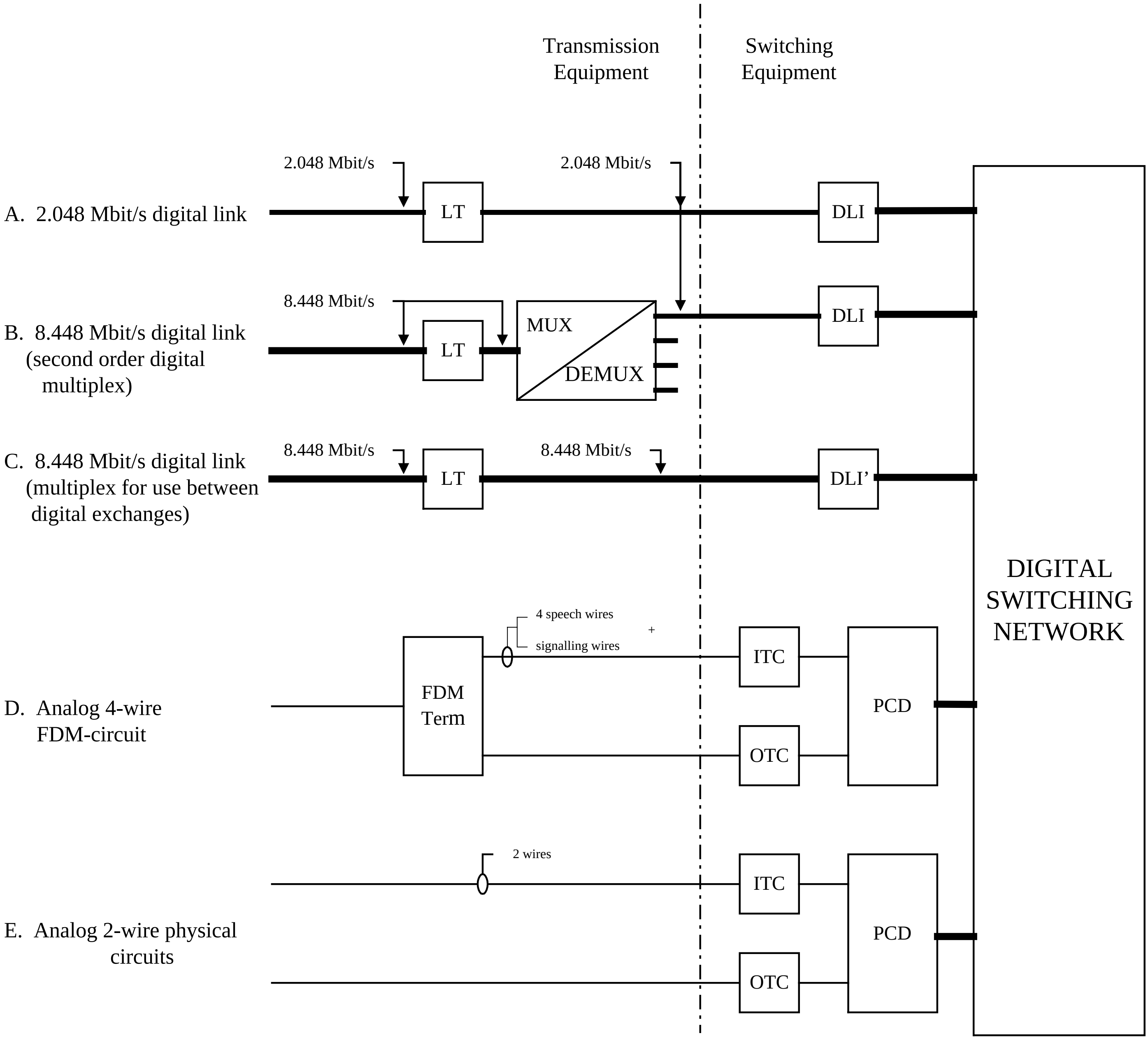
Transmission Environment

Mr. H. Leijon, ITU

UNION INTERNATIONALE DES TELECOMMUNICATIONS
INTERNATIONAL TELECOMMUNICATION UNION
UNION INTERNACIONAL DE TELECOMUNICACIONES

Transmission environment

The analogue switching will be forced out by the digital switching. The figure below shows different kinds of digital links and analogue circuits connected to a digital switching network.



Explanation of symbols:
LT = Line Terminal containing facilities for power feeding, fault location and regeneration
MUX/DEMUX = Multiplexor/demultiplexor is a unit performing multiplexing and demultiplexing between primary order multiplexes (links of type A) and secondary order multiplexes (links of type B)
DLI and DLI' = Digital Line Interface Unit containing facilities for signalling extraction, code conversion, frame extraction and alignment, alarms and fault indication

Figure 1 : Digital links and analogue circuits connected to a digital switching network

1. Purpose of the transmission plan

The purpose of the transmission plan is to lay down guiding principles and regulations for the design of the transmission elements in a telephone network, with a view to offering telephone subscribers an acceptable speech transmission quality at acceptable costs.

2. Parameters of the transmission plan

The primary factors that determine the speech transmission quality are the “reference equivalent” and the “securing of stability”, and these should therefore be included as parameters in all transmission plans.

2.1 The reference equivalent

The reference equivalent (RE) for a telephone system (from microphone to receiver case) is a measure of the system’s capacity to transmit speech power from the speaker to the listener and is determined by means of a reference system called NOSFER, which is administered by the CCITT Laboratory in Geneva.

Figure 2 illustrates how the total reference equivalent for an ordinary connection is obtained by adding together the equivalents or attenuation values of the component parts.

