All drawings appearing in this Recommendation have been done in Autocad.
Supplement No. 2

xe ""§IMPEDANCE STRATEGY FOR TELEPHONE INSTRUMENTS AND DIGITAL LOCAL EXCHANGES IN THE BRITISH TELECOM NETWORK

1 Introduction

When planning the introduction of digital local exchanges it is essential to take into account the subjective performance offered to customers. This will, of course, include provision of overall loudness ratings within an acceptable range of values. Noise, distortion and other impairments also need to be adequately controlled. However, it is also important to consider those parameters largely influenced by the impedances associated with telephone instruments, local lines and exchanges. In particular acceptance values of sidetone and echo/stability losses need to be obtained. These parameters are influenced by the choice of:

i) Input and balance impedances of telephone instruments,

ii) Input and balance impedances of the digital exchange hybrid,

iii) Impedances of the 2–wire local lines.

This contribution outlines the impedance strategy adopted for telephone instruments and digital local exchanges in the British Telecom network. It is shown that there are major advantages in adopting complex impedances both for the exchange hybrid and for new telephone instruments. The contribution includes calculations of sidetone, echo and stability balance return losses based on a sample of 1800 local lines in the British Telecom network.

2 Impedance strategy for a digital local exchange

2.1 In order to adequately control echo and stability losses in the digital network the nominal hybrid balance impedance ZB for lines of up to 10 dB attenuation is based on a 3 element network. This network consists of a resistor in series with a parallel resistor/capacitor combination, i.e.:
Figure 1 - CCITT 88130

With appropriate component values it has been found that this network can give significantly improved echo and stability balance return losses compared with a resistive network.

2.2 The nominal exchange input impedance ZI is also based on a 3 element network of the same form as the balance impedance ZB. This network, with suitable component values, is required to give an acceptable sidetone performance on the lower loss lines. It has been found that a 600 W resistive input impedance gives unacceptable sidetone performance on these lower loss lines.

3 Impedance strategy for telephone instruments

It should be noted that the digital local exchange is designed to operate with a low feeding current (» 40 mA). The telephone instrument will therefore be operating as though it were connected to a long line on a conventional analogue exchange. In particular, any regulation function will be disabled.

The input impedance of present instruments is, under low current feeding conditions, substantially resistive. It has been found that there is a significant improvement in echo/stability balance return losses at the exchange hybrid if the telephone input impedance is also made complex. The preferred impedance is close to the design value for the exchange balance impedance ZB.

4 Background to calculated results

This section includes the results of calculating STMR values, echo and stability balance return losses for a range of local connections.

Four groups of exchange lines have been used where the groups have mean attenuations of 1 dB, 3 dB, 6 dB and 9 dB. Each group consists of at least 100 samples of local lines in the British Telecom network with attenuations within 1 dB of the mean value for the group.

Two telephone instruments have been used with identical characteristics except for input impedance. One instrument retains a conventional, substantially resistive impedance; the other instrument uses a complex capacitive input impedance. The sidetone balance impedance is, in both cases, designed to match long lengths of 0.5 mm Cu cable.

Two cases for the exchange hybrid impedances are considered. The strategy outlined in Section 2 is used i.e., complex input and balance impedance, and for comparison purposes, a conventional “transmission equipment” hybrid is assumed with nominal 600 W input and balance impedances.

Using a computer program, values of echo and stability balance return losses, and sidetone masking rating are calculated for the four exchange line groups with the two telephone instruments and two exchange line hybrids.

5 Results

5.1 *Sidetone values*

For this case the comparison is made between a 600 W exchange input impedance and a complex input impedance. (It should be noted that the STMR values have been calculated as in

Recommendation P.79 of the Blue Book).

Note – The exchange input impedance has the following approximate values:

R1 = 300 W, R2 = 1000 W, C = 220 nF (see Figure 1).

The results are summarized in Table 1 below:

TABLE 1

Calculated values of STMR

Mean value of STMR (dB)				
Exchange termination	Attenuation of local line group (dB)			
	1	3	6	9
600 W	2.6	5.2	8.1	12.4

Complex termination	
	13.9
	14.8
	12.7
	13.0

It is clear from Table 1 that a 600 W termination gives far from satisfactory results with shorter local lines which will include at least 50% of local lines in the British Telecom network. Use of a complex input impedance improves these STMR values by approximately 10 dB and the values are closer to the recommended values given in Recommendation G.121.

These results show that a complex input impedance is essential for the case of sensitive telephone instruments directly connected to digital exchange hybrids. The performance with a resistive impedance is in fact worse than the performance on a conventional analogue exchange because of the low feeding current and impedance masking effect of the digital exchange.

5.2 *Echo and stability balance return losses*

As far as impedance is concerned the most important factor is the choice of the balance impedance for the exchange line hybrid as this determines the network echo and stability performance. Initially a comparison is made between a 600 W impedance and a complex impedance assuming existing telephone instruments. Having chosen a balance impedance it is then shown that a further improvement can be made by considering the telephone input impedance.

5.2.1 *Exchange balance impedance*

Table 2 below shows the summarized results for mean values of echo balance return loss (calculated according to Recommendation G.122, Volume III.1, of the Blue Book), and stability balance return loss.

