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TECHNICAL CONDITIONS FOR SMALL DIAMETER CO-AXIAL PAIRS (1)

R Article 1 - Application

Small diameter coaxial pairs are suitable for the transmission of 4-wire carrier frequency systems in the 60 to 1300 kc/s frequency band, the same frequencies being used for both transmission directions. In cases where it is more economical to do so, they should also be used for the transmission of 2-wire carrier frequency systems in the 60 to 1300 kc/s frequency band, different frequencies being used for each direction of transmission.

(1) Obligatory regulations are preceded by an asterisk thus : *

(revised on 1-1-1984)

R Article 2 - Profitability

2.1. The profitability of operating carrier frequency systems over small diameter coaxial pairs compared with the operation of communications at audio frequency, or with that of carrier frequencies over balanced pairs, depends on certain conditions which should be studied in detail. Special consideration should be given to the following points :

2.1.1. Over lines where the laying of cables proves necessary for other reasons, the opportunity should be taken at the same time to include coaxial pairs in the telecommunications cables.

2.1.2. If the coaxial pairs are not used to the fullest extent by carrier frequency telephone circuits they are only economic above a minimum number of circuits.

2.1.3. The various carrier frequency telephone circuits only become economic if they are operated beyond a minimum distance.

2.1.4. If it is necessary to derive telephone circuits from a carrier frequency system, the number of telephone circuits operated on the partial lines should not be too small.

2.2. It is recommended that a comparison should be made between the profitability of the various solutions, in view of the fact that the cost may be different on the various Railways. In addition, the use of coaxial pairs can be dictated solely by operating reasons, for example the absence of interference, and this should be taken into account in calculating the profitability.

* Article 3 - Definition

Small diameter coaxial pairs shall be understood as being those with the following nominal dimensions :

- diameter of the internal conductor : 1.2 mm
- internal diameter of the external conductor : 4.4 mm
- thickness of the external conductor : 0.18mm or 0.15mm optional.

R Article 4 - Arrangement of small diameter coaxial pairs in composite cables

4.1. Cables containing small diameter coaxial pairs may also include balanced pairs.

4.2. When coaxial pairs are arranged in a cable layer with star-quads or as combinable pairs, the external diameter of certain cable elements in this layer should be increased to make the cable as uniform as possible.

4.3. If this arrangement is unsuitable, a cable layer should be formed with the coaxial pairs only, placing them preferably in the centre.

NOTE : To avoid restricting the manufacturing alternatives on the part of the makers, the latter may exercise their [illegible] regarding details of manufacture, insofar as compliance with the electrical values allows.

* Article 5 - Electrical values of manufactured lengths (standard length 425 m)

5.1. Insulation resistance measured with direct current at a temperature of + 20°C.

5.1.1. Between the internal and external conductors : 5 ≥ GΩ/km.

5.1.2. If coaxial pairs are used for carrier frequency systems with floating potential, the insulation resistance between an external conductor on the one hand, and the other external conductors, the other conductors in the cable, and the metal cable sheathing on the other, must be ≥ 0.1 GΩ/km.

5.2. Linear resistance measured with direct current at a temperature of + 20°C.

5.2.1. Internal conductor : ≤ 16.5 Ω/km.

5.2.2. External conductor for a thickness of 0.18 mm : ≤ 7.5 Ω/km
for a thickness of 0.15 mm : ≤ 8.5 Ω/km

5.3. Characteristic impedance at 1000 kc/s

5.3.1. Nominal value 75 Ω.

5.3.2. Average value of manufactured lengths forming part of a repeater section 75 ± 1.5 Ω.

5.3.3. Difference in the value of a manufactured length in a repeater section in relation to the average value : ≤ 1 Ω.

5.3.4. If, in a national network, the manufactured lengths are laid according to a grouping plan, the average value defined in 5.3.2. can be 75 ± 2 Ω, and the difference in the value of a manufactured length defined in 5.3.3. can be ≤ 3 Ω, provided the conditions of Article 6 are met.