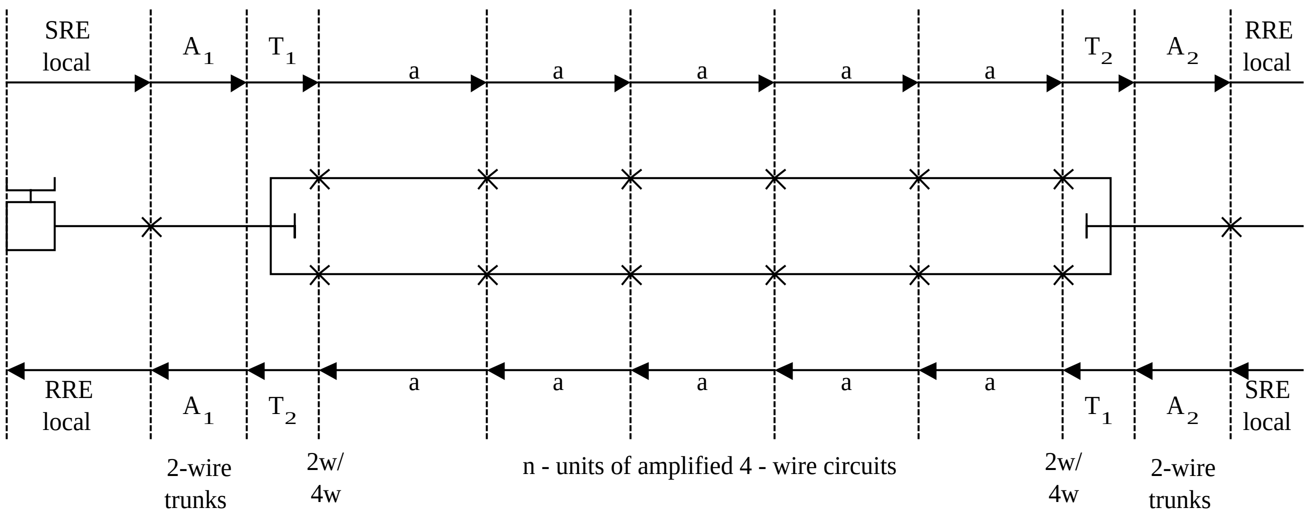


Figure 2

National connection
Distribution of the total reference equivalent

Using the designations as per Figure 2, we can state the reference equivalent of the connection as follows:

$$RE = SRE_{loc} + A_1 + T_1 + n \times a + T_2 + A_2 + RRE_{loc}$$

Note

Here and in the following text, T_1 and T_2 denote the attenuation (reference equivalent) at terminating points of at transition points (2-wire/4-wire and 4-wire/2-wire) through a hybrid circuit. Note that T and T_2 do not need to be equal to the attenuation of the physical hybrid circuit. The attenuation of the hybrid circuit can be compensated for in different ways.

For an international connection, the attenuation (reference equivalent) for international lines is to be added (see Figure 3).

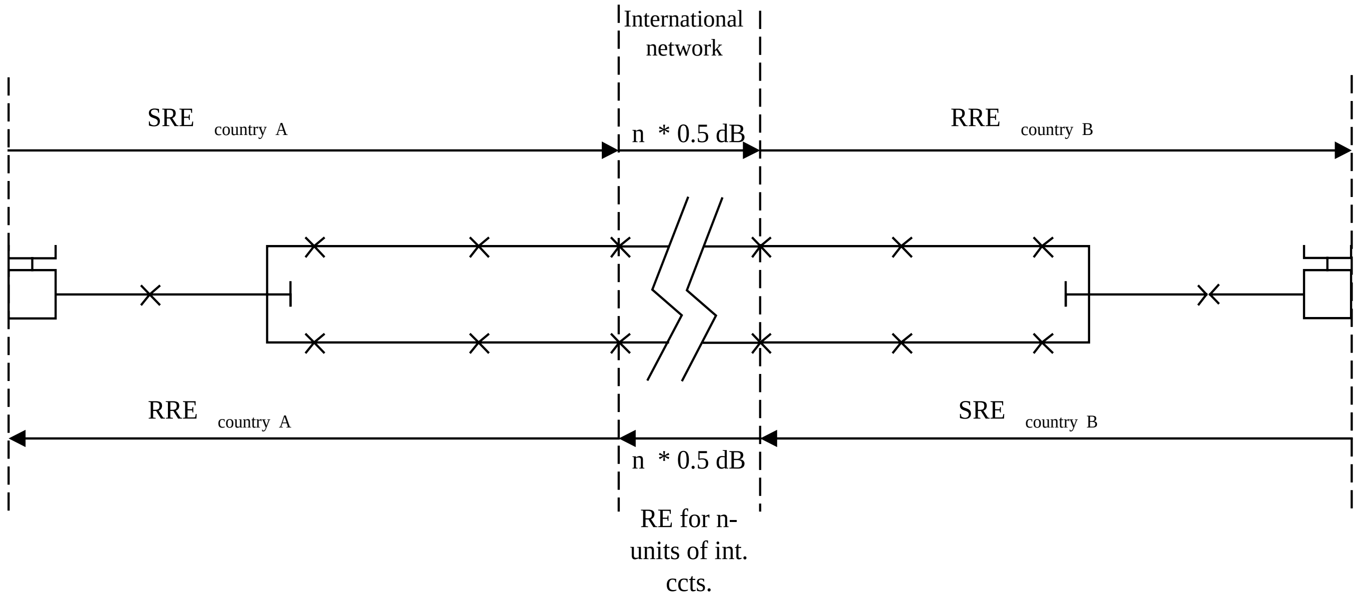


Figure 3 : International connection
Distribution of the total reference equivalent

According to CCITT, the nominal attenuation on an international line should be $0.5\ dB$. Using designations as per Figure 3, we can state the reference equivalent as follows:

Total RE from A to B = $SRE_{country\ A} + n \times 0.5 + RRE_{country\ B}\ dB$

Total RE from B to A = $SRE_{country\ B} + n \times 0.5 + RRE_{country\ A}\ dB$

The national parts (SRE and RRE in Figure 3) can be further divided as per Figure 4, which shows the section between the subscriber set and the international exchange.

