All drawings appearing in this Recommendation have been done in Autocad.

Supplement No. 1

xe ""§DEFINITION OF RELATIVE LEVELS, TRANSMISSION LOSS
AND ATTENUATION/FREQUENCY DISTORTION FOR DIGITAL EXCHANGES
WITH COMPLEX IMPEDANCES AT Z INTERFACES

1 Introduction

During the studies of Study Group XI on transmission characteristics of exchanges it has been recognized that digital local exchanges may require complex impedances at the subscriber line interface (see Recommendation Q.552). These complex impedances result in difficulties with defining relative levels, transmission loss and attenuation/frequency distortion.

This Supplement gives the basis for coherent definitions which are in accordance with the principles outlined by Study Group XII in the G.100 series of Recommendations, Fascicle III.1.

2 Relative levels

There is a clear statement by Study Group XII that relative levels (*L*) – even at ports of complex impendance – relate to power (in general, apparent power) at a reference frequency of 1000 Hz. Accordingly, at a point of zero relative level (i.e. transmission reference point, cf. Recommendation G.101, item § 5.3.1) and at an impedance *Z*, the reference power of 1 mW[1]) (at 1000 Hz) corresponds to a voltage:

$$U\text{o} = \qquad (1)$$

It follows that generally at a point of relative level *L* the voltage will be

$$U = 10L/20\ . \qquad (2)$$

and that consequently the level *L* can be expressed as

$$L = 20 \log \qquad (3)$$

This is the basis for a coherent definition of transmission loss, and subsequently of attenuation/frequency distortion, as derived below.

Note – In the future, measurements should be made at 1020 Hz.

1) Watt is the unit of apparent power as well as of real power.

3 nominal transmission loss

In the field of telecommunications, it is a well–established practice to define the nominal transmission loss (*NL*) between two points as the difference between the relative levels associated with these points. If, for instance, for a "connection through a digital exchange" the relative level at the input is Li, and at the output, Lo, then the nominal loss is

$$NL = L\text{i} - L\text{o} \tag{4}$$

Figures 1 and 2

Taking into account that according to the definition of the power reference circuit (Figure 1), E is frequency–independent, one obtains from equations (3) and (4) the nominal loss.

$$NL = 20 \log \; + 10 \log \tag{5}$$

It may be noted that equation (5) represents the "composite loss" (ITU definition 05.20) at 1000 Hz. The composite loss is the only measure of attenuation that allows adding of the losses of "half–channels" (i.e. A–D and D–A) regardless of the specific impendances at the input and output ports.

4 attenuation/frequency distortion

"Attenuation distortion" or "loss distortion" is the result of imperfect amplitude/frequency response and is generally specified in addition to the relative levels of a transmission section, from which the nominal transmission loss is derived. The definition of the attenuation/frequency distortion (*LD*) is well established: it is the difference between the actual response of voltage versus frequency $U(f)$ and the ideal (planned) response of voltage versus frequency $U^*(f)$, referred to the corresponding difference at 1000 Hz:

$$LD = \; - \tag{6}$$

Equation (6) can be rewritten as follows:

$$LD = 20 \log \; - 20 \log \tag{7}$$

For practical reasons the ideal response of voltage versus frequency, $U^*(f)$, is flat. Taking this into account, equation (7) reduces further to

$$LD = 20 \log \tag{8}$$

It should be noted that equation (8) is valid regardless of whether $Z01$ is equal to $Z02$ or not. However, impedance matching at input ($Z01$` $Z01$) and output ($Z02$` $Z02$) is assumed. A measurement in accordance with equation (8) is entirely in conformity with existing measuring techniques.

5 Conclusions

Nominal transmission loss and attenuation/frequency distortion are essential loss parameters. Their definitions in Sections 3 and 4 are based on the definition of relative (power) levels at 1000 Hz in accordance with Study Group XII which has stated the following advantages:

1) an illustrative indication of passband performance (especially with regard to band–edge distortion and extraneous ripples);
2) a loss definition in accordance with the relative level definition;
3) the loss values are relevant to singing margin evaluation;
4) the loudness insertion loss will be (almost) equal to the exchange loss;
5) additivity with a fair degree of accuracy;
6) the definition is also suitable for half exchange loss currently envisaged by Study Group XI.