5.4. Permissible values of the reflection coefficient.

5.4.1. For all manufactured lengths of a repeater section : ≤ 0.6 % (reflection attenuation ≥ 5.2 N).

5.4.2. For 80% of manufactured lengths of a repeater section: ≤ 0.4 % (reflection attenuation ≥ 5.5 N).

5.5 Crosstalk at 60 kc/s between small diameter coaxial pairs: Basic value of far-end crosstalk (far-end crosstalk attenuation loss attenuation of the manufactured length).

$$a_f - a \geq 13N - \ln \frac{l}{425}$$

5.6. Dielectric strength tests

5.6.1. An alternating voltage of 1000 V_{eff} at 50 c/s, or a continuous voltage of 1500V, is applied to the manufactured lengths between the internal and external conductors, for a period of 2 minutes.

5.6.2. An alternating voltage of 2000 V_{eff} at 50 c/s, is applied for a period of 2 minutes between the external conductors, on the one hand, and the other conductors on the other, if the carrier frequency system incorporates external conductors to earth.

5.6.3. An alternating voltage of 2000 V_{eff} at 50 c/s, is applied to the manufactured lengths between an external conductor and the other conductors or metal sheaths, for a period of 2 minutes, if the carrier frequency system does not incorporate external conductors to earth (floating potential).

* Art. 6 - Electrical values of the repeater sections (standard length 6 or 8 km)

6.1. Insulation resistance measured with direct current at a temperature of + 10° C.

6.1.1. Between the internal and external conductors: $\geqslant$ 5 G Ω/km.

6.1.2. If the co-axial pairs are operated by carrier frequency systems with a floating potential, the insulation resistance between an external conductor on the one hand, and the other external conductors, the other conductors in the cable, and the metal cable sheathing on the other, must be : $\geqslant$ 0,1 G Ω/km.

6.2. Linear resistance measured with direct current at a temperature of + 10° C.

6.2.1. Internal conductor : $\leqslant$ 15.9 Ω/km.

6.2.2. External conductor : for a thickness of 0.18 mm : $\leqslant$ 7.2 Ω/km
for a thickness of 0.15 mm : $\leqslant$ 8.2 Ω/km

6.3. Characteristic impedance, at 1000 kc/s :
difference in relation to the nominal value : $\leqslant$ 1.5 Ω .

6.4. Permissible values of the reflection coefficient $\leqslant$ 0,8%.

6.5. Linear attenuation at a temperature of + 10° C.

6.5.1. Nominal value at 1000 kc/s : 610 mN/km
Permissible difference in relation to the nominal value : 23 mN/km.

6.5.2. Permissible difference of anyone of the repeater sections situated between two main repeater centres in relation to the average value of these sections : $\leqslant$ 10 mN/km

6.5.3. Attenuation as a function of frequency, defined in terms of the ratio between the attenuation at 60 kc/s ($\alpha 60$) and the attenuation at 1000 kc/s ($\alpha 1000$).

The ratio $\frac{\alpha 60}{\alpha 1000}$ lies between 0.276 and 0.294

for an external conductor 0,18 mm in thickness.

The ratio $\frac{\alpha 60}{\alpha 1000}$ lies between 0.288 and 0.305

for an external conductor 0,15 mm in thickness.

6.6. Crosstalk between small diameter co-axial pairs at 60 kc/s :
Basic value of the far-end crosstalk (far-end crosstalk attenuation, less attenuation of the repeater section).

6.6.1. for a standard length of 6 km :

$$af = a \; 10.2 \; N - \ln \frac{\ell}{6}$$

where ℓ is the length in kilometers

6.6.2. for a standard length of 8 km :

$$af = a \; 9.9 \; N - \ln \frac{\ell}{8}$$

where ℓ is the length in kilometers.