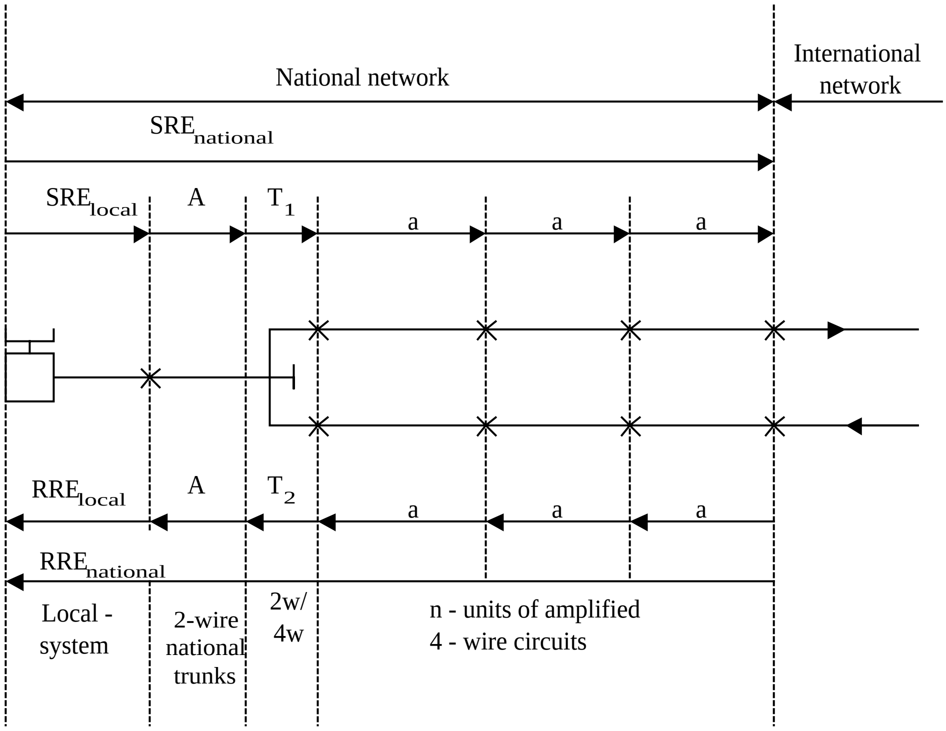


Figure 4 : International connection. Distribution of the national parts SRE_{nat} and RRE_{nat}

Using the designations as per Figure 4, we can state the reference equivalent as follows:

$$SRE_{nat} = SRE_{loc} + A + T_1 + n \times a$$

$$RRE_{nat} = RRE_{loc} + A + T_2 + n \times a$$

2.2 Stability requirements

Each of the hybrid circuits in the telephone connection, as per Figure 5, has a balance circuit for balancing 2-wire lines. Such balancing can never be perfect, as a certain degree of "crosstalk" will result between the speech directions from and to the amplified 4-wire line.

Figures 5-7 illustrate the stability requirements.

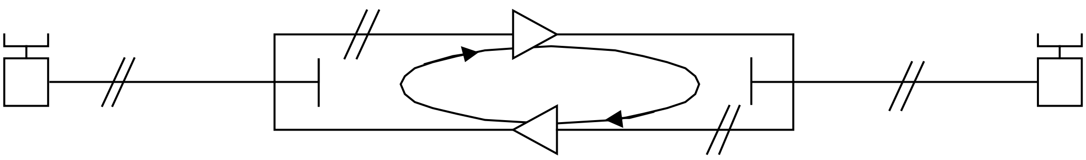


Figure 5

Arbitrary telephone connection including amplified lines

The attenuation round the loop in Figure 5 is to be ≥ 0 + a margin. Otherwise, self-oscillation may occur in the system; the line may start "singing".

The "loop attenuation" may be distributed as per Figure 6.

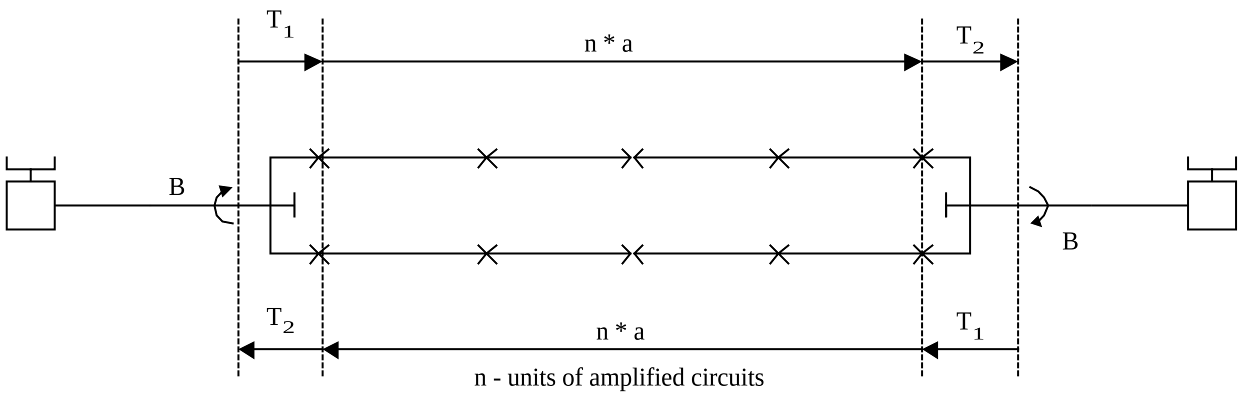


Figure 6

National connection

Let us study the speech currents in the 2-wire terminal of the hybrid circuit that come from the 4-wire line: $\underline{B}$ is a measure of the quality of the hybrid circuit balance and indicates (in decibel) the RELATION between the power that should be generated to the subscriber if the balance were perfect, and the power which - due to unbalance in the hybrid circuit - is "reflected" back to the 4-wire line.

