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ACOUSTICAL TRANSMISSION LOSSES IN TELEPHONE CONNECTIONS

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Introduction

With the introduction of digital technology into telephone speech links it will in principle, be possible to provide connections of optimum loudness quite independent of the distance separating participants in a conversation. Some years will elapse before this fortunate situation exists on a wide-spread basis but now is the appropriate time to study its consequences. Naturally subjective tests are necessary to obtain definitive information but these are expensive and laborious. However, computer models are now available which enable the quality of any proposed connection to be predicted fairly precisely. TCAM (Telephone Connection Assessment Model) is a mechanistic model representing the basic structure of the system being modelled and therefore suitable for the present study.

Clearly it is necessary to have detailed knowledge of the several acoustic paths involved and the paper briefly discusses the problems arising in obtaining this. Attention is focused mainly upon the noise paths which are not, at this time, fully understood. Use is made of the TCAM model's capacity to allow for changes in human telephonic behaviour which arise from various physical conditions such as overall connection loss and room noise. It is these changes in behaviour which contribute much to the difficulties in making measurements on telephone systems. TCAM attempts to quantify the consequences of behavioural patterns and give a measure of their effect upon the efficiency of a speech link. A valuable result of the study is the improvement in TCAM which has been achieved.

Transmission Paths

In principle, information concerning the several transmission paths is obtained from laboratory or field measurements but in practice such measurements are not easy to undertake. In addition to the basic path from the lips of a talker to the ear of a listener at the remote end of a connection there are several more paths to be considered, as follows:

1) The path by which noise arising electrically in the connection reaches the ear of the listener.

2) Room noise surrounding a participant in a conversation enters the ear by two paths, firstly via leakage between the earcap and the pinna, and secondly around the electrical sidetone path from microphone to earpiece.

3) The sidetone path by which a talker hears his own voice is a complex one consisting of several individual paths in parallel:

   a) A path from microphone to earphone via the electrical circuit.

b) A mechanical path within the user's head.

c) An acoustic path from the mouth to the ear via the leakage between the earcap and the pinna.

d) A mechanical path along the handset handle.

The task of measuring these paths is far from easy and yet information concerning them is clearly necessary if the predictions made by the model are to be meaningful. Some of these paths are shown in Figure 1. In this paper attention is mainly devoted to 3 a) and 3 c).

Transmission Path Measurement

Superficially it may be thought that placing a small calibrated microphone (say a probe) at a talker's lips and a similar microphone at the entrance to a listener's ear canal would enable measurement to be made of the mouth-to-ear loss of a connection. A difficulty with this approach is clearly the definition of the points to be used for the measurements. Such points must be, and indeed are, defined and the loss between them readily obtained by use of artificial mouths and ears, but the major problems remain. There are concerned with the coupling between these points and the mouths and ears of actual telephone users. While difficulties arise in defining talking positions the problems at the ear are much greater.

In order that results may be obtained nominal couplings, e.g. artificial ear, are assumed but it is recognised that the relationships between nominal couplings and real ones are complex and certainly not constant. The following factors affect the problem:

a) Size and shape of handset. b) Sidetone control. c) Overall loudness loss. d) Noise in the circuit and in the room. e) Distortions on the transmission system. f) Head dimensions of telephone users.

Telephone networks must serve the vast majority of the population and accordingly it is legitimate to assume standard head dimensions and cater for a range of variations around them. Thus a rudimentary 'artificial head' may be used upon which a handset is located with the microphone properly orientated to give a suitable mouth-to-mouthpiece distance. With short handsets this distance is naturally less than with long ones.

A further technique is the measurement of the speech voltage at the output of the telephone microphone under conversation conditions to obtain information about variations in mouth coupling arising from factors occurring in conversation. This information gives the combined effect of the various factors and does not enable individual ones to be studied. With carbon microphones a further difficulty arises from the variation in microphone sensitivity with sound pressure. Naturally some of these difficulties may be overcome by using probe microphones at a variety of points and making various electrical measurements but this paper is concerned with a different approach. Figure 2 shows the change in speech voltage with overall loss.

Computer Aided Measurement

A computer model may be designed to represent the structures of the various

paths involved and introduced as an element in the TCAM model. Results obtained by running TCAM will depend upon the values assumed for the various parameters in the sub-models but these results may be checked by experimental evidence. The experimental evidence, obtained from laboratory arrangements corresponding to the paths being modelled, provides a means of adjusting the chosen parameter values. Thus this method of obtaining the necessary information overcomes many of the difficulties inherent in making direct measurements which have been referred to.
As an example, the structure of the model of sources and paths for noise is shown in Figure 3 in which Paths 1 and 2 are for room noise. Path 1 represents the loss LRNE in the leakage path between the earcap and the pinna and Path 2 is the sidetone path via the telephone transducers and electrical circuit. Path 3 is the circuit noise path. The quantities in the boxes, unless referred to elsewhere, are: a) LMEST - Loss in the sidetone path mouth-to-ear. b) DELSM - Correction for the difference between speech and noise sensitivity of the microphone. c) SJE(AE) - Sensitivity between Junction and Artificial Ear. d) LE - Quantity relating rear ear and Artificial Ear sensitivity.