6.7. Dielectric strength tests between internal and external conductors : 1000 V continued for a period of 2 minutes.

R Art. 7 - Measurements

7.1. Measurements taken in the factory on manufactured lengths.

7.1.1. The insulation resistance of each co-axial pair is measured for all manufactured lengths.

7.1.2. The linear resistance of each co-axial pair is measured for all manufactured lengths.

7.1.3. The characteristic impedance of all co-axial pairs should be measured at both ends of all manufactured lengths. Its value is determined from the values of the balance network best matching the line, when the reflection coefficient is measured.

7.1.4. The reflections should be measured on all co-axial pairs from one or both ends of all manufactured lengths. The pulse method is recommended. For the purpose of this measurement, a pulse should be used in which the spectral distribution of energy is fairly uniform up to 8 Mc/s, subsequently decreasing slowly. The distant ends of the co-axial pairs should be terminated by a balancing network reproducing the characteristic impedance of the line.

At the measuring end, the input impedance should be compared with a balance. The amplitude of the reflected pulses which appear on the screen and their time lag in relation to the pulses transmitted, depend on the size of the reflection coefficient and the distance from the reflection point to the measuring point.

The balances at the measuring end and the distant end are adjusted so that no reflected pulse due to the terminations appears. To be suitable for use, the measured value should be corrected to take into account the fact that the distortion of the reflected pulse compared with the transmitted pulse depends upon the nature of the reflection point and its distance from the measuring point. The corrections depend upon the composition of the coaxial pairs and the form of the pulse used.

The greatest reflection coefficient $r\ max = \frac{\Delta Z\ max}{Z_\infty}$

gives the value of the maximum reflection point with respect to the characteristic impedance.

7.1.5. Crosstalk should only be measured on a small number of manufactured lengths taken at random. During the measurements, the external conductors of the coaxial pairs should be connected at both ends to the metal sheath of the cable. The cable sheath should be earthed at the measuring point. The coaxial pairs are terminated by a resistance of 75 Ω.

During measuring, the cable conductors which are not involved should neither be earthed or connected to the sheath.

7.1.6. All coaxial pairs of all manufactured lengths should be subjected to the dielectric strength test referred to in 5.6.

7.2. Measurements made during installation.

7.2.1. During installation, the Contractor should take the following measurements :

7.2.1.1. The measuring method is the one described in 7.1.4. Measuring should always be effected on several manufactured lengths, in order to detect also any reflections at junction points.

7.2.1.2. The dielectric strength should be measured continuously on each coaxial pair. This measurement provides assurance that the dielectric strength condition is also complied with at the junction points.

7.3. Acceptance measurements

7.3.1. The following measurements are taken on the repeater sections.

7.3.2. The linear resistance and the insulation resistance should be measured on all coaxial pairs. The temperature correction should be taken into account. The measurement values are converted to a temperature of + 10° C.

7.3.3. The characteristic impedance of each coaxial pair should be measured at each end of the repeater section. The input impedance measurement is taken in the 500 to 1500 kc/s frequency band, the coaxial pair being terminated by a resistance of 75 Ω. An average smooth curve is prepared from the results obtained. At 1000 kc/s the value of this average curve should be between 73.5 and 76.5 Ω.

Consideration can also be given to the real component (Z_∞) of the impedance of the most suitable balance which was used for the reflection measurements. A correction is necessary to obtain the value at 1000 kc/s. This method should generally have preference, since it gives the simplest and quickest solution.

7.3.4. The impedance regularity should be measured by impulses introduced into the coaxial pair. The echo of these impulses is observed at the outset. The effect of the attenuation distortion to which the impulses on the coaxial pair are subjected can be corrected either by calculation or by automatic or manual correction by means of line networks.

7.3.5. The attenuation constant, the overall loss or the attenuation coefficient must be measured on each coaxial pair in each repeater section. The attenuation is determined by measuring the levels, the end of the circuit being terminated by a resistance of 75 Ω. In order to have the generator and the level receiver at the same measuring point, two coaxial pairs can be connected together at the distant end.