If we add together the attenuation values round the loop as per Figure 6, we get:

$$2\times(B + T_1 + T_2 + n\times a) \quad dB$$

Thus, the stability condition for a national connection can be expressed as follows:

$$2\times(B + T_1 + T_2 + n\times a) \geq 0 + margin \;\; dB$$

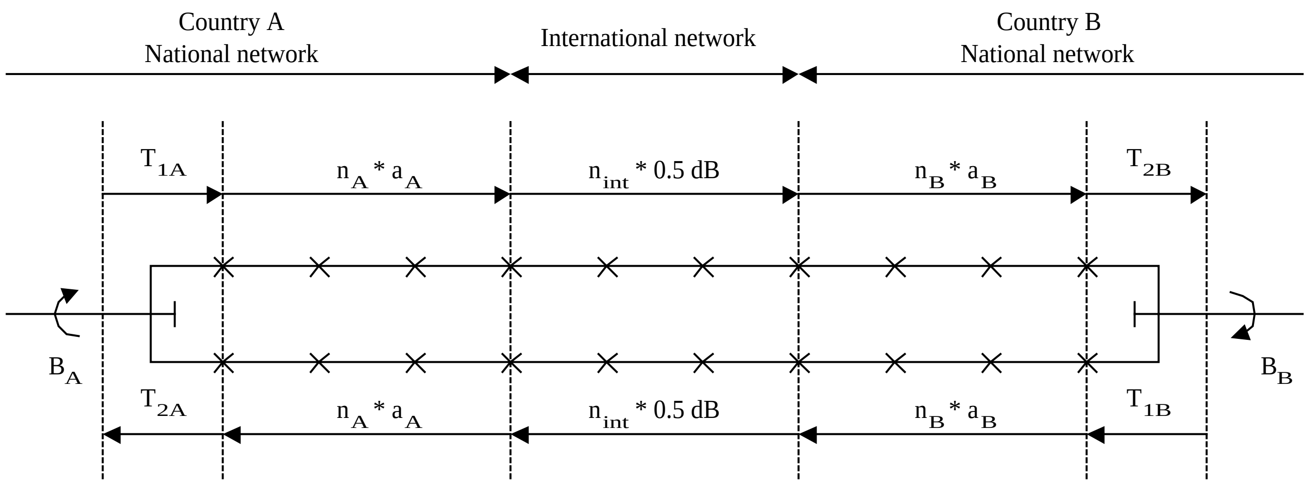


Figure 7

International connection

If we add together the attenuation values round the loop as per Figure 7, we get:

$$(B_A + T_{1A} + T_{2A} + 2n_A \times a_A) + (B_B + T_{1B} + T_{2B} + 2n_B \times a_B) + n_{int} \times 1 \ \ dB$$

Thus, we can express the stability requirements for an international connection as follows:

$$(B_A + T_{1A} + T_{2A} + 2n_A \times a_A) + (B_B + T_{1B} + T_{2B} + 2n_B \times a_B) + n_{int} \times 1 \geq 0 + margin \ \ dB$$

To maintain the stability in international traffic, each administration must prepare a transmission plan which keeps the country's contribution to the total attenuation round the loop at an adequate value.

Consequently, the value of $T_1 + T_2$ and $\underline{a}$ must be based on the value of the hybrid circuit balance B that the administration considers attainable in the national network.

3. Structure of the transmission plan

The reference equivalent is the most important transmission parameter used for dimensioning purposes. Thus, the primary task of the transmission plan is to establish the maximum permissible reference equivalent and to indicate how the reference equivalent is to be distributed over the national network in order to offer all subscribers an acceptable speech quality at a reasonable total cost.

3.1 CCITT requirements

The national transmission plan must meet the requirements imposed by the CCITT recommendations on the country's part of an international connection. The most important of these recommendations is the one that deals with the reference equivalent between the international exchange and an arbitrary subscriber, and the one that deals with the stability requirements.

Thus, CCITT has specified requirements concerning the national contributions, SRE and MRE, to the total reference equivalent, and - as a protection against instability - requirements on the national network's contribution (S) to the total attenuation round the 4-wire loop.

