constant with frequency). An adaptor was made for plugging the headphones into, and two 180Ω resistors were incorporated in it to pad out the effective headphone impedance to 600Ω.



2.2 TESTING ON THE ARTIFICIAL EAR

The test set-up comprised of the following:

(a) Artificial Ear type 4153

(b) Sine Generator type 1023

(c) Measuring Amplifier type 2607

(d) Chart Recorder type 2305.

All of the above items were manufactured by Brüel and Kjaer.

Note

The output of the sine generator is 50Ω. This was padded out to 600Ω by including a 560Ω resistor inside the connecting plug. Since the impedance of the headphones is now 600Ω, 6 dB is lost across the effective generator output impedance. The meter on the sine generator indicates the open circuit output voltage and so this value was increased by 6 dB in order to give the volage appearing across the headphones. A preliminary value of - 18 dBV was chosen for the headphone voltage. (Corresponding to the preferred listening level for a telephone earpiece). To reduce low frequency noise (predominant) the signals from the microphone was filtered between 22.5 Hz to 22.5 KHz in the measuring amplifier. After setting the equipment up, frequency responses were obtained from the chart recorder. The responses for both earphones were found to be similar with dips and peaks of about 7 to 15 dB in amplitude above 2 KHz. (See Figs. 1.3 and 2.3). These dips were due to the 'cavity' effect caused by the air space between the condenser microphone in the artificial ear and the diaphragm of the headphone. The cavity causes standing waves (resonances) to be set-up where the wavelength of the sound is equivalent in size to the various path lengths in the cavity.

Note the frequency response shape was very similar for various signal amplitudes within the dynamic range of the headphones. When a dummy ear made of plasticine was inserted, the undulations in the response were reduced in amplitude and also shifted up slightly in the frequency range. (See Fig. 3.3). It was therefore decided to perform tests using human ears in order to obtain an accurate calibration corresponding to use in real conditions.

In order to obtain these results, a very small microphone was included in the right ear to monitor the sound pressure in the ear. A 'Knowles' miniature condenser microphone was used for this.

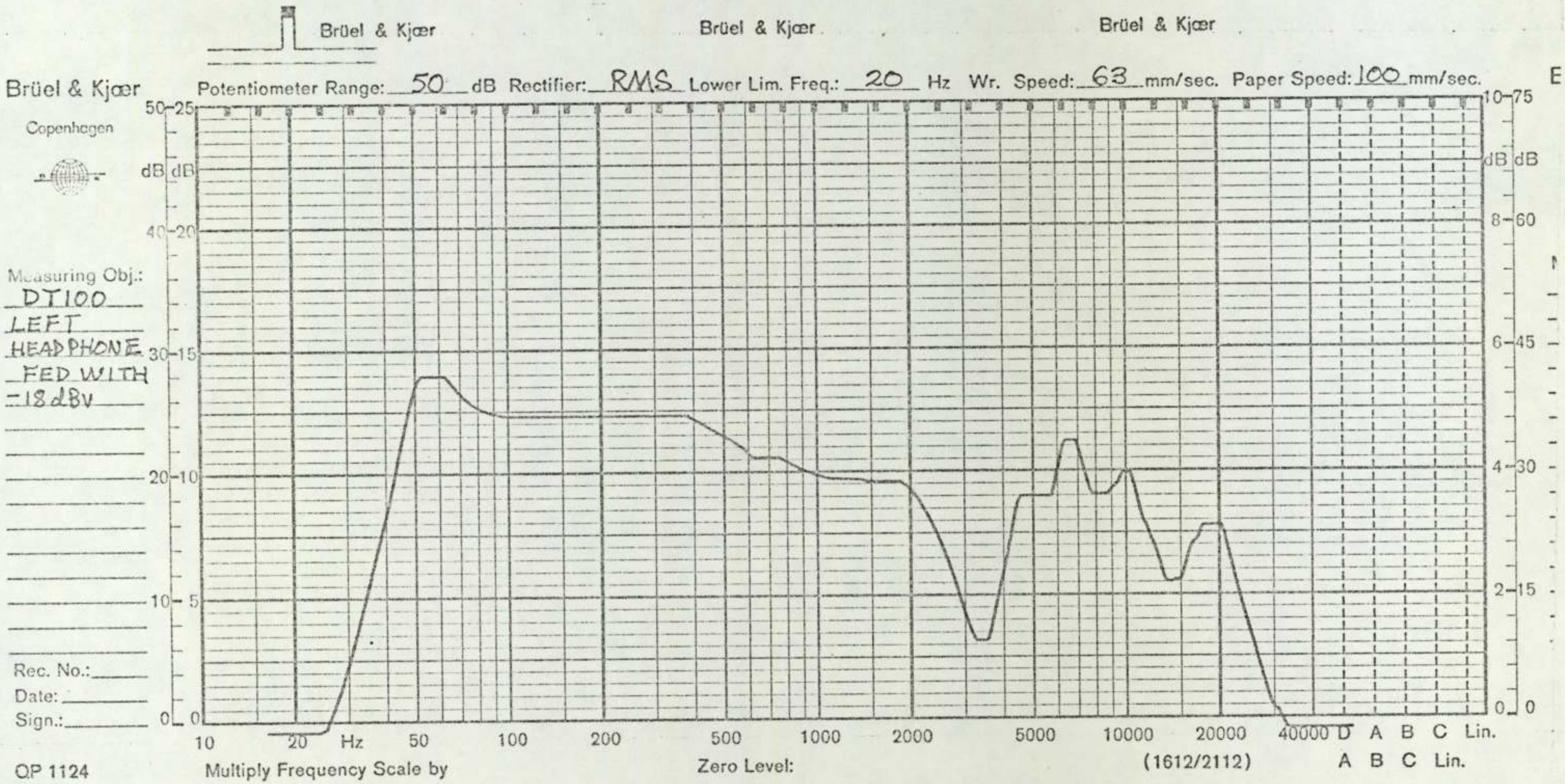
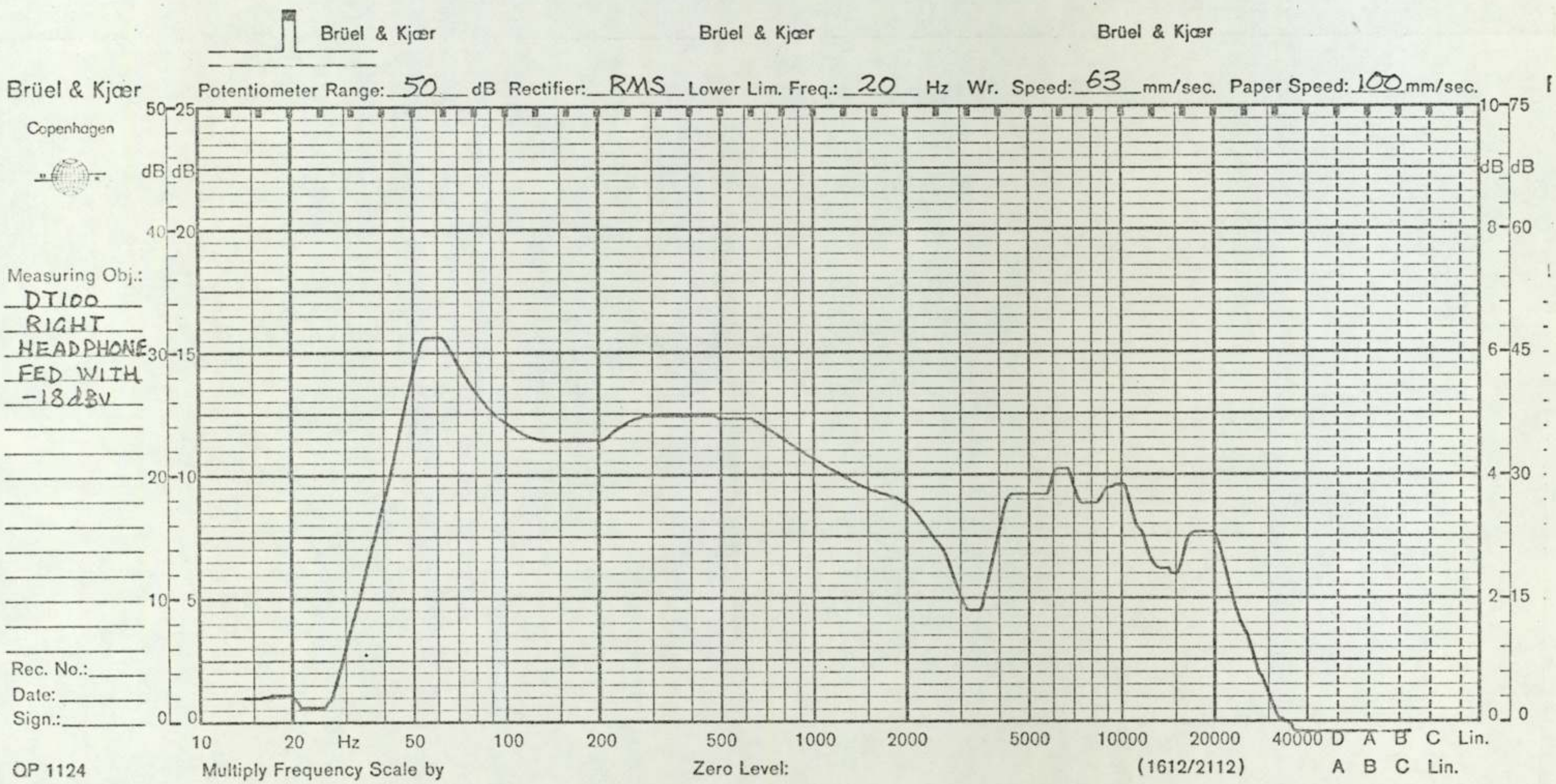
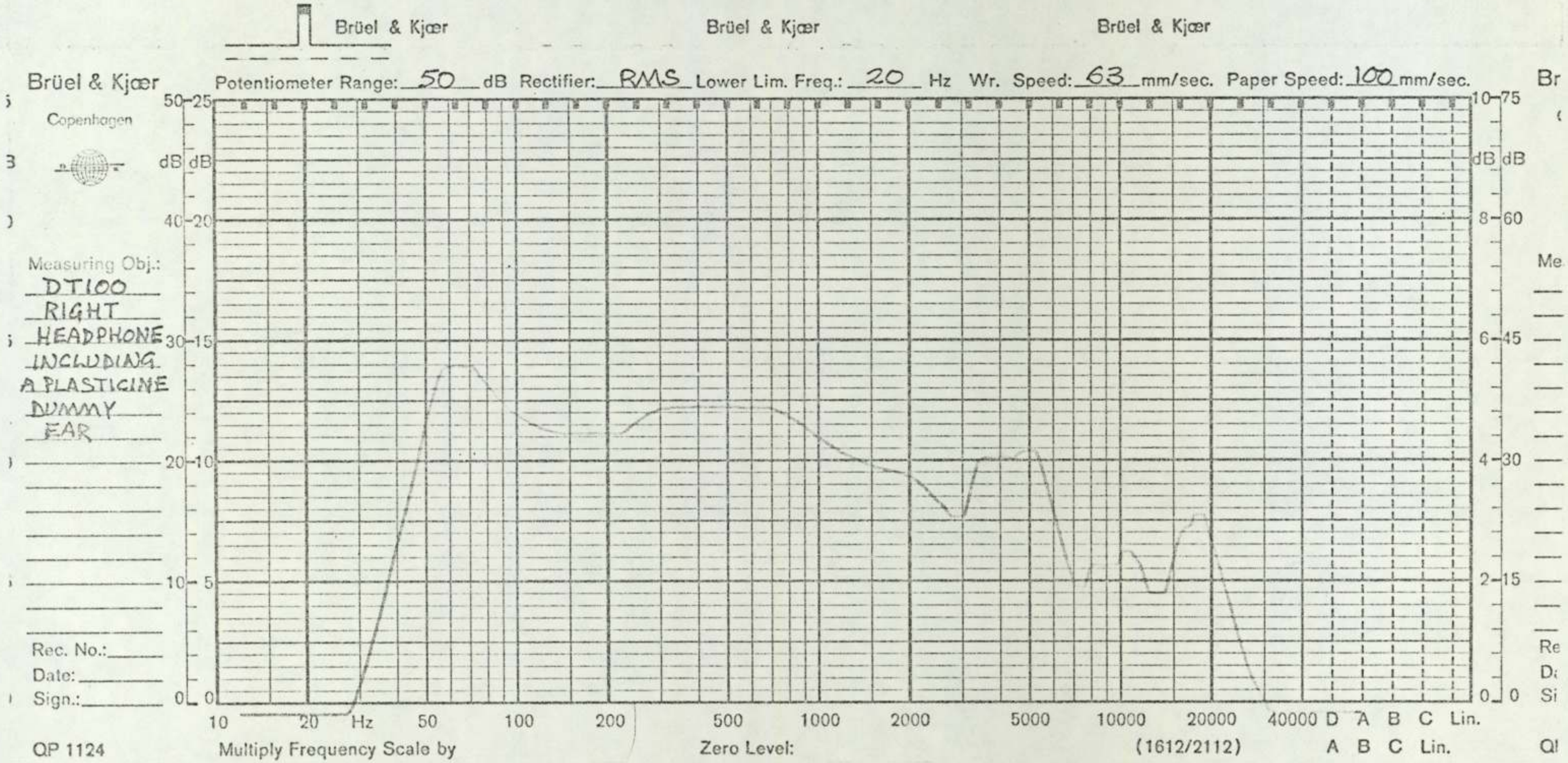

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 63 mm/sec. Paper Speed: 100 mm/sec.
E
Measuring Obj.:
DT100
LEFT
HEADPHONE
FED WITH
-18 dBV
Rec. No.:
Date:
Sign.:
QP 1124
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
Multiply Frequency Scale by
Zero Level:
(1612/2112)
10 75
8 60
6 45
4 30
2 15
0 0

FIG 1.3



Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 63 mm/sec. Paper Speed: 100 mm/sec.
Measuring Obj.:
DT100
RIGHT
HEADPHONE
FED WITH
-18dBV
Rec. No.:
Date:
Sign.:
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
10 75
8 60
6 45
4 30
2 15
0 0
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 2.3

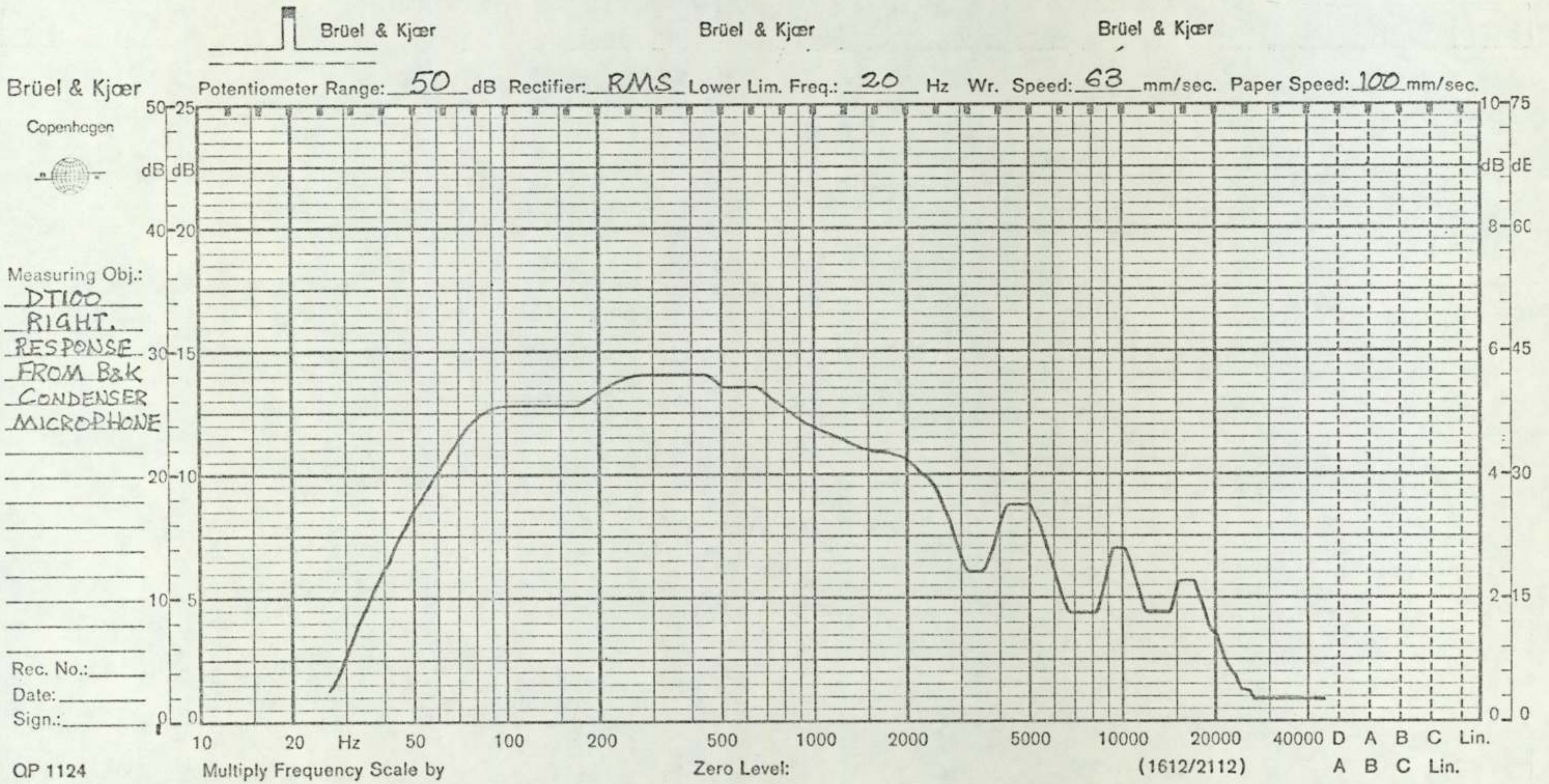


Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 63 mm/sec. Paper Speed: 100 mm/sec.
dB dB
Measuring Obj.:
DT100
RIGHT
HEADPHONE
INCLUDING
A PLASTICINE
DUMMY
EAR
Rec. No.:
Date:
Sign.:
QP 1124
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 3.3

To calibrate the Knowles microphone, it was inserted into the cavity between the artificial ear and the headphone diaphragm. The headphone frequency response was then obtained on the chart recorder initially using the B & K condenser microphone, and then using the now present Knowles microphone. From these results, the difference in responses was used in conjunction with the calibration chart for the B & K microphone, thus giving the calibration of the Knowles microphone.

The responses from the microphones are shown in Figs. 4.3 and 5.3. It is seen that serious inconsistency occurs at frequencies above 1 KHz. Since the Knowles microphone was fixed onto the headphone it was nearer to the diaphragm than the B & K microphone. Again the cavity effect was taking place. To overcome this, the Knowles microphone was removed from the headphone and positioned near to the B & K microphone, using plasticine and a telephone earpiece was used as the sound source. (The plasticine also acting as an efficient sealant against sound leakage). The cavity was now much smaller. The responses for the two microphones are shown in Figs. 6.3 and 7.3, and show a much better consistency. It was decided to mount the microphone close to the point where the sound enters the ear (e.r.p.) for accurate pressure responses.



Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 63 mm/sec. Paper Speed: 100 mm/sec.
Measuring Obj.:
DT100
RIGHT.
RESPONSE
FROM B&K
CONDENSER
MICROPHONE
Rec. No.:
Date:
Sign.:
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
10 75
8 60
6 45
4 30
2 15
0 0
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 4.3

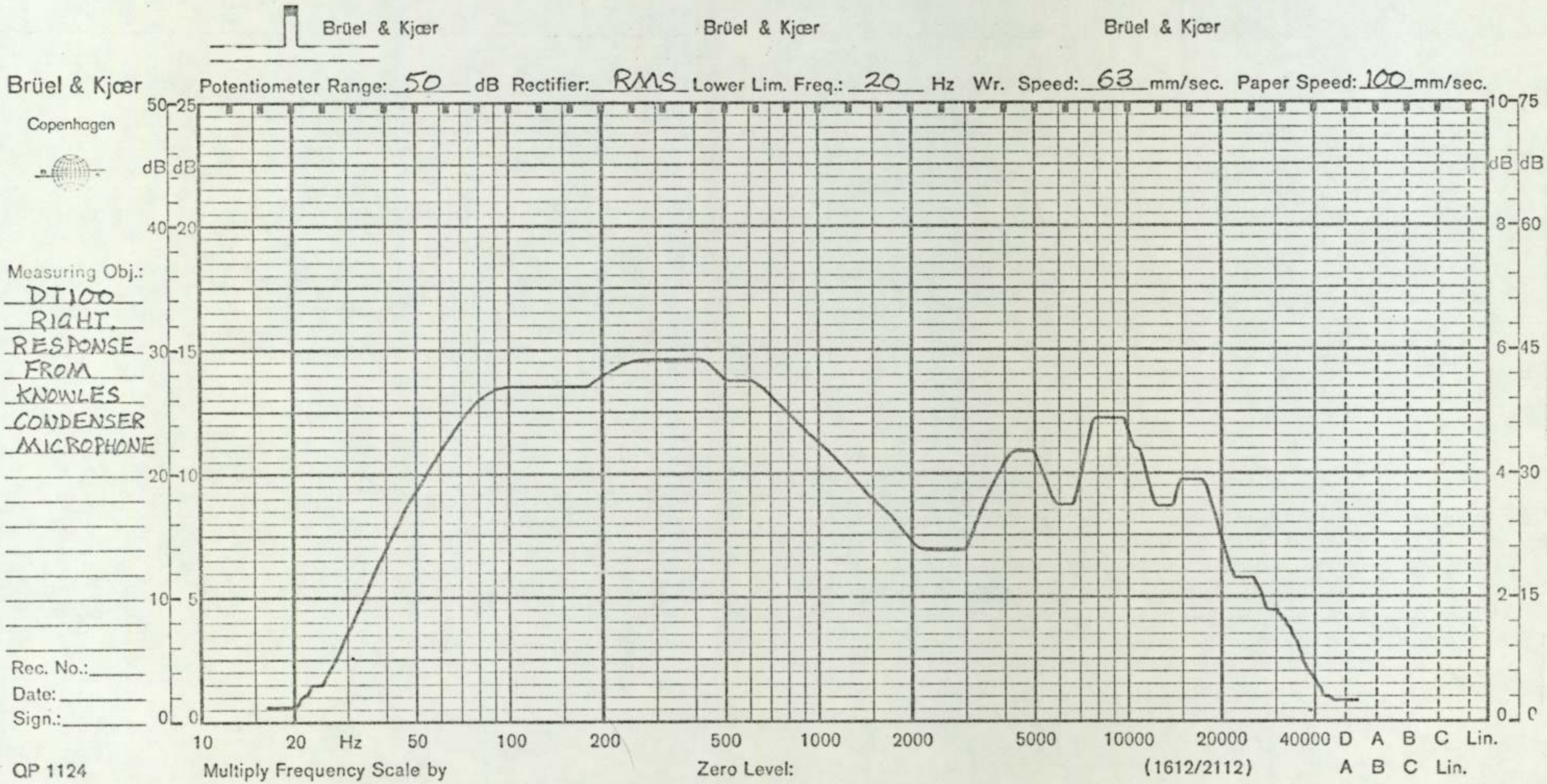
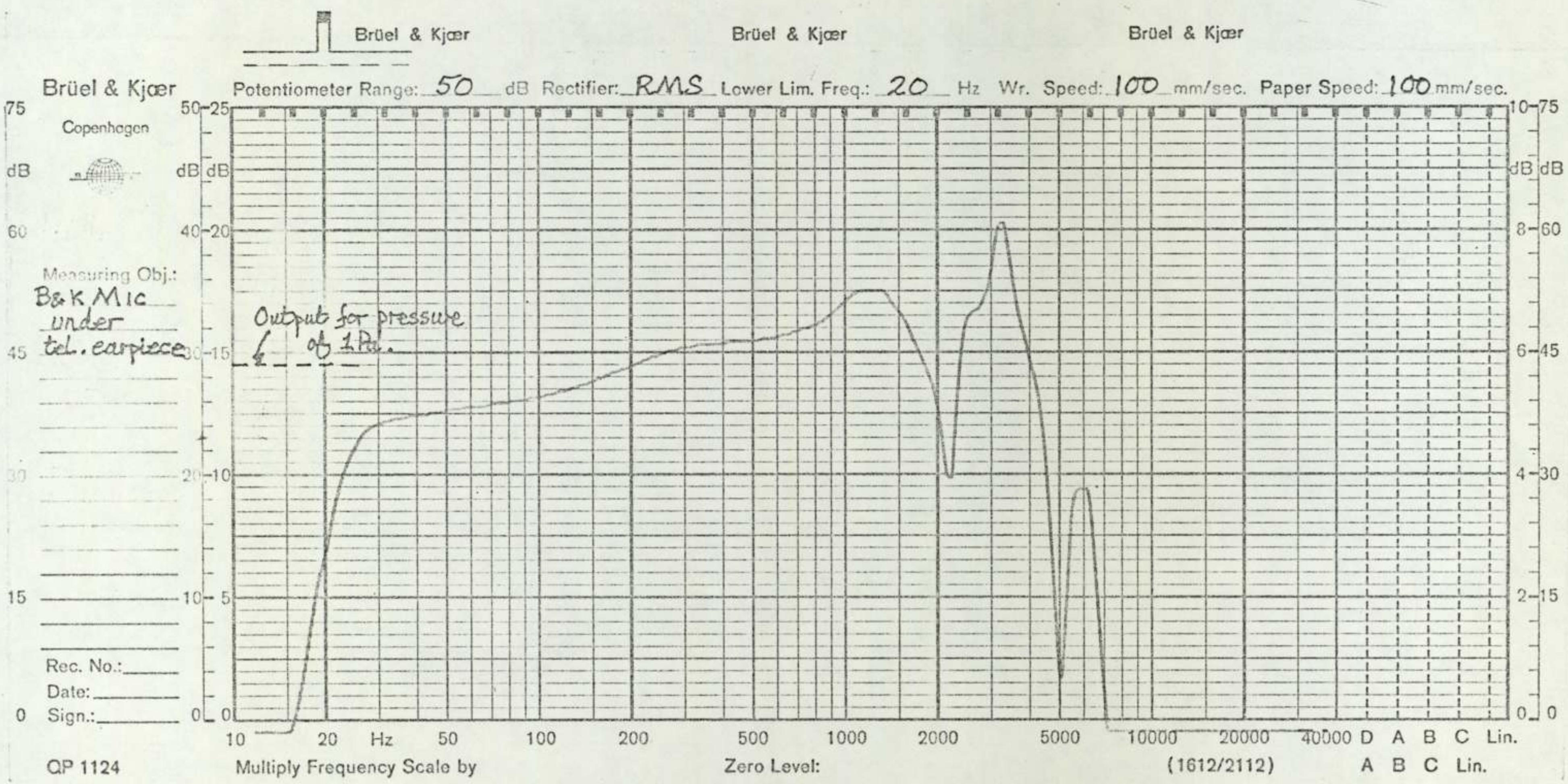

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 63 mm/sec. Paper Speed: 100 mm/sec.
Measuring Obj.:
DT100
RIGHT.
RESPONSE
FROM
KNOWLES
CONDENSER
MICROPHONE
Rec. No.:
Date:
Sign.:
QP 1124
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
10 75
dB dB
8 60
6 45
4 30
2 15
0 0
10
20
Hz
50
100
200
500
1000
2000
5000
10000
20000
40000
D A B C Lin.
A B C Lin.
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 5.3



Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 100 mm/sec. Paper Speed: 100 mm/sec.
Measuring Obj.: B&K Mic under tel. earpiece
Output for pressure of 1Pa.
Rec. No.:
Date:
Sign.:
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.

FIG 6.3

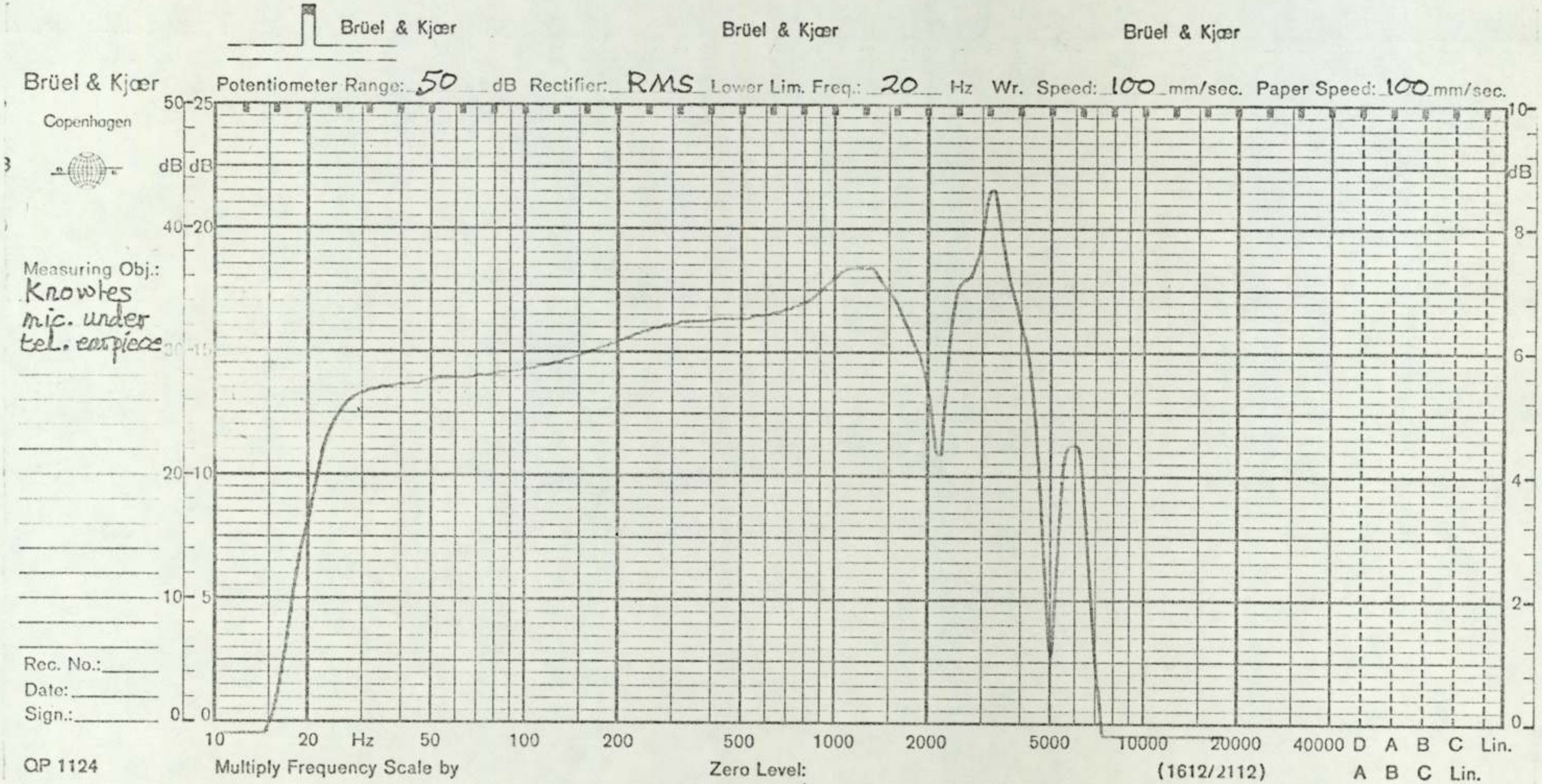

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 100 mm/sec. Paper Speed: 100 mm/sec.
Measuring Obj.: Knowles mic. under tel. earpiece
Rec. No.:
Date:
Sign.:
QP 1124
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
dB
10
8
6
4
2
0
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000 D A B C Lin.
Multiply Frequency Scale by
Zero Level:
(1612/2112)
A B C Lin.

FIG 7.3

2.3 INTERPRETATION OF THE RESULTS

The sound calibrator (giving a pressure of 1 Pascal at 1 kHz) was applied to the B & K microphone. This produced a voltage on the measuring amplifier of -40 dBV. Thus the sensitivity is -40 dBV/Pa. (The gain of the pre-amplifier accompanying the microphone is -2.2 dB and so the actual open circuit sensitivity of the microphone at 1 kHz is -37.8 dBV/pa). Figs. 6.3 and 7.3 show that at1 kHz the Knowles microphone is 2.5 dB more sensitive than the B & K microphone at 1 kHz. The sensitivity therefore for the Knowles microphone is -37.5 dBV/Pa at 1 kHz.

Note

The input impedance of the measuring amplifier is 1 MΩ in parallel with 50 pF and so the voltage loss across the 1.8KΩ output impedance of the Knowles microphone is negligible. The calibration chart for the Knowles microphone arising from these results is shown in Fig. 13.3. Details on the calibration of the B & K microphone are given in Figs. 11.3 and 12.3.

2.4 CALIBRATING THE HEADPHONES ON A REAL EAR

The signal level for calibrating the headphones was chosen as -18 dBV, as an approximation to the preferred loudness for a telephone earphone. In order to arrive at a more representative level for headphones, continuous speech was fed into them and the sound level adjusted until the most comfortable listening level was obtained.

Calibration Chart for
Condenser Microphone
Cartridge Type 4133

Brüel & Kjær
Denmark

Serial No. . 557921. . . .

Open Circuit Sensitivity at 1013 mbar

-37.1 . . . dB re. 1 V per N/m² (Pa) or . . . 14.0 . mV per N/m²

This Calibration is traceable to the National Bureau of Standards, Washington D.C.

Open Circuit Correction Factor:

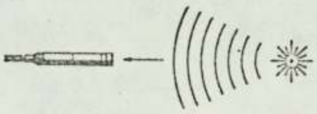
K_0*) = . +11.1 . . . . dB

Cartridge Capacitance:

C = ... 18.0 . . . pF

Leakage Resistance tested at 52 % relative humidity $> 10^{16}\ \Omega$.

Frequency Response Characteristics:
The upper curve is the open circuit free field characteristic, valid for the Microphone Cartridge with protecting grid. Sound waves perpendicular to diaphragm (see Fig.). The lower curve is the open circuit pressure response recorded with electrostatic actuator.



*) Subtract the gain of the preamplifier (see back of this card) from K_0 to get the actual correction factor K. (See instruction manual for the use of K).

1 N/m² = 10 dynes/cm² = 10 μbar = 1 Pascal.

BC 0034

Conditions of Tests:

Frequency: 250 Hz

Barometric Pressure: . . . . . 1015 . . mbar

Relative Humidity: . . . . 34 . . %

Teperature: . . . . 23 . . °C

Date: 18.12.75 . . . . Signature: . . . .

Summarized Specifications

Outside Diameter:
0.52 in. (13.2 mm) with protecting grid.
0.50 in. (12.7 mm) without protecting grid.

Coupler Mounting Thread (grid thread):
0.50 in. (12.7 mm) 60UNS2.

Frequency Response Characteristic:
Frequency below which free-field response shall be flat within ± 2 dB: 40 kHz.

Lower Limiting Frequency (−3 dB) as determined by pressure equalization is between 1 Hz and 3 Hz.

Resonance Frequency: approx. 25 kHz (overdamped).

Equivalent Air Volume at 1 atm. about 0.01 cm³.

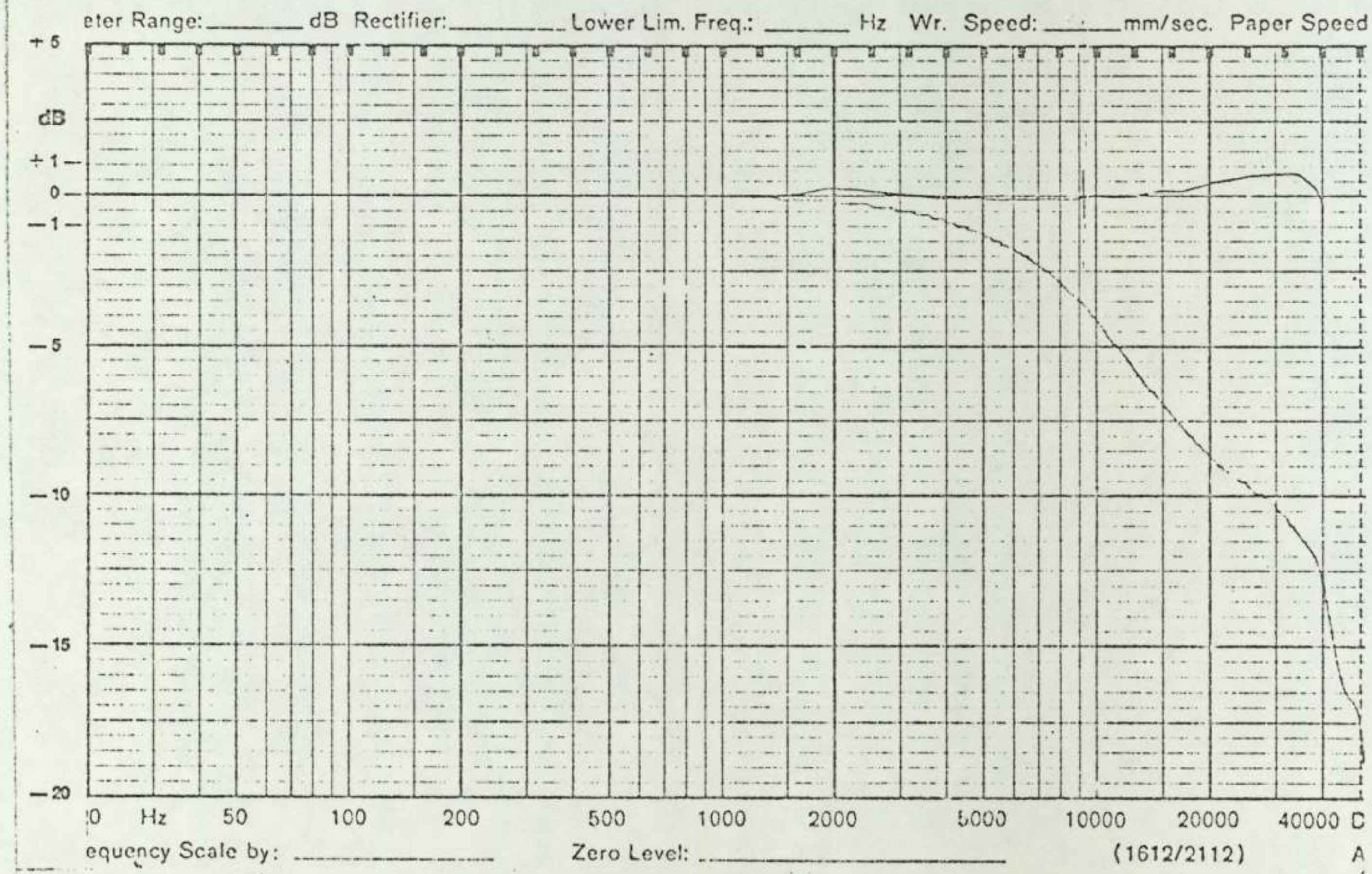
Ambient Pressure: Influence on sensitivity approx. −0.1 dB for + 10 % pressure change.

Temperature Coefficient between −50 and + 60 °C. Less than ± 0.006 dB/°C.

Relative Humidity: The influence of humidity does not exceed 0.1 dB in the absence of condensation.

Dynamic Range: Sound Pressure Level below which the total harmonic distortion remains less than 1 %: 154 dB.

FIG 11.3



CALIBRATION CURVE FOR THE B&K MICROPHONE

FIG 12.3

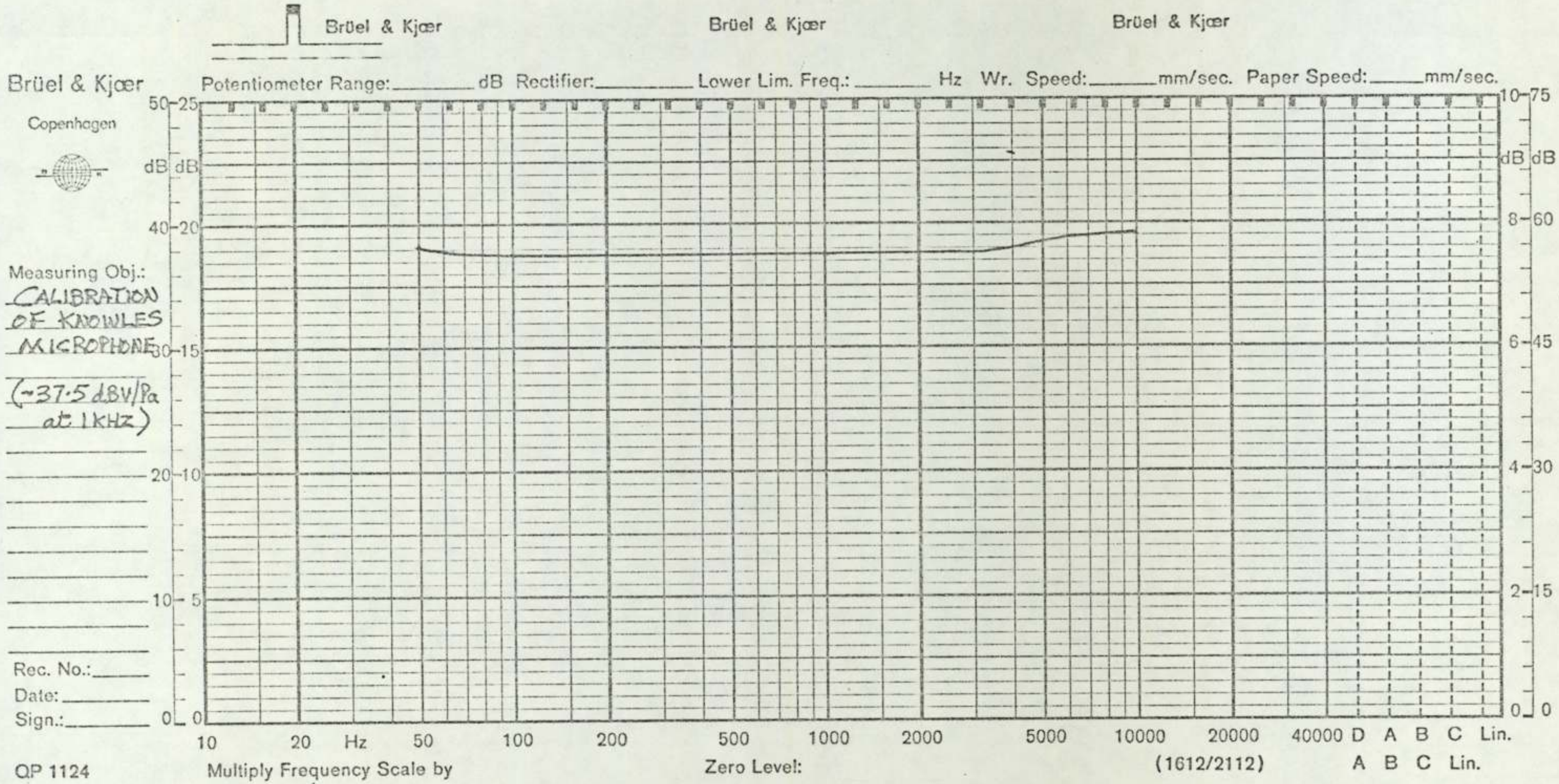

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: ______ dB Rectifier: ______ Lower Lim. Freq.: ______ Hz Wr. Speed: ______ mm/sec. Paper Speed: ______ mm/sec.
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
dB dB
10 75
8 60
6 45
4 30
2 15
0 0
Measuring Obj.:
CALIBRATION OF KNOWLES MICROPHONE
(-37.5 dBV/Pa at 1KHz)
Rec. No.:
Date:
Sign.:
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 13.3

This was initially done with sound in one ear only, and then sound in both ears. With one ear only, a level of -18 dBV was quite loud and clear but the absence of sound in the other ear produced a certain amount of strain for that ear. (The effect was that of a 'pressure' on the ear). Levels above -18 dBV were too loud. Reducing the level by 10 dB made the sound fainter but still clear with much less strain on the other ear. Sound in both ears caused no strain at all with a speech level of -18 dBV.

A calibration was made on a real ear at - 18 dBV and the response is shown in Fig. 14.3.

Because of the uncertainty in preferred listening level, an experiment was conducted using subjects listening under various conditions. Since speech in one ear only occurs in telephony, it was decided not to have speech in both ears, but to have noise in one ear, with speech and noise in the other ear. Each of the subjects had their real ear pressure response recorded. It was found that all the responses were very similar over the frequency range of interest. From the results, an 'average' response was obtained. This was then used to find the receiving sensitivity of the headphones on real ears.

CORRECTION FACTORS 'K' and 'C'

The presence of the Knowles microphone will reduce the volume of the cavity and so cause the true sensitivity characteristic to deviate slightly with frequency. The

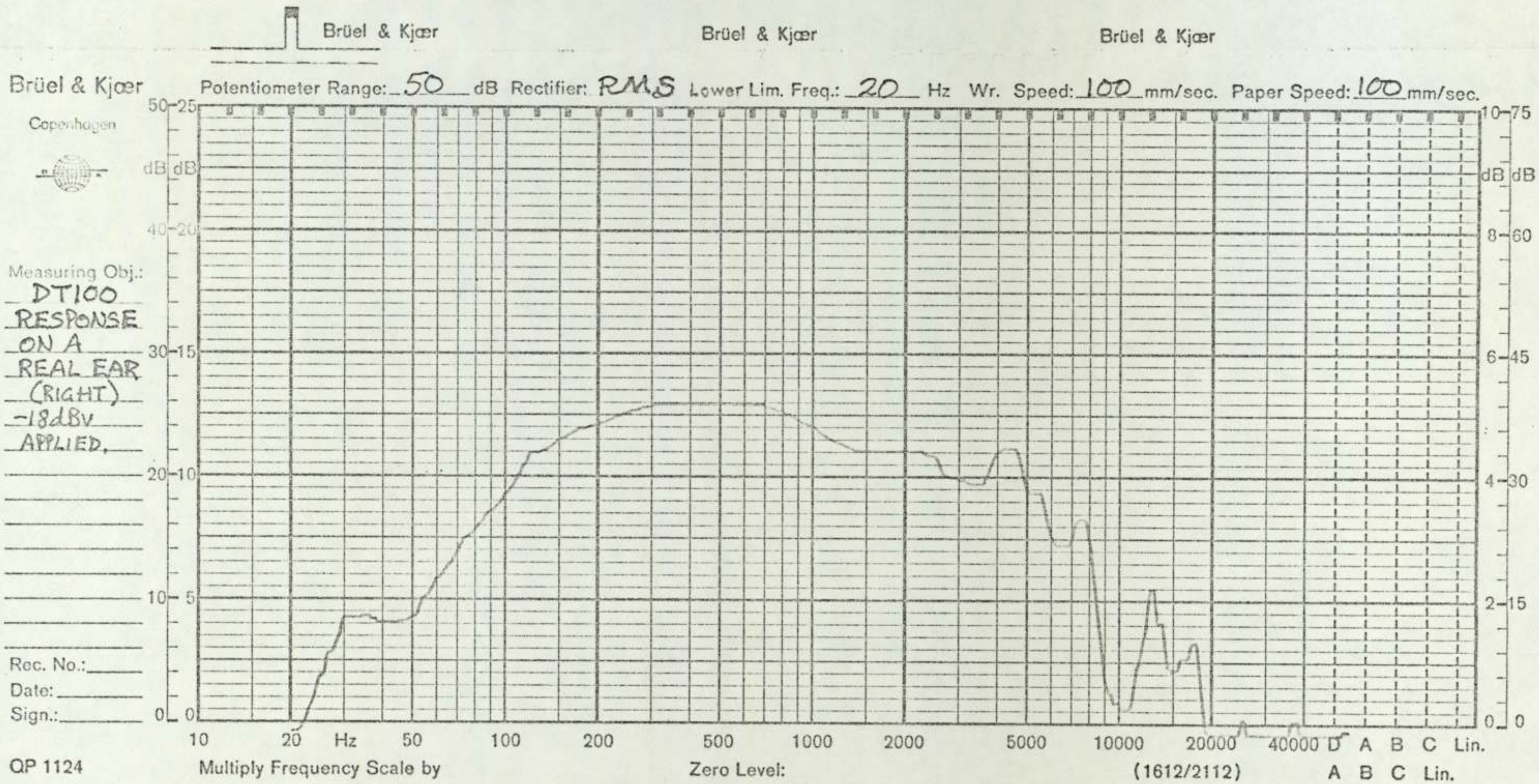

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 20 Hz Wr. Speed: 100 mm/sec. Paper Speed: 100 mm/sec.
Measuring Obj.:
DT100
RESPONSE
ON A
REAL EAR
(RIGHT)
-18dBV
APPLIED.
Rec. No.:
Date:
Sign.:
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
10 75
8 60
6 45
4 30
2 15
0 0
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 14.3

true shape was arrived at by obtaining the frequency response for the headphone from the chart recorder, using the artificial ear. Responses were obtained from the B & K microphone for the case where the Knowles microphone was present, and then for its absence. (See Figs. 15.3 and 16.3). The difference in levels from the responses at each frequency point is the 'K' factor. By using the K factor, the true receiving sensitivity of the headphone for the right ear was found. By obtaining the true response for both right and left headphones on the artificial ear, the 'C' factor was found from the difference at each frequency point. (See Figs. 17.3 and 18.3). This was applied to the sensitivity values for the right headphone to yield the sensitivities for the left headphone.

Table 1.3 shows the K and C factors.

Table 2.3 derives S_R for the right headphone.

Table 3.3 then derives S_R for the left headphone.

Table 4.3 gives S_R for both headphones at the ISO recommended range of frequencies. (From using the PO-ISO computer program).

This completes the calibration of the headphones.

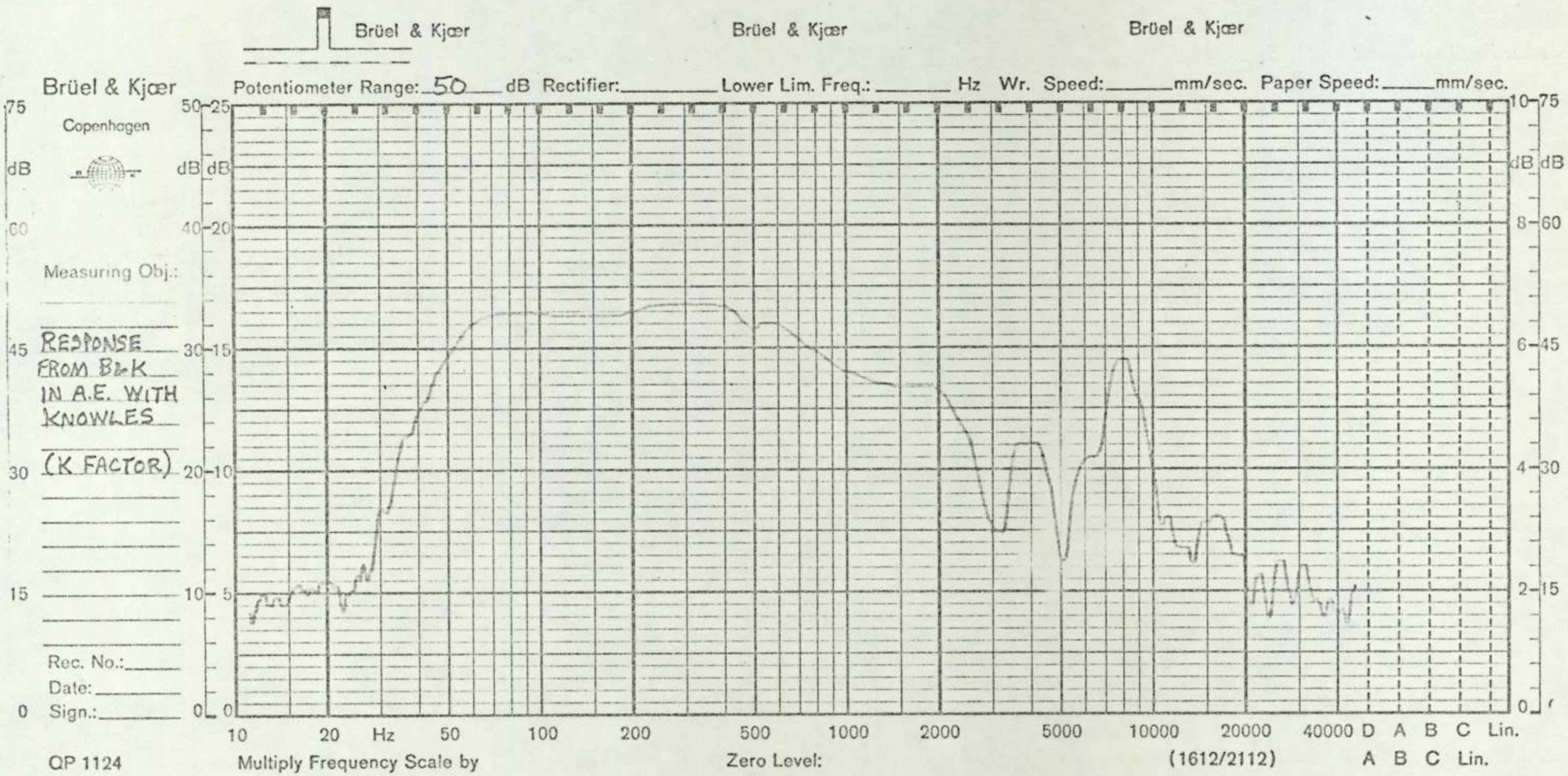

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: Lower Lim. Freq.: Hz Wr. Speed: mm/sec. Paper Speed: mm/sec.
Measuring Obj.:
RESPONSE FROM B&K IN A.E. WITH KNOWLES (K FACTOR)
Rec. No.:
Date:
Sign.:
75 60 45 30 15 0
50 40 30 20 10 0
25 20 15 10 5 0
dB dB dB
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
10 8 6 4 2 0
75 60 45 30 15
dB dB
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 15.3

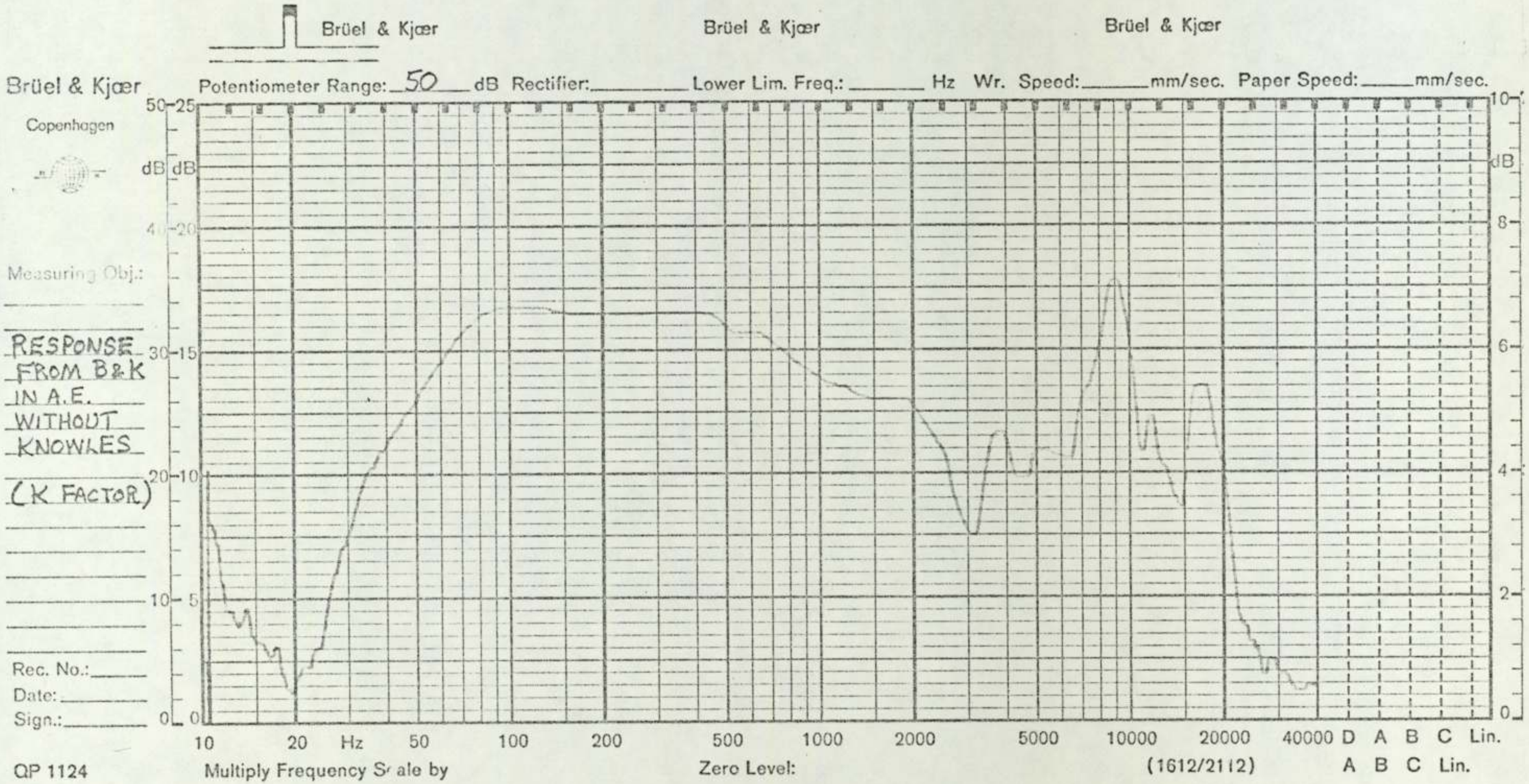

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: Lower Lim. Freq.: Hz Wr. Speed: mm/sec. Paper Speed: mm/sec.
Measuring Obj.:
RESPONSE FROM B&K IN A.E. WITHOUT KNOWLES
(K FACTOR)
Rec. No.:
Date:
Sign.:
dB dB
50 25
40 20
30 15
20 10
10 5
0 0
dB
10
8
6
4
2
0
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

FIG 16.3

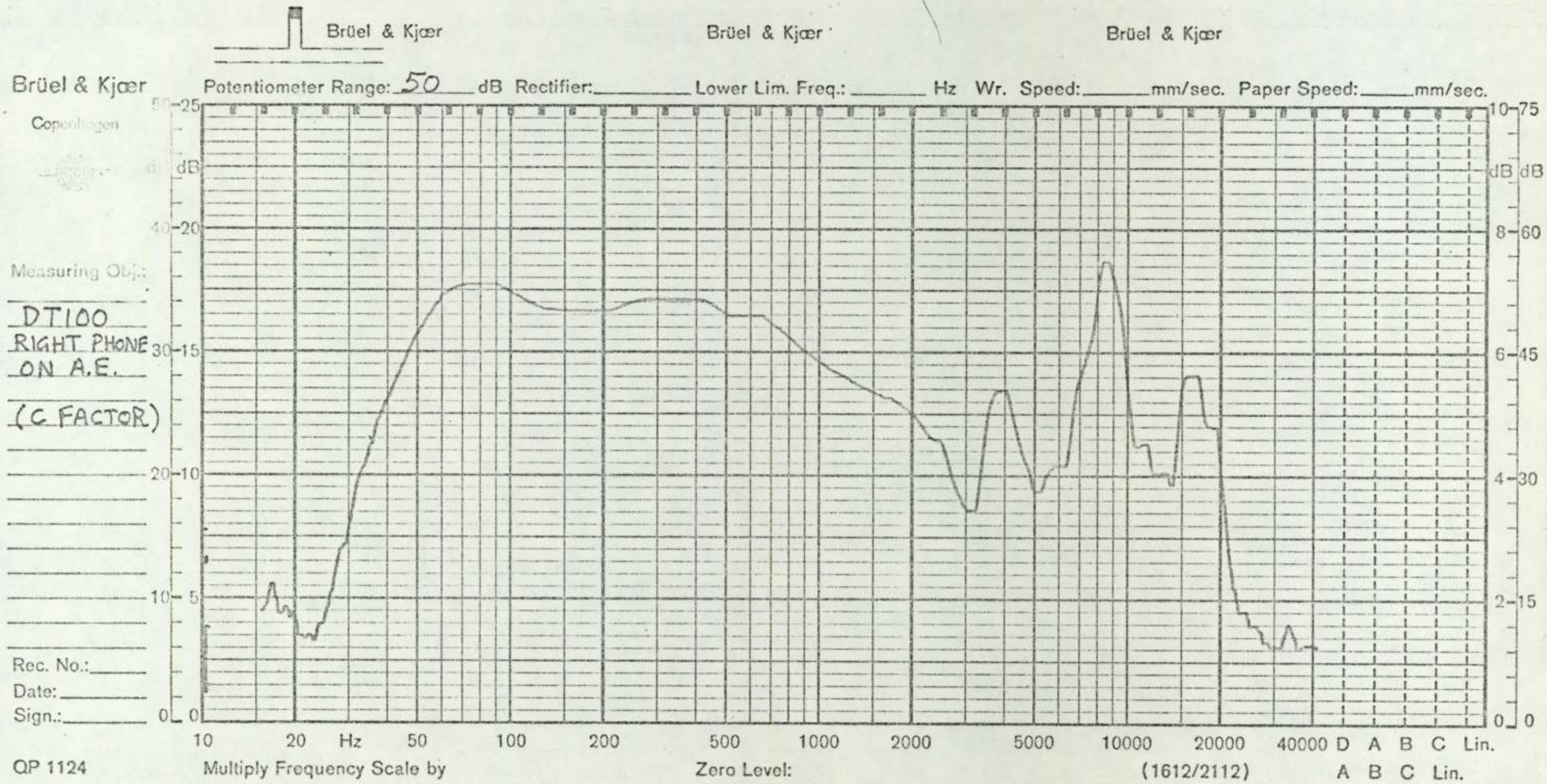

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: Lower Lim. Freq.: Hz Wr. Speed: mm/sec. Paper Speed: mm/sec.
Measuring Obj.:
DT100
RIGHT PHONE
ON A.E.
(C FACTOR)
Rec. No.:
Date:
Sign.:
dB
dB dB
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)

Fig 17.3

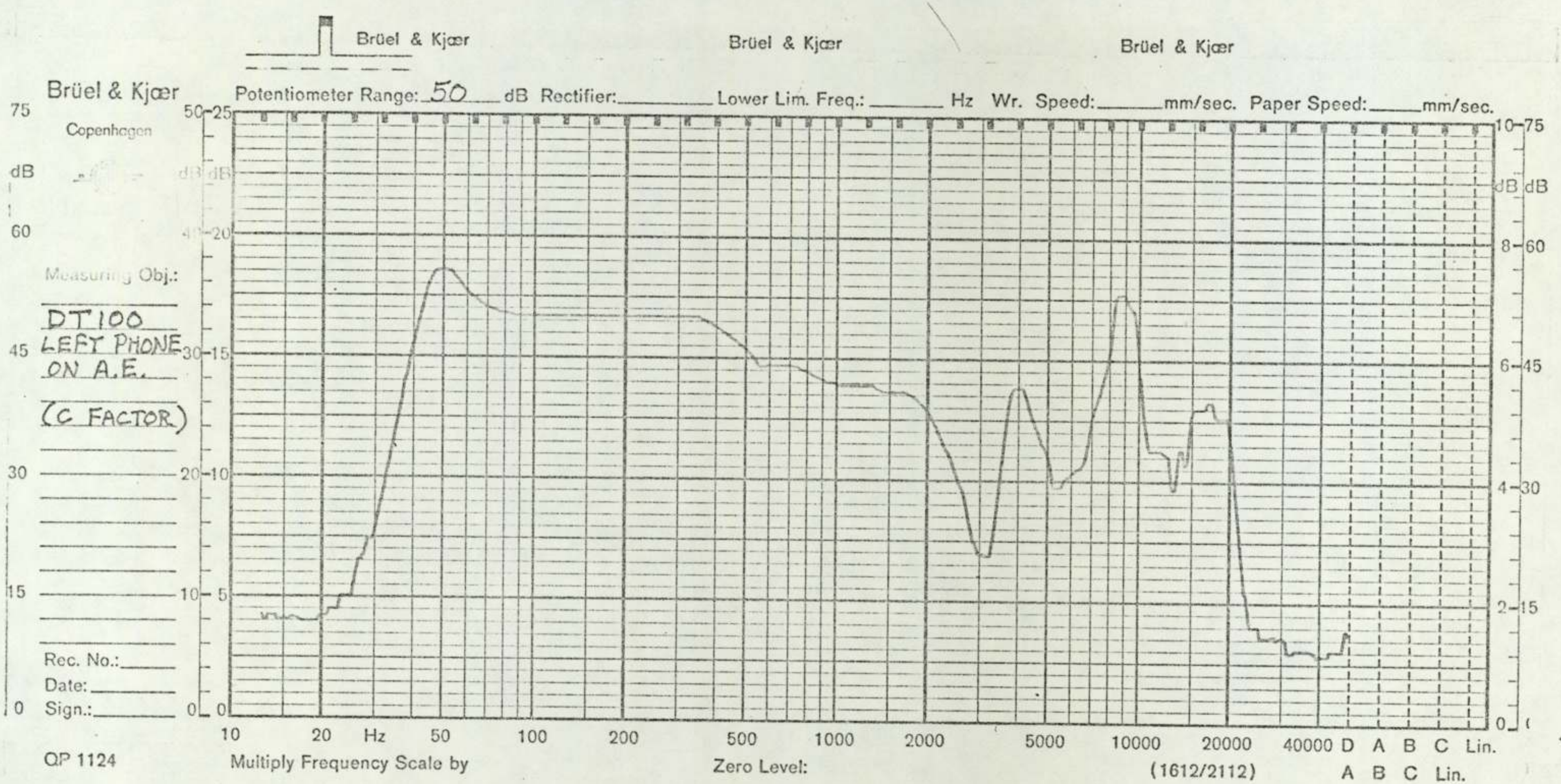

Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Brüel & Kjær
Copenhagen
Potentiometer Range: 50 dB Rectifier: Lower Lim. Freq.: Hz Wr. Speed: mm/sec. Paper Speed: mm/sec.
Measuring Obj.:
DT100
LEFT PHONE
ON A.E.
(C FACTOR)
Rec. No.:
Date:
Sign.:
QP 1124
Multiply Frequency Scale by
Zero Level:
(1612/2112)
10 20 Hz 50 100 200 500 1000 2000 5000 10000 20000 40000
D A B C Lin.
A B C Lin.
dB

FIG 18.3

P.O. Freq. (HZ.)	Col.1 (dB)	Col.2 (dB)	"K" Col.3 (dB)	Col.4 (dB)	Col.5 (dB)	"C" Col.6 (dB)
100	33.4	33	0.4	35	33.2	-1.8
200	33	33	0	33.2	33.2	0
300	33	33.6	-0.6	34.2	33.2	-1
400	33	33.2	-0.2	34.2	32.6	-2
500	32	31.6	0.4	33	30.8	-2.2
600	31.4	32	-0.6	33	29.4	-3.6
800	29.6	29.8	-0.2	31	29	-2
1000	27.6	28	-0.4	29.2	28	-1.2
1250	26.8	27	-0.2	27.6	27.8	0.2
1600	26	26.8	-0.8	26.4	27.2	0.8
2000	25.4	27.6	-2.2	25	25.4	0.4
2500	22	23	-1	22	20	-2
3000	15	15	0	17	14	-3
3500	23	22	1	27	22	-5
4000	22	22	0	27	27.6	0.6
5000	22	21	1	18.8	22	1.2
6000	21.2	20.8	0.4	20.8	20.6	-0.2
8000	30	29	1	35	30	-5

TABLE 1.3 CORRECTION FACTORS "K" AND "C"

Note, Col.1 shows response with microphone absent
Col.2 shows response with microphone present
Col.3 = Col.1 - Col.2
Col.4 shows response from the right headphone
Col.5 shows response from the left headphone
Col.6 = Col.5 - Col.4
Sr(corrected) = Sr(uncorrected) + K
Sr(left) = Sr(right) + C

P.O. Freq. (Hz)	Col.1 Vc dB	Col.2 Em dBuV	Col.3 Em -dBV	Col.4 Ss dBV/Pa	Col.5 Sr* dBPa/V	Col.6 K dB	Col.7 Sr dBPa/V
100	26.6	68.4	51.6	-37.5	-3.1	0.4	-2.7
200	33	74.8	45.2	-37.5	3.3	0	3.3
300	33.2	75	45	-37.5	3.5	-0.6	2.9
400	33.4	75.2	44.8	-37.5	3.7	-0.2	3.5
500	33.4	75.2	44.8	-37.5	3.7	0.4	4.1
600	33.4	75.2	44.8	-37.5	3.7	-0.6	3.1
800	33	74.8	45.2	-37.5	3.3	-0.2	3.1
1000	32	73.8	46.2	-37.5	2.3	-0.4	1.9
1250	30.5	72.3	47.7	-37.5	0.8	-0.2	0.6
1600	30	71.8	48.2	-37.5	0.3	-0.8	-0.5
2000	30	71.8	48.2	-37.5	0.3	-2.2	-1.9
2500	30	71.8	48.2	-37.5	0.3	-1	-0.7
3000	28.6	70.4	49.6	-37.5	-1.1	0	-1.1
3500	27	68.8	51.2	-37.5	-2.7	1	-1.7
4000	29	70.8	49.2	-38	-0.2	0	-0.2
5000	30	71.8	48.2	-38.5	1.3	1	2.3
6000	28.7	70.5	49.5	-39	0.5	0.4	0.9
8000	29.8	71.6	48.4	-39	1.6	1	2.6

TABLE 2.3 Calculating Sr for DT100 headphones (right ear)

Note, Es=-11dBV (From average of real ear responses)
Col.1 shows readings obtained from the chart recorder
Col.2 is given by Em(dBuV) = Vc(dB)+41.8
Col.3 is given by Em(-dBV) = Em(dBuV)-120
Col.4 shows Ss for the Knowles microphone
Col.5 shows Sr uncorrected (Sr*=Em-Es-Ss)
Col.6 shows the correction factor "K"
Col.7 shows Sr corrected (Sr=Sr*+K)

P.O. Freq. (Hz)	Sr (Right) dBPa/V	"C" dB	Sr (Left) dBPa/V
100	-2.7	-1.8	-4.5
200	3.3	0	3.3
300	2.9	-1	1.9
400	3.5	-2	1.5
500	4.1	-2.2	1.9
600	3.1	-3.6	-0.5
800	3.1	-2	1.1
1000	1.9	-1.2	0.7
1250	0.6	0.2	0.8
1600	-0.5	0.8	0.3
2000	-1.9	0.4	-1.5
2500	-0.7	-2	-2.7
3000	-1.1	-3	-4.1
3500	-1.7	-5	-6.7
4000	-0.2	0.6	0.4
5000	2.3	1.2	3.5
6000	0.9	-0.2	0.7
8000	2.6	-5	-2.4

TABLE 3.3 Sr for the DT100 headphones (both ears) where Sr(left) = Sr(right)+C

FREQ.(Hz)	Sr(left)	Sr(right)
100	-4.5	-2,7
125	-2.5	-1.2
160	0.2	0.9
200	3.3	3.3
250	2.6	3.1
315	1.8	3.0
400	1.5	3.5
500	1.9	4.1
630	-0.3	3.1
800	1.1	3.1
1000	0.7	1.9
1250	0.8	0.6
1600	0.3	-0.5
2000	-1.5	-1.9
2500	-2.7	-0.7
3150	-4.9	-1.3
4000	0.4	-0.2
5000	3.5	2.3
6300	0.2	1.2
8000	-2.4	2.6

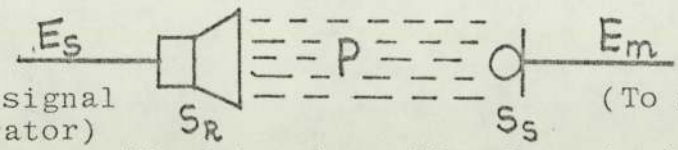
TABLE 4.3 Sr for the DT100 headphones

CALIBRATING THE DT100 HEADPHONES

(Obtaining the receiving sensitivity (S_R) on a real ear).

The real ear receiving response was obtained from the chart recorder, using the Knowles microphone to monitor the sound pressure.

Consider the set-up:



(From signal generator) (Headphone) (Knowles mic.) (To measuring amplifier)

On a linear basis,

$$S_R = P/E_S \quad \therefore \quad P = E_S . S_R \qquad (1)$$

$$S_S = Em/P \quad \therefore \quad P = Em/S_S \qquad (2)$$

Equating 1 and 2 gives

$$E_S . S_R = Em/S_S$$

$$\therefore \quad S_R = \frac{Em}{E_S . S_S}$$

On a dB basis,

$$\underset{(dBPa/V)}{S_R} = \underset{(dBV)}{Em} - \underset{(dBV)}{E_S} - \underset{(dBV/pa)}{S_S}$$

Note, With E_S = - 11dBV at 500 Hz (the peak of the response), Em = 75 dBμV on the measuring amplifier. On the chart recorder, V_c = 35.6 dB. Em - $V_c \doteq 39.4$, therefore the true dBμV from the chart recorder is $V_c + 39.4$.

CHAPTER 3. SECTION 2.

DESCRIPTION OF THE EXPERIMENTS IN PREFERRED LISTENING LEVEL, AND INITIAL RESULTS.

2. DESCRIPTION OF THE EXPERIMENTS IN PREFERRED LISTENING LEVEL

2.1 These consisted of three sets of subjective tests, with the subjects receiving the speech material under various noise conditions, from the Beyer DT100 headphones.

Set 1

The subjects consisted of 4 males and 4 females aged between 20 and 45 years. Each subject received speech and noise in the right ear, and noise alone in the left ear. The speech S was presented at 10 random levels, with the noise at two levels, N1 and N2. Thus there were four distinct treatments.

i.e. N1 S+N1 ------A

N1 S+N2 ------B

N2 S+N1 ------C

N2 S+N2 ------D

These four treatments ABC and D were presented in random order to the eight subjects. For each treatment, the speech was presented at 10 randomly selected levels from a certain range.

Latin squares were used to randomise the treatments and the order of level presentation. (Computer programs P1 and P2 were constructed to generate the latin squares). Thus 8 re-arrangements of ABCD were required. (Note, the total number of re-arrangements possible is 4P4 = 4!/0!= 24. This fills six latin squares). For 8 re-arrangements, only two latin square were required. (See Fig. 19.3).

With four treatments presented to 8 subjects and

LATIN SQR-ALPHALATIN SQR-ALPHA

```
 100 REM LATIN SQR-ALPHA
 110 PRINT"□▣  TO GENERATE A LATIN SQUARE  ▣▣"
 120 INPUT"NUMBER OF ELEMENTS ON ONE SIDE ";E
 130 DIMA$(2*E),B$(E,E),R$(E,E),C$(E,E)
 140 FORI=1TOE:READA$(I):A$(I+E)=A$(I):NEXTI
 150 PRINT"▣▣▣ GENERATING "
 160 OPEN3,4:CMD3
 170 PRINT"LATIN SQUARE":PRINT"************"
 180 PRINT#3:CLOSE3
 190 FORJ=1TOE:FORI=1TOE
 200 B$(J,I)=A$(I+J-1)
 210 NEXTI:NEXTJ
 220 REM GENERATE RANDOM PERMUTATION
 230 OPEN3,4:CMD3
 240 PRINT"O▣RDER OF ROW CHANGE IS:"
 250 GOSUB580
 260 PRINT#3:CLOSE3
 270 REM INTERCHANGE ROWS
 280 FORJ=1TOE:FORI=1TOE
 290 L=A(J):R$(J,I)=B$(L,I)
 300 NEXTI:NEXTJ
 310 REM INTERCHANGE ROWS WITH COLUMNS
 320 REM FEED R BACK IN TO B
 330 FORJ=1TOE:FORI=1TOE
 340 B$(J,I)=R$(I,J)
 350 NEXTI:NEXTJ
 360 REM GENERATE RANDOM PERMUTATION
 370 OPEN3,4:CMD3
 380 PRINT"O▣RDER OF COLUMN CHANGE IS:"
 390 GOSUB580
 400 PRINT#3:CLOSE3
 410 REM INTERCHANGE COLUMNS
 420 FORJ=1TOE:FORI=1TOE
 430 L=A(J):C$(J,I)=B$(L,I)
 440 NEXTI:NEXTJ
 450 REM CHANGE COLUMNS BACK TO ROWS
 460 REM FEED C BACK INTO B
 470 FORJ=1TOE:FORI=1TOE
 480 B$(J,I)=C$(I,J)
 490 NEXTI:NEXTJ
 500 REM LATIN SQUARE NOW COMPLETE
 510 REM PRINTING-OUT
 520 OPEN3,4:CMD3:PRINT
 530 FORJ=1TOE:PRINT"▣"J"▣   ";
 540 FORI=1TOE:PRINTB$(J,I)"  ";:NEXTI
 550 PRINT:PRINT:NEXTJ
 560 PRINT#3:CLOSE3
 570 END
 580 FORP=1TOE
 590 S=RND(VAL(TI$)/317)
 600 K=INT(E*RND(-RND(S))+1)
 610 A(P)=K
 620 FORQ=P-1TO1STEP-1
 630 IFA(P)=A(Q)THEN600
 640 NEXTQ:NEXTP
 650 FORP=1TOE:PRINTA(P);:NEXTP
 660 RETURN
 670 DATA A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z
 680 REM D.C.HOWSE  13-JAN-1981
READY.
```

PROGRAM P1

(TO GENERATE AN ALPHABETIC LATIN SQUARE)

LATIN SQR-DATALATIN SQR-DATA

```
 100 REM LATIN SQR-DATA
 110 PRINT"   TO GENERATE A LATIN SQUARE   "
 120 INPUT"NUMBER OF ELEMENTS ON ONE SIDE ";E
 130 DIMA(2*E),B(E,E),R(E,E),C(E,E)
 140 PRINT"TYPE IN YOUR "E" NUMBERS"
 150 FORI=1TOE
 160 PRINT"ELEMENT "I;:INPUTA(I)
 170 A(I+E)=A(I):NEXTI
 180 PRINT" GENERATING "
 190 OPEN3,4:CMD3
 200 PRINT"LATIN SQUARE":PRINT"************"
 210 PRINT#3:CLOSE3
 220 FORJ=1TOE:FORI=1TOE
 230 B(J,I)=A(I+J-1)
 240 NEXTI:NEXTJ
 250 REM GENERATE RANDOM PERMUTATION
 260 OPEN3,4:CMD3
 270 PRINT"ORDER OF ROW CHANGE IS:"
 280 GOSUB610
 290 PRINT#3:CLOSE3
 300 REM INTERCHANGE ROWS
 310 FORJ=1TOE:FORI=1TOE
 320 L=A(J):R(J,I)=B(L,I)
 330 NEXTI:NEXTJ
 340 REM INTERCHANGE ROWS WITH COLUMNS
 350 REM FEED R BACK IN TO B
 360 FORJ=1TOE:FORI=1TOE
 370 B(J,I)=R(I,J)
 380 NEXTI:NEXTJ
 390 REM GENERATE RANDOM PERMUTATION
 400 OPEN3,4:CMD3
 410 PRINT"ORDER OF COLUMN CHANGE IS:"
 420 GOSUB610
 430 PRINT#3:CLOSE3
 440 REM INTERCHANGE COLUMNS
 450 FORJ=1TOE:FORI=1TOE
 460 L=A(J):C(J,I)=B(L,I)
 470 NEXTI:NEXTJ
 480 REM CHANGE COLUMNS BACK TO ROWS
 490 REM FEED C BACK INTO B
 500 FORJ=1TOE:FORI=1TOE
 510 B(J,I)=C(I,J)
 520 NEXTI:NEXTJ
 530 REM LATIN SQUARE NOW COMPLETE
 540 REM PRINTING-OUT
 550 OPEN3,4:CMD3:PRINT
 560 FORJ=1TOE:PRINT""J"  ";
 570 FORI=1TOE:PRINTB(J,I);:NEXTI
 580 PRINT:PRINT:NEXTJ
 590 PRINT#3:CLOSE3
 600 END
 610 FORP=1TOE
 620 S=RND(VAL(TI$)/317)
 630 K=INT(E*RND(-RND(S))+1)
 640 A(P)=K
 650 FORQ=P-1TO1STEP-1
 660 IFA(P)=A(Q)THEN630
 670 NEXTQ:NEXTP
 680 FORP=1TOE:PRINTA(P);:NEXTP
 690 RETURN
 700 REM D.C.HOWSE  12-JAN-1981
READY.
```

PROGRAM P2

(TO GENERATE A NUMERIC LATIN SQUARE)

LATIN SQUARE
****

Order of row change is:
 3 1 4 2

Order of column change is:
 4 2 3 1

[illegible]	B	D	A	C
[illegible]	D	B	C	A
[illegible]	C	A	B	D
[illegible]	A	C	D	B

LATIN SQUARE
****

Order of row change is:
 2 1 3 4

Order of column change is:
 4 3 1 2

[illegible]	A	D	B	C
[illegible]	D	C	A	B
[illegible]	B	A	C	D
[illegible]	C	B	D	A

FIG. 19.3

FIG. 20.3

LATIN SQUARE
****

Order of row change is:
1 10 8 6 4 9 7 2 5 3

Order of column change is:
7 8 4 5 10 6 3 1 9 2

[illegible]	40	60	71	91	0	20	51	11	80	31
[illegible]	20	40	51	71	80	91	31	0	60	11
[illegible]	71	91	11	31	40	51	0	60	20	80
[illegible]	31	51	80	0	91	11	60	20	71	40
[illegible]	0	11	40	60	51	80	20	71	31	91
[illegible]	91	20	31	51	60	71	11	80	40	0
[illegible]	51	71	0	11	20	31	80	40	91	60
[illegible]	60	80	91	20	11	40	71	31	0	51
[illegible]	11	31	60	80	71	0	40	91	51	20
[illegible]	80	0	20	40	31	60	91	51	11	71

LATIN SQUARE
****

Order of row change is:
1 4 2 9 10 8 7 6 3 5

Order of column change is:
4 6 10 8 1 9 7 3 5 2

[illegible]	71	20	0	60	11	80	40	51	91	31
[illegible]	40	80	51	11	71	31	0	20	60	91
[illegible]	91	40	11	80	31	0	60	71	20	51
[illegible]	31	71	60	20	80	40	91	11	51	0
[illegible]	51	91	80	40	0	60	20	31	71	11
[illegible]	11	51	40	91	60	20	71	0	31	80
[illegible]	0	31	20	71	40	91	51	80	11	60
[illegible]	80	11	91	51	20	71	31	60	0	40
[illegible]	20	60	31	0	51	11	80	91	40	71
[illegible]	60	0	71	31	91	51	11	40	80	20

LATIN SQUARE
****

FIG. 21.3

Order of row change is:
9 10 6 8 7 1 5 3 4 2

Order of column change is:
1 2 7 3 6 8 9 4 5 10

[illegible]	80	0	91	11	71	20	40	31	51	60
[illegible]	0	11	20	31	91	40	60	51	71	80
[illegible]	20	40	31	60	11	51	71	80	0	91
[illegible]	60	80	71	0	51	91	20	11	31	40
[illegible]	40	60	51	80	31	71	91	0	11	20
[illegible]	11	31	40	51	20	60	80	71	91	0
[illegible]	91	20	11	40	0	31	51	60	80	71
[illegible]	51	71	80	91	60	0	11	20	40	31
[illegible]	71	91	0	20	80	11	31	40	60	51
[illegible]	31	51	60	71	40	80	0	91	20	11

LATIN SQUARE
****

Order of row change is:
4 10 7 6 3 9 8 1 2 5

Order of column change is:
7 2 8 5 10 4 9 6 3 1

[illegible]	0	91	11	60	51	40	31	80	20	71
[illegible]	20	11	40	71	80	51	60	91	31	0
[illegible]	51	60	71	11	20	0	91	31	80	40
[illegible]	31	40	51	0	91	80	71	11	60	20
[illegible]	80	71	0	40	31	20	11	60	91	51
[illegible]	91	0	20	51	60	31	40	71	11	80
[illegible]	71	80	91	31	40	11	20	51	0	60
[illegible]	40	31	60	91	0	71	80	20	51	11
[illegible]	60	51	80	20	11	91	0	40	71	31
[illegible]	11	20	31	80	71	60	51	0	40	91

each treatment given at 10 random speech levels, this means that 32 lists of 10 random levles were required. This number was covered by generating four 10 x 10 latin squares giving 40 lists. (See Figs. 20.3 and 21.3).