The results of the measurements must be converted to a temperature of + 10° C (see Appendix).

In order to obtain an overall view, the attenuation should be measured with respect to the frequency, in the 60 kc/s to 1300 kc/s band, of the coaxial pairs of a repeater section from each Manufacturer.

On the other repeater sections a record of the attenuation at 60 kc/s and 1000 kc/s only is taken, and the ratio $\frac{\alpha_{60}}{\alpha_{1000}}$ is calculated, the uniformity of which also assumes evenness of the attenuation variation with respect to the frequency.

7.3.6. The near-end crosstalk attenuation should be measured at 60 kc/s on some repeater sections only between all coaxial pairs.

For the sake of convenience, measurement should be effected from an easily accessible repeater point. Measuring takes place on the coaxial pair terminating in a resistance of 75 Ω.

The far-end crosstalk attenuation should be measured only if the cable includes at least 4 coaxial pairs. Measuring should be effected at one end of the repeater section between all coaxial pairs.

7.3.7. It is recommended that the dielectric strength tests in accordance with 6.7., should be carried out on each repeater section.

APPENDIX

CONVERSION OF MEASURING VALUES

OF REPEATER SECTIONS AT A TEMPERATURE OF + 10° C.

1. Determination of the temperature of the cable

The resistance of 1km of central conductor, at a temperature of + 20° C, under direct current, intended to serve as an average value for all lengths constituting a repeater section, is determined from measurements effected in the factory on manufactured lengths. Let R_o be this value. A central conductor resistance of R_t Ω / km is measured on the repeater section at t° C. Taking a temperature coefficient of 0.393%/° C, the temperature of the cable is then :

$$t = 20 - \frac{Ro - Rt}{Ro} \; 254 \; (°C).$$

2. Conversion of the measured value of the insulation resistance of the external conductor to the value for + 10° C. (see Article 6.1.)

The temperature coefficient is 0.6%/°C. This gives a conversion factor of :

$$1 - 0.006 \; (10-t)$$

by which the measured value must be multiplied.

3. Conversion of the linear resistance measurements to values for + 10°C (see Article 6.2.)

In view of the fact that temperature differences are usually small when measurements are taken in relation to + 10°C. It suffices to take into consideration a temperature coefficient of 0.4 %/° C. This gives a conversion factor of :

$$1 + 0.004 \; (10-t)$$

by which the measured values must be multiplied.

4. Conversion of the linear attenuation measurement to values for + 10°C (see Article 6.5.)

At high frequencies, the temperature coefficient equals almost

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half of the temperature coefficient of the resistance under direct current. This increases when the frequency decreases. It is 0.2[illegible] for frequencies above 300 kc/s.

At 60 kc/s the figure is slightly above this value. This increase also depends on the composition of the coaxial pairs. For small diameter coaxial pairs and at 60 kc/s, this coefficient should not exceed 0.25%/°C. Serious errors can be avoided if a constant temperature coefficient of 0.2%/°C is used for the conversion of the values measured. This gives a conversion factor of :

$$1 + 0.002\ (10 - t)$$

by which the measured values must be multiplied.

APPLICATION

With effect from 1st January, 1966 for obligatory regulations (from 1st January, 1968 as regards Points 5.6.2, 5.6.3, 6.6, 6.6.1, 6.6.2, and 6.6.3.).

All Railways in the Union.

RECORD REFERENCES

Headings under which the question has been dealt with :

- Use of co-axial cables by the Railways.

(17th Committee -5.T.- : Paris, May 1961 ; Portsmouth, May 1962; Paris, May 1963 ; Berne, May 1964 ; Leipzig, May 1965).

- Revision of leaflet No. 759: "Technical conditions for small diameter co-axial pairs".

(17th Committee -5.T.-: Stockholm, May 1967).