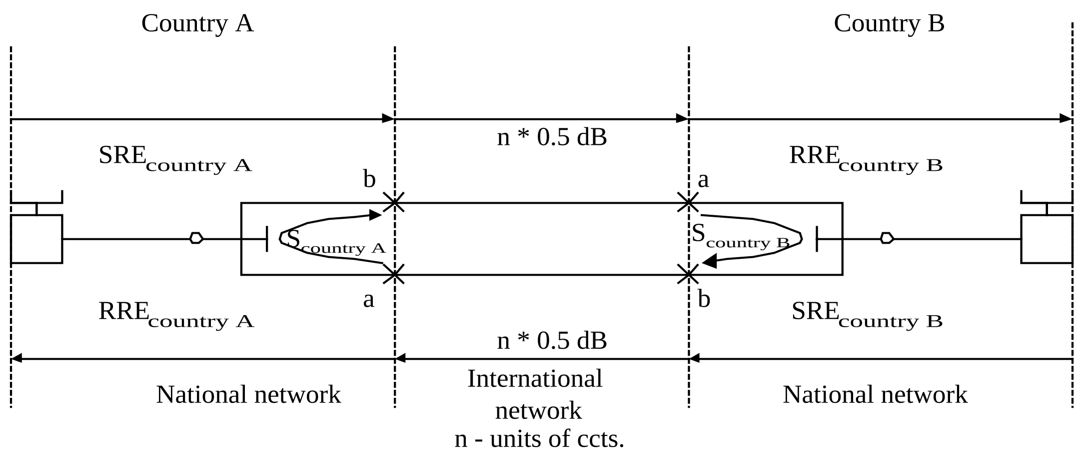


Figure 8

International connection. As regards individual national parts, CCITT has specified maximum values for SRE and RRE and a minimum value for S

Virtual switching point

a and *b* are so-called virtual switching points, with relative levels -4.0 dBr and -3.5 dBr, respectively (see Figure 9). *t* represents a point on the 2-wire side of the hybrid circuit.

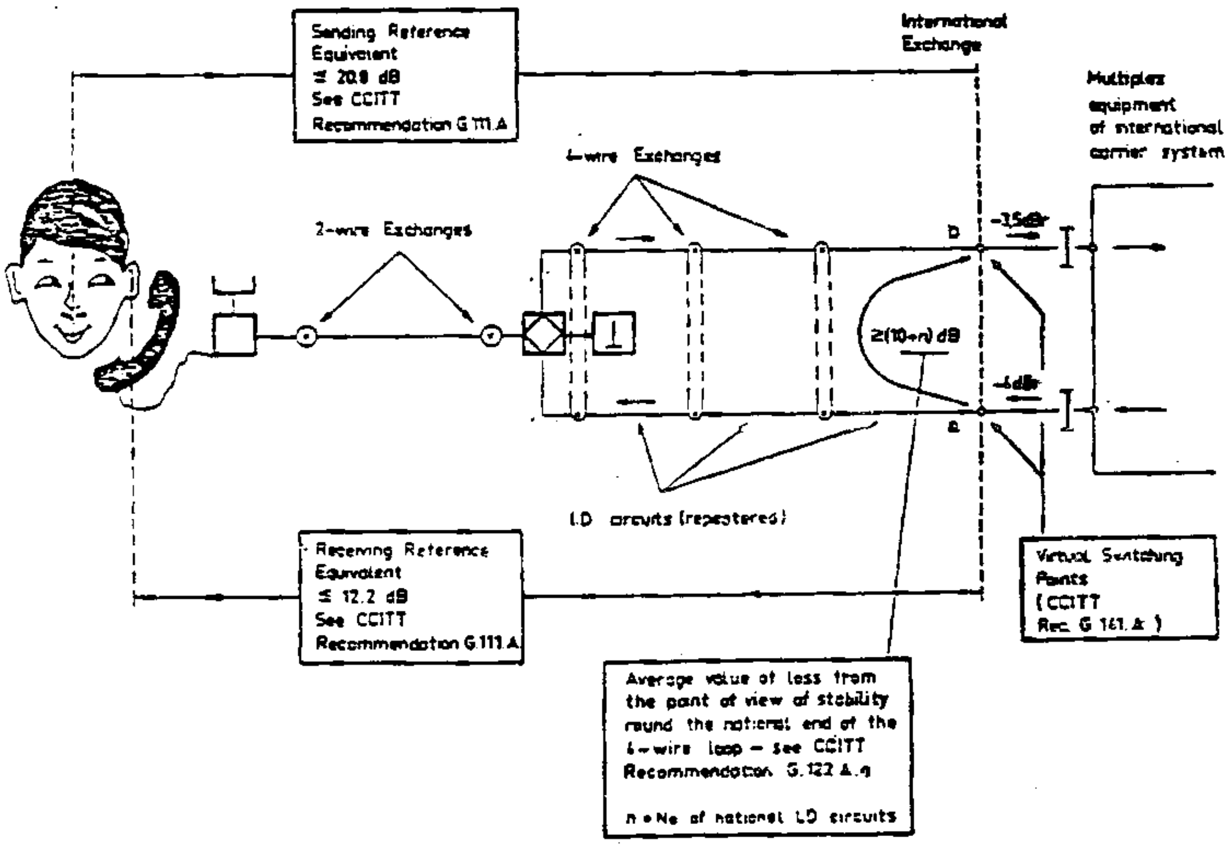


Figure 9

Virtual switching points and their relation to reference equivalent and stability requirements

A well-defined boundary (in terms of level) must be provided between the international and national networks in order to permit unambiguous wording of these requirements and application in all national networks. If the physical switching point in the international exchange is chosen as boundary, the requirements will not be unambiguous, as the level conditions at this switching point may vary from one international exchange to another.

Instead, the concept “virtual switching point” (VSP has been introduced. This fictitious switching point has been allocated fixed level values based on the international line: -3.5 dBr for the outgoing speech direction (to the international line) and -4.0 dBr for the incoming speech direction. The position of VSP can always be determined in an exchange with known level conditions.

In accordance with CCITT’s recommendations, the VSPs in Figures 8 and 9 have been designated *a* for the incoming speech direction (-4.0 dBr) and *b* for the outgoing speech direction (-3.5 dBr).

The applicable CCITT requirements can now be formulated as follows.