Note – The complex balance impedance has approximate values R1 = 370 W, R2 = 620 W, C = 310 nF (see Figure 1).

TABLE 2

Calculated values of mean echo (stability) balance return losses assuming existing telephone input impedance

Exchange balance impedance	Attenuation of local line group dB			
	Mean value of echo (stability) balance return 1loss dB			
	1	3	6	9
600 W	22.5 (13.9)	12.9 (7.5)	9.4 (6.2)	8.3 (6.0)
Complex impedance	10.2 (8.0)	13.8 (9.1)	15.2 (11.2)	17.1 (12.9)

In addition to calculating mean values for the distributions it is important to consider the edges of the distributions. This is especially true for echo and stability performance where it is the worst case values that are likely to cause network difficulties.

Table 3 shows the minimum values of calculated echo and stability balance return losses for the samples of lines considered. The values for stability balance return loss are those given in brackets.

TABLE 3

Calculated values of minimum echo (stability) balance return losses assuming existing telephone input impedance

	Minimum value of echo (stability) balance return loss dB			
Exchange balance impedance	Attenuation of local line group dB			
	1	3	6	9
600 W	20 (13)	11 (5)		

8 (4)

6 (3)

Complex impedance

9 (7)

11 (7)

12 (9)

11 (7)

With the exception of the 1 dB sample of lines it can be seen from Table 2 that the complex impedance results in mean values for the distributions which are higher than the corresponding values using a 600 W impedance. The improvement is particularly marked for the higher loss exchange lines. When the minimum values of the distributions are also taken into account (Table 3) there is a clear advantage in using the complex balance impedance. A similar advantage would also be obtained with non–speech devices such as data modems which have an impedance similar to that of the telephone instrument (assuming a low feeding current).

5.2.2 *Telephone input impedance*

Having chosen a suitable complex balance impedance for the exchange hybrid, the options for changing the telephone input impedance can be considered. Tables 4 and 5 present calculated results for the distributions of echo and stability balance return losses at the exchange hybrid, comparing the effect of complex and resistive telephone input impedances.

Note – The input impedance has nominal values R1 = 370 W, R2 = 620 W, C = 310 nF. (See Figure 1.)

TABLE 4

Calculated value of mean echo (stability) balance return losses assuming complex exchange balance impedance

Mean value of echo (stability) balance return loss dB

Telephone input impedance	Attenuation of local line group dB			
	1	3	6	9
Resistive	10.2 (8.0)	13.8 (9.1)	15.2 (11.2)	17.1 (12.9)
Complex	29.0 (23.6)	21.0 (13.9)	16.9 (12.8)	17.0 (11.8)

TABLE 5

Calculated value of minimum echo (stability) balance return losses assuming complex exchange balance impedance

Telephone input impedance	Mean value of echo (stability) balance return loss dB			
	Attenuation of local line group dB			
	1	3	6	9
Resistive	9 (7)	11 (7)	12 (9)	11 (7)
Complex	24 (18)	15 (11)		

13 (10)

10 (7)

The results in Tables 4 and 5 show a significant improvement in echo and stability balance return losses for the lower loss local lines. There is little difference for the higher loss lines as the balance return loss is primarily determined by the cable characteristics. It can be concluded that there is a clear advantage in designing future telephone instruments with a complex input impedance.

6 New telephone instruments in the existing analogue network

In § 5.2.2 the advantages of a complex telephone input impedance have been illustrated when used with digital exchanges. However, there are also advantages if these instruments are used on conventional analogue exchanges.

The sidetone balance impedance of instruments is generally optimised around the capacitive impedance of unloaded cable. If the telephone input impedance is also capacitive then the sidetone performance of instruments on own exchange calls can be improved. The improvement will be most marked when both instruments are on short lines hence the sidetone is largely determined by the input impedance of the other instrument. This situation is widely encountered on analogue PABXs where the majority of extensions are of low loss.

7 Application to other voiceband terminal equipment

The discussions in this paper have concentrated on telephone instruments. However the conclusions concerning telephone input impedance can equally be applied to other voiceband equipment, e.g., data modems. Work in Study Group XII has shown that higher speed modem services require signal to listener echo ratios approaching 25 dB for successful operation. If the data modem adopts a complex input impedance then the improvements in stability balance return losses (and hence signal to listener echo ratio) discussed in § 5.2.2 can be obtained.

8 Summary and conclusions

This paper has considered aspects of an impedance strategy for the local network with the introduction of digital local exchanges and new telephone instruments.

Calculations based on a large sample of local lines in the British Telecom network have shown that:

i) The input impedance of the digital exchange must take into account the sidetone performance of the telephone instruments. To provide acceptable sidetone performance it has been found necessary to provide a complex input impedance which more closely matches the sidetone balance impedance of the telephone instrument.

ii) Adopting a complex exchange balance impedance gives a significant improvement in echo and stability balance return losses. This improvement is considered necessary to provide adequate echo performance in the digital network without requiring extensive use of echo control devices.

iii) A further improvement in echo and stability losses is obtained by using a complex input impedance for new telephone instruments. This impedance also improves the sidetone performance of connections on analogue exchanges.

iv) The conclusions are also relevant to other voiceband apparatus. Signal to listener echo ratios on voiceband data connections can be improved if the modems use a complex input impedance.