LRNE and LE are obtained for users holding the earphone pressed closely to the ear and standard values are published for use internationally. Therefore using such standard values for these items enables TCAM to provide good predictions of circuit performance when transmission conditions are unfavourable, that is for high loss circuits under noisy conditions. However, the use of these values under favourable circuit conditions, such as will be normal with digital transmission, must produce substantial errors in the predictions.

Accordingly the additional quantities YE and ZE have been introduced as shown in Figure 3. These arise because under favourable conditions users will have no need to hold the earpiece closely to the pinna and this has two related effects. Firstly, the leakage attenuation between the earcap and the pinna will decrease and this is represented by the shunt loss YE. Secondly, loosening of the coupling between earphone and ear has the effect of reducing earphone sensitivity and this is represented by the series loss ZE. Although YE and ZE vary in a mutually related way the precise relationship between them is, at present, unclear. When the earphone is held closely to the ear it is assumed that YE has a very large value of say 100 dB which leaves LRNE unaffected and ZE has a value of 0 dB. These values provide starting points to provide appropriate values under other conditions.

Experimental Results

At the present time the set of experimental results which is of particular interest has been provided by the Hungarian Telephone Administration (ref.1). It is concerned with making subjective judgments between the interfering effects of circuit noise and room noise when either is present alone. In this experiment judgments were made with various combinations of the transmission losses of the principal speech path and the sidetone path. Changes in these losses result in listeners moving the earphone nearer to, or further from, their ear according to the net 'speech-to-noise ratio' at it. The noise paths are affected in two ways, firstly the direct earphone-to-ear coupling and secondly the leakage between the earcap and the pinna. These changes are inter-related with each other and with the 'speech-to-noise ratio'.

Measured values are given for the sound pressure at point B in Figure 3 for the circuit noise judged to be subjectively equivalent for a number of combinations

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of overall circuit loss and sidetone path loss. TCAM predicts very well the measured values when using standard values of LE and LRNE if the transmission conditions are poor, but when transmission conditions are improved the measured values at point B can be as much as 20 dB greater than the TCAM predicted values. Table 1 summarises part of the results. Four levels of room noise were used, three speech levels, and five sidetone loss values. Column 1 gives the room noise in dBA, and columns 3, 5 and 7 the equivalent circuit noise measured at point B in Figure 3.

TABLE 1 (for STRE=23dB

Room noise (dBA)	Speech SP=90dB		Speech SP=80dB		Speech SP=70dB	
	SP/RN (dB)	Equiv.cct noise(dB)	SP/RN (dB)	Equiv.cct noise(dB)	SP/RN (dB)	Equiv.cct noise(dB)
1	2	3	4	5	6	7
50	40	59	30	54	20	45
60	30	63	20	57.5	10	51
70	20	67	10	61	0	58
80	10	72	0	65.5	-10	64

The difference between column 1 and the corresponding values in columns 3, 5 and 7 represent the attenuations of paths 1 and 2 of Figure 3 in parallel. When sidetone attenuation is low (say STRE = 3dB) the attenuations are roughly 4 dB smaller.

Conclusions

This study is continuing. It is already clear, however, that users adapt to changed conditions and it is concluded that network planning should allow for customers to use comfortably loose couplings.

References

1. CCITT Study Group X11, Contribution COM X11-No.95 (Hungary) Period 1977-80.

2. RICHARDS D. L. & WHORWOOD R. W., "Transmission Planning of Digital Telephone Networks" ISSLS-80, Munich, September 1980.

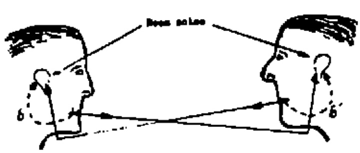

Fig.1(a) Paths in face-to-face conversation

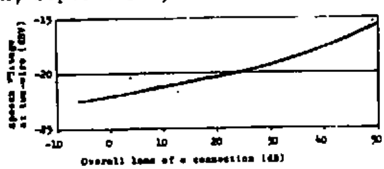

Fig. 2 Typical speech voltage at two-wire of telephone instrument

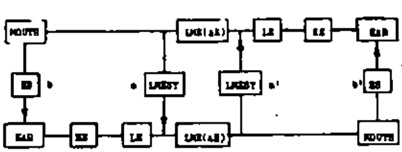

Fig. 1 Selection of paths involved in a telephone connection

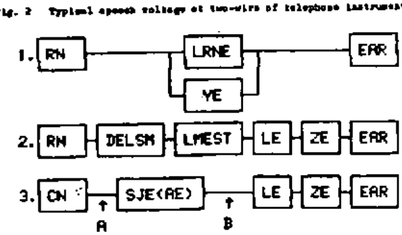

FIG. 3 SOURCES & PATHS FOR NOISE