3.2 Maximum nominal reference equivalent for sending and reception

For 97 % of the incoming and outgoing international connections in a medium-size country,

the nominal value of the reference equivalent for sending between a subscriber and the first international line shall be SRE ≤ 20.8 dB;

the nominal value of the reference equivalent for reception between the same points shall be RRE ≤ 12.2 dB.

SRE and RRE are to be measured at points on the international line (the virtual switching points) where the relative level is -3.5 dBr in the sending direction and -4.0 dBr in the receiving direction.

Each administration is free to distribute these reference equivalents over the different lines within the country, provided that the stability requirements are met.

When distributing the attenuation over the national network, administrations normally require the lowest possible attenuation in the 4-wire long-distance network (attenuation values $\underline{a}$, T_1 *and* T_2 in Figure 4), in order to provide the highest possible attenuation for the 2-wire, unamplified part of the telephone network. Usually, a very large portion of the total cost represents the 2-wire, unamplified part of the telephone network. Usually, a very large portion of the total cost represents the 2-wire subscriber lines and the junction lines within local areas. Thus, high attenuation means cheaper cables of smaller diameter.

3.3 Attenuation S along the path a-t-b in Figure 8, considering the stability on international connections:

a To obtain sufficient stability on international connections, the attenuation between the virtual switching points $\underline{a}$ and $\underline{b}$, along the path a-t-b in the national network, must be at least (6+n) dB, where n represents the number of 4-wire lines in the national part of the connection.

This requirement applies to the frequency range 0-4 kHz.

The requirement applies to all terminating conditions and normal function (also before answer and after clearing).

b When preparing new transmission plans, administrations should aim at a mean value for the attenuation along the path a-t-b of at least (10+n) dB.

Here, the dimensioning value $S = 10 + n \ dB$ represents the “margin” for securing stability. The reason for the high S value is that an international connection may be established over several amplified lines whose degrees of amplification vary somewhat.

3.4 Examples of transmission plans

Below follow some examples of transmission plans which meet CCITT’s requirements on reference equivalent and stability. The values given in the examples refer to the virtual switching points (VSP) $\underline{a}$ and $\underline{b}$.

Designations for partial attenuation values, etc., used previously are also indicated in Figure 9, where:

RRE = the reference equivalent for reception in VSP $\underline{a}$

SRE = the reference equivalent for sending in VSP $\underline{b}$

S = the attenuation a-t-b as regards stability

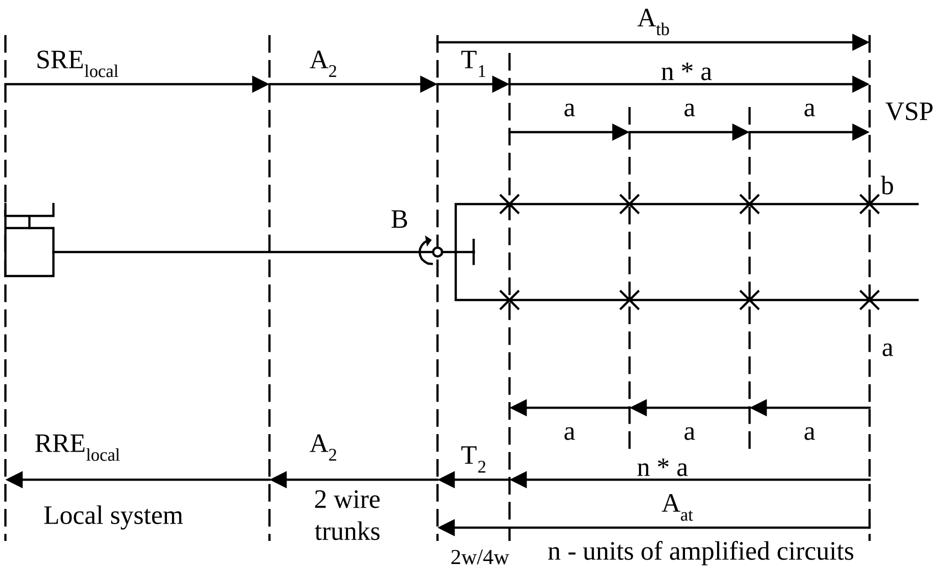


Figure 10

Designations

By means of these designations, CCITT requirements can be stated as follows:

$$RRE = RRE_{loc} + A_2 + T_2 + n \times a \leq 12.2 \ dB$$

$$SRE = SRE_{loc} + A_2 + T_1 + n \times a \leq 20.8 \ dB$$

$$S = B + T_1 + T_2 + 2n \times a = B + A_a + A_b \geq 10 + n \ dB$$

The required values of the attenuation $\underline{a}$ on 4-wire lines and of the terminating attenuation values T_1 and T_2 are obtained by regulating the amplification or levels of the amplified lines by means of attenuators, and by using amplified hybrid circuits.

The interconnection points ($\underline{x}$ in the figures) are usually fictitious in the same way as the virtual switching points in the international exchange.