The Range of Speech Levels

From a preliminary trial, the following range was used. (The levels given are in - dBV).

10 14 18 22 26 30 34 38 42 46

These ten levels cover a range of 36 dB in steps of 4 dB.

To assist in quick selection of these levels at random, a unit called a "random attenuator" was used. This is made up from a set of switchable attenuators. Each of the ten attenuators is preset to the required value and then brought into circuit with a ten position selector switch. The unit can present attenuations of 2-20 dB in steps of 2 dB for the ten switchable settings. It also has a further common input attenuator of 2-20 dB.

To accommodate the 36 dB range, the switches were set as follows:

ATTEN. REQD. (DB)	4	8	12	16	20	24	28	32	36	40
ATTEN. NUMBER (ON SELECTOR)	1	2	3	4	5	6	7	8	9	10
ATTENUATION (dB)	2	6	10	14	18	4	8	12	16	20
INPUT ATTEN.(dB)	2	2	2	2	2	20	20	20	20	20

By arranging the input speech voltage to be at - 6dBV, the above attenuations will give the required range of speech levels.

The value of attenuation required from the switchable attenuator is set on a thumbwheel switch having 10 positions, numbered 1 to 9 to 0. (Where 1 corresponds to 2 dB and 0 to 20 dB). The input attenuator is also controlled by a similar thumbwheel switch. A table of switch positions versus speech level can now be set up.

i.e.

SPEECH LEVEL (-dBV)	10	14	18	22	26	30	34	38	42	46
SWITCH POSITIONS	11	31	51	71	91	20	40	60	80	00

Note, for the switch positions, the 1st digit is the selected attenuator setting, the 2nd digit is the input attenuator setting.

These switch position numbers were then put directly into the latin square, and so a list of random switch positions was obtained.

Noise Levels

For the noise levels N1 and N2, value of 40 dBA and 60 dBA were chosen. (These represent sound levels in the ear judged to be quiet and fairly loud). In order to know what the equivalent amount of electrical noise (in dBV) would be to feed across the headphones to produce these sound pressures, a tabular approach was used. The following section explains this approach.

2.2 Determining the Noise Voltage (V_N) Across the Headphones to Produce a Noise Pressure (P_N) Inside Them on an Ear

The approach used determines the levels at different frequency points in the ISO range. The spectrum density of the Gaussian noise used was initially considered and put at an arbitrary value of 1μV/Hz. (The spectrum is flat). Multiplying this by the bandwith represented by the ISO centre frequency gave the power in that band (W_3). The equivalent voltage (V_f) at each frequency point was then found as follows:

$$W_B(\mu W) = \frac{V_f^{\,2}}{R} \times 10^6 \qquad (R = 600\Omega)$$

$$\therefore\ 10 \log W_B = 10 \log \left[\frac{V_f^{\,2}}{R} \times 10^6 \right]$$

$$= 20 \log V_f - 10 \log R + 10 \log 10^6$$

i.e. $\underset{(dB\mu W)}{W_B} = \underset{(dBV)}{V_f} - 27.8 + 60$

$$\therefore\ \underset{(dBV)}{V_f} = \underset{(dB\mu W)}{W_B} - 32.2$$

By taking the receive sensitivity of the headphone into account, the unweighted pressure in the ear was found.

Applying the 'A' weightings gave the weighted pressure P_f in the ear for each frequency. The rms sound pressure in the ear was then found in the following way: (Note, the rms is taken rather than the average value since it gives rise to sound intensity or loudness - in the same way that rms voltage is used to calculate electrical power).

Have P_f in dBA (relative to one Pascal) at 20 frequencies.

Convert to a linear basis, is. $10^{P_f/20}$

Squaring gives $10^{P_f/10} = P_Q^2$ (say)

Obtain $\sum_{1}^{20} P_Q^2 = S$, say

Then, (for a complex waveform), rms value = $S^{\frac{1}{2}}$

Converting back to dBA,

$$P_N = 20 \log_{10}(S)^{\frac{1}{2}} = 10 \log_{10} S$$

Adding 94 gives P_N in dBA above reference acoustic pressure.

Note, by finding the rms value of V_f, the level V_N (in dVB) to inject across the headphones (of 600Ω impedance) is given to give P_N. (Required to be 40 dBA and 60 dBA for the experiment). The tabulations used are shown in Tables 5.3 and 6.3.

From Table 6.3

V_N = 10 log 5.34 = <u>7.3 dBV*</u>

I.S.O. Freq. (Hz.)	B.W. (Hz)	Wb dBuW	Vf -dBV	Sr right dBPa/V	Vf+Sr -dBPa	A weight dB	Pf -dBA
100	22.4	13.5	18.7	-2.7	21.4	-19.1	40.5
125	29.6	14.7	17.5	-1.2	18.7	-17.1	35.8
160	37.5	15.7	16.5	0.9	15.6	-14.2	29.8
200	44.7	16.5	15.7	3.3	12.4	-10.9	23.3
250	57	17.5	14.7	3.1	11.6	-8.9	20.5
315	74.3	18.7	13.5	3.0	10.5	-6.7	17.2
400	92.2	19.6	12.6	3.5	9.1	-4.8	13.9
500	114	20.6	11.6	4.1	7.5	-3.2	10.7
630	149	21.7	10.5	3.1	7.4	-2.0	9.4
800	184	22.7	9.5	3.1	6.4	-0.8	7.2
1000	224	23.5	8.7	1.9	6.8	0	6.8
1250	296	24.7	7.5	0.6	6.9	0.6	6.3
1600	375	25.7	6.5	-0.5	7.0	1.0	6.0
2000	447	26.5	5.7	-1.9	7.6	1.2	6.4
2500	570	27.6	4.6	-0.7	5.3	1.3	4.0
3150	743	28.7	3.5	-1.3	4.8	1.2	3.6
4000	922	29.6	2.6	-0.2	2.8	1.0	1.8
5000	1140	30.6	1.6	2.3	-0.7	0.5	-1.2
6300	1490	31.7	0.5	1.2	-0.7	0	-0.7
8000	1840	32.7	-0.5	2.6	-3.1	-1.1	-2.0

TABLE 5.3 To find the pressure in the right ear for a noise spectrum density of 1uW/Hz in 600 ohms

Note, Wb is 10log10 of the power per band
Vf = Wb-32.2
Pf = Vf+Sr+A

I.S.O. Freq. (Hz)	$10^{Vf/10}$ ($\times 10^{-2}$)	$10^{Pf/10}$ ($\times 10^{-3}$)
100	1.4	0.09
125	1.8	0.26
160	2.2	1.05
200	2.7	4.68
250	3.4	8.91
315	4.5	19.1
400	5.5	40.7
500	6.9	85.1
630	8.9	114.8
800	11.2	191
1000	13.5	209
1250	17.8	234
1600	22.4	251
2000	26.9	229
2500	34.7	398
3150	44.7	437
4000	55	661
5000	69.2	1318
6300	89.1	1175
8000	112.2	1584
	Sum=534	Sum=6961.69

TABLE 6.3 To find the rms of Vf and Pf in Table 5.3

P.O. Freq. (Hz)	(Ss600) Smj -dBV/Pa
100	-
200	19.8
300	16.3
400	13.8
500	11.8
600	10.8
800	8.8
1000	7.8
1250	6.8
1600	4.8
2000	1.3
2500	-0.7
3000	2.8
3500	14.8
4000	19.8
5000	19.8
6000	29.8
8000	29.8

TABLE 7.3 Sending sensitivity of the handset used to make the speech recordings (SLR = 3.93)

$P_N = 10 \log 6.96 + 94 = 102.4$ dBA

Thus, for $P_N = 40$ dBA, $V_N = 7.3-(102.4 - 40) = \underline{-55.1 \text{ dBV}}$

$P_N = 60$ dBA, $V_N = 7.3-(102.4 - 60) = \underline{-35.1 \text{ dBV}}$

*Note, V_N may also be found from $\sum_{1}^{20}$(Bandwidth Power) = P_B, say, and finding $20 \log\left[\sqrt{P_B \times 600}\right]$.

i.e. Adding up bandwidth powers gives $P_B = 8851.7$

$\therefore V_N = 10 \log(8851.7 \times 600 \times 10^{-6})$

$= \underline{7.3 \text{ dBV}}$

This value of V_N is the rms noise voltage in a bandwidth of 100 Hz - 8 kHz.

For the experiment an "Elgenco" Type 624A noise generator was used having a Gaussian distribution. The level at the output terminals was quoted to be within ± 1 dB over the range 20 Hz - 20 kHz. An output meter calibrated in rms volts is included in the instrument. In order to have a better calibration, a bandpass filter covering the ISO frequency range was connected to the output and the level then measured on the SV5B. This then gave the required readings for V_N.

Relevant Computer Programs

Program P3 calculates the spectrum density from centre ISO frequency levels obtained via the B & K bandpass filter set, and stores it in a data file.

Program P4 sets up a data file containing a spectrum density that is entered in from the keyboard.

Program P5 sets up a data file containing the receive sensitivities for the DT100 headphones. (See Table 4.3).

Program P6 then calculates the sound pressure level in the ear due to a particular signal spectrum applied to the headphones.

Subjective Rating - Opinion Scores

The subjects opinions on the test conditions were based on a loudness preference scale. (This is opinion scale number 4A in the British Post Office).

i.e. A Much louder than preferred

B Louder than preferred

C Preferred

D Quieter than preferred

E Much quieter than preferred.

A further scale was used for a "quality" basis. (Opinion scale 12).

i.e. A Excellent

B Good

C Fair

D Poor

E Bad

```
SD&*SD&*

100 REM SD&RMS CALC
110 CLR:CR$=CHR$(13):R=0
120 PRINT"□■ TO FIND SPECTRUM DENSITY              "
130 PRINT"■  FOR REPRESENTATIVE LEVELS AT          "
140 PRINT"■    CENTRE ISO FREQUENCIES              "
150 PRINT"■       AND OVERALL RMS VOLTAGE          "
160 DIMF(2,20),V1(20),V2(20)
170 REM ISO FREQUENCIES AND BANDWIDTHS
180 DATA 100,125,160,200,250,315,400,500,630,800
190 DATA 1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
200 DATA 22.4,29.6,37.5,44.7,57,74.3,92.2,114,149,184
210 DATA 224,296,375,447,570,743,922,1140,1490,1840
220 REM READ FREQUENCY DATA
230 FORJ=1TO2:FORI=1TO20:READF(J,I):NEXTI:NEXTJ
240 REM SPECTRUM DENSITY CALCULATIONS
250 PRINT"■■TYPE IN FILENAME ";
260 INPUTF1$
270 PRINT"■TYPE IN LEVEL (IN DBV)
280 FORJ=1TO20:PRINTF(1,J)"HZ ";:INPUTV1(J)
290 R=R+10↑(V1(J)/10)
300 V2(J)=V1(J)*2-10*LOG(F(2,J))/LOG(10):NEXTJ
310 OPEN3,4:OPEN4,4,2:OPEN5,4,1
320 D1$="                  ":D2$="               "
330 PRINT#3,"SPECTRUM FOR "F1$:PRINT#3
340 PRINT#3,"FREQ.(HZ)       BAND LEVEL (DBV)          SPECTRUM DENSITY
350 PRINT#3,"                                           (DBV↑2/HZ)
360 PRINT#4,"9999";D1$;"S99.9";D2$;"S999.9"
370 FORJ=1TO20
380 PRINT#5,F(1,J),V1(J),V2(J)
390 NEXTJ:PRINT#3
400 R1=10*LOG(R)/LOG(10):R2=INT(10*R1+0.5)/10
410 PRINT#3:PRINT#3,"RMS="R2"DBV"
420 CLOSE5:CLOSE4
430 PRINT#3:CLOSE3
440 INPUT"■SAVE SPECTRUM";S$
450 IFS$="Y"THEN480
460 IFS$="N"THEN520
470 GOTO440
480 F$="0:"+F1$+",S,W":OPEN2,8,2,F$
490 PRINT#2,F1$;CR$;
500 FORJ=1TO20:PRINT#2,V2(J);CR$;:NEXTJ:CLOSE2
510 PRINT"■"F1$" NOW STORED ON DISK"
520 PRINT"■■*****END*****":END
READY.
```

PROGRAM P3

```
I0I*

 100 REM DENS SET-UP
 110 REM SET-UP OF SPECTRUM DENSITY
 120 PRINT"  SET-UP OF SPECTRUM DENSITY (DBV↑2/HZ) "
 130 INPUT" TYPE IN TODAY'S DATE ";DA$
 140 INPUT" TYPE IN FILENAME ";F1$
 150 CR$=CHR$(13):PRINT
 160 DEF FNC(X)=INT(10*X+.5)/10
 170 DIMF(20),S(20)
 180 REM ISO FREQUENCIES
 190 DATA 100,125,160,200,250,315,400,500,630,800
 200 DATA 1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
 210 REM READ FREQUENCY DATA
 220 FORJ=1TO20:READF(J):NEXTJ
 230 REM INPUT SPECTRUM S(J) DBV↑2/HZ
 240 PRINT"TYPE IN DENSITY FOR EACH OF THE"
 250 PRINT" FOLLOWING REPRESENTATIVE FREQUENCIES "
 260 FORJ=1TO20:PRINTF(J);"HZ",
 270 OPEN3,0:INPUT#3,S(J):CLOSE3:PRINT:NEXTJ
 280 F$="@0:"+F1$+",S,W":OPEN2,8,2,F$:PRINT" WRITING FILE ";F1$
 290 PRINT#2,F1$;CR$;
 300 FORJ=1TO20:PRINT#2,S(J);CR$;:NEXTJ:CLOSE2
 310 OPEN3,4
 320 OPEN4,4,2
 330 OPEN5,4,1
 340 D$="      "
 350 PRINT#3,F1$:PRINT#3
 360 PRINT#3," FREQ.    SPECTRUM "
 370 PRINT#3,"  HZ      DBV↑2/HZ "
 380 PRINT#3
 390 PRINT#4,"9999";D$;"S999.9"
 400 FORI=1TO20:PRINT#5,F(I);
 410 PRINT#5,FNC(S(I));:PRINT#5
 420 NEXTI:PRINT#3
 430 CLOSE5:CLOSE4
 440 PRINT#3,;DA$:PRINT#3:CLOSE3
 450 PRINT"  *****END*****":END
READY.
```

PROGRAM P4

```
SR SE*SR SE*

 100 REM SR SET-UP
 110 PRINT"  SETTING-UP SR FOR BEYER DT100 "
 120 CLR:CR$=CHR$(13):F1$="SR-DT100"
 130 DIMF(20),S(2,20)
 140 DATA100,125,160,200,250,315,400,500,630,800
 150 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
 160 FORJ=1TO20:READF(J):NEXTJ
 170 REM SR(LEFT) FOR DT100
 180 DATA-4.5,-2.5,0.2,3.3,2.6,1.8,1.5,1.9,-0.3,1.1
 190 DATA0.7,0.8,0.3,-1.5,-2.7,-4.9,0.4,3.5,0.2,-2.4
 200 REM SR(RIGHT) FOR DT100
 210 DATA-2.7,-1.2,0.9,3.3,3.1,3.0,3.5,4.1,3.1,3.1
 220 DATA1.9,0.6,-0.5,-1.9,-0.7,-1.3,-0.2,2.3,1.2,2.6
 230 FORK=1TO2:FORJ=1TO20:READS(K,J):NEXTJ:NEXTK
 240 PRINT" SAVING DATA ON DISK (DRIVE 0)
 250 OPEN2,8,2,"@0:SR-DT100,S,W"
 260 PRINT#2,F1$;CR$;
 270 FORK=1TO2:FORJ=1TO20:PRINT#2,S(K,J);CR$;:NEXTJ:NEXTK
 280 CLOSE2
 290 INPUT" HARD COPY";HC$
 300 IFHC$="Y"THEN330
 310 IFHC$="N"THEN440
 320 GOTO290
 330 OPEN3,4:OPEN4,4,2:OPEN5,4,1
 340 PRINT#3,"SR FOR DT100":PRINT#3,"************":PRINT#3
 350 D1$="                ":D2$="          "
 360 PRINT#3,"FREQ.(HZ)        SR(LEFT)      SR(RIGHT)"
 370 PRINT#3,"______________   ____________  ______________"
 380 PRINT#4,"9999";D1$;"S99.9";D2$;"S99.9"
 390 FORJ=1TO20
 400 PRINT#5,F(J),S(1,J),S(2,J)
 410 NEXTJ:PRINT#3
 420 CLOSE5:CLOSE4
 430 PRINT#3:CLOSE3
 440 PRINT"   *****END*****":END
READY.
```

PROGRAM P.5

SPL*SPL*

```
100 REM SPL IN EAR
110 A$="  TO CALCULATE SPL IN EAR FROM SPECTRUM "
120 B$=" DENSITY ":PRINTA$:PRINTB$
130 OPEN15,8,15:REM DISK COMMAND CHANNEL
140 DEF FNC(X)=INT(10*X+.5)/10:LT=LOG(10)
150 DIMF(2,20),S(20),R(2,20),A(20),M(2)
160 REM ISO FREQUENCIES AND BANDWIDTHS
170 DATA 100,125,160,200,250,315,400,500,630,800
180 DATA 1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
190 DATA 22.4,29.6,37.5,44.7,57,74.3,92.2,114,149,184
200 DATA 224,296,375,447,570,743,922,1140,1490,1840
210 FORJ=1TO2:FORI=1TO20:READF(J,I):NEXTI:NEXTJ
220 REM 'A' WEIGHTS
230 DATA-19.1,-17.1,-14.2,-10.9,-8.9,-6.7,-4.8,-3.2,-2.0,-0.8
240 DATA0,0.6,1.0,1.2,1.3,1.2,1.0,0.5,0,-1.1
250 FORJ=1TO20:READA(J):NEXTJ
260 REM SPECTRUM DENSITY
270 PRINT"TYPE IN SPECTRUM DENSITY FILENAME
280 INPUTFD$:F1$=FD$:GOSUB610
290 INPUT#1,N$:PRINT""N$" FOUND"
300 FORJ=1TO20:INPUT#1,S(J):NEXTJ:CLOSE1
310 REM INPUT SR FOR DT100
320 F1$="SR-DT100":GOSUB610
330 INPUT#1,N$:PRINT""N$" FOUND"
340 FORK=1TO2:FORJ=1TO20:INPUT#1,R(K,J):NEXTJ:NEXTK:CLOSE1
350 INPUT"TYPE IN SPL REQ'D (IN DBA) ";L
360 FORK=1TO2:P=0:Q=0:FORJ=1TO20
370 VF=S(J)+10*LOG(F(2,J))/LT:PF=VF+R(K,J)+A(J)
380 P=P+10↑(VF/10):Q=Q+10↑(PF/10):NEXTJ
390 P=10*LOG(P)/LT:Q=10*LOG(Q)/LT+94
400 M(K)=L-Q+P:NEXTK
410 PRINTA$:PRINTB$
420 PRINT:PRINT
430 PRINT"FOR A SPL OF "L"DBA ,USING SPECTRUM
440 PRINT"DENSITY FOR "FD$","
450 PRINT" THE RMS VOLTAGE ACROSS "F1$" MUST BE":PRINT
460 PRINT ""FNC(M(1))"DBV (LEFT HEADPHONE),OR:":PRINT
470 PRINT""FNC(M(2))"DBV (RIGHT HEADPHONE)
480 IFHC$="Y"THEN540
490 INPUT"HARD COPY ";HC$
500 IFHC$="N"THEN550
510 IFHC$="Y"THEN530
520 GOTO490
530 OPEN3,4:CMD3:GOTO410
540 PRINT#3:CLOSE3
550 PRINT"        *****END*****":END
560 REM FILE-HANDLING SUBROUTINES
570 INPUT#15,EN$,EM$,ET$,ES$:REM DISK ERROR TRAP
580 IFEN$="00"THENRETURN
590 PRINT"ERROR ON DISK"
600 PRINTEN$,EM$,ET$,ES$:CLOSE1:END
610 F$="0:"+F1$+",S,R":OPEN1,8,2,F$:GOSUB570:RETURN
READY.
```

PROGRAM P6

Setting Up the Experiment

A sentence, 'the fourth big expedition relied too much on native help" was spoken by a male talker and recorded onto an endless loop of magnetic tape on a high quality tape recorder. (REVOX model A77). The talkers spectrum density was then found using the B & K bandpass filter set and the SV5B[11] speech voltmeter at the headphone terminals. Table 7.3 gives the receiving sensitivity of the handset used in making the recordings, and Table 8.3 shows the spectrum obtained for the talker.

About six minutes of continuous speech from the same talker at constant level was then recorded. (Narrative taken from Winston Churchill's book: "My early life".) After this, a set of random sentences (grammatically correct but without meaning) was recorded at constant talking level from the same talker. This recorded speech material was then used in the experiments for determining the preferred listening level of speech.

Noise

For the noise sources, two ELGENCO type 624A white noise generators were used. The outputs were fed into a band-pass filter which limited the range of frequencies to between 100 Hz and 8 kHz. (See Table 9.3). Computer programs P8 and P9 were assembled to print-out a set of charts of opinion scales. The subject then placed a tick in the box adjacent to the appropriate opinion on the print-out. (See Fig. 22.3). These results were then "de-randomised" (see Fig. 23.3) into quantal response charts, (produced by

SPECTRUM FOR RWW

FREQ. (Hz)	BAND LEVEL (dBV)	SPECTRUM DENS. (dBV↑2/Hz)
100	-24.7	-62.9
125	-21.2	-57.1
160	-15.4	-46.5
200	-14.5	-45.5
250	-11.4	-40.3
315	- 8.4	-35.5
400	- 5.7	-31.0
500	- 7.7	-35.9
630	-12.2	-46.1
800	-10.9	-44.4
1000	-15.4	-54.3
1250	-16.3	-57.3
1600	-16.7	-59.1
2000	-18.8	-64.1
2500	-14.1	-55.7
3150	-17.5	-63.7
4000	-28.5	-86.6
5000	-38.0	-106.5
6300	-40.7	-113.1
8000	-42.2	-117.0

TABLE 8.3

NOISE

FREQ. (Hz)	SPECTRUM (dBV↑2/Hz)
100	-31.1
125	-31.1
160	-31.1
200	-31.1
250	-31.1
314	-31.1
400	-31.1
500	-31.1
630	-31.1
800	-31.1
1000	-31.1
1250	-31.1
1600	-31.1
2000	-31.1
2500	-31.1
3150	-31.1
4000	-31.1
5000	-31.1
6300	-31.1
8000	-31.1

TABLE 9.3

```
OPINION CH*OPINION CH*

 100 REM OPINION CHART
 110 PRINT"   TO PRINT OPINION SCORE CHARTS "
 120 INPUT" HOW MANY CHARTS ";L
 130 OPEN3,4:CMD3:G$="            └┘ "
 140 FORK=1TOL
 150 IFK>1THEN170
 160 GOTO180
 170 FORF=1TO5:PRINT,CHR$(10):NEXTF
 180 PRINT"          SUBJECT NO.         CONDITION
 190 PRINT"
 200 FORJ=1TO10
 210 PRINT
 220 PRINT"          LEVEL "J
 230 PRINT"
 240 PRINTG$"MUCH LOUDER THAN PREFERRED
 250 PRINTG$"LOUDER THAN PREFERRED
 260 PRINTG$"PREFERRED
 270 PRINTG$"QUIETER THAN PREFERRED
 280 PRINTG$"MUCH QUIETER THAN PREFERRED
 290 NEXTJ:NEXTK
 300 PRINT#3:CLOSE3
 310 PRINT"  *****END*****"
 320 REM DC HOWSE  17-FEB-1981
READY.
```

PROGRAM P8

```
EFF*EFF*

 100 REM EFFORT CHART
 110 PRINT"]] TO PRINT OPINION SCORE CHARTS "
 120 INPUT"]HOW MANY CHARTS ";L
 130 OPEN3,4:CMD3:G$="           |_| "
 140 FORK=1TOL
 150 IFK>1THEN170
 160 GOTO180
 170 FORF=1TO5:PRINT,CHR$(10):NEXTF
 180 PRINT"          SUBJECT NO.        CONDITION
 190 PRINT"
 200 FORJ=1TO10
 210 PRINT
 220 PRINT"          LEVEL "J
 230 PRINT"
 240 PRINTG$"EXCELLENT
 250 PRINTG$"GOOD
 260 PRINTG$"FAIR
 270 PRINTG$"POOR
 280 PRINTG$"BAD
 290 NEXTJ:NEXTK
 300 PRINT#3:CLOSE3
 310 PRINT"]]*****END*****"
 320 REM DC HOWSE  17-FEB-1981
READY.
```

PROGRAM P9

```
QUA*QUA*

 100 REM QUANTAL RESP.
 110 PRINT"] ▒TO PRINT-OUT PREFERENCE SCALE CHART "
 120 INPUT"▒HOW MANY CHARTS ";C
 130 OPEN6,4,6
 140 PRINT#6,CHR$(18)
 150 OPEN3,4:CMD3
 160 FORK=1TOC
 170 V=-6
 180 IFK>1THEN200
 190 GOTO210
 200 FORI=1TO5:PRINTCHR$(10):NEXTI
 210 PRINT"      SUBJECT          CONDITION    "
 220 PRINT
 230 PRINT"      ___________      _______________"
 240 PRINT:PRINT
 250 L$="    ___________________________________________________________"
 260 S$="|          |           |            |
 270 PRINTL$
 280 PRINT"      |TEST | LEVEL | LOUDER | PREFERRED | QUIETER |
 290 PRINTL$
 300 FORJ=1TO10
 310 V=V-4
 320 IFJ=10THEN350
 330 PRINT"      |"J"  |"V"DBV"S$
 340 GOTO360
 350 PRINT"      |"J" |"V"DBV"S$
 360 PRINTL$
 370 NEXTJ:NEXTK
 380 PRINT#3:CLOSE3:PRINT#6,CHR$(24)
 390 PRINT"▒▒*****END*****":END
 400 REM DC HOWSE  20-FEB-1981
READY.
```

PROGRAM P10

```
OPINION RE*OPINION RE*

 100 REM OPINION RESP.
 110 PRINT"□ ▒TO PRINT-OUT PREFERENCE SCALE CHART "
 120 INPUT"▒HOW MANY CHARTS ";C
 130 OPEN6,4,6
 140 PRINT#6,CHR$(18)
 150 OPEN3,4:CMD3
 160 FORK=1TOC
 170 V=-6
 180 IFK>1THEN200
 190 GOTO210
 200 FORI=1TO5:PRINTCHR$(10):NEXTI
 210 PRINT"     SUBJECT          CONDITION    "
 220 PRINT
 230 PRINT"     __________      ____________"
 240 PRINT:PRINT
 250 L$="     ______________________________________________________________"
 260 S$="|          |        |        |        |       |"
 270 PRINTL$
 280 PRINT"     |TEST | LEVEL | EXCELLENT | GOOD | FAIR | POOR | BAD
 290 PRINTL$
 300 FORJ=1TO10
 310 V=V-4
 320 IFJ=10THEN350
 330 PRINT"     |"J"  |"V"DBV"S$
 340 GOTO360
 350 PRINT"     |"J" |"V"DBV"S$
 360 PRINTL$
 370 NEXTJ:NEXTK
 380 PRINT#3:CLOSE3:PRINT#6,CHR$(24)
 390 PRINT"▒▒*****END*****":END
 400 REM DC HOWSE  20-FEB-1981
READY.
```

PROGRAM P11

FIG 22.3 Subjects opinion scoring chart

SUBJECT NO. CONDITION

LEVEL 1

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 2

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 3

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 4

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 5

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 6

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 7

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 8

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 9

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

LEVEL 10

|_| MUCH LOUDER THAN PREF.
|_| LOUDER THAN PREF.
|_| PREFERRED
|_| QUIETER THAN PREF.
|_| MUCH QUIETER THAN PREF.

FIG 22.3/A Subjects opinion scoring chart

SUBJECT NO.   CONDITION

LEVEL 1

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 2

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 3

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 4

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 5

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 6

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 7

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 8

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 9

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

LEVEL 10

|_| EXCELLENT
|_| GOOD
|_| FAIR
|_| POOR
|_| BAD

SUBJECT CONDITION

TEST	LEVEL	LOUDER	PREFERRED	QUIETER
1	-10 dBV			
2	-14 dBV			
3	-18 dBV			
4	-22 dBV			
5	-26 dBV			
6	-30 dBV			
7	-34 dBV			
8	-38 dBV			
9	-42 dBV			
10	-46 dBV			

FIG 23.3 Table for de-randomising results

SUBJECT   CONDITION

TEST	LEVEL	EXELLENT	GOOD	FAIR	POOR	BAD
1	-10 dBV					
2	-14 dBV					
3	-18 dBV					
4	-22 dBV					
5	-26 dBV					
6	-30 dBV					
7	-34 dBV					
8	-38 dBV					
9	-42 dBV					
10	-46 dBV					

FIG 23.3/A Table for de-randomising results

computer programs P10 and P11) to enable a full statistical analysis to be made on the results.

B & K Band Pass Filter Set Type 1612

This was used to pass the speech in bands having intervals of 1/3 octaves. (The centre frequencies follow the ISO range). The level from each band was measured on the SV5B speech voltmeter.

A selector and an input transformer constitutes the input circuit. By means of the selector switch the signal is either applied direct to the input of the filters or to a 10:1 step down transformer coupled in series with the filters.

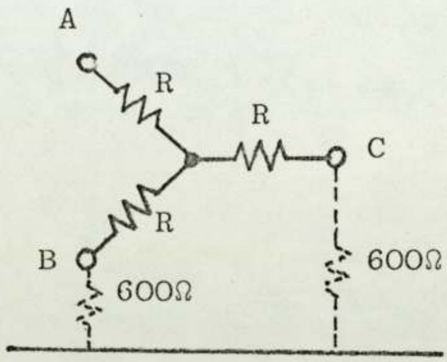
Inserting the transformer allows a higher source impedance (up to 1kΩ) to be used, whereas 10Ω is required when the signal is applied directly. Thus, using the transformer results in a 20 dB lower sensitivity. (Actually found to be 20.3 dB ± 0.1 dB over the range 100 Hz to 8 kHz. Note, to keep the flux in the filter cores below the saturation value, the peak voltage on the filter inputs should be no higher than 1.4 volts. (Thus 14 volts is the maximum peak voltage when the transformer is switched in).

The attenuation is approximately 20 dB at ± 1/3 octave from the central frequency.

A rated value of 100 kΩ is suggested for load resistance on the output. Loading by 10 kΩ causes the amplitude vs frequency characteristic of the output stage to slope off at low frequencies. (Below 100 Hz).

Signal Mixing Pad

In order to mix the speech and noise signals, a simple matched mixing pad was used as shown below:



For 600Ω looking in A,

$$R + \frac{(R+600)}{2} = 600$$

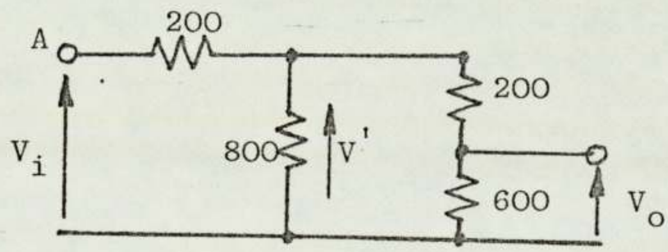
$$2R + R + 600 = 1200$$

$$\therefore 3R = 600$$

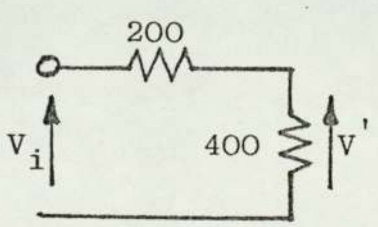
$$\underline{R = 200\Omega}$$

If V_i is applied to input A, (the other inputs being terminated in 600Ω), it will be attenuated and appear as V_o at C.

i.e.



Consider V'



$$V' = V_i \cdot \frac{400}{600} = \frac{2}{3} V_i$$

$$\text{But } V_o = V' \cdot \frac{600}{800} = \frac{3}{4} V'$$

$$\therefore V_o = \frac{3}{4} \cdot \frac{2}{3} V_i = \underline{\frac{V_i}{2}}$$

Thus, there is 6 dB attenuation of voltage across the pad.

Summary of the test conditions for the experiments in preferred listening level

The preferred listening level was initially obtained for speech and noise having a bandwidth of 100 HZ to 8 KHZ. Two opinion scales were used, namely loudness preference and listening opinion. (This was done to see the dependance of the results on the opinion scale chosen). The type of speech was also taken into consideration, (narrative taken from a novel, and random sentences). The right ear was chosen to always receive the speech and noise together, the left ear being given a "background" noise, as described previously. Thus, experiments PLL 1 to 4 were given the following conditions:

PLL - 1

a) Speech using material from a novel accompanied with random noise. (A combination of 40 dBA and 60 dBA in both ears, thus forming conditions A, B, C and D).

b) Bandwidth to be 100 HZ to 8 KHZ.

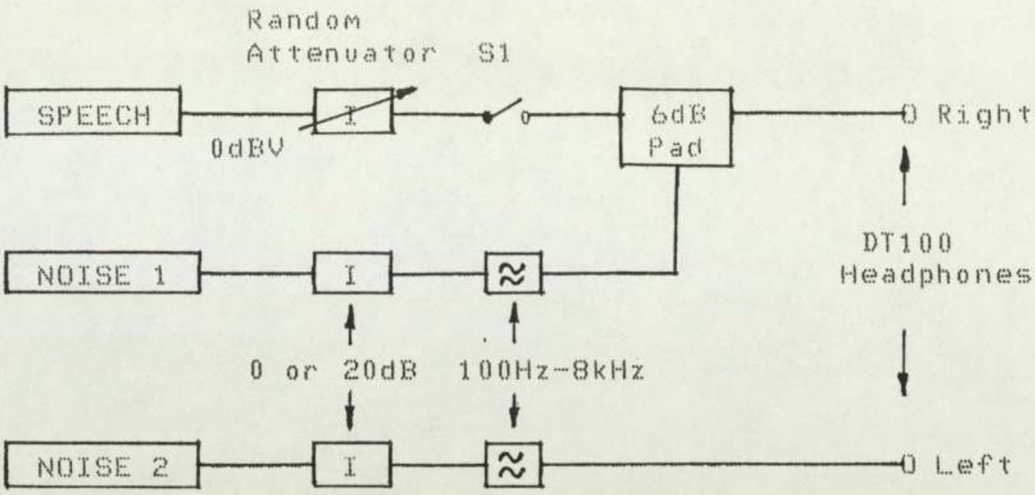
c) Preferred listening level based on loudness preference.

PLL - 2

As in PLL - 1 but with the preferred listening level based on listening opinion.

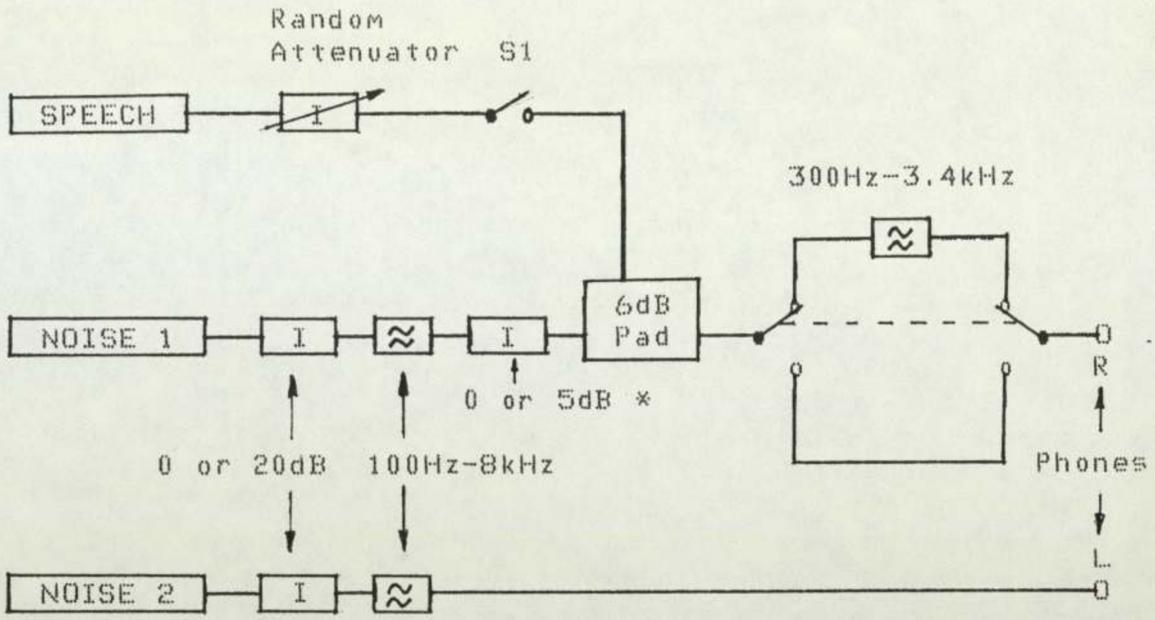
PLL - 3 and 4

As in PLL - 1 and 2 but with speech using random sentences. (These are probably a better representation of everyday telephone speech in word content, as written material tends to be more restricted in its range of words over a few



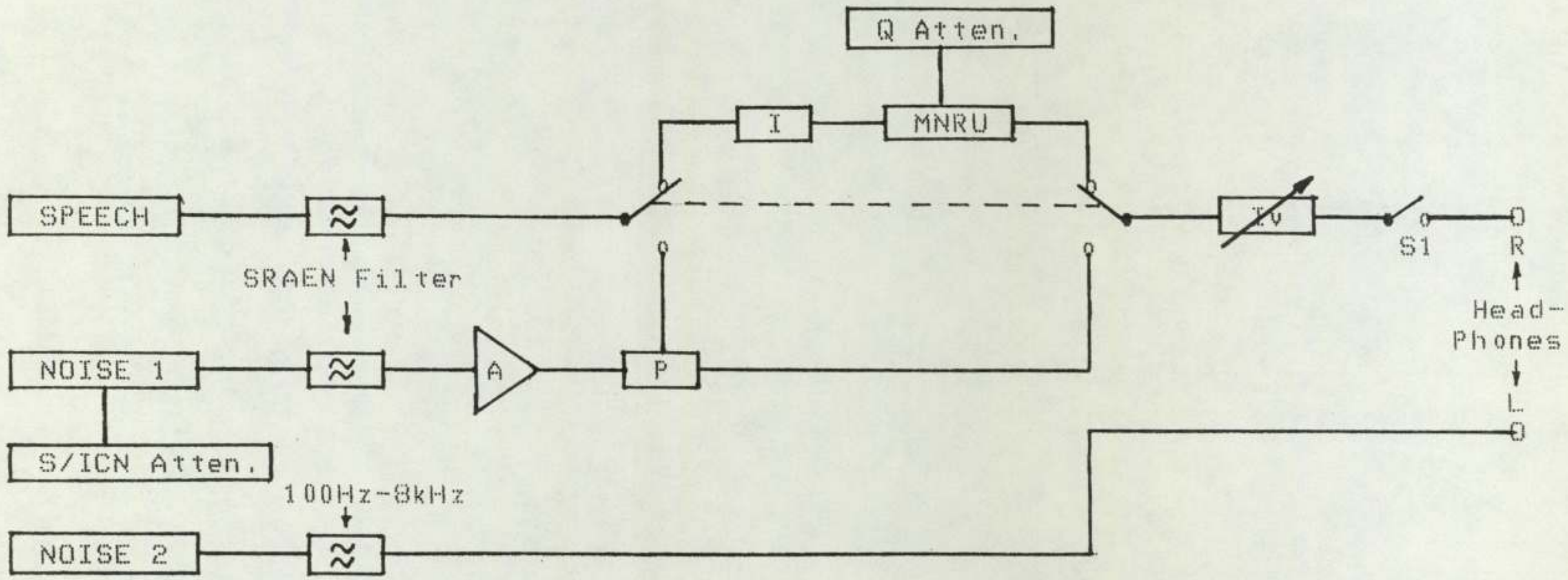
To account for the 6dB loss across the mixing pad, the speech to the random attenuator was presented at a nominal level of 0dBV. (Similarly, noise generator no.1 was also increased in level by 6dB)
Note, the left headphone is 1 dB less sensitive than the right headphone over the ISO frequency range.
The speech generator consisted of a high quality tape recording of speech from a talker using a linear microphone.
Switch S1 was used to remove the speech during adjustment of the random attenuator between tests.

DIAGRAM 1.3 Electrical layout for experiments PLL-1 to 4



* Noise source no.1 is reduced in level by 5dB for the 100Hz - 8kHz bandwidth condition,to keep the same respective dBA of random noise sound pressure in the ear

DIAGRAM 2.3 Electrical layout for experiments PLL-5 to 8



The SRAEN filter limits the signal to within 300Hz-3.4kHz.
Amplifier A is used when high noise levels are required.
(The noise source gave insufficient output for these levels.)
Attenuator I is used to balance the loss in the mixing pad P. (6dB)
Variable attenuator Iv is the "random" attenuator.
The ICN level is set with the switch in position 2.
Note, the minimum loss setting in the random attenuator is 4dB.

DIAGRAM 3.3 Electrical layout for experiments PLL-9 to 16

SUBJECT 6 CONDITION C (PLL-1)

TEST	LEVEL	LOUDER	PREFERRED	QUIETER
1	-10 dBV	✓		
2	-14 dBV		✓	
3	-18 dBV		✓	
4	-22 dBV		✓	
5	-26 dBV			✓
6	-30 dBV		✓	
7	-34 dBV			✓
8	-38 dBV			✓
9	-42 dBV			✓
10	-46 dBV			

The mean preferred level is $\frac{12+24}{2} + \frac{28+32}{2}$ =20dBV

FIG 24.3 Table illustrating a crossover

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	2	2	2	2	1	1	1	0	0
2	4	4	3	2	2	2	2	1	1	0
3	4	4	3	2	2	2	2	1	1	0
4	3	2	2	1	2	2	1	2	1	0
5	3	2	3	2	1	1	1	1	0	0
6	3	2	2	2	2	1	1	1	1	0
7	3	2	2	2	2	1	1	1	1	0
8	4	4	3	2	2	1	1	1	0	0

Data file PLL-1(2/A)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
3	2	2	2	1	1	1	0	0	0
3	3	2	2	1	1	1	0	0	0
3	3	2	1	2	1	1	0	0	0
3	2	1	2	1	1	1	1	0	0
3	2	2	2	1	1	1	0	0	0
2	2	2	1	1	1	1	0	0	0
2	2	2	1	1	1	1	0	0	0
3	2	1	1	1	1	0	0	0	0

Data file PLL-1(2/B)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	2	2	2	2	2	1	1	0	0
2	3	2	3	2	2	2	2	1	1	0
3	4	3	3	2	2	1	1	1	0	0
4	3	2	3	1	2	2	1	1	0	0
5	4	3	3	2	2	1	1	1	0	0
6	3	2	2	2	1	2	1	1	1	0
7	3	2	2	2	2	2	2	1	1	0
8	4	3	2	1	1	1	1	0	0	0

Data file PLL-1(2/C)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
2	2	2	1	1	1	0	0	0	0
3	2	2	2	1	1	1	0	0	0
3	2	2	1	1	1	0	0	0	0
3	2	2	2	1	1	1	0	0	0
2	2	1	1	1	1	0	0	0	0
2	2	1	1	1	1	0	0	0	0
2	2	1	1	1	1	1	0	0	0
3	2	3	2	2	1	1	1	0	0

Data file PLL-1(2/D)

TABLE 10.3 Subjects ratings for experiment PLL-1

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	2	3	4	4	4	3	2	1	1	0
2	3	3	2	2	2	2	1	1	1	0
3	4	4	3	3	3	3	3	1	1	1
4	3	3	4	4	3	3	2	2	1	0
5	2	3	3	3	2	2	0	1	0	0
6	3	4	3	3	3	2	2	0	0	0
7	4	4	3	3	3	2	2	1	1	0
8	4	4	4	4	3	2	2	2	1	0

Data file PLL-2(2/A)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
2	3	3	2	2	2	1	0	0	0
3	3	2	2	1	0	0	0	0	0
4	3	3	3	2	1	1	0	0	0
3	3	3	3	2	2	1	1	0	0
3	3	2	2	1	1	0	0	0	0
4	3	3	2	2	1	0	0	0	0
4	3	3	3	2	2	1	1	0	0
3	3	3	2	2	1	0	0	0	0

Data file PLL-2(2/B)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	2	3	3	4	3	3	2	2	2	1
2	3	3	3	3	2	2	1	1	1	1
3	3	3	3	3	2	1	1	1	1	0
4	3	3	3	3	3	2	2	1	1	0
5	3	4	3	3	1	1	1	2	0	1
6	4	4	3	3	2	2	2	1	0	1
7	4	4	4	3	3	2	2	2	2	1
8	4	4	3	2	2	2	1	1	1	1

Data file PLL-2(2/C)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
2	4	3	2	2	1	0	0	0	0
3	4	3	3	2	1	1	1	0	0
4	4	3	3	2	1	1	1	1	0
2	3	3	3	2	1	1	1	0	0
3	3	3	2	2	1	1	0	0	0
4	3	2	2	2	1	0	0	0	0
4	3	3	2	2	2	2	1	0	0
4	4	3	3	3	1	1	0	0	0

Data file PLL-2(2/D)

TABLE 11.3 Subjects ratings for experiment PLL-2

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	2	2	2	2	1	1	1	0
2	3	3	2	2	2	2	2	1	1	1
3	4	3	3	2	2	2	2	1	1	1
4	3	2	2	2	1	1	1	1	0	0
5	4	3	3	2	2	2	1	1	0	0
6	3	3	2	2	2	1	1	1	0	0
7	4	3	2	2	2	1	1	1	0	0
8	4	3	2	2	1	1	1	0	0	0

Data file PLL-3(2/A)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
3	2	2	2	1	1	1	1	0	0
3	2	2	2	1	1	1	0	0	0
4	3	3	2	1	1	1	0	0	0
3	2	2	2	1	1	0	0	0	0
3	3	2	2	2	1	1	1	0	0
3	3	2	2	1	1	0	0	0	0
3	3	2	2	2	1	1	1	0	0
3	3	2	1	1	1	1	1	0	0

Data file PLL-3(2/B)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	2	2	2	2	1	1	1	1
2	3	3	2	2	2	2	1	1	1	1
3	4	3	3	2	2	1	1	1	1	0
4	3	2	2	1	2	1	1	0	0	0
5	4	3	3	2	2	2	1	1	0	0
6	3	3	3	2	2	2	1	1	1	1
7	4	3	3	2	2	2	1	0	0	0
8	4	3	3	2	2	1	1	1	1	1

Data file PLL-3(2/C)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
3	2	2	1	1	1	1	0	0	0
3	2	2	2	2	1	1	0	0	0
4	3	2	2	2	1	1	0	0	0
3	2	1	2	1	1	1	0	0	0
3	3	2	2	2	1	1	1	0	0
3	3	2	2	2	1	1	1	0	0
3	3	2	2	1	1	1	0	0	0
3	3	2	2	2	1	1	1	0	0

Data file PLL-3(2/D)

TABLE 12.3 Subjects ratings for experiment PLL-3

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	2	4	4	4	3	2	1	1	1	0
2	3	3	3	2	2	2	1	1	1	0
3	4	4	4	3	3	3	3	2	2	1
4	3	4	3	3	3	3	3	2	1	1
5	4	4	4	3	3	2	1	0	0	0
6	3	3	4	4	3	2	1	1	0	0
7	2	3	4	4	3	2	1	1	1	0
8	3	3	3	4	4	2	2	1	1	1

Data file PLL-4(2/A)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
4	4	4	3	2	1	1	1	0	0
3	3	2	2	2	1	1	0	0	0
4	4	3	3	2	1	1	1	0	0
3	3	3	3	2	2	1	0	0	0
3	3	3	2	1	1	1	0	0	0
3	3	3	2	2	2	1	1	0	0
3	3	3	3	2	1	0	0	0	0
3	3	2	2	1	1	1	0	0	0

Data file PLL-4(2/B)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	2	4	4	4	3	3	2	2	2	1
2	3	3	4	3	2	2	2	1	1	0
3	4	4	4	3	3	3	3	2	2	1
4	3	3	4	4	3	3	3	2	2	1
5	4	4	3	3	2	2	1	1	0	0
6	3	3	3	3	3	2	2	1	0	0
7	3	4	3	3	2	2	1	1	0	0
8	3	3	3	3	4	4	2	2	1	1

Data file PLL-4(2/C)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
4	4	3	3	2	2	1	0	0	0
3	3	2	2	2	1	1	0	0	0
4	4	4	3	2	2	2	1	0	0
3	4	3	3	2	1	1	0	0	0
3	2	2	2	1	1	0	0	0	0
3	3	4	3	2	1	1	0	0	0
3	3	3	2	2	1	0	0	0	0
3	3	3	3	2	2	1	1	0	0

Data file PLL-4(2/D)

TABLE 13.3 Subjects ratings for experiment PLL-4

sentences. The electrical layout for experiments PLL - 1 to 4 is shown in Diagram 1.3. Tables 10.3 to 13.3 show the de-randomised results obtained from these four experiments. Each block of data gives the opinion score from 8 subjects for each of the 10 levels of speech presented under the 4 combinations of random noise. The preferred listening level for the subjects was found by considering the quantal response charts for each subject and obtaining the mean preferred level in dBV. The tables shown in Figs. 23.3 and 23.3/A were used to give the quantal response charts. Crossovers due to errors in judgement were noticed (an example is shown in Fig. 24.3) for about 19% of the decisions during the initial experiments, but they became less frequent as the subjects "learned" to judge more correctly.

Experiments PLL - 5 to PLL - 8

The electrical layout is shown in Diagram 2.3.
In these experiments, the subjective effect of reducing the speech bandwidth of 100 HZ to 8 KHZ down to 300 HZ to 3.4 KHZ was investigated. Before performing the tests, the objective reduction in speech level was measured on the SV5B speech voltmeter[8] (by switching a SRAEN filter in and out of the speech path) and found to be 1 dB. (This difference was consistant over various passages of speech). For random noise, the reduction was 4 dB. The theoretical reductions in voltage, and sound pressure in the ear, were found from calculations done on the PET computer using program P6, and are shown in the following table, for the

right-hand headphone. Here, the talkers spectrum was inputted and the rms headphone volts and corresponding sound pressure calculated from this in the bandwidth chosen.

Table 32.3

	Random Noise			Speech		
	Vh	S.P.L. in ear		Vh	S.P.L. in ear	
	dBV	(Un-weighted) dB	dBA	dBV	(Un-weighted) dB	dBA
100 HZ to 8 KHZ	8.37	103.73	103.52	-8.43	89.02	84.8
300 HZ to 3.4 KHZ	4.04	98.55	98.54	-8.66	88.81	84.75
Difference Δ	4.33	5.18	4.98	0.23	0.21	0.05

CALCULATED SOUND PRESSURES

Vh = headphone voltage

Δ = difference due to bandwidth reduction

Mathematically, the reduction for random noise is:

$$10 \log_{10} \frac{8 - 0.1}{3.4 - 0.3} = \underline{4.1 \text{ dB}}$$

For the subjective tests, random sentences were used for the speech material. Test condition 'A' was used for each experiment (40 dBA of noise in both ears). The results for PLL - 5 were based on loudness preference and those for PLL - 6 on listening opinion.

Presenting the two sets of band-limited speech at random will introduce a further effect (enhancement) whereby speech quality may affect the intelligability to a greater degree than if the two sets were presented separately. To show this effect, experiments PLL-7 and

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	2	2	2	1	1	0	0	0
2	3	3	2	2	1	1	1	0	0	0
3	4	4	3	2	2	1	1	1	0	0
4	4	3	2	2	2	2	1	1	0	0
5	3	2	2	2	1	1	0	0	0	0
6	3	2	2	1	1	1	0	0	0	0
7	3	2	2	2	1	1	1	0	0	0
8	3	3	2	2	1	1	1	0	0	0

Data file PLL-5(2/A)

300Hz-3.4kHz

LEVEL 2

1	2	3	4	5	6	7	8	9	10
2	3	4	4	3	2	2	2	1	0
3	3	3	2	2	2	1	1	0	0
4	4	4	3	3	3	3	2	2	1
3	4	4	3	3	3	2	2	2	1
3	3	3	2	2	2	1	1	0	0
3	3	3	3	2	2	1	1	0	0
3	4	4	3	3	2	2	1	1	0
3	4	4	3	3	2	1	1	0	0

Data file PLL-6(2/A)

300Hz-3.4kHz

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	2	2	2	1	1	1	0	0
2	3	3	2	2	1	1	1	1	1	0
3	4	3	3	2	2	1	1	1	1	0
4	4	3	2	2	2	2	1	1	0	0
5	3	2	2	1	1	1	1	1	0	0
6	3	3	2	2	2	1	1	0	0	0
7	3	2	2	1	1	1	1	1	0	0
8	3	3	2	2	1	1	1	0	0	0

Data file PLL-7(2/A-1)

300Hz-3.4kHz

LEVEL 4

1	2	3	4	5	6	7	8	9	10
4	3	2	2	2	1	1	1	1	0
3	3	2	2	2	1	1	0	0	0
4	3	3	3	2	2	2	1	1	1
4	3	3	2	2	2	1	1	1	1
3	3	2	2	2	1	1	1	0	0
3	3	2	2	2	1	1	1	0	0
4	3	3	2	2	1	1	1	1	0
4	4	3	3	2	2	1	1	0	0

Data file PLL-7(2/A-2)

100Hz-8kHz

Table 14.3 Subjects ratings for experiments PLL-5 to 7

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	4	4	3	2	2	1	0	0
2	4	4	3	3	2	2	1	1	0	0
3	3	4	4	3	3	2	2	1	1	0
4	2	3	4	4	3	3	2	1	1	0
5	4	3	3	3	2	2	1	0	0	0
6	3	3	4	3	3	2	1	0	0	0
7	4	4	4	3	3	2	2	1	0	0
8	3	3	3	3	2	1	1	0	0	0

Data file PLL-8(2/A-1)

300Hz-3.4kHz

LEVEL 2

1	2	3	4	5	6	7	8	9	10
2	3	4	3	3	2	2	2	1	1
3	4	4	3	3	2	2	1	0	0
3	4	4	3	3	3	2	1	1	1
3	3	4	4	3	3	3	2	1	1
3	3	4	3	2	2	2	1	1	0
3	3	4	4	3	2	2	1	0	0
3	4	3	2	2	2	1	1	0	0
2	3	4	3	3	2	1	1	0	0

Data file PLL-8(2/A-2)

100Hz-8kHz

TABLE 15.3 Subjects ratings for experiment PLL-8

8 were performed. (Again based on the two opinion scales). Thus, experiments PLL-5 and 6 used band-limited speech in the range 300 HZ to 3.4 KHZ only. (A SRAEN filter was used for this). Experiments PLL-7 and 8 used speech having bandwidths of 300 HZ to 3.4 3.4 KHZ and 100 HZ to 8 KHZ presented at random. The random sequence was generated on the PET computer.

Consider the following conditions;

If '1' corresponds to a bandwidth of 300 - 3.4 KHZ

'2' corresponds to a bandwidth of 100 - 8 KHZ,

the sequence for the 10 levels of speech was;

1 2 1 1 2 1 2 2 1 2 for condition 1, with '1' and '2' interchanged for the corresponding levels in condition 2. (The subject then received all the levels twice, each level presented in conditions 1 and 2). The subjects opinion scores for experiments PLL - 5 to 8 are shown in Tables 14.3 and 15.3.

Experiments PLL - 9 to 16

The electrical layout is shown in Diagram 3.3. In these experiments, the preferred listening level was found in the presence of random noise and also speech-correlated noise, each type of noise being presented at random. Again, the two opinion scales were used. As in the bandwidth reduction experiments, randomly interleaved sequences of the conditions '1' and '2' were used, but now they correspond to random noise and speech-correlated noise respectively.

The 10 levels of speech were presented for 4 different "signal-to-injected circuit noise" (S/ICN) ratios, with corresponding "signal-to-speech correlated noise" (Q) values. As a guide, the equivalent Q values were taken from published results[12] (given for a single speech level). Choosing intervals of 5 dB between the Q values to cover a range of 15 dB corresponded to intervals of about 8 dB for the equivalent S/ICN values. The following table shows the values used.

Table 33.3

Q (dB)	5	10	15	20
S/ICN (dB)	6	14	22	30
Experiment	PLL-9 and 10	Pll-11 and 12	PLL-13 and 14	PLL-15 and 16

For the low signal/noise ratios, the speech levels were increased by 8 dB to give a wider dynamic range. Thus, - 2 dBV to - 38 dBV speech levels were used in experiments PLL-9 to 12, and - 10 dBV to - 46 dBV for experiments PLL-13 to 16. For the levels of random noise, if the speech voltage Vs is -2 dBV then for a S/ICN ratio of 6 dB, the noise voltage Vn is Vs - S/ICN = - 8 dBV etc. To adjust the Q value, the attenuator built into the MNRU[6] was used. The noise in the left ear was kept at 40 dBA. Tables 16.3 to 19.3 give the subjects opinion scores obtained from these experiments.

LEVEL 1

Subjects	1	2	3	4	5	6	7	8	9	10
1	4	3	3	2	1	1	1	1	0	0
2	4	3	3	3	4	4	1	0	0	0
3	4	3	3	2	2	2	1	1	1	1
4	4	4	3	2	2	1	1	1	0	0
5	4	3	2	2	1	1	1	1	0	0
6	4	4	3	2	2	1	1	1	0	0
7	3	3	2	2	2	1	1	1	1	0
8	4	3	3	2	2	1	1	1	0	0

Data file PLL-9(2/R)
(Random noise)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
4	3	2	2	2	2	1	1	1	1
4	3	2	2	2	2	1	1	1	0
4	3	3	2	2	2	2	1	1	1
3	3	3	2	2	2	2	1	1	1
3	3	2	2	2	2	1	1	1	1
4	3	2	2	2	2	1	1	1	0
3	3	2	2	2	2	1	1	1	0
4	3	2	2	2	2	1	1	1	0

Data file PLL-9(2/C)
(Correlated noise)

LEVEL 3

Subjects	1	2	3	4	5	6	7	8	9	10
1	0	1	1	1	1	0	0	0	0	0
2	1	1	2	2	2	2	1	1	0	0
3	2	3	3	2	2	2	1	1	0	0
4	1	1	2	2	1	1	1	1	1	0
5	1	1	1	1	1	0	0	0	0	0
6	1	2	2	2	2	2	2	1	1	0
7	1	1	2	3	2	2	2	1	1	0
8	1	1	2	2	1	1	1	1	0	0

Data file PLL-10(2/R)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
0	1	1	1	1	2	1	1	0	0
1	2	2	2	2	2	2	2	1	0
2	3	3	2	2	2	2	1	1	1
2	3	3	2	2	2	2	1	0	0
1	1	2	2	2	2	1	1	0	0
2	2	3	3	2	2	2	1	1	0
2	3	3	3	3	3	2	2	1	1
2	2	3	2	2	2	1	1	0	0

Data file PLL-10(2/C)

TABLE 16.3 Subjects ratings for experiments PLL-9 and 10
Range of speech levels is -2dBV to -38dBV

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	4	3	3	2	2	1	1	1	1	0
2	4	3	3	2	2	2	1	1	0	0
3	4	3	3	2	2	2	1	1	1	1
4	4	3	3	2	2	2	1	1	0	0
5	4	3	2	2	2	1	1	1	0	0
6	4	4	3	2	2	2	1	1	0	0
7	4	3	3	2	2	1	1	1	0	0
8	4	4	3	3	2	2	1	1	0	0

Data file PLL-11(2/R)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
3	3	2	2	2	1	1	1	1	0
3	3	2	2	2	1	1	1	1	1
3	3	3	2	2	2	2	1	1	0
3	3	3	2	2	2	1	1	1	1
3	3	2	2	2	1	1	1	1	0
3	3	2	2	2	2	1	1	0	0
3	3	2	2	2	1	1	1	0	0
4	3	3	2	2	2	1	1	0	0

Data file PLL-11(2/C)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	1	2	2	2	2	2	1	1	1	1
2	1	1	1	2	2	2	1	1	1	0
3	1	1	2	3	2	2	1	1	1	0
4	1	2	2	2	3	3	2	2	2	1
5	2	2	2	3	2	1	1	1	0	0
6	2	2	2	3	3	3	2	2	1	1
7	1	1	2	2	2	2	1	1	0	0
8	1	2	2	3	2	2	1	1	1	0

Data file PLL-12(2/R)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
1	1	2	2	1	1	1	1	1	0
1	2	2	2	1	1	1	1	1	0
1	2	3	3	2	2	1	1	1	0
2	2	3	3	3	3	3	2	1	1
2	2	3	3	2	2	1	1	0	0
2	2	3	3	3	3	2	2	1	0
1	2	2	3	2	1	1	1	1	0
2	2	3	3	2	2	2	1	1	0

Data file PLL-12(2/C)

TABLE 17.3 Subjects ratings for experiments PLL-11 and 12

Range of speech levels is -2dBV to -38dBV

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	2	2	2	1	1	1	1	1	
2	3	2	2	2	1	1	1	0	0	0
3	4	3	3	2	2	1	1	1	1	1
4	3	3	3	2	2	2	2	1	1	0
5	3	3	2	2	2	2	1	1	1	0
6	3	3	2	2	2	1	1	0	0	0
7	3	2	2	2	1	1	1	1	1	0
8	4	4	3	3́	3	2	2	2	0	0

Data file PLL-13(2/R)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
3	2	2	2	2	1	1	1	1	1
3	2	2	1	1	1	1	1	0	0
3	3	3	2	2	1	1	1	0	0
3	3	2	2	2	2	1	1	1	1
3	3	2	2	1	1	1	1	1	0
3	2	2	2	2	1	1	0	0	0
3	2	2	2	2	1	1	1	0	0
3	2	2	2	1	1	1	1	0	0

Data file PLL-13(2/C)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	3	3	3	2	2	2	1	1
2	3	3	3	3	2	2	2	1	1	0
3	3	4	3	3	3	2	2	2	1	1
4	3	4	4	3	3	3	3	2	1	1
5	3	4	3	2	2	2	1	1	0	0
6	2	3	4	3	3	2	2	1	0	0
7	3	3	3	2	2	2	2	1	1	0
8	3	4	3	3	2	2	2	1	1	0

Data file PLL-14(2/R)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
3	3	3	2	2	2	2	1	1	0
3	3	3	2	2	2	2	2	1	0
3	4	3	3	2	2	2	2	1	1
3	4	4	4	4	3	3	2	2	1
3	4	3	3	2	2	1	1	1	0
3	3	3	3	2	2	1	1	0	0
4	4	3	3	3	2	2	1	1	0
3	4	4	3	3	2	2	1	1	0

Data file PLL-14(2/C)

TABLE 18.3 Subjects ratings for experiments PLL-13 and 14
Range of speech levels is -10dBV to -46dBV

LEVEL 1

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	3	2	2	2	2	2	1	1	0
2	3	2	2	2	1	1	1	1	0	0
3	4	3	3	2	2	2	2	2	1	1
4	3	3	2	2	2	2	1	1	1	0
5	3	2	2	2	1	1	1	1	0	0
6	3	2	2	2	2	2	1	1	0	0
7	3	3	2	2	1	1	1	1	0	0
8	3	3	2	2	2	1	1	1	1	0

Data file PLL-15(2/R)

LEVEL 2

1	2	3	4	5	6	7	8	9	10
3	2	2	2	2	1	1	1	1	0
3	2	2	1	1	1	1	1	0	0
4	3	3	2	2	2	2	1	1	0
3	3	2	2	2	2	1	1	1	0
3	2	2	2	1	1	1	1	1	0
3	3	2	2	1	1	1	1	0	0
3	3	2	2	1	1	1	1	1	0
3	3	2	2	2	2	1	1	1	0

Data file PLL-15(2/C)

LEVEL 3

SUBJECTS	1	2	3	4	5	6	7	8	9	10
1	3	4	4	4	4	3	3	2	2	1
2	3	4	4	3	2	2	2	1	0	0
3	4	4	4	3	3	3	3	2	1	1
4	3	3	3	4	4	3	3	2	1	1
5	3	4	4	3	3	2	2	1	1	1
6	3	4	4	3	2	2	1	1	1	0
7	3	4	4	4	3	3	2	1	1	0
8	3	4	3	3	3	3	2	1	1	1

Data file PLL-16(2/R)

LEVEL 4

1	2	3	4	5	6	7	8	9	10
3	3	4	4	3	3	2	2	1	1
3	4	3	3	2	2	2	1	0	0
4	4	4	3	3	3	3	2	1	1
3	3	3	4	4	4	3	2	1	1
3	4	3	3	2	1	1	1	1	0
3	4	4	3	2	2	1	1	0	0
3	4	4	4	3	3	2	1	1	0
3	4	3	3	3	3	2	1	1	1

Data file PLL-16(2/C)

TABLE 19.3 Subjects ratings for experiments PLL-15 and 16

Range of speech levels is -10dBV to -46dBV

CHAPTER 3. SECTION 3.

ANALYSIS OF RESULTS FROM THE P.L.L. EXPERIMENTS.

Analysing the results from experiment PLL - 1

The averages of the preferred listening level (in dBV) for the 8 subjects are shown in Table 20.3. Applying the t-test to these sample means gives the range in which the population mean lies.

If $\bar{x}$ is the sample mean,

u is the population mean,

s is the sample standard deviation,

n is the number of samples,

then $\frac{\bar{x} - u}{s/\sqrt{n}}$ has a t distribution with n-1 degrees of freedom.

The range in which u lies (within certain confidence limits) can be found as follows:

The number of degrees of freedom is 8 - 1 = 7. For 95% confidence that u lies within the range $\bar{x} \pm t_c\ S/\sqrt{n-1}$, then t_c is looked-up in the tables of t-distribution as $t_{\frac{\alpha}{2}}(n-1)$, i.e. $t_{.025}(7)$. Thus, the range in which u lies is $\bar{x} \pm 2.365 \times S/\sqrt{7}$

i.e. Range = $\bar{x} \pm 0.89S$.

For condition A, $\bar{x} = 22.4$

$$S^2 = \sum_1^n (x_i - \bar{x})^2/n = \frac{1}{n}\sum_1^n x_i^2 - \bar{x}^2$$

$$= 509.625 - (22.4)^2 = 7.89$$

$S \doteq 2.8$

The range for u is 22.4 ± 2.5

CONDITION	A	B	C	D
SUBJECT	(dBV)	(dBV)	(dBV)	(dBV)
1	20	18	22	14
2	26	20	26	18
3	28	20	24	16
4	21	16	21	18
5	20	18	24	12
6	20	14	20	12
7	20	14	24	12
8	24	14	18	22
MEAN	22.4	16.8	22.4	15.5
Std. Dev.	2.8	2.1	2.2	3.4

TABLE 20.3 Preferred listening levels from PLL-1

For conditions A, B, C and D, the ranges are as follows:

Condition	A	B	C	D
Range	22.4 ± 2.5	16.8 ± 1.9	22.4 ± 2.0	15.5 ± 3.0

These preferred speech voltages can now be converted into preferred sound pressures. Using computer program P6 with the talkers spectrum;

-22.4 dBV yeilds 70.8 dBA (conditions A and C)

-16.8 dBV yeilds 76.4 dBA (Condition B)

-15.5 dBV yeilds 77.7 dBA (Condition D)

Note, 0 dBV yeilds 93.2 dBA.

An analysis of variance was performed about the means in order to test the significance of the results. Referring to Table 21.3 the number of rows (r) = 8, and the number of columns (k) = 4.

If T relates to the treatments (with r and K levels) then summing over T,

$$\sum_{1}^{r}\frac{(T.j)^2}{K} = \frac{47912}{4} = 11978 \qquad \sum_{1}^{k}\frac{(Ti)^2}{r} = \frac{97414}{8} = 12177$$

$$\sum\sum x_{ij}^{2} = 12438 \qquad T.. = 616 \quad \frac{T..^2}{4x8} = 11858$$

Thus, the variation of row means from the grand mean is 11978 - 11858 = 120

The variation of column means from the grand mean is 12177 - 11858 = 319

SUBJECT	CONDITION A	B	C	D	T.r	$(T.r)^2$
1	20	18	22	14	74	5476
2	26	20	26	18	90	8100
3	28	20	24	16	88	7744
4	21	16	21	18	76	5776
5	20	18	24	12	74	5476
6	20	14	20	12	66	4356
7	20	14	24	12	70	4900
8	24	14	18	22	78	6084

Tk.	179	134	179	124
$(Tk.)^2$	32041	17956	32041	15376
Means	22.4	16.8	22.4	15.5

TABLE 21.3 Two way analysis of variance about the means for PLL-1

The total variation is 12438 - 11858 = 580

The random variation (error) is 580 - 120 - 319 =141

Thus the analysis of variance table is:

Source	Deg. of freedom.	Sum of Squares.	Mean Square
Among rows	7	120	17.14
Among cols.	3	319	106.33
Within (error)	21	141	6.71
Total	31	580	

For the rows, (subjects)

$F_{.05}\left[r-1,\ (r-1)(k-1)\right] = F_{.05}\left[7,21\right] = 2.49$

$F_r = \frac{17.14}{6.71} = 2.55$. Since 2.55 is a little greater than 2.49, the hypothesis is that the row (subjects) means are equal, is just rejected at 5% significance. However, $F_{.025}\left[7,21\right] = 2.97$ and so the hypothesis would be accepted at this level, indicating that there is general agreement between the subjects.

For the columns, (treatments)

$F_{.05}\left[k-1,\ (r-1)(k-1)\right] = F_{.05}\left[3,21\right] = 3.07$ (5% significance)

$F_k = \frac{106.33}{14.14} = 7.52$. $F_{.005}\left[3,21\right] = 5.73$ (0.5% significance)

The hypothesis that the column means are equal is thus rejected, indicating that the subjects opinions are valid for each experiment, and are not simply the result of error between the experiments. This type of analysis thus provides a check on the assumption that certain results from the experiment are significant or not.

In order to ease the amount of computation in analysing the results from the experiments, computer programs were used wherever possible. Such a program was used for the analysis of variance. The analysis was applied to;

a) The subjects mean preferred listening level versus conditions A, B, C and D as just described.

b) The subjects opinion scores versus speech level for each of the four conditions A, B, C and D.

Mean Opinion Scores

The subjects mean opinion scores (i.e, the mean of all the subjects in a particular experiment, for each treatment) are given by the 2-way analysis program as part of the analysis of results. They are given for the ten speech levels presented under the various conditions, and are the primary set of results from which the preferred listening level along with other parameters, are found.

Tables 22.3 to 31.3 give the subjects mean opinion scores for all the experiments in preferred listening level, along with the results from a 2-way analysis of variance.

Dispersion between subjects

1. Dispersion in opinion scores

From the analysis of the subjects opinion scores, the variance due to treatments (o_B^2) will give a measure of the dispersion or "spread" in decisions from the subjects. Since (mean sq. between - mean sq. within)

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	1/A	1/B	1/C	1/D
10	3.4	2.8	3.4	2.8
14	2.8	2.3	2.4	2.0
18	2.5	1.8	2.5	1.8
22	1.9	1.5	1.8	1.4
26	1.9	1.1	1.8	1.1
30	1.4	1.0	1.6	1.0
34	1.1	0.9	1.3	0.5
38	1.1	0.1	0.9	0.1
42	0.5	0	0.4	0
46	0	0	0	0

Analysis of variance

Grand Mean	1.65	1.14	1.59	1.04

Source of Variance	Mean Squares			
Subjects	0.66	0.23	0.27	0.6
Levels	8.61	7.15	8.28	6.2
Error	0.22	0.12	0.21	0.11

TABLE 22.3 Mean opion scores and analysis of variance table for experiment PLL-1

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL- 2/A	2/B	2/C	2/D
10	3.1	3.3	3.3	3.3
14	3.5	3.0	3.5	3.5
18	3.3	2.8	3.1	2.9
22	3.3	2.4	3.0	2.5
26	2.9	1.8	2.3	2.1
30	2.4	1.3	1.9	1.1
34	1.8	0.5	1.5	0.9
38	1.1	0.3	1.4	0.5
42	0.8	0	1.0	0.1
46	0.1	0	0.8	0

Analysis of variance

Grand Mean	2.21	1.51	2.16	1.69

Source of Variance	Mean Squares			
Subjects	1.58	0.78	0.91	0.58
Levels	11.56	13.18	8.08	13.92
Error	0.29	0.16	0.28	0.22

TABLE 23.3 Mean opion scores and analysis of variance table for experiment PLL-2

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	3/A	3/B	3/C	3/D
10	3.5	3.1	3.5	3.1
14	2.9	2.6	2.9	2.6
18	2.3	2.1	2.6	1.9
22	2.0	1.9	1.9	1.9
26	1.8	1.3	2.0	1.6
30	1.5	1.0	1.6	1.0
34	1.3	0.8	1.0	1.0
38	0.9	0.5	0.8	0.4
42	0.4	0	0.6	0
46	0.3	0	0.5	0

Analysis of variance

Grand Mean	1.66	1.33	1.74	1.35

Source of Variance	Mean Squares			
Subjects	0.71	0.25	0.51	0.31
Levels	8.70	9.34	8.51	9.11
Error	0.14	0.12	0.15	0.10

TABLE 24.3 Mean opion scores and analysis of variance table for experiment PLL-3

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	4/A	4/B	4/C	4/D
10	3.0	3.3	3.1	3.3
14	3.5	3.3	3.5	3.3
18	3.6	2.9	3.5	3.0
22	3.4	2.5	3.3	2.6
26	3.0	1.8	2.8	1.9
30	2.3	1.3	2.6	1.4
34	1.6	0.9	2.0	0.9
38	1.1	0.4	1.5	0.3
42	0.9	0	1.0	0
46	0.4	0	0.5	0

Analysis of variance

Grand Mean	2.28	1.61	2.38	1.65

Source of Variance	Mean Squares			
Subjects	1.19	0.64	1.71	1.17
Levels	11.47	13.48	9.22	14.24
Error	0.32	0.15	0.28	0.16

TABLE 25.3 Mean opion scores and analysis of variance table for experiment PLL-4

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	5/A	6/A		
10	3.3	3.0		
14	2.8	3.5		
18	2.1	3.6		
22	1.9	2.9		
26	1.4	2.6		
30	1.1	2.3		
34	0.8	1.6		
38	0.3	1.4		
42	0	0.8		
46	0	0.3		

Analysis of variance

Grand Mean	1.35	2.19		

Source of Variance	Mean Squares			
Subjects	0.77	2.04		
Levels	10.41	10.59		
Error	0.11	0.17		

TABLE 26.3 Mean opion scores and analysis of variance table for experiments PLL-5&6

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	7/A1	7/A2	8/A1	8/A2
10	3.3	3.6	3.3	2.8
14	2.8	3.1	3.4	3.4
18	2.1	2.5	3.6	3.9
22	1.8	2.3	3.3	3.1
26	1.5	2.0	2.6	2.8
30	1.1	1.4	2.0	2.3
34	1.0	1.1	1.5	1.9
38	0.8	0.9	0.6	1.3
42	0.3	0.5	0.3	0.5
46	0	0.3	0	0.4

Analysis of variance

Grand Mean	1.45	1.76	2.05	2.21

Source of Variance	Mean Squares			
Subjects	0.49	0.83	0.71	0.87
Levels	8.73	10.12	15.31	11.45
Error	0.12	0.12	0.21	0.20

TABLE 27.3 Mean opion scores and analysis of variance table for experiments PLL-7&8

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	9/R	9/C	10/R	10/C
10	3.9	3.1	1.0	1.5
14	3.3	3.0	1.4	2.1
18	2.8	2.4	1.9	2.5
22	2.1	2.0	1.9	2.1
26	1.8	2.0	1.5	2.0
30	1.3	1.5	1.3	2.1
34	1.0	1.1	1.0	1.6
38	0.9	1.0	0.8	1.3
42	0.3	0.6	0.4	0.5
46	0.1	0.3	0	0.3

Analysis of variance

Grand Mean	1.73	1.70	1.10	1.60

Source of Variance	Mean Squares			
Subjects	0.25	0.23	2.06	2.06
Levels	12.77	7.53	2.97	4.41
Error	0.15	0.12	0.19	0.18

TABLE 28.3 Mean opion scores and analysis of variance table for experiments PLL-9&10

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	11/R	11/C	12/R	12/C
10	4.0	3.6	1.3	1.5
14	3.3	3.0	1.6	1.9
18	2.9	2.3	1.9	2.6
22	2.1	2.0	2.5	2.8
26	2.0	2.0	2.3	2.0
30	1.6	2.0	2.1	1.9
34	1.0	1.3	1.3	1.5
38	1.0	1.0	1.3	1.3
42	0.3	1.0	0.9	0.9
46	0.1	0.5	0.4	0.1

Analysis of variance

Grand Mean	1.83	1.86	1.54	1.64

Source of Variance	Mean Squares			
Subjects	0.19	0.17	1.14	1.74
Levels	13.12	7.40	3.50	4.90
Error	0.1	0.09	0.16	0.16

TABLE 29.3 Mean opion scores and analysis of variance table for experiments PLL-11&12

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL- 13/R	13/C	14/R	14/C
10	3.1	3.0	2.9	3.1
14	2.6	2.4	3.5	3.6
18	2.3	2.1	3.3	3.3
22	2.0	1.9	2.8	2.9
26	1.6	1.6	2.5	2.5
30	1.3	1.1	2.1	2.1
34	1.1	1.0	2.0	1.9
38	0.8	0.9	1.4	1.4
42	0.6	0.4	0.8	1.0
46	0.3	0.3	0.4	0.3

Analysis of variance

Grand Mean	1.56	1.46	2.15	2.20

Source of Variance	Mean Squares			
Subjects	0.63	0.40	0.89	1.43
Levels	6.92	6.36	8.69	9.39
Error	0.14	0.12	0.16	0.16

TABLE 30.3 Mean opion scores and analysis of variance table for experiments PLL-13&14

Speech Level (-dBV)	MEAN OPINION SCORES Experiment PLL-			
	15/R	15/C	16/R	16/C
10	3.1	3.1	3.1	3.1
14	2.6	2.6	3.9	3.8
18	2.1	2.1	3.8	3.5
22	2.0	1.9	3.4	3.4
26	1.6	1.5	3.0	2.8
30	1.5	1.4	2.6	2.6
34	1.3	1.1	2.3	2.0
38	1.1	1.0	1.4	1.4
42	0.5	0.8	1.0	0.8
46	0.1	0	0.6	0.5

Analysis of variance

Grand Mean	1.60	1.55	2.50	2.38

Source of Variance	Mean Squares			
Subjects	0.91	0.60	1.03	1.34
Levels	6.72	6.78	10.64	10.86
Error	0.10	0.10	0.21	0.25

TABLE 31.3 Mean opion scores and analysis of variance table for experiments PLL-15&16

$= n\sigma_B^2$, then $\sigma_B^2 = \frac{MSB - \sigma_0^{\ 2}}{n}$

Thus, the spread is σ_B opinion units.

Eg. For PLL - 2 condition A, (see table 23.3)

$$\sigma_B = \sqrt{\frac{1.58 - 0.29}{10}} = 0.36 \text{ opinion units}$$

The spread in the decisions of the subjects for all of the experiments is given by Fig. 25.3.

2. Spread in decisions about the mean preferred listening level

When the subjects decisions are based on loudness preference, the range covering the mean preferred value before it gets either too loud or too quiet, can be found by considering the mean louder-to-preferred, and mean preferred-to-quieter boundaries judged by the subjects.

Table 35.3 shows the range in which the mean values of preferred listening level lie for experiment PLL - 1. The range is given for both the results from the t-test (range 1) and the range covering the "louder than preferred" to "quieter than preferred" boundaries, (range 2). Similar tables were constructed from the other experiments based on loudness preference and the mean values obtained from these are shown in Table 35.3.

Experiments PLL-1 to 4

PLL	1/A	1/B	1/C	1/D	3/A	3/B	3/C	3/D
Spread	0.21	0.10	0.08	0.22	0.24	0.11	0.19	0.15

PLL	2/A	2/B	2/C	2/D	4/A	4/B	4/C	4/D
Spread	0.36	0.25	0.25	0.19	0.30	0.22	0.38	0.32

Experiments PLL-5 to 8

PLL	5/A	7/A1	7/A2
Spread	0.26	0.19	0.27

PLL	6/A	8/A1	8/A2
Spread	0.43	0.22	0.26

Experiments PLL-9 to 16

PLL	9/R	9/C	11/R	11/C	13/R	13/C	15/R	15/C
Spread	0.10	0.09	0.10	0.10	0.22	0.17	0.29	0.22

PLL	10/R	10/C	12/R	12/C	14/R	14/C	16/R	16/C
Spread	0.43	0.43	0.31	0.40	0.27	0.36	0.29	0.33

FIG 25.3 Tables showing the spread in decisions between the subjects

	Condition	A			B			C			D		
	Boundary	L/P	P	P/Q	L/P	P	P/Q	L/P	P	P/Q	L/P	P	P/Q
SUBJECT	1	12	20	28	12	18	24	12	22	32	8	14	20
	2	20	26	32	16	20	24	16	26	36	12	18	24
	3	20	28	36	16	20	24	20	24	28	12	16	20
	4	12	21	30	12	16	20	16	21	26	12	18	24
	5	16	20	24	12	18	24	20	24	28	8	12	16
	6	12	20	28	8	14	20	12	20	28	8	12	16
	7	12	20	28	8	14	20	12	24	36	8	12	16
	8	20	24	28	12	14	16	16	18	20	16	22	28
	Mean (-dBV)	15.5	22.4	29.3	12.0	16.8	21.5	15.5	22.4	29.3	10.5	15.5	20.5
	SPL (dBA)	77.7	70.8	63.9	81.2	76.4	71.7	77.7	70.8	63.9	82.7	77.7	72.7
	Std. Dev.		2.8			2.1			2.2			3.4	

Note, L/P represents "louder than preferred"
P represents "preferred"
P/Q represents "quieter than preferred"

TABLE 34.3 Results obtained from experiment PLL-1

EXPERIMENT PLL-	1/A	1/B	1/C	1/D	5/A	7/A1	9/R	11/R	13/R	15/R
MEAN (dBA)	70.8	76.4	70.8	77.7	73.2	72.9	77.4	76.0	71.5	70.7
Std. Dev. (dB)	2.8	2.1	2.2	3.4	2.7	3.0	2.0	1.7	3.4	3.8
RANGE 1	2.5	1.9	2.0	3.0	2.4	2.6	1.8	1.5	3.0	3.4
RANGE 2	13.8	9.5	13.8	10.0	10.5	10.0	8.5	11.0	12.5	15.5

EXPERIMENT PLL-	3/A	3/B	3/C	3/D	7/A2	9/C	11/C	13/C	15/C
MEAN (dBA)	69.9	73.4	69.0	72.7	68.7	77.2	76.2	73.0	72.0
Std. Dev. (dB)	2.8	1.2	1.0	1.9	3.0	2.2	1.7	2.5	3.6
RANGE 1	2.5	1.1	0.9	1.7	2.6	2.0	1.5	2.3	3.2
RANGE 2	14.5	9.5	12.5	11.5	11.0	13.0	15.5	12.5	13.0

Note, RANGE 1 results from applying the t-test and is the 95% confidence interval.
RANGE 2 covers the L/P to P/Q boundaries within which the preferred level lies.

TABLE 35.3 Results from the experiments based on loudness preference.

Experiment PLL-	2/A	2/B	2/C	2/D	6/A	8/A1
Mean p.l.1 (dBA)	76	83	81	83	77	78
Mean Opin. Score	3.5	3.3	3.4	3.4	3.6	3.6

Experiment PLL-	4/A	4/B	4/C	4/D	8/A2
Mean p.l.1 (dBA)	75	83	77	81	75
Mean Opin. Score	3.6	3.3	3.5	3.4	3.6

Experiment PLL-	10/R	12/R	14/R	16/R
Mean p.l.1 (dBA)	80	79	79	77
Mean Opin. Score	1.8	2.2	3.2	3.7

Experiment PLL-	10/C	12/C	14/C	16/C
Mean p.l.1 (dBA)	81	79	79	77
Mean Opin. Score	2.3	2.5	3.3	3.6

TABLE 36.3 Preferred listening levels based on "quality"

A graphical presentation of the mean opinion scores

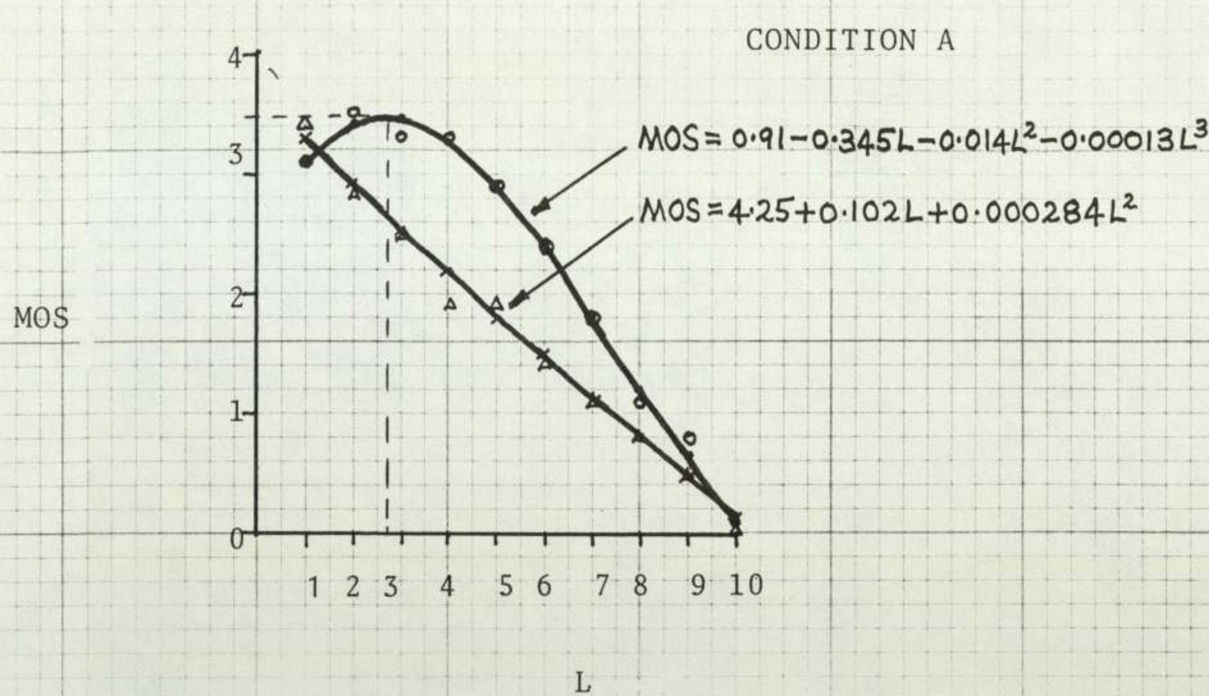
The mean opinion scores from the subjects plotted against speech level give distinct characteristics for the type of opinion score chosen, as shown by Figs. 27.3 to 36.3. It is seen that the loudness preference scale tends to give a straight line whereas the "quality" opinion scale produces a parabola. The mean preferred listening level for experiments using the "quality" opinion scale, is found by projecting down from the tangent to the maxima of the curve, representing the highest score for that range of treatments. The preferred speech level (in dBV) is then converted into sound pressure (in dBA), as before. Table 35.3 shows the preferred listening levels obtained from the experiments which used the "quality" opinion scale. The sound pressures are rounded up to the nearest dB.

Curve Fitting

In order to obtain an equation describing the curve characteristics, a computer program using the "orthogonal polynomials" method was initially used. This enabled the error between the true and fitted values to be observed as the degree of the equation to fit the curve was increased, thus indicating the minimum required degree for the equation.

Another computer program was then used with the fitted data to obtain the polynomial coefficients of the curve fitting equation. In the graphs, the true points are shown along with their fitted curve. The speech levels are standardised into a range of L values from 1 to 10.

For experiments PLL - 9 to 12, the speech level is given by 2 + 4 (L - 1) in (-dBV), and for all the other experiments, the level is 10 + 4 (L-1) in (-dBV).



Note, o and • are the true and fitted points on the quality scale.
Δ and × are the true and fitted points on the loudness preference scale.

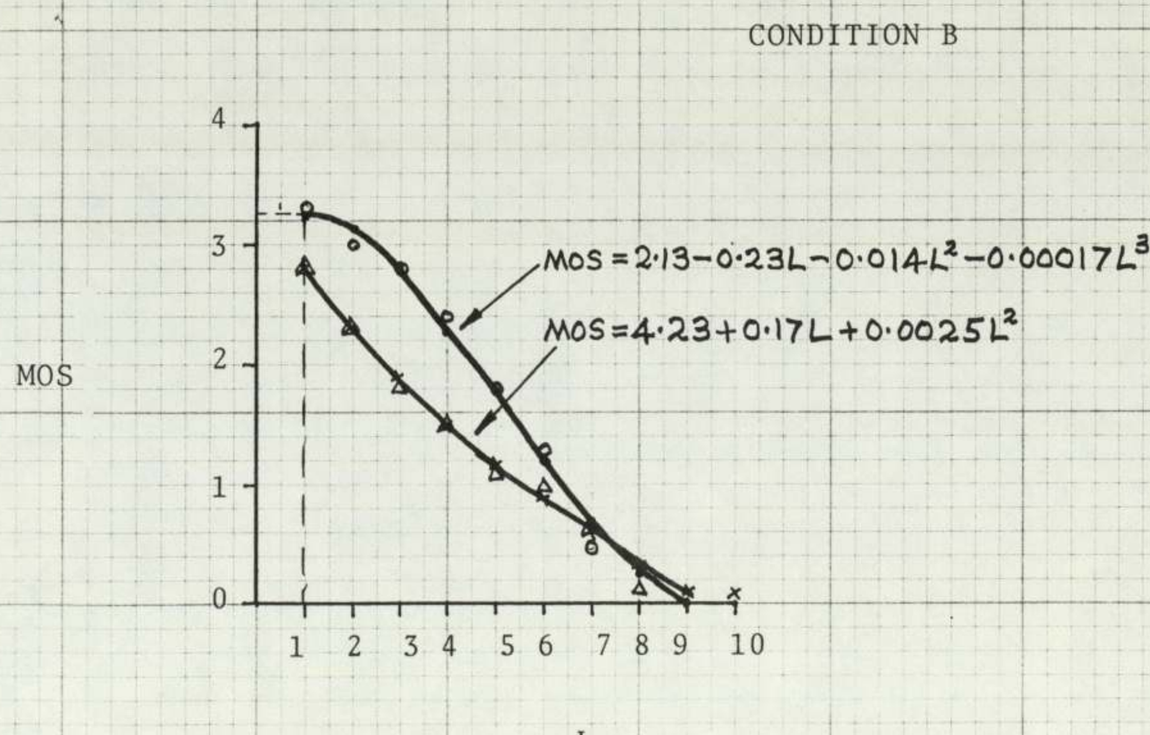
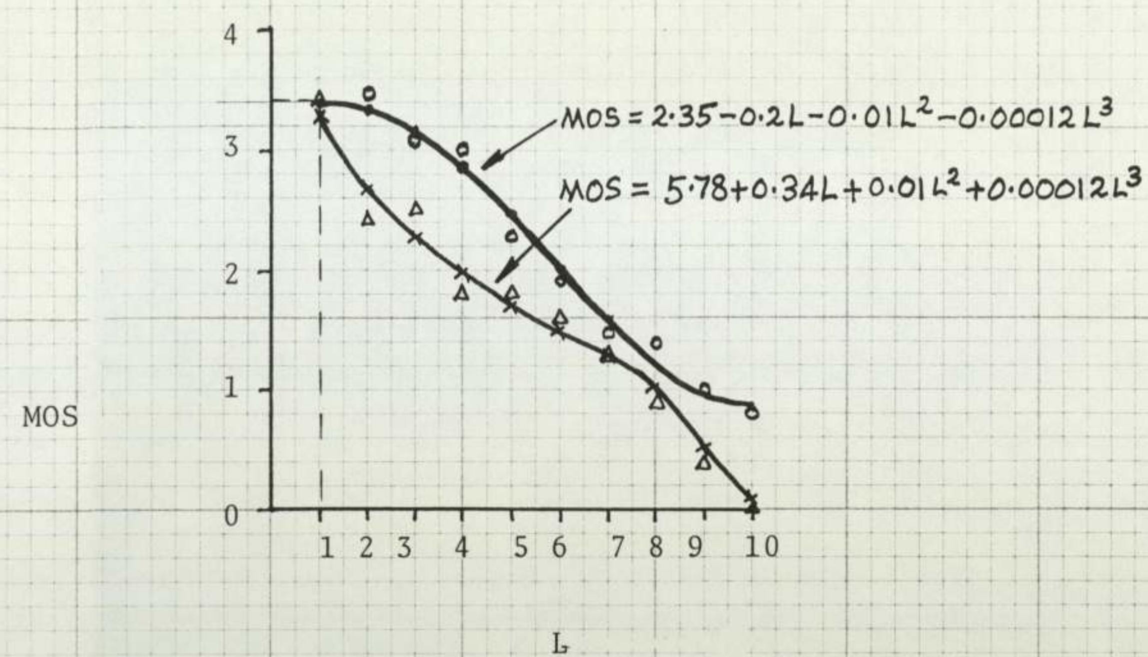


Fig. 27.3 Mean opinion score versus speech level for experiments PLL-1 and 2

(L = -10 to -46 dBV)

CONDITION C



Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

CONDITION D

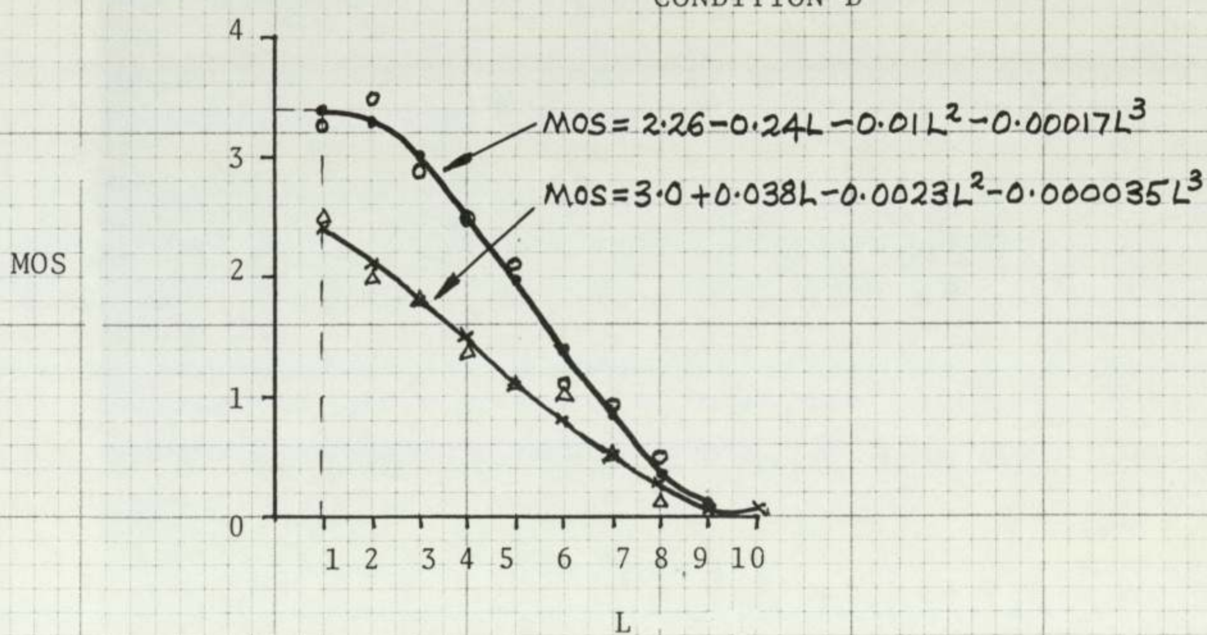
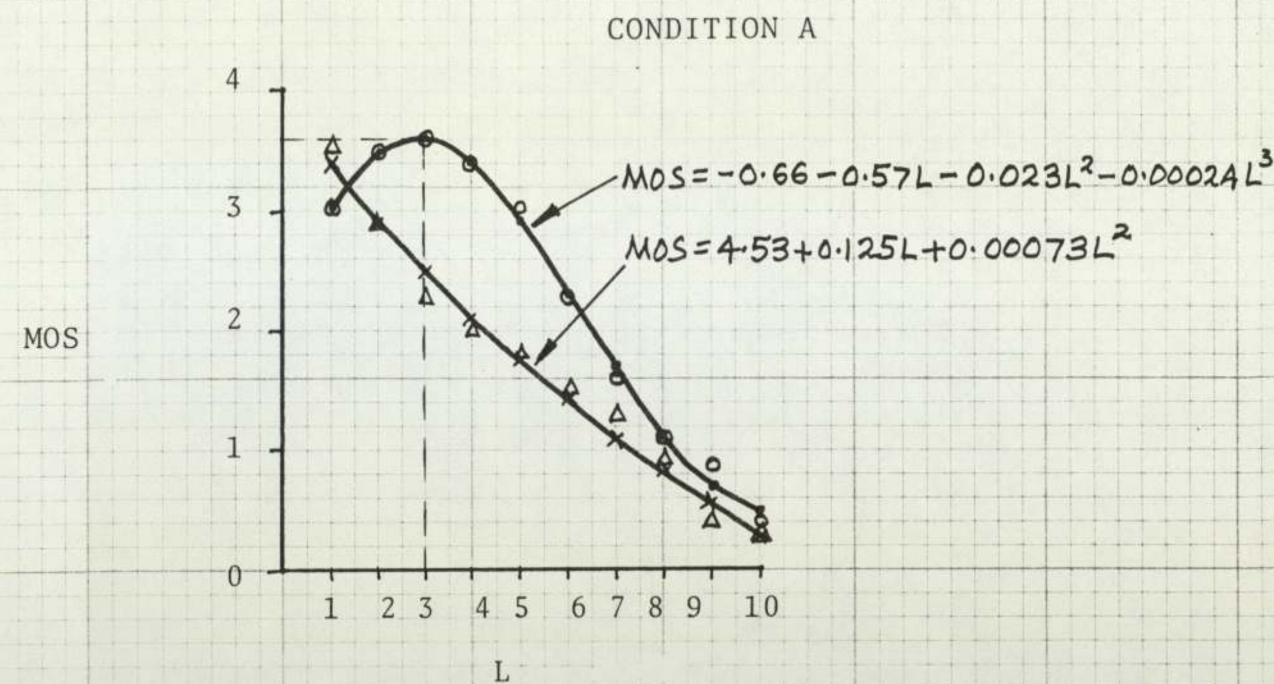


Fig. 28.3 Mean opinion score versus speech level for experiments PLL - 1 and 2 (L = -10 to -46 dBV)



Note, o and • are the true and fitted points on the quality scale.
Δ and × are the true and fitted points on the loudness preference scale.

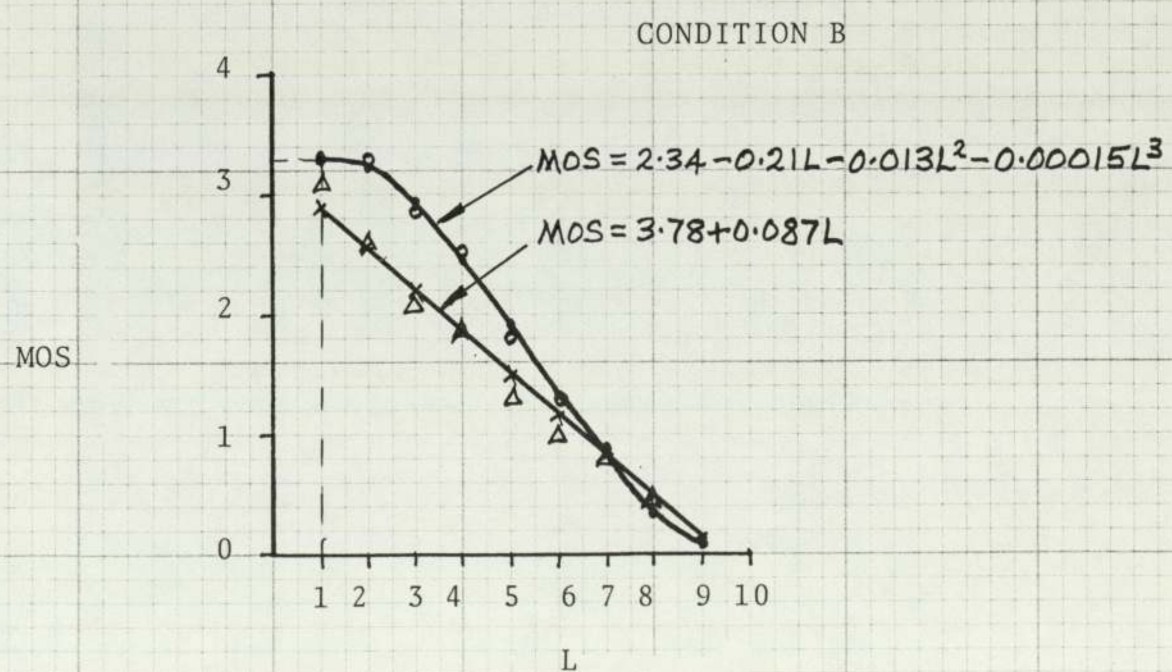
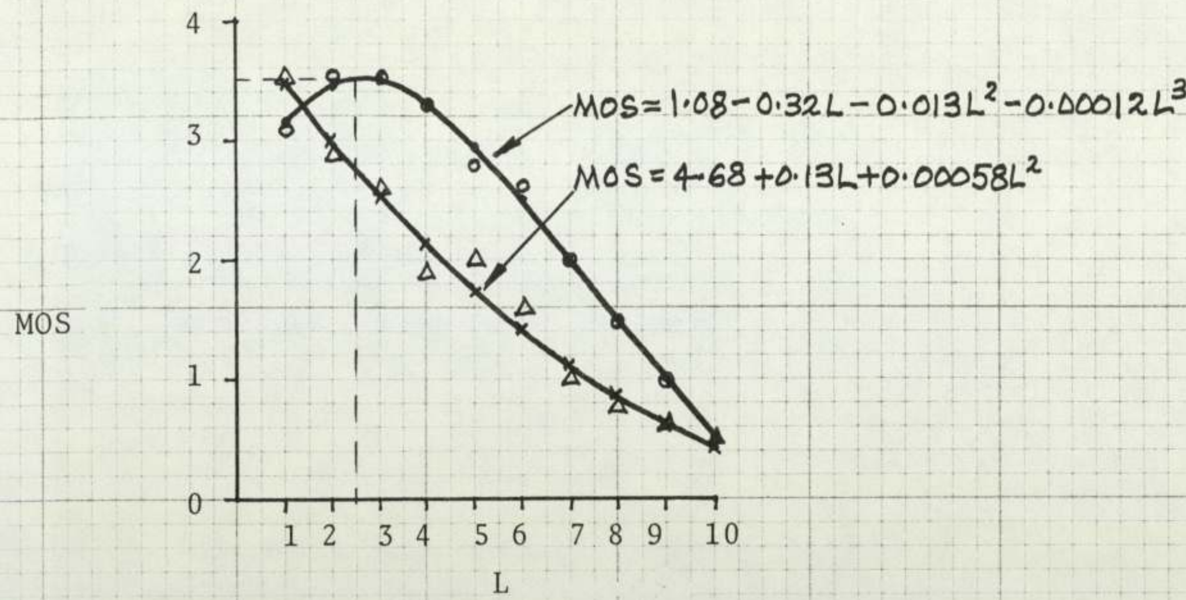


Fig. 29.3 Mean opinion score versus speech level for experiments PLL - 3 and 4 (L = -10 to -46 dBV)

CONDITION C



Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

CONDITION D

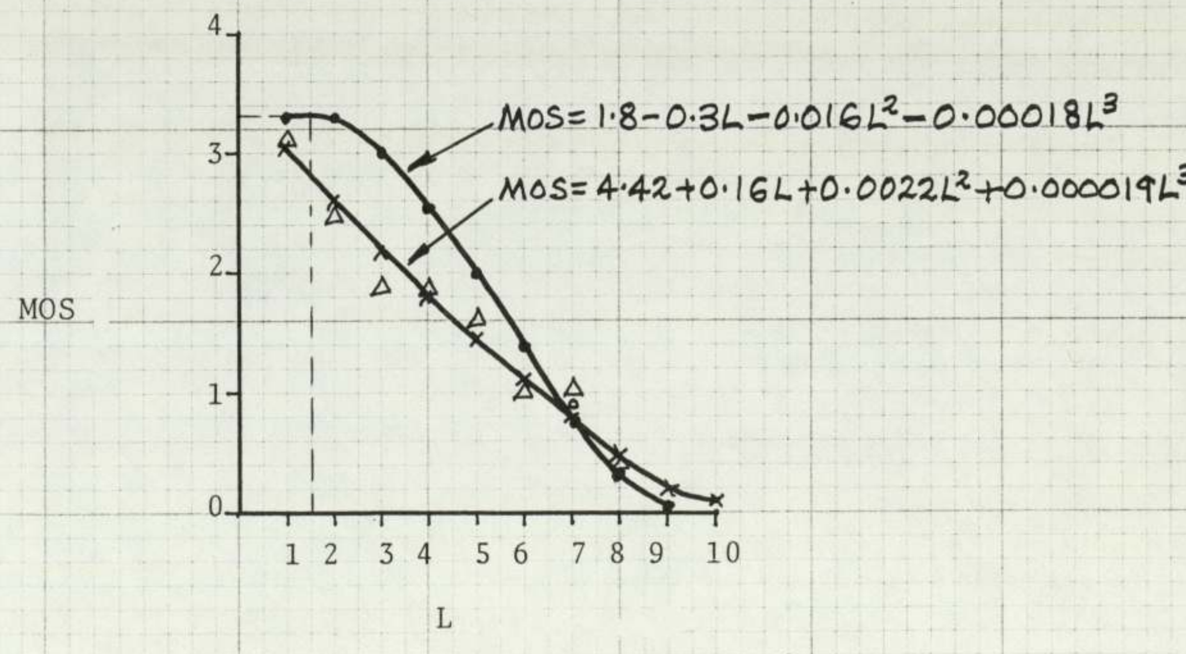
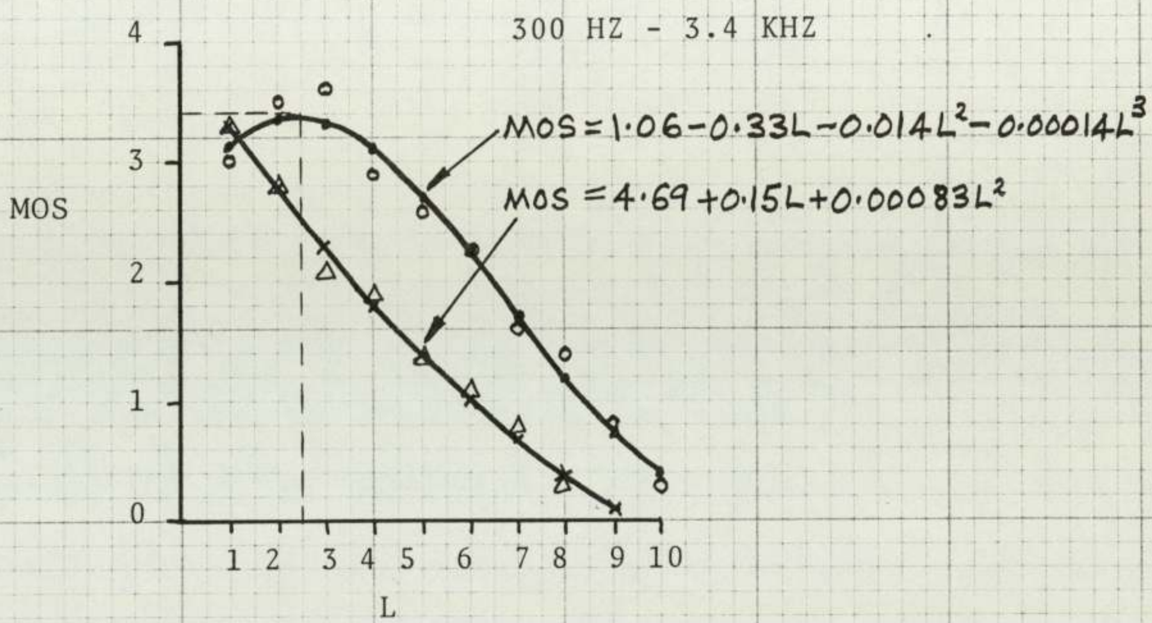


Fig. 30.3 Mean opinion score versus speech level for experiments PLL 3 and 4 (L = -10 to -46 dBV).

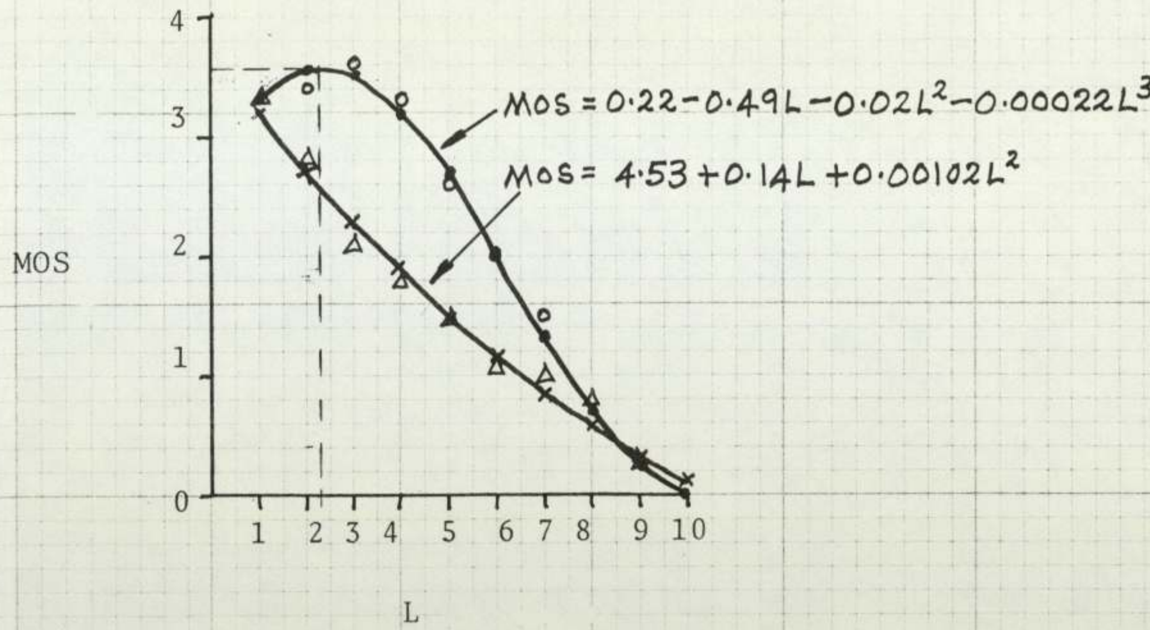


Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

Fig. 31.3 Mean opinion score versus speech level for experiments PLL - 5 and 6.

(L = -10 to -46 dBV)

300 HZ - 3.4 KHZ



Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

100 HZ - 8 KHZ

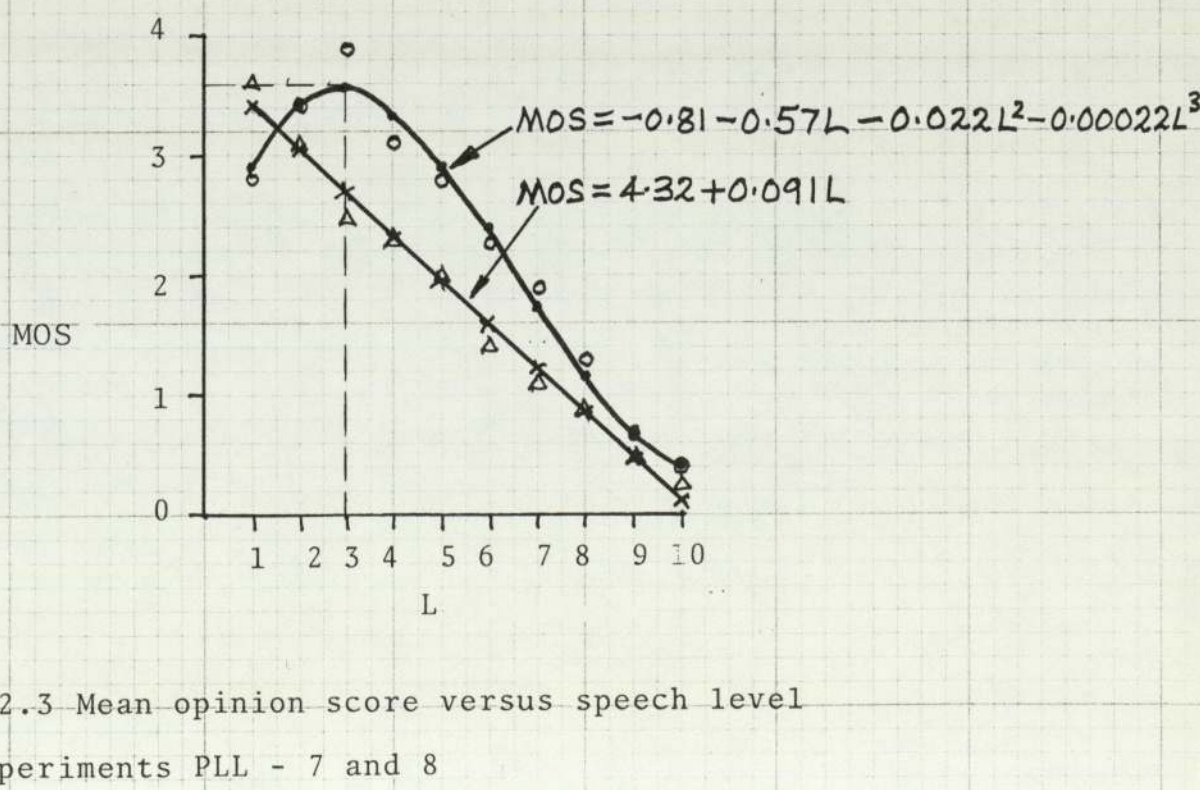
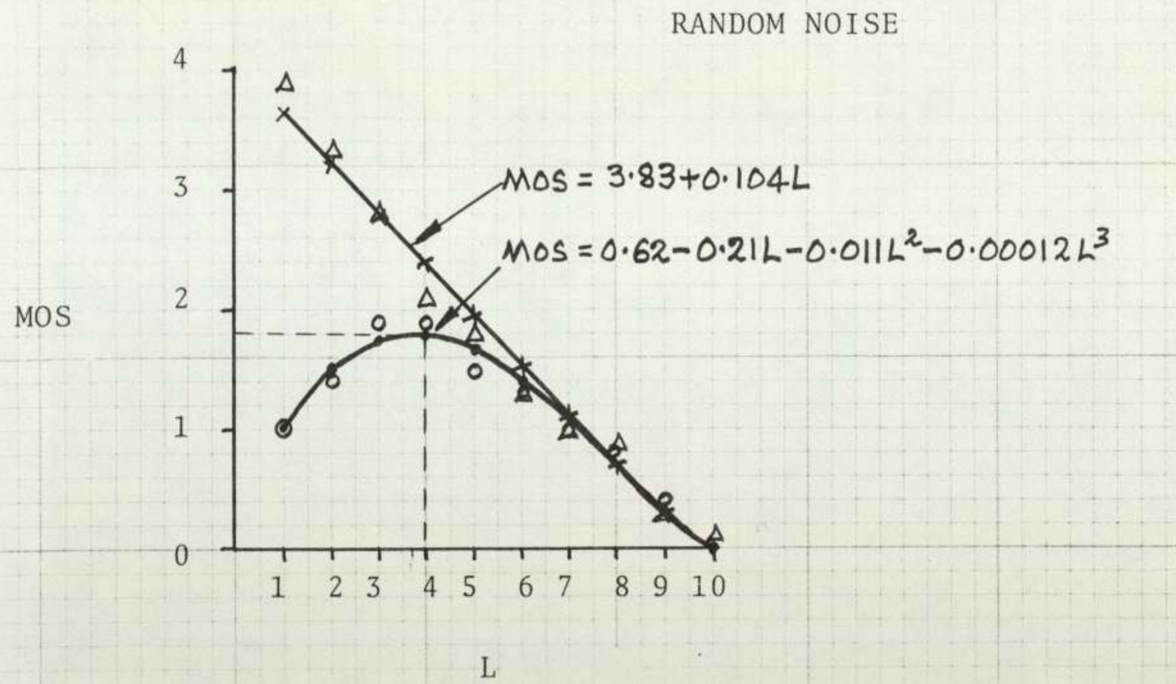


Fig. 32.3 Mean opinion score versus speech level for experiments PLL - 7 and 8

(L = -10 to -46 dBV)



Note, o and ● are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

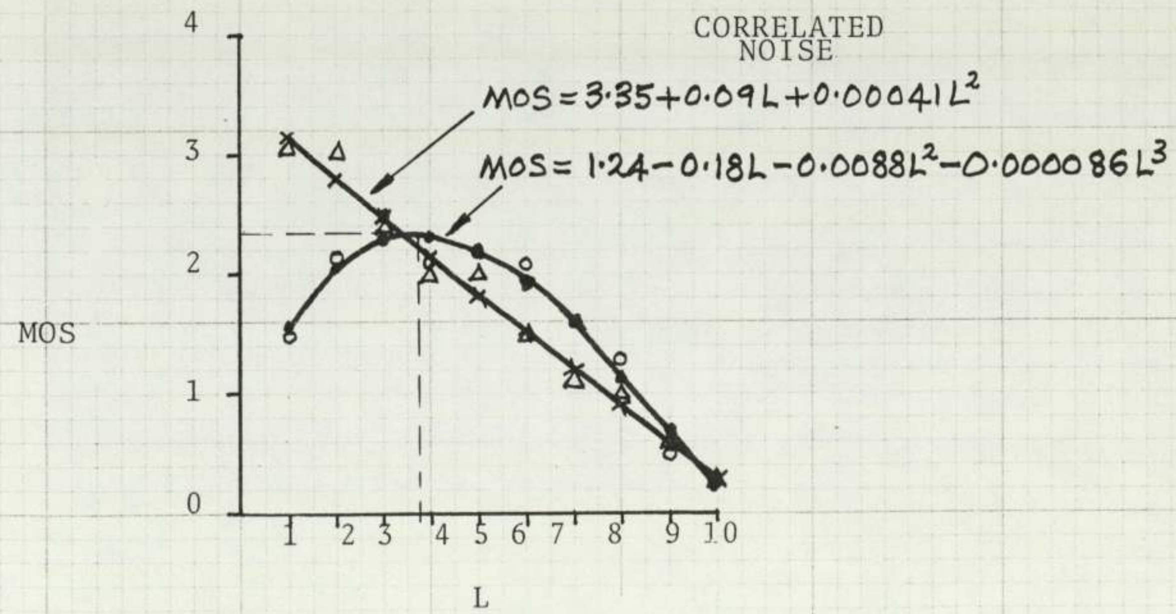
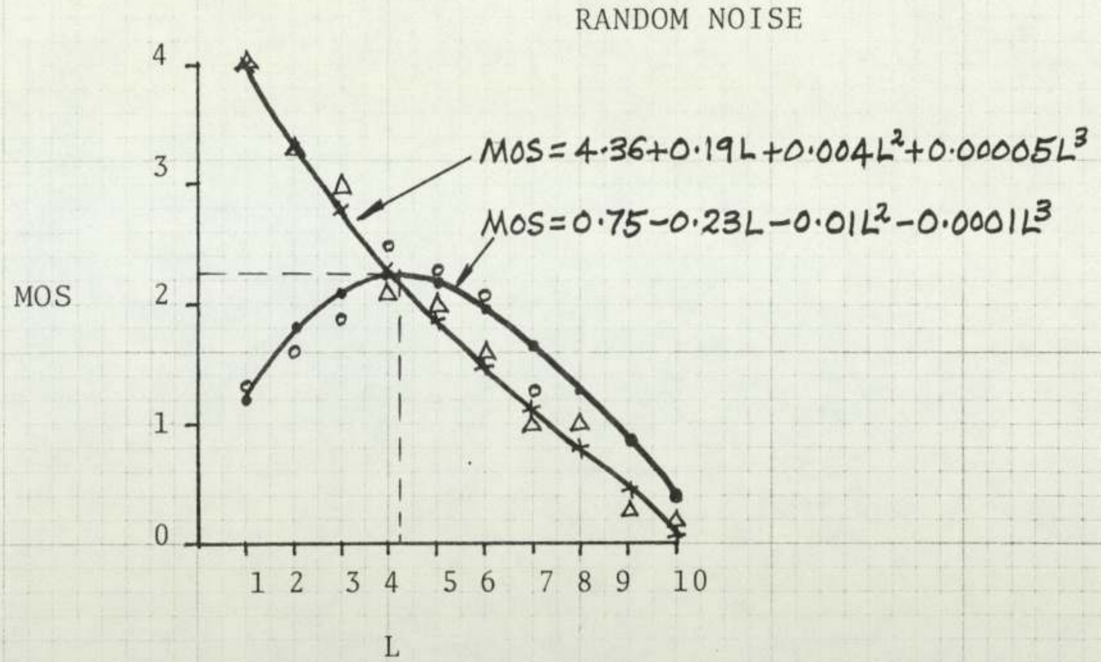


Fig. 33.3 Mean opinion score versus speech level for experiments PLL - 9 and 10.
(L = -2 to -38 dBV)



Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

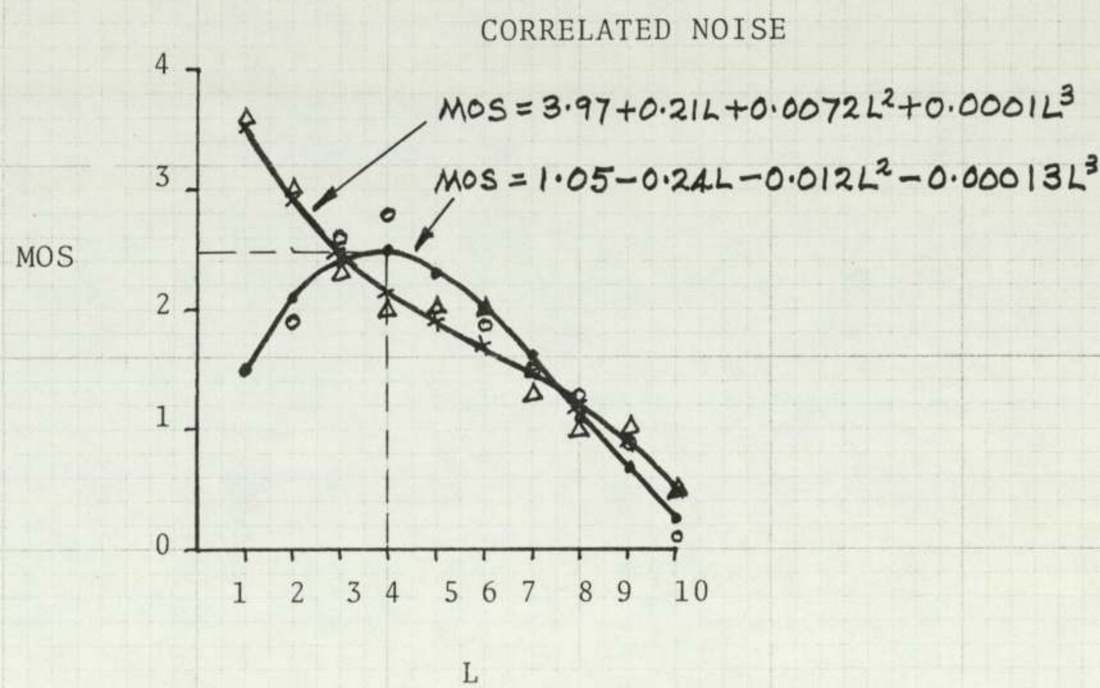
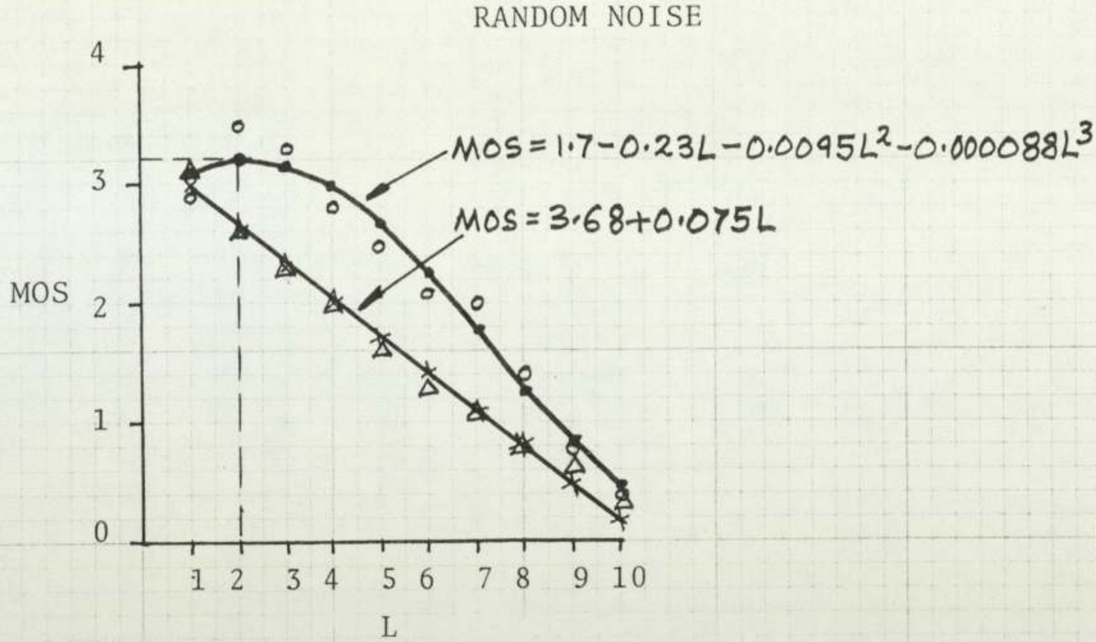


Fig. 34.3 Mean opinion score versus speech level for experiments PLL - 11 and 12
(L = -2 to -38 dBV)



Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

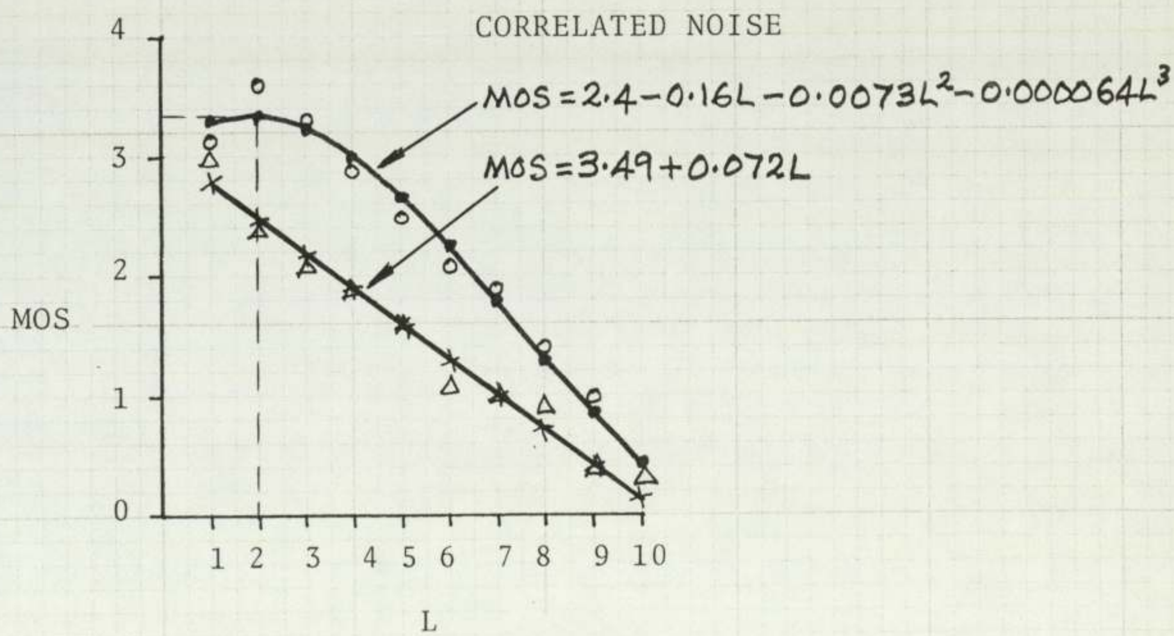
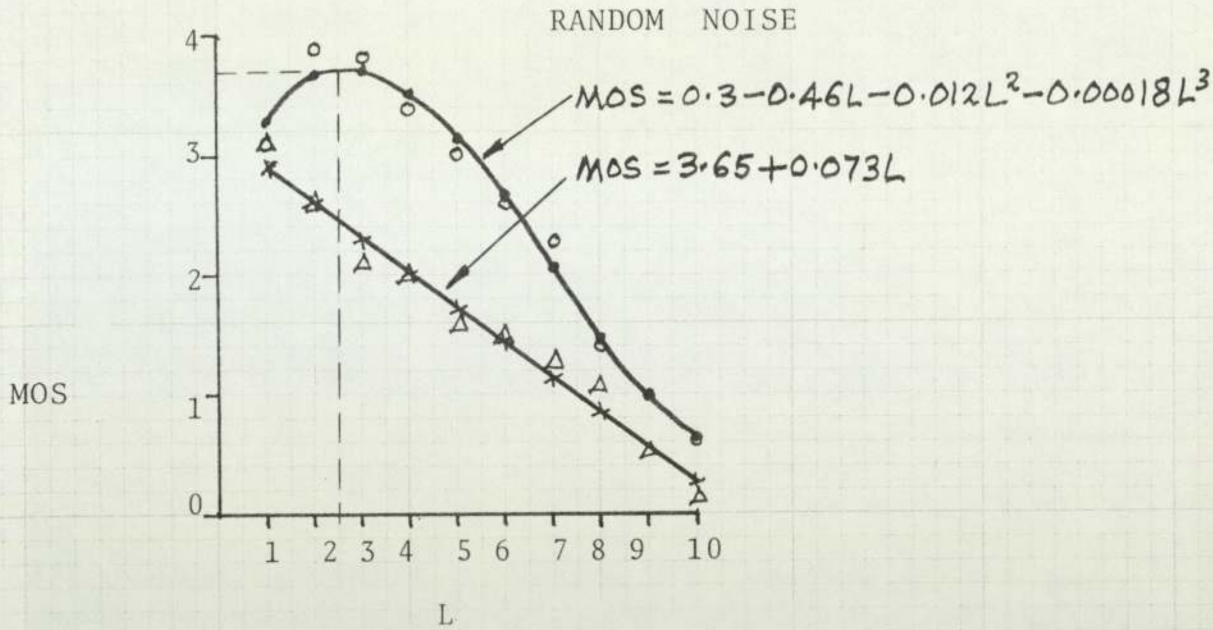


Fig. 35.3 Mean opinion score versus speech level for experiments PLL - 13 and 14 (L = -10 to -46 dBV)



Note, o and • are the true and fitted points on the quality scale.
Δ and X are the true and fitted points on the loudness preference scale.

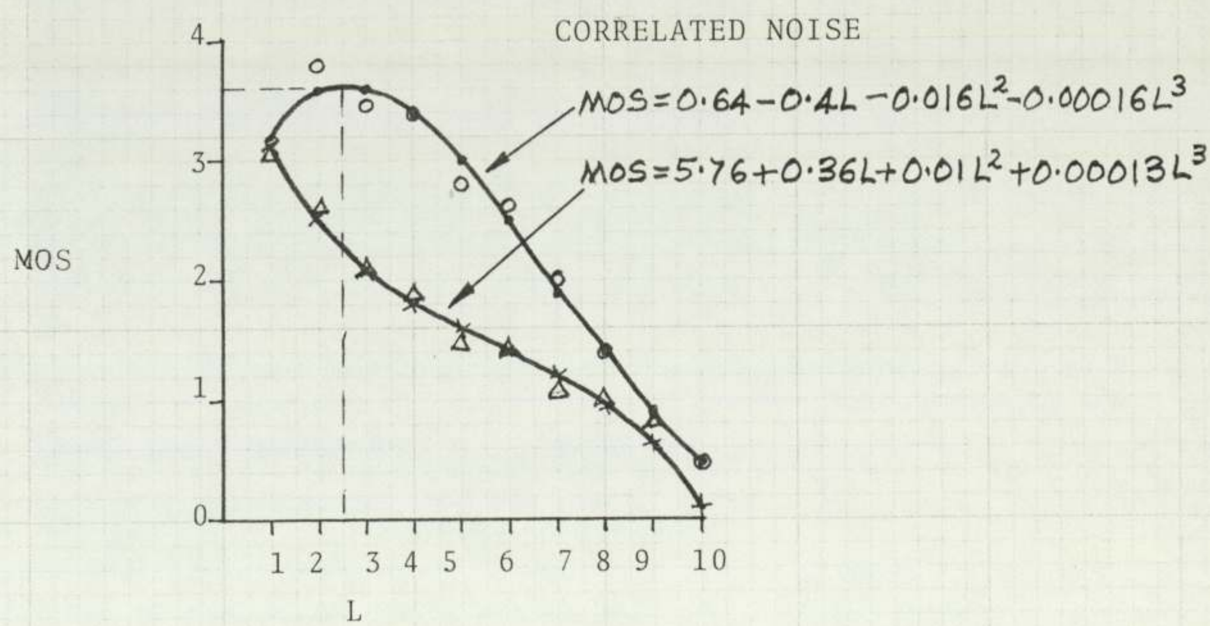
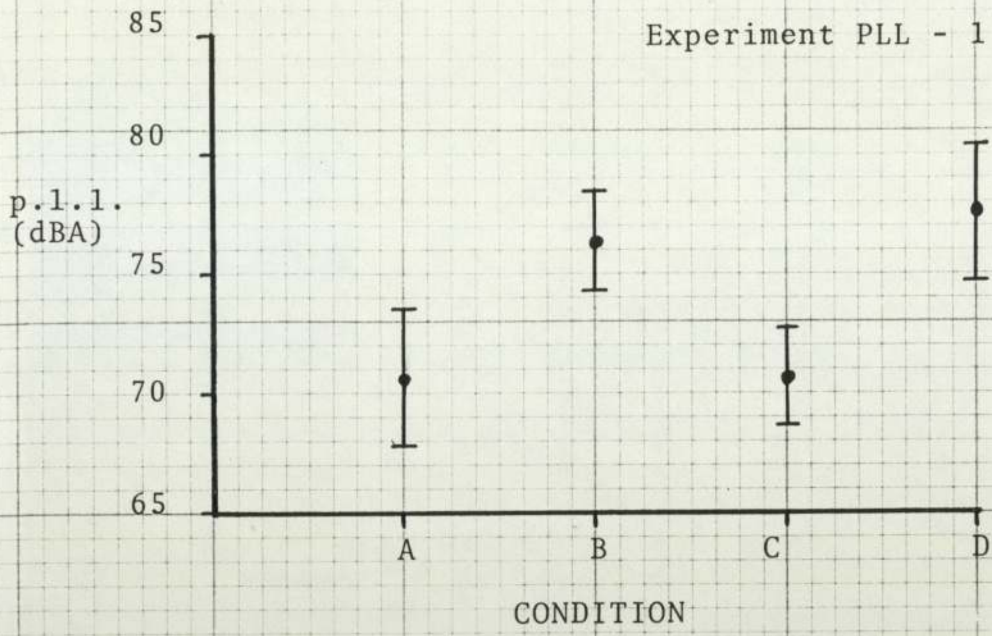


Fig. 36.3 Mean opinion score versus speech level for experiments PLL - 15 and 16.
(L = -10 to -46 dBV)

Checking the validity of the results

To get an idea of the validity of the results between different test conditions, inspection of the range in which the p.l.l. falls (i.e. the 95% confidence limits) will be an indication. If the ranges were to lie one within another, this would indicate that the subjects were unable to distinguish between the conditions presented. Figures 37.3 and 38.3 show the ranges obtained for the appropriate experiments based on loudness preference. (The results are obtained from Table 35.3 where Range 1 is the 95% confidence interval).



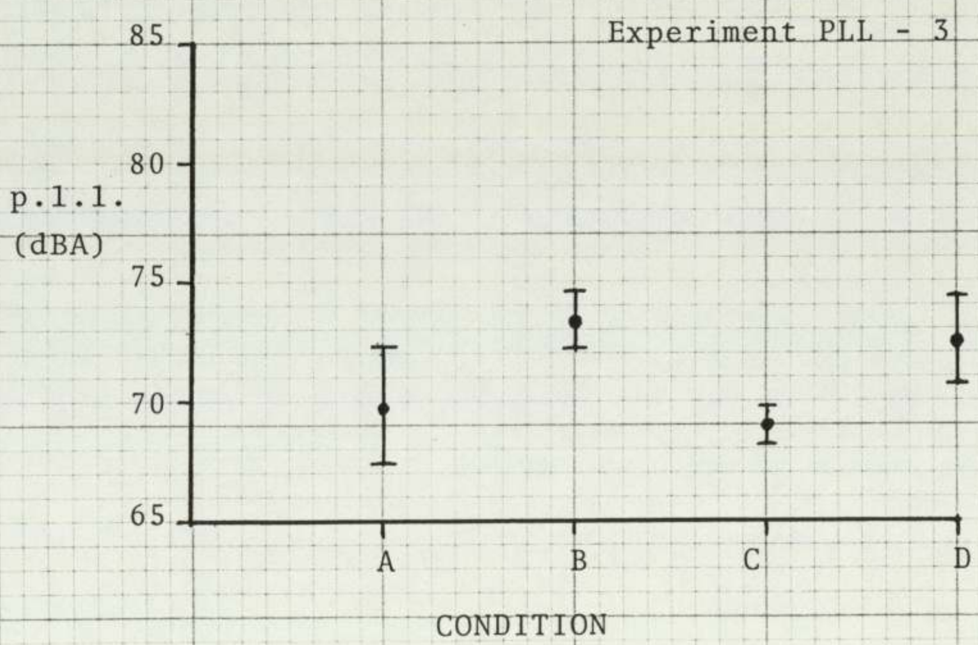
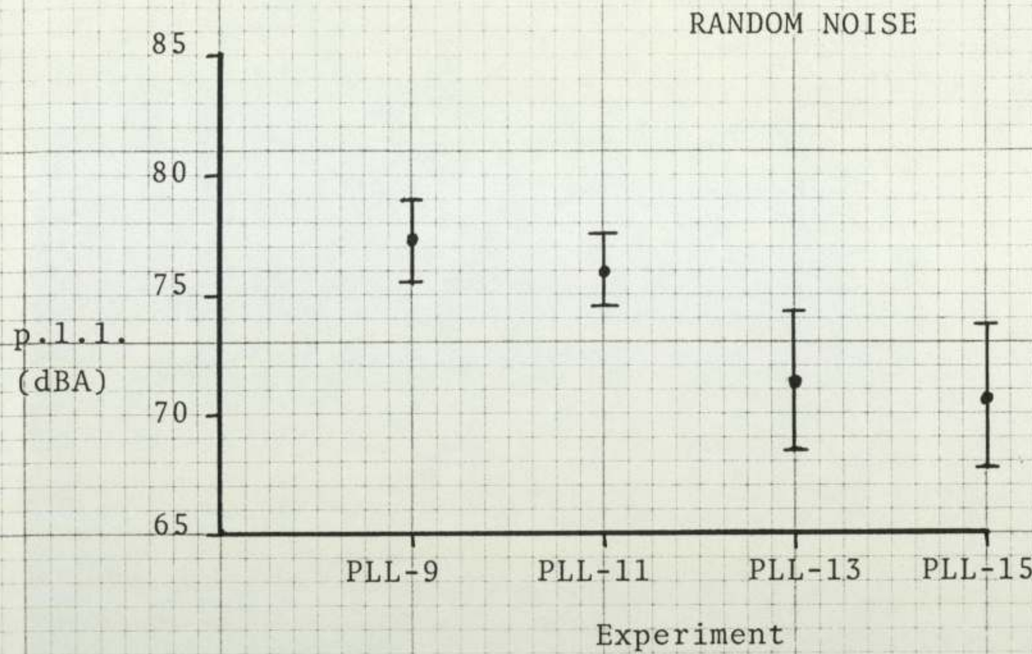


Fig. 37.3 Range of preferred listening levels from experiments PLL - 1 and 3.



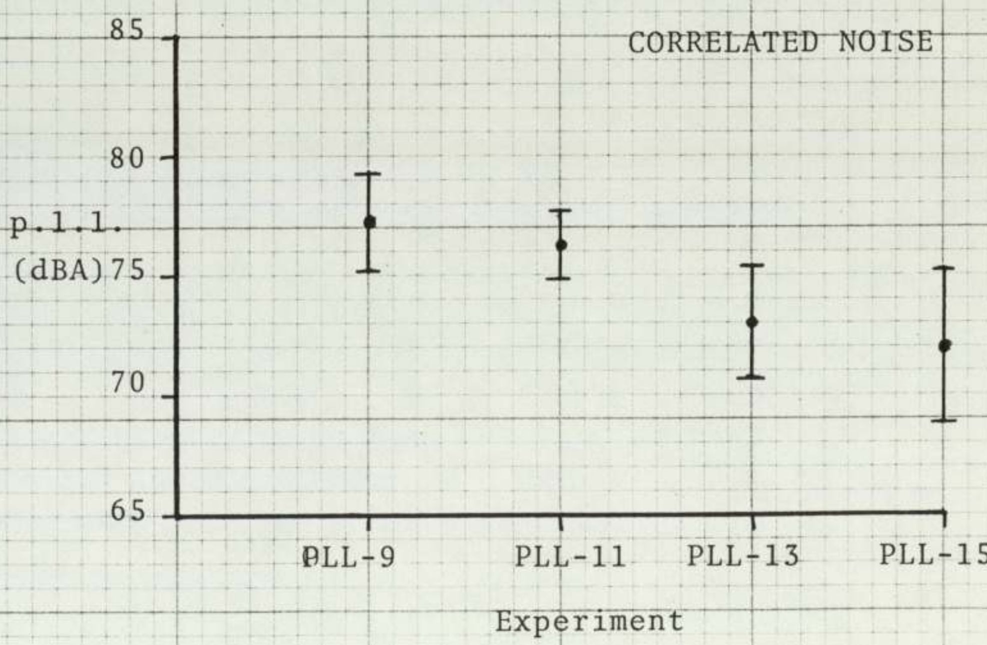


Fig. 38.3 Range of preferred listening levels from experiments PLL - 9, 11, 13 and 15

CHAPTER 3. SECTION 4.

DISCUSSION OF RESULTS FROM THE P.L.L. EXPERIMENTS.

Discussion of results from the preferred listening level experiments

From Figs. 37.3 and 38.3 in Section 3, it is noticed that as the level of noise increases, the range of uncertainty (i.e. the 95% confidence limits) reduces. This indicates that the subjects can distinguish between noise levels better when they are relatively high. (The speech probably has a masking effect on the lower noise levels).

In Section 3, Table 35.3 shows the results obtained from the experiments based on the loudness preference opinion scale, and Table 36.3 shows the results when based on the quality opinion scale. In all cases, it is seen that changing the random noise level in the left ear from 40 dBA to 60 dBA has little effect on the preferred listening level of the speech in the right ear. In fact, from tests done elsewhere[1] it appears that the attenuation in sound level between the ears is about 50 dB. The results from conditions A and C can thus be averaged, and similarly for conditions B and D. This produces Table 37.3 which gives the preferred listening level (p.l.l.) of speech when accompanied by a particular noise level, for experiments PLL - 1 to 4.

Table 38.3 is a re-arrangement of Table 37.3 to show the change in p.l.l. which occurs with the type of speech material chosen. Table 38.3 indicates that the p.l.l. is reduced when random sentences are used,

Opinion Scale	LOUDNESS PREF.				QUALITY			
Experiment PLL-	1 (N)		3 (RS)		2 (N)		4 (RS)	
Noise Level (dBA)	40.0	60.0	40.0	60.0	40.0	60.0	40.0	60.0
p.l.l (dBA)	70.8	77.1	69.5	73.1	79.0	83.0	76.0	82.0
Mean Opin. Score					3.5	3.4	3.6	3.4

TABLE 37.3

Opinion Scale	LOUDNESS PREF.				QUALITY			
Noise Level (dBA)	40		60		40		60	
Speech Material	N	RS	N	RS	N	RS	N	RS
p.l.l (dBA)	70.8	69.5	77.1	73.1	79.0	76.0	83.0	82.0
Difference (dB)	1.3		4.0		3.0		1.0	

TABLE 38.3 Note, N refers to narrative material
RS refers to random sentences

RESULTS FROM EXPERIMENTS PLL-1 to 4

although the differences may have been smaller had the subjects received more experience in the experiments at the time.

Because of the generality of random sentences, it was decided to use these throughout the rest of the experiments. From Table 37.3 it is also seen that the difference in p.l.l. due to choice of opinion scales is 8.2 dB with 40 dBA of noise, and 5.9 dB with 60 dBA of noise when based on the narrative type of speech material. When based on random sentences, it is 6.5 dB with 40 dBA of noise, and 8.9 dB with 60 dBA of noise. Although no particular trend is apparent in these figures, the difference in p.l.l. between the opinion scales is noted as the experiments progress.

From the curves shown in Figs. 27.3 to 30.3 (Sec.3) it is seen that for conditions B and D (60 dBA of noise present with the speech), two points are lost due to insufficient speech level. For this reason, the speech levels over the range (covering 36 dB) were increased by 8dB for experiments PLL - 9 to 12 where high noise levels were present.

The effects of bandwidth reduction

Referring back to Tables 35.3 and 36.3, the experimental results from the effect of bandwidth reduction on p.l.l. are summarised in Table 39.3. In order to gain a comparison between experiments having similar conditions, Table 40.3 was formed. From Table 40.3, it is seen that there

Noise Level = 40dBA

Opinion Scale	Loudness Pref.			Quality		
Experiment PLL-	5/A	7/A1	7/A2	6/A	8/A1	8/A2
p.l.l. (dBA)	73.2	72.9	68.7	77.0	78.0	75.0
Mean Opinion Score				3.4	3.6	3.6
Spread (Op.Units)	0.26	0.19	0.27	0.43	0.22	0.26
Bandwidth (Hz)	300-3.4K		100-8K	300-3.4K		100-8K

TABLE 39.3

	Bandwidth = 100Hz - 8kHz			
Opinion Scale	Loudness Pref		Quality	
Experiment PLL-	7/A2	3	8/A2	4
p.l.l. (dBA)	68.7	69.5	75.0	76.0
Mean Opinion Score			3.6	3.6
Spread (Opin. Units)	0.27	0.24	0.26	0.3

TABLE 40.3

Comparisons between experiments PLL-5 to 8 is good agreement for the p.l.l. when the bandwidth is 100 HZ - 8 KHZ between experiments PLL - 3 and PLL - 7/A2 (the difference is 0.8 dB) and also between PLL - 4 and PLL - 8/A2 (a difference of about 1 dB). There is a difference in the p.l.l. of about 6 dB between the opinion scales.

Experiments PLL - 7 and 8 were formed in order to see whether an 'enhancement' effect could be shown when the two bandwidths were presented at random. Referring to Table 39.3, by comparing the results for PLL - 5 with those from PLL - 7/A1, the preferred listening levels are very similar (when based on loudness preference), but PLL - 6 and PLL - 8/A1 show an increase in p.l.l. of 1 dB in the enhancement experiment (i.e. when based on quality).

For a bandwidth of 300 HZ - 3.4 KHZ, and 40 dBA of noise, it is seen that the p.l.l. is about 73 dBA when based on loudness preference, and 78 dBA based on quality. (The difference in p.l.l. between the opinion scales here is 5 dB). The effect therefore of reducing the bandwidth is to increase the p.l.l. by about 4.2 dB when based on loudness preference (comparing PLL - 7/A1 with 7/A2), and 3 dB when based on quality, (comparing PLL - 8/A1 with 8/A2). The theoretical reduction (using 'A' weighings) was only 0.05 dB.

When asked for their comments, the subjects indicated that the absence of the "bassy" parts of the speech had no adverse effect on the intelligability, and some even preferred it this way.

The effects of random and speech correlated noise on p.l.l. and their equivalence

The results from experiments PLL - 9 to 16 give the p.l.l. of speech when accompanied by either random or speech-correlated noise. In each experiment, the signal and noise were attenuated together to keep the signal/noise ratio constant. The bandwidth used was 300 HZ to 3.4 KHZ. Tables 41.3 and 42.3 show the results obtained. From the p.l.l. and signal/ratio the level of noise accompanying the speech was found as follows:- If N is the noise level (in dBA) and S is the speech level (in dBA), then S - N is the signal/noise ratio R, (in dB). Thus, the noise level is S - R (in dBA).

It is seen from Tables 41.3 and 42.3 (and also Figure 39.3) that the p.l.l. reduces as the S/N ratio increases. When based on quality, the M.O.S. increases as the S/N ratio increases.

It is also noticed from Fig. 39.3 that generally, the difference in p.l.l. between the two opinion scales decreases as conditions get worse (i.e. as the noise level increases).

Comparing experiments (PLL - 5, 7/A1) and PLL - 13/R (see Table 35.3 in Sec.3) they all use a bandwidth of 300 KZ - 3.4 KHZ with a noise level of about 40 dBA. The difference in p.l.l. is about 1.5 dB between (PLL - 5, 7/A1) and PLL - 13/R, and suggests that presenting a constant noise level with the speech level varying may produce a slightly different p.l.l. compared with

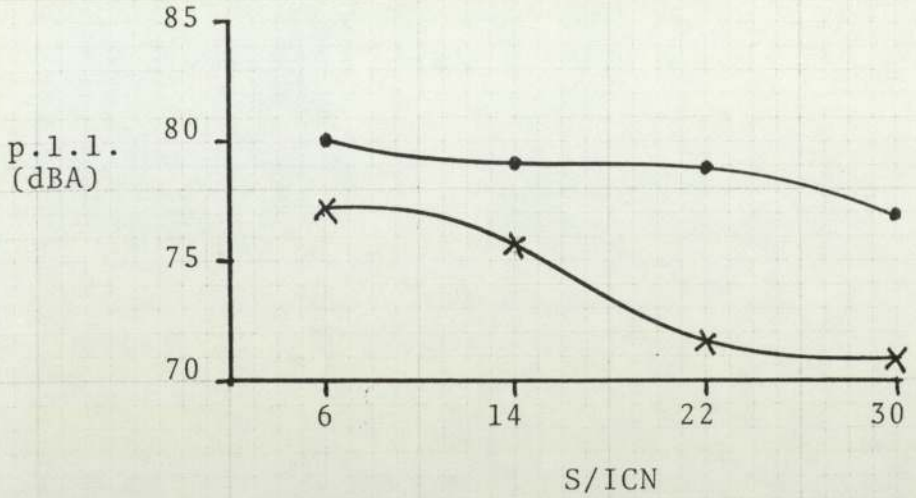
Opinion Scale	LOUDNESS PREF.							
Experiment PLL-	9/R	9/C	11/R	11/C	13/R	13/C	15/R	15/C
S/N Ratio (dB)	6	5	14	10	22	15	30	20
Noise Type	R	C	R	C	R	C	R	C
Noise Level (dBA)	71.4	72.2	62.0	66.2	49.5	58.0	40.7	52.0
p.l.l. (dBA)	77.4	77.2	76.0	76.2	71.5	73.0	70.7	72.0

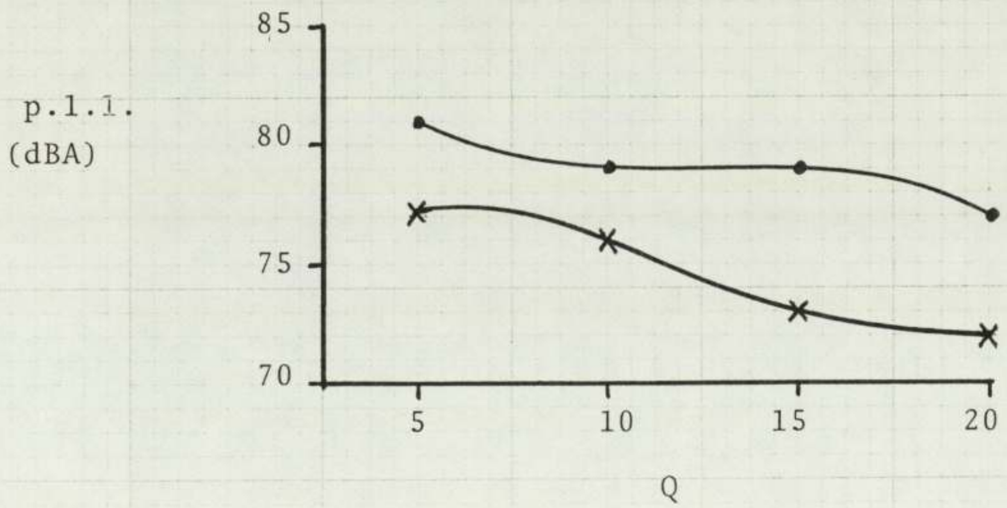
TABLE 41.3 Results based on loudness preference.
from experiments PLL-9,11,13, & 15

Note, R = Random noise
C = Correlated noise

Opinion Scale	QUALITY							
Experiment PLL-	10/R	10/C	12/R	12/C	14/R	14/C	16/R	16/C
S/N Ratio (dB)	6	5	14	10	22	15	30	20
Noise Type	R	C	R	C	R	C	R	C
Noise Level (dBA)	75	76	69	73	61	68	53	63
p.l.l. (dBA)	80	81	79	79	79	79	77	77
Mean Opin. Score	1.8	2.3	2.2	2.5	3.2	3.3	3.7	3.6

TABLE 42.3 Results based on quality.
from experiments 10,12,14, & 16





X are the results based on loudness preference.

• are the results based on quality.

Fig. 39.3 Showing the difference in p.l.l. between opinion scales. (Taken from Tables 41.3 and 42.3) presenting a constant S/N ratio with the signal and noise varying proportionally together.

The Subjective Equivalence of Q and S/ICN

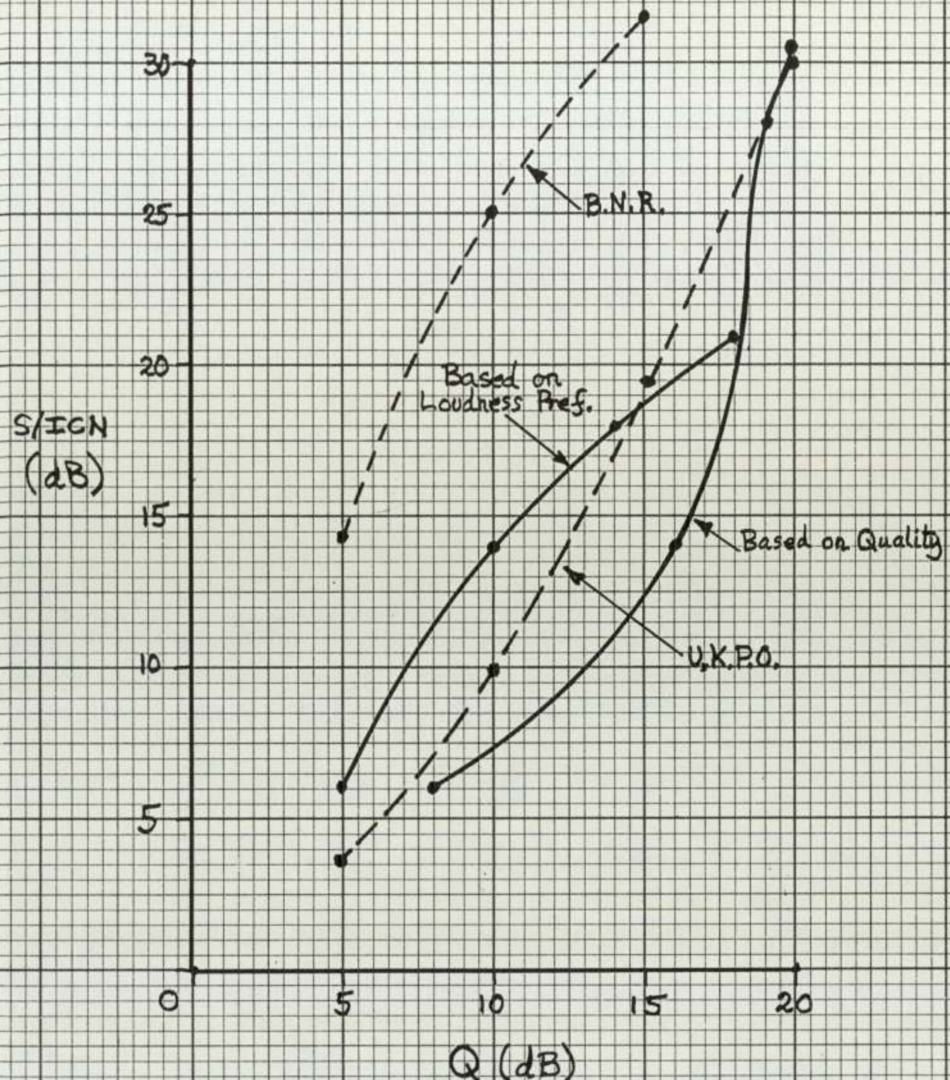
At the present, equivalence between S/ICN and Q as found by various organisations, is based on one listening level of speech only. (For example, Bell Northern use -27 dBV on a Western Electric 500 type telephone set. This yeilds a sound pressure level in the ear of about 86 dBA).

Experiments PLL-9 to 16 will produce a relationship between Q and S/ICN based on a series of listening levels. Various curves showing the equivalence of Q and S/ICN can be obtained from the experimental results, as will be shown in the following sections.

By equating the preferred listening levels for Q and S/ICN (shown in Fig. 39.3) equivalence curves can be obtained based on the two opinion scales used. These are shown in Fig. 40.3. Also included for comparison purposes are curves obtained by the United Kingdom Post Office (U.K.P.O. at that time, now British Telecom) and Bell Northern Research (B.N.R.)[12] which used the comparison adjustment method to obtain their results. It is seen that the results found here lie closer to those found by the U.K.P.O.

When the results from experiments using the quality opinion scale are used, a relationship is obtained by equating the mean opinion scores for S/ICN and Q, (which are related to a preferred listening level in the experiments).

The results to be plotted are obtained from Table



QUALITY

p.l.l.	80	79	78	77
Q	8	16	19	20
S/ICN	6	14	28	30

LOUDNESS PREF.

p.l.l.	77	76	74	72
Q	5	10	14	18
S/ICN	6	14	18	21

Fig. 40.3 S/ICN and Q equivalence based on Fig. 39.3

36.3 (Sec.3). The method is illustrated in Fig. 41.3 and the equivalence curve is shown in Fig.42.3. Also shown for comparison purposes are curves obtained by the U.K.P.O. and B.N.R. organisations. Here, a different curve is obtained to that found from equating loudness preference levels.

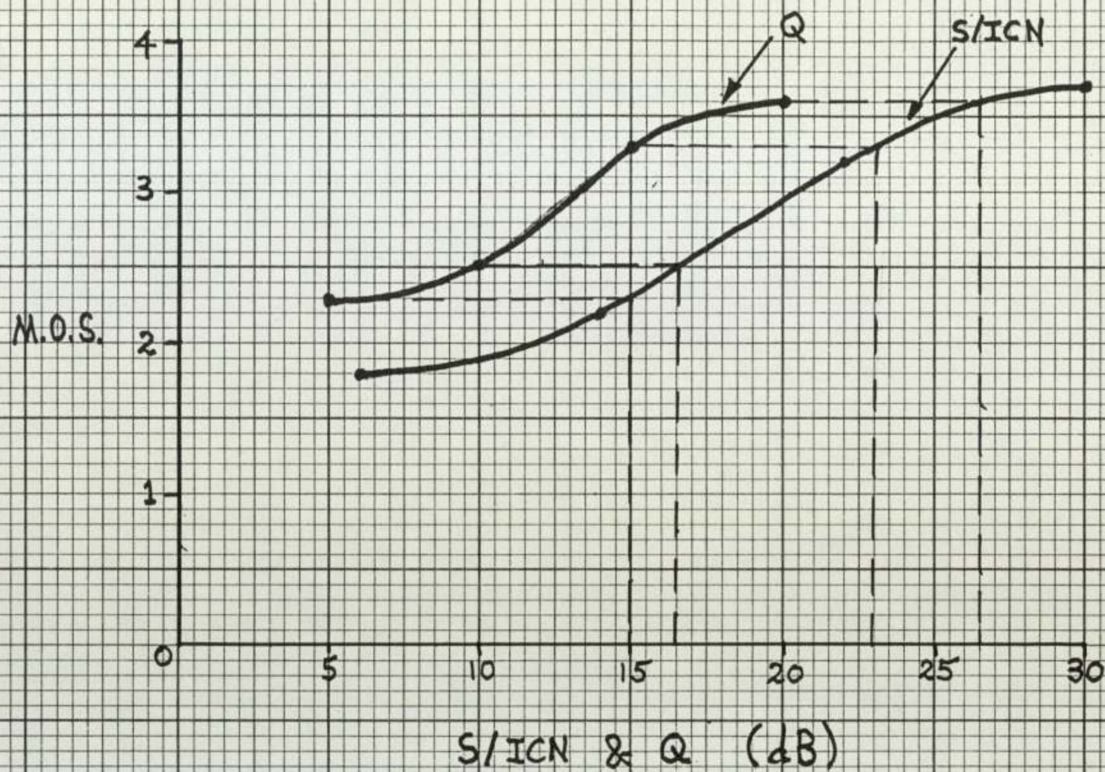
By equating the mean opinion scores for S/ICN and Q at particular speech levels, the resulting curves will show whether or not the equivalence does in fact vary according to the speech level. Figs. 43.3 and 44.3 show how the equivalence data (shown in Tables 44.3 and 45.3) is obtained for various levels of speech (-10 dBV to -34 dBV in steps of 6 dBV) for the results based on loudness preference. Note, in order to gain an initial idea of the trend of the results, a straight line relationship was assumed for the signal-to-noise ratio versus M.O.S. relationship at each particular speech level. More accurate results may have been obtained by fitting a set of curves to the points using a curve fit algorithm.

The set of equivalence curves obtained is shown in Fig. 45.3. Here it is seen that the relationship between Q and S/ICN is strongly dependant on the speech level when the loudness preference opinion scale is used.

Figs. 46.3 and 47.3 show how the equivalence data (shown in Tables 46.3 and 47.3) is obtained with the results based on the quality opinion scale.

The set of equivalence curves obtained is shown in Fig. 48.3. Here it is seen that the dependance is a lot less than that for the results based on loudness preference, but it is still present. It is noticed that the curves are grouped roughly between those found by the U.K.P.O. and B.N.R. organisations. Note, the U.K.P.O. and B.N.R. curves shown are based on comparison tests. The results obtained from the experiments do in fact lie closer to those found by various organisations when they also used the rating method, (based on quality). The curves shown in Fig. 49.3 show equivalence curves obtained by the various organisations[12] where it is seen that better agreement is obtained by all when they base their results on the rating method.

The various results found from the sets of experiments in preferred listening level can now be incorporated into Stage 5 of the TCAM model to give the extent to which preferred listening level is affected by random noise, quantising distortion and bandwidth.

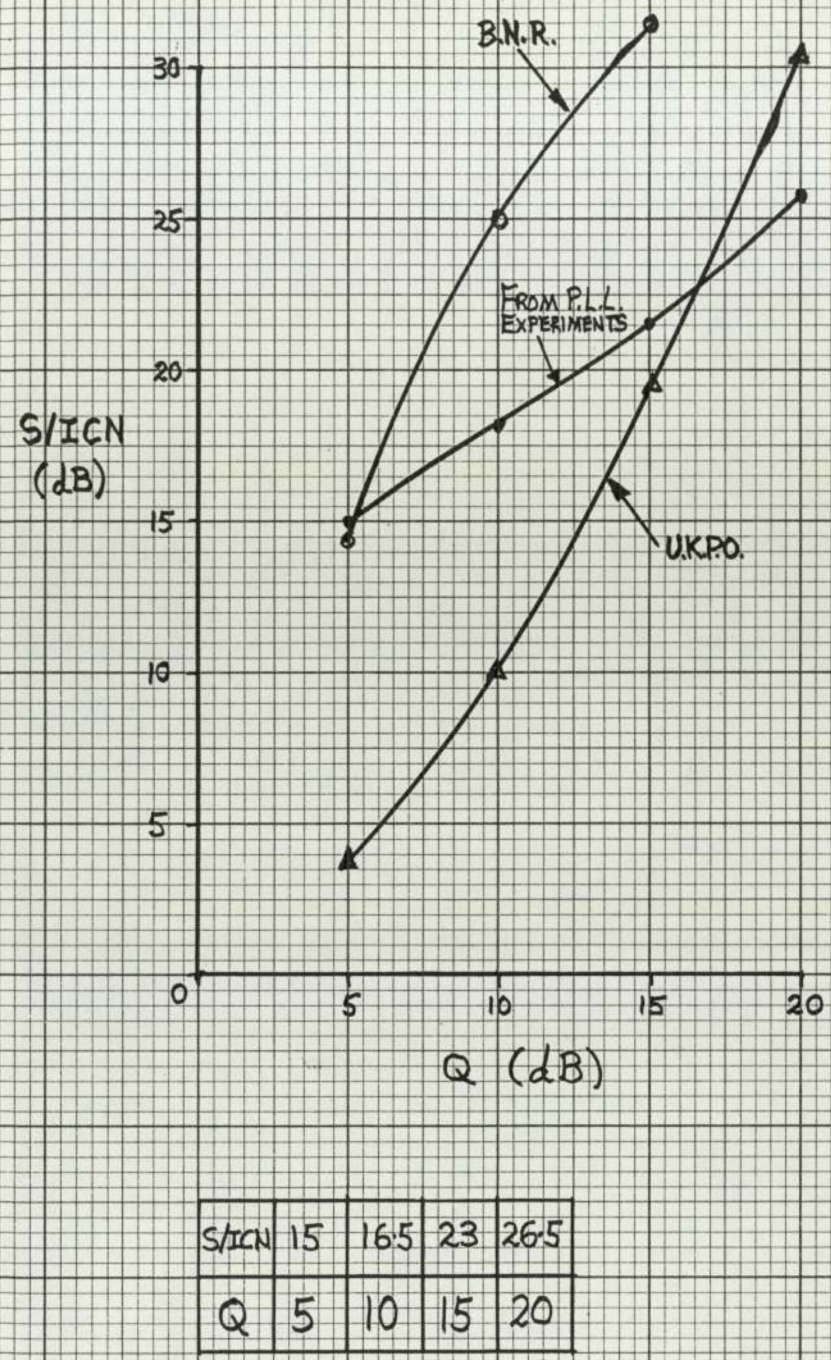


MOS	1·8	2·2	3·2	3·7
S/ICN	6	14	22	30

MOS	2·3	2·5	3·3	3·6
Q	5	10	15	20

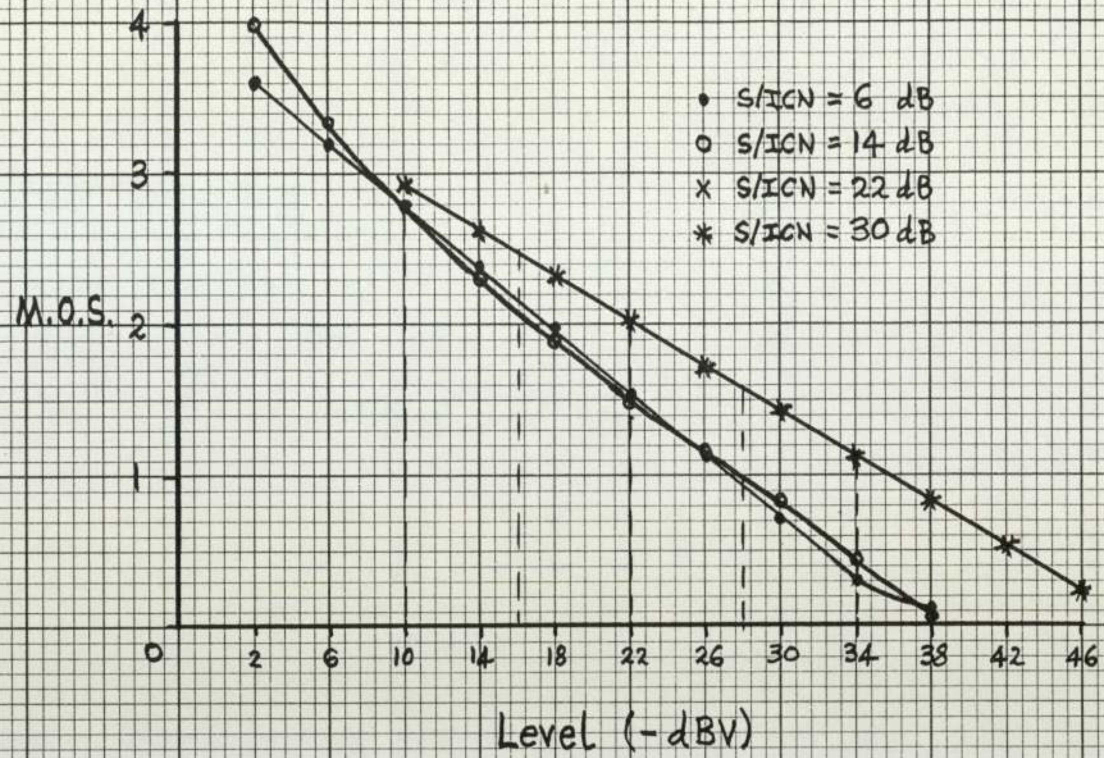
Q	5	10	15	20
S/ICN	15	16·5	23	26·5

Fig. 41.3 Determing the relationship between Q and S/ICN when based on the quality opinion scale.



S/ICN	15	16·5	23	26·5
Q	5	10	15	20

Fig. 42.3 Relationships between Q and S/ICN.



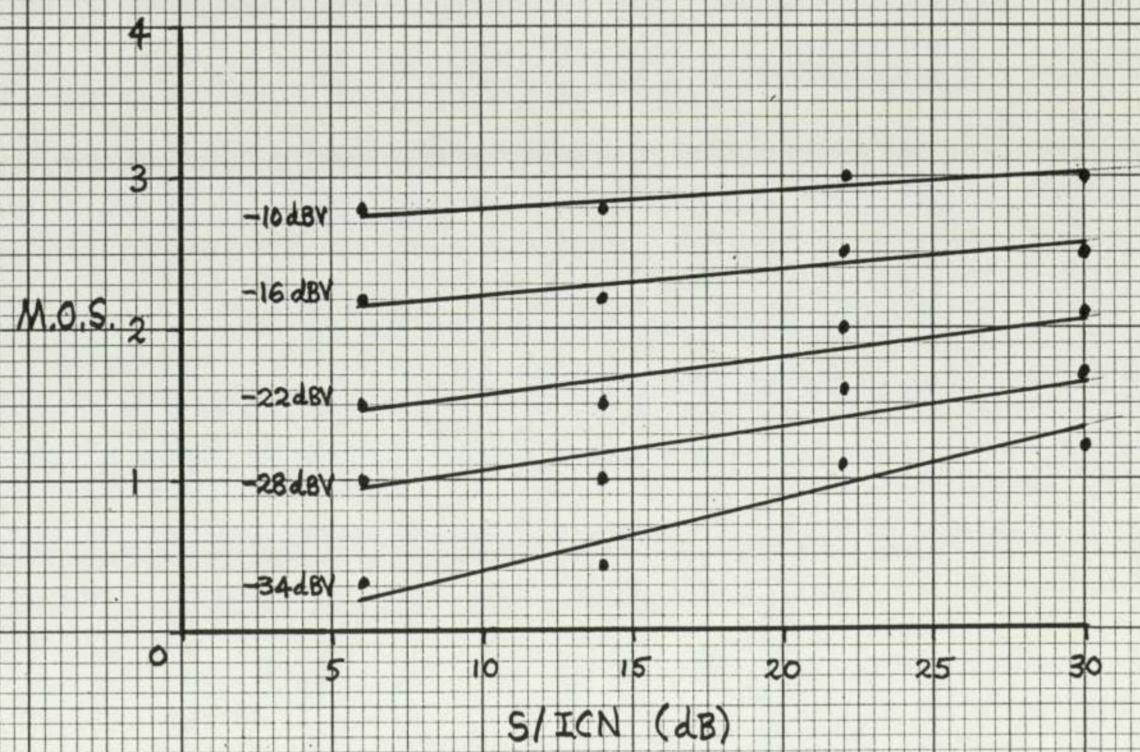


Fig. 43.3. Obtaining MOS vs S/ICN for various levels of speech. (Based on loudness preference).

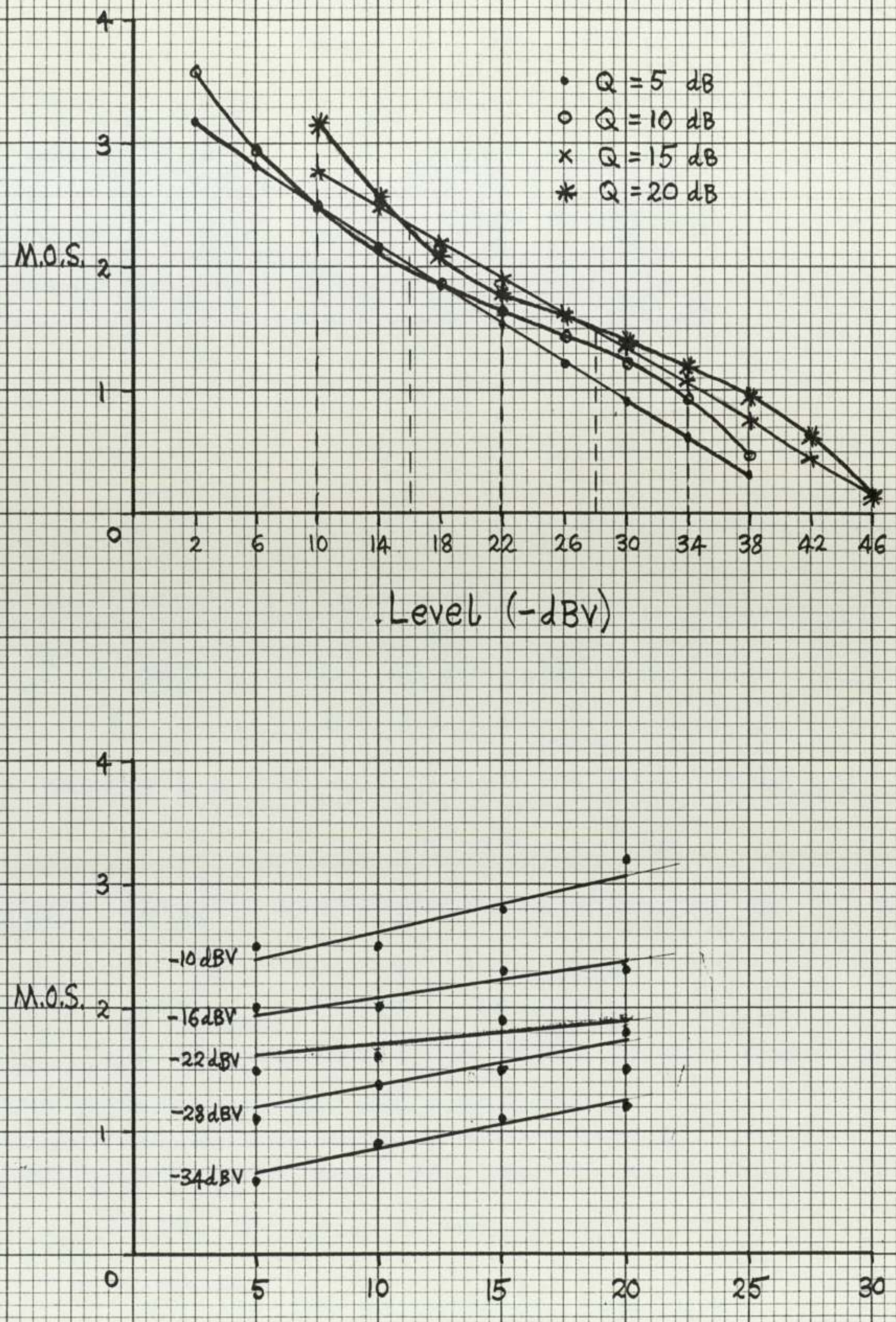


Fig. 44.3. Obtaining MOS vs Q for various levels of speech. (Based on oudness preference).

LEVEL (-dBV)	M.O.S.			
10.0	2.8	2.8	2.8	3.0
16.0	2.2	2.2	2.5	2.5
22.0	1.5	1.5	2.0	2.1
28.0	1.0	1.0	1.6	1.6
34.0	0.3	0.4	1.1	1.2
S/ICN (dB)	6	14	22	30

LEVEL (-dBV)	M.O.S.			
10.0	2.5	2.5	2.8	3.2
16.0	2.0	2.0	2.3	2.3
22.0	1.5	1.6	1.9	1.8
28.0	1.1	1.4	1.5	1.5
34.0	0.6	0.9	1.1	1.2
Q (dB)	5	10	15	20

TABLE 44.3 Values for equating Q with S/ICN
(Based on loudness preference)

LEVEL (-dBV)					
10.0	M.O.S.	2.8	2.9	2.95	3.0
	Q	14	16	18	19
	S/ICN	10	18	23	28
16.0	M.O.S	2.2	2.25	2.3	2.4
	Q	14	15	17	20
	S/ICN	9	12	15	20
22.0	M.O.S.	1.5	1.6	1.8	1.9
	Q	3	5	15	19
	S/ICN	8	12	20	24
28.0	M.O.S.	1.2	1.3	1.5	1.6
	Q	5	8	14	16
	S/ICN	15	18	25	29
34.0	M.O.S.	0.7	0.9	1.0	1.2
	Q	6	11	14	19
	S/ICN	16	21	23	27

TABLE 45.3 Values for Q vs S/ICN at various speech levels. (Based on loudness preference)

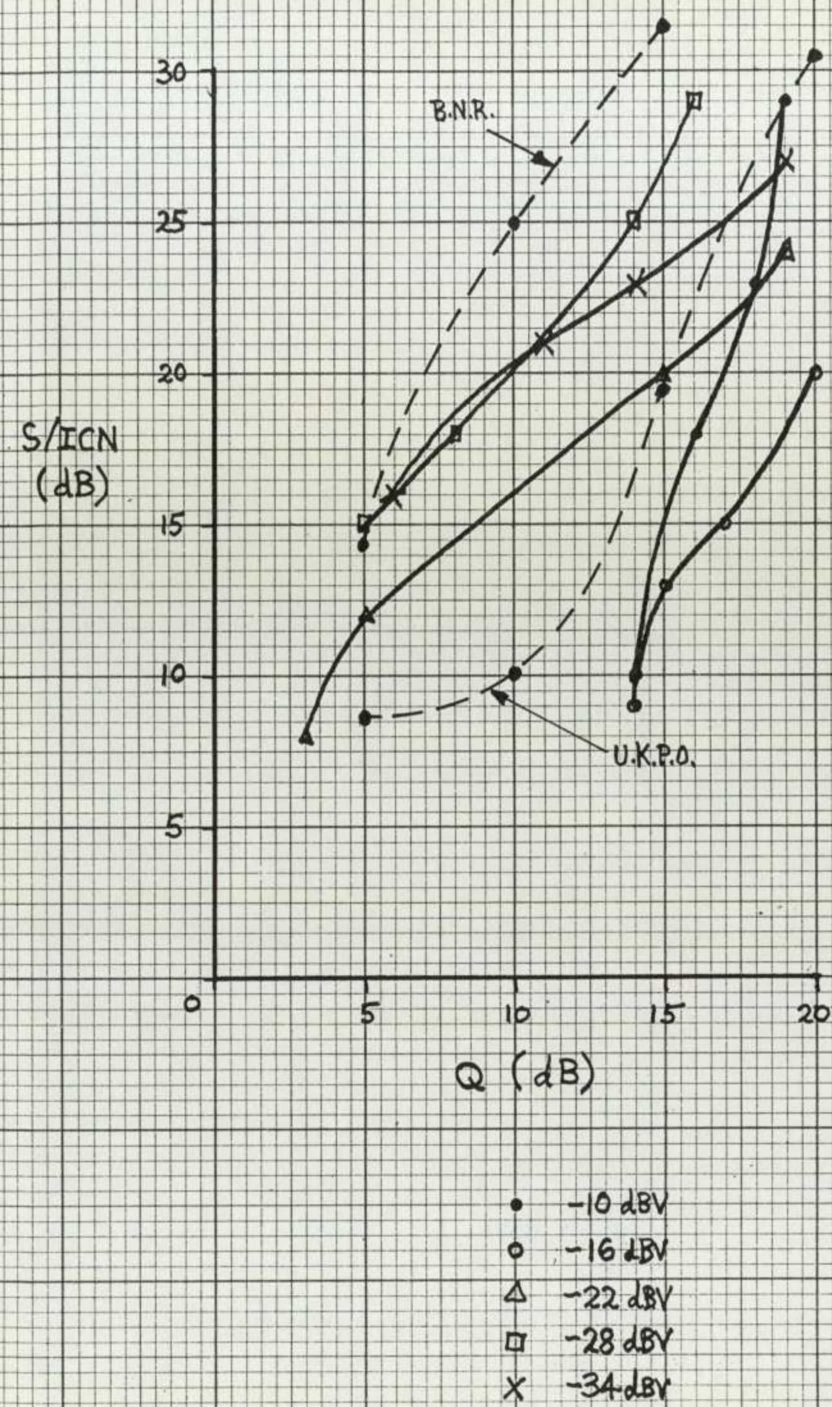
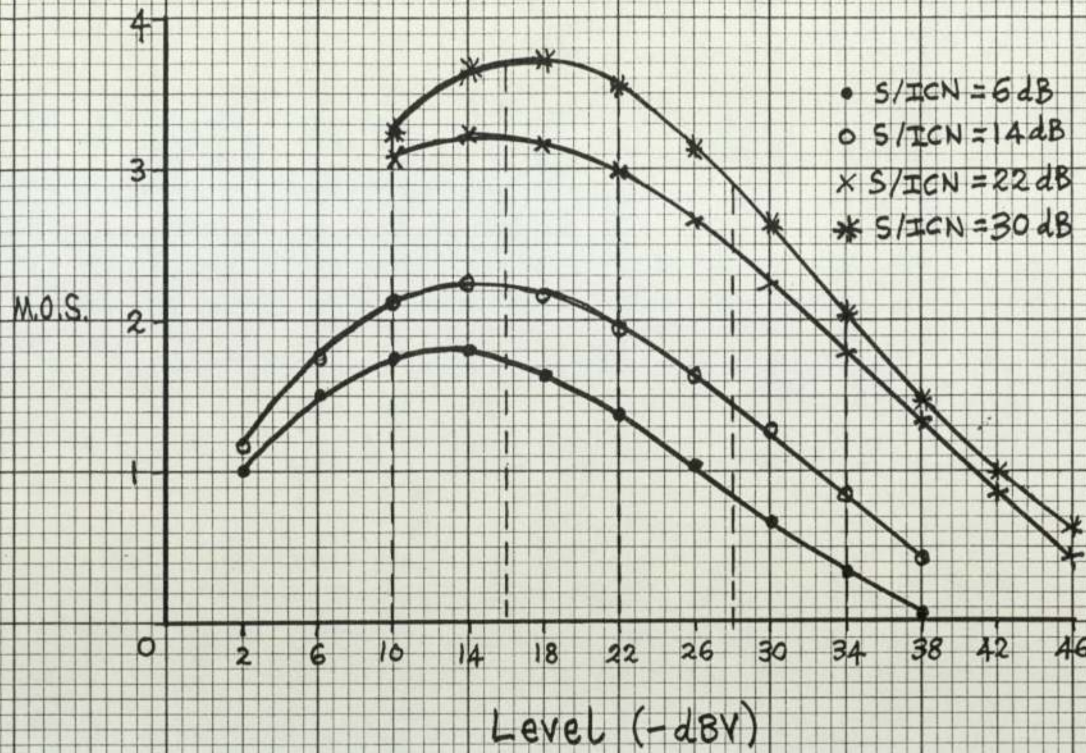


Fig. 45.3 Showing the dependance of Q vs S/ICN with speech level. (Based on loudness preference).



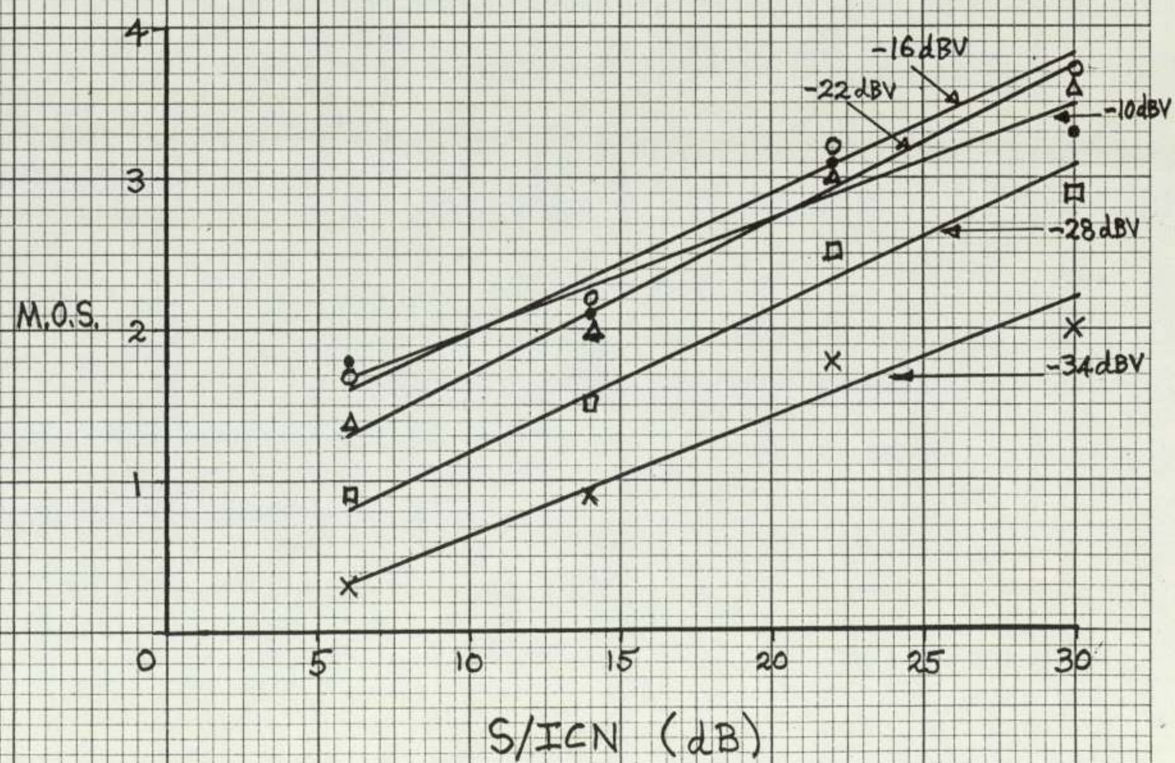


Fig. 46.3 Obtaining MOS vs S/ICN for various levels of speech. (Based on quality).

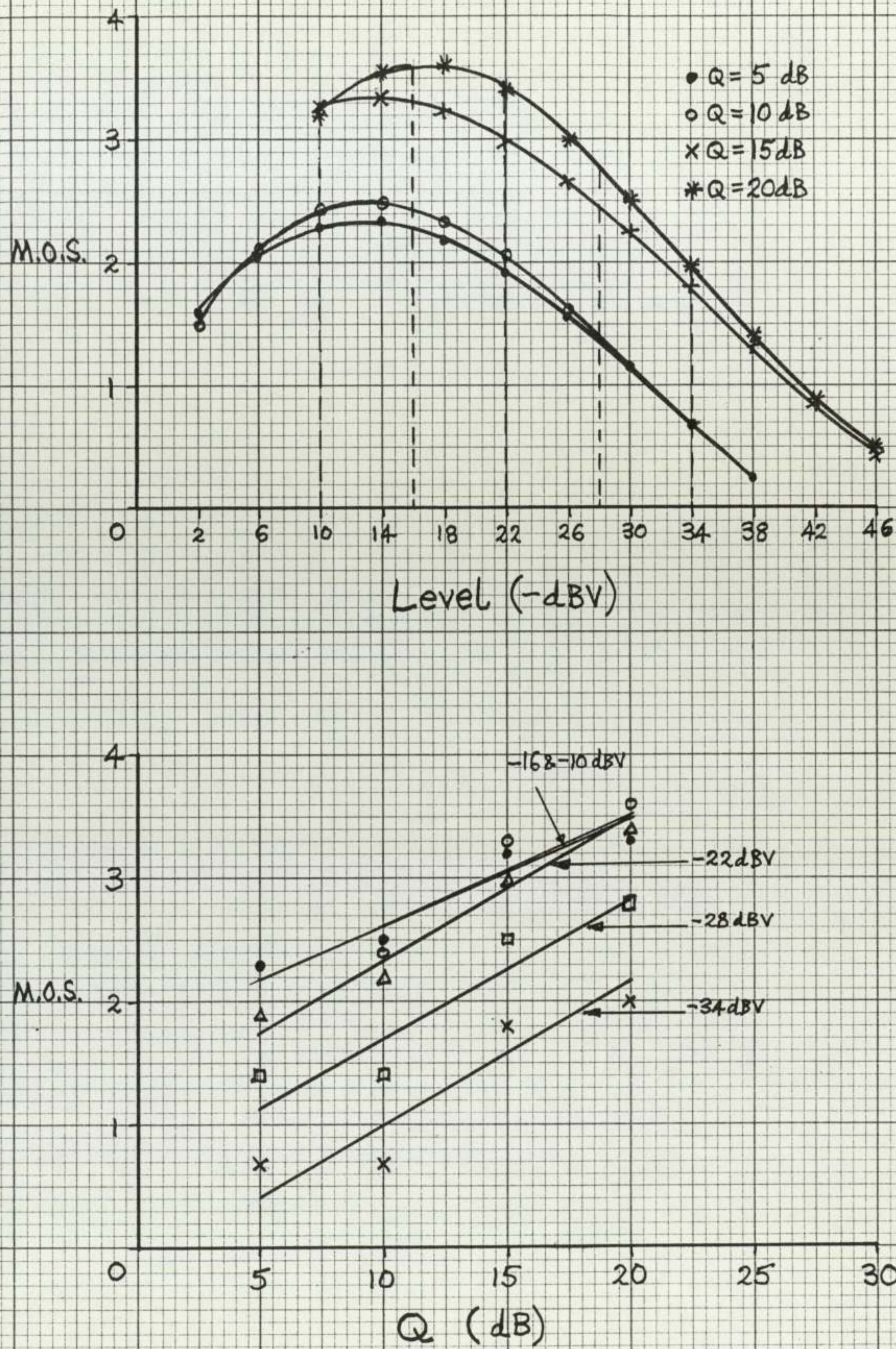


Fig. 47.3 Obtaining MOS vs S/ICN for various levels of speech. (Based on quality).

LEVEL (-dBV)	M.O.S.			
10.0	1.8	2.1	3.1	3.3
16.0	1.7	2.2	3.2	3.7
22.0	1.4	2.0	3.0	3.6
28.0	0.9	1.5	2.5	2.9
34.0	0.3	0.9	1.8	2.0
S/ICN (dB)	6	14	22	30

LEVEL (-dBV)	M.O.S.			
10.0	2.3	2.5	3.2	3.3
16.0	2.3	2.4	3.3	3.6
22.0	1.9	2.2	3.0	3.4
28.0	1.4	1.4	2.5	2.8
34.0	0.7	0.7	1.8	2.0
Q (dB)	5	10	15	20

TABLE 46.3 Values for equating Q with S/ICN
(Based on quality)

LEVEL (-dBV)					
10.0	M.O.S.	2.2	2.6	3.0	3.5
	Q	5	10	14.5	20
	S/ICN	13	18	24	30
16.0	M.O.S	2.2	2.6	3.0	3.5
	Q	5	10	14.5	20
	S/ICN	12.5	16.5	21	26.5
22.0	M.O.S.	1.7	2.3	2.9	3.5
	Q	5	10	15	20
	S/ICN	10	16	22	27.5
28.0	M.O.S.	1.1	1.7	2.3	2.8
	Q	5	10	15.5	20
	S/ICN	9	15.5	21.5	27
34.0	M.O.S.	0.4	1.0	1.6	2.2
	Q	5	10	15	20
	S/ICN	7	14.5	22	30

TABLE 47.3 Values for Q vs S/ICN at various speech levels. (Based on quality)

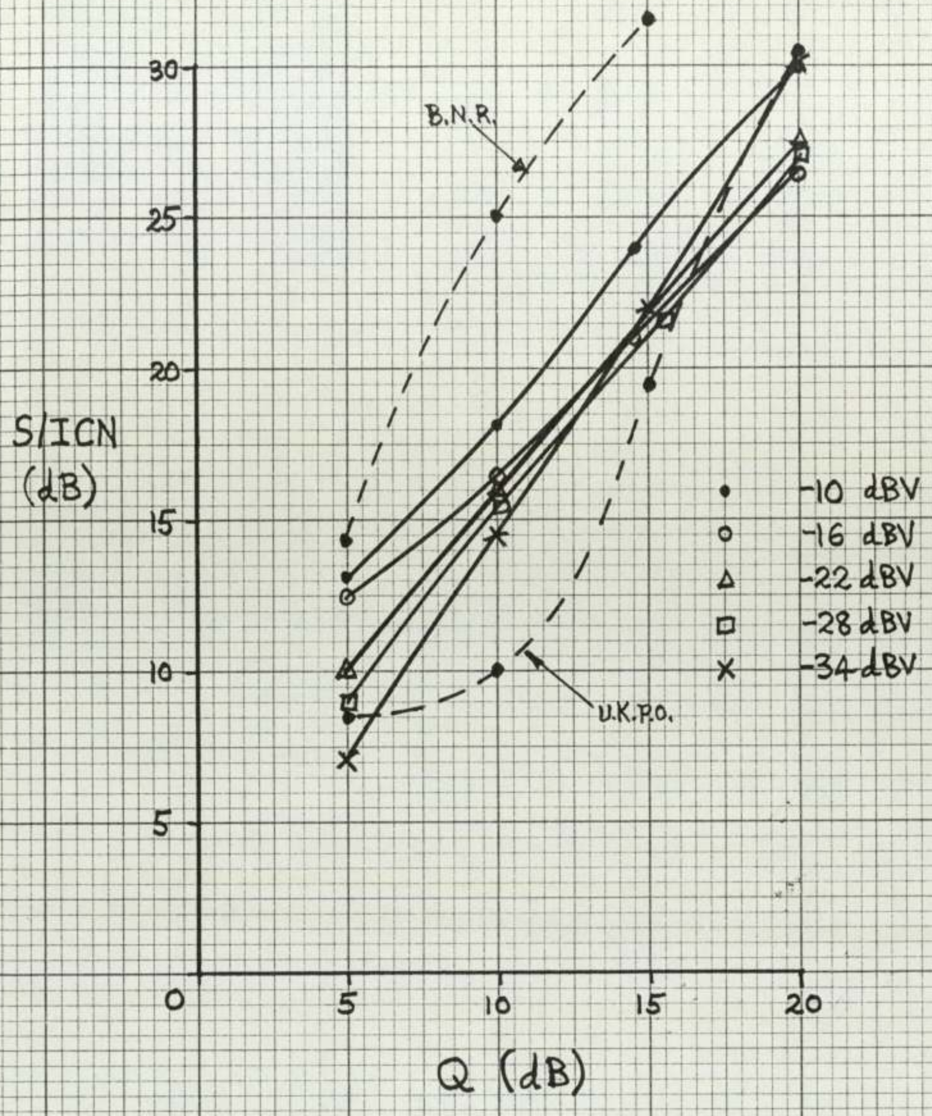


Fig. 48.3 Showing the dependance of Q vs S/ICN with speech level. (Based on quality).

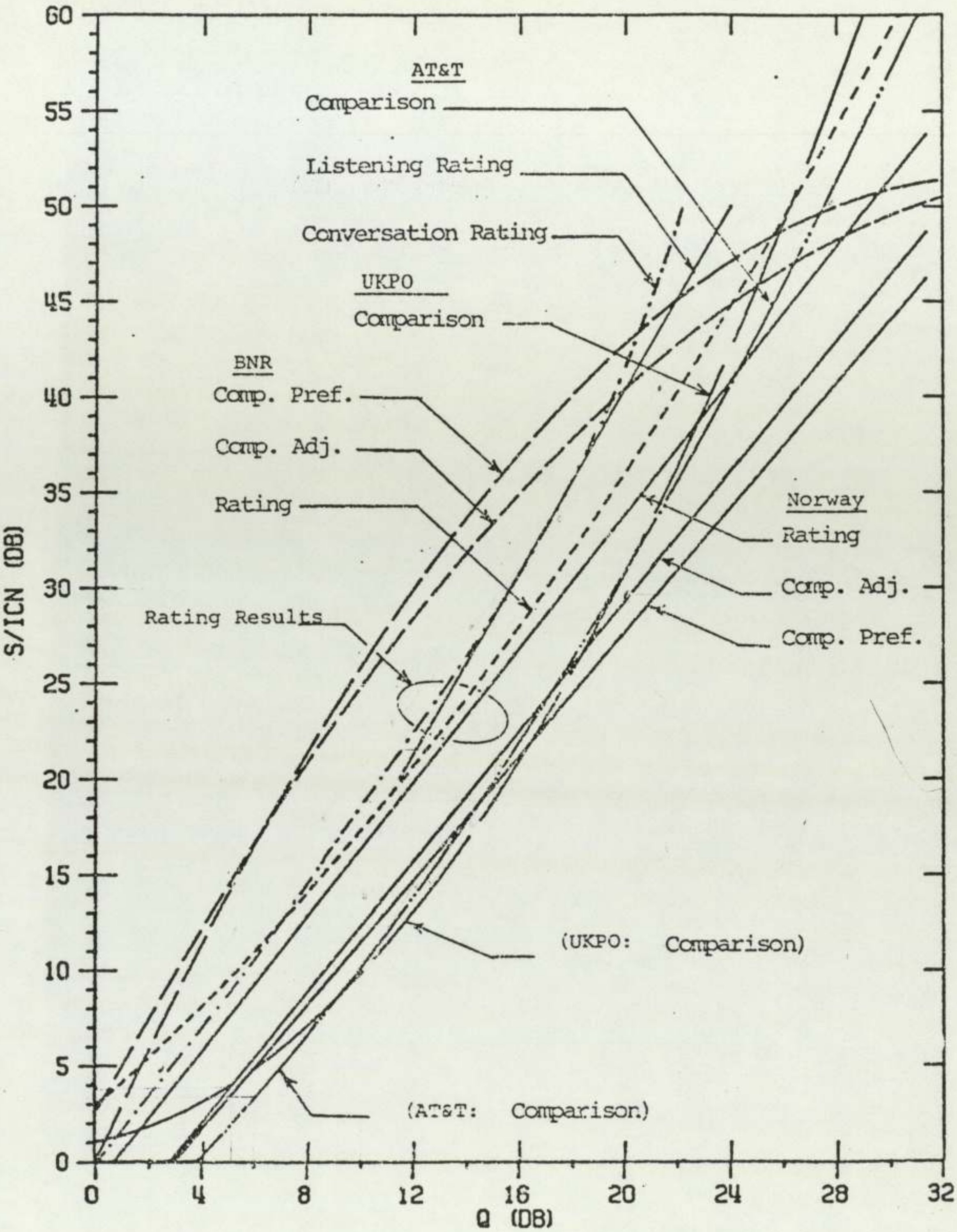


Fig. 49.3 S/ICN vs Q for various organisations.

APPENDIX I

USER INSTRUCTIONS FOR T.C.A.M.

INTRODUCTION

TCAM has been implemented on the PET computing system installed in the pulse communications laboratory at the University. The system comprises a PET (16K) computer, together with tape and dual drive floppy disk units for program storage, and a printer.

To run TCAM, three floppy disks are used. Disks 1 and 2 are used to set up a connection and determine its objective characteristics. (Disk 2 contains information on the various types of telephone handset that may be used).

Disk 3 contains programs to determine the subjective characteristics of the connection. An 'Archives' disk is used to store the objective characteristics for connections previously set up. An 'Auxiliary' disk is available which contains programs used for diagnostics and checking intermediate results.

The programming language used is an extended form of BASIC, however, the instructions used to run the programs are very simple and so the user does not need to be familiar with the language. The ISO recommended range of frequencies is used in the calculation procedures embodied in various programs.

POINTS TO BEAR IN MIND WHEN RUNNING TCAM

(a) In order to cause action to a command or response you have typed in, you must always press the RETURN key.

(b) To stop the computer at any time during program operation, press the STOP key.

(c) To continue after stopping program execution, type in CONT followed by RETURN key.

(d) If the response to a prompt from the computer is 'yes' or 'no', type in YES or NO followed by RETURN key.

(e) If by accident, nonsense is typed in responding to a prompt, an error message will appear and a new response must then be typed in.

The message is:

INCORRECT ENTRY - Try again

(f) Once TCAM is running, you can return to the information program at any time (once computer has halted program execution) by typing in:

GOTO5 followed by RETURN key.

AVAILABLE OPTIONS FOR TYPES OF TELEPHONE SET EXISTING AT PRESENT

CODE	COMMENTS
746Z) 746A) 746L)	UK Post Office type 746 telephone set under zero, average or limiting line conditions
RSN1	Reference Standard Telephone Set
DIG1) DIG2)	Digital telephone set
WE5Z) WE5A) WE5L)	Western Electric type 500 telephone set under zero, average or limiting line conditions.

NOTE, the user may set-up any other telephone data and represent it by a 4-letter code.

TCAM RUNNING INSTRUCTIONS

The starting point is the information program, which is obtained in the following way:

Insert 'TCAM STARTER' cassette into cassette player. Press SHIFT and STOP keys together. (This gives load and run command).

At this point the computer will supply instructions for further procedures. These are described as follows.

1. CENTRALISE DISKS 1 & 2
2. INSERT DISK 1 IN DRIVE #Ø
3. INSERT DISK 2 IN DRIVE #1
4. CLOSE BOTH DRIVE DOORS
5. PRESS SPACE BAR TO CONTINUE

After following these instructions, the screen will clear and the following appear:

PRESS 'STOP' ON TAPE #1
REWIND TAPE AND REMOVE
THEN PRESS SPACE BAR TO CONTINUE

After doing this, the screen will clear and the following appear:

TO RUN TCAM, TYPE IN:-

LOAD DØ, 8

THEN TYPE IN:-

RUN

After doing this, the screen clears and the following appears.

INFORMATION PROGRAM

DF SETTING UP OR MODIFYING FIXED DATA FILES
TF SETTING UP OR MODIFYING TELEPHONE DATA FILES
OC OPTIONS FOR CONNECTION ELEMENTS
SC SETTING UP A CONNECTION
CR CONNECTION RECALL
FL FILE LOCATION
PR PRINT-OUT OF RESULTS FROM STAGE 2
AV ARCHIVING RESULTS FROM STAGE 2
RC RECALLING A CONNECTION FROM ARCHIVES
ST RUN STAGE 3 (WITH OLD U-FILES)
TT TRANSFER U1 & U3 FILES TO DISK 3
WHICH OF THE ABOVE DO YOU REQUIRE ?

Choose the option you require by typing in the corresponding two code letters, followed by RETURN key.

For further information on any of the above options, consult Table 1 (overleaf).

For information on the electrical elements available, consult Table 2 (overleaf).

OPTION	PAGE NO.	TABLE I.
DF	227	
TF	230	
OC	206,208	
SC	207	
CR	214	
FL	217	
PR	219	
AV	221	
RC	222	
ST	224	
TT	225	

OPTION	PAGE NO.	TABLE 2.
SFB	233	
HFB	228	
IFB	226,233	
CHF	228,234	
ATT	234	
TXL	234	
ULC	234	
LCJ	228,234	
TFR	235	
LAT	235	
MCC	235	
AAL	235	
LCO	236	

OPTIONS FOR CONNECTION ELEMENTS

This program provides a hard copy of the options available for the electrical elements that may be used to set up a connection (see Fig. 1). After the list has been printed, the information program may be returned to by pressing the space bar.

SETTING UP A CONNECTION

The connection has to be described in a certain way. In order to understand the method adopted for this the following example will be used.

(See Fig. 3 for a more extensive example of a connection).

Simple exchange to exchange

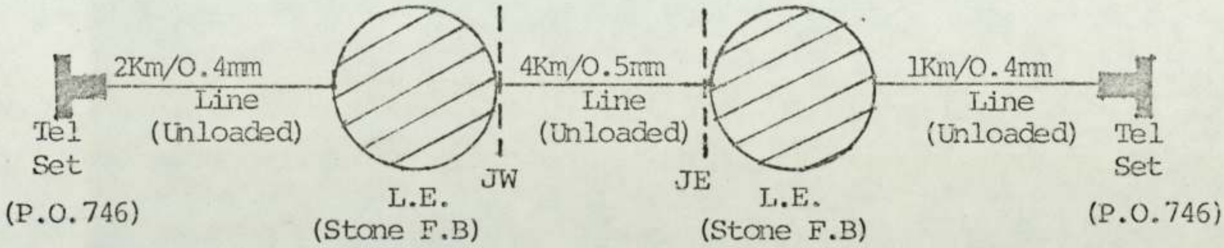


Fig. 2

The information needed to describe this is:

(i) Type of telephone set.

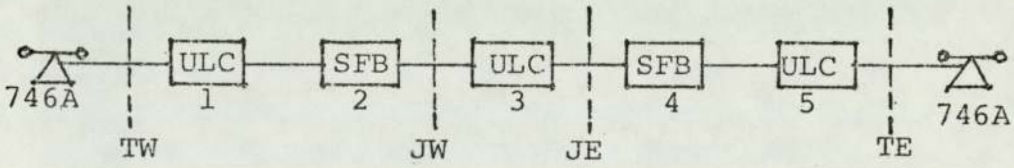
(ii) Type of feeding bridge.

(iii) Line parameters

(iv) Position of the junction interfaces (JW & JE).

(v) Nominal loss between JW and JE. (Say, 6 dB).

The convention used to represent this connection is



There are five elements in the connection

Element 1 is unloaded cable, gauge = 0.4mm, Length = 2km

Element 2 is a Stone feeding bridge

Element 3 is unloaded cable, gauge = 0.5 mm, length = 4 km.

Element 4 is a Stone feeding bridge

Element 5 is unloaded cable, gauge = 0.4 mm, length = 1 km.

OPTIONS FOR CONNECTION ELEMENTS
****

ELECTRICAL ELEMENTS

```
SFB    STONE FEEDING BRIDGE
HFB    HAYES FEEDING BRIDGE
IFB    IDEAL FEEDING BRIDGE
CHF    CHANNEL FILTER TYPE I4
ATT    ATTENUATOR 600 OHMS, VARIABLE LOSS
TXL    TRANSMISSION LINE
        WITH VARIABLE PRIMARY CONSTANTS C&R
ULC    UNLOADED CABLE WITH VARIABLE LENGTH
        AND GAUGE [0.4 OR 0.5MM]
LCJ    LOADED CABLE JUNCTION
        [4.5DB LOSS], 0.6 OR 0.9MM GAUGE
TFR    TRANSFORMER, TURNS RATIO INPUTTED
        AS N. (IE, 1:N IS PRI:SEC)
LAT    LATTICE, INPUT SERIES & 'SHUNT' IMPEDANCES
        AS R AND/OR L AND/OR C
MCC    MUTUALLY COUPLED COILS
AAL    AT&T ARTIFICIAL LINE
```

LCO   LUMPED COMPONENTS

note, in connection set-up program,
after inputting LCO describe which of
the following you wish to set-up:-

```
RSE   RESISTANCE IN SERIES
LSE   INDUCTANCE IN SERIES
CSE   CAPACITANCE IN SERIES
ZSE   IMPEDANCE IN SERIES
RSH   RESISTANCE IN SHUNT
LSH   INDUCTANCE IN SHUNT
CSH   CAPACITANCE IN SHUNT
ZSH   IMPEDANCE IN SHUNT
```

FIG. 1.

Upon running the program the following will appear on the screen:

SETTING UP THE CONNECTION
****

Input no. of electrical elements in the connection

ELEMENT 1 ? *ULC*

Gauge of ULC ? (mm) *0.4*

Length ? (km) *2*

ELEMENT 2 ? *SFB*

ELEMENT 3 ? *ULC*

Gauge of ULC ? *0.5*

Length ? (km) *4*

ELEMENT 4 ? *SFB*

ELEMENT 5 ? *ULC*

Gauge of ULC ? *0.4*

Length ? (km) *1*

ELEMENT DESCRIPTIONS NOW COMPLETE ? *Y*

Note, if the answer to the above question had been N, then a message would appear saying:

DESCRIPTION DOES NOT COMPLY WITH NUMBER OF ELEMENTS INPUTTED PRESS "RETURN" FOR ANOTHER ATTEMPT

The connection set-up program would be run again, the user then making a fresh attempt.

If the elements description is complete, the user is given the opportunity to obtain the image impedance and attenuation of any of the elements at one of the 150 frequencies.

This is illustrated as follows: (Note. Users response to computer prompts is shown in italics).

DO YOU REQUIRE THE NOM. LOSS FOR ANY OF THESE ELEMENTS *YES*
(The screen clears).

<u>IMAGE IMPEDANCE & ATTENUATION</u>

TYPE IN ELEMENT NO. FOR WHICH YOU REQUIRE XL 2

```
INPUT FREQ. AT WHICH YOU REQUIRE XL 1ØØØ
AT 1ØØØ Hz, XL FOR ELEMENT  2 is 1 DB
IMAGE IMPEDANCE = 1227.5 OHMS

A FURTHER FREQUENCY ? N
DO  YOU REQUIRE XL FOR ANY OTHER ELEMENTS ? N
PRESS SPACE BAR TO CONTINUE
```

Control is now passed on to the interface positions program. The screen will clear and the following information will present itself:

```
INTERFACES
**********
```

Junction "JW" (West End), "JE"(East End)

International "IW" (West End), "IE" (East End)

INTERFACE POSITIONS

After the interface has been identified, give its position by inputting the two elements between which it occurs (in order of sequence).

```
POSITION OF JW ?   2, 3
NEXT INTERFACE ?   JE
POSITION OF JE ?   3, 4
```

INPUT NOM. LOSS BETWEEN JW AND JE (DB) *6*
Control is now passed on to the telephone options program. (The screen clears)

TELEPHONE OPTIONS

```
INPUT OPTION FOR WEST TELEPHONE 746A
INPUT OPTION FOR EAST TELEPHONE 746A

TELEPHONE DATA NOW STORED.
```

Control is now passed on to the cascading program. (The screen clears).

CASCADING PROGRAM NOW RUNNING

I = 1, 2, 3, 4, 5

The cascading program involves a lot of calculation procedures and will take several minues to run. After this, control is passed on to the insertion and transmission loss program. Appearing on the screen will be the following information:

CALCULATING INSERTION LOSSES

XTJ(W) XJJ XJT(E) XTT

INSERTION LOSSES NOW COMPUTED

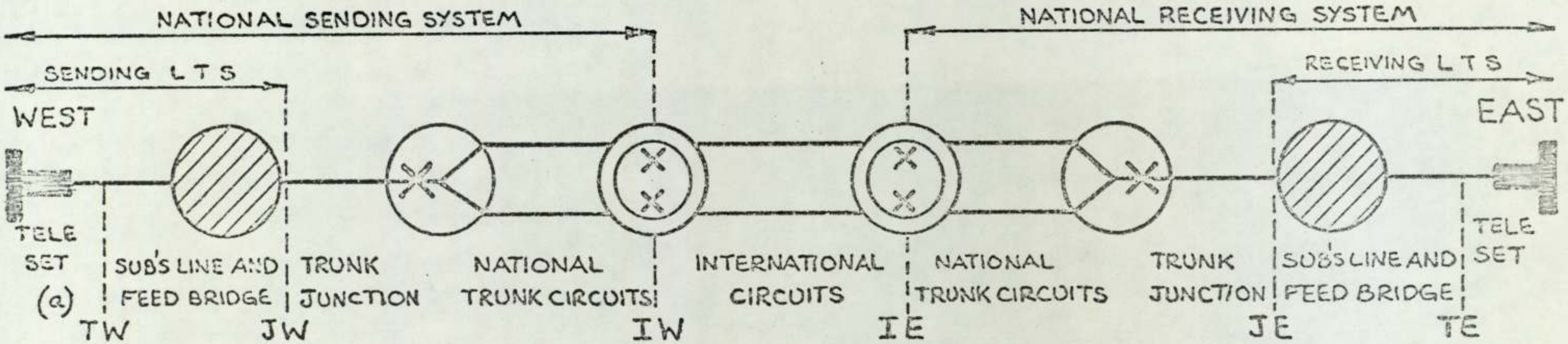
(The screen clears).

CALCULATING TRANSMISSION LOSSES

SUMJ(W) SUJE(W)
SUMJ(E) SUJE(E)
ZL(W) XL(E) LUME XIMP
LMEST(W) LMEST(E)

PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM

At this stage the user will wish to obtain a copy of the results from running the programs. These will be connection recall (CR) and the print-out of results (PR).



X ≡ Switching point

≡ 2 wire working (analogue)

≡ 4 wire working (digital or FDM)

≡ Local Telephone Exchange

≡ Group Switching Centre (2wire to 4 wire)

≡ International Switching Centre (4 wire)

TW ≡ Telephone Set (WEST station)
TE ≡ Telephone Set (EAST station)
JW ≡ Junction West
JE ≡ Junction East
IW ≡ International West
IE ≡ International East

FIG. 3.

LOUDNESS RATINGS (EXAMPLE 10 1-2-1980)
****

(WEST TO EAST)	(EAST TO WEST)
SLR = 2.7	SLR = 2.7
RLR =-3.6	RLR =-3.6
JLR = 15.9	JLR = 15.9
SLR(N) = 7.4	SLR(N) = 7.4
RLR(N) = 1.1	RLR(N) = 1.1
ILR = 6.1	ILR = 6.1
OLR = 14.3	OLR = 14.3
STLR(W) = 8.7	STLR(E) = 8.7
STMR(W) = 5.9	STMR(E) = 5.9
VL(W) =-15.8	VL(E) =-15.8

FIG. 4

CONNECTION RECALL

This program recalls the connection description and prints it out as a hard copy. (See Figs. 5 & 6).

After the description has been printed, the user presses the space bar to return to the information program.

Note this program will handle up to a maximum of 30 electrical elements. If there is more than this in the connection, a message will appear on the screen, i.e. :

NUMBER OF ELEMENTS IS TOO LARGE !

(PROGRAMMED FOR A MAX. OF 30 ONLY)

CONNECTION DESCRIPTION IS:-

```
746Z-SFB-ULC-HFB-746Z
(TW)  1    2   3 (TE)
```

INTERFACE POSITIONS

JUNCTION WEST IS BETWEEN ELEMENTS 1 AND 2
JUNCTION EAST IS BETWEEN ELEMENTS 2 AND 3

NOMINAL LOSS (JW-JE) = 6DB

SUPPLEMENTARY INFORMATION

```
ELEMENT 1  R=4ØØ OHMS
           L=3H
           C=1UF
ELEMENT 2  GAUGE (MM) = Ø.5
           LENGTH (KM) = 5.9
           ---
ELEMENT 3  R1=33 OHMS, R2=4ØØ OHMS, R3=16K
           L1=3.75MH, L2=5H, L3=Ø.55H
           C=2UF
```

Fig. 5

CONNECTION DESCRIPTION IS : -

```
746A-ULC-SFB-ATT-CHF-ATT-HFB-746Z
(TW)  1   2   3   4   5   6  (TE)
```

INTERFACE POSITIONS

JUNCTION WEST IS BETWEEN ELEMENTS 2 AND 3
INT'NAL WEST IS BETWEEN ELEMENTS 3 AND 4
INT'NAL EAST IS BETWEEN ELEMENTS 4 AND 5
JUNCTION EAST IS BETWEEN ELEMENTS 5 AND 6

NOMINAL LOSS (JW-JE) = 8DB

SUPPLEMENTARY INFORMATION

```
ELEMENT 1  GAUGE (MM) = Ø.4
           LENGTH (KM) = 2
           ---
ELEMENT 2  R=4ØØ OHMS
           L=3H
           C=1UF
ELEMENT 3  LOSS (DB) = 5
           ---
           ---
ELEMENT 4  TYPE 1-4
           ZC=6ØØ OHMS
           ---
ELEMENT 5  LOSS (DB) =  3
           ---
           ---
ELEMENT 6  R1=33 OHMS, R2=4ØØ OHMS, R3=16K
           L1=3.75MH, L2=5H, L3=Ø.55H
           C=2UF
```

Fig. 6

FILE LOCATION

This program gives the positions of the data files containing insertion and transmission losses. It is a semi-diagnostic program and is normally not used. An example of the hard copy print-out obtained from this program is shown by Fig. 7. Pressing the space bar then returns the user back to the information program.

INSERTION LOSSES
****

DESCRIPTION	FILE NO.
XTJ(W)	54
XJJ	55
XJT(E)	56
XTI(W)	57
XII	58
XIT(E)	59
XTT	6Ø

TRANSMISSION LOSSES
****

DESCRIPTION	FILE NO.
SUMJ(W),SUJE(W)	61
SUMI(W),SUIE(W)	62
SUMJ(E),SUJE(E)	63
SUMI(E),SUIE(E)	64
XJJ,XII	65
ZL(W) [RL & IM]	66
ZL(E) [RL & IM]	67
LUME(W-E),LUME(E-W)	68
XIMP(W-E),XIMP(E-W),XL	69
LMEST(W)	7Ø
LMEST(E)	71

Fig. 7

PRINT-OUT OF RESULTS FROM STAGE 2

A hard copy print-out of all the insertion and transmission losses for the connection may be obtained by running this program.

Fig. 8 gives a table of the order in which these results will appear.

A complete set of results for a typical connection is given at the end of this handbook.

Upon running the program, the following will appear on the screen:

```
PRINT-OUT OF RESULTS FROM STAGE 2

PRINTING OUT INSERTION LOSSES
PRINTING OUT TRANSMISSION LOSSES
END OF PRINT-OUT FROM STAGE 2
PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
```

INSERTION LOSSES

XTJ(W)	XJJ	XJT(E)	XTI(W)	XII	XIT(E)	XTT

TRANSMISSION LOSSES

U1

SUMJ(W)	SUJE(W)	SUMJ(E)	SUJE(E)	XJJ
SUMI(W)	SUIE(W)	SUMI(E)	SUIE(E)	XII

U2 & U3

ZL(W)(RL)	ZL(W)(IM)	ZL(E)(RL)	ZL(E)(IM)	XL
LUME(W-E)	LUME(E-W)	XIMP(W-E)	XIMP(E-W)	
LMEST(W)	LMEST (E)			

Fig. 8

ARCHIVING RESULTS FROM STAGE 2

The facility to store the results from stage 2 for various telephone connections is provided by the archives disk.

Upon choosing this option, the screen clears and the following presents itself:

TRANSFERRING RESULTS FROM STAGES 1 & 2 TO ARCHIVES

NOTE! SUPPLEMENTARY INFORMATION IS NOT CARRIED FORWARD

REMOVE DISK FROM DRIVE 1, AND (AFTER CENTRALISING)
INSERT ARCHIVES DISK
PRESS SPACE BAR TO CONTINUE AND THEN CLOSE
DRIVE 1 DOOR

(The screen clears)

DESCRIPTION AND RESULTS FROM STAGE 2
NOW ARCHIVED

PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM

RECALLING A CONNECTION FROM ARCHIVES

Upon selecting this option, the following appears on the screen:

REMOVE DISK FROM DRIVE 1, AND (AFTER CENTRALISING)
INSERT ARCHIVES DISK
PRESS SPACE BAR TO CONTINUE AND THEN CLOSE
DRIVE 1 DOOR

(The screen clears)

CONNECTION LOCATION

(A list of connections is printed-out by the printer).

DO YOU WISH TO LOCATE A FILE ? *NO*

PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM.

If the answer to the last question had been *YES* then the following would appear on the screen:

WHICH FILE NUMBER DO YOU REQUIRE ? *4*

DO YOU WISH TO PRINT OUT CONNECTION PLUS U-FILES (DU)
OR TRANSFER CONNECTION ETC. TO DISK 3 ? *DU*

At this point, the computer will go through the routine of making a hard copy of the connection description omitting supplementary information and the U files for the connection chosen.

Pressing the space bar then returns the user back to the information program.

If TR had been selected, the screen would clear and the following appear:

TRANSFER OF U1 & U3 FILES TO DISK 3

IS DISK 3 IN DRIVE Ø ? *NO*
REMOVE DISK FROM DRIVE Ø AND (AFTER CENTRALISING),
INSERT DISK 3.
PRESS SPACE BAR TO CONTINUE AND THEN CLOSE
DRIVE Ø DOOR

TRANSFERENCE TO DISK 3 NOW COMPLETE.

(Note, this point would have been reached without any user action if the answer to the last question had been *YES*.)

TYPE IN 'ERASE' TO ERASE OLD R-FILES *ERASE*

(OLD R-FILES NOW ERASED).

DO YOU WISH TO RUN STAGE 3 ? *NO*

------------------ END ---------------------

This concludes TCAM as DISK 1 is no longer present in DRIVE Ø. If you wish to obtain the information program, make a fresh start by using the "TCAM STARTER" tape cassette.

If the answer to the final question had been *YES*, the following would then appear on the screen:

REMOVE BOTH DISKS FROM THEIR DRIVES.
AFTER CENTRALISING, INSERT DISK 3 IN DRIVE 1.
PRESS SPACE BAR TO CONTINUE AND THEN CLOSE
DRIVE 1 DOOR.

(The screen clears).

CALCULATING LOUDNESS RATINGS

CALCULATING LOUDNESS RATING (W-E)
CALCULATING VL(W)
(SPEECH VOLTAGE AT JW)

CALCULATING LOUDNESS RATINGS (E-W)
CALCULATING VL(E)
(SPEECH VOLTAGE AT JE)

(The screen clears)

PRINTING OUT OF LOUDNESS RATINGS

The computer now prints out a hard copy of loudness ratings for the connection in W-E and E-W directions as shown in Fig. 4. After this the computer prints on the screen:

END OF STAGE 3

This concludes the TCAM run as DISK 1 is not present in DRIVE Ø. If you wish to obtain the information program, make a fresh start by using the "TCAM STARTER" tape cassette.

RUNNING STAGE 3

Choosing this option causes the following to appear on the screen:

RUNNING STAGE 3 (WITH EXISTING U-FILES ON DISK 3)

REMOVE DISK FROM DRIVE 1, AND (AFTER CENTRALISING INSERT DISK 3.
PRESS SPACE BAR TO CONTINUE AND THEN CLOSE DRIVE 1 DOOR.

(The screen clears).

CALCULATING LOUDNESS RATINGS

CALCULATING LOUDNESS RATINGS (W-E)
CALCULATING VL(W)
(SPEECH VOLTAGE AT JW)
CALCULATING LOUDNESS RATINGS (E-W)
CALCULATING VL(E)
(SPEECH VOLTAGE AT JE)

(The screen clears)

PRINTING OUT OF LOUDNESS RATINGS

The computer now prints out a hard copy of loudness ratings for the connection in W-E and E-W directions, as shown in Fig. 4. After this, the computer prints on the screen:

END OF STAGE 3

This concludes the TCAM run as DISK 1 is not present in DRIVE Ø. To obtain the information program, make a fresh start by using the "TCAM STARTER" tape cassette.

TRANSFERRING U1 & U3 FILES TO DISK 3

Choosing this option causes the following to appear on the screen:

TRANSFER OF U1 & U3 FILES FROM DISK 1 TO DISK 3

REMOVE DISK FROM DRIVE 1, AND (AFTER CENTRALISING) INSERT DISK 3.
PRESS SPACE BAR TO CONTINUE AND THEN CLOSE DRIVE 1 DOOR.
TYPE IN 'ERASE' TO ERASE OLD R FILES
(OLD R-FILES NOW ERASED)

TRANSFERRING NEW FILES
U-FILES NOW TRANSFERRED TO DISK 3.

END OF STAGE 2

DO YOU WISH TO RUN STAGE 3 ? *NO*

---------------------- END ----------------

PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM.

Note. If the answer to the last question had been *YES*, stage three would have been run in the manner described by the "ST" option. (As illustrated on previous page).

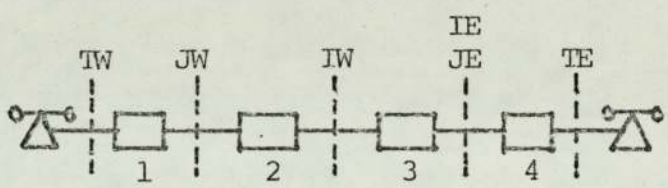
USE OF THE IDEAL FEEDING BRIDGE

The interfaces present in a connection are the telephone set interface, junction and international (if present) interfaces. Although the telephone interface is not stipulated in the connection set-up procedure, it must be borne in mind.

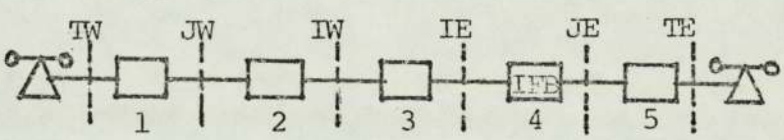
If any of the interfaces coincide, the computer will cause errors unless steps are taken to avoid this situation.

A convenient way of overcoming this problem is to separate the interfaces with a loss-less network (known as an "ideal feeding bridge").

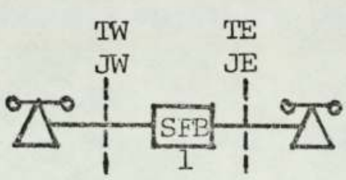
E.g.



Must be represented as:

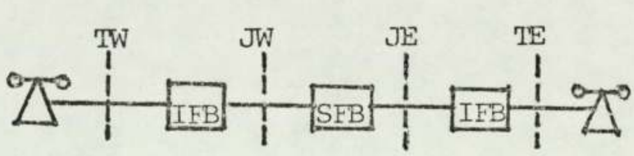


Also,



(Own exchange call with zero line)

Must be represented as:



SETTING UP OR MODIFYING 'FIXED' DATA FILES

This option is not normally used and is only required when it is necessary to change the fundamental data relating to one of these fixed files, or to set-up a new disk.

The fixed data files contain the characteristics of:

(a) Stone, Hayes and Ideal Feeding Bridges

(b) Channel Filter (Type 1-4)

(c) Loaded-cable (Section with 4.5 dB nom. loss, 0.6 or 0.9 mm gauge).

After selecting this option, the following appears on the screen:

SET-UP OF FEEDING BRIDGE AND CHANNEL FILTER DATA

FEEDING BRIDGES

IDEAL FEEDING BRIDGE (IFB)
STONE FEEDING BRIDGE (SFB)
HAYES FEEDING BRIDGE (HFB)

DO YOU WISH TO MODIFY ANY OF THESE DATA FILES ? *YES*

(No to this question would take the user on to channel filter set-up).

WHICH FILE DO YOU WISH TO MODIFY ? *IFB*

SETTING-UP IFB

IFB NOW STORED

WANT TO MODIFY ANY FURTHER FEEDING BRIDGE DATA FILES ? *YES*

WHICH FILE DO YOU WISH TO MODIFY ? *SFB*

SETTING-UP SFB

INPUT R,L AND C (OHMS, MH, NF)
4ØØ, 3ØØØ, 1ØØØ
SFB DATA NOW STORED
WANT TO MODIFY ANY FURTHER FEEDING
BRIDGE DATA FILES ? *YES*
WHICH FILE DO YOU WISH TO MODIFY? *HFB*

SETTING UP HFB

INPUT R1, R2, R3, L1, L2, L3, C (OHMS, MH NF)
33,4ØØ, 16ØØØ, 3.75, 5ØØØ, 55Ø, 2ØØØ
HFB NOW STORED
WANT TO MODIFY ANY FURTHER FEEDING BRIDGE
DATA FILES ? *NO*

(The screen clears)

SETTING-UP CHANNEL FILTER (TYPE 1-4)

DO YOU WISH TO SET-UP CHF ? *YES*

(Answering NO to this question takes the user to loaded cable set-up).

USE OLD OR NEW DATA ? *NEW*

(Answering OLD causes the computer to use the existing set of data contained in the program, and then reply "CHF NOW STORED" then transferring user to loaded cable set-up).

INPUT LOSS (DB) AT EACH OF THE FOLLOWING
FREQUENCIES:-

100 Hz ? *4.7*
125 Hz ? *3.8*

.
.
.
.
.

8000 Hz *60*

ANY CORRECTIONS *NO*

CHF NOW STORED

(The screen clears)

LOADED CABLE JUNCTION

DO YOU WISH TO SET-UP LCJ ? *NO*

END OF SET-UP PROCEDURE
FOR FIXED DATA FILES ON DISK 1

PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM

If the answer to the last question had been *YES*, the following would present itself:

```
SETTING-UP OF LCJ (4.5 DB LOSS)

TYPE IN GAUGE (Ø.6 OR Ø.9 mm) ?     Ø.6
SET-UP OF LOADING COIL DATA
SET-UP OF FULL LINE SECTION
SET-UP OF HALF LINE SECTION
CASCADING SECTIONS
CASC FOR 4(C*F)
1  2  3  4
LCJ (Ø.6 MM) NOW SET-UP
DO YOU WISH TO SET-UP LCJ AGAIN ?   YES

SETTING-UP OF LCJ (4.5 DB LOSS)

TYPE IN GAUGE (Ø.6 OR Ø.9 MM) ?   Ø.9
SET-UP OF LOADING COIL DATA
SET-UP OF FULL LINE SECTION
SET-UP OF HALF LINE SECTION
CASCADING SECTIONS
CASC FOR 1Ø(C*F)
1  2  3  4  5  6  7  8  9  1Ø
LCJ (Ø.9 MM) NOW SET-UP
DO YOU WISH TO SET-UP LCJ AGAIN ?   NO

END OF SET-UP PROCEDURE
FOR FIXED DATA FILES ON DISK 1

PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
```

SETTING-UP OR MODIFYING TELEPHONE DATA FILES

This option enables the user to set-up data files containing information of any telephone set that can be described by the four parameters ZC, ZSO, SS and SR. Note, a separate program is available which sets-up RSN1 from its equivalent circuit). Upon choosing this option, the following presents itself:-

CENTRALISE & INSERT DISK 2 IN DRIVE 1 & CLOSE
DOOR
THEN PRESS SPACE BAR TO CONTINUE

(The screen clears).

SET-UP OF TELEPHONE DATA

Do you wish to print-out names of telephone sets stored on disk ? *NO*

TYPE IN WHICH OPTION YOU REQUIRE

746Z

(The screen clears)

SETTING-UP 746Z.

NEW OR OLD FILE ? *NEW*

ARE YOU ENTERING ZC IN CARTESIAN (CC)
OR POLAR (PC) CO-ORDINATES ?

PC

TYPE IN MODULUS AND ARGUMENT OF ZC AS FOLLOWS:

```
100 HZ MODULUS ?   135
       ARGUMENT ?   12

125 HZ MODULUS ?   138
  .    ARGUMENT ?   13
  .
  .
  .
  .
8000 HZ MODULUS ?  384
        ARGUMENT ?  83
```

ANY CORRECTIONS ? *NO*

TYPE IN MODULUS AND ARGUMENT OF ZSO AS FOLLOWS:

```
100 HZ MODULUS ?    3000
  .    ARGUMENT ?   -90
  .
  .
  .
```

```
ANY CORRECTIONS ? NO
DO YOU WISH TO SET-UP SS OR SS600? SS
TYPE IN SS AS EACH FREQUENCY DEMANDS
100 HZ ?   -18.8
   .
   .
   .
   .
   .
8000 HZ ?  -71.8

DO YOU WISH TO SET-UP SR OR SR600 ?
TYPE IN SR AS EACH FREQUENCY DEMANDS
100 HZ        32.2
   .
   .
   .
   .
   .
8000 HZ ?    -99

TEL. DATA NOW STORED.
```

A hard copy is now made of the data that has been set-up. The user then presses the space bar to return to the information program.

Note, if the reply to the first question had been *"YES"* a hard copy of all the telephone set files stored on the disk would be printed-out. (see page 34a).

Note, if the reply to the prompt "NEW OR OLD FILE" had been "OLD" the user would be given the opportunity to modify only the data that required modifying, e.g. changing SS only whilst leaving SR, ZC and ZSO at their original values.

Other non-user programs exist regarding telephone set data. These are:

(a) RSN1 SET UP

This sets up RSN1 from the equivalent circuits for ZC and ZSO, and uses data statements containing SS and SR data.

(b) DISKTRAN

This transfers telephone file data from disk 2 onto the spare disk 2.

(c) TRANSTEL

This transfers telephone file data from disk 2 onto a tape cassette. (For security purposes).

(d) TEL TRANS

This transfers telephone file data from cassette tape onto disk 2.

(e) CHECKTEL

This produces a print-out on the VDU of the telephone data in any of the respective data files.

(f) PTF

This will provide a hard copy of a telephone set data file present on a disk in either drive 1 OR Ø.

(g) DATUM

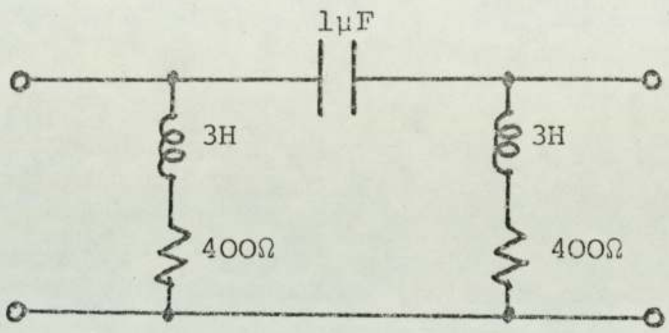
This is used to initially set the contents of the 'STD' (stored telephone data) data file.

INFORMATION ON ELECTRICAL ELEMENTS

All the following electrical elements are simulated by 4 terminal reciprocal networks.

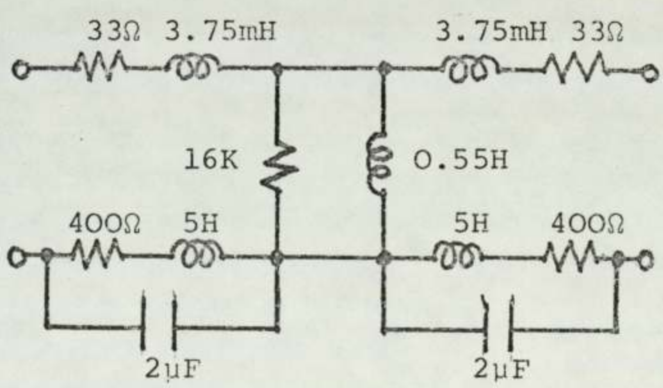
Stone Feeding Bridge

Only "SFB" need be specified. The data is stored in a fixed data file, and is derived from the following equivalent circuit



Hayes Feeding Bridge

Again, only "HFB" need be specified. The equivalent circuit is:



Ideal Feeding Bridge

Specified by "IFB". This is actually a unit matrix. (Equivalent to a zero loss network, or solid piece of wire possessing no resistance, inductance or capacitance.) See page 28 for further information on use of IFB.

Channel Filter

Specifying "CHF" assigns data for a channel filter type 1-4, which is based on the filter characteristic for both send and receive directions of a codec. It has a characteristic impedance of 600Ω.

The user may select one or more sections in tandem.

Attenuator

Specified by "ATT". It has a fixed characteristic impedance of 600Ω, but the insertion loss (in dB) is chosen by the user.

Transmission Line "TXL"

Any line may be simulated by typing in its primary constants. This simplified version needs only series resistance per Km, shunt capacitance per Km and line length (in km). It is assumed that series inductance and shunt (leakage) resistance are negligible.

Unloaded Cable. "ULC"

The commonest gauges encountered in local telephone cables are 0.5mm and 0.6mm. The primary constants for these are stored in the computer program. The user therefore has merely to choose the desired gauge and state the length of line.

Loaded Cable Junction "LCJ"

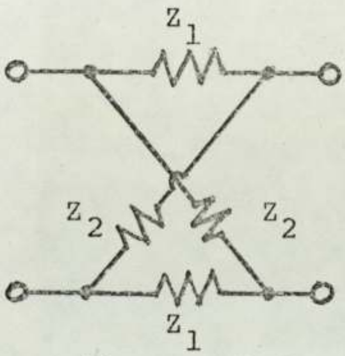
LCJ simulates a section of loaded cable having a nominal loss of 4.5 dB. 0.6 mm or 0.9 mm gauges are available and the user merely has to select which one of these he requires, and how many sections he requires in tandem.

TRANSFORMER "TFR"

This simulates an ideal transformer. (i.e. it is 100% efficient). It is described by inputting the turns ratio as 1:n. (Primary to secondary with primary on the west side).

Lattice "LAT"

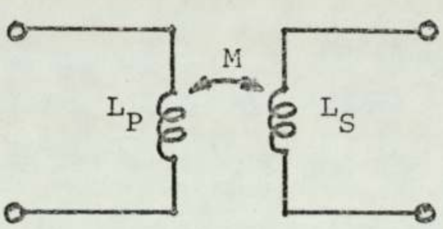
LAT will simulate the lattice network shown below



Z_1 and Z_2 may contain series resistance, inductance and capacitance. If any of these parameters do not exist, type in Ø when asked for their values.

Mutually coupled coils "MCC"

This simulates two coils being mutually coupled as shown below. Description is by inputting primary inductance, secondary inductance and the mutual inductance.



AT & T Artificial line "AAL"

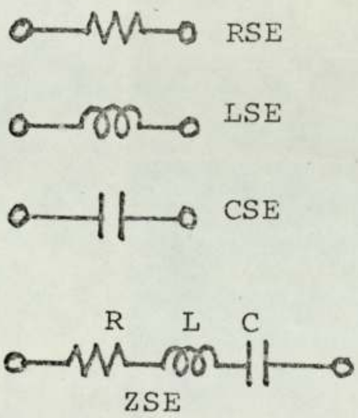
This is set-up in a "fixed" data file and is thus completely specified by the code-AAL.

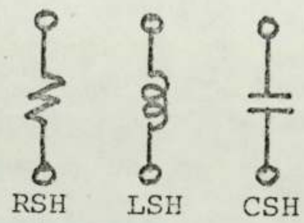
LUMPED COMPONENTS "LCO"

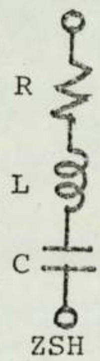
These consist of pure R,L or C in series or shunt, or combinations of R, L and C in series to form a series impedance, or R, L and C in series to form a shunt impedance. The figure shown below shows the representation and codes for the lumped components available.

Series

Shunt







(Type in value Ø for R, L or C if they do not exist)

(If R or L or C do not exist type in the value Ø)

To obtain any of the above elements, first type in LCO and then reply to the prompt from the computer with the required code for the element chosen. The values are entered in ohms, milli-henries or nano-farads.

THE AUXILIARY DISK

Three special programs exist on this disk, which are not normally used when running TCAM. Special disk operating instructions have to be used to recall each program. The programs are:

P1 - Hard copy of telephone set parameters.
P2 - Copy of an array from a data file.
P3 - Print-out of an E1 file.

To obtain a program, insert AUX DISK in drive Ø, close drive door and type in OPEN 1, 8, 15 : PRINT ~~##~~ 1, "IØ": CLOSE 1 followed by RETURN key.

P1 causes a print-out of SS, SR, ZC and ZSO data from any of the telephone-set data files.

To obtain P1, type in LOAD "Ø": P1", 8 (return)

The screen clears and the following appears:

HARD COPY OF TELEPHONE SET PARAMETERS

TYPE IN DRIVE NO. OF DISK CONTAINING THE TELEPHONE DATA *1*

TYPE IN TELEPHONE DATA FILE NAME *D 12*

IS OUTPUT TO BE IN CARTESIAN (CC) OR
POLAR (PC) CO-ORDINATES ? *PC*

(Data is printed-out)

RE-RUN ? *No*

------------- END ----------

An example of the print-out is given in Fig. 9.

P2 enables a copy (either on paper or screen) to be obtained of the data in a 20 x 1, 20 x 2, or 20 x 8 matrix.

To obtain P2, type in LOAD "Ø: P2", 8 (return)
The screen clears and the following appears:

COPY OF AN ARRAY FROM A DATA FILE

TYPE IN DRIVE NO. OF DISK CONTAINING THE DATA FILE *1*

TYPE IN FILE NAME OF DATA FILE *D 43*

HARD COPY ? *Yes*

HOW MANY ARRAYS IN DATA FILE ? *2*

IS ARRAY 1 20 x 8, 20 x 2 OR 20 x 1 ? *20 x 1*

(Computer prints-out 20 numbers - one for each frequency)

IS ARRAY 2 20 x 8, 20 x 2 OR 20 x 1 ? *20 x 2*

(Prints-out 20 sets of 2 numbers)

RE-RUN ? *No*

---------------------- END --------------------

Note, this program is usefully applied after obtaining data file locations, (using the "FL" option on DISK 1 information program).

To obtain P3, type in LOAD" Ø : P3", 8 (return) The screen clears out and the following appears:

PRINTING E1-FILE
ENTER TODAYS DATE *18th April, 1980*
TYPE IN FILE NAME OF E1-FILE *D 27*

(A hard copy of a 20 x 8 array is printed-out together with file name and date of printing).

RE-RUN ? *No*

---------------------- END --------------------

D 12 746Z (POLAR CO-ORDINATES)

FREQ.(HZ)	SEND SENS	REC SENS	MOD ZC	ARG ZC	MOD ZSO	ARG ZSO
100	-18.8	+23.2	+ 135.0	+12.0	+3000.0	-90.0
125	-18.3	+23.7	+ 138.0	+13.0	+2700.0	-90.0
160	-17.6	+22.9	+ 142.0	+14.0	+2500.0	-90.0
200	-16.9	+21.1	+ 145.0	+15.0	+2204.0	-90.0
250	-16.3	+23.3	+ 150.0	+17.0	+1900.0	-90.0
315	-15.8	+23.4	+ 155.0	+18.0	+1540.0	-90.0
400	-15.7	+23.8	+ 164.0	+19.0	+1239.0	-90.0
500	-15.5	+23.6	+ 172.0	+20.0	+1044.0	-90.0
630	-14.7	+23.2	+ 184.0	+21.0	+ 960.0	-80.0
800	-12.8	+22.8	+ 191.0	+22.0	+ 721.0	-71.0
1000	- 9.2	+22.7	+ 202.0	+22.0	+ 619.0	-62.0
1250	- 6.5	+23.5	+ 209.0	+22.0	+ 538.0	-52.0
1600	- 8.6	+24.8	+ 211.0	+26.0	+ 470.0	-41.0
2000	-10.2	+22.5	+ 227.0	+29.0	+ 424.0	-29.0
2500	-12.0	+19.0	+ 240.0	+32.0	+ 394.0	-17.0
3150	-10.4	+23.1	+ 246.0	+39.0	+ 380.0	- 5.0
4000	-21.4	+12.0	+ 283.0	+48.0	+ 400.0	+ .0
5000	-32.8	-40.7	+ 308.0	+58.0	+ 400.0	+ .0
6300	-46.8	-90.7	+ 348.0	+69.0	+ 400.0	+ .0
8000	-71.8	-99.0	+ 384.0	+83.0	+ 400.0	+ .0

FIG. 9

```
TEST 5-JUNE-1980
****************

CONNECTION DESCRIPTION IS :-

RSN1-ULC-SFB-LCJ-ATT-CHF-LCJ-SFB-ULC-RSN1
(TW)  1   2   3   4   5   6   7   8  (TE)

INTERFACE POSITIONS
-------------------

JW IS BETWEEN ELEMENTS  2  AND  3
IW IS BETWEEN ELEMENTS  3  AND  4
IE IS BETWEEN ELEMENTS  5  AND  6
JE IS BETWEEN ELEMENTS  6  AND  7

NOMINAL LOSS (JW-JE) = 15  DB

SUPPLEMENTARY INFORMATION
-------------------------

ELEMENT 1   GAUGE = 0.4MM
            LENGTH =  1.6KM
            ---

ELEMENT 2   R= 400 OHMS
            L= 3000 MH
            C= 1000 NF

ELEMENT 3   GAUGE (MM) = 0.6
            ---
            ---

ELEMENT 4   LOSS =  6DB
            ---
            ---

ELEMENT 5   TYPE I-4
            ZC=600 OHMS
            ---

ELEMENT 6   GAUGE (MM) = 0.6
            ---
            ---

ELEMENT 7   R= 400 OHMS
            L= 3000 MH
            C= 1000 NF

ELEMENT 8   GAUGE = 0.4MM
            LENGTH =  4.5KM
            ---
```

TEST 5-JUNE-1980
****

INSERTION LOSSES

FREQ.(HZ)	XTJ(W)	XJJ	XJT(E)	XTI(W)	XII	XIT(E)	XTT
100	+ 4.7	+ 21.2	+ 6.3	+ 7.7	+ 10.7	+ 9.9	+ 28.1
125	+ 3.6	+ 20.2	+ 5.7	+ 7.0	+ 9.8	+ 9.3	+ 26.0
160	+ 3.1	+ 19.2	+ 5.6	+ 6.6	+ 8.8	+ 9.0	+ 24.2
200	+ 2.8	+ 17.4	+ 5.7	+ 6.4	+ 7.2	+ 8.8	+ 22.1
250	+ 2.7	+ 17.0	+ 5.8	+ 6.3	+ 6.8	+ 8.6	+ 21.4
315	+ 2.7	+ 16.4	+ 5.9	+ 6.2	+ 6.3	+ 8.6	+ 20.9
400	+ 2.7	+ 16.0	+ 6.1	+ 6.2	+ 6.0	+ 8.7	+ 20.8
500	+ 2.7	+ 15.8	+ 6.3	+ 6.3	+ 6.0	+ 9.0	+ 21.3
630	+ 2.7	+ 15.6	+ 6.5	+ 6.4	+ 6.0	+ 9.7	+ 22.1
800	+ 2.8	+ 15.3	+ 6.9	+ 6.7	+ 6.0	+ 10.7	+ 23.3
1000	+ 2.8	+ 14.8	+ 7.3	+ 7.0	+ 5.9	+ 11.5	+ 24.1
1250	+ 3.0	+ 14.9	+ 8.0	+ 7.0	+ 5.9	+ 11.9	+ 24.6
1600	+ 3.2	+ 16.3	+ 8.9	+ 7.4	+ 6.2	+ 13.1	+ 26.4
2000	+ 3.5	+ 16.1	+ 10.0	+ 8.5	+ 6.2	+ 15.3	+ 29.2
2500	+ 3.9	+ 16.4	+ 11.3	+ 8.4	+ 6.0	+ 15.9	+ 29.8
3150	+ 4.4	+ 18.4	+ 12.8	+ 10.0	+ 7.5	+ 18.5	+ 35.3
4000	+ 5.0	+ 79.3	+ 14.5	+ 32.1	+ 28.0	+ 41.9	+101.3
5000	+ 5.6	+ 99.0	+ 16.3	+ 68.6	+ 66.0	+ 79.4	+144.5
6300	+ 6.3	+ 99.0	+ 18.3	+ 95.9	+ 66.0	+108.0	+146.7
8000	+ 7.1	+ 99.0	+ 20.6	+121.1	+ 66.0	+134.6	+148.9

TRANSMISSION LOSSES

FREQ.(HZ)	SUMJ(W)	SUJE(W)	SUMJ(E)	SUJE(E)	XJJ
100	- 39.3	- 15.3	- 40.9	- 16.9	+ 21.2
125	- 31.2	- 8.2	- 33.3	- 10.3	+ 20.2
160	- 23.2	- 2.7	- 25.7	- 5.2	+ 19.2
200	- 19.0	+ 3.2	- 21.9	+ .3	+ 17.4
250	- 15.9	+ 6.8	- 19.0	+ 3.7	+ 17.0
315	- 13.9	+ 9.8	- 17.1	+ 6.6	+ 16.4
400	- 12.6	+ 11.4	- 16.0	+ 8.0	+ 16.0
500	- 11.9	+ 12.0	- 15.5	+ 8.4	+ 15.8
630	- 11.5	+ 12.2	- 15.3	+ 8.4	+ 15.6
800	- 10.6	+ 12.3	- 14.7	+ 8.2	+ 15.3
1000	- 9.4	+ 12.6	- 13.9	+ 8.1	+ 14.8
1250	- 8.2	+ 12.3	- 13.2	+ 7.3	+ 14.9
1600	- 6.6	+ 12.7	- 12.3	+ 7.0	+ 16.3
2000	- 6.3	+ 12.2	- 12.8	+ 5.7	+ 16.1
2500	- 5.5	+ 11.5	- 12.9	+ 4.1	+ 16.4
3150	- 5.2	+ 11.3	- 13.6	+ 2.9	+ 18.4
4000	- 11.4	- .1	- 20.9	- 9.6	+ 79.3
5000	- 17.5	- 14.5	- 28.2	- 25.2	+ 99.0
6300	- 25.3	- 29.5	- 37.3	- 41.5	+ 99.0
8000	- 33.7	- 44.3	- 47.2	- 57.8	+ 99.0

FREQ.(HZ)	SUMI(W)	SUIE(W)	SUMI(E)	SUIE(E)	XII
100	- 42.3	- 18.3	- 44.5	- 20.5	+ 10.7
125	- 34.6	- 11.6	- 36.9	- 13.9	+ 9.8
160	- 26.7	- 6.2	- 29.1	- 8.6	+ 8.8
200	- 22.6	- .4	- 25.0	- 2.8	+ 7.2
250	- 19.5	+ 3.2	- 21.8	+ .9	+ 6.8
315	- 17.4	+ 6.3	- 19.8	+ 3.9	+ 6.3
400	- 16.1	+ 7.9	- 18.6	+ 5.4	+ 6.0
500	- 15.5	+ 8.4	- 18.2	+ 5.7	+ 6.0
630	- 15.2	+ 8.5	- 18.5	+ 5.2	+ 6.0
800	- 14.5	+ 6.4	- 18.5	+ 4.4	+ 6.0
1000	- 13.6	+ 8.4	- 18.1	+ 3.9	+ 5.9
1250	- 12.2	+ 8.3	- 17.1	+ 3.4	+ 5.9
1600	- 10.8	+ 8.5	- 16.5	+ 2.8	+ 6.2
2000	- 11.3	+ 7.2	- 18.1	+ .4	+ 6.2
2500	- 10.0	+ 7.0	- 17.5	- .5	+ 6.0
3150	- 10.8	+ 5.7	- 19.3	- 2.8	+ 7.5
4000	- 38.5	- 27.2	- 48.3	- 37.0	+ 28.8
5000	- 80.5	- 77.5	- 91.3	- 88.3	+ 66.0
6300	-114.9	-119.1	-127.0	-131.2	+ 66.0
8000	-147.7	-158.3	-161.2	-171.8	+ 66.0

FREQ.(HZ)	ZL(W)(RL)	ZL(W)(IM)	ZL(E)(RL)	ZL(E)(IM)	XL
100	+ 1972.8	- 149.9	+ 2645.5	- 553.0	+15.0
125	+ 1777.6	- 45.7	+ 2470.2	- 485.0	+15.0
160	+ 1815.7	+ 48.8	+ 2479.3	- 536.0	+15.0
200	+ 1969.5	+ 10.4	+ 2488.0	- 757.6	+15.0
250	+ 2058.2	- 173.5	+ 2318.5	- 1043.5	+15.0
315	+ 2026.9	- 412.4	+ 1979.4	- 1250.9	+15.0
400	+ 1914.1	- 623.0	+ 1587.4	- 1297.8	+15.0
500	+ 1743.2	- 830.6	+ 1260.8	- 1228.6	+15.0
630	+ 1409.0	- 951.5	+ 1001.0	- 1077.1	+15.0
800	+ 1107.2	- 838.1	+ 843.2	- 907.0	+15.0
1000	+ 999.5	- 692.1	+ 757.6	- 797.2	+15.0
1250	+ 1006.3	- 597.5	+ 673.1	- 739.2	+15.0
1600	+ 997.2	- 863.4	+ 519.2	- 654.6	+15.0
2000	+ 650.0	- 764.4	+ 464.6	- 534.1	+15.0
2500	+ 691.1	- 799.5	+ 405.4	- 477.9	+15.0
3150	+ 457.1	- 632.6	+ 377.7	- 403.0	+15.0
4000	+ 176.9	- 549.5	+ 348.1	- 334.8	+15.0
5000	+ 14.8	- 23.8	+ 19.5	- 22.5	+15.0
6300	+ 148.9	+ 4.7	+ 217.5	+ 7.5	+15.0
8000	+ 199.2	- 240.3	+ 257.0	- 254.7	+15.0

FREQ.(HZ)	LUME(W-E)	LUME(E-W)	XIMP(W-E)	XIMP(E-W)
100	+ 73.1	+ 73.1	+ 1.9	+ 1.9
125	+ 58.0	+ 58.0	+ 1.4	+ 1.4
160	+ 43.7	+ 43.7	+ .3	+ .3
200	+ 32.1	+ 32.1	- 1.7	- 1.7
250	+ 25.0	+ 25.0	- 2.3	- 2.3
315	+ 19.4	+ 19.4	- 2.9	- 2.9
400	+ 16.5	+ 16.5	- 3.1	- 3.1
500	+ 15.7	+ 15.7	- 2.7	- 2.7
630	+ 15.9	+ 15.9	- 2.2	- 2.2
800	+ 15.9	+ 15.9	- 1.4	- 1.4
1000	+ 15.3	+ 15.3	- 1.1	- 1.1
1250	+ 14.6	+ 14.6	- 1.3	- 1.3
1600	+ 14.1	+ 14.1	- .5	- .5
2000	+ 16.6	+ 16.6	+ 1.0	+ 1.0
2500	+ 16.5	+ 16.5	+ .1	+ .1
3150	+ 21.0	+ 21.0	+ 3.7	+ 3.7
4000	+103.5	+103.5	+ 67.5	+ 67.5
5000	+165.9	+165.9	+108.1	+108.1
6300	+189.3	+189.3	+107.5	+107.5
8000	+212.8	+212.8	+106.3	+106.3

FREQ.(HZ)	LMEST(W)	LMEST(E)
100	+ 53.2	+ 52.3
125	+ 39.1	+ 39.0
160	+ 26.6	+ 27.0
200	+ 17.1	+ 17.9
250	+ 10.9	+ 9.9
315	+ 3.8	+ 3.4
400	+ 1.8	- 1.3
500	- 1.3	- 3.7
630	- 5.5	- 3.1
800	- 7.9	- 7.3
1000	- 12.5	- 13.5
1250	- 10.1	- 11.3
1600	- 11.1	- 13.6
2000	- 13.6	- 14.6
2500	- 15.9	- 15.9
3150	- 17.0	- 16.6
4000	- .2	- .7
5000	+ 18.7	+ 18.5
6300	+ 33.4	+ 33.3
8000	+ 67.5	+ 67.6

APPENDIX 2

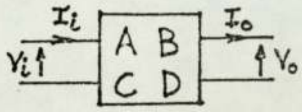
THEORETICAL DERIVATIONS

(Finding the A.B.C.D. parameters for the transmission elements).

THE USE OF ABCD PARAMETERS AND CASCADING OF.

An explanation has already been given in terms of the function of ABCD parameters. The application to particular circuits will now be examined-

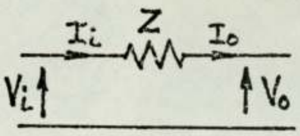
Generally



$$\begin{vmatrix} V_i \\ I_i \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_o \\ I_o \end{vmatrix} \quad \text{ie, } V_i = AV_o + BI_o$$

$$I_i = CV_o + DI_o$$

For series impedance



$$V_i = V_o + IZ \;,\; I_o = I_i$$

ie $V_i = 1V_o + ZI_o$

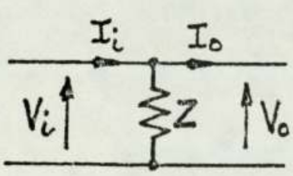
$$I_i = OV_o + 1\, I_i$$

$\therefore$ A = 1 B = Z

C = O D = 1

The matrix is $\begin{vmatrix} 1 & Z \\ O & 1 \end{vmatrix}$

For shunt impedance

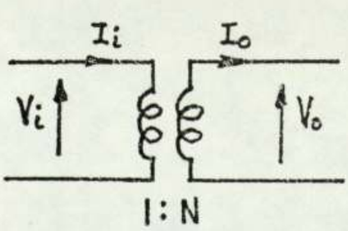


$$V_i = 1\, V_o + OI_o$$

$$I_i = \frac{1}{Z} V_o + 1\, I_o$$

The matrix is $\begin{vmatrix} 1 & O \\ 1/Z & 1 \end{vmatrix}$

For a transformer

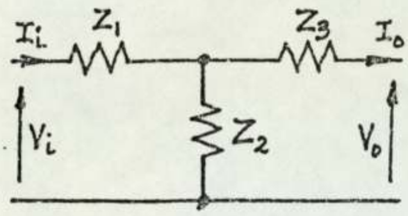


$$V_i = \frac{V_o}{N} + OI_o$$

$$I_i = ØV_o + \frac{I_o}{N}$$

The matrix is $\begin{vmatrix} 1/N & O \\ O & 1/N \end{vmatrix}$

For a 'T' Network



$$V_i = V_o + Z_3 I_o + Z_1 I_i \quad \ldots\ldots\ldots\ldots \quad 1$$

$$I_i = \frac{V_o + Z_3 I_o}{Z_2} + I_o \quad \ldots\ldots\ldots\ldots \quad 2$$

From 2, $I_i = \frac{V_o}{Z_2} + I_o \left(1 + \frac{Z_3}{Z_2} \right)$

$$\therefore \underline{C = 1/Z_2} \qquad \underline{D = 1 + \frac{Z_3}{Z_2}}$$

2 in 1, $V_i = V_o + Z_3 I_o + Z_1 \left(\frac{V_o}{Z_2} + I_o \left(1 + \frac{Z_3}{Z_2} \right) \right)$

$$= V_o + Z_3 I_o + V_o \frac{Z_1}{Z_2} + I_o \left(Z_1 + \frac{Z_1 Z_3}{Z_2} \right)$$

$$= V_o \left(1 + \frac{Z_1}{Z_2} \right) + I_o \left(Z_1 + Z_3 + \frac{Z_1 Z_3}{Z_2} \right)$$

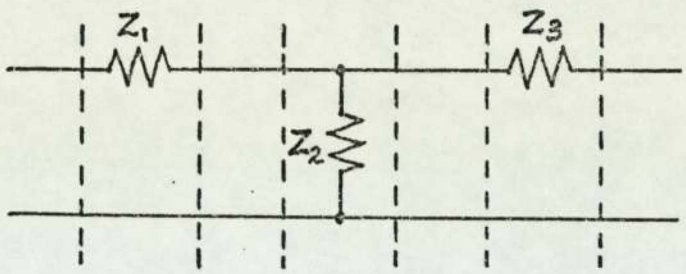
$$\therefore A = 1 + \frac{Z_1}{Z_2} \qquad B = Z_1 + Z_3 + \frac{Z_1 Z_3}{Z_2}$$

Thus, the matrix is

$$\begin{vmatrix} 1 + \frac{Z_1}{Z_2} & Z_1 + Z_3 + \frac{Z_1 Z_3}{Z_2} \\ \frac{1}{Z_2} & 1 + \frac{Z_3}{Z_2} \end{vmatrix}$$

A much more direct way of obtaining this result is to 'cascade' the basic elements making up the network, together.

ie,



$$\begin{vmatrix} 1 & Z \\ 0 & 1 \end{vmatrix} \quad \begin{vmatrix} 1 & 0 \\ 1/Z & 1 \end{vmatrix} \quad \begin{vmatrix} 1 & Z \\ 0 & 1 \end{vmatrix}$$

Cascading:

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} 1 & Z_1 \\ 0 & 1 \end{vmatrix} \begin{vmatrix} 1 & 0 \\ \frac{1}{Z_2} & 1 \end{vmatrix} \begin{vmatrix} 1 & Z_3 \\ 0 & 1 \end{vmatrix}$$

$$= \begin{vmatrix} 1 + \frac{Z_1}{Z_2} & Z_1 \\ \frac{1}{Z_2} & 1 \end{vmatrix} \begin{vmatrix} 1 & Z_3 \\ 0 & 1 \end{vmatrix}$$

$$= \begin{vmatrix} 1 + \frac{Z_1}{Z_2} & Z_1 + Z_3 + \frac{Z_1 Z_3}{Z_2} \\ \frac{1}{Z_2} & 1 + \frac{Z_3}{Z_2} \end{vmatrix}$$

Thus yielding the previous result obtained.

Note,

If A = D, the network will be symmetrical.

(In this case, Z_3 would equal Z_1)

If AD - BC = 1, the network will be reciprocal

CASCADING COMPLEX MATRICES ON THE COMPUTER.

Generally, each of the parameters A,B,C and D will be complex. Let small case represent the real components and large case the imaginary components.

If arrays A1 and A2 contain two complex matrices which are to be cascaded together, they must be represented as follows:

$$A1 = \left| a_1 \; A_1 \; b_1 \; B_1 \; c_1 \; C_1 \; d_1 \; D_1 \right| \qquad A2 = \left| a_2 \; A_2 \; b_2 \; B_2 \; c_2 \; C_2 \; d_2 \; D_2 \right|$$

This is the form in which they are stored in the computer. (Shown for one frequency only.)

In mathematical form

$$A1 = \begin{vmatrix} a_1 + jA_1 & B_1 + jB_1 \\ c_1 + jC_1 & d_1 \pm jD_1 \end{vmatrix} = \begin{vmatrix} A1(1) + A1(2) & A1(3) + jA1(4) \\ A1(5) + jA1(6) & A1(7) + jA1(8) \end{vmatrix}$$

To cascade, start initially with a unit matrix M, and then assign the products to M until the cascadings are complete.

ie $M = 1$

$M = M * A1$

$M = M * A2$

etc.

<u>To find the cascaded products of A1 and A2.</u>

$$\text{Let} \quad \begin{vmatrix} a_1 + jA_1 & b_1 + jB_1 \\ c_1 + jC_1 & d_1 + jD_1 \end{vmatrix} * \begin{vmatrix} a_2 + jA_2 & b_2 + jB_2 \\ c_2 + jC_2 & d_2 + jD_2 \end{vmatrix} = M$$

hen,

$$M = \begin{vmatrix} (a_1 + jA_1)(a_2 + jA_2) & (a_1 + jA_1)(b_2 + jB_2) \\ +(b_1 + jB_1)(c_2 + jC_2) & +(b_1 + jB_1)(d_2 + jD_2) \\ (c_1 + jC_1)(a_2 + jA_2) & (c_1 + jC_1)(b_2 + jB_2) \\ +(d_1 + jD_1)(c_2 + jC_2) & +(d_1 + jD_1)(d_2 + jD_2) \end{vmatrix}$$

$$= \begin{vmatrix} (a_1a_2-A_1A_2) + j(A_1a_2 + a_1A_2) & (a_1b_2-A_1B_2) + j(A_1b_2 + a_1B_2) \\ +(b_1c_2-B_1C_2) + j(B_1c_2 + b_1C_2) & +(b_1d_2-B_1D_2) + j(B_1d_2 + b_1D_2) \\ (c_1a_2-C_1A_2) + j(C_1a_2 + c_1A_2) & (c_1b_2-C_1B_2) + j(C_1b_2 + c_1B_2) \\ +(d_1c_2-D_1C_2) + j(D_1c_2 + d_1C_2) & +(d_1d_2-D_1D_2) + j(D_1d_2+d_1D_2) \end{vmatrix}$$

e

$$M(1) = a_1a_2-A_1A_2 + b_1c_2-B_1C_2$$

$$M(2) = A_1a_2+a_1A_2 + B_1c_2+b_1C_2$$

$$M(3) = a_1b_2-A_1B_2 + b_1d_2-B_1D_2$$

$$M(4) = A_1b_2+a_1B_2 + B_1d_2+b_1D_2$$

$$M(5) = c_1a_2-C_1A_2 + d_1c_2-D_1C_2$$

$$M(6) = C_1a_2+c_1A_2 + D_1c_2+d_1C_2$$

$$M(7) = c_1b_2-C_1B_2 + d_1d_2-D_1D_2$$

$$M(8) = C_1b_2+ c_1B_2+ D_1d_2+d_1D_2$$

or

```
M(1)= A1(1)*A2(1)-A1(2)*A2(2)+A1(3)*A2(5)-A1(4)*A2(6)
M(2)= A1(2)*A2(1)+A1(1)*A2(2)+A1(4)*A2(5)+A1(3)*A2(6)
M(3)= A1(1)*A2(3)-A1(2)*A2(4)+A1(3)*A2(7)-A1(4)*A2(8)
M(4)= A1(2)*A2(3)+A1(1)*A2(4)+A1(4)*A2(7)+A1(3)*A2(8)
M(5)= A1(5)*A2(1)-A1(6)*A2(2)+A1(7)*A2(5)-A1(8)*A2(6)
M(6)= A1(6)*A2(1)+A1(5)*A2(2)+A1(8)*A2(5)+A1(7)*A2(6)
M(7)= A1(5)*A2(3)-A1(6)*A2(4)+A1(7)*A2(7)-A1(8)*A2(8)
M(8)= A1(6)*A2(3)+A1(5)*A2(4)+A1(8)*A2(7)+A1(7)*A2(8)
```

Here these form the M = A1*A2 instructions for the computer, (shown for one frequency only).

To cover the twenty 150 frequencies, the instructions are included in a For J = 1 To 20 . . . . . NEXT J loop.

```
ie  For J = To 20
    M(J,1) = A1(J,1)*(A2(J,1)-A1(J,2)*A2(J,2)+ . . . . . . . . . . . .etc


    M(J,8)= . . . . . . . . . . . . . . .
    NEXT J
```

TO SHOW THAT THE PRODUCT OF RECIPROCAL

MATRICES IS ALSO RECIPROCAL

If the product of 2 reciprocal matrices is reciprocal, then since matrices are multiplied together two at a time, the product of n reciprocal matrices will also be reciprocal.

$$\begin{bmatrix} a_1 b_1 \\ c_1 d_1 \end{bmatrix} \begin{bmatrix} a_2 b_2 \\ c_2 d_2 \end{bmatrix} \doteq \begin{bmatrix} a_1 a_2 + b_1 c_2 & a_1 b_2 + b_1 d_2 \\ c_1 a_2 + d_1 c_2 & c_1 b_2 + d_1 d_2 \end{bmatrix} = \begin{bmatrix} A_1 B_1 \\ C_1 D_1 \end{bmatrix}$$

Now, if reciprocal,

$$A_1 D_1 - B_1 C_1 = 1$$

ie, $(a_1 a_2 + b_1 c_2)(c_1 b_2 + d_1 d_2) - (a_1 b_2 + b_1 d_2)(c_1 a_2 + d_1 c_2)$

$= 1$

Expanding,

$$\cancel{a_1 c_1 d_2 b_2} + \cancel{b_1 d_1 c_2 d_2} + b_1 c_1 c_2 b_2 + a_1 d_1 a_2 d_2$$

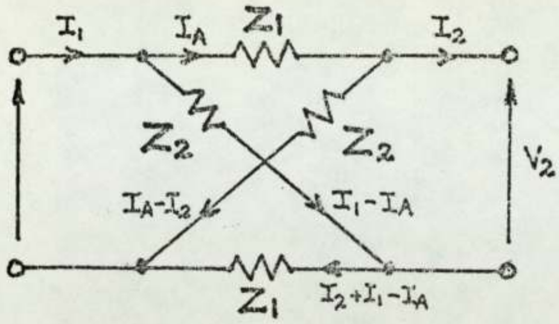
$$- \cancel{a_1 c_1 d_2 b_2} - \cancel{b_1 d_1 c_2 d_2} - b_1 c_1 a_2 d_2 - a_1 d_1 b_2 c_2$$

$$= - c_2 b_2 (a_1 d_1 - b_1 c_1) + a_2 d_2 \; (a_1 d_1 - b_1 c_1)$$

(each bracket struck through and marked "1")

$$= a_2 d_2 - c_2 b_2 \;\; = \underline{\underline{1}}$$

TO FIND THE A B C D PARAMETERS OF A SYMMETRICAL LATTICE



$$V_1 = AV_2+BI_2$$

$$I_1 = CV_2+DI_2$$

$$V_1 = Z_2(I_1-I_A) + Z_1(I_2+I_1-I_A)$$

$$= Z_2I_1 - Z_2I_A + Z_1I_2 + Z_1I_1 - Z_1I_A$$

also

$$V_1 = Z_1I_A + Z_2(I_A - I_2) = Z_1I_A + Z_2I_A - Z_2I_2$$

$$\therefore Z_2I_1-Z_2I_A+Z_1I_2+Z_1I_1-Z_1I_A = Z_1I_A + Z_2I_A - Z_2I_2$$

$$I_1(Z_1+Z_2) + I_2(Z_1+Z_2) = I_A(Z_1+Z_2+Z_1+Z_2)$$

i.e. $\cancel{(Z_1+Z_2)}(I_1+I_2) = I_A.2\cancel{(Z_1+Z_2)}$

$$\therefore I_A = \frac{I_1+I_2}{2} \quad \text{- - - - - - - - - - - - - - - - - - (1)}$$

For ABCD;

$$V_1 = Z_1(I_2+I_1-I_A) + V_2+Z_1I_A = V_2+Z_1I_2 + Z_1I_1 \quad \text{- - - - (2)}$$

$$I_1 = \frac{V_2+Z_1I_A}{Z_2} + I_A = \frac{V_2}{Z_2} + \frac{Z_1}{Z_2}I_A + I_A$$

$$= \frac{V_2}{Z_2} + (1+\frac{Z_1}{Z_2})(\frac{I_1+I_2}{2})$$

$$= \frac{V_2}{Z_2} + \frac{I_2}{2}(1+\frac{Z_1}{Z_2}) + \frac{I_1}{2}(1+\frac{Z_1}{Z_2})$$

$$\therefore I_1(1-\tfrac{1}{2}(1+\frac{Z_1}{Z_2})) = \frac{V_2}{Z_2} + \frac{I_2}{2}(1+\frac{Z_1}{Z_2})$$

$$\therefore I_1 = \frac{V_2}{Z_2(1-\frac{1}{2}(1+\frac{Z_1}{Z_2}))} + \frac{I_2.\frac{1}{2}(1+\frac{Z_1}{Z_2})}{1-\frac{1}{2}(1+\frac{Z_1}{Z_2})}$$

$$\text{Thus } C = \frac{1}{Z_2 - \frac{Z_2}{2}(1+\frac{Z_1}{Z_2})} = \frac{1}{Z_2 - \frac{Z_2}{2} - \frac{Z_1}{Z_2}} = \frac{1}{\frac{Z_2}{2} - \frac{Z_1}{2}} = \frac{2}{Z_2 - Z_1}$$

$$D = \frac{1}{\frac{1}{\frac{1}{2}(1+\frac{Z_1}{Z_2})} - 1} = \frac{1}{\frac{2Z_2}{Z_1+Z_2} - 1} = \frac{Z_1+Z_2}{2Z_2 - Z_1 - Z_2} = \frac{Z_1+Z_2}{Z_2-Z_1}$$

Subst. in (2),

$$V_1 = V_2 + Z_1 I_2 + Z_1\left(\frac{2V_2}{Z_2-Z_1} + \frac{(Z_1+Z_2)}{Z_2-Z_1} I_2\right)$$

$$= V_2 \cdot \left(1 + \frac{2Z_1}{Z_2-Z_1}\right) + I_2\left(Z_1 + Z_1\left(\frac{Z_1+Z_2}{Z_2-Z_1}\right)\right)$$

$$\therefore \quad A = \frac{Z_2 - Z_1 + 2Z_1}{Z_2 - Z_1} \quad \frac{Z_2+Z_1}{Z_2-Z_1}$$

$$B = Z_1\left(1 + \frac{Z_1+Z_2}{Z_2-Z_1}\right) = Z_1\left(\frac{Z_2 - Z_1 + Z_1 + Z_2}{Z_2-Z_1}\right)$$

$$= Z_1\left(\frac{2Z_2}{Z_2-Z_1}\right) = \frac{2Z_1Z_2}{Z_2-Z_1}$$

$$\text{Thus, } \begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} \frac{Z_2+Z_1}{Z_2-Z_1} & \frac{2Z_1Z_2}{Z_2-Z_1} \\ \frac{2}{Z_2-Z_1} & \frac{Z_2+Z_1}{Z_2-Z_1} \end{vmatrix}$$

Check

AD-BC = 1 for reciprocal network.

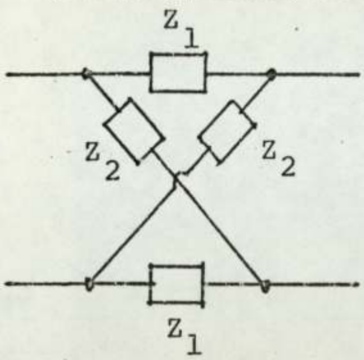
(Also, A = D for symmetrical network).

$$\therefore \left(\frac{Z_2+Z_1}{Z_2-Z_1}\right)^2 - \frac{2Z_1Z_2}{Z_2-Z_1} \cdot \frac{2}{Z_2-Z_1}$$

$$= \frac{Z_2^2+Z_1^2+2Z_1Z_2-4Z_1Z_2}{Z_2^2+Z_1^2-2Z_1Z_2}$$

$$= \frac{Z_2^2+Z_1^2-2Z_1Z_2}{Z_2^2+Z_1^2-2Z_1Z_2} = \underline{\underline{1}}$$

TO EXPRESS THE ABCD PARAMETERS FOR THE LATTICE IN COMPLEX FORM



$$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} = \begin{vmatrix} \frac{Z_2+Z_1}{Z_2-Z_1} & \frac{2Z_1 Z_2}{Z_2-Z_1} \\ \frac{2}{Z_2-Z_1} & \frac{Z_2+Z_1}{Z_2-Z_1} \end{vmatrix}$$

For A' $(= A + ja)$

$$A' = \frac{Z_2+Z_1}{Z_2-Z_1} = \frac{(R_2+jX_2)+(R_1+jX_1)}{(R_2+jX_2)-(R_1+jX_1)}$$

$$= \frac{(R_2+R_1)+j(X_2+X_1)}{(R_2-R_1)+j(X_2-X_1)}$$

Let $K_1 = R_2+R_1$

$K_2 = R_2-R_1$

$K_3 = X_2+X_1$

$K_4 = X_2-X_1$

$$= \frac{K_1+jK_3}{K_2+jK_4}$$

$$= \frac{(K_1+jK_3)(K_2-jK_4)}{K_2^{\,2} + K_4^{\,2}}$$

Let $K_5 = K_2^{\,2}+K_4^{\,2}$

Then, $A = \dfrac{K_1K_2+K_3K_4}{K_5} = D$

$$a = \frac{K_2K_3-K_1K_4}{K_5} = d$$

For B' (= B + jb)

$$B' = \frac{2Z_1Z_2}{Z_2-Z_1} = \frac{2(R_1+jX_1)(R_2+jX_2)}{(R_2+jX_2)-(R_1+jX_1)}$$

$$= \frac{2((R_1R_2-X_1X_2)+j(X_1R_2+R_1X_2))}{(R_2-R_1)+j(X_2-X_1)}$$

$$= \frac{2(K_6+jK_7)}{K_2+jK_4}$$

Let $K_6 = R_1R_2-X_1X_2$

$K_7 = X_1R_2+R_1X_2$

$$= \frac{2(K_6+jK_7)(K_2-jK_4)}{K_2^2+K_4^2}$$

$$= \frac{2((K_2K_6+K_4K_7) + j(K_2K_7-K_4K_6))}{K_5}$$

$$\therefore \quad B = \frac{2(K_2K_6+K_4K_7)}{K_5}$$

$$b = \frac{2(K_2K_7-K_4K_6)}{K_5}$$

For C' (=C+jC)

$$C' = \frac{2}{Z_2-Z_1} = \frac{2}{(R_2+jX_2)-(R_1+jX_1)}$$

$$= \frac{2}{(R_2-R_1)+j(X_2-X_1)} = \frac{2}{K_2+jK_4}$$

$$= \frac{2(K_2-jK_4)}{K_2^2+K_4^2} = \frac{2K_2}{K_5} - j\frac{2K_4}{K_5}$$

$$\therefore \quad C = \frac{2K_2}{K_5} \qquad c = \frac{-2K_4}{K_5}$$

IMPLEMENTING IN BASIC FOR THE PET COMPUTER

'Series' Impedance

(If component does not exist, type in ϕ)

```
INPUT "Resistance";  R1
INPUT "Inductance";  L1
INPUT "Capacitance"; C1
C$ = "Series Impedance; R = " + STR$ (R1) + "Ohms, L = " + STR$ (L1)
     + "mH, C = " + STR$ (C1) + "nF"
```

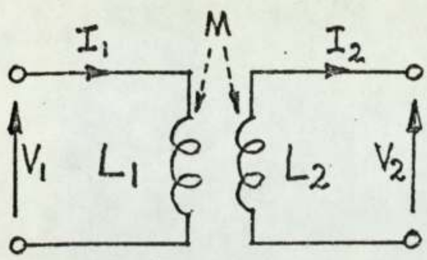
'Shunt' Impedance

```
INPUT "Resistance";  R2
INPUT "Inductance";  L2
INPUT "Capacitance"; C2
D$ = "Shunt Impedance; R = " + STR$ (R2) + "Ohms, L = " + STR$ (L2)
     + "mH, C = " + STR$ (C1) + "nF"
E$ = "___"

      For J = 1 to 20
      ω = 2 * π * F(J)
700   L3 = ω * L1
710   If C1 = ϕ then 730
720   C3 = 1/(ω * C1) :GO TO 740
730   C3 = ϕ
740   L4 = ω * L2
750   If C2 = ϕ then 770
760   C4 = 1/(ω *  C2): GO TO 780
770   C4 = ϕ
780   X1 = L3 - C3 : X2 = L4 - C4
790   K1 = R2 + R1 : K2 = R2 - R1
```

```
800   K3 = X2 + X1 : K4 = X2 - X1
810   K5 = K2 ↑ 2 + K4 ↑ 2
820   K6 = R1 * R2 - X1 * X2 : K7 = X1 * R2 + R1 * X2
830   A(J,1) = (K1 * K2 + K3 * K4)/K5
840   A(J,2) = (K2 * K3 - K1 * K4)/K5
850   A(J,3) = 2 * (K2 * K6 + K4 * K7) 1 K5
860   A(J,4) = 2 * (K2 * K7 - K4 * K6) 1 K5
870   A(J,5) = 2 * K2/K5
880   A(J,6) =-2 * K4/K5
890   A(J,7) = A(J,1)
900   A(J,8) = A(J,2)
910   Next J
```

TO FIND THE A B C D PARAMETERS FOR MUTUALLY COUPLED COILS



$$V_1 = AV_2 + BI_2$$

$$I_1 = CV_2 + DI_2$$

$$V_1 = j\omega L_1\ I_1 - j\omega MI_2 \quad \text{———} 1$$

$$V_2 = j\omega L_2\ I_2 - j\omega MI_1 \quad \text{———} 2$$

from 2,

$$I_1 = \frac{V_2 + j\omega L_2\ I_2}{j\omega M}$$

sub in 1,

$$V_1 = \frac{\cancel{j\omega}L_1}{\cancel{j\omega}M} \left|V_2 + j\omega L_2\ I_2\right| - j\omega MI_2$$

$$= \frac{L_1V_2}{M} + \frac{j\omega L_1 L2}{M}\ I_2 - j\omega MI_2$$

$$= \frac{L_1}{M}\ V_2 + j\omega\ \frac{(L_1L_2 - M)\ I_2}{M}$$

$$\therefore \quad A = \frac{L_1}{M} \qquad B = j\omega \left|\frac{L_1L_2 - M^2}{M}\right|$$

from 1,

$$I_1 = \frac{V_1 + j\omega M I_2}{j\omega L_1} = \frac{V_1}{j\omega L_1} + \frac{M}{L_1} I_2$$

$$= \frac{(AV_2 + BI_2)}{j\omega L_1} + \frac{M}{L_1} I_2$$

$$= \frac{\cancel{L_1}}{j\omega M \cancel{L_1}} V_2 + I_2 \frac{(\cancel{j\omega}(L_1 L_2 - M^2)}{\cancel{j\omega} L_1 M} + \frac{M)}{L_1}$$

$$\text{ie, } I_1 = \frac{-j}{\omega M} V_2 + I_2 \frac{(L_1 L_2 - M^2}{L_1 M} + \frac{M)}{L_1}$$

$$\therefore \quad C = \frac{-j}{\omega M}$$

$$D = \frac{L_1 L_2 - \cancel{M^2} + \cancel{M^2}}{L_1 M} = \frac{L_2}{M}$$

Thus,

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} \frac{L_1}{M} & j\omega \left|\frac{L_1 L_2 - M^2}{M}\right| \\ \frac{-j}{\omega M} & \frac{L_2}{M} \end{vmatrix}$$

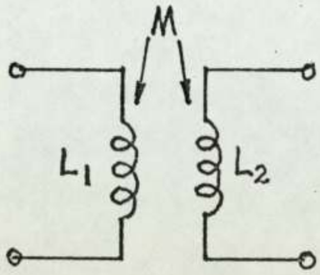
(non-symmetrical)
as $A \neq D$

$$AD - BC = \frac{L_1 L_2}{M_2} - \frac{\cancel{\omega}}{\cancel{\omega} M^2}(L_1 L_2 - M^2)$$

$$= \frac{\cancel{L_1 L_2}}{\cancel{M_2}} - \frac{\cancel{L_1 L_2}}{\cancel{M_2}} + \frac{\cancel{M^2}\ 1}{\cancel{M^2}\ 1}$$

$= \underline{\underline{1}}$ therefore the network is reciprocal.

TO EXPRESS THE A B C D PARAMETERS IN COMPLEX FORM FOR TWO MUTUALLY COUPLED COILS



$$\begin{vmatrix} A' B' \\ C' D' \end{vmatrix} = \begin{bmatrix} \frac{L_1}{M} & j\omega\left[\frac{L_1 L_2 - M^2}{M}\right] \\ \frac{-j}{\omega M} & \frac{L_2}{M} \end{bmatrix}$$

Input L_1, L_2, M

$A' = A + ja \quad \therefore \quad \underline{A = \frac{L_1}{M}} \qquad a = 0$

$B' = B + jb \quad \therefore \quad \underline{B = 0} \qquad b = \frac{\omega}{M}\ (L_1 L_2 - M^2)$

$C' = C + jc \quad \therefore \quad \underline{C = 0} \qquad c = \frac{-1}{\omega M}$

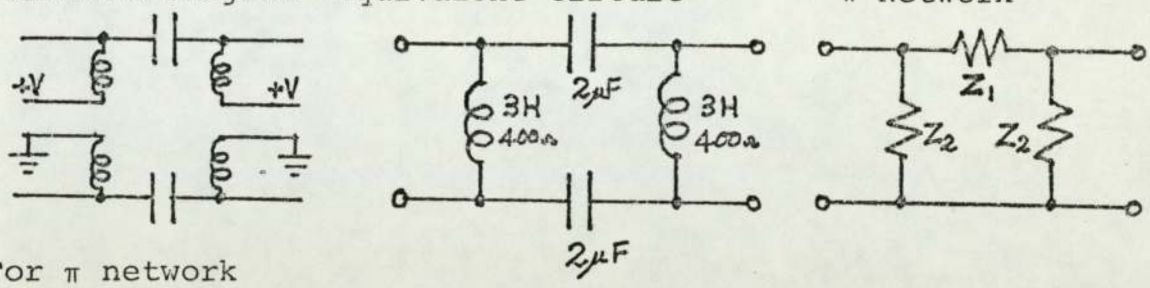
$D' = D + jd \quad \therefore \quad \underline{D = \frac{L_2}{M}} \qquad d = 0$

Thus:

```
          For = J = 1 to 20
            ω = 2 *π * F(J)
        A(J,1) = L1/M
        A(J,2) = 0
        A(J,3) = 0
        A(J,4) = ω*(L1*L2 - M↑2)/M
        A(J,5) = 0
        A(J,6) = -1/(ω*M)
        A(J,7) =L2/M
        A(J,8) = 0
        Next J
```

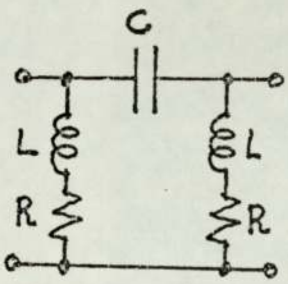
TO FIND A,B,C,D PARAMETERS OF A STONE FEEDING BRIDGE

Circuit Diagram Equivalent Circuit π Network



For π network

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} 1 & 0 \\ 1/Z_2 & 1 \end{vmatrix} \begin{vmatrix} 1 & Z_1 \\ 0 & 1 \end{vmatrix} \begin{vmatrix} 1 & 0 \\ 1/Z_2 & 1 \end{vmatrix}$$



$$= \begin{vmatrix} 1+\frac{Z_1}{Z_2} & Z_1 \\ \frac{Z_1+2Z_2}{Z_2^{\,2}} & 1+\frac{Z_1}{Z_2} \end{vmatrix} \equiv \begin{vmatrix} a + jA & b+jB \\ c+jC & d+jD \end{vmatrix}$$

Equivalent π network

$$\frac{Z_1}{Z_2} = \frac{1}{j\omega C(R+j\omega L)} = \frac{1}{j\omega cR-\omega^2 LC} = \frac{-1}{\omega^2 LC-j\ CR}$$

$$= \frac{-\omega^2 LC-j\omega CR}{(\omega^2 LC)^2+(\omega CR)^2}$$

Thus, $a = 1 - \dfrac{\omega^2 LC}{(\omega^2 LC)^2+(\omega CR)^2} = 1- \dfrac{1}{\omega^2 LC+\frac{(\omega CR)^2}{\omega^2 LC}}$

$$A = \frac{-\omega CR}{(\omega^2 LC)^2+(\omega CR)^2} = \frac{-1}{\omega CR + \frac{(\omega^2 LC)^2}{\omega CR}}$$

d = a, D = A (By symmetry)

$$Z_1 = \frac{1}{j\omega C} = \frac{-j}{\omega C} \qquad \therefore\ b = 0, B = \frac{-1}{\omega C}$$

$$\frac{Z_1+2Z_2}{Z_2^{\,2}} = \frac{\frac{1}{j\omega C}+2R+2j\omega L}{(R+j\omega L)^2}$$

$$= \frac{2R+j(2\omega L - \frac{1}{\omega C})}{R^2-\omega^2L^2+2j\omega LR} = \frac{2R+j(2\omega L - \frac{1}{\omega C}}{(R^2-\omega^2L^2)+j(2\omega LR)}$$

$$= \frac{|2R+j(2\omega L - \frac{1}{\omega C})||(R^2-\omega^2L^2)-j(2\omega LR)|}{(R^2-\omega^2L^2)^2+(2\omega LR)^2}$$

$$= \frac{2R(R^2-\omega^2L^2)+(2\omega L-\frac{1}{\omega C})(2\omega LR)+j|(2\omega L-\frac{1}{\omega C})(R^2-\omega^2L^2)-4\omega LR^2|}{R^4+\omega^4L^4-2R^2\omega^2L^2+4\omega^2L^2R^2}$$

$$= \frac{2R^3-2\omega^2L^2R+4\omega^2L^2R-2\frac{LR}{C}+j|2\omega LR^2+\frac{\omega L^2}{C}-\frac{R^2}{\omega C}-2\omega^3L^3-4\omega LR^2|}{R^4+\omega^4L^4+2\omega^2L^2R^2}$$

$$= \frac{2R^3+2\omega^2L^2R-2\frac{LR}{C}+j(\frac{\omega L^2}{C}-\frac{R^2}{\omega C}-2\omega LR^2-2\omega^3L^3)}{R^4+\omega^4L^4+2\omega^2L^2R^2}$$

$$\therefore \qquad c = \frac{2(R^3+\omega^2L^2R-\frac{LR}{C})}{R^4+\omega^4L^4+2\omega^2L^2R^2} = \frac{2(R^3+(\omega L)^2R-\frac{LR}{C})}{R^4+(\omega L)^4+2(\omega LR)^2}$$

$$C = \frac{\frac{\omega^2L^2-R^2}{\omega C} - 2\omega LR^2-2\omega^3L^3}{R^4+\omega^4L^4+2\omega^2L^2R^2}$$

Re-writing to save on computer calculations,

$$c = \frac{2R(R^2+(\omega L)^2 - L/C)}{R^4+(\omega L)^4+2(\omega LR)^2}$$

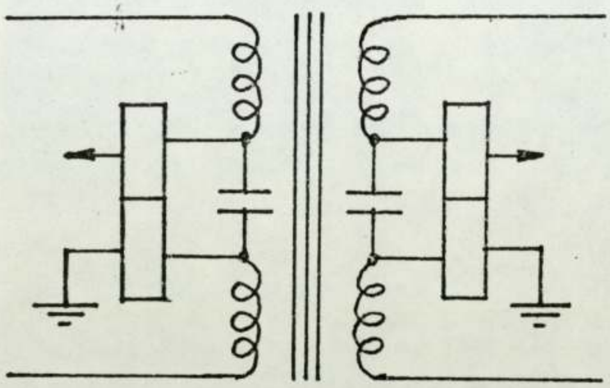
$$\text{and } C = \frac{\frac{(\omega L)^2-R^2}{\omega C} - 2\omega LR^2-2(\omega L)^3}{R^4+(\omega L)^4+2(\omega LR)^2}$$

IMPLEMENTING IN BASIC

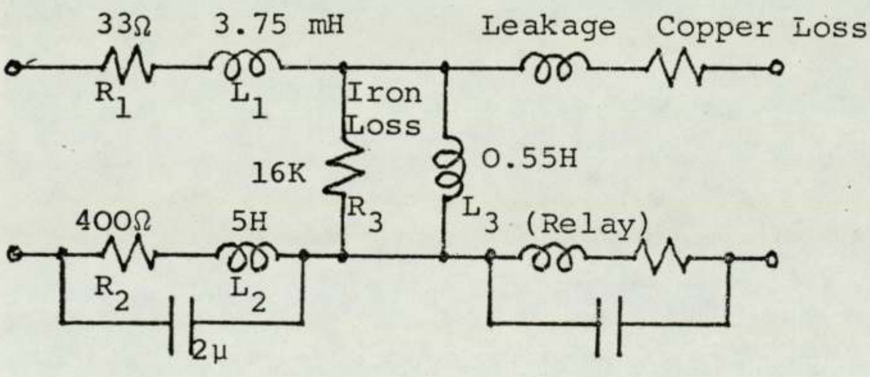
```
For J = 1 to 20
    W = 2*PI+F(J)
    S1 = ((W*L)↑2-R↑2)/(W*C)-2*W*L*R↑2-2*(W*L)↑3
    S2 = R↑4+(W*L)↑4+2*(W*L*R)↑2
    A(J,1)=1-1/(W↑2*L*C+(W*C*R)↑2/(W↑2*L*C))
    A(J,2) =-1/(W*C*R+(W↑2*L*C)↑2/(W*C*R))
    A(J,3) = 0
    A(J,4) = -1/(W*C)
    A(J,5) = 2*R*(R↑2)+(W*L)↑2 - L/C)/S2
    A(J,6) = S1/S2
    A(J,7) = A(J,1)
    A(j,8) = A(j,2)
    NEXT J
```

TO FIND A B C D PARAMETERS OF A HAYES FEEDING BRIDGE

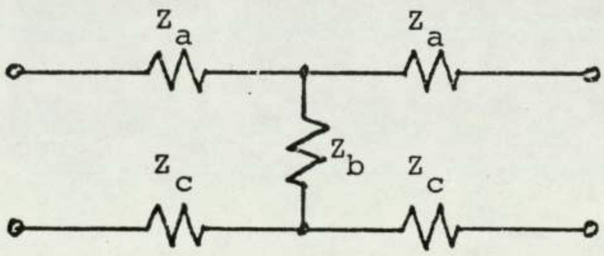
Circuit Diagram



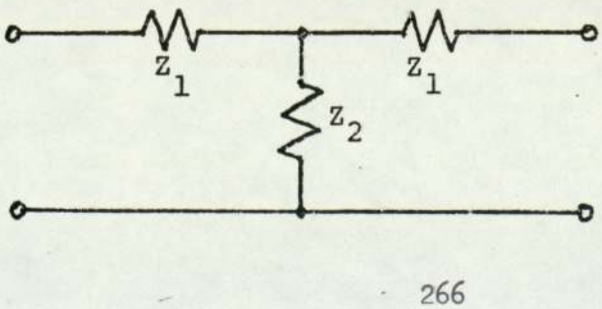
Equivalent Circuit



Balanced T Equivalent



Symmetrical T



$Z_1 = Z_a + Z_c$

$Z_2 = Z_b$

$$Z_a = R_1 + j\omega L$$

$$Z_b = \frac{R_3 + j\omega L_3}{R_3 + j\omega L_3} = Z_2$$

$$Z_c = \frac{\frac{1}{j\omega C}(R_2 + j\omega L_2)}{\frac{1}{j\omega C} + R_2 + j\omega L_2} = \frac{R_2 + j\omega L_2}{1 - \omega^2 CL_2 + j\omega CR_2}$$

$$Z_1 = Z_a + Z_c$$

$$= \underbrace{R_1 + j\omega L_1}_{K} + \frac{R_2 + j\omega L_2}{1 - \omega^2 CL_2 + j\omega CR_2}$$

$$= K + \frac{(R_2 + j\omega L_2)((1 - \omega^2 CL_2) - j\omega CR_2)}{\underbrace{(1 - \omega^2 CL_2)^2}_{(S1)^2} + \underbrace{(\omega CR_2)^2}_{(S2)^2}}$$

$$= K + \frac{R_2(S1) + \omega L_2(S2) + j(\omega L_2(S1) - R_2(S2)}{(S1)^2 + (S2)^2}$$

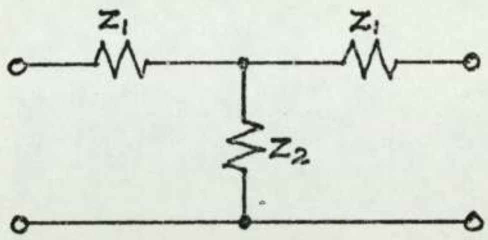
$$= R_1 + j\omega L_1 + \frac{R_2(S1) + \omega L_2(S2)}{(S1)^2 + (S2)^2} + j\frac{\omega L_2(S1) - R_2(S2)}{(S1)^2 + (S2)^2}$$

i.e. $$X_1 = R_1 + \frac{R_2(S1) + \omega L_2(S2)}{(S1)^2 + (S2)^2}$$

$$Y_1 = \omega L_1 + \frac{\omega L_2(S1) - R_2(S2)}{(S1)^2 + (S2)^2} \qquad (Z_1 = X_1 + jY_1)$$

Now,

A B C D parameters for symmetrical T,



$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} 1 & Z_1 \\ 0 & 1 \end{vmatrix} \begin{vmatrix} 1 & 0 \\ 1/Z_2 & 1 \end{vmatrix} \begin{vmatrix} 1 & Z_1 \\ 0 & 1 \end{vmatrix}$$

i.e. $$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} = \begin{vmatrix} 1 + \frac{Z_1}{Z_2} & 2Z_1 + \frac{Z_1^2}{Z_2} \\ \frac{1}{Z_2} & 1 + \frac{Z_1}{Z_2} \end{vmatrix} = \begin{vmatrix} a + jA & b + jB \\ c + jC & d + jD \end{vmatrix}$$

$$\frac{1}{Z_2} = \frac{R_3 + j\omega L_3}{j\omega L_3 R_3} = \frac{1}{R_3} - j\frac{1}{\omega L_3} = C'$$

$$\therefore\ c = \frac{1}{R_3} \qquad C = \frac{-1}{\omega L_3}$$

FOR A' (= D')

$A' = 1 + \frac{Z_1}{Z_2}$ $\therefore$ Find $\frac{Z_1}{Z_2} = \frac{Z_1}{C1+jC2}$ where $C1 = \frac{1}{R_3}$ $C_2 = \frac{-1}{\omega L_2}$

Now, $Z_1 = X1 + jY1$

$$\therefore\ \frac{Z_1}{Z_2} = (X1 + jY1)(C1 + jC2)$$

$$= X1.C1 - Y1.C2 + j(Y1.C1 + X1.C2)$$

Thus, $R_L(\frac{Z_1}{Z_2}) = X1.C1 - Y1.C2$

$Im(\frac{Z_1}{Z_2}) = Y1.C1, + X1.C2$

Thus $a = 1 + R_L(\frac{Z_1}{Z_2})$, $A = Im(\frac{Z_1}{Z_2})$

$d = a,\ D = A$

For B'

$B' = 2Z_1 + \frac{Z_1^2}{Z_2^2}$ $\qquad$ $2Z_1 = 2X1 + j2Y1$

$$\frac{Z_1^2}{Z_2} = (X1 + jY1)^2 (C1 + jC2)$$

$$= (|X1^2 - Y1^2| + j2X1.Y1)(C1 + jC2)$$

$$= C1(X1^2 - Y1^2) - 2X1.Y1.C2 + j(2X1.Y1.C1 + C2(X1^2 - Y1^2)$$

i.e. $R_L(\frac{Z_1^2}{Z_2^2}) = C1(X1^2 - Y1^2) - 2X1.Y1.C2$

$Im(\frac{Z_1^2}{Z_2}) = C2(X1^2 - Y1^2) + 2X1.Y1.C1$

$\therefore$ $b = 2X1 + C1(X1^2 - Y1^2) - 2X1.Y1.C2$

$B = 2Y1 + C2(X1^2 - Y1^2) + 2X1.Y1.C1$

Let $C3 = X1^2 - Y1^2.C4 = 2X1.Y1$

Thus, have for the A B C D parameters,

$a = 1 + X1.C1 - Y1.C2$

$A = Y1.C1. \times X1.C2$

$b = 2X1 + C1.C3 - C2.C4$

$B = 2Y1 + C2.C3 + C1.C4$

$c = C1$

$C = C2$

$d = a$

$D = A$

where, $C1 = 1/R_3$

$C2 = 1/\omega L_3$

$C3 = X1^2 - Y1^2$

$C4 = 2X1.Y1$

where, $$X1 = R_1 + \frac{R_2.S1+\omega L_2.S2}{S3}$$

$$Y1 = \omega L_1 + \frac{\omega L_2.S1-R_2.S2}{S3}$$

where, $$S1 = 1-\omega^2 CL_2$$

$$S2 = \omega CR_2,\ S3 = S1^2+S2^2$$

IMPLEMENTING IN BASIC

```
(Input R1, L1, R2, L2, R3, L3, C)

For J = 1 to 20
W      = 2*PI*F(J)
S1     = 1 - W↑2*C*L2
S2     = W*C*R2
S3     =S1↑2 + S2↑2
X1     = R1 + (R2*S1 + W*L2*S2)/S3
Y1     = W*L1 + (W*L2*S1 - R2*S2)/S3
C1     =1/R3
C2     = -1/(W*L3)
C3     = X1↑2 - Y1↑2
C4     = 2*X1*Y1
A(J,1) = 1 + X1*C1 - Y1*C2
A(J,2) = Y1*C1 + X1*X2
A(J,3) = 2*X1 +    C1*C3 - C2*C4
A(J,4) = 2*Y1 + C2*C3 + C1*C4
A(J,5) = C1
A(J,6) = C2
A(J,7) = A(J,1)
A(J,8) = A(J,2)
Next J
```

TO FIND THE ABCD PARAMETERS FOR A CHANNEL FILTER. (CHF)

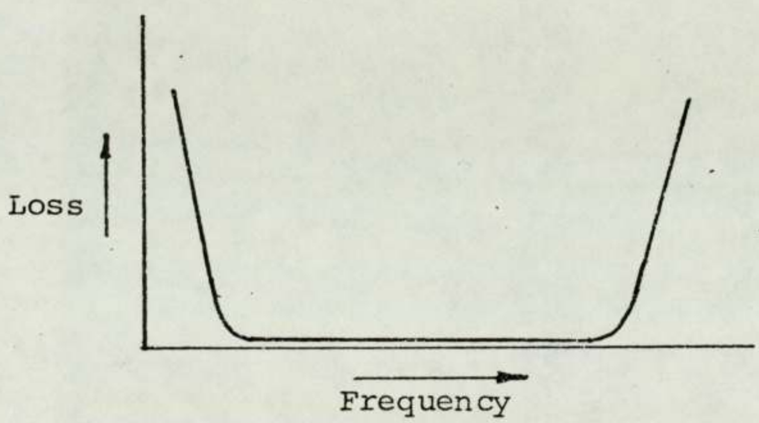
These were obtained from a graph showing attenuation against frequency for a type 1-4 channel filter. The filter is treated as a "frequency dependant attenuator".

Simplifying assumptions are:

a) The characteristic impedance is constant at 600Ω.

b) There is no phase change from input to output.

(valid for 2-wire working). ie there are no imaginary components.



Let L = Loss in dB

$S = 10^{L/20}$ $(L = 20 \log s_{10})$

Z = Characteristic Impedance

Then, (as previously shown)

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} \frac{S^2 + 1}{2S} & Z\frac{S^2 - 1}{2S} \\ \frac{1}{Z}\frac{S^2 - 1}{2S} & \frac{S^2 + 1}{2S} \end{vmatrix}$$

for each separate frequency.

In the computer program, there is a facility which automatically takes into account the number of channel filters in tandem.

(The same facility also exists for the loaded cable junctions).

This is implemented as follows:

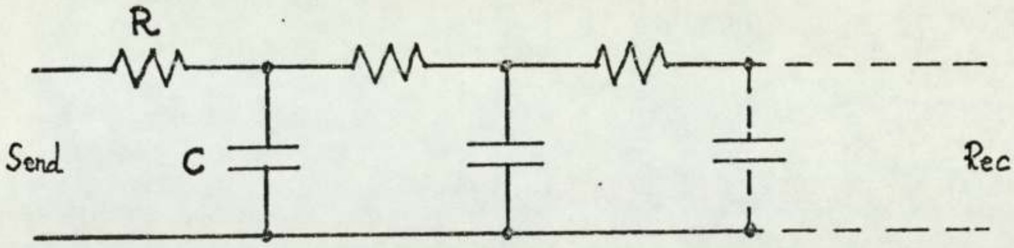
```
PRINT "How many CHF's in tandem?";
INPUT E
FOR J = 1 to E
K(I) = 18
I = I + 1
NEXT J
I = I - 1
NEXT I
```

<u>Eg</u> I = 6, E = 3

I	---	6	7	8	---
K(I)		18	18	18	

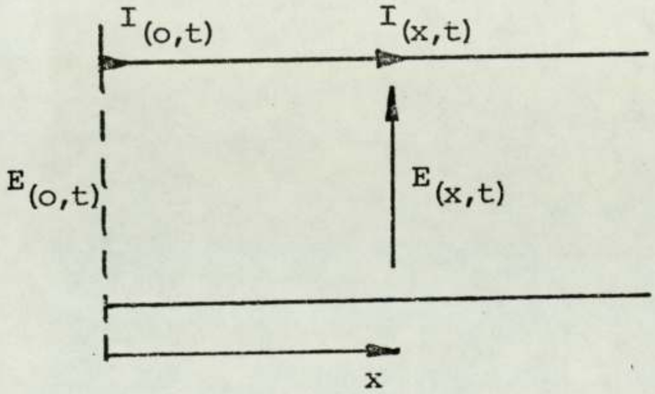
TO FIND THE ABCD PARAMETERS OF TRANSMISSION LINE (TXL)

(R & C ONLY)



Here, $G = 0$, $L = 0$

$$Z_o = \frac{R+j\omega L}{G+j\omega C} = \frac{R}{j\omega C}$$



Laplace Transform,

$$Z_o(s) = \frac{R+SL}{G+SC} = \frac{R}{SC}$$

$$\frac{\partial E_{(x,t)}}{\partial x} = -RI_{(x,t)} \qquad \frac{\partial I_{(x,t)}}{\partial x} = \frac{-C\partial E}{\partial t}{}_{(x,t)}$$

$\mathcal{L}T$ wrt t, ($\mathcal{L}T$ signifies Laplace Transform)

$$\frac{\partial E_{(x,s)}}{\partial x} = -RI_{(x,s)} \qquad \frac{\partial I_{(x,s)}}{\partial x} = -SCE_{(x,s)} + CE_{(x,s)}$$

$E_{(x,o)} = 0$ (line initially discharged)

$$\therefore \quad \frac{\partial E_{(x,s)}}{\partial x} = -RI_{(x,s)} \qquad \frac{\partial I_{(x,s)}}{\partial x} = -SCE_{(x,s)}$$

$\mathcal{L}T$ wrt x,

$$pE_{(p,s)} - E_{(o,s)} = -RI_{(p,s)} \quad \text{——1}$$

$$pI_{(p,s)} - I_{(o,s)} = -SCE_{(p,s)} \quad \text{——2}$$

For $E_{(p,s)}$, from 2

$$I_{(p,s)} = \frac{I_{(o,s)} - CSE_{(p,s)}}{P}$$

Subst. in 1,

$$pE_{(p,s)} - E_{(o,s)} = -\frac{R}{P}\left|I_{(o,s)} - SCE_{(p,s)}\right|$$

$$\therefore \quad E_{(p,s)} = \frac{E_{(o,s)}}{P} - \frac{R}{p^2}\left|I_{(o,s)} - SCE_{(p,s)}\right|$$

$$= \frac{E_{(o,s)}}{P} - \frac{RI_{(o,s)}}{p^2} + \frac{SCE_{(p,s)}}{p^2}$$

$$\therefore \quad E_{(p,s)}\left\{1 - \frac{SC}{p^2}\right\} = \frac{E_{(o,s)}}{P} - \frac{RI_{(o,s)}}{p^2}$$

$$E_{(p,s)} = \frac{p^2}{p^2 - SC}\left|\frac{E_{(o,s)}}{P} - \frac{RI_{(o,s)}}{p^2}\right|$$

$$\text{ie} \quad E_{(p,s)} = \frac{pE_{(o,s)} - RI_{(o,s)}}{p^2 - SC} \quad \text{———} 3$$

For $I_{(p,s)}$, from 1,

$$E_{(p,s)} = \frac{E_{(o,s)} - RI_{(p,s)}}{P}$$

Subst. in 2,

$$pI_{(p,s)} - I_{(o,s)} = -\frac{SC}{P}\left|E_{(o,s)} - RI_{(p,s)}\right|$$

$$\therefore \quad I_{(p,s)} = \frac{I_{(o,s)}}{P} - \frac{SC}{p^2}\left|E_{(o,s)} - RI_{(p,s)}\right|$$

$$= \frac{I_{(o,s)}}{P} - \frac{SCE_{(o,s)}}{p^2} + \frac{SCRI_{(p,s)}}{p^2}$$

$$\therefore \quad I_{(p,s)} \quad 1-\frac{SCR}{p^2} = \frac{I_{(o,s)}}{P} - \frac{SCE_{(o,s)}}{p^2}$$

$$\therefore \quad I_{(p,s)} = \frac{p^2}{p^2-SCR}\left|\frac{I_{(o,s)}}{P} - \frac{SCE_{(o,s)}}{p^2}\right|$$

$$\text{ie} \quad I_{(p,s)} = \frac{p^{I}{}_{(o,s)}{}^{-SCE}{}_{(o,s)}}{p^2-SCR} \quad \text{———} 4$$

From 3, for $\mathcal{L}r^{-1}$ let $\mu^2 = SCR$, poles at $(p^2-\mu^2) = 0 = (p+\mu)(p-\mu)$

ie $p = \pm\mu$

$$E_{(p,s)} = \left.\frac{\{_{p}E_{(o,s)}{}^{-RI}{}_{(o,s)}\}e^{px}}{(p+\mu)(p-\mu)}\right|_{p = \pm\mu}$$

$$\underset{p = -\mu}{\text{Residue}} = \frac{\{-_{\mu}E_{(o,s)}{}^{-RI}{}_{(o,s)}\}e^{-\mu x}}{2\mu}$$

$$\underset{p = \mu}{\text{Residue}} = \frac{\{_{\mu}E_{(o,s)}{}^{-RI}{}_{(o,s)}\}e^{\mu x}}{2\mu}$$

$$\therefore \quad E_{(x,s)} = \frac{1}{2\mu}\left|(\mu E_{(o,s)}+RI_{(o,s)})e^{-\mu x} + (\mu E_{(o,s)}-RI_{(o,s)}e^{\mu x}\right|$$

$$= \frac{1}{2}(E_{(o,s)}|e^{-\mu x}+e^{\mu x}|) + \frac{R}{2\mu}(I_{(o,s)}|e^{-\mu x}-e^{\mu x}|)$$

$$\text{ie } E_{(x,s)} = E_{(o,s)}\text{ch}\mu x - \frac{R}{\mu} I_{(o,s)}\text{sh}\mu x \quad \text{—————} 5$$

From 4, for $\mathcal{L}^{-1}$

poles at $(p^2-\mu^2) = 0$ $\qquad (p + \mu)(p - \mu) = 0$

$\therefore \quad p = \pm\mu$

$$I_{(p,s)} = \frac{\{pI_{(o,s)} - SCE_{(o,s)}\}\, e^{px}}{(p + \mu)(p - \mu)} \Bigg| \; p = \pm\mu$$

Residual

$$p = -\mu, = \frac{\{-\mu I_{(o,s)} - SCE_{(o,s)}\}\, e^{-\mu x}}{-2\mu}$$

$$= \frac{\{\mu x I_{(o,s)} + SCE_{(o,s)}\}\, e^{-\mu x}}{2\mu}$$

Residual

$$p = \mu, = \frac{\{\mu I_{(o,s)} - SCE_{(o,s)}\}\, e^{\mu x}}{2\mu}$$

$$\therefore \quad I_{(x,s)} = \frac{1}{2\mu} \begin{vmatrix} \mu I_{(o,s)} e^{-\mu x} + SCE_{(o,s)} e^{-\mu x} \\ +\mu I_{(o,s)} e^{\mu x} - SCE_{(o,s)} e^{\mu x} \end{vmatrix}$$

$$= \frac{1}{2} I_{(o,s)} \left| e^{\mu x} + e^{-\mu x} \right| - \frac{SC}{2\mu} E_{(o,s)} \left| e^{\mu x} - e^{-\mu x} \right|$$

ie $\quad I_{(x,s)} = I_{(o,s)} \mathrm{ch}\mu x - \frac{SC}{\mu} E_{(o,s)} \mathrm{sh}\mu x$ ——— 6

But $\mu = \sqrt{SCR}$

$\therefore$ 5 becomes,

$$E_{(x,s)} = E_{(o,s)} \mathrm{ch}\mu x - \sqrt{\frac{R}{SC}}\, I_{(o,s)} \mathrm{sh}\mu x$$

$$I_{(x,s)} = I_{(o,s)} ch\mu x - \frac{SC}{R} I_{(o,s)} sh\mu x$$

But $Z_o = \sqrt{\frac{R}{SC}}$

Hence, in matrix form

$$\begin{vmatrix} E_{(x,s)} \\ I_{(x,s)} \end{vmatrix} = \begin{vmatrix} ch\mu x & - Z_o sh\mu x \\ \frac{-1}{Z_o} sh\mu x & ch\mu x \end{vmatrix} \begin{vmatrix} E_{(o,s)} \\ I_{(o,s)} \end{vmatrix}$$

Let $\gamma = \mu$ (γ is used more conventionally)

Then ABCD parameters are:

$$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} = \begin{vmatrix} ch\gamma x & - Z_o sh\gamma x \\ \frac{-1}{Z_o} sh\gamma x & ch\gamma x \end{vmatrix}$$

(Have used A'-D' as this is the inverse of the matrix eqn defined in ABCD notation)

ie have here,

$$\begin{vmatrix} V_o \\ I_o \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} \begin{vmatrix} V_i \\ I_i \end{vmatrix}$$

Thus have, (B' and C' become +ve, see note * on next page).

$$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} = \begin{vmatrix} ch\gamma L & Z_o sh\gamma L \\ \frac{1}{Z_o} sh\gamma L & ch\gamma L \end{vmatrix}$$ (inverse matrix)

$$= \begin{vmatrix} a+_jA & b+_jB \\ c+_jC & d+_jD \end{vmatrix}$$

$a + {}_jA = R_L(ch\gamma L) + I_m(ch\gamma L)$

$d + {}_jD = a + {}_jA$

$b + {}_jB = R_L(Z_o \mathrm{sh}\gamma L) + I_m(Z_o \mathrm{sh}\gamma L)$

$c + {}_jC = R_L(\frac{1}{Z_o} \mathrm{sh}\gamma L) + I_m(\frac{1}{Z_o} \mathrm{sh}\gamma L)$

<u>For A' and D'</u>

$\mathrm{ch}\gamma L = \mathrm{ch}\alpha L \cos\beta L + {}_j\mathrm{sh}\alpha L \sin\beta L$ (from expansion of $\mathrm{ch}(\alpha+{}_j\beta)L$ since $\gamma = \alpha+{}_j\beta$)

$\therefore$ $\underline{a = \mathrm{ch}\alpha L \cos\beta L = d}$

$\underline{A = \mathrm{sh}\alpha L \sin\beta L = D}$

<u>For B' and C'</u>

Let $Z_o = R_o + {}_jX_o$

$\mathrm{sh}\gamma L = n + {}_jN$

then $Z_o \mathrm{sh}\, L = (R_o + {}_jX_o)(n + {}_jN) = (R_o n - X_o N) + {}_j(X_o n + R_o N)$

$\therefore$ $b = R_o n - X_o N$

$B = X_o n + R_o N$

$\mathrm{sh}\gamma L = \mathrm{sh}\alpha L \cos\beta L + {}_j\mathrm{ch}\alpha L \sin\beta L$ (from expansion of $\mathrm{sh}(\alpha+{}_j\beta)L$ since $\gamma = \alpha + {}_j\beta$)

$\therefore$ $n = \mathrm{sh}\alpha L \cos\beta L$

$N = \mathrm{ch}\alpha L \sin\beta L$

*Note, the ABCD parameters as worked out here, are inverse to the definition previously used.

ie $\begin{vmatrix} V_i \\ I_i \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_o \\ I_o \end{vmatrix}$

Here, $\begin{vmatrix} E_{(x,s)} \\ I_{(x,s)} \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} \begin{vmatrix} E_{(x,o)} \\ I_{(x,o)} \end{vmatrix}$

ie $\begin{vmatrix} V_o \\ I_o \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} \begin{vmatrix} V_i \\ I_i \end{vmatrix}$

$A' = \mathrm{ch}\gamma L$

$B' = -Z_o \mathrm{sh}\gamma L$

$C' = \frac{-1}{Z_o} \mathrm{sh}\gamma L$

$D' = \mathrm{ch}\gamma L$

Inverting,

$$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} = \frac{1}{A'\,D' - B'\,C'} \begin{vmatrix} D' & -B' \\ -C' & A' \end{vmatrix}$$

$A'D'-B'C' = ch^2\gamma L - sh^2\gamma L = 1$ (as would be expected for a reciprocal network)

Thus,

$$\begin{vmatrix} V_i \\ V_i \end{vmatrix} = \begin{vmatrix} ch\gamma L & Z_o sh\gamma L \\ \frac{1}{Z_o} sh\gamma L & ch\gamma L \end{vmatrix} \begin{vmatrix} V_o \\ I_o \end{vmatrix}$$

Note, A = D as have a symmetrical network here.

Where:

Z_o = Characteristic Impedance

γ = Propagation Constant

L = Line length

$$Z_o = R_o + {}_jX_o = \sqrt{\frac{R+{}_j\omega L}{G+{}_j\omega C}}$$

Also, $\gamma = \alpha + {}_j\beta = \sqrt{(R+{}_j\omega L)(G+{}_j\omega C)}$

$$\frac{Z_o}{\gamma} = \frac{\sqrt{R+{}_j\omega L}}{\sqrt{G+{}_j\omega C}} \cdot \frac{1}{\sqrt{R+{}_j\omega L}\cdot\sqrt{G+{}_j\ C}} = \frac{1}{G+j\omega C}$$

$$\therefore \quad Z_o + \frac{\alpha+{}_j\beta}{G+{}_j\omega C}$$

Or,

$$\gamma Z_o = \sqrt{R+{}_j\omega L}\cdot\sqrt{G+{}_j\omega C}\cdot \frac{\sqrt{R+{}_j\omega L}}{\sqrt{G+{}_j\omega C}}$$

$$= R+{}_j\omega L$$

$$\therefore \quad Z_o = \frac{R+{}_j\omega L}{\alpha+{}_j\beta}$$

Use first form,

$$Z_o = \frac{\alpha + j\beta}{G + j\ C} = \frac{(\alpha + j\beta)(G - j\omega C)}{G^2 + \omega^2 + C^2}$$

$$\therefore \quad R_o = \frac{\alpha G + \omega\beta C}{G^2 + \ ^2C^2}$$

$$X_o = \frac{\beta G - \alpha\omega C}{G^2 + \omega^2 C^2}$$

$$\text{Now,} \quad \alpha = \sqrt{\tfrac{1}{2}\left(\underbrace{\sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)}}_{U} + \underbrace{(RG-\omega^2LC)}_{V}\right)} \qquad \beta = \sqrt{\tfrac{1}{2}(U-V)}$$

For R&C only, $\alpha = \beta$ as $RG - \omega^2 LC = O$

$(L = O,\ G = O)$

$$\therefore \quad \alpha = \sqrt{\frac{\omega CR}{2}}$$

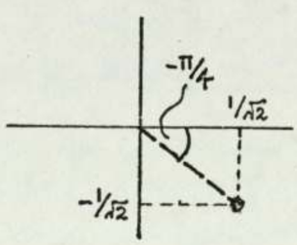
$$\text{ie} \quad R_o = \frac{\alpha\omega C}{\omega^2 C^2} = \frac{\alpha}{\omega C} = \frac{\sqrt{\frac{\omega CR}{2}}}{\omega C} = \underline{\sqrt{\frac{R}{2\omega C}}}$$

$$X_o = \frac{-\alpha\omega C}{\omega^2 C^2} = -\sqrt{\frac{R}{2\omega C}}$$

<u>Side-note</u>,

ie $R_o = -X_o$

$$\text{Now,} \quad Z_o = \sqrt{\frac{R + j\omega L \rightarrow 0}{G \rightarrow 0 + j\omega C}} = \sqrt{\frac{R}{j\omega C}}$$

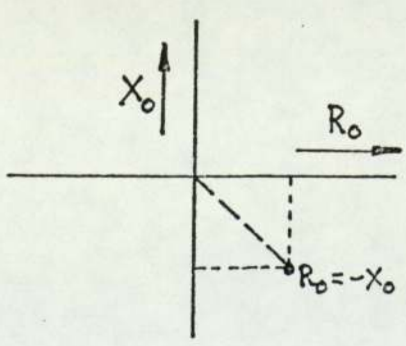


$$\text{Or,} \quad Z_o = \sqrt{-j}\sqrt{\frac{R}{\omega C}}$$

$$\sqrt{-j} = \sqrt{e^{-j\frac{\pi}{2}}} = e^{-j\frac{\pi}{4}}$$

ie $1\ e^{-j\frac{\pi}{4}}$

For mod = 1, $R_L = \frac{1}{\sqrt{2}}$ $\quad m = \frac{-1}{\sqrt{2}}$



X_o is -ve (capacative)

ie $R_L = -I_m$ $\qquad ((\frac{1}{\sqrt{2}})^2(\frac{1}{\sqrt{2}})^2 = 1)$

$\therefore \quad b = R_o n - X_o N$

$$= \sqrt{\frac{R}{2\omega C}} \cdot sh\alpha L \cos\beta L + \sqrt{\frac{R}{2\omega C}} \cdot ch\alpha L \sin\beta L$$

ie $\quad b = \sqrt{\frac{R}{2\omega C}} \left| sh\alpha L \cos\beta L + ch\alpha L \sin\beta L \right|$

$B = X_o n + R_o N$

$$= -\sqrt{\frac{R}{2\omega C}} \cdot sh\alpha L \cos\beta L + \sqrt{\frac{R}{2\omega C}} \cdot ch\alpha L \sin\beta L$$

ie $B = \sqrt{\frac{R}{2\omega C}} \left| ch\alpha L \sin\beta L - sh\alpha L \cos\beta L \right|$

For C'

$$\frac{1}{Z_o} sh\gamma L = \frac{n + jN}{R_o + jX_o} = \frac{(n+jN)(R_o + jX_o)}{R_o^2 + X_o^2}$$

$$= \frac{nR_o + NX_o + j(NR_o - nX_o)}{R_o^2 + X_o^2}$$

ie,

$$c = \frac{R_o n + X_o N}{R_o^2 + X_o^2}$$

$$c = \frac{R_o N - X_o n}{R_o^2 + X_o^2}$$

$$R_o^2 + X_o^2 = \left\{\sqrt{\frac{R}{2\omega C}}\right\}^2 + \left\{-\sqrt{\frac{R}{2\omega C}}\right\}^2 = \frac{R}{\omega C}$$

$$= \left\{\sqrt{\frac{R}{2\omega C}}\ sh\alpha L\ \cos\beta L - \sqrt{\frac{R}{2\omega C}}\ .\ ch\alpha L\ \sin\beta L\right\}\ .\ \frac{\omega C}{R}$$

$$= \sqrt{\frac{R}{2\omega C}\ .\ \frac{(\omega C)^2}{R^2}}\ \left|sh\alpha L\ \cos\beta L - ch\alpha L\ \sin\beta L\right|$$

ie $$= \sqrt{\frac{\omega C}{2R}}\ \left|sh\alpha L\ \cos\beta L - ch\alpha L\ \sin\beta L\right|$$

$$C = \left\{\sqrt{\frac{R}{2\omega C}}\ ch\alpha L\ \sin\beta L + \sqrt{\frac{R}{2\omega C}}\ sh\alpha L\ \cos\beta L\right\}.\ \frac{\omega C}{R}$$

ie $$C = \sqrt{\frac{\omega C}{2R}}\ \left|ch\alpha L\ \sin\beta L + sh\alpha L\ \cos\beta L\right|$$

Thus have,

$a = ch\alpha L\ \cos\alpha L = d$

$A = sh\alpha L\ \sin\alpha L = D$

$b = \sqrt{\frac{R}{2\omega C}}\ (sh\alpha L\ \cos\alpha L + ch\alpha L\ \sin\alpha L)$

$B = \sqrt{\frac{R}{2\omega C}}\ (ch\alpha L\ \sin\alpha L - sh\alpha L\ \cos\alpha L)$

$c = \sqrt{\frac{\omega C}{2R}}\ (sh\alpha L\ \cos\alpha L - ch\alpha L\ \sin\alpha L)$

$C = \sqrt{\frac{\omega C}{2R}}\ (ch\alpha L\ \sin\alpha L + sh\alpha L\ \cos\alpha L)$

Let $S \equiv \alpha\ L$

$D \equiv L$

then $S = \sqrt{\frac{\omega CR}{2}}\ .\ D$ $\qquad S^2 = \frac{\omega CR}{2}\ .\ D^2$

Let $L \equiv \sqrt{\frac{R}{2\omega C}}$

$M \equiv \sqrt{\frac{\omega C}{2R}} = S/(R.D)$ ⟶ $\qquad M^2 = \frac{\omega C}{2R} = \frac{\omega CRD^2}{2}\ .\ \frac{1}{R^2D^2}$

$G \equiv sh\ S\ .\ \cos\ S$

$H \equiv ch\ S\ .\ \sin\ S$

ie $M^2 = \frac{\omega S^2}{R^2D^2}\ \therefore\ M = \frac{S}{R.D}$

Then,

$$A(J,1) = \frac{H}{\sin S} \cos S = H/\tan S$$

$$A(J,2) = \frac{G}{\cos S} \sin S = G.\tan S$$

A(J,3) = L(G+H)

A(J,4) = L(H-G)

A(J,5) = M(G-H)

A(J,6) = M(H+G)

A(J,7) = A(J,1)

A(J,8) = A(J,2)

Can further simplify by putting

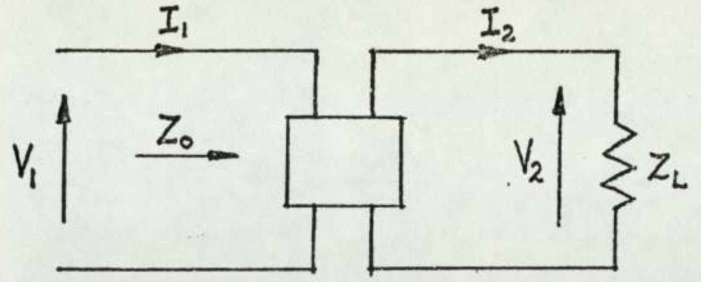
D1 = (G+H)

D2 = (G-H)

ie,

```
For J  = 1 to 20
 W     = 2*π*F(J)
 S     = SQR(W*C*R/2)*D
 L     = SQR(R/(2*W*C))
 M     = S/(R*D)
 G     = (EXP(S)-1/EXP(S))* COS (S)/2
 H     = (EXP(S)+1/EXP(S))* SIN (S)/2
 D1    = G+H
 D2    = G-H
 A(J,1) = H/TAN (S)
 A(J,2) = G*TAN (S)
 A(J,3) = L*D1
 A(J,4) = -L*D2
 A(J,5) = M*D2
 A(J,6) = M*D1
 A(J,7) = A(J,1)
 A(J,8) = A(J,2)
NEX J
```

TO FIND THE ABCD PARAMETERS OF AN ATTENUATOR



$$Z_L = \frac{V_2}{I_2}$$

$$S = \frac{I_1}{I_2} \therefore \text{Image Att} = 20 \log_{10} S$$

$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_2 \\ I_2 \end{vmatrix} \qquad \therefore V_1 = AV_2 + BI_2 = (A + B/ZL)V_2$$

$$I_1 = CV_2 + DI_2 = (C+D/ZL)V_2$$

$$\therefore Zo = \frac{V_1}{I_1} = \frac{A+B/ZL}{C+D/ZL} = \frac{AZL+B}{CZL+D}$$

If matched, i.e. $Z_L = Z_C = Z_O = Z$

then $CZ^2 + DZ = AZ + B$

Network is symmetrical $\therefore A = D$ thus $CZ^2 = B$ ....(1)

Also, $S = \frac{I_1}{I_2}$ $I_1 = CV_2 + DI_2$

$$= CZ_LI_2 + DI_2$$

$\therefore S = CZ_L + D$ ....(2)

Network is reciprocal $\therefore AD - BC = 1$ but $A = D$

$\therefore A^2 = BC + 1$ but $B = CZ^2$

$\therefore A^2 = C^2Z^2 + 1$ ....(3)

From equation 2, $S = CZ + A$ $\therefore A^2 = (S - CZ)^2$
.........(4)

Equate 3 & 4, $1 + (CZ)^2 = (S - CZ)^2 = S^2 + (CZ)^2 - 2SCZ$

$\therefore S^2 - 1 - 2CZS = 0$

$$\therefore C = \frac{S^2-1}{2SZ} = \underline{\frac{1}{Z} \cdot \frac{S^2-1}{2S}}$$

$$B = CZ^2 = \underline{Z \cdot \frac{S^2-1}{2S}}$$

Here,

$A = D = S - CZ$ (from eqn 2)

$$= S - \left(\frac{S^2 - 1}{2S}\right) = \frac{2S^2 - S^2 + 1}{2S}$$

ie $A = \frac{S^2 + 1}{2S}$

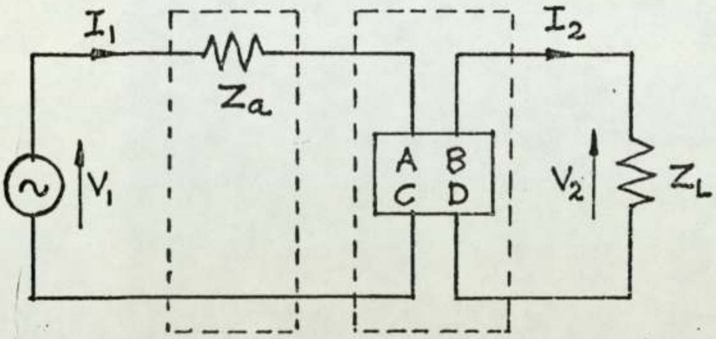
$$\therefore \begin{vmatrix} A & B \\ C & D \end{vmatrix} \quad \begin{vmatrix} \frac{S^2 + 1}{2S} & Z . \frac{S^2 - 1}{2S} \\ \frac{1}{Z} . \frac{S^2 - 1}{2S} & \frac{S^2 + 1}{2S} \end{vmatrix}$$

Z = Characteristic Impedance

Note, if X = Image Attenuation

then, $X = 20 \log_{10} S$

TO FIND THE INSERTION LOSS OF A 2 PORT NETWORK

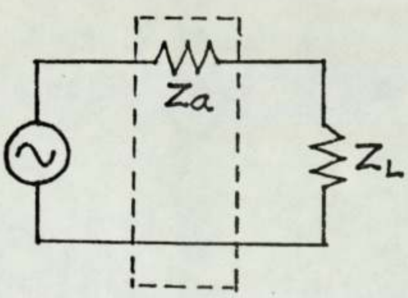


$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A^1 & B^1 \\ C^1 & D^1 \end{vmatrix} \begin{vmatrix} V_2 \\ I_2 \end{vmatrix}$$

Amalgamate Za into network,

then $\begin{vmatrix} A^1 & B^1 \\ C^1 & D^1 \end{vmatrix} = \begin{vmatrix} 1 & Za \\ 0 & 1 \end{vmatrix} * \begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} A + CZa & B + DZa \\ C & D \end{vmatrix}$

Without network,



$\begin{vmatrix} A & B \\ C & D \end{vmatrix} \quad \begin{matrix} 1 & Za \\ 0 & 1 \end{matrix}$

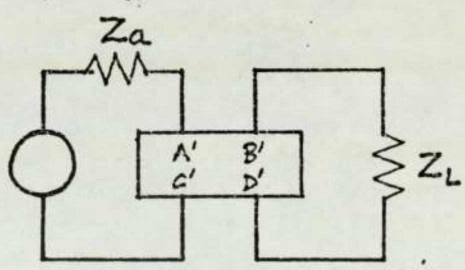
$V_1 = V_2 + Za\, I_2$

$I_2 = V_2 / Z_L$

$\therefore \dfrac{V_1}{V_2} = 1 + \dfrac{Za}{Z_L}$

$\therefore V_2 = \dfrac{V_1}{1 + \dfrac{Za}{Z_L}}$

With network,



$V_1 = A^1 V_2^1 + D^1 I_2{}^1$

$I_2{}^1 = V_2{}^1 / Z_L$

$\therefore \dfrac{V_1}{V_2{}^1} = A^1 + \dfrac{B^1}{Z_L}$

$= A + CZa + (B + DZa)/Z_L$

$\therefore V_2{}^1 = \dfrac{V_1}{A + CZa + \dfrac{B + DZa}{Z_L}}$

$$\text{Insertion loss} = 20 \log \frac{V_2}{V_2^1}$$

$$\frac{V_2}{V_2^1} = \frac{\dfrac{V_1}{1 + \dfrac{Za}{Z_L}}}{\dfrac{V_1}{A + C\,Za + \dfrac{B + DZa}{Z_L}}} = \frac{A + CZa + \dfrac{B + DZa}{Z_L}}{1 + \dfrac{Za}{Z_L}}$$

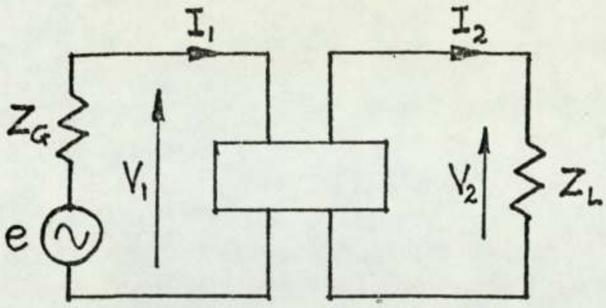
or,

$$\frac{V_2}{V_2^1} = \frac{AZ_L + CZaZ_L + DZa + B}{Z_L + Za} = R \text{ (say)}$$

then,

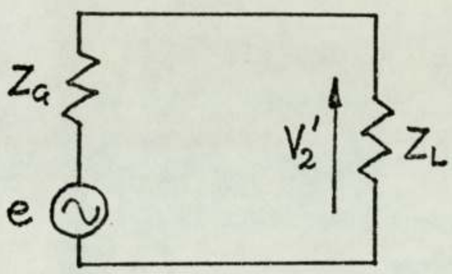
$$\text{insertion loss} = 20 \log R$$

AN ALTERNATIVE WAY OF FINDING THE INSERTION LOSS



$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} \qquad \begin{vmatrix} A & B \\ C & D \end{vmatrix} \qquad \begin{vmatrix} V_2 \\ I_2 \end{vmatrix}$$

Without Network,



$$V_2^1 = e. \frac{Z_L}{Z_L + Z_G}$$

$$R = \frac{V_2^1}{V_2} = \frac{e.\dfrac{Z_L}{Z_L + Z_G}}{e\left(\dfrac{1}{A + \dfrac{B}{Z_L} + CZ_G + D\dfrac{Z_G}{Z_L}}\right)}$$

$$= \frac{Z_L}{Z_G + Z_L} \left(A + \frac{B}{Z_L} + CZ_G + \frac{DZ_G}{Z_L}\right)$$

$$= \frac{AZ_L + B + CZ_G Z_L + DZ_G}{Z_L + Z_G}$$

With Network,

For V_2,

$$e = V_1 + I_1 Z_G$$

$$= AV_2 + BI_2 + Z_G(CV_2 + DI_2)$$

$$I_2 = V_2/Z_L$$

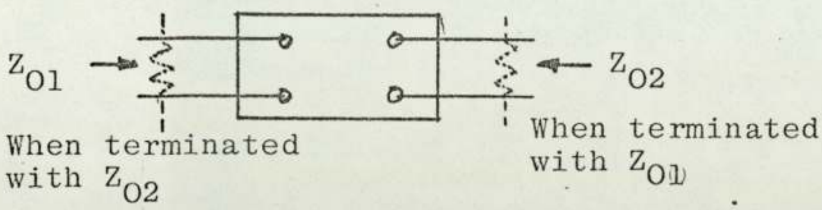
$$\therefore e = AV_2 + \frac{BV_2}{Z_L} + Z_G C V_2 + Z_G \frac{DV_2}{Z_L}$$

$$\therefore \frac{e}{V_2} = A + \frac{B}{Z_L} + CZ_G + \frac{DZ_G}{Z_L}$$

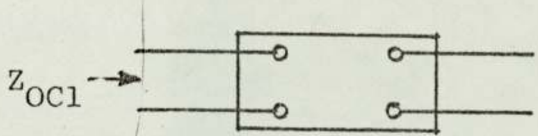
hence, $L = 20 \log_{10} R$

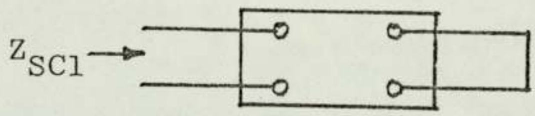
Image Impedance

Consider a 2-port network and the impedance Z presented at the ports under various conditions:



When symmetrical, $Z_{O1} = Z_{O2} = Z_{char}$.





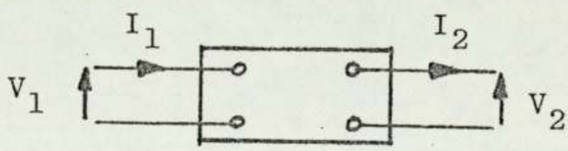
Similarly for Z_{OC2} and Z_{SC2}

For any reciprocal network,

$$Z_o = \sqrt{Z_{oc} . Z_{sc}}$$

in ABCD form

$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_2 \\ I_2 \end{vmatrix}$$



i.e. $V_1 = AV_2 + BI_2$

$I_1 = CV_2 + DI_2$

When $I_2 = 0$,

$$\frac{V_1}{I_1} = \frac{A}{C} = Z_{oc_1}$$

When $V_2 = 0$,

$$\frac{V_1}{I_1} = \frac{B}{D} = Z_{sc_1}$$

$$\therefore Z_{o1} = \sqrt{\frac{A}{C} . \frac{B}{D}}$$

Z_{O2} is obtained by inverting the above matrix and taking account of current direction

i.e. $\begin{vmatrix} V_2 \\ I_2 \end{vmatrix} = \begin{vmatrix} D & B \\ C & A \end{vmatrix} \begin{vmatrix} V_1 \\ I_1 \end{vmatrix}$

i.e. $V_2 = DV_1 + BI_1$

$I_2 = CV_1 + AI_1$

When $I_1 = 0$,

$$\frac{V_2}{I_2} = \frac{D}{C} = Z_{oc2}$$

When $V_1 = 0$

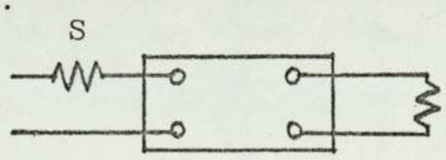
$$\frac{V_2}{I_2} = \frac{B}{A} = Z_{sc2}$$

$$\therefore \quad Z_{o2} = \sqrt{\frac{D}{C} \cdot \frac{B}{A}}$$

Image Attenuation

This is the insertion loss of a network when terminated in its image impedances

i.e.



$$R = \frac{AL + CSL + DS + B}{S + L}$$

Here, $S = Z_{o1}$ Thus image attenuation = $20 \log_{10} R$

$L = Z_{o2}$

Expressions for Implementation in BASIC

$$Z_{o1}^2 = \frac{AB}{CD} = \frac{(a+jA)(b+jB)}{(c+jC)(d+jD)} = \frac{ab-AB+j(aB+Ab)}{cd-CD+j(cD+Cd)} = \frac{U3+jU4}{V3+jV4}$$

$$= \frac{(U3+jU4)(V3-jV4)}{V3^2 + V4^2} = \frac{U3.V3+U4.V4}{V3^2+V4^2} - \frac{jU4.U3-U3.V4}{V3^2+V4^2}$$

i.e. $Z_{O1}{}^2 = \frac{N1}{D1} + j\frac{N2}{D1}$

(Similarly $Z_{O2}{}^2 = \frac{BD}{AC} = \frac{(b+jB)(d+jD)}{(a+jA)(c+jC)} = \frac{N3}{D2} + j\frac{N4}{D2}$)

To find Z_{O1}, convert to polar co-ordinates

i.e. $Z_{O1}{}^2 = R_1 \angle \theta_1$ $\quad \therefore Z_{O1} \doteq \sqrt{R_1} \angle \theta_1/2$

where

$$R_1 \doteq \sqrt{(\frac{N1}{D1})^2 + (\frac{N2}{D1})^2}$$

$$\theta_1 \doteq \tan^{-1} (\frac{N2}{N1})$$

Similarly,

$$Z_{O2} = \sqrt{R_2} \angle \theta_2/2$$

where

$$R_2 = \sqrt{(\frac{N3}{D2})^2 + (\frac{N4}{D2})^2}$$

$$\theta_2 = \tan^{-1}(\frac{N4}{N3})$$

Image attenuation is then found by converting Z_{O1} and Z_{O2} back into source (S) and load (L) in Cartesian form. i.e. S1 + jS2 and L1 + jL2.

Thus,

$$S1 = \sqrt{R_1}.\ \cos(\theta_1/2), \qquad S2 = \sqrt{R_1}.\ \sin(\theta_1/2)$$

$$L1 = \sqrt{R_2}.\ \cos(\theta_2/2), \qquad L2 = \sqrt{R_2}.\ \sin(\theta_2/2)$$

These are then substituted into the expression for insertion loss (the BASIC implementation for this is given in Chapter 2 under 'Insertion Loss') to yeild the image attenuation.

Note

Only the LOG symbol (meaning Log_e) is provided on the PET computer.

To obtain $\log_{10}$, divide the natural log of the number by $\log_e(10)$.

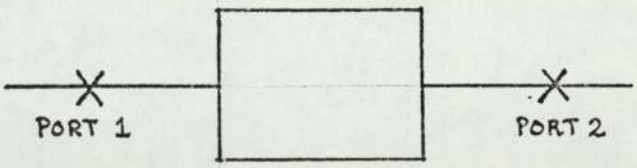
i.e. Let $\log_{10}x = y$

then $x = 10^y$

$$\log_e x = \log_e 10^y = y\log_e 10$$

$$\therefore y = \frac{\log_e x}{\log_e 10} \quad \text{i.e.} \quad \underline{\log_{10}x = \frac{\log_e x}{\log_e 10}}$$

A B C D IN COMPLEX FORM FOR 2W-4W-2W SECTION



Let Z_1 & Z_2 be the impedances presented by port 1 & port 2 in the absence of loop transmission.

Z_3 & Z_4 be the impedances which when connected across port 1 & port 2 give infinite tranhybrid loss.

G_1 & G_2 be the voltage gains under matched conditions at the output port relative to an input at port 1 and port 2 in the absence of loop transmission.

NOTE: these are complex and include the delays.

Input Z1, Z2, Z3, Z4, G1, G2 in complex form.

ie, Z1 = R1 + jX1

Z2 = R2 + jX2

Z3 = R3 + jX3

Z4 = R4 + jX4

G1 = T1 + jX2

G2 = T3 + jT4

All arrays except R1 to R4 (Input at 20 freq's)

Then, $$A = \frac{1}{2G1}\left[1 + \frac{4G1G2Z2Z3}{(Z1 + Z3)(Z2 + Z4)}\right]$$

$$B = \frac{Z2}{2G1}\left[1 - \frac{4G1G2Z3Z4}{(Z1 + Z3)(Z2 + Z4)}\right]$$

$$C = \frac{1}{2G1Z1}\left[1 - \frac{4G1G2X1Z2}{(Z1+Z3)(Z2+Z4}\right]$$

$$D = \frac{Z2}{2G1Z1}\left[1 + \frac{4G1G2Z1Z4}{(Z1+Z3)(Z2+Z4)}\right]$$

Common forms are:

$$\underbrace{\frac{1}{2G1}}_{E1} \quad \underbrace{\frac{4G1G2}{(Z1 + Z3)(Z2 + Z4)}}_{E2} \qquad\qquad \frac{1}{2G1} \quad \underbrace{\frac{4G1G2}{(Z1 + Z3)(Z2 + Z4)}}_{E3}$$

$$E1 = \frac{1}{2(T1 + jT2)} = \frac{T1 - jT2}{2(T1^2 + T2^2)}$$

let $K1 = 2(T1^2 + jT2^2)$

then,

$$\underline{E1 = K2 + jK3}$$

where,

$$K2 = \frac{T1}{K1} \quad K3 = -\frac{T2}{K1}$$

$$E2 = \frac{4(T1 + jT2)(T3 + j\,T4)}{\left[(R1 + R3) + j\,(X1 + X3)\right]\left[(R2 + R4 + j\,(X2 + X4)\right]}$$

$$= \frac{4((T1\,T3 - T2\,T4) + j\,(T2\,T3 + T1\,T4))}{(R1 + R3)(R2 + R4) - (X1 + X3)(X2 + X4) + j\left[(X1 + X3)(R2 + R4) + (R1 + R3)(X2 + X4)\right]}$$

$$= \frac{K4 + jK5}{K5 + jK7}$$

where,

$$K4 = 4(T1\,T3 - T2\,T4)$$

$$K5 = 4(T2\,T3 + T1\,T4)$$

$$K6 = (R1 + R3)(R2 + R4) - (X1 + X3)(X2 + X4)$$

$$K7 = (X1 + X3)(R2 + R4) + (R1 + R3)(X2 + X4)$$

$$\text{i.e. } E_2 = \frac{K4K6+K5K7}{K8} +j \frac{K5K6 - K4K7}{K8}$$

then,

$$E2 = \frac{(K4 + j\ K5)(K6 - j\ K7)}{K6^2 + K7^2}$$

where,

$$K8 = K6^2 + K7^2$$

$$E3 = E1 . E2$$

$$= (K2 + j\ K3)(K4\ K6 + K5\ K7) + j\ (K5\ K6 - K4\ K7)) / K8$$

$$= \frac{1}{K8} \begin{cases} K2\ (K4\ K6 + K5\ K7) - K3\ (K5\ K6 - K4\ K7) \\ +j\ (k3(K4\ K6 + K5\ K7) + K2\ (K5\ k6 - K4\ K7)) \end{cases}$$

let $K9 = K4\ K6 + K5\ K7$

$K10 = K5\ K6 - K4\ K7$

then,

$\underline{E3 = K11 + j\ K12}$

where,

$K11 = (K2\ K9 - K3\ K10)/K8$

$K12 = (K3\ K9 + K2\ K10)/K8$

Thus, now have

$A^1 = E1 + E3 . Z2 . Z3$

$B^1 = E1 . Z2 - E3 . Z2 . Z3 . Z4$

$C^1 = E1/Z1 - E3 . Z2$

$D^1 = E1 . Z2/Z1 + E3 . Z2 . Z4$

($\therefore$ Symmetrical when Z1 = Z2, Z3 = Z4

$$A^1 = E1 + E3 . Z2 . Z3$$

$$= K2 + jK3 + (K11 + j\,K12)(R2 + j\,X2)(R3 + j\,X3)$$

$$= K2 + j\,K3 + (K11 + j\,K12)\left[(R2\,R3 - X2\,X3) + j(X2\,R3 + R2\,X3)\right]$$

$$= K2 + j\,K3 + K11(R2\,R3 - X2\,X3) - K12(X2\,R3 + R2\,X3)$$

$$+ j\,(K12(R2\,R3 - X2\,X3) + K11(X2\,R3 + R2\,X3))$$

let $K13 = R2\,R3 - X2\,X3$

$K14 = X2\,R3 + R2\,X3$

then,

$$A^1 = K2 + j\,K3 + K11.\,K13 - K12.\,K14 + j(K12.\,K13 + K11.\,K14)$$

ie,

$$\underline{A = K2 + K11.\,K13 - K12.\,K14}$$

$$\underline{a = K3 + K12.\,K13 + K11.\,K14}$$

$$B^1 = E1.\,Z2 - E3.Z2.\,Z3.\,Z4$$

$$= (K2 + j\,K3)(R2 + j\,X2) - (K11 + j\,K12)(R2 + j\,X2)(R3 + j\,X3)(R4 + j\,X4)$$

$$= K2\,R2 - K3\,X2 + j\,(k3\,R2 + K2\,X\,2)$$

$$- \{(K11\,R2 - K12\,X\,2) + j\,(K12\,R2 + K11\,X\,2)\}\{(R3\,R4 - X3\,X4) + j\,(X3\,R4 + R3\,X4)\}$$

$$= K2\,R2 - K3\,X2 + j(K3\,R2 + K2\,X\,2)$$

$$- \Big\{(K11\,R2 - K12\,X2)(R3\,R4 - X3\,X4) - (K12\,R2 + K11\,X2)(X3\,R4 + R3\,X\,4)$$

$$+ j\left[(K12\,R2 + K11\,X\,2)(R3\,R4 - X3\,X4) + (K11\,R2 - K12\,X2)(X3\,R4 + R3\,X4)\right]\Big\}$$

let $K15 = R3\ R4 - X3\ X4$

$K16 = X3\ R4 + R3\ X4$

$K17 = K11\ R2 - K12\ X2$

$K18 = K12\ R2 + K11\ X2$

then,

$$B^1 = K2\ R2 - K3\ X2 + j\ (K3\ R2 + K2\ X2) - K17\ K15 + K18\ K16 - j\ (K18\ K15 + K17\ K16)$$

thus,

$$\underline{B = K2 \cdot R2 - K3 \cdot X2 - K17 \cdot K15 + K18 \cdot K16}$$

$$\underline{b = K3 \cdot R2 + K2 \cdot X2 - K18 \cdot K15 - K17 \cdot K16}$$

$$C^1 = E1/Z1 - E3 \cdot Z2$$

$$= \frac{(K2 + j\ K3)(R1 - j\ X1)}{R1^2 + X1^2} - (K11 + j\ K12)(R2 + j\ X2)$$

let $K19 = R1^2 + X1^2$

then,

$$C^1 = \frac{K2\ R1 + K3\ X1}{K19} + j\ \frac{(K3\ R1 - K2\ X1)}{K19} - \left\{ K11\ R2 - K12\ X2 + j\ (K12\ R2 + K11\ X2) \right\}$$

$$\therefore \quad \underline{C = (K2 \cdot R1 + K3 \cdot X1)/K19 - K11 \cdot R2 + K12 \cdot X2}$$

$$\underline{c = (K3 \cdot R1 - K2 \cdot X1)/K19 - K12 \cdot R2 - K11 \cdot X2}$$

$$D^1 = E1 \cdot Z2/Z1 + E3 \cdot Z2 \cdot Z4$$

$$= \frac{(K2 + j\ K3)(R2 + j\ X2)(R1 - j\ X1)}{R1^2 + X1^2} + (K11 + j\ K12)(R2 + j\ X2)(R4 + j\ X4)$$

let $K19 = R1^2 + X1^2$

Then,

$$D^1 = \left[(K2\ R2 - K3\ X2) + j\ (K3\ R2 + K2\ X2) \right] (R1 - j\ X1)/K19$$

$$+ \left[K11\ R2 - K12\ X2 + j\ (K12\ R2 + K11\ X2) \right] (R4 + j\ X4)$$

$$= \left[(K2\ R2 - K3\ X2)\ R1 + (K3\ R2 + K2\ X2)\ X1 + j\ \left\{ (K3\ R2 + K2\ X2)\ R1 - (K2\ R2 - K3\ X2)\ X1 \right\} \right] /K19 + (K11\ R2 - K12\ X2)\ R4 - (K12\ R2 + K11\ X2)\ X4 + j\ \left[(K12\ R2 + K11\ X2)\ R4 + (K11\ R2 - K12\ X2)\ X4 \right]$$

let K20 = K2 R2 - K3 X2

K21 = K3 R2 + K2 X2

K22 = K11 R2 - K12 X2

K23 = K12 R2 + K11 X2

then,

<u>D = (K20. R1 + K21. X1)/K19 + K22. R4 - K23. X4</u>

<u>d = (K21. R1 - K20. X1)/K19 + K23. R4 + K22. X4</u>

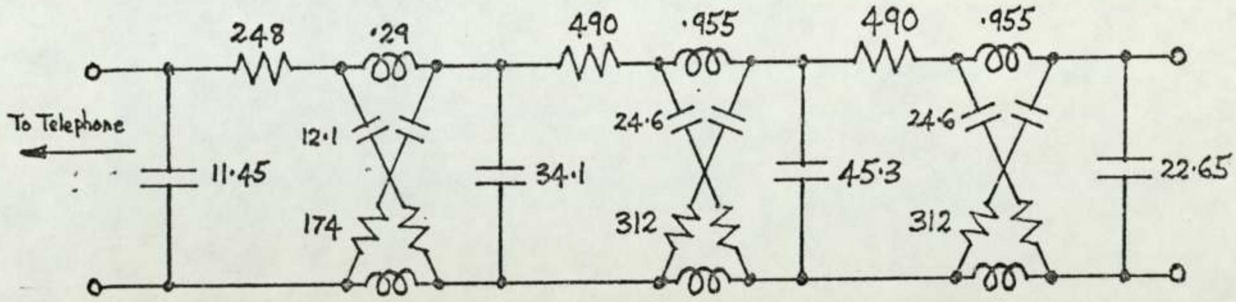
<u>IMPLEMENTING ON PET</u>

```
For J = 1 to 20
 K1 = 2*(T1(J)↑2 + T2(J)↑2)
 K2 = T1(J)/K1 : K3 = - T2(J)/K1
 K4 = 4*(T1(J)*T3(J) - T2(J)*T4(J))
 K5 = 4*(T2(J)*T3(J) + T1(J)*T4(J))
 K6 = (R1 + R3)*(R2 + R4) - (X1(J) + X3(J)*(X2(J) + X4(J))
```

```
K7=(X1(J) + X3(J)*(R2 + R4) + (R1 + R3)*(X2(J) + X4(J))
K8 = K6 ↑2 + K7↑ 2
K9 = K4*K6 + K5*K7: LO = K5*K6 - K4*K7
L1 = (K2*K9 - K3*LO)/K8
L2 = (K3*K9 + K2*LO/K8
L3 = R2*R3 - X2(J)*X3(J) ;
L4 = X2(J)*R3 + R2*X3(J)
L5 = R3*R4 - X3(J)*X4(J)
L6 = X3(J)*R4 + R3*X4(J)
L7 = L1*R2 - L2*X2(J)
L8 = L2*R2 * LI*X2(J)
L9 = R1 ↑2 + X1(J) ↑2
MO = K2*R2 - K3*X2(J)
M1 = K3*R2 + K2*X2(J)
M2 = LI*R2 - L2*X2(J)
M3 = L2*R2 + LI*X2(J)
A(J ,1) = K2 + LI*L3 - L2*L4
A(J ,2) = K3 + L2*L3 + LI*L4
A(J,3) = K2*R2 - K3*X2(J) - L7*L5 + L8*L6
A(J,4) = K3*R2 + K2*X2(J) - L8*L5 - L7*L6
A(J,5) = (K2*R1 + K3*X1(J))/L9- L1*R2* L2*X2(J)
A(J,6) = (K3*R1 - K2*X1(J))/L9 - L2*R2 - L1*X2(J)
A(J,7) =(MO*R1 + M1*X1(J))/L9 + M2*R4 - M3*X4(J)
A(J,8) = (M1*R1 - MO*X1(J))/L9 + M3*4 + M2*X4(J)
Next J
```

SETTING-UP THE AT&T ARTIFICIAL LINE (AAL)

The circuit diagram for this line (representing limiting conditions) is shown below. Note, units are in Ω , nF and m H.



The overall ABCD parameters are obtained by cascading all the individual sections together.

ie Set up a connection as shown below:

```
CSH-RSE-LAT-CSH:RSE:LAT-CSH-RSE-LAT-CSH
 1   2   3   4 : 5 : 6   7   8   9  10
               :   :
              JW  JW
```

The junction positions are arbitrarily chosen.

The ABCD parameters are now obtained by running TCAM and then picking out the overall product array and storing in a fixed date file.

Derivation of parameters to describe local telephone circuits.

Note

x denotes electrical losses

L denotes acoustical losses.

S_S (MATCHED SENDING SENSITIVITY)

This relates to the voltage (V_c) across a matched termination to the sound pressure (PM) that would exist at the mrp if the handset were not present. (mrp is mouth reference point, and is a point 25 mm horizontally in front of the mouth). It is dependant on both line conditions and frequency, and is usually expressed in units of dB relative to 1 volt per Pascal (dBV/Pa).

Because it is difficult to place a matched termination on a telephone set, the measurement may be made with a high impedance termination. Thus, the voltage across a matched termination is ½ (-6dB) that of the voltage across a high Z termination (Z >> 600 Ω).

$$\text{Thus, } S_S = \frac{E_C \times \frac{1}{2}}{PM}$$

or, in dBV/Pa,

$$S_S = E_C(\text{dBV}) + 20 \log \tfrac{1}{2} - PM(\text{dBPa})$$

S_R (MATCHED RECEIVING SENSITIVITY)

This relates the sound pressure (P_e) in an artificial ear (AE) when a signal source (E) is applied at the line terminals, to the voltage (V_c) produced if the signal source was terminated with an impedance matched to it. Here, the source impedance is made equal to Z_C. (The impedance the telephone set presents to line). Thus, it is only necessary to measure the voltage at the line terminals. The point at which the sound pressure is measured at the ear is known as the "ear reference point" (erp).

When making measurements for S_R, considerable disparity is found to occur between those made with a real ear, and those with an artificial ear, and is known as the real ear loss, (L_E). This is mainly caused by earcap leakage. Thus, the L_E for the type of handset used must be known in order to correct the artificial ear measurements.

$$\text{Thus, } S_R = \frac{P_e}{E_c \times \frac{1}{2}}$$

IMPEDANCE FOR ZERO SIDETONE (Z_{SO})

Z_{SO} is that impedance which, when connected across the line terminals of a telephone set, causes complete suppression of sidetone. (ie zero voltage across the earphone, when a signal is being sent from a microphone.

USE OF A 600 Ω TERMINATION

600 Ω is an arbitrary figure. (Being approximately the modulus of the characteristic impedance of cables in use at the time it was chosen). Thus, S_{S600} relates to the volts developed across a 600 Ω termination of a telephone set, to the sound pressure at the mrp.

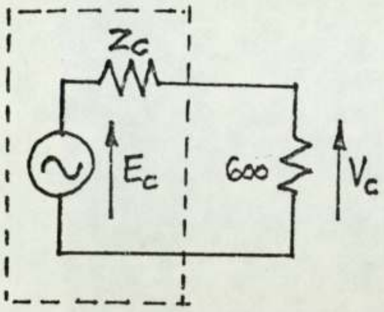
Similarly for S_{R600}. (600 Ω source applied to line, and 600 Ω termination).

$$\text{Now, } S_S = \frac{E_c/2}{PM} \qquad \text{——— 1 (Matched load)}$$

Let Z_c = impedance presented to line

V_c = volts across 600 Ω termination

FOR S_S600



$$V_c = \frac{E_c \cdot 600}{Z_c + 600}$$

$$S_{S600} = \frac{V_c}{PM}$$

$$\therefore \quad S_S600 = \frac{E_c \cdot 600}{P_M(Z_c + 600)}$$

from 1, $PM = \frac{E_c}{2S_S}$

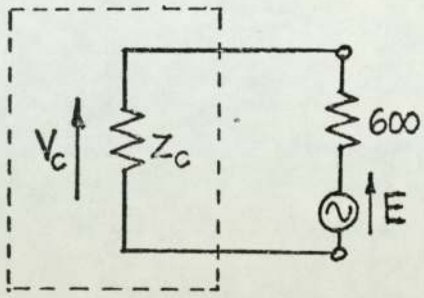
$$\therefore \quad S_{S600} = \frac{E_c \cdot 600}{\frac{E_c}{2S_S}(Z_c + 600)} = \frac{S_S \cdot 2 \times 600}{Z_c + 600}$$

or, in dBV/Pa

$$S_{S600} = S_S + 20 \log_{10} \frac{2 \times 600}{|Z_c + 600|}$$

For S_{R600}

$$S_R = \frac{P_e}{E/2} \qquad \text{—— 2 (Matched source)}$$



$$V_c = E.\frac{Z_c}{Z_c + 600}$$

$$S_{R600} = \frac{P_e}{V_c}$$

$$\therefore \quad S_{R600} = \frac{P_e}{E.\frac{Z_c}{Z_c + 600}}$$

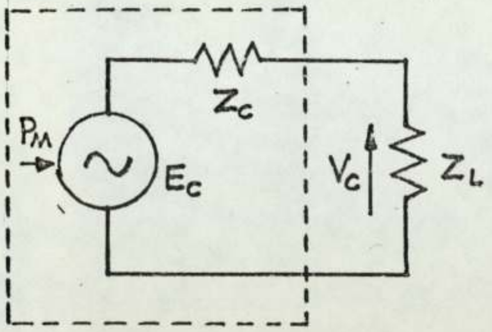
from 2, $P_e = \frac{S_R.E}{2}$

$$\therefore \quad S_{R600} = \frac{S_R.\not{E}}{2\not{E}.\frac{Z_c}{Z_c + 600}} = S_R.\frac{Z_c + 600}{2.Z_c}$$

or, in dBPa/V, $\underline{S_{R600} = S_R + 20 \log_{10} \frac{|Z_c + 600|}{2|Z_c|}}$

USE OF TELEPHONE SENSITIVITIES

SEND



$V_c = S_S \cdot P_M$

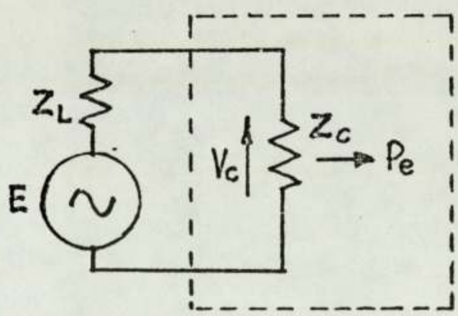
If, $Z_L = Z_C$,

$$S_S P_M = \frac{E_C}{2}$$

If, $Z_L \neq Z_C$

$$S_S P_M = E_C \cdot \frac{Z_L}{Z_L + Z_C}$$

REC



$P_e = V_C \cdot S_R$

(Irrespective of Z_L)

although V_c changes with Z_L

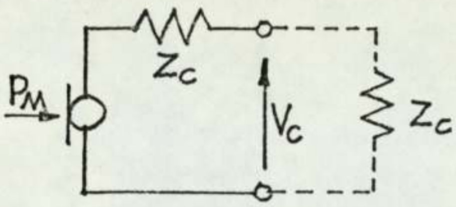
If, $Z_L = Z_C$,

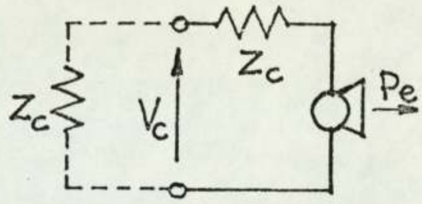
$$P_e = \frac{E}{2} \cdot S_R$$

If, $Z_L \neq Z_C$

$$P_e = E \cdot \frac{Z_C}{Z_L + Z_C} \cdot S_R$$

MATCHED SEND AND RECEIVE SENSITIVITIES



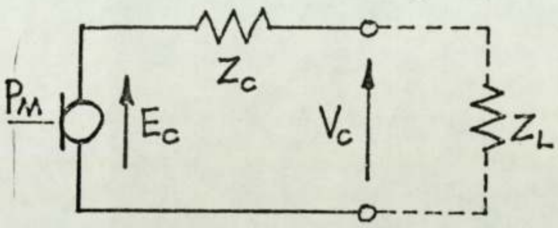


$$V_C = P_M + S_S$$

(dBV) (dBPa) (dBV/Pa)

$$P_e = V_c + S_R$$

(dBPa) (dBV) (dBPa/V)



E_c = Open circuit terminal voltage

If $Z_L = Z_C$ then $V_c = E_c/2$

If $Z_L \neq Z_c$ then $V_c^1 = E_C \cdot \frac{Z_L}{Z_L + Z_C} = 2Vc \cdot \frac{Z_L}{Z_L + Z_C}$

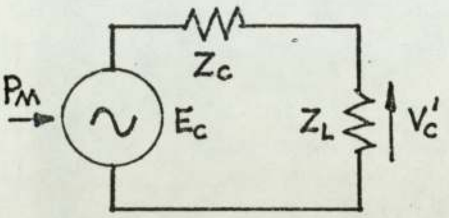
or,

$$V_c^1 = E_c + 20 \log_{10} \frac{|Z_L|}{|Z_L + Z_C|}$$

$$\text{ie, } V_c^1 = V_c + 20 \log_{10} \frac{2|Z_L|}{|Z_L + Z_C|}$$

SIDETONE

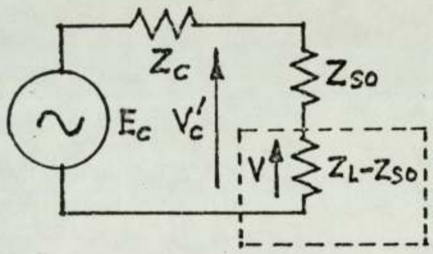
The sidetone path loss between mrp and erp is dependent on the line impedance (Z_L) to which the telephone set is connected.



$$V'_C = E_C \cdot \frac{Z_L}{Z_L + Z_C} \qquad \text{———— 1}$$

$$P_M = \frac{E_C}{2S_S} \quad \therefore \quad V'_C = S_S \cdot P_M \cdot \frac{2Z_L}{Z_L + Z_C}$$

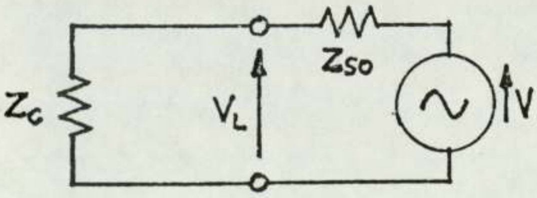
Consider Z_L as Z_{SO} in series with $Z_L - Z_{SO}$ ———— 2



$$V = V'_C \cdot \frac{Z_L - Z_{ZO}}{Z_L}$$

Assume for now, that V is a controlled source which is independant of E_C.

Let V produce zero sidetone. Without E_C, V produces a voltage V_L across the line terminals.



$$V_L = V \cdot \frac{Z_C}{Z_C + Z_{SO}}$$

ie, $V_L + V'_C \cdot \dfrac{Z_L - Z_{SO}}{Z_L} \cdot \dfrac{Z_C}{Z_C + Z_{SO}}$

V_L causes a pressure P_e of:

$P_e = V_L \cdot S_R$ ie, $P_e = S_R \cdot V'_C \cdot \dfrac{Z_L - Z_{SO}}{Z_L} \cdot \dfrac{Z_C}{Z_C + Z_{SO}}$

Let L_{MEST} be sidetone path loss. ———— 3

Represent this by the ratio $\frac{P_M}{P_e}$

From, 2, $P_M = \frac{V'_C(Z_L + Z_C)}{S_S.2Z_L}$

Thus,

$$L_{MEST} = \frac{\dfrac{V'_C.(Z_L + Z_C)}{S_S.2Z_L}}{S_R.V'_C.\dfrac{Z_L - Z_{SO}}{Z_L}\,.\,\dfrac{Z_C}{Z_C + Z_{SO}}}$$

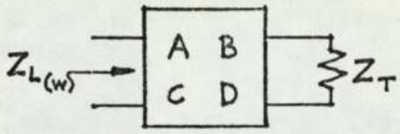
$$= \frac{Z_L + Z_C}{S_S.S_R.2Z_L} \,.\, \frac{Z_L(Z_C + Z_{SO})}{Z_C(Z_L - Z_{SO})}$$

ie, $L_{MEST} = \frac{(Z_L + Z_C)(Z_C + Z_{SO})}{S_S.S_R.2Z_C(Z_L - Z_{SO})}$

or, in dB,

$$L_{MEST} = -S_S - S_R + 20 \log_{10} \frac{|Z_L + Z_C||Z_C + Z_{SO}|}{2|Z_C||Z_L - Z_{ZO}|}$$

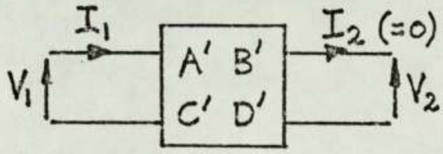
Z_L may be obtained from the ABCD parameters of the transmission network, and the Z_C of the 'east' tel set. ie:



Let Z_T be terminating imp. at the east end. $(= Z_{C(E)})$

($Z_{L(W)}$ = imp. in send direction)

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} 1 & 0 \\ 1/Z_T & 1 \end{vmatrix} = \begin{vmatrix} A + B/Z_T & B \\ C + D/Z_T & D \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix}$$

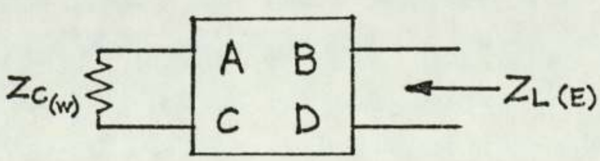


$$\begin{vmatrix} V_1 \\ V_2 \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} \begin{vmatrix} V_2 \\ I_2 \end{vmatrix}$$

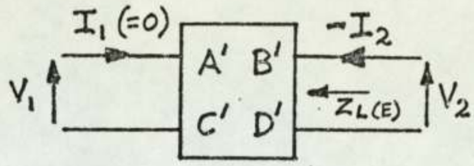
$$Z_{L(W)} = \frac{V_1}{I_1} \quad \text{ie, } Z_{L(W)} = \frac{A'V_2 + \cancel{B'I_2}\to 0}{C'V_2 + \cancel{D'I_2}\to 0} = \frac{A + \frac{B}{Z_T}}{C + \frac{D}{Z_T}}$$

$$\text{ie, } \underline{Z_{L(W)} = \frac{AZ_{C(E)} + B}{CZ_{C(E)} + D}}$$

The impedance presented to the east tel set is $Z_{L(E)}$



$$\begin{vmatrix} 1 & 0 \\ 1/Z_C & 1 \end{vmatrix} \begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} A & B \\ A/Z_C + C & B/Z_C + D \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix}$$



$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} \begin{vmatrix} V_2 \\ -I_2 \end{vmatrix}$$

Inverting, $$\begin{vmatrix} V_2 \\ -I_2 \end{vmatrix} = \begin{vmatrix} D' & -B' \\ -C' & A' \end{vmatrix} \begin{vmatrix} V_1 \\ I_1 \end{vmatrix} \quad (\Delta = A'D' - B'D' = 1)$$

$$\therefore \quad Z_{L(E)} = \frac{V_2}{I_2} = \frac{D'V_1 - B'I_1 \overset{0}{}}{C'V_1 - A'I_1 \underset{0}{}} = \frac{B/Z_C + D}{A/Z_C + C}$$

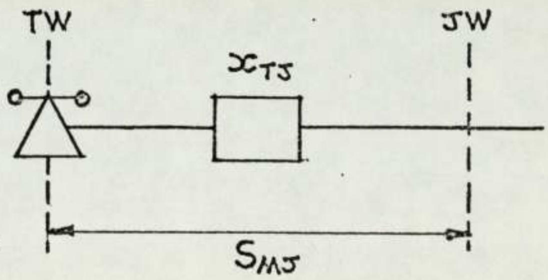
$$\text{ie,} \quad \underline{Z_{L(E)} = \frac{B + DZ_{C(W)}}{A + CZ_{C(W)}}}$$

The sens. of the local tel cct. from the mrp to 600 Ω junc. is denoted by S_{MJ}.

If V_{600} = volts across 600 Ω termination of local tel set.

P_M = Sound pressure at mrp

$$S_{MJ} = \frac{V_{600}}{PM}$$



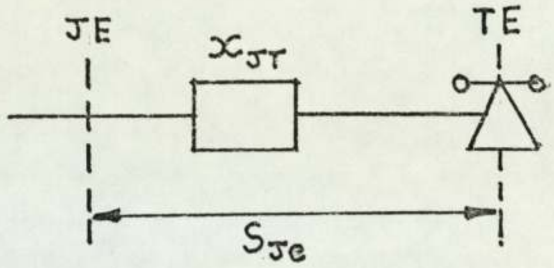
$S_{MJ} \neq S_{S600}$ by the insertion loss X_{TJ}

ie, $\underline{S_{MJ} = S_{S600} - X_{TJ}}$, (but $S_{S600} = S_S + 20 \log \frac{2 \times 600}{|Z_C + 600|}$)

$$\text{or,} \quad \underline{S_{MJ} = S_S - X_{TJ} + 20 \log \frac{2 \times 600}{|Z_C + 600|}} \qquad \text{———— 13}$$

The sens. of the local tel cct. from a 600 Ω junc. to the erp of an artificial ear is denoted by S_{Je}.

$S_{Je} = \frac{P_e}{V_{600}}$



S_{JE} differs from S_{R600}

by the ins. loss X_{JT}

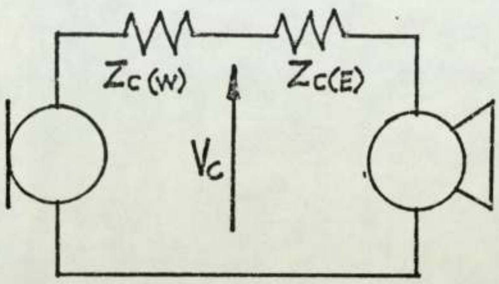
ie, $S_{Je} = S_{R600} - X_{JT}$ (but $S_{R600} = S_R + 20 \log \frac{2Z_C}{|600 + Z_C|}$

or, $S_{Je} = S_R - X_{JT} + 20 \log \frac{2|Z_C|}{|Z_C + 600|}$ ——————— 14

COMPLETE CONNECTIONS

The overall loss of a connection from mrp to erp (of an artificial ear) is denoted by L_{Me}.

Consider the tel sets connected directly together:



If, $Z_{C(E)} = Z_{C(W)}$

$$V_C = \frac{E_C}{2}$$

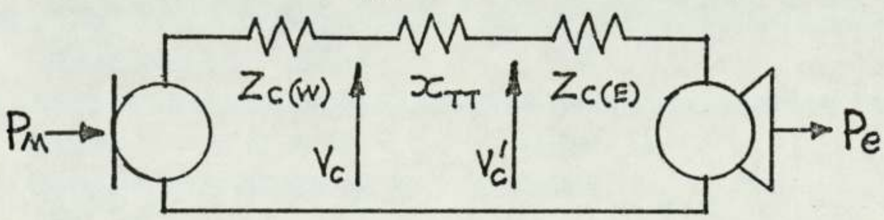
If $S_{C(E)} \neq Z_{C(W)}$

then, $V'_C = E_C \cdot \frac{Z_{C(E)}}{Z_{C(W)} + Z_{C(E)}} = 2V_C \cdot \frac{Z_{C(E)}}{Z_{C(W)} + Z_{C(E)}}$

or, $V'_C = V_C + 20 \log \frac{2|Z_{C(E)}|}{|Z_{C(W)} + Z_{C(E)}|}$ ———————— 15

Now,

Insert a transmission path between the telephones, having an insertion loss X_{TT}.



$L_{Me_{(W-E)}} = P_{M(W)} - P_{e(E)}$

but, $P_{e(E)} = V'_C + S_{R(E)}$

$P_{M(W)} = V_C - S_{S(W)}$

$\therefore \; L_{Me_{(W-E)}} = V_C - S_{S(W)} + X_{TT} - V'_C - S_{R(E)}$ ———————— 16

Subst 15 in 16,

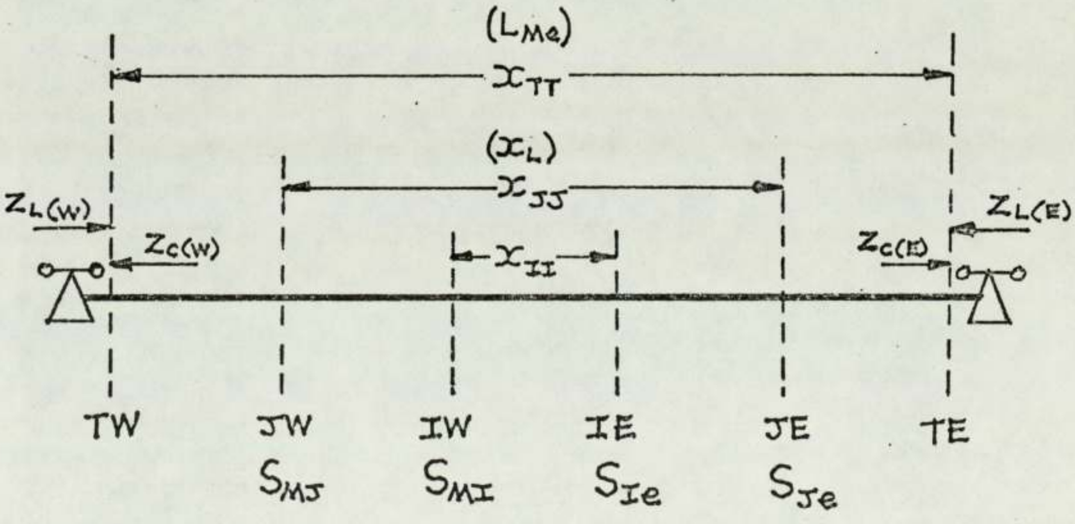
$$L_{Me_{(W-E)}} = \cancel{V_C} - S_{S(W)} + X_{TT} - \cancel{V_C} + 20 \log \frac{|Z_{C(W)} + Z_{C(E)}|}{2|Z_{C(E)}|} = S_{R(E)}$$

$$\text{ie, } L_{Me_{(W-E)}} = X_{TT} - S_{S(W)} - S_{R(E)} + 20 \log \frac{|Z_{C(W)} + Z_{C(E)}|}{2|Z_{C(E)}|}$$

Similarly,

$$L_{Me_{(E-W)}} = X_{TT} - S_{S(E)} - S_{R(W)} + 20 \log \frac{|Z_{C(E)} + Z_{C(W)}|}{2|Z_{C(W)}|}$$

REPRESENTATION OF PARAMETERS



Since the calcs. are based on 600 Ω junctions, there will be a discrepancy between L_{Me} (the true mouth to artificial ear loss) and the sum of the losses. For planning purposes the loss between the junc's. is expressed as a nominal loss (at 800 Hz) called X_L. Clearly, this does not take into account atten/freq distortion and mismatch. A quantity X_{imp} may be introduced in order to obtain a measure of this discrepancy. X_{imp} is termed the impairment loss.

$$X_{imp} = L_{Me} - (-S_{UMJ} - S_{UJe} + X_L)$$

<u>SIDETONE PATH LOSS</u> (L_{MEST})

As shown previously,

$$L_{MEST} = -S_S - S_R + 20 \log \frac{|Z_L + Z_C||Z_C + Z_{SO}|}{2|Z_C|\ |Z_L - Z_{SO}|}$$

$$\therefore \quad L_{MEST(W)} = -S_{S(W)} - S_{R(W)} + 20 \log \frac{|Z_{L(W)} + Z_{C(W)}||Z_{C(W)} + Z_{SO(W)}|}{|2 Z_{C(W)}||Z_{L(W)} - Z_{SO(W)}|}$$

$$L_{MEST(E)} = -S_{S(E)} - S_{R(E)} + 20 \log \frac{|Z_{L(E)} + Z_{C(E)}||Z_{C(E)} + Z_{SO(E)}|}{2|Z_{C(E)}||Z_{L(E)} - Z_{SO(E)}|}$$

APPENDIX 3

PROGRAMS TO IMPLEMENT T.C.A.M.

```
100 REM TCAM STARTING PROGRAM
110 N=60:GOSUB390
120 SYS38027
130 PRINT""
140 C$="T":D$="C":E$="A":F$="M"
150 PRINT"":FORI=1TO39:PRINTC$;:NEXT:FORI=1TO22:PRINT""D$;:NEXT
                                                    :PRINT""
160 FORI=1TO38:PRINT""E$"";:NEXT:PRINTC$
170 FORI=1TO23:PRINT""F$"";:NEXT
180 PRINTTAB(7);" TCAM - STARTING PROGRAM "
190 GOSUB370:PRINT"1. CENTRALISE DISKS 1 & 2
200 GOSUB370:PRINT"2. INSERT DISK 1 IN DRIVE #0
210 GOSUB370:PRINT"3. INSERT DISK 2 IN DRIVE #1
220 GOSUB370:PRINT"4. CLOSE BOTH DRIVE DOORS
230 GOSUB370:PRINT"5. PRESS SPACE BAR TO CONTINUE
240 GOSUB380
250 GETA$:IFA$=""THEN250
260 OPEN1,8,15:PRINT#1,"I"
270 PRINT"PRESS 'STOP' ON TAPE #1
280 PRINT"REWIND TAPE AND REMOVE
290 PRINT"THEN PRESS SPACE BAR TO CONTINUE
300 GETA$:IFA$=""THEN300
310 D$="0:P1"
320 PRINT"TO RUN TCAM, TYPE IN :-
330 PRINT"      LOAD D$,8
340 PRINT"THEN TYPE IN :-
350 PRINT"      RUN
360 END
370 PRINTTAB(4);"";:RETURN
380 N=120
390 POKE59459,255:FORI=1TON:NEXTI
400 POKE59459,0
410 IFN=60THEN430
420 N=60:GOTO390
430 RETURN
READY.
```

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P1 (DISK1)
110 CLR:GOSUB4570
120 PRINT"⌧ INFORMATION PROGRAM ⌧"
130 PRINT"⌧DF⌧  SETTING-UP OR MODIFYING FIXED          DATA FILES
140 PRINT"⌧TF⌧  SETTING-UP OR MODIFYING TELEPHONE      DATA FILES
150 PRINT"⌧OC⌧  OPTIONS FOR CONNECTION ELEMENTS
160 PRINT"⌧SC⌧  SETTING UP A CONNECTION
180 PRINT"⌧FL⌧  FILE LOCATION
190 PRINT"⌧PR⌧  PRINT-OUT OF CONNECTION DATA
200 PRINT"⌧AV⌧  ARCHIVING RESULTS FROM STAGE 2
210 PRINT"⌧RC⌧  RECALLING A CONNECTION FROM ARCHIVES
220 PRINT"⌧ST⌧  RUN STAGE 3 (WITH OLD U-FILES)
222 PRINT"⌧TT⌧  TRANSFER U1 & U3 TO DISK 3
230 PRINT"⌧WHICH OF THE ABOVE DO YOU REQUIRE ";
240 INPUT L$
260 IF L$="FL" THEN 370
270 IF L$="OC" THEN 380
280 IF L$="PR" THEN 400
290 IF L$="SC" THEN 600
300 IF L$="DF" THEN 420
310 IF L$="AV" THEN 430
320 IF L$="TF" THEN 440
330 IFL$="ST"THEN480
340 IFL$="RC"THEN550
342 IFL$="TT"THEN485
350 GOSUB4530
360 GOTO240
370 LOAD"0:P9",8
380 LOAD"0:P4",8
400 LOAD"0:P10",8
410 LOAD"0:P5",8
420 LOAD"0:P2",8
430 LOAD"0:P12",8
440 PRINT"⌧CENTRALISE & INSERT DISK 2 IN DRIVE 1 &  CLOSE DOOR
450 PRINT"THEN PRESS SPACE BAR TO CONTINUE
460 GETA$:IFA$=""THEN460
470 OPEN1,8,15:PRINT#1,"I1":LOAD"1:P1",8
480 PRINT"⌧ RUNNING STAGE 3 (WITH EXISTING U-FILES   ON DISK 3)":GOT
485 PRINT"⌧ TRANSFER OF U1 & U3 FILES FROM DISK 1 "                49
486 PRINT"⌧  TO DISK 3
490 PRINT"⌧⌧REMOVE DISK FROM DRIVE 1, AND (AFTER"
500 PRINT" CENTRALISING) INSERT DISK 3
510 PRINT"PRESS SPACE BAR TO CONTINUE AND THEN     CLOSE DRIVE 1 DOOR
520 GETA$:IFA$=""THEN520
530 OPEN1,8,15:PRINT#1,"I1":CLOSE1
535 IFL$="ST"THEN540
538 LOAD"1:P7",8
540 LOAD"1:P35",8
550 PRINT"⌧⌧REMOVE DISK FROM DRIVE 1, AND (AFTER"
560 PRINT" CENTRALISING) INSERT ARCHIVES DISK
570 PRINT"PRESS SPACE BAR TO CONTINUE AND THEN     CLOSE DRIVE 1 DOOR
580 GETA$:IFA$=""THEN580
590 LOAD"1:P2",8
600 PRINT"⌧⌧SETTING UP THE CONNECTION
610 PRINT"⌧TYPE IN TITLE OF CONNECTION AND DATE OF SET-UP
620 INPUT T$
```

```
630 PRINT"█TYPE IN NO. OF ELECTRICAL ELEMENTS
640 INPUT"▶▶◀▌█▌";N
650 DIM K(N),F(20),B(8),A(20,8),D(N),V1(8),V2(8),V3(8),X(20),Z(20)
660 FORJ=1TO20:READF(J):NEXT
670 FORJ=1TO8:READV1(J):NEXT
680 FORJ=1TO8:READV2(J):NEXT
690 FORJ=1TO8:READV3(J):NEXT
700 DATA100,125,160,200,250,315,400,500,630,800,1000,1250,1600
710 DATA2000,2500,3150,4000,5000,6300,8000
720 DATA1,0,1,1,0,0,1,0,1,0,0,0,1,1,1,0
730 DATA1,0,0,0,0,0,1,0
740 T=0
750 FORI=1TON+1
760 IFI=N+1THEN3790
770 PRINT"ELEMENT ";I;"  ";
780 INPUTB$
790 IFB$="LCO"THEN940
800 IFB$="SFB"THEN2030
810 IFB$="HFB"THEN2050
820 IFB$="IFB"THEN2070
830 IFB$="CHF"THEN2090
840 IFB$="LCJ"THEN2090
850 IFB$="ATT"THEN2790
860 IFB$="ULC"THEN2290
870 IFB$="TXL"THEN2480
880 IFB$="TFR"THEN2990
890 IFB$="LAT"THEN3130
900 IFB$="MCC"THEN3550
910 IFB$="AAL"THEN2270
920 GOSUB4530
930 GOTO780
940 PRINT"█LUMPED COMPONENTS
950 PRINT"IDENTIFY COMPONENT
960 INPUTB$
970 IFB$="LSE"THEN1070
980 IFB$="CSE"THEN1130
990 IFB$="RSE"THEN1190
1000 IFB$="ZSE"THEN1720
1010 IFB$="RSH"THEN1270
1020 IFB$="LSH"THEN1340
1030 IFB$="CSH"THEN1400
1040 IFB$="ZSH"THEN1720
1050 GOSUB4530
1060 GOTO960
1070 PRINT"TYPE IN VALUE OF LSE (MH)  ";
1080 D(I)=4
1090 INPUT"▶▶◀▌█▌";L1
1100 C$=STR$(L1)
1110 C$="INDUCTANCE = "+C$+"MH"
1120 L1=L1*1E-3:U=1:GOTO1250
1130 PRINT"TYPE IN VALUE OF CSE (NF)  ";
1140 D(I)=7
1150 INPUT"▶▶◀▌█▌";C1
1160 C$=STR$(C1)
1170 C$="CAPACITANCE = "+C$+"NF"
1180 C1=C1*1E-9:U=2:GOTO1250
1190 PRINT"TYPE IN VALUE OF RSE (OHMS)  ";
1200 D(I)=1
```

```
1210 INPUT"■■■■■";R1
1220 C$=STR$(R1)
1230 C$="RESISTANCE = "+C$+"OHMS"
1240 U=3
1250 FORJ=1TO8:B(J)=V1(J):NEXT
1260 GOTO1470
1270 PRINT"TYPE IN VALUE OF RSH (OHMS)  ";
1280 D(I)=10
1290 INPUT"■■■■■";R1
1300 C$=STR$(R1)
1310 C$="RESISTANCE = "+C$+"OHMS"
1320 U=4
1330 GOTO1460
1340 PRINT"TYPE IN VALUE OF LSH (MH)  ";
1350 D(I)=13
1360 INPUT"■■■■■";L1
1370 C$=STR$(L1)
1380 C$="INDUCTANCE = "+C$+"MH"
1390 L1=L1*1E-3:U=5:GOTO1460
1400 PRINT"TYPE IN VALUE OF CSH (NF) ";
1410 D(I)=16
1420 INPUT"■■■■■";C1
1430 C$=STR$(C1)
1440 C$="CAPACITANCE = "+C$+"NF"
1450 C1=C1*1E-9:U=6
1460 FORJ=1TO8:B(J)=V2(J):NEXT
1470 FORJ=1TO20
1480 FORM=1TO8
1490 A(J,M)=B(M)
1500 NEXTM
1510 W=2*π*F(J)
1520 ON U GOTO 1530,1550,1580,1610,1640,1660
1530 A(J,4)=B(4)*W*L1
1540 GOTO1560
1550 A(J,4)=-B(4)/(W*C1)
1560 A(J,3)=0
1570 GOTO1680
1580 A(J,3)=B(3)*R1
1590 A(J,4)=0
1600 GOTO1680
1610 A(J,5)=B(5)/R1
1620 A(J,6)=0
1630 GOTO1680
1640 A(J,6)=-B(6)/(W*L1)
1650 GOTO1670
1660 A(J,6)=B(6)*W*C1
1670 A(J,5)=0
1680 NEXTJ
1690 D$="---"
1700 E$="---"
1710 GOTO3700
1720 REM ZSE & ZSH
1730 PRINT"■■SETTING-UP ";B$
1740 PRINT"--------------■"
1750 PRINT"INPUT VALUES OF SERIES CONNECTED          RESISTANCE (OHMS
1760 PRINT" INDUCTANCE (MH),"
1770 PRINT" CAPACITANCE (NF)■"
1780 INPUT"RES■■■■■";R:INPUT"IND■■■■■";L:INPUT"CAP■■■■■";C
1790 L1=L*1E-3:C1=C*1E-9
1800 IFB$="ZSH"THEN1890
1810 FORJ=1TO20:W=2*π*F(J)
1820 A(J,1)=1:A(J,2)=0:A(J,3)=R
```

```
1830 L2=W*L1
1840 IFC=0THENC2=0:GOTO1860
1850 C2=1/(W*C1)
1860 A(J,4)=L2-C2
1870 A(J,5)=0:A(J,6)=0:A(J,7)=1:A(J,8)=0:NEXTJ
1880 GOTO1970
1890 FORJ=1TO20:W=2*π*F(J)
1900 A(J,1)=1:A(J,2)=0:A(J,3)=0:A(J,4)=0
1910 L2=W*L1
1920 IFC=0THENC2=0:GOTO1940
1930 C2=1/(W*C1)
1940 X=L2-C2
1950 A(J,5)=R/(R↑2+X↑2):A(J,6)=-X/(R↑2+X↑2)
1960 A(J,7)=1:A(J,8)=0:NEXTJ
1970 C$="RESISTANCE = "+STR$(R)+"OHMS"
1980 D$="INDUCTANCE = "+STR$(L)+"MH"
1990 E$="CAPACITANCE = "+STR$(C)+"NF"
2000 IFB$="ZSH"THEN2020
2010 D(I)=55:GOTO3700
2020 D(I)=58:GOTO3700
2030 REM SFB
2040 K(I)=15:D(I)=22:NEXTI
2050 REM HFB
2060 K(I)=16:D(I)=25:NEXTI
2070 REM IFB
2080 K(I)=17:D(I)=28:NEXTI
2090 REM CHF&LCJ ELEMENTS IN TANDEM
2100 IFB$="LCJ"THEN2140
2110 PRINT"HOW MANY CHF'S IN TANDEM  ";
2120 INPUT"▮▮▮▮▮▮";E
2130 T1=18:T2=31:GOTO2240
2140 PRINT"HOW MANY LCJ'S IN TANDEM  ";
2150 INPUT"▮▮▮▮▮▮";E:T2=34
2160 PRINT"GAUGE OF LCJ (MM)  ";
2170 INPUTG$
2180 IFG$="0.6"THEN2220
2190 IFG$="0.9"THEN2230
2200 GOSUB4530
2210 GOTO2170
2220 T1=19:GOTO2240
2230 T1=20
2240 FORJ=1TOE:K(I)=T1:D(I)=T2
2250 I=I+1:NEXTJ
2260 I=I-1:NEXTI
2270 REM AAL
2280 K(I)=21:D(I)=52:NEXTI
2290 REM ULC
2300 D(I)=40
2310 PRINT"GAUGE OF ULC (MM)  ";
2320 INPUTG$
2330 IFG$="0.4"THEN2380
2340 IFG$="0.5"THEN2400
2350 GOSUB4530
2360 GOTO2320
2370 REM PRI.CONST'S /KM OF ULC (0.4MM)
2380 C=4.2E-8:R=273:GOTO2410
2390 REM PRI.CONST'S /KM OF ULC (0.5MM)
2400 C=4.7E-8:R=169
2410 PRINT"LENGTH (KM)  ";
2420 C$="GAUGE = "+G$+"MM"
2430 INPUT"▮▮▮▮▮▮";D1
```

```
2440 D$=STR$(D1)
2450 D$="LENGTH = "+D$+"KM"
2460 E$="---"
2470 GOTO2590
2480 REM TXL
2490 D(I)=43
2500 PRINT"TYPE IN PRIMARY CONSTANTS (C&R) IN NANO FARADS AND OHMS
2510 INPUT"▮▮▮▮▮";C,R                                              PER KM
2520 C$=STR$(C):D$=STR$(R)
2530 C$="CAPACITANCE = "+C$+"NF/KM"
2540 D$="RESISTANCE = "+D$+"OHMS/KM"
2550 C=C*1E-9
2560 PRINT"LENGTH (KM)  ";
2570 INPUT"▮▮▮▮▮";D1:E$=STR$(D1)
2580 E$="LENGTH = "+E$+"KM"
2590 REM LINE FORMULAE
2600 FORJ=1TO20
2610 W=2*π*F(J)
2620 S=SQR(W*C*R/2)*D1
2630 L=SQR(R/(2*W*C))
2640 M=S/(R*D1)
2650 G=(EXP(S)-1/EXP(S))*COS(S)/2
2660 H=(EXP(S)+1/EXP(S))*SIN(S)/2
2670 D2=G+H
2680 D3=G-H
2690 A(J,1)=H/TAN(S)
2700 A(J,2)=G*TAN(S)
2710 A(J,3)=L*D2
2720 A(J,4)=-L*D3
2730 A(J,5)=M*D3
2740 A(J,6)=M*D2
2750 A(J,7)=A(J,1)
2760 A(J,8)=A(J,2)
2770 NEXTJ
2780 GOTO3700
2790 REM ATT
2800 D(I)=37
2810 PRINT"TYPE IN REQ'D LOSS (DB)  ";
2820 INPUT"▮▮▮▮▮";L:C$=STR$(L)
2830 C$="LOSS = "+C$+"DB"
2840 D$="---":E$="---"
2850 S=10↑(L/20)
2860 S1=(S↑2+1)/(2*S)
2870 S2=(S↑2-1)/(2*S):Z=600
2880 FORJ=1TO20
2890 A(J,1)=S1
2900 A(J,2)=0
2910 A(J,3)=S2*Z
2920 A(J,4)=0
2930 A(J,5)=S2/Z
2940 A(J,6)=0
2950 A(J,7)=S1
2960 A(J,8)=0
2970 NEXTJ
2980 GOTO3700
2990 REM TFR
3000 D(I)=19
3010 PRINT"TYPE IN TURNS RATIO  ";
3020 INPUT"▮▮▮▮▮";N1:C$=STR$(N1)
3030 C$="TURNS RATIO = 1:"+C$
3040 D$="---":E$="---"
3050 FORJ=1TO20
```

```
3060 FORM=1TO8
3070 A(J,M)=V3(M)
3080 NEXTM
3090 A(J,1)=1/N1
3100 A(J,7)=1/N1
3110 NEXTJ
3120 GOTO3700
3130 REM LAT
3140 D(I)=46
3150 PRINT"LATTICE NETWORK"
3160 PRINT"SERIES IMPEDANCE":PRINT"----------------"
3170 INPUT"RESISTANCE (OHMS) ";R1
3180 INPUT"INDUCTANCE (MH) ";L1
3190 INPUT"CAPACITANCE (NF) ";C1
3200 C$="SERIES IMPEDANCE; R="+STR$(R1)+"OHMS, L="+STR$(L1)+"MH, C="
3210 C$=C$+STR$(C1)+"NF"
3220 PRINT"SHUNT IMPEDANCE":PRINT"---------------"
3230 INPUT"RESISTANCE (OHMS) ";R2
3240 INPUT"INDUCTANCE (MH) ";L2
3250 INPUT"CAPACITANCE (NF) ";C2
3260 D$="SHUNT IMPEDANCE; R="+STR$(R2)+"OHMS, L="+STR$(L2)+"MH, C="
3270 D$=D$+STR$(C2)+"NF":E$="---"
3280 L1=L1*1E-3:C1=C1*1E-9
3290 L2=L2*1E-3:C2=C2*1E-9
3300 FORJ=1TO20
3310 W=2*π*F(J)
3320 L3=W*L1
3330 IFC1=0THEN3350
3340 C3=1/(W*C1):GOTO3360
3350 C3=0
3360 L4=W*L2
3370 IFC2=0THEN3390
3380 C4=1/(W*C2):GOTO3400
3390 C4=0
3400 X1=L3-C3:X2=L4-C4
3410 K1=R2+R1:K2=R2-R1
3420 K3=X2+X1:K4=X2-X1
3430 K5=K2↑2+K4↑2
3440 K6=R1*R2-X1*X2:K7=X1*R2+R1*X2
3450 A(J,1)=(K1*K2+K3*K4)/K5
3460 A(J,2)=(K2*K3-K1*K4)/K5
3470 A(J,3)=2*(K2*K6+K4*K7)/K5
3480 A(J,4)=2*(K2*K7-K4*K6)/K5
3490 A(J,5)=2*K2/K5
3500 A(J,6)=-2*K4/K5
3510 A(J,7)=A(J,1)
3520 A(J,8)=A(J,2)
3530 NEXTJ
3540 GOTO3700
3550 REM MCC
3560 D(I)=49
3570 PRINT" MUTUALLY COUPLED COILS"
3580 PRINT"INPUT PRIMARY INDUCTANCE (MH) ":INPUT"";L1
3590 PRINT"INPUT SECONDARY INDUCTANCE (MH) ":INPUT"";L2
3600 PRINT"INPUT MUTUAL INDUCTANCE (MH) ":INPUT"";M
3610 L3=L1*1E-3:L4=L2*1E-3:M1=M*1E-3
3620 FORJ=1TO20:W=2*π*F(J)
3630 A(J,1)=L3/M:A(J,2)=0:A(J,3)=0
3640 A(J,4)=W*(L3*L4-M1↑2)/M1:A(J,5)=0
3650 A(J,6)=-1/(W*M1):A(J,7)=L4/M1:A(J,8)=0:NEXTJ
3660 C$="PRIMARY INDUCTANCE = "+STR$(L1)+"MH"
3670 D$="SECONDARY INDUCTANCE = "+STR$(L2)+"MH"
```

```
3680 E$="MUTUAL INDUCTANCE = "+STR$(M)+"MH"
3690 GOTO3700
3700 T=T+1:K(I)=T+26:Y$="D"+STR$(K(I))
3710 REM WRITING INTO DATA FILE
3720 GOSUB4500
3730 FORJ=1TO20
3740 FORK=1TO8
3750 PRINT#2,A(J,K);CHR$(13);:NEXTK:NEXTJ
3760 PRINT#2,C$;CHR$(13);D$;CHR$(13);E$;CHR$(13);
3770 CLOSE2
3780 NEXTI
3790 REM CHECK
3800 PRINT"ARE ELEMENT DESCRIPTIONS NOW COMPLETE  ";
3810 INPUTH$
3820 IFH$= "YES"THEN3930
3830 IFH$="NO"THEN3860
3840 GOSUB4530
3850 GOTO3810
3860 PRINT"■DESCRIPTION DOES NOT COMPLY WITH NUMBER OF ELEMENTS
3870 PRINT"TYPE IN 'FRESH' FOR ANOTHER ATTEMPT            INPUTTED
3880 INPUTH$
3890 IFH$="FRESH"THEN3920
3900 GOSUB4530
3910 GOTO3880
3920 CLR:GOTO600
3930 REM SUB PROG FOR NOM LOSS (XL)
3940 PRINT"■DO YOU REQUIRE THE NOM. LOSS FOR ANY OF THESE ELEMENTS ";
3950 INPUTR$
3960 IFR$="YES"THEN4010
3970 IFR$="NO"THEN4410
3980 GOSUB4530
3990 GOTO3950
4000 GOTO3950
4010 PRINT"■■■ IMAGE IMPEDANCE & ATTENUATION "
4020 PRINT"■■TYPE IN ELEMENT NO. FOR WHICH YOU         REQUIRE XL
4030 INPUT"■■■■■■";E
4040 Y$="D"+STR$(K(E))
4050 GOSUB4490
4060 FORJ=1TO20
4070 FORK=1TO8
4080 INPUT#2,A(J,K):NEXTK:NEXTJ:CLOSE2
4090 REM IMAGE IMPEDANCE & ATTENUATION
4100 FORJ=1TO20
4110 S1=SQR(A(J,1)↑2+A(J,2)↑2)
4120 S2=SQR(A(J,3)↑2+A(J,4)↑2)
4130 S3=SQR(A(J,5)↑2+A(J,6)↑2)
4140 IFS2=0THEN4200
4150 IFS3=0THEN4200
4160 Z(J)=SQR(S2/S3)
4170 R=S1+S3*Z(J)/2+S2/(2*Z(J))
4180 X(J)=INT(10*(20*LOG(R)/LOG(10))+0.5)/10
4190 GOTO4210
4200 X(J)=0
4210 NEXTJ
4220 PRINT"INPUT FREQ. AT WHICH YOU REQ. XL
4230 INPUT"■■■■■■";F
4240 J=INT(10*LOG(F)/LOG(10)-18.5)
4250 PRINT"AT";F(J);"HZ, XL FOR ELEMENT";E;"IS";X(J);"DB"
4260 PRINT" IMAGE IMPEDANCE = ";Z(J);"OHMS"
4270 PRINT"■A FURTHER FREQUENCY ";
4280 INPUTH$
```

```
 4290 IFH$="YES"THEN4220
 4300 IFH$="NO"THEN4330
 4310 GOSUB4530
 4320 GOTO4280
 4330 PRINT"DO YOU REQUIRE XL FOR ANY OTHER ELEMENTS ";
 4340 INPUTR$
 4350 IFR$="YES"THEN4010
 4360 IFR$="NO"THEN4390
 4370 GOSUB4530
 4380 GOTO4340
 4390 PRINT"PRESS SPACE BAR TO CONTINUE"
 4400 GETA$:IFA$=""THEN4400
 4410 Y$="D 25":GOSUB4500
 4420 PRINT#2,N;CHR$(13);
 4430 FORI=1TON:PRINT#2,K(I);CHR$(13);:NEXTI
 4440 FORI=1TON:PRINT#2,D(I);CHR$(13);:NEXTI
 4450 CLOSE2
 4460 Y$="D 26":GOSUB4500
 4470 PRINT#2,T$;CHR$(13);T:CLOSE2
 4480 LOAD"0:P5",8
 4490 Z$=",S,R":X$="0:":GOTO4510
 4500 Z$=",S,W":X$="@0:"
 4510 Y$=X$+Y$+Z$
 4520 OPEN2,8,2,Y$:RETURN
 4530 GOSUB4560
 4540 PRINT"INCORRECT ENTRY-TRY AGAIN"
 4550 RETURN
 4560 POKE59459,255:FORI1=1TO100:NEXTI1
 4570 POKE59459,0:RETURN
READY.
```

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P2 (DISK1)
110 CLR:GOSUB1920
120 PRINT"□▒SET-UP OF FEEDING BRIDGE AND
130 PRINT"▒CHANNEL FILTER DATA
140 PRINT"▯FEEDING BRIDGES
150 PRINT"----------------▯"
160 PRINT"IDEAL FEEDING BRIDGE  (IFB)
170 PRINT"STONE FEEDING BRIDGE  (SFB)
180 PRINT"HAYES FEEDING BRIDGE  (HFB)":PRINT
190 DIM A(20,8),F(20),U(8)
200 FOR J=1 TO 20
210 READ F(J)
220 NEXT J
230 REM 20 ISO FREQ'S
240 DATA 100,125,160,200,250,315,400,500,630,800,1000,1250,1600,2000
250 DATA 2500,3150,4000,5000,6300,8000
260 PRINT"DO YOU WISH TO MODIFY ANY OF THESE DATA FILES ";
270 INPUT M$
280 IF M$="NO" THEN 1300
290 IF M$="YES" THEN 320
300 GOSUB1910
310 GOTO 270
320 PRINT"WHICH FILE DO YOU WISH TO MODIFY ";
330 INPUT N$
340 IF N$="SFB" THEN 450
350 IF N$="HFB" THEN 720
360 IF N$="IFB" THEN 1120
370 GOSUB1910
380 GOTO 330
390 PRINT"▯WANT TO MODIFY ANY FURTHER FEEDING      BRIDGE DATA FILES
400 INPUT T$
410 IF T$="YES" THEN 320
420 IF T$="NO" THEN 1300
430 GOSUB1910
440 GOTO 400
450 PRINT"▯▒SETTING-UP SFB":PRINT
460 PRINT"INPUT R,L AND C  (OHMS,MH,NF)
470 INPUT R,L,C
480 C$=STR$(R)
490 D$=STR$(L)
500 E$=STR$(C)
510 C$="R="+C$+" OHMS"
520 D$="L="+D$+" MH"
530 E$="C="+E$+" NF"
540 L=L*1.0E-3
550 C=C*1.0E-9
560 FOR J=1 TO 20
570 W=2*π*F(J)
580 S1=((W*L)↑2-R↑2)/(W*C)-2*W*L*R↑2-2*(W*L)↑3
590 S2=R↑4+(W*L)↑4+2*(W*L*R)↑2
600 A(J,1)=1-1/(W↑2*L*C+(W*C*R)↑2/(W↑2*L*C))
610 A(J,2)=-1/(W*C*R+(W↑2*L*C)↑2/(W*C*R))
620 A(J,3)=0
630 A(J,4)=-1/(W*C)
640 A(J,5)=2*R*(R↑2+(W*L)↑2-L/C)/S2
```

```
650 A(J,6)=S1/S2
660 A(J,7)=A(J,1)
670 A(J,8)=A(J,2)
680 NEXT
690 Y$="D 15":GOSUB1830
700 PRINT"SFB DATA NOW STORED
710 GOTO 390
720 PRINT"⌧⌧SETTING-UP HFB";:PRINT
730 PRINT"INPUT R1;R2,R3,L1,L2,L3,C  (OHMS,MH,NF)
740 INPUT R1,R2,R3,L1,L2,L3,C
750 C$=STR$(R1)
760 D$=STR$(L1)
770 E$=STR$(C)
780 F$=STR$(R2)
790 H$=STR$(L2)
800 J$=STR$(R3)
810 K$=STR$(L3)
820 C$="R1="+C$+" OHMS, R2="+F$+" OHMS, R3="+J$+" OHMS"
830 D$="L1="+D$+" MH, L2="+H$+" MH, L3="+K$+" MH"
840 E$="C="+E$+" NF"
850 L1=L1*1.0E-3
860 L2=L2*1.0E-3
870 L3=L3*1.0E-3
880 C=C*1.0E-9
890 FOR J=1 TO 20
900 W=2*π*F(J)
910 S1=1-W↑2*C*L2
920 S2=W*C*R2
930 S3=S1↑2+S2↑2
940 X1=R1+(R2*S1+W*L2*S2)/S3
950 Y1=W*L1+(W*L2*S1-R2*S2)/S3
960 C1=1/R3
970 C2=-1/(W*L3)
980 C3=X1↑2-Y1↑2
990 C4=2*X1*Y1
1000 A(J,1)=1+X1*C1-Y1*C2
1010 A(J,2)=Y1*C1+X1*C2
1020 A(J,3)=2*X1+C1*C3-C2*C4
1030 A(J,4)=2*Y1+C2*C3+C1*C4
1040 A(J,5)=C1
1050 A(J,6)=C2
1060 A(J,7)=A(J,1)
1070 A(J,8)=A(J,2)
1080 NEXT
1090 Y$="D 16":GOSUB1830
1100 PRINT"⌧HFB NOW STORED
1110 GOTO 390
1120 PRINT"⌧⌧SETTING-UP IFB
1130 U(1)=1
1140 FOR K=2 TO 8
1150 U(K)=0
1160 NEXT K
1170 U(7)=1
1180 U(8)=0
1190 FOR R=1 TO 20
1200 FOR C=1 TO 8
1210 A(R,C)=U(C)
1220 NEXT C
1230 NEXT R
1240 C$="ZERO LOSS (UNIT MATRIX)"
1250 D$="---"
1260 E$="---"
```

```
1270 Y$="D 17":GOSUB1830
1280 PRINT"▒IFB NOW STORED
1290 GOTO 390
1300 PRINT"▒":PRINT"▒SETTING-UP CHANNEL FILTER (TYPE I-4)"
1310 DIM L(20),S(20)
1320 PRINT"▒DO YOU WISH TO SET-UP CHF ";
1330 INPUT T$
1340 IF T$="NO" THEN 1820
1350 IF T$="YES" THEN 1380
1360 GOSUB1910
1370 GOTO 1330
1380 PRINT"USE OLD OR NEW DATA ";
1390 INPUTT$
1400 IFT$="OLD"THEN1570
1410 IFT$="NEW"THEN1430
1420 GOSUB1910
1430 PRINT"▒INPUT LOSS (DB) AT EACH OF THE FOLLOWING FREQUENCIES :-"
1440 FORJ=1TO20:PRINTF(J);" HZ",
1450 OPEN3,0:INPUT#3,L(J):CLOSE3:PRINT:NEXTJ
1460 PRINT"▒ANY CORRECTIONS ";:INPUTT$
1470 IFT$="YES"THEN1500
1480 IFT$="NO"THEN1620
1490 GOSUB1910
1500 PRINT"WHICH FREQUENCY ";:INPUTF1
1510 J=INT(10*LOG(F1)/LOG(10)-18.5)
1520 PRINT"INSERT CORRECT VALUE ";:INPUTF(J)
1530 PRINT"ANY MORE CORRECTIONS ";:INPUTT$
1540 IFT$="YES"THEN1500
1550 IFT$="NO"THEN1620
1560 GOSUB1910
1570 FOR J=1 TO 20
1580 READ L(J)
1590 NEXT J
1600 DATA 4.7,3.8,2.8,1.2,0.8,0.3,0,0,0,0,-0.1,-0.1,0.2,0.2,0,1.5,22.
                                                                60,60,60
1610 FOR J=1 TO 20
1620 S(J)=10↑(L(J)/20)
1630 NEXT J
1640 Z=600
1650 FOR J=1 TO 20
1660 S1=(S(J)↑2+1)/(2*S(J))
1670 S2=(S(J)↑2-1)/(2*S(J))
1680 A(J,1)=S1
1690 A(J,2)=0
1700 A(J,3)=S2*Z
1710 A(J,4)=0
1720 A(J,5)=S2/Z
1730 A(J,6)=0
1740 A(J,7)=S1
1750 A(J,8)=0
1760 NEXT J
1770 C$="TYPE I-4"
1780 D$="ZC=600 OHMS"
1790 E$="---"
1800 Y$="D 18":GOSUB1830
1810 PRINT:PRINT"CHF NOW STORED
1820 CLR:LOAD"0:P3",8
1830 Z$=",S,W":X$="@0:"
1840 Y$=X$+Y$+Z$
1850 OPEN2,8,2,Y$
1860 FORJ=1TO20
1870 FORK=1TO8:PRINT#2,A(J,K);CHR$(13);:NEXTK
1880 NEXTJ
```

```
1890 PRINT#2,C$;CHR$(13);D$;CHR$(13);E$
1900 CLOSE2:RETURN
1910 PRINT"▒WRONG INPUT■-TRY AGAIN"
1920 POKE59459,255:FORI=1TO60:NEXTI
1930 POKE59459,0:RETURN
READY.
```

P3P3

```
 1 GOTO100
 5 LOAD"0:P1",8
 100 REM P3 (DISK1)
 110 PRINT"]LOADED CABLE JUNCTION
 120 PRINT:PRINT"DO YOU WISH TO SET-UP LCJ ";
 130 INPUT D$
 140 IF D$="YES"THEN180
 150 IF D$="NO"THEN1440
 160 PRINT"WRONG INPUT-TRY  AGAIN
 170 GOTO 130
 180 PRINT:PRINT"SETTING-UP OF LCJ (4.5 DB LOSS)
 190 PRINT"---------------------------------":PRINT
 200 DIM B(8),F(20),A1(20,8),A2(20,8),A3(20,8),M1(20,8),M2(20,8)
 210 FOR J=1 TO 20
 220 READ F(J)
 230 NEXT
 240 DATA 100,125,160,200,250,315,400,500,630,800,1000
 250 DATA 1250,1600,2000,2500,3150,4000,5000,6300,8000
 260 C=4.1E-8
 270 D=1.83
 280 PRINT"TYPE IN GAUGE (0.6 OR 0.9)MM ";
 290 INPUT G$
 300 IF G$="0.9" THEN 370
 310 IF G$="0.6" THEN 340
 320 PRINT"WRONG INPUT-TRY AGAIN
 330 GOTO 290
 340 R=109:Y$="D 19"
 350 C$="GAUGE (MM) = 0.6
 360 GOTO 390
 370 R=55:Y$="D 20"
 380 C$="GAUGE (MM) = 0.9
 390 D$="---"
 400 E$="---"
 410 PRINT"SET-UP OF LOADING COIL DATA
 420 FOR K=1 TO 8
 430 READ B(K)
 440 NEXT
 450 DATA 1,0,3,1,0,0,1,0
 460 FOR J=1 TO 20
 470 FOR K=1 TO 8
 480 A1(J,K)=B(K)
 490 A1(J,4)=B(4)*2*π*F(J)*0.088
 500 NEXT K
 510 NEXT J
```

```
520 PRINT"SET-UP OF FULL LINE SECTION
530 GOSUB 640
540 FOR J=1 TO 20
550 FOR K=1 TO 8
560 A2(J,K)=A3(J,K)
570 NEXT K
580 NEXT J
590 PRINT"SET-UP OF HALF LINE SECTION
600 D=0.915
610 GOSUB 640
620 GOTO 830
630 REM LINE FOMULAE
640 FOR J=1 TO 20
650 W=2*π*F(J)
660 S=SQR(W*C*R/2)*D
670 L=SQR(R/(2*W*C))
680 M=S/(R*D)
690 G=(EXP(S)-1/EXP(S))*COS(S)/2
700 H=(EXP(S)+1/EXP(S))*SIN(S)/2
710 D1=G+H
720 D2=G-H
730 A3(J,1)=H/TAN(S)
740 A3(J,2)=G*TAN(S)
750 A3(J,3)=L*D1
760 A3(J,4)=-L*D2
770 A3(J,5)=M*D2
780 A3(J,6)=M*D1
790 A3(J,7)=A3(J,1)
800 A3(J,8)=A3(J,2)
810 NEXTJ
820 RETURN
830 PRINT"CASCADING SECTIONS
840 FOR J=1 TO 20
850 FOR K=1 TO 8
860 M1(J,K)=A1(J,K)
870 M2(J,K)=A2(J,K)
880 NEXT K
890 NEXT J
900 GOSUB 1500
910 FORJ=1TO20:FORK=1TO8:M1(J,K)=M2(J,K):NEXTK:NEXTJ
920 IF G$="0.9" THEN 950
930 X=4
940 GOTO 960
950 X=10
960 PRINT"CASC FOR";X;"(C*F)"
970 FOR J=1 TO 20
980 M2(J,1)=1
990 FOR K=2 TO 6
1000 M2(J,K)=0
1010 NEXT K
1020 M2(J,7)=1
1030 M2(J,8)=0
1040 NEXT J
1050 FOR V=1 TO X
1060 PRINTV;
1070 GOSUB 1500
1080 NEXT V
1090 FOR J=1 TO 20
1100 FOR K=1 TO 8
1110 M1(J,K)=A3(J,K)
1120 NEXT K
1130 NEXT J
```

```
1140 GOSUB 1500
1150 FOR J=1 TO 20
1160 FOR K=1 TO 8
1170 M1(J,K)=M2(J,K)
1180 M2(J,K)=A1(J,K)
1190 NEXT K
1200 NEXT J
1210 GOSUB 1500
1220 FOR J=1 TO 20
1230 FOR K=1 TO 8
1240 M1(J,K)=M2(J,K)
1250 M2(J,K)=A3(J,K)
1260 NEXT K
1270 NEXT J
1280 GOSUB 1500
1290 Z$=",S,W":X$="@0:"
1300 Y$=X$+Y$+Z$
1310 OPEN2,8,2,Y$
1320 FORJ=1TO20
1330 FORK=1TO8:PRINT#2,M2(J,K);CHR$(13);:NEXTK:NEXTJ
1340 PRINT#2,C$;CHR$(13);D$;CHR$(13);E$
1350 CLOSE2
1360 PRINT:PRINT"LCJ (";G$;"MM) NOW SET-UP"
1370 PRINT"DO YOU WISH TO SET-UP LCJ AGAIN ";
1380 INPUT T$
1390 IF T$="YES" THEN1430
1400 IF T$="NO" THEN1440
1410 PRINT"▒WRONG INPUT▒-TRY AGAIN
1420 GOTO 1380
1430 CLR:GOTO180
1440 PRINT:PRINT"▒END OF SET-UP PROCEDURE"
1450 PRINT"▒FOR FIXED DATA FILES ON DISC 1"
1460 PRINT"▒▒PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
1470 GETA$:IFA$=""THEN1470
1480 LOAD"0:P1",8
1490 REM CASCADING ROUTINE
1500 FOR J=1 TO 20
1510 FOR K=1 TO 8
1520 NEXT K
1530 B(1)=M1(J,1)*M2(J,1)-M1(J,2)*M2(J,2)+M1(J,3)*M2(J,5)-M1(J,4)*M2(J,
1540 B(2)=M1(J,2)*M2(J,1)+M1(J,1)*M2(J,2)+M1(J,4)*M2(J,5)+M1(J,3)*M2(J,
1550 B(3)=M1(J,1)*M2(J,3)-M1(J,2)*M2(J,4)+M1(J,3)*M2(J,7)-M1(J,4)*M2(J,
1560 B(4)=M1(J,2)*M2(J,3)+M1(J,1)*M2(J,4)+M1(J,4)*M2(J,7)+M1(J,3)*M2(J,
1570 B(5)=M1(J,5)*M2(J,1)-M1(J,6)*M2(J,2)+M1(J,7)*M2(J,5)-M1(J,8)*M2(J,
1580 B(6)=M1(J,6)*M2(J,1)+M1(J,5)*M2(J,2)+M1(J,8)*M2(J,5)+M1(J,7)*M2(J,
1590 B(7)=M1(J,5)*M2(J,3)-M1(J,6)*M2(J,4)+M1(J,7)*M2(J,7)-M1(J,8)*M2(J,
1600 B(8)=M1(J,6)*M2(J,3)+M1(J,5)*M2(J,4)+M1(J,8)*M2(J,7)+M1(J,7)*M2(J,
1610 FOR K=1 TO 8
1620 M2(J,K)=B(K)
1630 NEXT K
1640 NEXT J
1650 RETURN
READY.
```

P4P4

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P4 (DISK 1)
110 PRINT" OPTIONS FOR CONNECTION ELEMENTS "
120 OPEN3,4:CMD3
130 PRINT"OPTIONS FOR CONNECTION ELEMENTS
140 PRINT"*******************************":PRINT:PRINT
150 PRINT"ELECTRICAL ELEMENTS
160 PRINT"___________________":PRINT
170 PRINT"SFB    STONE FEEDING BRIDGE
180 PRINT"HFB    HAYES FEEDING BRIDGE
190 PRINT"IFB    IDEAL FEEDING BRIDGE
200 PRINT"CHF    CHANNEL FILTER TYPE I4
210 PRINT"ATT    ATTENUATOR 600 OHMS, VARIABLE LOSS
220 PRINT"TXL    TRANSMISSION LINE
230 PRINT"        WITH VARIABLE PRIMARY CONSTANTS C&R
240 PRINT"ULC    UNLOADED CABLE WITH VARIABLE LENGTH
250 PRINT"        AND GAUGE [0.4 OR 0.5MM]
260 PRINT"LCJ    LOADED CABLE JUNCTION
270 PRINT"        [4.5DB LOSS], 0.6 OR 0.9MM GAUGE
280 PRINT"TFR    TRANSFORMER, TURNS RATIO INPUTTED
290 PRINT"        AS N. (IE, 1:N IS PRI:SEC)
300 PRINT"LAT    LATTICE, INPUT SERIES & 'SHUNT' IMPEDANCES
310 PRINT"        AS R AND/OR L AND/OR C
320 PRINT"MCC    MUTUALLY COUPLED COILS
330 PRINT"AAL    AT&T ARTIFICIAL LINE
340 PRINT:PRINT
350 PRINT"LCO   LUMPED COMPONENTS
360 PRINT"-------------------
370 PRINT"NOTE, IN CONNECTION SET-UP PROGRAM,
380 PRINT"AFTER INPUTTING LCO DESCRIBE WHICH OF
390 PRINT"THE FOLLOWING YOU WISH TO SET-UP:-":PRINT
400 PRINT"RSE   RESISTANCE IN SERIES
410 PRINT"LSE   INDUCTANCE IN SERIES
420 PRINT"CSE   CAPACITANCE IN SERIES
430 PRINT"ZSE   IMPEDANCE IN SERIES
440 PRINT"RSH   RESISTANCE IN SHUNT
450 PRINT"LSH   INDUCTANCE IN SHUNT
460 PRINT"CSH   CAPACITANCE IN SHUNT
470 PRINT"ZSH   IMPEDANCE IN SHUNT
480 PRINT#3,:CLOSE3
490 PRINT"PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
500 GETA$:IFA$=""THEN500
510 LOAD"0:P1",8
READY.
```

P5P5

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P5 (DISK 1)
110 REM INTERFACE POSITIONS
120 CLR
130 DIM A(20,8),M(20,8),W(8),P(4)
140 PRINT"INTERFACE POSITIONS"
150 D$="D 25":GOSUB1320
160 INPUT#2,N
170 DIMK(N)
180 FORI=1TON:INPUT#2,K(I):NEXTI:CLOSE2
190 D$="D 26":GOSUB1320
200 INPUT#2,T$,T:CLOSE2
210 PRINT"INTERFACES ARE:
220 PRINT"JUNCTION WEST (JW) & JUNCTION EAST (JE)
230 PRINT"INTERNAT WEST (IW) & INTERNAT EAST (IE)
240 PRINT"AFTER TYPING IN INTERFACE,GIVE IT'S      POSITION.
250 PRINT"IE,TYPE IN THE NUMBERS OF THE  TWO ELEMENTS
260 PRINT"BETWEEN    (IN ORDER OF
270 PRINT"POSITION OF JW  ";                       SEQUENCE)
280 GOSUB 510
290 P(1)=X
300 PRINT"NEXT INTERFACE  ";
310 INPUTD$
320 IFD$="JE"THEN380
330 IFD$="IW"THEN420
340 IFD$="JW"THEN490
350 IFD$="IE"THEN500
360 PRINT"INCORRECT ENTRY-TRY AGAIN
370 GOTO310
380 PRINT"POSITION OF JE  ";
390 GOSUB510
400 P(4)=X
410 GOTO530
420 PRINT"POSITION OF IW  ";
430 GOSUB510
440 P(2)=X
450 PRINT"POSITION OF IE  ";
460 GOSUB510
470 P(3)=X
480 GOTO380
490 PRINT"INCORRECT-JW HAS ALREADY BEEN TYPED IN - TRY AGAIN":GOTO 310
500 PRINT"INCORRECT-IW HAS NOT YET BEEN TYPED IN - TRY AGAIN":GOTO 310
510 INPUT"";X,Y
520 RETURN
530 PRINT"INPUT NOM. LOSS BETWEEN JW AND JE (DB)  ";
540 INPUT"";X
920 D$="D 26":GOSUB1330
925 PRINT#2,T$;CHR$(13);
930 FORI=1TO4:PRINT#2,P(I);CHR$(13);:NEXTI
940 PRINT#2,X;CHR$(13);T:CLOSE2
950 LOAD"0:P6",8
1320 F$=",S,R":E$="0:":GOTO1340
1330 F$=",S,W":E$="@0:"
1340 D$=E$+D$+F$
1350 OPEN2,8,2,D$
1360 RETURN
READY.
```

P6P6

```
 1 GOTO100
 5 LOAD"0:P1",8
 100 REM P6 (DISK 1)
 110 PRINT"▯█TELEPHONE OPTIONS██
 120 DIMA1(20,2),A2(20,2),A3(20),A4(20)
 130 PRINT"█INPUT OPTION FOR WEST TELEPHONE  ";
 140 GOSUB230
 150 D$="D 23":GOSUB420
 160 GOSUB310
 170 PRINT"█INPUT OPTION FOR EAST TELEPHONE  ";
 180 GOSUB230
 190 D$="D 24":GOSUB420
 200 GOSUB310
 210 PRINT"██TELEPHONE DATA NOW STORED
 220 LOAD"0:P7",8
 230 INPUTO$
 240 GOSUB370
 250 INPUT#2,O$
 260 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
 270 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
 280 FORJ=1TO20:INPUT#2,A3(J):NEXTJ
 290 FORJ=1TO20:INPUT#2,A4(J):NEXTJ
 300 CLOSE2:RETURN
 310 PRINT#2,O$;CHR$(13);
 320 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);CHR$(13);:NEXTK:NEXTJ
 330 FORJ=1TO20:FORK=1TO2:PRINT#2,A2(J,K);CHR$(13);:NEXTK:NEXTJ
 340 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
 350 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
 360 CLOSE2:RETURN
 370 F$=",S,R":E$="1:"
 390 D$=E$+O$+F$
 400 OPEN2,8,2,D$
 410 RETURN
 420 F$=",S,W":E$="@0:"
 430 D$=E$+D$+F$
 440 OPEN2,8,2,D$
 450 RETURN
READY.
```

P7P7

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P7 (DISK 1)
110 PRINT"▒▒▒CASCADING PROGRAM NOW RUNNING▒
120 CLR
130 DIM A(20,8),M(20,8),W(8),P(4)
150 D$="D 25":GOSUB1320
160 INPUT#2,N
170 DIMK(N)
180 FORI=1TON:INPUT#2,K(I):NEXTI:CLOSE2
190 D$="D 26":GOSUB1320
200 INPUT#2,T$
210 FORI=1TO4:INPUT#2,P(I):NEXTI
220 INPUT#2,X,T:CLOSE2
570 Q=T+27
580 GOSUB1230
590 FORI=1TOP(1)
600 GOSUB960
610 NEXTI
620 GOSUB1200
630 FORI=P(1)+1TOP(4)
640 GOSUB960
650 NEXTI
660 GOSUB1200
670 FORI=P(4)+1TON
680 GOSUB960
690 NEXTI
700 GOSUB1200
710 IFP(2)*P(3)=0THEN840
720 FORI=1TOP(2)
730 GOSUB960
740 NEXTI
750 GOSUB1200
760 FORI=P(2)+1TOP(3)
770 GOSUB960
780 NEXTI
790 GOSUB1200
800 FORI=P(3)+1TON
810 GOSUB960
820 NEXTI
830 GOSUB1200
840 D$="D"+STR$(Q):GOSUB1320
850 GOSUB980
860 D$="D"+STR$(Q+1):GOSUB1320
870 GOSUB980
880 D$="D"+STR$(Q+2):GOSUB1320
890 GOSUB980
900 GOSUB1150
910 PRINT"PRODUCT ARRAYS NOW IN DATA FILES
920 D$="D 26":GOSUB1330
925 PRINT#2,T$;CHR$(13);
930 FORI=1TO4:PRINT#2,P(I);CHR$(13);:NEXTI
940 PRINT#2,X;CHR$(13);Q:CLOSE2
950 LOAD"0:P8",8
960 D$="D"+STR$(K(I)):GOSUB1320
970 PRINT"I=";I
980 FORJ=1TO20
990 FORK=1TO8:INPUT#2,A(J,K):NEXTK:NEXTJ
1000 CLOSE2
```

```
1010 FORJ=1TO20
1020 W(1)=M(J,1)*A(J,1)-M(J,2)*A(J,2)+M(J,3)*A(J,5)-M(J,4)*A(J,6)
1030 W(2)=M(J,2)*A(J,1)+M(J,1)*A(J,2)+M(J,4)*A(J,5)+M(J,3)*A(J,6)
1040 W(3)=M(J,1)*A(J,3)-M(J,2)*A(J,4)+M(J,3)*A(J,7)-M(J,4)*A(J,8)
1050 W(4)=M(J,2)*A(J,3)+M(J,1)*A(J,4)+M(J,4)*A(J,7)+M(J,3)*A(J,8)
1060 W(5)=M(J,5)*A(J,1)-M(J,6)*A(J,2)+M(J,7)*A(J,5)-M(J,8)*A(J,6)
1070 W(6)=M(J,6)*A(J,1)+M(J,5)*A(J,2)+M(J,8)*A(J,5)+M(J,7)*A(J,6)
1080 W(7)=M(J,5)*A(J,3)-M(J,6)*A(J,4)+M(J,7)*A(J,7)-M(J,8)*A(J,8)
1090 W(8)=M(J,6)*A(J,3)+M(J,5)*A(J,4)+M(J,8)*A(J,7)+M(J,7)*A(J,8)
1100 FORU=1TO8
1110 M(J,U)=W(U)
1120 NEXTU
1130 NEXTJ
1140 RETURN
1150 D$="D"+STR$(Q+C):GOSUB1330
1160 FORJ=1TO20
1170 FORK=1TO8:PRINT#2,M(J,K);CHR$(13);:NEXTK:NEXTJ
1180 CLOSE2
1190 C=C+1:RETURN
1200 GOSUB1150
1210 GOSUB1230
1220 RETURN
1230 FORU=1TO8:READW(U):NEXT
1240 DATA1,0,0,0,0,0,1,0
1250 RESTORE
1260 FORR=1TO20
1270 FORH=1TO8
1280 M(R,H)=W(H)
1290 NEXTH
1300 NEXTR
1310 RETURN
1320 F$=",S,R":E$="0:":GOTO1340
1330 F$=",S,W":E$="@0:"
1340 D$=E$+D$+F$
1350 OPEN2,8,2,D$
1360 RETURN
1400 D$="D 25":GOSUB1320
READY.
```

```
1140 GOSUB 1500
1150 FOR J=1 TO 20
1160 FOR K=1 TO 8
1170 M1(J,K)=M2(J,K)
1180 M2(J,K)=A1(J,K)
1190 NEXT K
1200 NEXT J
1210 GOSUB 1500
1220 FOR J=1 TO 20
1230 FOR K=1 TO 8
1240 M1(J,K)=M2(J,K)
1250 M2(J,K)=A3(J,K)
1260 NEXT K
1270 NEXT J
1280 GOSUB 1500
1290 Z$=",S,W":X$="@0:"
1300 Y$=X$+Y$+Z$
1310 OPEN2,8,2,Y$
1320 FORJ=1TO20
1330 FORK=1TO8:PRINT#2,M2(J,K);CHR$(13);:NEXTK:NEXTJ
1340 PRINT#2,C$;CHR$(13);D$;CHR$(13);E$
1350 CLOSE2
1360 PRINT:PRINT"LCJ (";G$;"MM) NOW SET-UP"
1370 PRINT"DO YOU WISH TO SET-UP LCJ AGAIN ";
1380 INPUT T$
1390 IF T$="YES" THEN1430
1400 IF T$="NO" THEN1440
1410 PRINT"▒WRONG INPUT▒-TRY AGAIN
1420 GOTO 1380
1430 CLR:GOTO180
1440 PRINT:PRINT"▒END OF SET-UP PROCEDURE"
1450 PRINT"▒FOR FIXED DATA FILES ON DISC 1"
1460 PRINT"▒▒PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
1470 GETA$:IFA$=""THEN1470
1480 LOAD"0:P1",8
1490 REM CASCADING ROUTINE
1500 FOR J=1 TO 20
1510 FOR K=1 TO 8
1520 NEXT K
1530 B(1)=M1(J,1)*M2(J,1)-M1(J,2)*M2(J,2)+M1(J,3)*M2(J,5)-M1(J,4)*M2(J,6)
1540 B(2)=M1(J,2)*M2(J,1)+M1(J,1)*M2(J,2)+M1(J,4)*M2(J,5)+M1(J,3)*M2(J,6)
1550 B(3)=M1(J,1)*M2(J,3)-M1(J,2)*M2(J,4)+M1(J,3)*M2(J,7)-M1(J,4)*M2(J,8)
1560 B(4)=M1(J,2)*M2(J,3)+M1(J,1)*M2(J,4)+M1(J,4)*M2(J,7)+M1(J,3)*M2(J,8)
1570 B(5)=M1(J,5)*M2(J,1)-M1(J,6)*M2(J,2)+M1(J,7)*M2(J,5)-M1(J,8)*M2(J,6)
1580 B(6)=M1(J,6)*M2(J,1)+M1(J,5)*M2(J,2)+M1(J,8)*M2(J,5)+M1(J,7)*M2(J,6)
1590 B(7)=M1(J,5)*M2(J,3)-M1(J,6)*M2(J,4)+M1(J,7)*M2(J,7)-M1(J,8)*M2(J,8)
1600 B(8)=M1(J,6)*M2(J,3)+M1(J,5)*M2(J,4)+M1(J,8)*M2(J,7)+M1(J,7)*M2(J,8)
1610 FOR K=1 TO 8
1620 M2(J,K)=B(K)
1630 NEXT K
1640 NEXT J
1650 RETURN
ADY.
```

P8P8

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P8 (DISK 1)
110 PRINT"□▩CALCULATING INSERTION LOSSES▩▩
120 CLR
130 D=LOG(10)
140 DIMA1(20,2),A2(20,2),A3(20),A4(20),M1(20,2),M2(20,2),M3(20),M4(2
150 DIMX1(20),X2(20),L1(20),L2(20),S1(20),S2(20),P(4),A(20,8),Z(2,20)
160 D$="D 26":GOSUB2820
170 INPUT#2,T$
180 FORK=1TO4:INPUT#2,P(K):NEXTK
190 INPUT#2,X,Q:CLOSE2
200 IFP(2)*P(3)=0THEN220
210 G=7:GOTO230
220 G=4
230 D$="D 23":GOSUB2820
240 INPUT#2,S$
250 GOSUB3050
260 GOSUB640
270 PRINT"XTJ(W) ";
280 GOSUB3090
290 FORJ=1TO20:S1(J)=A1(J,1):S2(J)=A1(J,2):NEXTJ
300 GOSUB960
310 PRINT"XJJ ";
320 GOSUB3110
330 GOSUB960
340 PRINT"XJT(E) ";
350 D$="D 24":GOSUB2820
360 INPUT#2,S$
370 GOSUB3300
380 FORJ=1TO20
390 L1(J)=M1(J,1):L2(J)=M1(J,2):NEXTJ
400 GOSUB960
410 IFG=7THEN470
420 PRINT"XTT
430 FORJ=1TO20
440 S1(J)=A1(J,1):S2(J)=A1(J,2):NEXTJ
450 GOSUB670
460 GOTO620
470 PRINT"XTI(W)
480 GOSUB3090
490 FORJ=1TO20:S1(J)=A1(J,1):S2(J)=A1(J,2):NEXTJ
500 GOSUB960
510 PRINT"XII ";
520 GOSUB3110
530 GOSUB960
540 PRINT"XIT(E) ";
550 FORJ=1TO20
560 L1(J)=M1(J,1):L2(J)=M1(J,2):NEXTJ
570 GOSUB960
580 PRINT"XTT
590 FORJ=1TO20
600 S1(J)=A1(J,1):S2(J)=A1(J,2):NEXTJ
610 GOSUB670
620 PRINT"▩INSERTION LOSSES NOW COMPUTED
630 GOTO990
640 D$="D"+STR$(Q+C):GOSUB2820
```

```
650 GOSUB3130
660 RETURN
670 FORJ=1TO20
680 Y1=A(J,5)*S1(J)-A(J,6)*S2(J)
690 Y2=A(J,6)*S1(J)+A(J,5)*S2(J)
700 P1=L1(J)*Y1-L2(J)*Y2+A(J,3)
710 P2=L1(J)*Y2+L2(J)*Y1+A(J,4)
720 U1=S1(J)+L1(J)
730 U2=S2(J)+L2(J)
740 V1=A(J,1)*L1(J)-A(J,2)*L2(J)+A(J,7)*S1(J)-A(J,8)*S2(J)
750 V2=A(J,2)*L1(J)+A(J,1)*L2(J)+A(J,8)*S1(J)+A(J,7)*S2(J)
760 W1=V1+P1:W2=V2+P2
770 T1=W1*U1+W2*U2
780 IFABS(T1)>1E13THEN800
790 GOTO810
800 T1=1E13
810 T2=W2*U1-W1*U2
820 IFABS(T2)>1E13THEN840
830 GOTO870
840 T2=1E13
870 R=SQR(T1↑2+T2↑2)/(U1↑2+U2↑2)
880 X1(J)=20*LOG(R)/D
890 GOTO910
910 NEXTJ
920 D$="D"+STR$(Q+C+G)
930 C=C+1:GOSUB2830
940 FORJ=1TO20:PRINT#2,X1(J);CHR$(13);:NEXTJ
950 CLOSE2:RETURN
960 GOSUB670
970 GOSUB640
980 RETURN
990 PRINT"CALCULATING TRANSMISSION LOSSES
1000 C=2*G
1010 PRINT"SUMJ(W) SUJE(W)
1020 D$="D 23":GOSUB2820
1030 GOSUB2870
1040 D$="D"+STR$(Q+G):GOSUB2820
1050 GOSUB2990
1060 GOSUB1870
1070 IFG=4THEN1150
1080 PRINT"SUMI(W) SUIE(W)
1090 D$="D 23":GOSUB2820
1100 GOSUB2870
1110 D$="D"+STR$(Q+G+3):GOSUB2820
1120 GOSUB2990
1130 GOSUB1870
1140 GOTO1170
1150 FORJ=1TO20:A3(J)=0:A4(J)=0:NEXTJ
1160 GOSUB1920
1170 PRINT"SUMJ(E) SUJE(E)
1180 D$="D 24":GOSUB2820
1190 GOSUB2870
1200 D$="D"+STR$(Q+G+2):GOSUB2820
1210 GOSUB2990
1220 GOSUB1870
1230 IFG=4THEN1310
1240 PRINT"SUMI(E) SUIE(E)
1250 D$="D 24":GOSUB2820
1260 GOSUB2870
1270 D$="D"+STR$(Q+G+5):GOSUB2820
1280 GOSUB2990
1290 GOSUB1870
```

```
1300 GOTO1330
1310 FORJ=1TO20:A3(J)=0:A4(J)=0:NEXTJ
1320 GOSUB1920
1330 REM RETRIEVAL OF XJJ & XII
1340 D$="D"+STR$(Q+G+1):GOSUB2820
1350 FORJ=1TO20:INPUT#2,A3(J):NEXTJ:CLOSE2
1360 IFG=4THEN1400
1370 D$="D"+STR$(Q+11):GOSUB2820
1380 GOSUB2960
1390 GOTO1410
1400 FORJ=1TO20:A4(J)=0:NEXTJ
1410 GOSUB1920
1420 PRINT"ZL(W) ";
1430 D$="D 24":GOSUB2820
1440 INPUT#2,S$
1450 GOSUB3050
1460 D$="D"+STR$(Q+G-1):GOSUB2820
1470 GOSUB3130
1480 FORJ=1TO20
1490 S1=A1(J,1):S2=A1(J,2)
1500 S3=A(J,1)*S1-A(J,2)*S2+A(J,3)
1510 S8=S3:GOSUB3330
1520 S3=S8
1530 S4=A(J,2)*S1+A(J,1)*S2+A(J,4)
1540 S8=S4:GOSUB3330
1550 S4=S8
1560 S5=A(J,5)*S1-A(J,6)*S2+A(J,7)
1570 S8=S5:GOSUB3330
1580 S5=S8
1590 S6=A(J,6)*S1+A(J,5)*S2+A(J,8)
1600 S8=S6:GOSUB3330
1610 S6=S8
1620 GOSUB1990
1630 NEXTJ
1640 GOSUB1960
1650 PRINT"ZL(E) ";
1660 D$="D 23":GOSUB2820
1670 INPUT#2,S$
1680 GOSUB3050
1690 FORJ=1TO20
1700 S1=A1(J,1):S2=A1(J,2)
1710 S3=A(J,7)*S1-A(J,8)*S2+A(J,3)
1720 S8=S3:GOSUB3330
1730 S3=S8
1740 S4=A(J,8)*S1+A(J,7)*S2+A(J,4)
1750 S8=S4:GOSUB3330
1760 S4=S8
1770 S5=A(J,5)*S1-A(J,6)*S2+A(J,1)
1780 S8=S5:GOSUB3330
1790 S5=S8
1800 S6=A(J,6)*S1+A(J,5)*S2+A(J,2)
1810 S8=S6:GOSUB3330
1820 S6=S8
1830 GOSUB1990
1840 NEXTJ
1850 GOSUB1960
1860 GOTO2020
1870 FORJ=1TO20
1880 M=SQR((A1(J,1)+600)↑2+A1(J,2)↑2)
1890 A3(J)=A3(J)-X1(J)+20*LOG(1200/M)/D
1900 A4(J)=A4(J)-X1(J)+20*LOG(2*SQR(A1(J,1)↑2+A1(J,2)↑2)/M)/D
1910 NEXTJ
```

```
1920 D$="D"+STR$(Q+C):GOSUB2830
1930 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
1940 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
1950 C=C+1:CLOSE2:RETURN
1960 D$="D"+STR$(Q+C):GOSUB2830
1970 FORK=1TO2:FORJ=1TO20:PRINT#2,Z(K,J);CHR$(13);:NEXTJ:NEXTK
1980 C=C+1:CLOSE2:RETURN
1990 S7=S5↑2+S6↑2
2000 Z(1,J)=(S3*S5+S4*S6)/S7:Z(2,J)=(S4*S5-S6*S3)/S7
2010 RETURN
2020 PRINT"LUME ";
2030 D$="D"+STR$(Q+2*G-1):GOSUB2820
2040 GOSUB2990
2050 D$="D 23":GOSUB2820
2060 GOSUB2870
2070 D$="D 24":GOSUB2820
2080 GOSUB3150
2090 FORJ=1TO20
2100 S1=SQR((A1(J,1)+M1(J,1))↑2+(A1(J,2)+M1(J,2))↑2)
2110 S2=2*SQR(A1(J,1)↑2+A1(J,2)↑2)
2120 S3=2*SQR(M1(J,1)↑2+M1(J,2)↑2)
2130 A3(J)=X1(J)-A3(J)-M4(J)+20*LOG(S1/S3)/D
2140 A4(J)=X1(J)-M3(J)-A4(J)+20*LOG(S1/S2)/D
2150 NEXTJ
2160 GOSUB1920
2170 PRINT"XIMP
2180 D$="D"+STR$(Q+2*G):GOSUB2820
2190 FORJ=1TO20:INPUT#2,X1(J):NEXTJ
2200 FORJ=1TO20:INPUT#2,X2(J):NEXTJ:CLOSE2
2210 D$="D"+STR$(Q+2*G+2):GOSUB2820
2220 FORJ=1TO20:INPUT#2,M3(J):NEXTJ
2230 FORJ=1TO20:INPUT#2,M4(J):NEXTJ:CLOSE2
2240 FORJ=1TO20
2250 A3(J)=A3(J)+X1(J)+M4(J)-X
2260 A4(J)=A4(J)+M3(J)+X2(J)-X
2270 NEXTJ
2280 FORJ=1TO20:M3(J)=X:NEXTJ
2290 D$="D"+STR$(Q+C):GOSUB2830
2300 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
2310 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
2320 FORJ=1TO20:PRINT#2,M3(J);CHR$(13);:NEXTJ:CLOSE2
2330 C=C+1:PRINT"LMEST(W) ";
2340 D$="D 23":GOSUB2820
2350 GOSUB2870
2360 D$="D"+STR$(Q+2*G+5):GOSUB2820
2370 GOSUB3270
2380 GOSUB2500
2390 PRINT"LMEST(E)
2400 D$="D 24":GOSUB2820
2410 GOSUB2870
2420 D$="D"+STR$(Q+2*G+6):GOSUB2820
2430 GOSUB3270
2440 GOSUB2500
2450 GOTO2680
2460 D$="D"+STR$(Q+C):GOSUB2830
2470 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
2480 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
2490 C=C+1:RETURN
2500 FORJ=1TO20
2510 S1=SQR((Z(1,J)+A1(J,1))↑2+(Z(2,J)+A1(J,2))↑2)
2520 S2=SQR((A1(J,1)+A2(J,1))↑2+(A1(J,2)+A2(J,2))↑2)
2530 S3=2*SQR(A1(J,1)↑2+A1(J,2)↑2)
```

```
2540 S4=SQR((Z(1,J)-A2(J,1))↑2+(Z(2,J)-A2(J,2))↑2)
2550 IFS4=0THEN2570
2560 GOTO2580
2570 S4=1E-10
2580 A3(J)=-A3(J)-A4(J)+20*LOG(S1*S2/(S3*S4))/D
2590 NEXTJ
2600 D$="D"+STR$(Q+C):GOSUB2830
2610 GOSUB3020
2620 C=C+1:RETURN
2680 LOAD"0:P10",8
2685 PRINT"⌧PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM"
2690 GETA$:IFA$=""THEN2690
2700 LOAD"0:P1",8
2820 F$=",S,R":E$="0:":GOTO2840
2830 F$=",S,W":E$="@0:"
2840 D$=E$+D$+F$
2850 OPEN2,8,2,D$
2860 RETURN
2870 INPUT#2,W$
2880 FORJ=1TO20:FORK=1TO2
2890 INPUT#2,A1(J,K)
2900 NEXTK:NEXTJ
2910 FORJ=1TO20:FORK=1TO2
2920 INPUT#2,A2(J,K)
2930 NEXTK:NEXTJ
2940 FORJ=1TO20
2950 INPUT#2,A3(J):NEXTJ
2960 FORJ=1TO20
2970 INPUT#2,A4(J):NEXTJ
2980 CLOSE2:RETURN
2990 FORJ=1TO20
3000 INPUT#2,X1(J):NEXTJ
3010 CLOSE2:RETURN
3020 FORJ=1TO20
3030 PRINT#2,A3(J);CHR$(13);:NEXTJ
3040 CLOSE2:RETURN
3050 FORJ=1TO20:FORK=1TO2
3060 INPUT#2,A1(J,K)
3070 NEXTK:NEXTJ
3080 CLOSE2:RETURN
3090 FORJ=1TO20:L1(J)=600:L2(J)=0:NEXTJ
3100 CLOSE2:RETURN
3110 FORJ=1TO20:S1(J)=600:S2(J)=0:NEXTJ
3120 CLOSE2:RETURN
3130 FORJ=1TO20:FORK=1TO8:INPUT#2,A(J,K):NEXTK:NEXTJ
3140 CLOSE2:RETURN
3150 INPUT#2,E$
3160 FORJ=1TO20:FORK=1TO2
3170 INPUT#2,M1(J,K)
3180 NEXTK:NEXTJ
3190 FORJ=1TO20:FORK=1TO2
3200 INPUT#2,M2(J,K)
3210 NEXTK:NEXTJ
3220 FORJ=1TO20
3230 INPUT#2,M3(J):NEXTJ
3240 FORJ=1TO20
3250 INPUT#2,M4(J):NEXTJ
3260 CLOSE2:RETURN
3270 FORK=1TO2:FORJ=1TO20
3280 INPUT#2,Z(K,J):NEXTJ:NEXTK
3290 CLOSE2:RETURN
```

```
3300 FORJ=1TO20:FORK=1TO2
3310 INPUT#2,M1(J,K):NEXTK:NEXTJ
3320 CLOSE2:RETURN
3330 IFS8>1E12THENS8=1E12
3340 RETURN
READY.
```

P9P9

```
 100 REM P9 (DISK1)
 110 PRINT"□▒FILE LOCATION▯▯"
 120 PRINT"(FOR LOCATING FILES ON DISK1 WHEN IN      DRIVE 0)▯"
 130 D$="D 26":GOSUB630
 140 INPUT#2,T$
 150 FORK=1TO4:INPUT#2,P(K):NEXTK
 160 INPUT#2,X,Q:CLOSE2
 170 IFP(2)*P(3)=0THEN190
 180 G=7:GOTO200
 190 G=4
 200 Y=Q+G:Z=Y+G
 210 OPEN3,4:CMD3
 220 PRINTT$:PRINT
 230 PRINT"INSERTION LOSSES"
 240 PRINT"__________________":PRINT
 250 PRINT"DESCRIPTION","FILE NO."
 260 PRINT"-----------","--------"
 270 PRINT"XTJ(W)                    ";Y
 280 PRINT"XJJ                       ";Y+1
 290 PRINT"XJT(E)                    ";Y+2
 300 IFG=4THEN340
 310 PRINT"XTI(W)                    ";Y+3
 320 PRINT"XII                       ";Y+4
 330 PRINT"XIT(E)                    ";Y+5
 340 PRINT"XTT                       ";Y+G-1
 350 PRINT:PRINT:PRINT
 360 PRINT"TRANSMISSION LOSSES"
 370 PRINT"____________________":PRINT
 380 PRINT"DESCRIPTION","FILE NO."
 390 PRINT"-----------","--------"
 400 PRINT"SUMJ(W),SUJE(W)           ";Z
 410 PRINT"SUMI(W),SUIE(W)           ";Z+1
 420 Z=Z+1
 430 PRINT"SUMJ(E),SUJE(E)           ";Z+1
 440 IFG=4THEN460
 450 PRINT"SUMI(E),SUIE(E)           ";Z+2
 460 Z=Z+1
 470 PRINT"XJJ,XII                   ";Z+2
 480 PRINT"ZL(W) [RL&IM]             ";Z+3
 490 PRINT"ZL(E) [RL&IM]             ";Z+4
 500 PRINT"LUME(W-E),LUME(E-W)       ";Z+5
 510 PRINT"XIMP(W-E),XIMP(E-W),XL";Z+6
 520 PRINT"LMEST(W)                  ";Z+7
 530 PRINT"LMEST(E)                  ";Z+8
 540 PRINT#3:CLOSE3
 550 PRINT"IS ANY FURTHER INFORMATION REQUIRED ";
 560 INPUTR$
 570 IFR$="YES"THEN610
 580 IFR$="NO"THEN620
 590 GOSUB670
 600 GOTO560
 610 LOAD"0:P1",8
 620 PRINT"▯▯-------END-------":END
 630 F$=",S,R":E$="0:"
 640 D$=E$+D$+F$
 650 OPEN2,8,2,D$
 660 RETURN
 670 PRINT"▤INCORRECT INPUT▤-TRY AGAIN":RETURN
READY.
```

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P10 (DISK 1)
105 CLR
110 PRINT"CONNECTION DESCRIPTION RECALL"
120 D$="D 25":GOSUB1390
130 INPUT#2,N
140 DIMK(N),D(N),P(4),A(20,8)
150 FORI=1TON:INPUT#2,K(I):NEXTI
160 FORI=1TON:INPUT#2,D(I):NEXTI:CLOSE2
170 D$="D 26":GOSUB1390
180 INPUT#2,T$
190 FORI=1TO4:INPUT#2,P(I):NEXTI
200 INPUT#2,X:CLOSE2
210 D$="D 23":GOSUB1390
220 INPUT#2,W$:CLOSE2
230 D$="D 24":GOSUB1390
240 INPUT#2,E$:CLOSE2
250 A$="RSELSECSERSHLSHCSHTFRSFBHFBIFBCHFLCJATTULCTXLLATMCCALLZSEZSH
260 OPEN3,4
270 PRINT#3,T$
280 H$="**************************************************************
290 L=LEN(T$):H$=LEFT$(H$,L)
300 PRINT#3,H$:PRINT#3:PRINT#3
310 PRINT#3,"CONNECTION DESCRIPTION IS :-":PRINT#3:PRINT#3
320 PRINT#3,W$;"-";
330 IFN>10THEN440
340 FORI=1TON
350 GOSUB930
360 NEXTI
370 GOSUB960
380 GOSUB980
390 FORI=1TON
400 PRINT#3," ";I;"";
410 NEXTI
420 GOSUB1060
430 GOTO1100
440 IFN>20THEN560
450 GOSUB690
460 FORI=11TON
470 GOSUB930
480 NEXTI
490 GOSUB960
500 PRINT#3,"      ";
510 FORI=11TON
520 GOSUB1020
530 NEXTI
540 GOSUB1040
550 GOTO1100
560 IFN>30THEN1080
570 GOSUB690
580 GOSUB810
590 FORI=21TON
600 GOSUB930
610 NEXTI
620 GOSUB960
630 PRINT#3,"      ";
640 FORI=21TON
```

```
650 GOSUB1020
660 NEXTI
670 GOSUB1040
680 GOTO1100
690 FORI=1TO10
700 GOSUB930
710 NEXTI
720 PRINT#3
730 GOSUB980
740 FORI=1TO10
750 GOSUB1000
760 NEXTI
770 PRINT#3
780 PRINT#3
790 PRINT#3,"      ";
800 RETURN
810 FORI=11TO20
820 GOSUB930
830 NEXTI
840 PRINT#3
850 PRINT#3,"      ";
860 FORI=11TO20
870 GOSUB1020
880 NEXTI
890 PRINT#3
900 PRINT#3
910 PRINT#3,"      ";
920 RETURN
930 B$=MID$(A$,D(I),3)
940 PRINT#3,B$;"-";
950 RETURN
960 PRINT#3,E$
970 RETURN
980 PRINT#3,"(TW)";
990 RETURN
1000 PRINT#3," ";I;"";
1010 RETURN
1020 PRINT#3,"";I;"";
1030 RETURN
1040 PRINT#3,"(TE)"
1050 RETURN
1060 PRINT#3," (TE)"
1070 RETURN
1080 PRINT"NUMBER OF ELEMENTS IS TOO LARGE !"
1090 PRINT"(PROGRAMMED FOR A MAX. OF 30 ONLY)"
1100 PRINT#3:PRINT#3,"INTERFACE POSITIONS"
1110 PRINT#3,"-------------------":PRINT#3
1120 PRINT#3,"JW IS BETWEEN ELEMENTS ";P(1);" AND ";P(1)+1
1130 IFP(2)*P(3)=0THEN1160
1140 PRINT#3,"IW IS BETWEEN ELEMENTS ";P(2);" AND ";P(2)+1
1150 PRINT#3,"IE IS BETWEEN ELEMENTS ";P(3);" AND ";P(3)+1
1160 PRINT#3,"JE IS BETWEEN ELEMENTS ";P(4);" AND ";P(4)+1
1170 PRINT#3
1180 PRINT#3,"NOMINAL LOSS (JW-JE) =";X;" DB":PRINT#3
1190 PRINT#3:PRINT#3,"SUPPLEMENTARY INFORMATION"
1200 PRINT#3,"-------------------------"
1210 FORI=1TON
1220 D$="D"+STR$(K(I))
1230 GOSUB1390
1240 FORJ=1TO20:FORK=1TO8:INPUT#2,A(J,K):NEXTK:NEXTJ
1250 INPUT#2,C$,D$,E$:CLOSE2
1260 PRINT#3:PRINT#3,"ELEMENT";I;"  ";C$
```

```
 1270 PRINT#3,"                    ";D$
 1280 PRINT#3,"                    ";E$
 1290 NEXTI
 1295 LOAD"0:P11",8
 1300 PRINT"▒▒PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
 1310 GETA$:IFA$=""THEN1310
 1360 LOAD"0:P1",8
 1370 CLOSE2:PRINT#3:CLOSE3
 1380 PRINT"--------END-------":END
 1390 F$=",S,R":E$="0:"
 1400 D$=E$+D$+F$
 1410 OPEN2,8,2,D$
 1420 RETURN
READY.
```

P11P11

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P11 (DISK 1)
110 PRINT"□▧PRINT-OUT OF RESULTS FROM STAGE 2▧▧
120 CLR
130 DEFFNA(X)=INT(10*X+0.5)/10
140 DIMF(20),P(4),A(7,20)
150 FORJ=1TO20:READF(J):NEXTJ
160 DATA100,125,160,200,250,315,400,500,630,800
170 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
180 OPEN3,4
190 OPEN4,4,1
200 OPEN5,4,2
210 D$="D 26":GOSUB1620
220 INPUT#2,T$
230 FORI=1TO4:INPUT#2,P(I):NEXTI
240 INPUT#2,X,Q:CLOSE2
250 G=7:IFP(2)*P(3)=0THENG=4
260 PRINT"PRINTING OUT INSERTION LOSSES"
270 Y=Q+G:Z=Y+G
280 GOSUB1540
290 PRINT#3:PRINT#3
300 PRINT#3,T$
310 A$="*****************************************************************
320 L=LEN(T$)
330 A$=LEFT$(A$,L)
340 PRINT#3,A$:PRINT#3:PRINT#3
350 PRINT#3,"INSERTION LOSSES"
360 PRINT#3,"________________":PRINT#3
370 IFG=7THEN470
380 PRINT#3,"FREQ.(HZ)   XTJ(W)     XJJ      XJT(E)     XTT
390 PRINT#3,"---------   -------   ------   ------    ------
400 P1$="9999         S999.9   S999.9   S999.9    S999.9"
410 PRINT#5,P1$
420 FORJ=1TO20
430 PRINT#4,F(J),A(1,J),A(2,J),A(3,J),A(4,J)
440 NEXTJ
450 GOTO580
460 GOSUB1540
470 PRINT#3,"FREQ.(HZ)  XTJ(W)     XJJ     XJT(E)      ";
480 PRINT#3,"XTI(W)     XII      XIT(E)     XTT"
490 PRINT#3,"---------  ------    ------    ";
500 PRINT#3,"------     ------    ------    ------    ------"
510 P1$="9999        S999.9   S999.9   S999.9     "
520 P2$="S999.9   S999.9   S999.9   S999.9"
530 P3$=P1$+P2$
540 PRINT#5,P3$
550 FORJ=1TO20
560 PRINT#4,F(J),A(1,J),A(2,J),A(3,J),A(4,J),A(5,J),A(6,J),A(7,J)
570 NEXTJ
580 PRINT"PRINTING OUT TRANSMISSION LOSSES
590 PRINT#3:PRINT#3
600 PRINT#3,"TRANSMISSION LOSSES"
610 PRINT#3,"___________________":PRINT#3
620 PRINT#3,"FREQ.(HZ)  SUMJ(W)     SUJE(W)     SUMJ(E)     SUJE(E)
630 PRINT#3,"---------  -------     -------     -------     -------
640 D$="D"+STR$(Z):GOSUB1620
```

```
650 FORJ=1TO20:INPUT#2,A(1,J):NEXTJ
660 FORJ=1TO20:INPUT#2,A(2,J):NEXTJ
670 CLOSE2
680 D$="D"+STR$(Z+2):GOSUB1620
690 FORJ=1TO20:INPUT#2,A(3,J):NEXTJ
700 FORJ=1TO20:INPUT#2,A(4,J):NEXTJ
710 CLOSE2
720 D$="D"+STR$(Z+4):GOSUB1620
730 FORJ=1TO20:INPUT#2,A(5,J):NEXTJ
740 FORJ=1TO20:INPUT#2,A(6,J):NEXTJ
750 CLOSE2
760 GOSUB1470
770 IFG=4THEN910
780 PRINT#3:PRINT#3
790 PRINT#3,"FREQ.(HZ)  SUMI(W)      SUIE(W)      SUMI(E)      SUIE(E)
800 PRINT#3,"---------  -------      -------      -------      -------
810 D$="D"+STR$(Z+1):GOSUB1620
820 FORJ=1TO20:INPUT#2,A(1,J):NEXTJ
830 FORJ=1TO20:INPUT#2,A(2,J):NEXTJ
840 CLOSE2
850 D$="D"+STR$(Z+3):GOSUB1620
860 FORJ=1TO20:INPUT#2,A(3,J):NEXTJ
870 FORJ=1TO20:INPUT#2,A(4,J):NEXTJ
880 CLOSE2
890 FORJ=1TO20:A(5,J)=A(6,J):NEXTJ
900 GOSUB1470
910 REM PRINT OUT ZL'S
920 D$="D"+STR$(Z+5):GOSUB1620
930 FORK=1TO2:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
940 CLOSE2
950 D$="D"+STR$(Z+6):GOSUB1620
960 FORK=3TO4:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
970 CLOSE2
980 D$="D"+STR$(Z+8):GOSUB1620
990 FORK=5TO7:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
1000 CLOSE2
1010 FORK=1TO7:FORJ=1TO20:A(K,J)=FNA(A(K,J)):NEXTJ:NEXTK
1020 PRINT#3:PRINT#3
1030 PRINT#3,"FREQ.(HZ)  ZL(W)(RL)   ZL(W)(IM)   ZL(E)(RL)   ZL(E)(I
1040 PRINT#3,"---------  ---------   ---------   ---------   -------
1050 P1$="9999       S99999.9    S99999.9    S99999.9    S99999.9
1060 PRINT#5,P1$
1070 FORJ=1TO20
1080 PRINT#4,F(J),A(1,J),A(2,J),A(3,J),A(4,J),A(7,J)
1090 NEXTJ
1100 REM LUME
1110 D$="D"+STR$(Z+7):GOSUB1620
1120 FORK=1TO2:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
1130 CLOSE2
1140 FORK=1TO2:FORJ=1TO20:A(K,J)=FNA(A(K,J)):NEXTJ:NEXTK
1150 PRINT#3:PRINT#3
1160 PRINT#3,"FREQ.(HZ)  LUME(W-E)   LUME(E-W)   XIMP(W-E)   XIMP(E-
1170 PRINT#3,"---------  ---------   ---------   ---------   -------
1180 P1$="9999       S999.9      S999.9      S999.9      S999.9"
1190 PRINT#5,P1$
1200 FORJ=1TO20
1210 PRINT#4,F(J),A(1,J),A(2,J),A(5,J),A(6,J)
1220 NEXTJ
1230 REM LMEST
1240 D$="D"+STR$(Z+9):GOSUB1620
1250 FORJ=1TO20:INPUT#2,A(1,J):NEXTJ
1260 CLOSE2
```

```
 1270 D$="D"+STR$(Z+10):GOSUB1620
 1280 FORJ=1TO20:INPUT#2,A(2,J):NEXTJ
 1290 CLOSE2
 1300 FORK=1TO2:FORJ=1TO20:A(K,J)=FNA(A(K,J)):NEXTJ:NEXTK
 1310 PRINT#3:PRINT#3
 1320 PRINT#3,"FREQ.(HZ)  LMEST(W)     LMEST(E)
 1330 PRINT#3,"---------  --------     --------
 1340 P1$="9999        S999.9       S999.9"
 1350 PRINT#5,P1$
 1360 FORJ=1TO20
 1370 PRINT#4,F(J),A(1,J),A(2,J)
 1380 NEXTJ
 1390 PRINT#3:CLOSE3:PRINT#4:CLOSE4:PRINT#5:CLOSE5
 1400 PRINT" END OF PRINT-OUT FROM STAGE  2 "
 1410 PRINT"PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
 1420 FORI=1TO50:GOTO1450
 1430 NEXTI
 1440 GOSUB1660:GOTO1420
 1450 GETA$:IFA$=""THEN1430
 1460 LOAD"0:P1",8
 1470 FORI=1TO6:FORJ=1TO20:A(I,J)=FNA(A(I,J)):NEXTJ:NEXTI
 1480 P1$="9999        S999.9       S999.9       S999.9       S999.9
 1490 PRINT#5,P1$                                              S999.9 "
 1500 FORJ=1TO20
 1510 PRINT#4,F(J),A(1,J),A(2,J),A(3,J),A(4,J),A(5,J)
 1520 NEXTJ
 1530 RETURN
 1540 FORI=1TOG
 1550 D$="D"+STR$(Y):GOSUB1620
 1560 Y=Y+1
 1570 FORJ=1TO20
 1580 INPUT#2,A(I,J):NEXTJ
 1590 CLOSE2:NEXTI
 1600 FORI=1TOG:FORJ=1TO20:A(I,J)=FNA(A(I,J)):NEXTJ:NEXTI
 1610 RETURN
 1620 F$=",S,R":E$="0:"
 1630 D$=E$+D$+F$
 1640 OPEN2,8,2,D$
 1650 RETURN
 1660 POKE59459,255:FORI=1TO50:NEXT
 1670 POKE59459,0:RETURN
READY.
```

P12P12

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P12 (DISK 1)
110 GOSUB760
120 CLR
130 PRINT"TRANSFERRING RESULTS FROM STAGES 1 & 2   TO ARCHIVES "
140 PRINT"NOTE! SUPPLEMENTARY INFORMATION IS NOT    CARRIED FORWARD
150 PRINT"REMOVE DISK FROM DRIVE 1, AND (AFTER"
160 PRINT" CENTRALISING) INSERT ARCHIVES DISK
170 PRINT"PRESS SPACE BAR TO CONTINUE AND THEN      CLOSE DRIVE 1 DOO
180 GETA$:IFA$=""THEN180
190 OPEN1,8,15:PRINT#1,"I1"
200 REM RETREIVING RESULTS
210 D$="D 23":GOSUB700
220 INPUT#2,S$:CLOSE2
230 D$="D 24":GOSUB700
240 INPUT#2,R$:CLOSE2
250 D$="D 25":GOSUB700
260 INPUT#2,N
270 DIMK(N),D(N),P(4),A(21,20)
280 FORI=1TON:INPUT#2,K(I):NEXTI
290 FORI=1TON:INPUT#2,D(I):NEXTI
300 CLOSE2
310 D$="D 26":GOSUB700
320 INPUT#2,T$
330 FORI=1TO4:INPUT#2,P(I):NEXTI
340 INPUT#2,X,Q
350 CLOSE2
360 G=7:IFP(2)*P(3)=0THENG=4
370 S=Q+2*G:C=1
380 FORI=1TO8
390 D$="D"+STR$(S):GOSUB700
400 FORK=CTOC+1:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
410 CLOSE2:C=C+2:S=S+1:NEXTI
420 D$="D"+STR$(S):GOSUB700
430 FORK=17TO19:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
440 CLOSE2
450 D$="D"+STR$(S+1):GOSUB700
460 FORJ=1TO20:INPUT#2,A(20,J):NEXTJ
470 CLOSE2
480 D$="D"+STR$(S+2):GOSUB700
490 FORJ=1TO20:INPUT#2,A(21,J):NEXTJ
500 CLOSE2
510 REM TRANSFERRING RESULTS
520 C=0
530 D$="D 4":GOSUB720
540 INPUT#2,C:CLOSE2
550 C=C+1
560 D$="D 4":GOSUB730
570 PRINT#2,C:CLOSE2
580 D$="D"+STR$(C):GOSUB730
590 PRINT#2,T$;CHR$(13);S$;CHR$(13);R$;CHR$(13);N;CHR$(13);
600 FORI=1TO4:PRINT#2,P(I);CHR$(13);:NEXTI
610 FORI=1TON:PRINT#2,D(I);CHR$(13);:NEXTI
620 PRINT#2,X;CHR$(13);Q;CHR$(13);
```

```
630 FORK=1TO21:FORJ=1TO20:PRINT#2,A(K,J);CHR$(13);:NEXTJ:NEXTK
640 CLOSE2
650 PRINT" DESCRIPTION AND RESULTS FROM STAGE 2 "
660 PRINT"  NOW ARCHIVED "
670 PRINT"PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
680 GETA$:IFA$=""THEN680
690 LOAD"0:P1",8
700 D$="0:"+D$+",S,R"
710 GOTO750
720 E$="1:":F$=",S,R":GOTO740
730 E$="@1:":F$=",S,W"
740 D$=E$+D$+F$
750 OPEN2,8,2,D$:RETURN
760 POKE59459,255:FORI=1TO60:NEXTI
770 POKE59459,0:RETURN
READY.
```

DISK*DISK*

```
 100 REM DISKTRAN (DISK 2)
 110 REM TRANSFERING TEL. FILES FROM DISK 2 TO DISK 2 (SPARE)
 120 PRINT"▒ DISK 2 SHOULD BE IN DRIVE#1 AND DISK 2  (SPARE) IN DRIVE0
 130 PRINT"PRESS SPACE BAR TO CONTINUE▒"
 140 GETA$:IFA$=""THEN140
 150 OPEN1,8,15:PRINT#1,"I":CLOSE1
 160 DIMA1(20,2),A2(20,2),A3(20),A4(20)
 170 PRINT"TYPE IN NAME OF TEL. SET ":INPUTO$
 180 D$="1:"+O$+",S,R":OPEN2,8,2,D$
 190 INPUT#2,O$:PRINT"▒";O$
 200 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):PRINTA1(J,K):NEXTK:NEXTJ
 210 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):PRINTA2(J,K):NEXTK:NEXTJ
 220 FORJ=1TO20:INPUT#2,A3(J):PRINTA3(J):NEXTJ
 230 FORJ=1TO20:INPUT#2,A4(J):PRINTA4(J):NEXTJ:CLOSE2
 240 REM WRITING ON DISK 2 (SPARE)
 260 PRINT"▒▒PRESS SPACE BAR TO TRANSFER TO DISK 2    (SPARE)
 270 GETA$:IFA$=""THEN270
 290 D$="@0:"+O$+",S,W":OPEN2,8,2,D$
 300 PRINT#2,O$;CHR$(13);
 310 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);CHR$(13);:NEXTK:NEXTJ
 320 FORJ=1TO20:FORK=1TO2:PRINT#2,A2(J,K);CHR$(13);:NEXTK:NEXTJ
 330 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
 340 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ:CLOSE2
 350 PRINTO$" DATA NOW STORED ON DISK 2 (SPARE)
 360 PRINT"▒▒-------END-------":END
READY.
```

CHECKTELCHECKTEL

```
100 REM CHECKTEL
110 CLR
160 PRINT"TYPE IN DRIVE NO. OF DISK CONTAINING THE TELEPHONE DATA ";
170 GETD$:IFD$=""THEN170
180 PRINTD$
190 IFD$="0"THEN220
200 IFD$="1"THEN230
210 PRINT"INCORRECT DRIVE NO.-ANSWER 0 OR 1":GOTO170
220 F$=",S,R":E$="0:":GOTO240
230 F$=",S,R":E$="1:"
240 DEF FNA(X)=INT(10*X+0.5)/10
250 DIMF(20),A1(20,2),A2(20,2),A3(20),A4(20)
260 FORJ=1TO20:READF(J):NEXTJ
270 DATA100,125,160,200,250,315,400,500,630,800
280 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
290 PRINT"▒TYPE IN TELEPHONE SET NAME ";
300 INPUTO$
320 D$=E$+O$+F$
330 OPEN2,8,2,D$
340 INPUT#2,O$
350 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
360 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
370 FORJ=1TO20:INPUT#2,A3(J):NEXTJ
380 FORJ=1TO20:INPUT#2,A4(J):NEXTJ
390 CLOSE2
400 PRINT"▒IS OUTPUT TO BE IN CARTESIAN (CC) OR      POLAR (PC)
410 INPUTC$
420 IFC$="CC"THEN590
430 IFC$="PC"THEN460
440 GOSUB63999
450 GOTO410
460 FORJ=1TO20
470 M=360/(2*π)
480 D1=SQR(A1(J,1)↑2+A1(J,2)↑2)
490 IFA1(J,1)=0THENA1(J,1)=0.001
500 IFA1(J,2)=0THENA1(J,2)=0.001
510 A1(J,2)=ATN(A1(J,2)/A1(J,1))*M
520 A1(J,1)=D1
530 D2=SQR(A2(J,1)↑2+A2(J,2)↑2)
540 IFA2(J,1)=0THENA2(J,1)=0.001
550 IFA2(J,2)=0THENA2(J,2)=0.001
560 A2(J,2)=ATN(A2(J,2)/A2(J,1))*M
570 A2(J,1)=D2
580 NEXTJ
590 FORJ=1TO20
600 FORK=1TO2
610 A1(J,K)=FNA(A1(J,K))
620 A2(J,K)=FNA(A2(J,K))
630 NEXTK
640 A3(J)=FNA(A3(J))
650 A4(J)=FNA(A4(J))
660 NEXTJ
670 PRINT"▒ "O$" ▒▒"
675 PRINT"A1"
676 PRINT"—"
680 FORJ=1TO20:PRINTA1(J,1),A1(J,2):NEXT
685 PRINT"A2"
686 PRINT"—"
```

```
690 FORJ=1TO20:PRINTA2(J,1),A2(J,2):NEXT
695 PRINT"A3"
696 PRINT"—"
700 FORJ=1TO20:PRINTA3(J):NEXT
705 PRINT"A4"
706 PRINT"—"
710 FORJ=1TO20:PRINTA4(J):NEXT
READY.
```

```
TELD*TELD*

 100 REM TELDATA-TAPE
 110 PRINT"INSERT TEL.DATA TAPE AND REWIND
 120 PRINT" THEN PRESS SPACE BAR TO CONTINUE
 130 GETA$:IFA$=""THEN130
 140 PRINT"
                 TEL.DATA ARCHIVES"
 150 FORI=1TO2000:NEXT
 160 PRINT"    ┌───────┬───────────┬───────┬───────────┐
 170 PRINT"    |CODE   | PROGRAM   |CODE   | PROGRAM   |
 180 PRINT"    ├───────┼───────────┼───────┼───────────┤
 190 PRINT"    |  A    |  RSN1     |  G    |  WE5Z     |
 200 PRINT"    |       |           |       |           |
 210 PRINT"    |  B    |  746Z     |  H    |  WE5A     |
 220 PRINT"    |       |           |       |           |
 230 PRINT"    |  C    |  746A     |  I    |  WE5L     |
 240 PRINT"    |       |           |       |           |
 250 PRINT"    |  D    |  746L     |  J    |  DLS1     |
 260 PRINT"    |       |           |       |           |
 270 PRINT"    |  E    |  DIG1     |  K    |           |
 280 PRINT"    |       |           |       |           |
 290 PRINT"    |  F    |  DIG2     |  L    |           |
 300 PRINT"    └───────┴───────────┴───────┴───────────┘
 310 PRINT"      SELECT THE CODE YOU REQUIRE
 320 GETC$:IFC$=""GOTO320
 330 IFC$<"A"ORC$>"L"GOTO320
 340 BS=ASC(C$)-64
 350 BS=BS*2000
 360 FT=.11594+.13985E-2*BS-.71234E-8*BS↑2+.24540E-13*BS↑3-3.5562
 370 FT=FT*19.7134*5.073E-2
 380 PRINT"(CODE "C$" CHOSEN)
 390 PRINT"PRESS FAST FORWARD ON TAPE #1
 400 IFPEEK(59411)<>53GOTO400
 410 FT=TI+FT*60
 420 IFTI<FTGOTO420
 430 POKE249,52:POKE59411,61:PRINT"PRESS STOP ON TAPE #1
 440 IFPEEK(249)<>0GOTO440
 450 PRINT"WRITING DATA ONTO TAPE (WT)
 460 PRINT" OR READING FROM TAPE (RT)   ";
 470 INPUTT$
 480 IFT$="WT"THEN510
 490 IFT$="RT"THEN520
 500 PRINT"TRY AGAIN":GOTO470
 510 LOAD"1:TRANSTEL",8
 520 LOAD"1:TELTRANS",8
 530 END
READY.
```

```
 100 REM TRANSTEL  (DISK2)
 110 PRINT"▒▒TRANSFER OF TEL. FILES TO TAPE
 120 DIMA1(20,2),A2(20,2),A3(20),A4(20)
 130 PRINT"▒▒TYPE IN FILE NAME":INPUTO$
 140 D$="1:"+O$+",S,R":OPEN2,8,2,D$
 150 INPUT#2,O$
 160 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
 170 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
 180 FORJ=1TO20:INPUT#2,A3(J):NEXT
 190 FORJ=1TO20:INPUT#2,A4(J):NEXT:CLOSE2
 200 PRINT"▒▒WRITING "O$" ONTO TAPE▒
 210 OPEN2,1,1,O$
 220 PRINT#2,O$;",";
 230 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);",";:NEXTK:NEXTJ
 240 FORJ=1TO20:FORK=1TO2:PRINT#2,A2(J,K);",";:NEXTK:NEXTJ
 250 FORJ=1TO20:PRINT#2,A3(J);",";:NEXTJ
 260 FORJ=1TO20:PRINT#2,A4(J);",";:NEXTJ:CLOSE2
 270 PRINT"▒▒"O$" DATA NOW STORED ON TAPE
 280 PRINT"▒▒-------END-------":END
READY.
```

TELTRANSTELTRANS

```
 100 REM TELTRANS  (DISK2)
 110 PRINT"■■TRANSFER OF TAPED TEL.FILES TO DISK2
 120 DIMA1(20,2),A2(20,2),A3(20),A4(20)
 130 OPEN2,1,0
 140 INPUT#2,O$
 150 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
 160 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
 170 FORJ=1TO20:INPUT#2,A3(J):NEXT
 180 FORJ=1TO20:INPUT#2,A4(J):NEXT:CLOSE2
 190 PRINT"■■WRITING "O$" ONTO DISK■
 200 D$="@1:"+O$+",S,W":OPEN2,8,2,D$
 210 C$="CHR$(13)"
 220 PRINT#2,O$;C$;
 230 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);C$;:NEXTK:NEXTJ
 240 FORJ=1TO20:PRINT#2,A3(J);C$;:NEXTJ
 250 PRINT"■■"O$" DATA NOW STORED ON DISK
 260 PRINT"■■-------END-------":END
READY.
```

RSN1*RSN1*

```
 100 REM RSN1 SET-UP (DISK 2)
 110 CLR:O$="RSN1"
 120 GOSUB580
 130 DIMA(20,2),A1(20,2),A2(20,2),A3(20),A4(20),F(20)
 140 FORJ=1TO20:READF(J):NEXTJ
 150 DATA100,125,160,200,250,315,400,500,630,800,1000,1250,1600,2000
 160 DATA2500,3150,4000,5000,6300,8000
 170 D=LOG(10)
 180 PRINT"□▒SET-UP OF RSN1▒
 190 R1=230:R2=570:C=9.2E-8
 200 GOSUB520
 210 FORJ=1TO20:FORK=1TO2:A1(J,K)=A(J,K):NEXTK:NEXTJ
 220 R1=310:R2=1400:C=1.7E-7
 230 GOSUB520
 240 FORJ=1TO20:FORK=1TO2:A2(J,K)=A(J,K):NEXTK:NEXTJ
 250 FORJ=1TO20:READA3(J):NEXTJ
 260 REM SEND SENSITIVITY (SS600)
 270 DATA-34.6,-27.6,-20.1,-16.2,-13.2,-11.2,-9.9,-9.2,-8.8,-7.8
 280 DATA-6.6,-5.2,-3.4,-2.8,-1.6,-0.8,-6.4,-11.9,-19,-26.6
 290 FORJ=1TO20
 300 M=20*LOG(SQR((A1(J,1)+600)↑2+A1(J,2)↑2))/D
 310 A3(J)=A3(J)+M-20*LOG(1200)/D
 320 NEXTJ
 330 FORJ=1TO20:READA4(J):NEXTJ
 340 REM RECEIVE SENSITIVITY (SR600)
 350 DATA-10.6,-4.6,0.4,6,9.5,12.5,14.1,14.7,14.9,15.1,15.4,15.3
 360 DATA15.9,15.7,15.4,15.7,4.9,-8.9,-23.2,-37.2
 370 FORJ=1TO20
 380 M=20*LOG(SQR((A1(J,1)+600)↑2+A1(J,2)↑2))/D
 390 A4(J)=A4(J)+M-20*LOG(2*SQR(A1(J,1)↑2+A1(J,2)↑2))/D
 400 NEXTJ
 420 OPEN2,8,2,"@1:O$,S,W"
 430 PRINT#2,O$;CHR$(13);
 440 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);CHR$(13);:NEXTK:NEXTJ
 450 FORJ=1TO20:FORK=1TO2:PRINT#2,A2(J,K);CHR$(13);:NEXTK:NEXTJ
 460 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
 470 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
 480 CLOSE2
 490 PRINT"▒▒RSN1 NOW SET-UP
 500 PRINT"▒▒-------END-------":END
 510 POKE59459,255:FORI=1TO60:NEXTI
 520 FORJ=1TO20
 530 W=2*π*F(J)
 540 A(J,1)=R1+R2/(1+(W*C*R2)↑2)
 550 A(J,2)=-W*C*R2↑2/(1+(W*C*R2)↑2)
 560 NEXTJ
 570 RETURN
 580 POKE59459,255:FORI=1TO60:NEXTI
 590 POKE59459,0:RETURN
READY.
```

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P1 (DISK2)
110 CLR:GOSUB1580
120 PRINT"□▣▣ SET-UP OF TELEPHONE DATA "
130 PRINT"▣DO YOU WISH TO PRINT-OUT NAMES OF
135 PRINT" TEL.SETS STORED ON DISK ";
140 INPUTR$
150 IFR$="YES"THEN190
160 IFR$="NO"THEN300
170 GOSUB1510
180 GOTO140
190 OPEN3,4
200 PRINT#3,"STORED TELEPHONE DATA"
210 PRINT#3,"**********************":PRINT#3:PRINT#3
220 GOSUB1530
230 INPUT#2,N,T$:CLOSE2
235 K=1
240 FORI=1TON*4STEP4
250 O$=MID$(T$,I,4)
260 PRINT#3,K,O$
270 K=K+1:NEXTI
280 PRINT#3:PRINT#3
290 PRINT#3," ----------------":CLOSE3
300 DIMA(20,2),A1(20,2),A2(20,2),A3(20),A4(20),F(20),H(20)
310 FORJ=1TO20:READF(J):NEXTJ
320 DATA100,125,160,200,250,315,400,500,630,800,1000,1250,1600
330 DATA2000,2500,3150,4000,5000,6300,8000
340 D=LOG(10):D1=π/180
350 PRINT"▣TYPE IN TEL. SET NAME
360 INPUTO$
370 PRINT"□▣▣ SETTING-UP ";O$;" "
380 PRINT"▣NEW OR OLD FILE ";
390 INPUTT$
400 IFT$="OLD"THEN440
410 IFT$="NEW"THEN440
420 GOSUB1500
430 GOTO390
440 D$="OPTION":GOSUB1550
450 PRINT#2,O$:CLOSE2
460 IFT$="NEW"THEN480
470 LOAD"1:P2",8
480 PRINT"▣ARE YOU ENTERING ZC IN CARTESIAN (CC) OR POLAR (PC)
490 INPUTC$
500 IFC$="CC"THEN540
510 IFC$="PC"THEN590
520 GOSUB1500
530 GOTO490
540 PRINT"TYPE IN REAL AND IMAGINARY COMPONENTS OF ZC AS FOLLOWS:
550 GOSUB1220
560 GOSUB1600
570 FORJ=1TO20:FORK=1TO2:A1(J,K)=A(J,K):NEXTK:NEXTJ
580 GOTO630
590 PRINT"TYPE IN MODULUS AND ARGUMENT OF ZC        AS FOLLOWS:
600 GOSUB1290
610 GOSUB1810
620 GOTO570
630 PRINT"▣ARE YOU ENTERING ZSO IN CARTESIAN (CC)   OR POLAR (PC)
640 INPUTC$
650 IFC$="CC"THEN690
660 IFC$="PC"THEN740
```

```
670 GOSUB1500
680 GOTO640
690 PRINT"TYPE IN REAL AND IMAGINARY COMPONENTS OF ZSO AS FOLLOWS:"
700 GOSUB1220
710 GOSUB1600
720 FORJ=1TO20:FORK=1TO2:A2(J,K)=A(J,K):NEXTK:NEXTJ
730 GOTO780
740 PRINT"TYPE IN MODULUS AND ARGUMENT OF ZSO      AS FOLLOWS:
750 GOSUB1290
760 GOSUB1810
770 GOTO720
780 PRINT"▓DO YOU WISH TO SET-UP SS OR SS600
790 INPUTC$
800 IFC$="SS"THEN840
810 IFC$="SS600"THEN880
820 GOSUB1500
830 GOTO790
840 PRINT"TYPE IN SS AS EACH FREQUENCY DEMANDS
850 GOSUB1420
860 GOSUB2030
870 GOTO920
880 PRINT"TYPE IN SS600 AS EACH FREQUENCY DEMANDS
890 GOSUB1420
900 GOSUB2030
910 B=0:GOSUB1450
920 FORJ=1TO20:A3(J)=H(J):NEXTJ
930 PRINT"▓DO YOU WISH TO SET-UP SR OR SR600
940 INPUTC$
950 IFC$="SR"THEN990
960 IFC$="SR600"THEN1030
970 GOSUB1500
980 GOTO940
990 PRINT"TYPE IN SR AS EACH FREQUENCY DEMANDS
1000 GOSUB1420
1010 GOSUB2030
1020 GOTO1070
1030 PRINT"TYPE IN SR600 AS EACH FREQUENCY DEMANDS
1040 GOSUB1420
1050 GOSUB2030
1060 B=1:GOSUB1450
1070 FORJ=1TO20:A4(J)=H(J):NEXTJ
1080 GOSUB1540
1090 PRINT#2,O$;CHR$(13);
1100 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);CHR$(13);:NEXTK:NEXTJ
1110 FORJ=1TO20:FORK=1TO2:PRINT#2,A2(J,K);CHR$(13);:NEXTK:NEXTJ
1120 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
1130 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
1140 CLOSE2
1150 PRINT"▓▓"O$" TEL DATA NOW STORED
1160 GOSUB1530
1170 INPUT#2,N,T$:CLOSE2
1180 N=N+1:T$=T$+O$
1190 D$="STD":GOSUB1550
1200 PRINT#2,N;CHR$(13);T$:CLOSE2
1210 LOAD"1:P3",8
1220 FORJ=1TO20
1230 PRINT"▓";F(J);" HZ.","REAL VALUE  ";
1240 INPUT"▓▓▓▓▓▓";A(J,1)
1250 PRINT"              IMAG VALUE  ";
1260 INPUT"▓▓▓▓▓▓";A(J,2)
1270 NEXTJ
1280 RETURN
```

```
1290 FORJ=1TO20
1300 PRINT"▚";F(J);" HZ.","MODULUS  ";
1310 INPUT"▐▙▚▌▌▌▌";A(J,1)
1320 PRINT"                ARGUMENT  ";
1330 INPUT"▐▙▚▌▌▌▌";A(J,2)
1340 NEXTJ
1350 RETURN
1360 FORJ=1TO20
1370 D2=A(J,1)*COS(A(J,2)*D1)
1380 A(J,2)=A(J,1)*SIN(A(J,2)*D1)
1390 A(J,1)=D2
1400 NEXTJ
1410 RETURN
1420 FORJ=1TO20
1430 PRINTF(J);" HZ.  ";:INPUT"▐▙▚▌▌▌▌";H(J):NEXTJ
1440 RETURN
1450 FORJ=1TO20
1460 P=20*LOG(SQR((A1(J,1)+600)↑2+A1(J,2)↑2))/D
1465 IFB=1THEN1475
1470 H(J)=H(J)+P-20*LOG(1200)/D:GOTO1480
1475 H(J)=H(J)+P-20*LOG(2*SQR(A1(J,1)↑2+A1(J,2)↑2))/D
1480 NEXTJ
1490 RETURN
1500 GOSUB1580
1510 PRINT"▚INCORRECT ENTRY▀-TRY AGAIN
1520 RETURN
1530 D$="1:STD,S,R":GOTO1560
1540 D$="@1:"+O$+",S,W":GOTO1560
1550 D$="@1:"+D$+",S,W":GOTO1560
1560 D$=E$+D$+F$:OPEN2,8,2,D$
1570 RETURN
1580 POKE59459,255:FORI=1TO60:NEXTI
1590 POKE59459,0:RETURN
1600 REM CORRECTIONS (CARTESIAN)
1610 PRINT"▚ANY CORRECTIONS ";
1620 INPUTT$
1630 IFT$="YES"THEN1670
1640 IFT$="NO"THEN1680
1650 GOSUB1500
1660 GOTO1620
1670 GOSUB1690
1680 RETURN
1690 REM INSERTING CORRECTIONS (CARTESIAN)
1700 GOSUB2230
1710 PRINT"INSERT CORRECT VALUES
1720 PRINT"REAL ";:INPUT"▐▙▚▌▌▌▌";A(J,1
1730 PRINT"IMAG ";:INPUT"▐▙▚▌▌▌▌";A(J,2)
1740 PRINT"▚ANOTHER CORRECTION ";
1750 INPUTT$
1760 IFT$="YES"THEN1700
1770 IFT$="NO"THEN1800
1780 GOSUB1500
1790 GOTO1750
1800 RETURN
1810 REM CORRECTIONS (POLAR)
1820 PRINT"▚ANY CORRECTIONS ";
1830 INPUTT$
1840 IFT$="YES"THEN1880
1850 IFT$="NO"THEN1890
1860 GOSUB1500
1870 GOTO1830
1880 GOSUB1910
```

```
1890 GOSUB1360
1900 RETURN
1910 REM INSERTING CORRECTIONS (POLAR)
1920 GOSUB2230
1930 PRINT"INSERT CORRECT VALUES
1940 PRINT"MOD ";:INPUT"▶▶▶■■■";A(J,1)
1950 PRINT"ARG ";:INPUT"▶▶▶■■■";A(J,2)
1960 PRINT"■ANOTHER CORRECTION ";
1970 INPUTT$
1980 IFT$="YES"THEN1650
1990 IFT$="NO"THEN2020
2000 GOSUB1500
2010 GOTO1970
2020 RETURN
2030 REM CORRECTIONS (SENS)
2040 PRINT"ANY CORRECTIONS ";
2050 INPUTT$
2060 IFT$="YES"THEN2100
2070 IFT$="NO"THEN2110
2080 GOSUB1500
2090 GOTO2050
2100 GOSUB2120
2110 RETURN
2120 REM INSERTING CORRECTION (SENS)
2130 GOSUB2230
2140 PRINT"INSERT CORRECT VALUE ";
2150 INPUT"▶▶▶■■■";H(J)
2160 PRINT"■ANOTHER CORRECTION ";
2170 INPUTT$
2180 IFT$="YES"THEN2130
2190 IFT$="NO"THEN2220
2200 GOSUB1500
2210 GOTO2170
2220 RETURN
2230 PRINT"WHICH FREQUENCY ";:INPUT"▶▶▶■■■";F1
2240 J=INT(10*LOG(F1)/D-18.5):RETURN
READY.
```

P2P2

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P2(DISK2)
110 CLR:GOSUB1540
120 D$="OPTION":GOSUB1500
130 INPUT#2,O$:CLOSE2
140 PRINT"▒▒ MODIFYING OLD ";O$;" DATA FILE "
150 DIMA(20,2),A1(20,2),A2(20,2),A3(20),A4(20),F(20);H(20)
160 FORJ=1TO20:READF(J):NEXTJ
170 DATA100,125,160,200,250,315,400,500,630,800,1000,1250,1600
180 DATA2000,2500,3150,4000,5000,6300,8000
190 D=LOG(10):D1=π/180
200 GOSUB1510
210 GOSUB2210
220 PRINT"▒▒DO YOU WISH TO MODIFY ZC ";
230 INPUTT$
240 IFT$="YES"THEN280
250 IFT$="NO"THEN290
260 GOSUB1470
270 GOTO230
280 GOSUB500
290 PRINT"DO YOU WISH TO MODIFY ZSO ";
300 INPUTT$
310 IFT$="YES"THEN350
320 IFT$="NO"THEN360
330 GOSUB1470
340 GOTO300
350 GOSUB640
360 PRINT"DO YOU WISH TO MODIFY SENDING SENS. ";
370 INPUTT$
380 IFT$="YES"THEN 420
390 IFT$="NO"THEN430
400 GOSUB1470
410 GOTO370
420 GOSUB790
430 PRINT"DO YOU WISH TO MODIFY REC. SENS. ";
440 INPUTT$
450 IFT$="YES"THEN490
460 IFT$="NO"THEN1100
470 GOSUB1470
480 GOTO440
490 GOSUB940
500 PRINT"▒ARE YOU ENTERING ZC IN CARTESIAN (CC) OR POLAR (PC)
510 INPUTC$
520 IFC$="PC"THEN600
530 GOSUB1470
540 GOTO510
550 PRINT"TYPE IN REAL AND IMAGINARY COMPONENTS OF ZC AS FOLLOWS:
560 GOSUB1190
570 GOSUB1560
580 FORJ=1TO20:FORK=1TO2:A1(J,K)=A(J,K):NEXTK:NEXTJ
590 RETURN
600 PRINT"TYPE IN MODULUS AND ARGUMENT OF ZC        AS FOLLOWS:
610 GOSUB1260
620 GOSUB1770
630 GOTO580
640 PRINT"▒ARE YOU ENTERING ZSO IN CARTESIAN (CC)   OR POLAR (PC)
```

```
650 INPUTC$
660 IFC$="CC"THEN700
670 IFC$="PC"THEN750
680 GOSUB1470
690 GOTO650
700 PRINT"TYPE IN REAL AND IMAGINARY COMPONENTS OF ZSO AS FOLLOWS:"
710 GOSUB1190
720 GOSUB1560
730 FORJ=1TO20:FORK=1TO2:A2(J,K)=A(J,K):NEXTK:NEXTJ
740 RETURN
750 PRINT"TYPE IN MODULUS AND ARGUMENT OF ZSO      AS FOLLOWS:
760 GOSUB1260
770 GOSUB1770
780 GOTO730
790 PRINT"DO YOU WISH TO MODIFY AS SS OR SS600
800 INPUTC$
810 IFC$="SS"THEN850
820 IFC$="SS600"THEN890
830 GOSUB1470
840 GOTO800
850 PRINT"TYPE IN SS AS EACH FREQUENCY DEMANDS
860 GOSUB1390
870 GOSUB1990
880 GOTO930
890 PRINT"TYPE IN SS600 AS EACH FREQUENCY DEMANDS
900 GOSUB1390
910 GOSUB1990
920 B=0:GOSUB1420
930 FORJ=1TO20:A3(J)=H(J):NEXTJ:RETURN
940 PRINT"DO YOU WISH TO MODIFY AS SR OR SR600
950 INPUTC$
960 IFC$="SR"THEN1000
970 IFC$="SR600"THEN1040
980 GOSUB1470
990 GOTO950
1000 PRINT"TYPE IN SR AS EACH FREQUENCY DEMANDS
1010 GOSUB1390
1020 GOSUB1990
1030 GOTO1090
1040 PRINT"TYPE IN SR600 AS EACH FREQUENCY DEMANDS
1050 GOSUB1390
1060 GOSUB1990
1070 B=1:GOSUB1420
1080 GOTO1100
1090 FORJ=1TO20:A4(J)=H(J):NEXTJ
1100 GOSUB1520
1110 PRINT#2,O$;CHR$(13);
1120 FORJ=1TO20:FORK=1TO2:PRINT#2,A1(J,K);CHR$(13);:NEXTK:NEXTJ
1130 FORJ=1TO20:FORK=1TO2:PRINT#2,A2(J,K);CHR$(13);:NEXTK:NEXTJ
1140 FORJ=1TO20:PRINT#2,A3(J);CHR$(13);:NEXTJ
1150 FORJ=1TO20:PRINT#2,A4(J);CHR$(13);:NEXTJ
1160 CLOSE2
1170 PRINT""O$" TEL DATA NOW STORED
1180 LOAD"1:P3",8
1190 FORJ=1TO20
1200 PRINT"";F(J);" HZ.","REAL VALUE  ";
1210 INPUT"";A(J,1)
1220 PRINT"                  IMAG VALUE  ";
1230 INPUT"";A(J,2)
1240 NEXTJ
1250 RETURN
1260 FORJ=1TO20
1270 PRINT"";F(J);" HZ.","MODULUS  ";
```

```
1280 INPUT"▘▙▚▉▊▋";A(J,1)
1290 PRINT"              ARGUMENT   ";
1300 INPUT"▘▙▚▉▊▋";A(J,2)
1310 NEXTJ
1320 RETURN
1330 FORJ=1TO20
1340 D2=A(J,1)*COS(A(J,2)*D1)
1350 A(J,2)=A(J,1)*SIN(A(J,2)*D1)
1360 A(J,1)=D2
1370 NEXTJ
1380 RETURN
1390 FORJ=1TO20
1400 PRINTF(J);" HZ.  ";:INPUT"▘▙▚▉▊▋";H(J):NEXTJ
1410 RETURN
1420 FORJ=1TO20
1430 P=20*LOG(SQR((A1(J,1)+600)↑2+A1(J,2)↑2))/D
1435 IFB=1THEN1445
1440 H(J)=H(J)+P-20*LOG(1200)/D:GOTO1450
1445 H(J)=H(J)+P-20*LOG(2*SQR(A1(J,1)↑2+A1(J,2)↑2))/D
1450 NEXTJ
1460 RETURN
1470 GOSUB1540
1480 PRINT"▒INCORRECT ENTRY▔-TRY AGAIN
1490 RETURN
1500 D$="1:OPTION,S,R":GOTO1530
1510 D$="1:"+O$+",S,R":GOTO1530
1520 D$="@1:"+O$+",S,W"
1530 OPEN2,8,2,D$:RETURN
1540 POKE59459,255:FORI=1TO60:NEXTI
1550 POKE59459,0:RETURN
1560 REM CORRECTIONS (CARTESIAN)
1570 PRINT"▚ANY CORRECTIONS ";
1580 INPUTT$
1590 IFT$="YES"THEN1630
1600 IFT$="NO"THEN1640
1610 GOSUB1470
1620 GOTO1580
1630 GOSUB1650
1640 RETURN
1650 REM INSERTING CORRECTIONS (CARTESIAN)
1660 GOSUB2190
1670 PRINT"INSERT CORRECT VALUES
1680 PRINT"REAL ";:INPUT"▘▙▚▉▊▋";A(J,1)
1690 PRINT"IMAG ";:INPUT"▘▙▚▉▊▋";A(J,2)
1700 PRINT"▚ANOTHER CORRECTION ";
1710 INPUTT$
1720 IFT$="YES"THEN1660
1730 IFT$="NO"THEN1760
1740 GOSUB1470
1750 GOTO1710
1760 RETURN
1770 REM CORRECTIONS (POLAR)
1780 PRINT"▚ANY CORRECTIONS ";
1790 INPUTT$
1800 IFT$="YES"THEN1840
1810 IFT$="NO"THEN1850
1820 GOSUB1470
1830 GOTO1790
1840 GOSUB1870
1850 GOSUB1330
```

```
1860 RETURN
1870 REM INSERTING CORRECTIONS (POLAR)
1880 GOSUB2190
1890 PRINT"INSERT CORRECT VALUES
1900 PRINT"MOD ";:INPUT"▶◼▶◼◼◼";A(J,1)
1910 PRINT"ARG ";:INPUT"▶◼▶◼◼◼";A(J,2)
1920 PRINT"▒ANOTHER CORRECTION ";
1930 INPUTT$
1940 IFT$="YES"THEN1640
1950 IFT$="NO"THEN1980
1960 GOSUB1470
1970 GOTO1930
1980 RETURN
1990 REM CORRECTIONS (SENS)
2000 PRINT"ANY CORRECTIONS ";
2010 INPUTT$
2020 IFT$="YES"THEN2060
2030 IFT$="NO"THEN2070
2040 GOSUB1470
2050 GOTO2010
2060 GOSUB2080
2070 RETURN
2080 REM INSERTING CORRECTION (SENS)
2090 GOSUB2190
2100 PRINT"INSERT CORRECT VALUE ";
2110 INPUT"▶◼▶◼◼◼";H(J)
2120 PRINT"▒ANOTHER CORRECTION ";
2130 INPUTT$
2140 IFT$="YES"THEN2090
2150 IFT$="NO"THEN2180
2160 GOSUB1470
2170 GOTO2130
2180 RETURN
2190 PRINT"WHICH FREQUENCY ";:INPUT"▶◼▶◼◼◼";F1
2200 J=INT(10*LOG(F1)/D-18.5):RETURN
2210 INPUT#2,O$
2220 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
2230 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
2240 FORJ=1TO20:INPUT#2,A3(J):NEXTJ
2250 FORJ=1TO20:INPUT#2,A4(J):NEXTJ:CLOSE2:RETURN
READY.
```

P3P3

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P3 (DISK2)
110 CLR
120 OPEN2,8,2,"1:OPTION,S,R"
130 INPUT#2,O$:CLOSE2
140 PRINT"■■PRINTING-OUT "O$" TEL SET DATA
150 PRINT"---------------------------------
160 OPEN3,4
170 OPEN4,4,1
180 OPEN5,4,2
190 F$=",S,R":E$="1:"
200 DEF FNA(X)=INT(10*X+0.5)/10
210 DIMF(20),A1(20,2),A2(20,2),A3(20),A4(20)
220 FORJ=1TO20:READF(J):NEXTJ
230 DATA100,125,160,200,250,315,400,500,630,800
240 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
250 D$=E$+O$+F$
260 OPEN2,8,2,D$
270 INPUT#2,O$
280 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
290 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
300 FORJ=1TO20:INPUT#2,A3(J):NEXTJ
310 FORJ=1TO20:INPUT#2,A4(J):NEXTJ
320 CLOSE2
330 PRINT"■IS OUTPUT TO BE IN CARTESIAN (CC) OR     POLAR (PC)
340 INPUTC$
350 IFC$="CC"THEN520
360 IFC$="PC"THEN390
370 GOSUB870
380 GOTO340
390 FORJ=1TO20
400 M=360/(2*π)
410 D1=SQR(A1(J,1)↑2+A1(J,2)↑2)
420 IFA1(J,1)=0THENA1(J,1)=0.001
430 IFA1(J,2)=0THENA1(J,2)=0.001
440 A1(J,2)=ATN(A1(J,2)/A1(J,1))*M
450 A1(J,1)=D1
460 D2=SQR(A2(J,1)↑2+A2(J,2)↑2)
470 IFA2(J,1)=0THENA2(J,1)=0.001
480 IFA2(J,2)=0THENA2(J,2)=0.001
490 A2(J,2)=ATN(A2(J,2)/A2(J,1))*M
500 A2(J,1)=D2
510 NEXTJ
520 FORJ=1TO20
530 FORK=1TO2
540 A1(J,K)=FNA(A1(J,K))
550 A2(J,K)=FNA(A2(J,K))
560 NEXTK
570 A3(J)=FNA(A3(J))
580 A4(J)=FNA(A4(J))
590 NEXTJ
600 P1$="9999          S99.9        S99.9       "
610 IFC$="CC"THEN640
620 P2$="S9999.9  S99.9        S9999.9   S99.9"
630 GOTO650
640 P2$="S9999.9   S9999.9    S9999.9   S9999.9"
650 P3$=P1$+P2$
```

```
 660 PRINT#5,P3$
 670 IFC$="CC"THEN700
 680 C1$="POLAR CO-ORDINATES"
 690 GOTO710
 700 C1$="CARTESIAN CO-ORDINATES"
 710 PRINT#3:PRINT#3:PRINT#3,O$;" (";C1$;")":PRINT#3
 720 IFC$="CC"THEN780
 730 PRINT#3,"FREQ.(HZ)  SEND SENS  REC SENS   MOD ZC   ARG ZC";
 740 PRINT#3,"      MOD ZSO   ARG ZSO"
 750 PRINT#3,"---------  ---------  --------   ------   ------";
 760 PRINT#3,"      -------   -------"
 770 GOTO820
 780 PRINT#3,"FREQ.(HZ)  SEND SENS  REC SENS   ZC(RL)    ZC(IM)";
 790 PRINT#3,"      ZSO(RL)   ZSO(IM)"
 800 PRINT#3,"---------  ---------  --------   -------   -------";
 810 PRINT#3,"      -------   -------"
 820 FORJ=1TO20
 830 PRINT#4,F(J),A3(J),A4(J),A1(J,1),A1(J,2),A2(J,1),A2(J,2)
 840 NEXTJ
 850 CLOSE2:PRINT#3:CLOSE3:PRINT#4:CLOSE4:PRINT#5:CLOSE5
 860 PRINT"PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
 870 GETA$:IFA$=""THEN870
 880 LOAD"0:P1",8
READY.
```

PTFPTF

```
 100 REM 'PTF'
 110 PRINT"□▣HARD COPY OF TELEPHONE SET PARAMETERS▣▣"
 120 OPEN3,4
 130 OPEN4,4,1
 140 OPEN5,4,2
 150 PRINT#3:PRINT#3
 160 PRINT"TYPE IN DRIVE NO. OF DISK CONTAINING THE TELEPHONE DATA ";
 170 INPUTD$
 190 IFD$="0"THEN220
 200 IFD$="1"THEN230
 210 PRINT"INCORRECT DRIVE NO.-ANSWER 0 OR 1":GOTO170
 220 F$=",S,R":E$="0:":GOTO240
 230 F$=",S,R":E$="1:"
 240 DEF FNA(X)=INT(10*X+0.5)/10
 250 DIMF(20),A1(20,2),A2(20,2),A3(20),A4(20)
 260 FORJ=1TO20:READF(J):NEXTJ
 270 DATA100,125,160,200,250,315,400,500,630,800
 280 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
 290 PRINT"▣TYPE IN TELEPHONE DATA FILE NAME ";
 300 INPUTO$
 320 D$=E$+O$+F$
 330 OPEN2,8,2,D$
 340 INPUT#2,O$
 350 FORJ=1TO20:FORK=1TO2:INPUT#2,A1(J,K):NEXTK:NEXTJ
 360 FORJ=1TO20:FORK=1TO2:INPUT#2,A2(J,K):NEXTK:NEXTJ
 370 FORJ=1TO20:INPUT#2,A3(J):NEXTJ
 380 FORJ=1TO20:INPUT#2,A4(J):NEXTJ
 390 CLOSE2
 400 PRINT"▣IS OUTPUT TO BE IN CARTESIAN (CC) OR      POLAR (PC)
 410 INPUTC$
 420 IFC$="CC"THEN590
 430 IFC$="PC"THEN460
 440 GOSUB1010
 450 GOTO410
 460 FORJ=1TO20
 470 M=360/(2*π)
 480 D1=SQR(A1(J,1)↑2+A1(J,2)↑2)
 490 IFA1(J,1)=0THENA1(J,1)=0.001
 500 IFA1(J,2)=0THENA1(J,2)=0.001
 510 A1(J,2)=ATN(A1(J,2)/A1(J,1))*M
 520 A1(J,1)=D1
 530 D2=SQR(A2(J,1)↑2+A2(J,2)↑2)
 540 IFA2(J,1)=0THENA2(J,1)=0.001
 550 IFA2(J,2)=0THENA2(J,2)=0.001
 560 A2(J,2)=ATN(A2(J,2)/A2(J,1))*M
 570 A2(J,1)=D2
 580 NEXTJ
 590 FORJ=1TO20
 600 FORK=1TO2
 610 A1(J,K)=FNA(A1(J,K))
 620 A2(J,K)=FNA(A2(J,K))
 630 NEXTK
 640 A3(J)=FNA(A3(J))
 650 A4(J)=FNA(A4(J))
 660 NEXTJ
 670 P1$="9999          S99.9        S99.9      "
 680 IFC$="CC"THEN710
 690 P2$="S9999.9  S99.9        S9999.9   S99.9"
```

```
 700 GOTO720
 710 P2$="S9999.9   S9999.9    S9999.9   S9999.9"
 720 P3$=P1$+P2$
 730 PRINT#5,P3$
 740 IFC$="CC"THEN770
 750 C1$="POLAR CO-ORDINATES"
 760 GOTO780
 770 C1$="CARTESIAN CO-ORDINATES"
 780 PRINT#3:PRINT#3:PRINT#3,O$;" (";C1$;")":PRINT#3
 790 IFC$="CC"THEN850
 800 PRINT#3,"FREQ.(HZ)  SEND SENS  REC SENS   MOD ZC   ARG ZC";
 810 PRINT#3,"      MOD ZSO   ARG ZSO"
 820 PRINT#3,"---------  ---------  --------   ------   ------";
 830 PRINT#3,"      -------   -------"
 840 GOTO890
 850 PRINT#3,"FREQ.(HZ)  SEND SENS  REC SENS   ZC(RL)    ZC(IM)";
 860 PRINT#3,"      ZSO(RL)   ZSO(IM)"
 870 PRINT#3,"---------  ---------  --------   -------   -------";
 880 PRINT#3,"     -------   -------"
 890 FORJ=1TO20
 900 PRINT#4,F(J),A3(J),A4(J),A1(J,1),A1(J,2),A2(J,1),A2(J,2)
 910 NEXTJ
 920 PRINT"█RE-RUN ? ";
 930 INPUTC$
 950 IFC$="YES"THEN290
 960 IFC$="NO"THEN990
 970 GOSUB1010
 980 GOTO930
 990 CLOSE2:PRINT#3:CLOSE3:PRINT#4:CLOSE4:PRINT#5:CLOSE5
 1000 PRINT"██-----END-----":END
 1010 PRINT"█INCORRECT ENTRY█-TRY AGAIN
 1020 RETURN
READY.
```

DA*DA*

```
 100 REM 'DATUM'
 110 REM DATUM PROG FOR STORED TELEPHONE DATA
 120 PRINT"DATUM FOR STD
 130 PRINT"**************
 140 PRINT"N";:INPUT"";N
 150 INPUT"T$";T$
 160 REM N=NO OF TEL SET NAMES
 170 REM T$=CONCATENATION OF TEL SET NAMES
 180 OPEN2,8,2,"@1:STD,S,W"
 190 PRINT#2,N;CHR$(13);T$:CLOSE2
 200 PRINT"DATUM NOW SET
 210 PRINT"-----END-----"
READY.
```

STORED TELEPHONE DATA
****

1	RSN1
2	746Z
3	746A
4	746L
5	DIG1
6	DIG2
7	DLS1

P7P7

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P7 (DISK3)
110 CLR
120 GOSUB1040
130 DIMA(15,20),P(4)
140 D$="D 26":GOSUB980
150 INPUT#2,T$
160 FORI=1TO4:INPUT#2,P(I):NEXTI
170 INPUT#2,X,Q:CLOSE2
180 D$="D 23":GOSUB980
190 INPUT#2,S$:CLOSE2
200 D$="D 24":GOSUB980
210 INPUT#2,R$:CLOSE2
220 G=7:IFP(2)*P(3)=0THENG=4
230 S=Q+2*G:C=1
240 FORI=1TO5
250 D$="D"+STR$(S):GOSUB980
260 FORK=CTOC+1:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
270 CLOSE2:C=C+2:S=S+1:NEXTI
280 S=S+3:D$="D"+STR$(S):GOSUB980
290 FORK=11TO13:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
300 CLOSE2
310 K=14:GOSUB340
320 K=15:GOSUB340
330 GOTO370
340 D$="D"+STR$(S+1):GOSUB980
350 FORJ=1TO20:INPUT#2,A(K,J):NEXTJ
360 S=S+1:CLOSE2:RETURN
370 REM TRANSFERRING U1 & U3 FILES TO DISK 3
380 PRINT"TYPE IN 'ERASE' TO ERASE OLD R-FILES
390 INPUTE$
400 IFE$="ERASE"THEN440
410 GOSUB1040
420 PRINT"▒INCORRECT ENTRY▒-TRY AGAIN
430 GOTO390
440 R=99
450 FORR1=39TO40
460 D$="D"+STR$(R1)
470 GOSUB1000
480 FORI=1TO9:PRINT#2,R;CHR$(13);:NEXTI
490 CLOSE2:NEXTR1
500 PRINT"▒(OLD R-FILES NOW ERASED)
510 PRINT"TRANSFERRING NEW FILES
520 REM U1(W-E)
530 D$="D 16":GOSUB1000
540 K=1:GOSUB1080
550 K=6:GOSUB1080
560 K=9:GOSUB1080
570 K=3:GOSUB1080
580 K=8:GOSUB1080
590 K=10:GOSUB1080
600 CLOSE2
610 REM U3(W-E)
620 D$="D 17":GOSUB1000
630 K=13:GOSUB1080
640 K=11:GOSUB1080
650 K=14:GOSUB1080
660 CLOSE2
```

```
 670 REM U1(E-W)
 680 D$="D 18":GOSUB1000
 690 K=5:GOSUB1080
 700 K=2:GOSUB1080
 710 K=9:GOSUB1080
 720 K=7:GOSUB1080
 730 K=4:GOSUB1080
 740 K=10:GOSUB1080
 750 CLOSE2
 760 REM U3(E-W)
 770 D$="D 19":GOSUB1000
 780 K=13:GOSUB1080
 790 K=12:GOSUB1080
 800 K=15:GOSUB1080
 810 CLOSE2
 820 D$="D 20":GOSUB1000
 830 PRINT#2,G;CHR$(13);T$;CHR$(13);S$;CHR$(13);R$:CLOSE2
 840 PRINT"▒U-FILES NOW TRANSFERRED TO DISK 3
 850 PRINT"▒▒▒END OF STAGE 2
 860 PRINT"▒DO YOU WISH TO RUN STAGE 3 ";
 870 INPUT A$
 880 IFA$="YES"THEN930
 890 IFA$="NO"THEN940
 900 GOSUB1040
 910 PRINT"▒INCORRECT ENTRY▒-TRY AGAIN
 920 GOTO870
 930 LOAD"1:P35",8
 940 PRINT"▒▒-----END-----"
 950 PRINT"▒PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
 960 GETA$:IFA$=""THEN960
 970 LOAD"0:P1",8
 980 D$="0:"+D$+",S,R":GOTO1010
 990 E$="1:":F$=",S,R":GOTO1010
 1000 E$="@1:":F$=",S,W"
 1010 D$=E$+D$+F$
 1020 OPEN2,8,2,D$
 1030 RETURN
 1040 POKE59459,255
 1050 FORI=1TO60:NEXTI
 1060 POKE59459,0
 1070 RETURN
 1080 FORJ=1TO20:PRINT#2,A(K,J);CHR$(13);:NEXTJ
 1090 RETURN
READY.
```

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P5 (DISK 3)
110 PRINT"□▩ SETTING-UP LE FILES "
120 CLR:PRINT
130 GOSUB630
140 DIMF(20),T(20)
150 DATA100,125,160,200,250,315,400,500,630,800
160 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
170 REM LE (PROV 1)
180 DATA20,16.5,12.5,8.4,4.9,1,-0.7,-2.2,-2.6,-3.2,
190 DATA-2.3,-1.2,-0.1,3.6,7.4,6.7,8.8,10,12.5,15
200 FORI=1TO20:READF(I):NEXTI
210 PRINT"USE EXISTING PROV 1 VALUES ?"
220 INPUTR$
230 IFR$="YES"THEN260
240 IFR$="NO"THEN280
250 GOTO210
260 FORI=1TO20:READT(I):NEXTI
270 GOTO430
280 PRINT"TYPE IN VALUE OF LE AT EACH OF THE
290 PRINT" FOLLOWING FREQUENCIES:-▩"
300 FORI=1TO20:PRINTF(I);"HZ",
310 OPEN3,0:INPUT#3,T(I):CLOSE3:PRINT:NEXTI
320 PRINT"ANY CORRECTIONS?";:INPUTV$
330 IFV$="YES"THEN360
340 IFV$="NO"THEN430
350 GOTO320
360 PRINT"WHICH FREQUENCY? ";:INPUTF3
370 I=INT(10*LOG(F3)/LOG(10)-18.5)
380 PRINT"INSERT CORRECT VALUE ";:INPUTT(I)
390 PRINT"ANOTHER CORRECTION? ";:INPUTM$
400 IFM$="YES"THEN360
410 IFM$="NO"THEN430
420 GOTO390
430 PRINT"TYPE IN FILE NO. FOR STORING LE ":INPUTN
440 REM TRANSFER TO FILE
450 D$="D"+STR$(N):D$="@1:"+D$+",S,W"
460 OPEN2,8,2,D$:PRINT"WRITING LE INTO FILE NO.";N
470 FORI=1TO20:PRINT#2,T(I);CHR$(13);:NEXTI:CLOSE2
480 PRINT"DATA NOW STORED
490 PRINT"PRINTING-OUT LE
500 D$="D"+STR$(N):D$="1:"+D$+",S,R"
510 OPEN2,8,2,D$
520 FORI=1TO20:INPUT#2,T(I):NEXTI:CLOSE2
530 OPEN3,4:OPEN4,4,1:OPEN5,4,2
540 P$="9999         S99.9"
550 PRINT#5,P$
560 PRINT#3,"FILE D";N
570 PRINT#3,"_________":PRINT#3
580 PRINT#3,"FREQ.(HZ)      LE
590 PRINT#3,"---------    ------
600 FORI=1TO20:PRINT#4,F(I),T(I):NEXTI
610 PRINT#3:CLOSE3:PRINT#4:CLOSE4:PRINT#5:CLOSE5
620 PRINT"▩▩-------END-------":END
630 POKE59459,255:FORI=1TO60:NEXTI
640 POKE59459,0:RETURN
READY.
```

P13P13

```
 1 GOTO100
 5 LOAD"0:P1",8
 100 REM P13 (DISK 3)
 110 GOSUB460
 120 CLR
 130 PRINT"⌐☒ ALLOCATING T2-FILES TO WEST & EAST "
 140 PRINT"☒  TELEPHONES
 150 DIMT1(20),T2(20)
 160 D$="D 20":GOSUB480
 170 INPUT#2,G,T$,S$,R$
 180 CLOSE2
 190 IFS$="RSN1"THEN230
 200 IFS$="DIG1"THEN230
 210 IFS$="PTPW"THEN240
 220 W=8:GOTO250
 230 W=9:GOTO250
 240 W=10
 250 IFR$="RSN1"THEN290
 260 IFR$="DIG1"THEN290
 270 IFR$="PTPE"THEN300
 280 E=8:GOTO310
 290 E=9:GOTO310
 300 W=11
 310 D$="D"+STR$(W):GOSUB480
 320 FORJ=1TO20:INPUT#2,T1(J):NEXTJ:CLOSE2
 330 D$="D"+STR$(E):GOSUB480
 340 FORJ=1TO20:INPUT#2,T2(J):NEXTJ:CLOSE2
 350 REM STORE FOR W-E
 360 D$="D 14":GOSUB490
 370 FORJ=1TO20:PRINT#2,T1(J);CHR$(13);:NEXTJ
 380 FORJ=1TO20:PRINT#2,T2(J);CHR$(13);:NEXTJ:CLOSE2
 390 REM STORE FOR E-W
 400 D$="D 15":GOSUB490
 410 FORJ=1TO20:PRINT#2,T2(J);CHR$(13);:NEXTJ
 420 FORJ=1TO20:PRINT#2,T1(J);CHR$(13);:NEXTJ:CLOSE2
 430 GOSUB460
 440 PRINT"☒FILES NOW ALLOCATED
 450 LOAD"1:P35",8
 460 POKE59459,255:FORI=1TO60:NEXTI
 470 POKE59459,0:RETURN
 480 E$="1:":F$=",S,R":GOTO500
 490 E$="@1:":F$=",S,W"
 500 D$=E$+D$+F$
 510 OPEN2,8,2,D$
 520 RETURN
READY.
```

P35P35'

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P35 (DISK 3)
110 PRINT"⌧⌧ CALCULATING LOUDNESS RATINGS ⌧"
120 CLR:GOSUB860
130 A$="W-E"
140 DIMF(2,20),T2(20),U1(6,20),U3(3,20),B(20),W(5,20),Y(20),L1(20),
                                                              R(20)
150 REM ISO FREQUENCIES AND BANDWIDTHS
160 DATA 100,125,160,200,250,315,400,500,630,800
170 DATA 1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
180 DATA 22.4,29.6,37.5,44.7,57,74.3,92.2,114,149,184
190 DATA 224,296,375,447,570,743,922,1140,1490,1840
200 REM READING FREQUENCY DATA
210 FORJ=1TO2:FORI=1TO20:READF(J,I):NEXTI:NEXTJ
220 REM W-WEIGHTING FOR LR (CITT P.XXE)
230 REM SLR W(1,I)
240 DATA 152,126,104,82.5,66.7,54.1,45.1,37.4,36.2,35.5
250 DATA 38.8,41.1,42.4,48.6,52.7,54.1,106,135,171,188
260 REM RLR W(2,I)
270 DATA 150,127,107,90.6,78.8,71.1,64.1,57.8,56.8,55.9
280 DATA 57.4,57.1,56,57.8,56.6,58.2,103,123,149,173
290 REM JLR W(3,I)
300 DATA 198,162,130,102,81,64.9,53.5,44.3,42.3,40.4
310 DATA 42.5,43.2,43,48.3,50.9,52.3,144,188,245,278
320 REM OLR W(4,I)
330 DATA 104,91.1,81.2,71.4,64.5,60.3,55.7,50.9,50.7,51
340 DATA 53.7,54.8,55.4,58.1,58.4,60,66.1,70.6,75.2,82.6
350 REM STM W(5,I) (LMEHS WITH LEAK)
360 DATA 94.4,90.4,89.8,86.4,81.9,78.5,78.2,72.8,67.6,58.4
370 DATA 49.7,48,48.7,50.6,49.8,48.4,49.2,48.3,48.1,51.7
380 REM READING W-WEIGHTING DATA
390 FORJ=1TO5:FORI=1TO20:READW(J,I):NEXTI,J
400 REM B'S DATA (FROM STL CONVERSATIONS)
410 DATA56,61.1,62.5,64.3,64,60.7,59.8,59.4,56.3,52.4
420 DATA47.6,45.2,44,41.4,38.8,34.7,31,27.8,26.1,25.5
430 REM READING B'S (SPEECH SPECTRUM) DATA
440 FORI=1TO20:READB(I):NEXTI
442 REM LE (PROV-1)
443 DATA 20,16.5,12.5,8.4,4.9,1,-.7,-2.2,-2.6,-3.2,0
444 DATA -2.3,-1.2,-.1,3.6,7.4,6.7,8.8,10,12.5
446 REM READING LE
448 FORI=1TO20:READT2(I):NEXTI
450 V1=16:V3=17:M1=39:GOTO510
460 V1=18:V3=19:M1=40
510 REM INPUTTING U1 & U3
520 D$="D"+STR$(V1):GOSUB830
530 FORK=1TO6:FORJ=1TO20:INPUT#2,U1(K,J):NEXTJ:NEXTK:CLOSE2
540 D$="D"+STR$(V3):GOSUB830
550 FORK=1TO3:FORJ=1TO20:INPUT#2,U3(K,J):NEXTJ:NEXTK:CLOSE2
560 PRINT"⌧USING T2-, U1- & U3-FILES TO SET UP LUME ("A$;")"
570 FORI=1TO20:L1(I)=-U1(1,I)+U3(1,I)+U3(2,I)-U1(2,I)+T2(I):NEXTI
580 PRINT"CALCULATING LOUDNESS RATINGS (";A$;")"
590 GOTO630
600 REM SUBROUTINE FOR LR
610 M=.225:S=0:FORI=1TO20:S=S+10↑(M*(Y(I)-W(J,I))/10):NEXT
620 R(K)=-10*LOG(S)/LOG(10)/M:RETURN
630 REM SLR, RLR, JLR, SLR(N), RLR(N), JLR(I), OLR, STLR, STMR
640 J=1:K=1:FORI=1TO20:Y(I)=U1(1,I):NEXTI:GOSUB600
```

```
650 J=2:K=2:FORI=1TO20:Y(I)=U1(2,I)-T2(I):NEXTI:GOSUB600
660 J=3:K=3:FORI=1TO20:Y(I)=-U1(3,I):NEXTI:GOSUB600
670 IFG=4THEN710
680 J=1:K=4:FORI=1TO20:Y(I)=U1(4,I):NEXTI:GOSUB600
690 J=2:K=5:FORI=1TO20:Y(I)=U1(5,I)-T2(I):NEXTI:GOSUB600
700 J=3:K=6:FORI=1TO20:Y(I)=-U1(6,I):NEXTI:GOSUB600
710 J=4:K=7:FORI=1TO20:Y(I)=-L1(I):NEXTI:GOSUB600
720 J=4:K=8:FORI=1TO20:Y(I)=-U3(3,I)-T2(I):NEXTI:GOSUB600
730 J=5:K=9:FORI=1TO20:Y(I)=-U3(3,I)-T2(I):NEXTI:GOSUB600
740 B$=LEFT$(A$,1)
750 PRINT"CALCULATING VL(";B$;")"
760 PRINT" (SPEECH VOLTAGE AT J";B$")"
770 S=0:FORI=1TO20:S=S+10↑((B(I)-94+U1(1,I))/10)*F(2,I):NEXT
780 VL=10*LOG(S)/LOG(10)
790 D$="D"+STR$(M1):GOSUB840
800 FORI=1TO9:PRINT#2,R(I);CHR$(13);:NEXTI:PRINT#2,VL:CLOSE2
810 IFA$="W-E"THENA$="E-W":GOTO460
820 LOAD"1:P45",8
830 E$="1:":F$=",S,R":GOTO850
840 E$="@1:":F$=",S,W"
850 D$=E$+D$+F$:OPEN2,8,2,D$:RETURN
860 POKE59459,255:FORI=1TO60:NEXTI
870 POKE59459,0:RETURN
READY.
```

P45P45

```
  1 GOTO100
  5 LOAD"0:P1",8
 100 REM P45 (DISK 3)
 110 CLR:GOSUB480
 120 DIMR1(9),R2(9):OPEN3,4
 130 DEFFNA(X)=INT(X*10+0.5)/10
 140 D$="D 20":GOSUB460
 150 INPUT#2,G,T$:CLOSE2
 160 PRINT"□▣ PRINTING-OUT OF LOUDNESS RATINGS "
 170 D$="D 39":GOSUB460
 180 FORJ=1TO9:INPUT#2,R1(J):NEXTJ:INPUT#2,V1:CLOSE2
 190 FORJ=1TO9:R1(J)=FNA(R1(J)):NEXTJ:V1=FNA(V1)
 200 D$="D 40":GOSUB460
 210 FORJ=1TO9:INPUT#2,R2(J):NEXTJ:INPUT#2,V2:CLOSE2
 220 FORJ=1TO9:R2(J)=FNA(R2(J)):NEXTJ:V2=FNA(V2)
 230 PRINT#3:PRINT#3
 240 PRINT#3,"LOUDNESS RATINGS  (";T$;")"
 250 PRINT#3,"****************":PRINT#3
 260 PRINT#3,"(WEST TO EAST)                    (EAST TO WEST)"
 270 PRINT#3,"--------------                    --------------"
 280 A$="    SLR =":B$=A$:I=1:GOSUB440
 290 A$="    RLR =":B$=A$:I=2:GOSUB440
 300 A$="    JLR =":B$=A$:I=3:GOSUB440
 310 IFG=4THEN350
 320 A$=" SLR(N) =":B$=A$:I=4:GOSUB440
 330 A$=" RLR(N) =":B$=A$:I=5:GOSUB440
 340 A$="    ILR =":B$=A$:I=6:GOSUB440
 350 A$="    OLR =":B$=A$:I=7:GOSUB440
 360 A$="STLR(W) =":B$="STLR(E) =":I=8:GOSUB440
 370 A$="STMR(W) =":B$="STMR(E) =":I=9:GOSUB440
 380 PRINT#3
 390 PRINT#3,"  VL(W) =";V1;CHR$(141);TAB(28);"   VL(E) =";V2
 400 GOSUB480:PRINT"▣▣▣END OF STAGE 3
 410 PRINT"▣▣PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM
 420 GETA$:IFA$=""THEN420
 430 LOAD"0:P1",8
 440 PRINT#3,A$;R1(I);CHR$(141);TAB(28);B$;R2(I)
 450 RETURN
 460 D$="1:"+D$+",S,R":OPEN2,8,2,D$
 470 RETURN
 480 POKE59459,255:FORI=1TO60:NEXTI
 490 POKE59459,0:RETURN
READY.
```

```
 100 REM DATUM (ARCHIVES DISK)
 110 PRINT"□▣ DATUM FOR STORAGE OF STAGE 2 DATA "
 120 PRINT"▣  ON ARCHIVES DISK
 130 PRINT"▣▣TYPE IN FILE NO. FOR START OF STORAGE
 140 PRINT" (INITIALLY 10 FOR A CLEAN DISK ";
 150 INPUTC
 160 C=C-1
 170 OPEN2,8,2,"@1:D 4,S,W"
 180 PRINT#2,C:CLOSE2
 190 PRINT"▣DATUM NOW SET AT";C+1
 200 PRINT"▣▣-------END-------":END
READY.
```

P2P2

```
 1 GOTO100
 5 LOAD"0:P1",8
 100 REM P2 (ARCHIVES DISK)
 110 CLR
 120 GOSUB530
 130 PRINT"CONNECTION LOCATION"
 140 OPEN3,4
 150 PRINT#3,"TITLE"," "," ","FILE N0."
 160 PRINT#3,"-----"," "," ","--------"
 170 D$="D 4":GOSUB450
 180 INPUT#2,C
 190 CLOSE2
 200 FORK=1TOC-9
 210 D$="D"+STR$(K+9):GOSUB450
 220 INPUT#2,T$
 230 CLOSE2
 240 PRINT#3,T$," "," ",K+9
 250 NEXTK
 260 PRINT"DO YOU WISH TO LOCATE A FILE ";
 270 INPUTT$
 280 IFT$="YES"THEN310
 290 IFT$="NO"THEN570
 300 GOSUB500
 310 PRINT"WHICH FILE NUMBER DO YOU REQUIRE ";
 320 INPUTF
 330 D$="D 4":GOSUB460
 340 PRINT#2,C;CHR$(13);F
 350 CLOSE2
 360 PRINT"DO YOU WISH TO PRINT-OUT CONNECTION PLUS U-FILES (DU)
 370 PRINT"OR TRANSFER CONNECTION ETC. TO DISK 3 (TR) ";
 380 INPUTT$
 390 IFT$="DU"THEN430
 400 IFT$="TR"THEN440
 410 GOSUB500
 420 GOTO380
 430 LOAD"1:P6",8
 440 LOAD"1:P8",8
 450 E$="1:":F$=",S,R"
 460 E$="@1:":F$=",S,W"
 470 D$=E$+D$+F$
 480 OPEN2,8,2,D$
 490 RETURN
 500 GOSUB530
 510 PRINT"INCORRECT ENTRY-TRY AGAIN"
 520 RETURN
 530 POKE59459,255
 540 FORI=1TO60:NEXTI
 550 POKE59459,0
 560 RETURN
 570 PRINT"PRESS SPACE BAR TO RETURN TO INFORMATION PROGRAM"
 580 GETA$:IFA$=""THEN580
 590 LOAD"0:P1",8
READY.
```

P7P7

```
 1 GOTO100
 5 LOAD"0:P1",8
 100 REM P7 (ARCHIVES DISK)
 110 CLR
 120 GOSUB970
 130 PRINT"]■ PRINTING OUT CONNECTION AND U-FILES "
 140 DEFFNA(X)=INT(10*X+0.5)/10
 150 DIMF(20)
 160 FORJ=1TO20:READF(J):NEXTJ
 170 DATA100,125,160,200,250,315,400,500,630,800
 180 DATA1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
 190 D$="D 4":GOSUB950
 200 INPUT#2,S,T
 210 CLOSE2
 220 D$="D"+STR$(T):GOSUB950
 230 INPUT#2,T$,S$,R$,N
 240 CLOSE2
 250 DIMA(21,20),P(4),D(N)
 260 D$="D"+STR$(T):GOSUB950
 270 INPUT#2,T$,S$,R$,N
 280 FORI=1TO4:INPUT#2,P(I):NEXTI
 290 FORI=1TON:INPUT#2,D(I):NEXTI
 300 INPUT#2,X,Q
 310 FORK=1TO21:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
 320 CLOSE2
 330 FORK=1TO21:FORJ=1TO20:A(K,J)=FNA(A(K,J)):NEXTJ:NEXTK
 340 IFP(2)*P(3)=0THEN360
 350 G=7:GOTO370
 360 G=4
 370 OPEN3,4
 380 OPEN4,4,1
 390 OPEN5,4,2
 400 PRINT#3,T$
 410 A$="*****************************************************
 420 L=LEN(T$):A$=LEFT$(A$,L)
 430 PRINT#3,A$:PRINT#3:PRINT#3
 440 PRINT#3,"TRANSMISSION LOSSES
 450 PRINT#3,"____________________":PRINT#3
 460 PRINT#3,"FREQ.(HZ)  SUMJ(W)     SUJE(W)     SUMJ(E)     SUJE(E)
 470 PRINT#3,"---------  -------     -------     -------     -------
 480 GOSUB920
 490 FORJ=1TO20
 500 PRINT#4,F(J),A(1,J),A(2,J),A(5,J),A(6,J),A(9,J)
 510 NEXTJ
 520 IFG=4THEN610
 530 PRINT#3:PRINT#3
 540 PRINT#3,"FREQ.(HZ)  SUMI(W)     SUIE(W)     SUMI(E)     SUIE(E)
 550 PRINT#3,"---------  -------     -------     -------     -------
 560 GOSUB920
 570 FORJ=1TO20
 580 PRINT#4,F(J),A(3,J),A(4,J),A(7,J),A(8,J),A(10,J)
 590 NEXTJ
 600 REM PRINT OUT ZL'S
 610 PRINT#3:PRINT#3
 620 PRINT#3,"FREQ.(HZ)  ZL(W)(RL)   ZL(W)(IM)   ZL(E)(RL)   ZL(E)(IM)
 630 PRINT#3,"---------  ---------   ---------   ---------   ---------
 640 P1$="9999       S99999.9    S99999.9    S99999.9    S99999.9
 650 PRINT#5,P1$
```

```
660 FORJ=1TO20
670 PRINT#4,F(J),A(11,J),A(12,J),A(13,J),A(14,J),A(19,J)
680 NEXTJ
690 REM LUME
700 PRINT#3:PRINT#3
710 PRINT#3,"FREQ.(HZ)  LUME(W-E)   LUME(E-W)   XIMP(W-E)   XIMP(E-W
720 PRINT#3,"---------  ---------   ---------   ---------   ---------
730 P1$="9999       S999.9      S999.9      S999.9      S999.9"
740 PRINT#5,P1$
750 FORJ=1TO20
760 PRINT#4,F(J),A(15,J),A(16,J),A(17,J),A(18,J)
770 NEXTJ
780 REM LMEST
790 PRINT#3:PRINT#3
800 PRINT#3,"FREQ.(HZ)  LMEST(W)    LMEST(E)
810 PRINT#3,"---------  --------    --------
820 P1$="9999       S999.9      S999.9"
830 PRINT#5,P1$
840 FORJ=1TO20
850 PRINT#4,F(J),A(20,J),A(21,J)
860 NEXTJ
870 PRINT#3:CLOSE3:PRINT#4:CLOSE4:PRINT#5:CLOSE5
880 PRINT"[illegible] END OF PRINT RUN "
890 PRINT"[illegible]PRESS SPACE BAR TO RETURN TO INFOMATION PROGRAM
900 GETA$:IFA$=""THEN900
910 LOAD"0:P1",8
920 P1$="9999       S999.9      S999.9      S999.9      S999.9
                                                        S999.9"
930 PRINT#5,P1$
940 RETURN
950 D$="1:"+D$+",S,R"
960 OPEN2,8,2,D$:RETURN
970 POKE59459,255:FORI=1TO60:NEXTI
980 POKE59459,0:RETURN
READY.
```

P6P6

```
 1 GOTO100
 5 LOAD"0:P1",8
 100 REM P6 (ARCHIVES DISK)
 110 CLR
 120 GOSUB1140
 130 PRINT"⌧ PRINTING OUT CONNECTION AND U-FILES "
 140 D$="D 4":GOSUB1160
 150 INPUT#2,C,F:CLOSE2
 160 D$="D"+STR$(F):GOSUB1160
 170 INPUT#2,T$,S$,R$,N
 180 DIMD(N),P(4)
 190 FORI=1TO4:INPUT#2,P(I):NEXTI
 200 FORI=1TON:INPUT#2,D(I):NEXTI
 210 INPUT#2,X,Q:CLOSE2
 220 A$="RSELSECSERSHLSHCSHTFRSFBHFBIFBCHFLCJATTULCTXLLATMCCAALZSEZS
 230 OPEN3,4
 240 PRINT#3,T$:PRINT#3:
 250 PRINT#3,"CONNECTION DESCRIPTION IS :-":PRINT#3:PRINT#3
 260 PRINT#3,W$;"-";
 270 IFN>10THEN380
 280 FORI=1TON
 290 GOSUB870
 300 NEXTI
 310 GOSUB900
 320 GOSUB920
 330 FORI=1TON
 340 PRINT#3," ";I;"";
 350 NEXTI
 360 GOSUB1000
 370 GOTO1040
 380 IFN>20THEN500
 390 GOSUB630
 400 FORI=11TON
 410 GOSUB870
 420 NEXTI
 430 GOSUB900
 440 PRINT#3,"        ";
 450 FORI=11TON
 460 GOSUB960
 470 NEXTI
 480 GOSUB980
 490 GOTO1040
 500 IFN>30THEN1020
 510 GOSUB630
 520 GOSUB750
 530 FORI=21TON
 540 GOSUB870
 550 NEXTI
 560 GOSUB900
 570 PRINT#3,"        ";
 580 FORI=21TON
 590 GOSUB960
 600 NEXTI
 610 GOSUB980
 620 GOTO1040
 630 FORI=1TO10
 640 GOSUB870
 650 NEXTI
```

```
 660 PRINT#3
 670 GOSUB920
 680 FORI=1TO10
 690 GOSUB940
 700 NEXTI
 710 PRINT#3
 720 PRINT#3
 730 PRINT#3,"      ";
 740 RETURN
 750 FORI=11TO20
 760 GOSUB870
 770 NEXTI
 780 PRINT#3
 790 PRINT#3,"      ";
 800 FORI=11TO20
 810 GOSUB960
 820 NEXTI
 830 PRINT#3
 840 PRINT#3
 850 PRINT#3,"      ";
 860 RETURN
 870 B$=MID$(A$,D(I),3)
 880 PRINT#3,B$;"-";
 890 RETURN
 900 PRINT#3,E$
 910 RETURN
 920 PRINT#3,"(TW)";
 930 RETURN
 940 PRINT#3," ";I;"";
 950 RETURN
 960 PRINT#3,"";I;"";
 970 RETURN
 980 PRINT#3,"(TE)"
 990 RETURN
 1000 PRINT#3," (TE)"
 1010 RETURN
 1020 PRINT"NUMBER OF ELEMENTS IS TOO LARGE !"
 1030 PRINT"(PROGRAMMED FOR A MAX. OF 30 ONLY)"
 1040 PRINT#3:PRINT#3,"INTERFACE POSITIONS"
 1050 PRINT#3,"-------------------":PRINT#3
 1060 PRINT#3,"JW IS BETWEEN ELEMENTS ";P(1);" AND ";P(1)+1
 1070 IFP(2)*P(3)=0THEN1100
 1080 PRINT#3,"IW IS BETWEEN ELEMENTS ";P(2);" AND ";P(2)+1
 1090 PRINT#3,"IE IS BETWEEN ELEMENTS ";P(3);" AND ";P(3)+1
 1100 PRINT#3,"JE IS BETWEEN ELEMENTS ";P(4);" AND ";P(4)+1
 1110 PRINT#3
 1120 PRINT#3,"NOMINAL LOSS (JW-JE) =";X;" DB":PRINT#3
 1130 LOAD"1:P7",8
 1140 POKE59459,255:FORI=1TO60:NEXTI
 1150 POKE59459,0:RETURN
 1160 D$="1:"+D$+",S,R"
 1170 OPEN2,8,2,D$:RETURN
READY.
```

P8P8

```
1 GOTO100
5 LOAD"0:P1",8
100 REM P8 (ARCHIVES DISK)
110 CLR
120 GOSUB1060
130 PRINT"□▨ TRANSFER OF U1 & U3 FILES TO DISK 3 ▨▨"
140 D$="D 4":GOSUB990
150 INPUT#2,S,T
160 CLOSE2
170 D$="D"+STR$(T):GOSUB990
180 INPUT#2,T$,S$,R$,N
190 CLOSE2
200 DIMA(21,20),P(4),D(N)
210 D$="D"+STR$(T):GOSUB990
220 INPUT#2,T$,S$,R$,N
230 FORI=1TO4:INPUT#2,P(I):NEXTI
240 FORI=1TON:INPUT#2,D(I):NEXTI
250 INPUT#2,X,Q
260 FORK=1TO21:FORJ=1TO20:INPUT#2,A(K,J):NEXTJ:NEXTK
270 CLOSE2
280 IFP(2)*P(3)=0THEN300
290 G=7:GOTO310
300 G=4
310 PRINT"IS DISK 3 IN DRIVE 0 ";
320 INPUTA$
330 IFA$="YES"THEN410
340 IFA$="NO"THEN370
350 GOSUB1030
360 GOTO320
370 PRINT"REMOVE DISK FROM DRIVE 0 AND (AFTER
380 PRINT" CENTRALISING), INSERT DISK 3
390 PRINT"PRESS SPACE BAR TO CONTINUE AND THEN      CLOSE DRIVE 0 DOO
400 GETA$:IFA$=""THEN400
410 REM TRANSFERRING U1 & U3 FILES TO DISK 3
420 OPEN1,8,15:PRINT#1,"I0":CLOSE1
430 D$="D 16":GOSUB1010
440 K=1:GOSUB970
450 K=6:GOSUB970
460 K=9:GOSUB970
470 K=3:GOSUB970
480 K=8:GOSUB970
490 K=10:GOSUB970
500 CLOSE2
510 D$="D 17":GOSUB1010
520 K=19:GOSUB970
530 K=17:GOSUB970
540 K=20:GOSUB970
550 CLOSE2
560 D$="D 18":GOSUB1010
570 K=5:GOSUB970
580 K=2:GOSUB970
590 K=9:GOSUB970
600 K=7:GOSUB970
610 K=4:GOSUB970
620 K=10:GOSUB970
630 CLOSE2
640 D$="D 19":GOSUB1010
650 K=19:GOSUB970
660 K=18:GOSUB970
```

```
 670 K=21:GOSUB970
 680 CLOSE2
 690 D$="D 20":GOSUB1010
 700 PRINT#2,G;CHR$(13);T$;CHR$(13);S$;CHR$(13);R$
 710 CLOSE2
 720 PRINT"TRANSFERRENCE TO DISK 3 NOW COMPLETE
 730 PRINT"TYPE IN 'ERASE' TO ERASE OLD R-FILES
 740 INPUTE$
 750 IFE$="ERASE"THEN780
 760 GOSUB1030
 770 GOTO740
 780 R=99
 790 FORR1=39TO40
 800 D$="D"+STR$(R1):GOSUB1010
 810 FORI=1TO11:PRINT#2,R;CHR$(13);:NEXTI
 820 CLOSE2
 830 NEXTR1
 840 PRINT"(OLD R-FILES NOW ERASED)
 850 PRINT"▮DO YOU WISH TO RUN STAGE 3 ";
 860 INPUTE$
 870 IFE$="YES"THEN910
 880 IFE$="NO"THEN1100
 890 GOSUB1030
 900 GOTO860
 910 PRINT"▮REMOVE BOTH DISKS FROM THEIR DRIVES.
 920 PRINT"AFTER CENTRALISING, INSERT DISK 3          IN DRIVE 1
 930 PRINT"PRESS SPACE BAR TO CONTINUE AND THEN       CLOSE DRIVE 1 DOO
 940 GETA$:IFA$=""THEN940
 950 PRINT#1,"I1"
 960 LOAD"1:P13",8
 970 FORJ=1TO20:PRINT#2,A(K,J);CHR$(13);:NEXTJ
 980 RETURN
 990 D$="1:"+D$+",S,R":OPEN2,8,2,D$
 1000 RETURN
 1010 D$="@0:"+D$+",S,W":OPEN2,8,2,D$
 1020 RETURN
 1030 GOSUB1060
 1040 PRINT"▮INCORRECT ENTRY▮-TRY AGAIN"
 1050 RETURN
 1060 POKE59459,255
 1070 FORI=1TO60:NEXTI
 1080 POKE59459,0
 1090 RETURN
 1100 PRINT"▮▮-------END-------":END
READY.
```

PRI D*PRI D*

```
 100 REM PRI DATA
 110 PRINT"▒COPY OF AN ARRAY FROM A DATA FILE"
 120 PRINT"▒▒":DEFFNA(X)=INT(X*10000+0.5)/10000
 130 DIMA(20,8),B(20,2),C(20)
 140 PRINT"TYPE IN DRIVE NO. OF DISK CONTAINING THE DATA FILE ";
 150 GETD$:IFD$=""THEN150
 160 PRINTD$
 170 IFD$="0"THEN200
 180 IFD$="1"THEN210
 190 PRINT"INCORRECT DRIVE N0.-ANSWER 0 OR 1":GOTO150
 200 F$=",S,R":E$="0:":GOTO220
 210 F$=",S,R":E$="1:"
 220 PRINT"▒TYPE IN FILE NAME OF DATA FILE
 230 INPUTD$
 240 T$=D$
 250 PRINT"▒HARD COPY ? ";
 260 INPUTR$
 270 IFR$="YES"THEN320
 280 IFR$="NO"THEN310
 290 GOSUB460
 300 GOTO260
 310 W=3:GOTO330
 320 W=4
 330 OPEN3,W:PRINT#3,T$:PRINT#3,"____":PRINT#3
 340 PRINT"▒HOW MANY ARRAYS IN DATA FILE
 350 INPUT"▒▒▒▒▒▒";N
 360 D$=E$+D$+F$
 370 OPEN2,8,2,D$
 380 FORI=1TON
 390 PRINT"▒IS ARRAY (";I;") 20X8,20X2 OR 20X1
 400 INPUTS$
 410 IFS$="20X8"THEN470
 420 IFS$="20X2"THEN500
 430 IFS$="20X1"THEN640
 440 GOSUB460
 450 GOTO400
 460 PRINT"INCORRECT ENTRY-TRY AGAIN":RETURN
 470 PRINT"▒A(REAL)  B(REAL)  C(REAL)  D(REAL)
 480 PRINT"A(IMAG)  B(IMAG)  C(IMAG)  D(IMAG)
 490 GOTO520
 500 PRINT"▒Z(REAL)  Z(IMAG)
 510 GOTO590
 520 FORJ=1TO20:FORK=1TO8:INPUT#2,A(J,K):NEXTK:NEXTJ
 530 FORJ=1TO20
 540 PRINT#3,FNA(A(J,1)),FNA(A(J,3)),FNA(A(J,5)),FNA(A(J,7))
 550 PRINT#3,FNA(A(J,2)),FNA(A(J,4)),FNA(A(J,6)),FNA(A(J,8)):PRINT#3
 560 NEXTJ
 570 PRINT#3
 580 GOTO690
 590 FORJ=1TO20:FORK=1TO2:INPUT#2,B(J,K):NEXTK:NEXTJ
 600 FORJ=1TO20
 610 PRINT#3,FNA(B(J,1)),FNA(B(J,2))
 620 NEXTJ
 630 GOTO690
 640 FORJ=1TO20:INPUT#2,C(J):NEXTJ
 650 FORJ=1TO20
 660 PRINT#3,FNA(C(J))
 670 NEXTJ
```

```
 680 PRINT#3
 690 NEXTI
 700 PRINT"▒RERUN ? ";
 710 INPUTR$
 720 IFR$="YES"THEN780
 730 IFR$="NO"THEN760
 740 GOSUB460
 750 GOTO710
 760 PRINT"▒---------END--------"
 770 CLOSE2:PRINT#3,:CLOSE3:END
 780 PRINT"▒":CLOSE2:PRINT#3,:CLOSE3:GOTO220
READY.
```

PRI E1PRI E1

```
 100 REM PRI E1
 110 PRINT"□PRINTING E1-FILE"
 120 DIM F(20),E1(20,8)
 130 DATA 100,125,160,200,250,315,400,500,630,800
 140 DATA 1000,1250,1600,2000,2500,3150,4000,5000,6300,8000
 150 FORI=1TO20:READF(I):NEXTI
 160 INPUT"ENTER TODAY'S DATE ";DA$
 170 PRINT"TYPE IN FILENAME OF E1-FILE ";:INPUTF1$
 180 D$="0:"+F1$+",S,R"
 190 OPEN2,8,2,D$
 200 FORJ=1TO20:FORK=1TO8:INPUT#2,E1(J,K):NEXTK:NEXTJ
 210 INPUT#2,C$,D$,E$
 220 CLOSE2
 230 GOSUB290:REM PRINT-OUT E1-FILE
 240 PRINT"RERUN? ";:INPUT"YES OR NO";RR$
 250 IFRR$="YES"THEN170
 260 IFRR$="NO"THEN280
 270 GOTO240
 280 PRINT"□□--------END--------":END
 290 REM SUBROUTINE FOR PRINTING
 300 PRINT"□E1-FILE ";F1$
 310 PRINT"FREQ.";"A(R)";"B(R)";"C(R)";"D(R)"
 320 PRINT"HZ";"A(I)";"B(I)";"C(I)";"D(I)"
 330 PRINT"--";"E1(J,1)";"E1(J,3)";"E1(J,5)";"E1(J,7)"
 340 PRINT"--";"E1(J,2)";"E1(J,4)";"E1(J,6)";"E1(J,8)"
 350 FORJ=1TO20:PRINTF(J);:FORK=1TO7STEP2:PRINTE1(J,K);:NEXTK:PRINT
 360 PRINT"--";:FORK=2TO8STEP2:PRINTE1(J,K);:NEXTK:PRINT:PRINT:NEXTJ
 370 PRINTC$:PRINTD$:PRINTE$
 380 PRINT"PRIXE1    ";DA$
 390 INPUT"HARD COPY? - YES OR NO ";HC$
 400 IFHC$="YES"THEN430
 410 IFHC$="NO"THEN680
 420 GOTO390
 430 REM***PRINTER
 440 OPEN3,4
 450 OPEN4,4,2
 460 OPEN5,4,1
 470 SK$=CHR$(29):SP$=CHR$(160)
 480 AA$="AAAA"
 490 SS$="    "
 500 PRINT#3,"E1-FILE ";F1$:PRINT#3
 510 PRINT#3,"FREQ.         A(R)           B(R)           C(R)           D(R
 520 PRINT#3,"              A(I)           B(I)           C(I)           D(I
 530 PRINT#3,"             E1(J,1)        E1(J,3)        E1(J,5)        E1(J
 540 PRINT#3,"             E1(J,2)        E1(J,4)        E1(J,6)        E1(J,
 550 PRINT#3," HZ           V/V            V/A            A/V            A/A
 560 PRINT#3
 570 FORJ=1TO20
 580 PRINT#4,"9999";SS$;"S9.9999999";SS$;"S99999.999";SS$;"S.9999999
 590 PRINT#4,SS$;"S9.9999999"
 600 PRINT#5,F(J);:FORK=1TO7STEP2:PRINT#5,E1(J,K);:NEXTK:PRINT#5
 610 PRINT#4,"          S9.9999999";SS$;"S99999.999";SS$;"S.99999999";
 620 PRINT#4,SS$;"S9.9999999"
 630 FORK=2TO8STEP2:PRINT#5,E1(J,K);:NEXTK:PRINT#5:PRINT#5
 640 NEXTJ:PRINT#3
 650 CLOSE5:CLOSE4
 660 PRINT#3,C$:PRINT#3,D$:PRINT#3,E$
 670 PRINT#3,"PRIXE1    ";DA$:CLOSE3
 680 RETURN
READY.
```

APPENDIX 4

SUITABILITY OF THE M.T.F. METHOD FOR TELEPHONY.

APPENDIX 4

DISCUSSION OF THE MTF METHOD FOR ASSESSING HIGH GRADE TELEPHONY CHANNELS

The modulation transfer function (MTF) method[15,16] was developed at the Institution for Perception (TNO) in the Netherlands for application to the assessment of relatively low quality speech paths, such as those found in an auditorium, where reverberation and echo are the dominant factors. It provides objective measurements that correlate well with subjective opinions (based on word articulation). The sensitivity of the system is such that it can resolve S/N ratios up to 15 dB. (i.e. 3% accuracy).

The suitability of this method for application to high grade telephony channels (having S/N ratios up to 35 dB) has been investigated, and it has been concluded that the sensitivity required could not be obtained without having to resort to considerable expense on high precision digital circuitry and a minicomputer. The following notes will explain this decision more fully:

The basic principle of the MTF method is to generate a test signal, the intensity of which is 100% modulated with a frequency F. The carrier of the test signal is broad band noise with a spectral shaping such that the long term power spectrum is equivalent to that of typical speech.

Note, the carrier is multiplied by a sinewave having frequency ½F. This results in the wanted sinusoidal pressure modulation with frequency F. (See Fig. 1.A4).

From the output signal, the reduced pressure modulation depth (m_k) is recorded for a sequence of successive modulation frequencies. The MTF is then obtained from a weighted sum of the various values of m_k.

Note, modulation and noise addition on a pressure basis is used to represent the physiological interpretation of signal and noise. (See Annex 1).

The S/N ratio may be determined from m as follows: (See Fig. 2.A4).

Fig. 2.A4 shows a sample of the output signal. Due to circuit noise and other degradations (represented by I_n) the original test intensity (I_t) has I_n added to it on a pressure basis and so effectively results in reduced modulation depth but unchanged modulation waveform.

From equation (1),

$$\frac{I_t}{I_n} = \frac{m}{1-m} \text{ (for each test frequency)}$$

and so $SNR = 10 \log(\frac{m}{1-m})$ dB (2)

Thus, for a known SNR, the corresponding value of m may be found by re-arranging equation (2) to give:

$$m = \frac{A}{1+A} \text{ where } A = 10^{(\frac{SNR}{10})} \quad (3)$$

For a high grade telephony channel having SNR up to 30-35 dB, m will correspond to 0.9990 - 0.9997. A resolution of 1 part in 10^4 (i.e. 0.01%) will provide a discrimination of 1 dB. Clearly, ordinary analogue techniques are quite unsuitable and so digital techniques have to be resorted to.

A resolution of 1 part in 10^4 will require an A/D convertor having 14 bits accuracy. ($2^{14} = 16,384$). This poses serious problems when working to such precision as externally induced noise and mains hum would be very difficult to eliminate.

Another factor which must be considered is inaccuracy due to finite sampling time, and also the number of samples required. (See Fig. 3.A4).

From Fig. 3.A4 it can be shown that:

$$\delta t = \left| \frac{1}{2F} \, 1 - \frac{2}{\pi} \sin^{-1}(1 - \frac{\varepsilon}{50}) \right| \quad (4)$$

(see Annex 3)

where ε = % error due to δt.

Thus, for F = 1KHz and 0.01% error, (ignoring amplitude error due to 14 bit sample).

$$\delta t = \frac{10^{-3}}{2} \left| 1 - \frac{2}{\pi} \sin\text{-}1(1 - \frac{0.01}{50}) \right| \quad \text{(angle in rads)}$$

= 6.36 µS (i.e. 157 KHz). This approaches the limit of conversion time for A/D converters and this limits the test frequency.

To store only one cycle of signal (1 mS) will require 157 x 14 bit samples, i.e. 2198 bits. In practice, at TNO sampling is taken over 8 cycles.

As an example of instrumentation difficulties, the user port on the PET computer on which TCAM is implemented can only handle 8 bits at a time and so the effective memory capacity required would be 157 x 16 bits x 8 = 2512 bytes which is not available (for machine code programs) inside the computer. Also, the rate at which the user port can receive data is only 40 Hz (via basic interpreter) or 50 KHz (machine code), it would therefore be unable to cope with a parallel bit rate of 157 kHz, in real time.

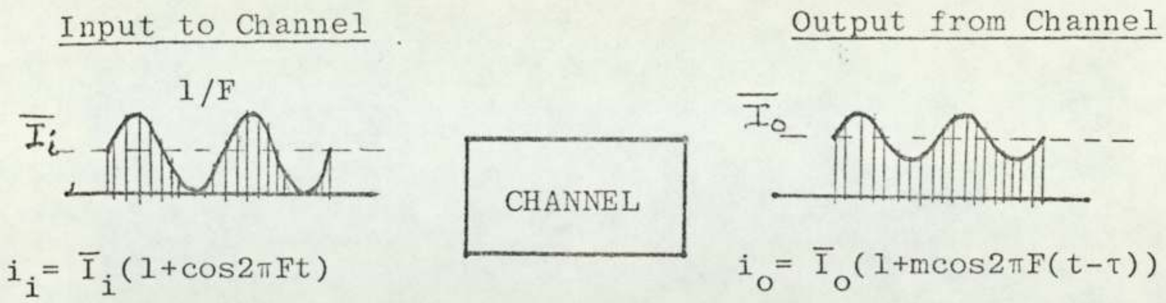
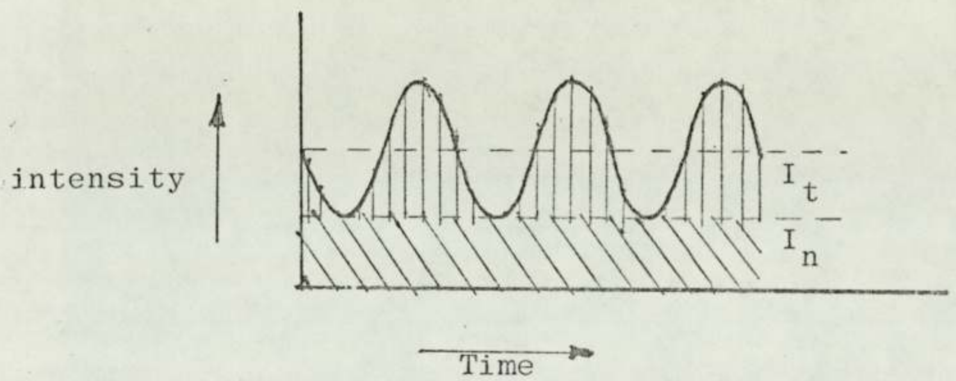
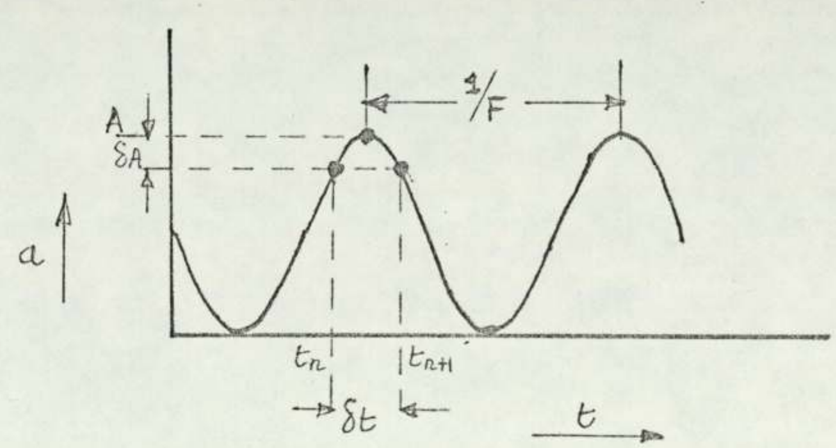


FIG. 1.A4



$$m = \frac{I_t}{I_t + I_n} \qquad (1)$$

FIG. 2.A4



δt = Time between samples

δA = Maximum amplitude error caused by finite value of δt. (True sampling point missed due to displacement of $\delta t/2$).

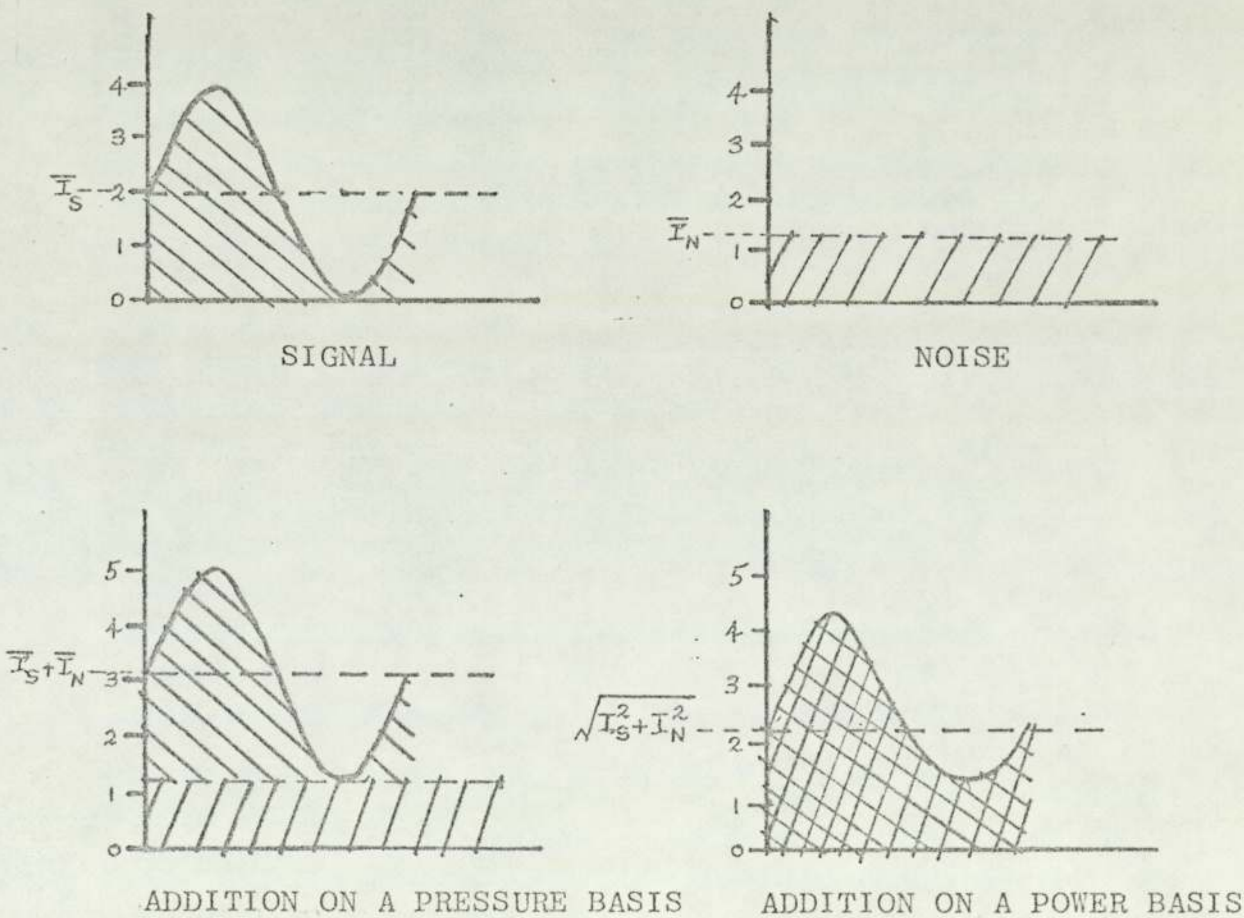
FIG. 3.A4

ANNEX 1

THE REASON FOR USING PRESSURE MODULATION IN THE MTF MODEL

When a person is listening to two sound sources, (e.g. whilst in conversation with someone he may also be hearing the sound from a television set), he can 'switch' concentration from one to the other, and so get an idea of the intelligence conveyed from both sources. To do this, his ear must perceive the sounds on an additive or 'pressure' basis. Similarly with speech and noise. (If perception was on a power or intensity basis, the original speech envelop would become distorted by the noise).

This effect is illustrated in Fig. 4.A4.



ANNEX 2

AMPLITUDE MODULATION

Let a carrier be modulated by a signal v_s where $v_s = B \cos\omega_s t$ and the carrier amplitude is A. The composite signal obtained by modulation is shown in Fig. 5.A4.

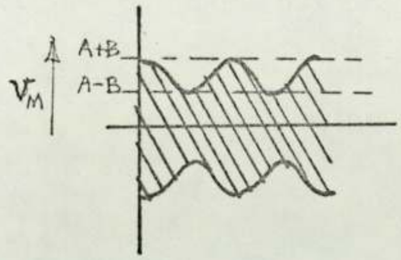


Fig. 5.A4

Consider the variations of A, (v_M) caused by v_s on the positive portion.

$$v_M = A + v_s$$

(When $v_s = 0$, amplitude returns to A)

$$\text{i.e. } v_M = A + B \cos t\omega_s t$$
$$= A(1 + \frac{B}{A} \cos\omega_s t)$$

Let m represent the modulation depth. i.e. $m = \frac{B}{A}$

Then $v_m = A(1 + m \cos\omega_s t)$ (5)

To determine m from a modulated carrier

Consider Fig. 6.A4

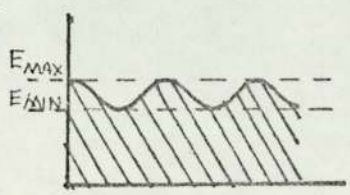


FIG. 6.A4

To find m in terms of E_{max} and E_{min}

$E_{max} = A + B$, $E_{min} = A - B$ (from Fig. 5.A4)

$\therefore \; A = E_{max} - B, \; B = A - E_{min}$

$\therefore \; A = E_{max} - A + E_{min}$

$2A = E_{max} + E_{min}$

$$\therefore \; A = \frac{E_{max} + E_{min}}{2} \qquad (6)$$

Similarly,

$B = E_{max} - A, \; A = B + E_{min}$

$$\therefore \quad B = E_{max} - B - E_{min}$$

$$2B = E_{max} - E_{Min}$$

$$\therefore \quad B = \frac{E_{max} - E_{min}}{2} \qquad (7)$$

Thus, $m = \frac{B}{A}$ from equations (6) and (7) gives:

$$m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \qquad (8)$$

ANNEX 3

ERROR DUE TO FINITE SAMPLING FREQUENCY

(To determine sampling interval in terms of required maximum error and signal frequency).

Consider Fig. 7.A4

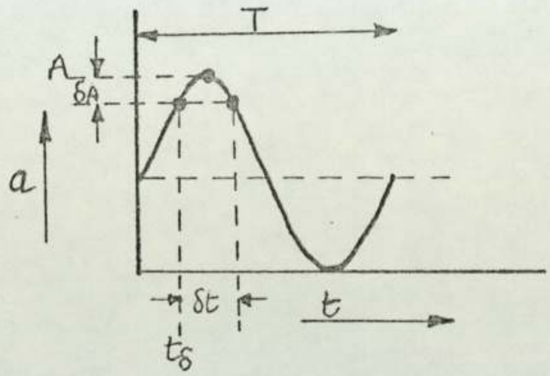


Fig. 7.A4

δt = time between samples (Assume sampling time << δt)
δA is max error caused by finite value of δt. (Max error occurs when displacement in time = $\delta t/2$).

Now, $a = \frac{A}{2}(1 + \sin\omega t)$

$$\frac{2a}{A} - 1 = \sin\omega t$$

$$\therefore\ t = \frac{1}{\omega}\sin^{-1}\left(\frac{2a}{A} - 1\right) \qquad (9)$$

$$\text{At A, } t = \frac{T}{4}, \text{ thus } \frac{\delta t}{2} = \frac{T}{4} - t_\delta \qquad (10)$$

At $a = A - \delta A$

have $t_\delta = \frac{1}{\omega}\sin^{-1}\left(\frac{2A - 2\delta A}{A} - 1\right)$ (from equation (9)

$$\text{i.e. } t_\delta = \frac{1}{\omega}\sin^{-1}\left(1 - \frac{2\delta A}{A}\right) \qquad (11)$$

but $\frac{\delta A}{A}$ = fractional error

thus if ε = % error ($= \frac{\delta A}{A} \times 100$)

then from equation (11),

$$t_\delta = \frac{1}{\omega}\sin^{-1}\left(1 - \frac{\varepsilon}{50}\right)$$

but $\omega = 2\pi F$ and $T = 1/F$

∴ combining equations (10) and (11),

$$\frac{\delta t}{2} = \frac{1}{4F} - \frac{1}{2\pi F}\sin^{-1}(1 - \frac{\varepsilon}{50})$$

i.e.

$$\delta t = \frac{1}{2F}\left[1 - \frac{2}{\pi}\sin^{-1}(1 - \frac{\varepsilon}{50})\right] \qquad (12)$$

APPENDIX 5

ADVANTAGES OF LOUDNESS RATINGS OVER REFERENCE EQUIVALENTS.

APPENDIX 5

ADVANTAGES OF USING LOUDNESS RATINGS[13,14] OVER REFERENCE EQUIVALENTS FOR PLANNING TELEPHONE NETWORKS

At present, the loudness loss of speech in various parts of a connection, is measured in terms of 'reference equivalents' in accordance with CCITT recommendations. It will be shown that they have the disadvantage of not being additive on a dB basis or on an overall basis. The British Post Office, however, use their own 'loudness rating' method of determining loudness loss, which does not have these disadvantages. A modified version of these loudness ratings has been proposed by CCITT which is now undergoing evaluation by study group XII.

A computer based telephone connection assessment model (TCAM has been developed at the University of Aston to facilitate the investigation of the transmission characteristics of any telephone connection. Setting up procedures and the interpretation of results are made in accordance with CCITT recommendations. The ISO recommended range of frequencies is used. (See frequency column in Table 1.A5).

Calculation procedures have been incorporated into the computer model which determine the reference equivalents, relative equivalents and (CCITT) loudness ratings for the various speech paths, making up a telephone connection. A lot of the connections being studied use the BPO 746 type telephone which incorporates a carbon microphone. (Various non-carbon type telephone sets are also used for other studies).

The sensitivity characteristics of telephone set microphones become difficult to obtain when the microphone happens to be of the carbon granule type. This is because the shape of its frequency response varies according to the sound pressure of the test signal used. Various procedures have been adopted in order to obtain a set of results that will cover the range of talkers found in practice. Although a completely satisfactory method has not yet been devised, one which gives a fair approximation for certain types of carbon microphone is the 'upper envelope' method, and this is the one adopted by the BPO.

A corresponding problem is encountered in the telephone earpiece due to uncertainty in the value of earphone coupling loss to be assumed in the calculations if the results are to represent conditions under which subjective determinations are made.

The sending and receiving sensitivities for the '746' are available for 3 different line conditions (zero, average (1.6Km/0.4mm copper) and limiting (5.9Km / 0.5 mm copper), each with a Stone FB). The way in which the sending sensitivities were measured (upper envelope method) gives sensitivities which tend to be too high, thus causing incorrect loudness ratings to be obtained. A correction has therefore to be made in order to use the appropriate data in the computer model. The corrections for sending and receiving were determined by setting up hypothetical connections for which the correct subjectively determined reference equivalents were known. The reference equivalents of the connection (using the upper envelope values of sensitivity for the telephone sets) were then calculated and found to be somewhat in error. An attenuator was then included in the send end and in the receive end oi the connection and, by successive approximateions, each set to a value which yielded the correct send and receive reference equivalents. Thus, the 'corrected' sensitivities were obtained by subtracting the attenuator value from the original sensitivity values at each frequency. These 'corrected' values are shown in Table 1.A5.

Note

Successive approximations had to be made when altering the attenuator values, because a straightforward addition of dB's could not be done. (Changing the sensitivity by X dB does not change the reference equivalent by the same number of dB but only by about 0.8X dB).

Study is in progress regarding the evolution of an all-digital telephone network and what problems will need to be overcome during the various stages of evolution. Using the computer model, reference equivalents and loudness ratings have been calculated for the speech paths in various connections (each with the three line conditions) were chosen, denoted by the letters A to G). Nominal overall reference equivalent or loudness rating, is given by the sum of the individual values for sending and receiving plus the value of nominal loss for the circuits connecting sending and receiving ends. Figures 2.A5 and 3.A5 show nominal overall and true overall reference equivalents/loudness ratings for these connections under average line conditions. These two graphs show that the additivity (on a nominal basis) of loudness ratings give much more realistic results than reference equivalents.

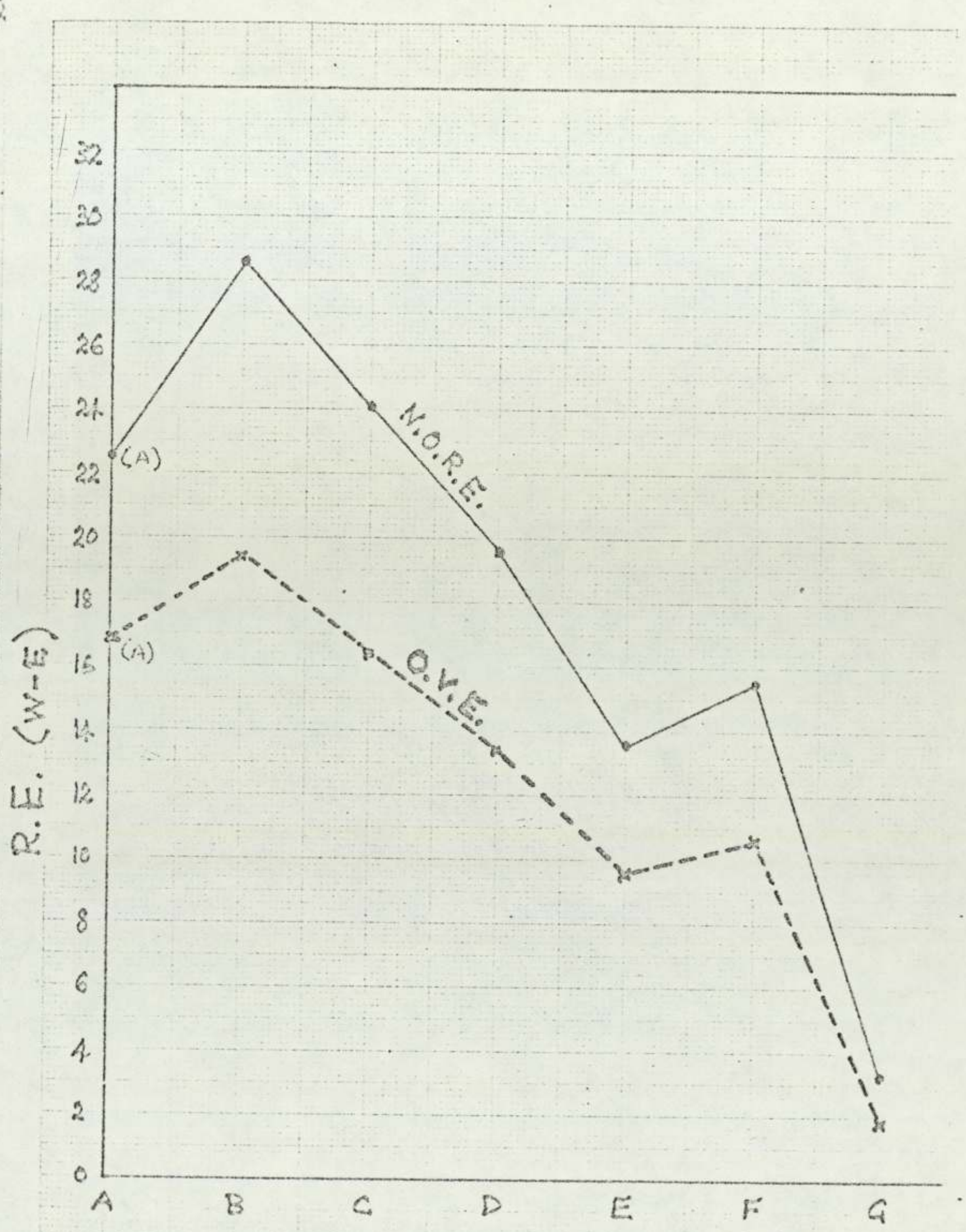
CONCLUSIONS

Computer based models work best when the system they are modelling has rational properties, and so loudness ratings are more suitable than reference equivalents which do not have the additivity properties that loudness ratings possess.

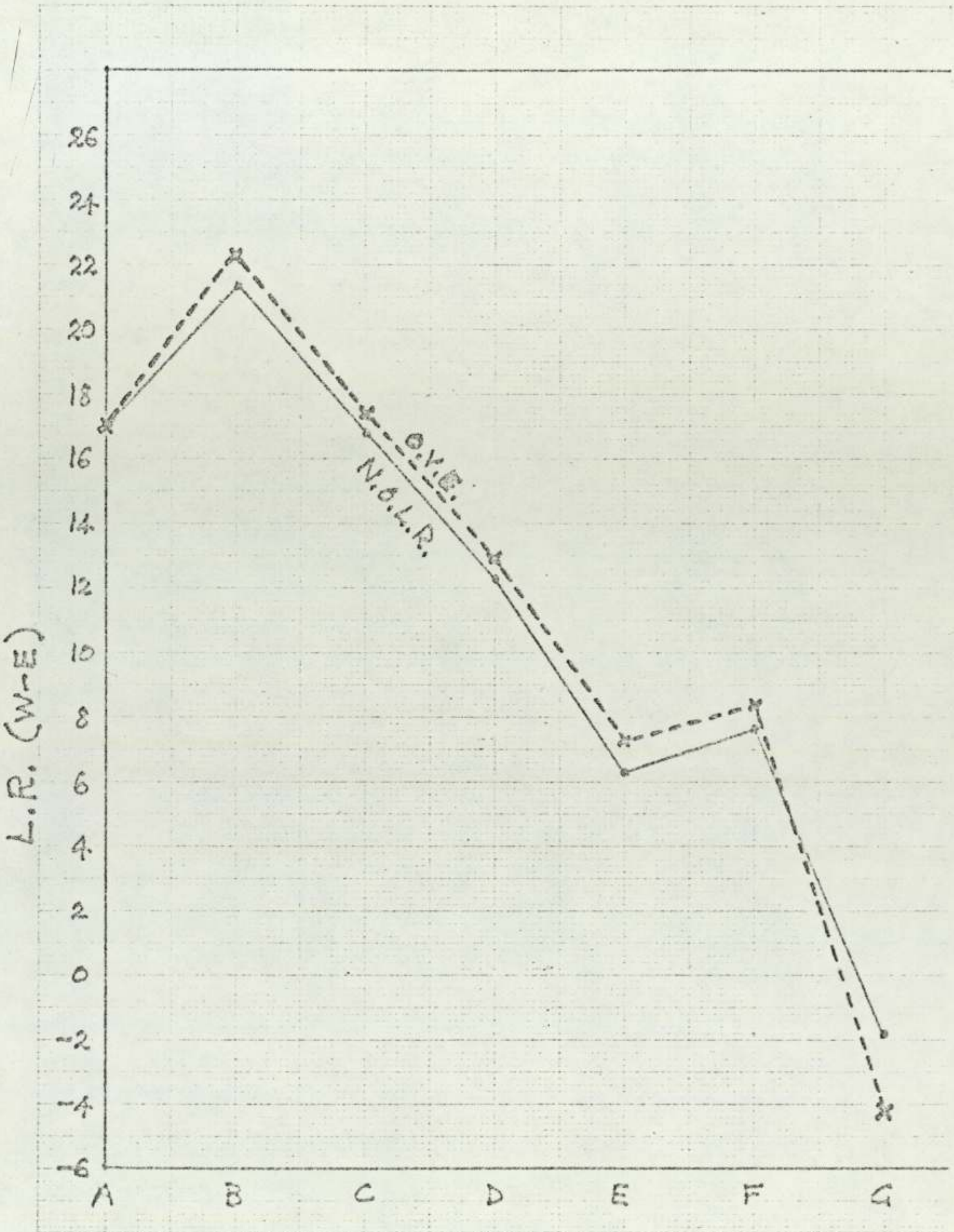
	Zero Line		Ave. Line		Lim. Line	
Frequency (Hz)	SS	SR	SS	SR	SS	SR
1ØØ	- 18.81	23.22	- 19.15	18.96	- 18.71	16.74
124	- 18.31	23.72	- 17.95	18.46	- 16.51	14.84
16Ø	- 17.61	22.92	- 16.75	17.Ø6	- 15.91	13.Ø4
2ØØ	- 16.91	21.12	- 16.25	14.76	- 15.21	13.84
25Ø	- 16.31	23.32	- 14.35	16.86	- 13.31	14.24
315	- 15.81	23.42	- 12.75	17.96	- 12.71	17.54
4ØØ	- 15.71	23.82	- 12.15	18.46	- 12.21	17.74
5ØØ	- 15.51	23.62	- 11.75	18.76	- 11.61	18.24
63Ø	- 14.71	23.22	- 9.95	19.16	- 1Ø.71	18.54
8ØØ	- 12.81	22.82	- 8.Ø5	19.Ø6	- 8.21	18.74
1ØØØ	- 9.21	22.72	- 3.85	19.56	- 4.21	19.24
125Ø	- 6.51	23.52	- Ø.95	2Ø.66	- 1.11	2Ø.14
16ØØ	- 8.61	24.82	- 2.75	22.Ø6	- 3.11	21.54
2ØØØ	- 1Ø.21	22.52	- 3.95	2Ø.76	- 4.31	2Ø.24
25ØØ	- 12.Ø1	19.Ø2	- 5.35	17.56	- 5.61	17.Ø4
315Ø	- 1Ø.41	23.12	- 3.55	21.96	- 4.31	22.24
4ØØØ	- 21.41	12.Ø2	- 14.15	11.86	- 14.51	11.84
5ØØØ	- 32.81	- 4Ø.78	- 27.95	-69.84	- 28.31	-5Ø.66
63ØØ	- 46.81	- 9Ø.78	- 45.75	-1Ø1.Ø4	- 46.71	-1ØØ.66
8ØØØ	- 71.81	-1ØØ.78	- 69.15	-1Ø1.Ø4	- 67.71	-100.66

TABLE 1.A5 CORRECTED SENSITIVITY/FREQUENCY CHARACTERISTICS FOR

BPO 746 TELEPHONE



CIRCUIT FIGURE 2.A5



CIRCUIT FIGURE 3.A5

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REFERENCES

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