3.5 Lumped loss and distributed loss

a) *Lumped loss*

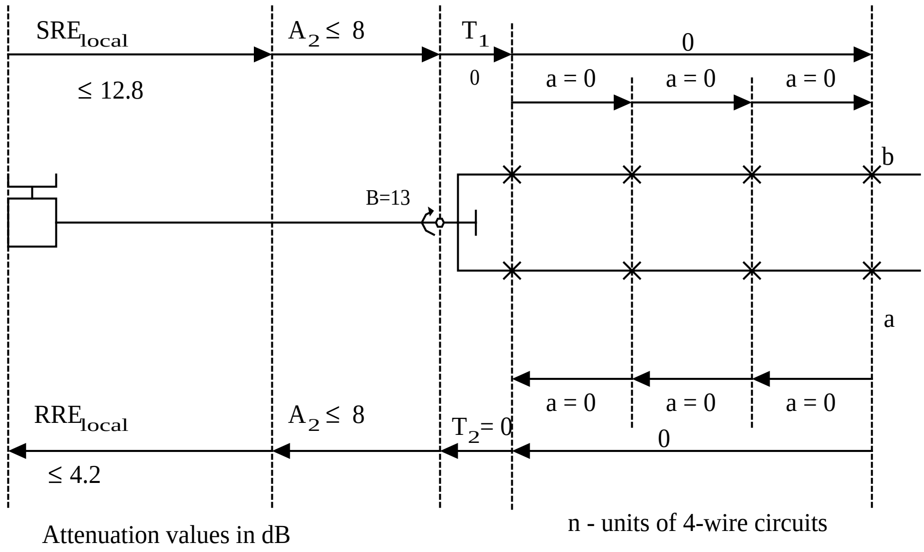


Figure 11

Example of transmission plan - lumped loss

$RRE \leq 4.2 + 8 = 12.2 \quad dB$ (independently of n)

$SRE \leq 12.8 + 8 = 20.8 \quad dB$ (independently of n)

$S = B = 13 \; dB$ meets the requirement $S \leq 10 + n \quad dB$, provided that the number of 4-wire links n is ≤ 3.

In the example above, the terminating attenuation values $T \; \& \; T_2$ are 0 (which may have been achieved by disconnecting attenuators on the amplified line or by means of an "amplified hybrid circuit"). This will impose strict requirements on the balancing B, which should have a mean value of ≥ 13 dB. On the other hand, high attenuation can be permitted in the local network.

b) *Distributed loss*

Another way of meeting the requirements on the attenuation a-t-b (i.e. $S \geq (10 + n)$) is to let each amplified national line contribute its attenuation value (so-called distributed loss), which is the opposite of lumped loss as per Figure 11. This contribution may, for instance, amount to 0.5 dB per line and speech direction, the requirements on the balance attenuation B being independent on the number of national amplified lines included in the connection.

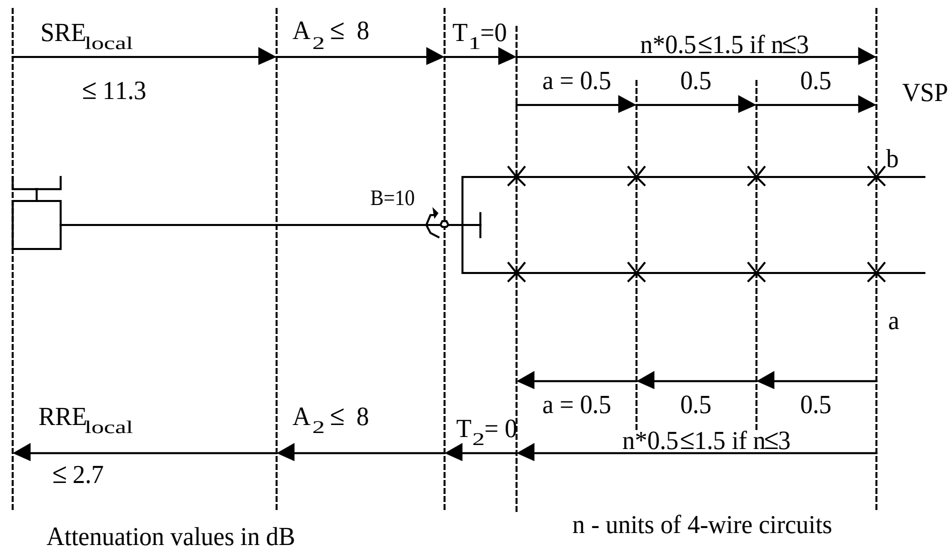


Figure 12

Distributed loss

$$RRE = 2.7 + 8 + n \times 0.5 = 10.7 + n \times 0.5 \leq 12.2 \quad dB \quad if \quad n \leq 3$$

$$SRE = 11.3 + 8 + n \times 0.5 = 19.3 + n \times 0.5 \leq 20.8 \quad dB \quad if \quad n \leq 3$$

$S = n \times 0.5 + 10 + n \times 0.5 = 10 + n \quad dB \quad (B = 10 \quad dB)$ meets the requirements $S \geq 10 + n \quad dB$, independently of the $\underline{n}$ value.

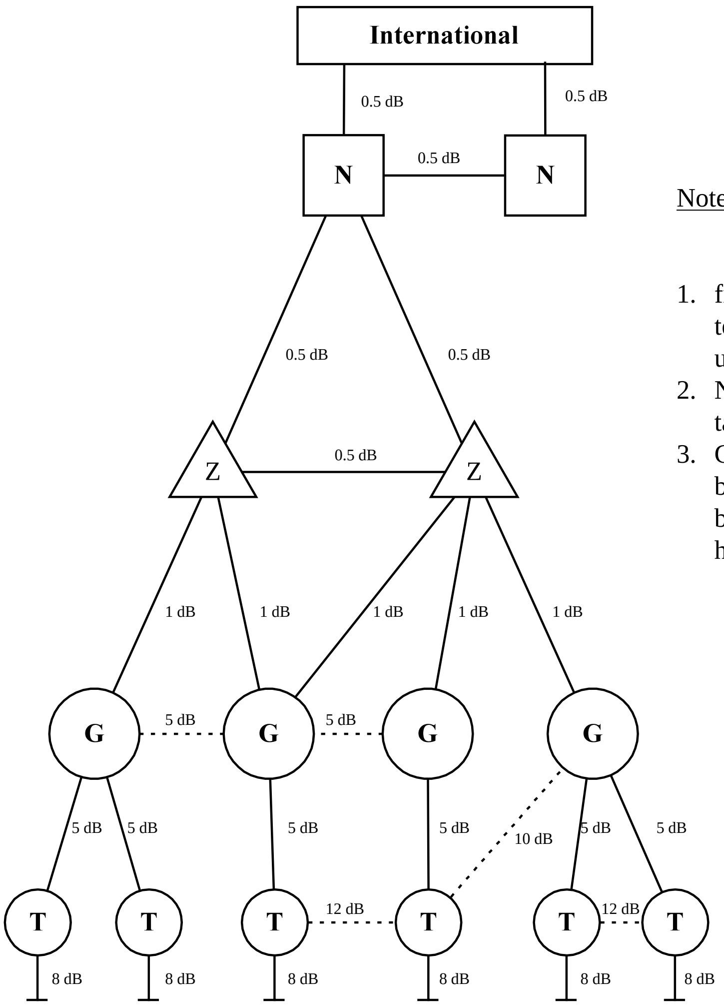
Here, it has been possible to reduce the hybrid circuit balance by 3 dB. In this case, the permissible attenuation in the 2-wire network will be as follows:

Sending: $SRE_{loc} + A_2 = 20.8 - n \times 0.5 \quad dB$

Reception: $RRE_{loc} + A_2 = 12.2 - n \times 0.5 \quad dB$

This means that the permissible attenuation is dependent on the number of 4-wire lines $\underline{n}$ between the hybrid circuit and the international exchange. If termination takes place in the international exchange (n = 0), the 2-wire network can be given the same attenuation value as in the case described in Figure 11, i.e. 1.5 dB above the value as per Figure 12. The subscriber density is usually highest around the international exchange.

As an example of a transmission plan, Figure 13 presents the transmission plan for the national network in Malaysia (where the distributed loss principle has been adopted).



Notes: Dotted lines are high-usage routes and will be used only as follows:

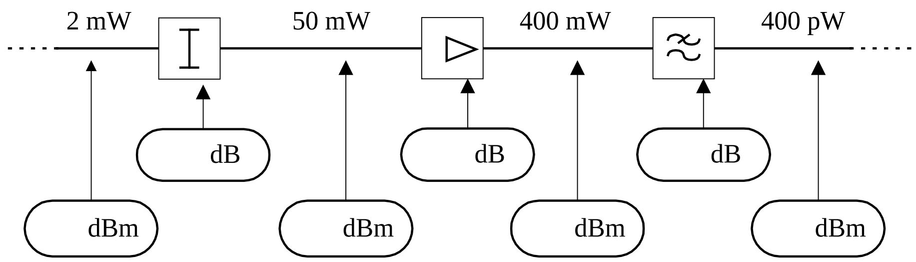
1. from group to group, group to terminal, or terminal to terminal exchanges where such high-usage routes exist;
2. No two high-usage routes will be used in tandem;
3. Group to group exchange high-usage routes will be used as second choice routes for traffic between terminal exchanges having their own high-usage routes.

Figure 13

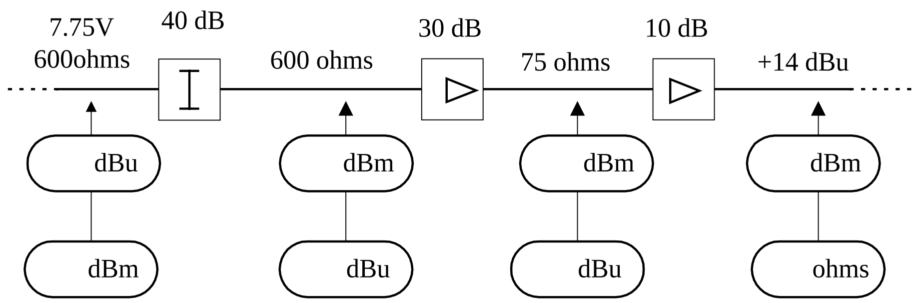
Allocation of maximum permissible reference equivalent in Malaysian national transmission plan

Exercises 1-4 : Fill in the missing decibel values

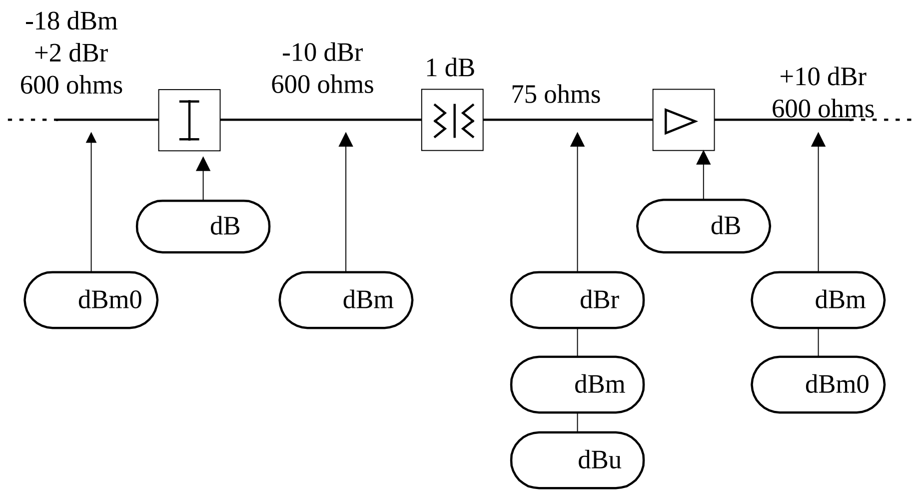
Exercise 1:



Exercise 2:



Exercise 3:



Exercise 4: