Zeitschrift: Technische Mitteilungen / Schweizerische Post-, Telefon- und Telegrafenbetriebe = Bulletin technique / Entreprise des postes, téléphones et télégraphes suisses = Bollettino tecnico / Azienda delle poste, dei telefoni e dei telegrafi svizzeri

Herausgeber: Schweizerische Post-, Telefon- und Telegrafenbetriebe

Band: 66 (1988)

Heft: 4

Artikel: Simple and accurate screening measurements on RF-cables up to 3 GHz

Autor: Eicher, Bernhard / Staeger, Christian / Szentkuti, Bàlint

DOI: https://doi.org/10.5169/seals-876242

Simple and accurate screening measurements on RF-cables up to 3 GHz

Bernhard EICHER, Christian STAEGER and Bàlint SZENTKUTI, Berne, Heinz FAHRNI, Solothurn

1 Introduction

Today, the electromagnetic compatibility (EMC) plays a dominant role in system design of various electronic equipment. In spite of ongoing integration of thousands of complex functions in very small circuits, interconnections to the 'outside world' are still necessary. Together with the electronic circuits, these interconnections are susceptible to electromagnetic interference problems. For these indispensable interconnections of circuits, screened cables and connectors are commonly used.

A test method for screening performance of interconnection elements should allow for measurements over *broad frequency ranges* and the method should provide test results reflecting the practical situation where such interconnections are used normally. A test method for high frequency coaxial connectors has already been described in [1, 2] and the so-called matched triaxial test method is now established as an IEC Standard.

The same method can also be extended to cable screening measurements [2]. Because of the more complex problem of measurements on cables or cable assemblies, this and other related test methods become very complicated to handle. The classical wire injection method, introduced by *E. P. Fowler* [3, 4, 5], was the first step to solve these problems. But the usual version of this set-up, originally provided up to 100 MHz, suffered from the poor matching and undefined attenuation beyond this value. Also, there was no information available on the capability of the wire injection testing beyond these frequencies.

To overcome these limitations, a new transmission type wire injection set-up has been developed and tested. The main objectives are:

- to develop a matched broadband ($f \geq 3$ GHz) wire injection circuit
- to investigate the feasibility of the wire injection test procedure to $f \geq 3$ GHz
- to perform a large set of comparative tests on various cables with the wire injection and the triaxial set-ups.

2 Screening tests

21 Basic relations

In this section, the results obtained in [6] are summarized. It deals with the screens of coaxial *c*ables *u*nder *t*est (CUT). The theory and the methods are generally applicable, and they are valid also for the screens of multiwire cables.

The screening effectiveness of a coaxial cable is tested by applying a well-defined current and voltage to the screen in a test set-up and measuring thereby the internally induced voltage. The ratio of these signals is measured as an attenuation. The *set-up* represents the *primary circuit*, also called *injection circuit* or *outer circuit*. The CUT itself is the *secondary circuit* or *inner circuit*. Usually the set-up consists of a matched transmission line, the screen under test being one of the conductors of this transmission line. The most common set-up is the triaxial one *(fig. 1a)*. But also other types of set-ups are available, e.g. the 'wire injection set-up' [3, 4] where the primary circuit consists of a two-wire transmission line *(fig. 1b)*. The concept for screening tests when using the currently known wire injection set-up is given in *figure 2*. Here, the internal circuit is matched.

For a general screen with nonnegligible capacitive coupling, the near end *and* the far end coupling measurements through the screen have to be performed in order to evaluate both intrinsic screen parameters Z_T and Z_F. Z_T is the (surface) transfer impedance (Ω/m) and $Z_F = j\omega C_T Z_{01} Z_{02}$ is the capacitive coupling impedance (Ω/m) with C_T as the feed through capacitance (F/m).

At frequencies below the cut-off frequency of the set-up, the coupling transfer function T is proportional to the intrinsic screen coupling impedances, i.e.

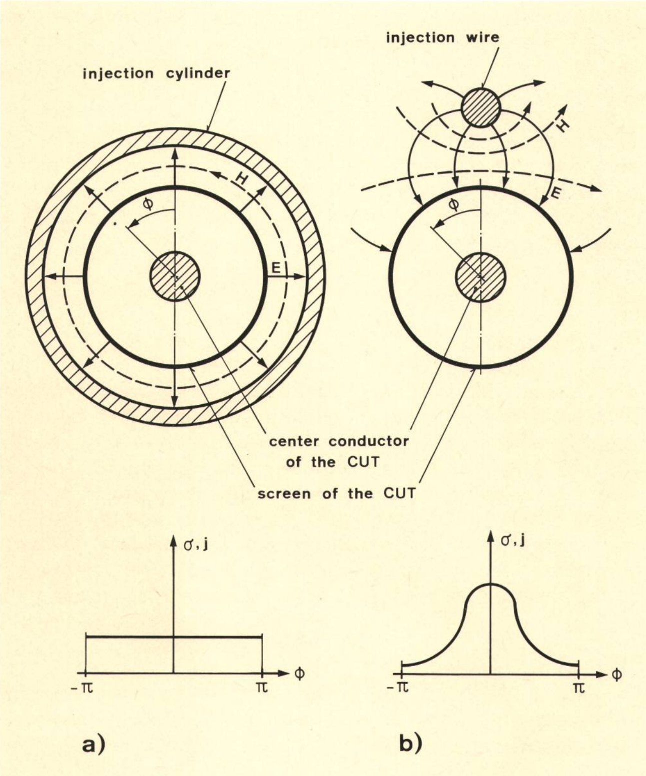


Fig. 1
Geometry and electric quantities in test set-ups

a)	Triaxial set-up
b)	Wire injection set-up
Top	Cross sections and primary electromagnetic fields (E, H)
Bottom	Primary charge and current densities on the screen
CUT	Cable under test

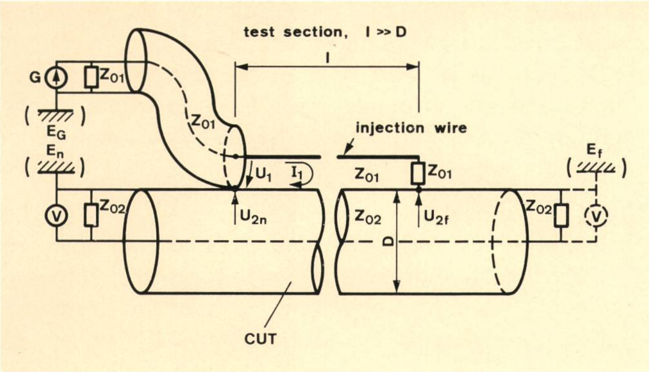


Fig. 2
Wire injection set-up [3, 4]

Subscripts	n, f: Near and far end
	1, 2: Primary (i.e. 'injection') and secondary circuits
CUT	Cable under test
Z_0	Characteristic impedance of circuit 1 and 2
G	Generator
V	Voltmeter
E	Usual earthing point for coaxial instruments
Note:	In a real test set-up the whole secondary circuit must be well-screened, including the load resistors and V

for $f < f_{c\substack{n\\f}}$:

$$T_{\substack{n\\f}} = (U_{2\substack{n\\f}}/\sqrt{Z_{02}})/(U_1/\sqrt{Z_{01}}) = \frac{|Z_F \pm Z_T|}{\sqrt{Z_{01}Z_{02}}}\cdot\frac{1}{2} \qquad (1)$$

where the plus sign refers to near end (subscript n) and the minus sign refers to far end (subscript f).

The cut-off frequencies are:

$$f_{c\substack{n\\f}} = \frac{c}{\pi l\,|\sqrt{\varepsilon_{r2}} \pm \sqrt{\varepsilon_{r1}}|} \qquad (2)$$

with $c = 3\cdot 10^8$ m/s

ε_{r1}, ε_{r2}: Relative permittivities of the transmission lines Z_{01} and Z_{02}.

Beyond the cut-off frequency, T is an oscillatory function of frequency. Its maxima are given by the relations

for $f > f_{c\substack{n\\f}}$:

$$\max (T_{\substack{n\\f}}) = \frac{|Z_F \pm Z_T|}{\sqrt{Z_{01}Z_{02}}}\cdot\frac{1}{2}\cdot\frac{f_{c\substack{n\\f}}}{f} \qquad (3)$$

The attenuation from the primary to the secondary circuit is:

$$A = -20 \log (T)\ \text{dB}.$$

Except for cables with loose and optimized single braid screens, the capacitive coupling is usually negligible and Z_T may be derived from either near end or far end measurement alone. The frequency response of such a typical cable is illustrated in *figure 3*. Due to the earth loops (section 23) and the limited quality of matching, it is reasonable to measure the near end coupling for $f < f_{cn}$ and the far end coupling beyond these frequencies. The phase equalization, i.e. by making $\varepsilon_{r1} \rightarrow \varepsilon_{r2}$, increases the far end cut-off frequency (equ. 2). Therefore, the frequency range where T_f is proportional to $Z_F + Z_T$ may be significally extended.

22 Wire injection versus coaxial test set-ups

The classical set-up to test coaxial cables is the triaxial one (fig. 1a). This is explained in the present version of IEC Publication 96-1. It was early recognized that the wire injection set-up (fig. 1b and 2) has clear advantages, when testing cables and cable assemblies [3, 4 and 5]. These advantages are: simple preparation of CUTs, simple and inexpensive set-up, direct access to the CUT during the test (checking for mechanical effects like bending, twisting, pressing, etc.), less earth loop problems than with triaxial set-ups (section 23). Are the test results identical when obtained by the triaxial and by the wire injection set-up? The test results of this paper will answer this question. Some preliminary views are given, partly relying on [5 and 6].

The most obvious difference between triaxial and wire injection set-up is the creation of a homogeneous current and charge distribution on the circumference of the screen (i.e. as function of Φ) by the triaxial set-up, while the wire injection set-up does not (proximity effect, see fig. 1).

Since the total coupling in a cross section of the screen is the sum of couplings on the cirumference, and furthermore Z_T and Z_F are related to the *total* current and charge on the screen, it can be proven that for a *homogeneous* screen practically the same Z_T and Z_F are obtained with both types of set-ups. A homogeneous screen means no variation with respect to Φ and z (longitudinal axis), i.e. a perfect tube. This is also correct for quasi homogeneous screens, i.e. for screens having many *small* openings or other small discontinuities *equally* distributed on the circumference.

Comparing the triaxial with the wire injection set-up when testing braid screens or spiral tape screens, there shall be no difference in Z_F (coupling through charges). But there could be a small difference in Z_T, caused by the fact that the contacts between the wires of the braid or the turns of the spiral tape are not perfect, giving rise

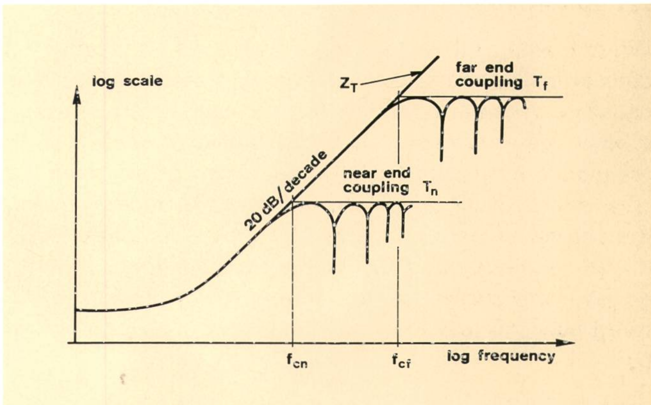


Fig. 3
Transfer impedance Z_T and coupling transfer functions $T_{n,f}$ for a typical braided screen with negligible capacitive coupling
Note: $[Z_T] = \Omega$/m and $[T] = 1$ have different dimensions
The scales were chosen in that way that Z_T and T coincide for $f < f_c$

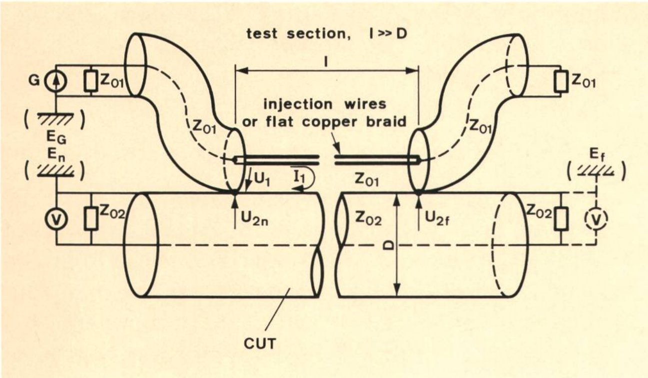


Fig. 4
New transmission type wire injection test set-up
Subscribts

n, f:	Near and for end
1, 2:	Primary (i.e. injection) and secondary circuits
CUT	Cable under test
Z_0	Characteristic impedance of circuit 1 and 2
G	Generator
V	Voltmeter
E	Usual earthing point for coaxial instruments

to the tendency of a helical current path. This tendency is limited by the unsymmetrical proximity effect of the wire injection circuit.

A clear difference between triaxial and wire injection test data shall be observed on screens having a single longitudinal discontinuity, like the slot of a 'cigarette wrap' foil. The injection wire, close to such a slot, may yield obviously worse screening effectiveness than the triaxial set-up. From *figure 1b*, it is concluded that the wire injection set-up simulates the fields existing on coaxial cables when installed near to other conductors. Thus, the wire injection test may be considered as a realistic worst case test, if performed correctly.

23 Earth loop problems

In order to avoid erroneous measurements, the practical problem of earth loops must not be forgotten. There are two types of problems:

- reduced primary current in the test section of the CUT
- primary currents trough poorly screened parts of the set-up and through instruments.

231 Reduced primary current

When making far end measurements with conventional coaxial instruments, the receiver (voltmeter in fig. 2) is usually earthed at E_f. At low frequencies, where resistive effects may dominate above inductive ones or due to resonance in the high kHz range, a part of the injection current may pass directly from E_f to E_G instead of taking the screen of the CUT as return path. This leads to reduced sensitivity and, far worse, even to measurement errors if the current on the screen is not directly monitored over the test section. This problem may be solved by

- avoiding far end measurements if possible at the lower frequency end (mainly in the kHz range)
- using common mode choke on the coaxial feed of the injection wire (being effective in the higher kHz range and beyond)
- using an isolating transformer either for the generator or receiver mains supply (if not in the same frame) or for the coaxial feed of the injection wire. (These measures are effective from the lowest frequency ranges on, but care should be taken to longitudinal resonances.)

These problems are more severe with the triaxial set-up (where normally the screen under test is the 'hot conductor' of the primary circuit), even for near end measurements. This can be overcome by reversing the phase of the outer circuit in the kHz and low MHz range [2]. Thus, the problems are reduced to those of the wire injection set-up.

232 Uncontrolled currents through poorly screened parts

In the following sections, recommended measures are provided to additionally screen the various parts of the set-up. However, special care is required concerning low frequency earth currents not returning through the coaxial feeding circuit but e.g. through → E_f → E_G or even through → E_n → E_G (fig. 2). These currents pass through parts of the set-up that are not under test and especially through the frame of the receiver. Therefore, the required sensitivity may not be obtained when measuring very high screening attenuation. The best method is the use of isolating transformers as proposed in section 231.

3 New wire injection set-up

The new set-up is an extension of the one given in figure 2. Its special features are: It uses two or more par-

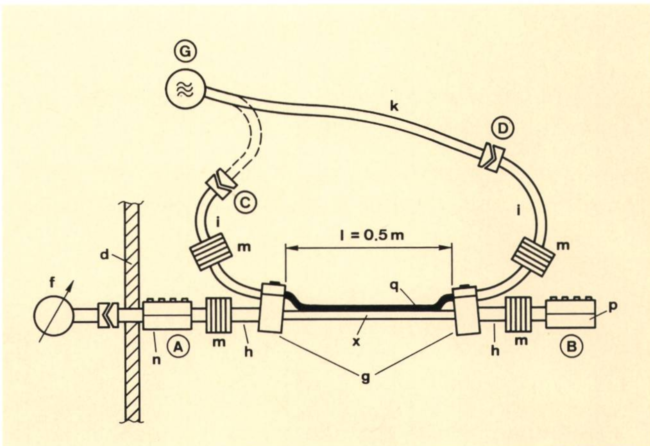


Fig. 5
Complete installation for practical transfer impedance measurements

A, B, C, D	Described in the text
X	Cable under test (CUT)
d	Screened room wall
G	Generator (synthesizer or tracking generator, etc.)
f	Test receiver (spectrum analyzer, network analyzer, etc.)
g	Launcher to injection wire
h	Brass tube for additional screening for CUT
i	Feeding cables for injection wire (low loss, approximatively 0.5 m)
k	Feeding cable from generator
m	Ferrite rings (length approximatively 100 mm)
n	Additional screening for connection between screened room and CUT
p	Additional screening for terminating resistance of CUT
q	Injection wire

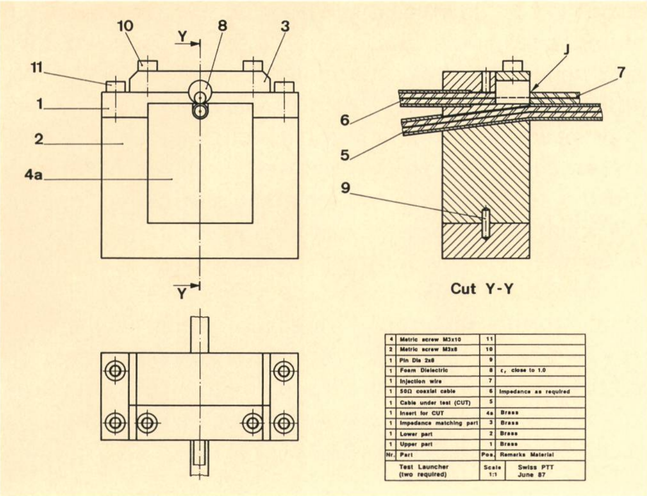


Fig. 6
Launcher for transmission type wire injection set-up

Table I. Explanation to figure 6

4	Metric screw M3 × 10	11	
2	Metric screw M3 × 8	10	
1	Pin Dia 2 × 8	9	
1	Foam Dielectric	8	ε, close to 1.0
1	Injection wire	7	
1	50 Ω coaxial cable	6	Impedance as required
1	Cable under test (CUT)	5	
1	Insert for CUT	4a	Brass
1	Impedance matching part	3	Brass
1	Lower part	2	Brass
1	Upper part	1	Brass
N₀	Part	Pos.	Remarks Material
	Test Launcher (two required)	Scale 1:1	Swiss PTT June 87

allel wires (instead of one) for the injection circuit and both ends of the wire are matched to a coaxial line. Therefore, the characteristic impedance of the new wire injection circuit can be easily adapted to that of the available test equipment to provide good matching over broad bandwidths. In addition, the non-negligible loss in the injection circuit can be cancelled by calibration.

Figure 4 is a sketch of the new wire injection configuration. At first sight, there seems to be little difference between figure 2 and figure 4. But looking at the details, the differences gain importance. This set-up makes it easy to exchange the generator location (instead of the voltmeter location) to perform far end measurements, i.e. no manipulation is required on the CUT.

Figure 5 shows the practical installation for transfer impedance measurements. Details of the launcher are given on *figure 6* for the injection wire circuit. The design of the feeding cable launcher is optimized to allow an optimum matching of the symmetrical TEM field in the coaxial feeding and terminating cable to the asymmetrical field along the parallel wire whilst maintaining a good mechanical strength for repeated use. Fine tuning of the discontinuity *J* can be made by varying the foam insert, Position 8. Matching can best be checked with a time domain reflectometer (TDR) measurement. The insert, Position 4a, can be replaced to match the size of the different CUTs by choosing an appropriate groove size. The size and the insulation of the injection wire should be chosen to provide the desired characteristic impedance in the primary circuit (strongly dependent of the size and the insulation of the CUT). In the case of 50 Ω characteristic impedance in the primary circuit, the use of two or more parallel wires (e.g. multiconductor flat cable for electronic circuit wiring) may be necessary *(fig. 7)*.

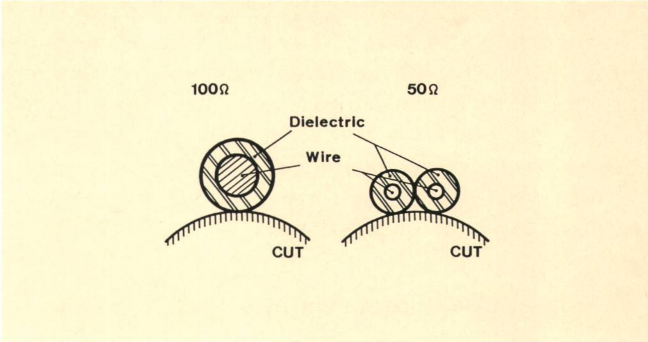


Fig. 7
Different impedances for the injection wire

Ferrite rings on all four terminals of the coupled section with at least 10 cm length should be used to prevent the excitation of the terminated end as antenna and in order to increase the impedance of the ground loop. Especially when measuring low transfer impedance values (double-, superscreened cables), the use of a screened room is suggested to prevent leakage into the receiving test equipment. Additionally, the connectors and the termination on the CUT must be screened according to *figure 8*.

The measurement instrumentation for high dynamic range transfer impedance tests consists of a tracking

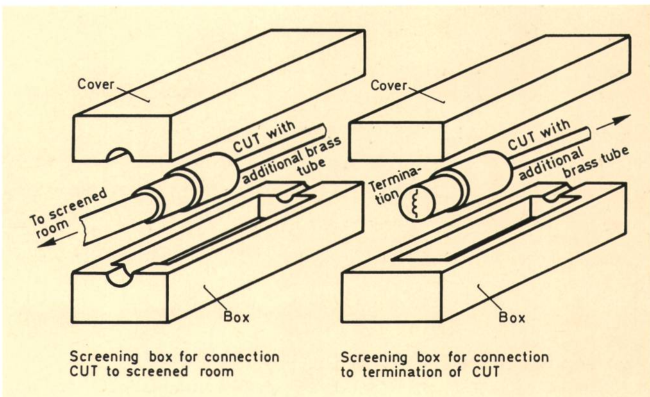


Fig. 8
Additional screening of connectors on the CUT

generator or synthesized signal generator, followed by a calibrated step attenuator. If transfer impedance values below 1 μΩ/m shall be measured, a power amplifier may be added. On the receiver side, low noise preamplifiers, followed preferably by a spectrum analyzer completes the test set-up. With modern test equipment, it is possible to control signal generator and receiver by a desktop computer for data aquisition and presentation.

4 Preparation of test samples (CUT)

For evaluation measurements of the wire injection set-up, the CUTs have been prepared to be used either in the reference triaxial set-up and in the wire injection set-up. This implied special mechanical requirements. In this paper, the requirements are given for wire injection measurements only. The triaxial set-up for cables is described in [2].

Outside the test length (0.5 m or 1 m recommended), the CUT must be additionally shielded with brass- or copper tubes *h (fig. 9)*. The shielding tubes must make contact to the cable screen *S* at *E* by soldering or crimping. If soldering is used, care must be taken not to overheat the cable dielectric. A good practice is to choose the shielding tube diameters such, that the CUT can be inserted without outer jacket and fixed by applying a standard crimping tool. The advantage of this method is the very close positioning of the tube end to the end of the removed cable jacket. The cable braid *S* is prevented from unravelling. Otherwise, this would yield improper test results. Another possibility is the use of wedges to contact nonsolderable aluminium foil/braid cables. Suitable connectors (N, SMA) have to be mounted on both ends of the CUT. The completed CUT shall be tested with a TDR for the electrical quality of the CUT itself. Bending forces must be avoided at the joints between tubes and test section of the CUT to prevent mechanical damage.

For limited frequency range, e.g. f<30 MHz, simpler measures are admitted [7].

5 Measurement procedure

The insertion loss can easily be taken into account in the new transmission type wire injection circuit. In our measurement procedure, a desktop controller first stores insertion loss measurement data of the primary circuit and the insertion loss of the CUT. Then the transfer impedance measurement data are processed.

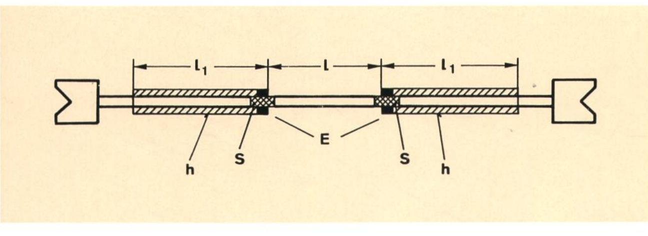
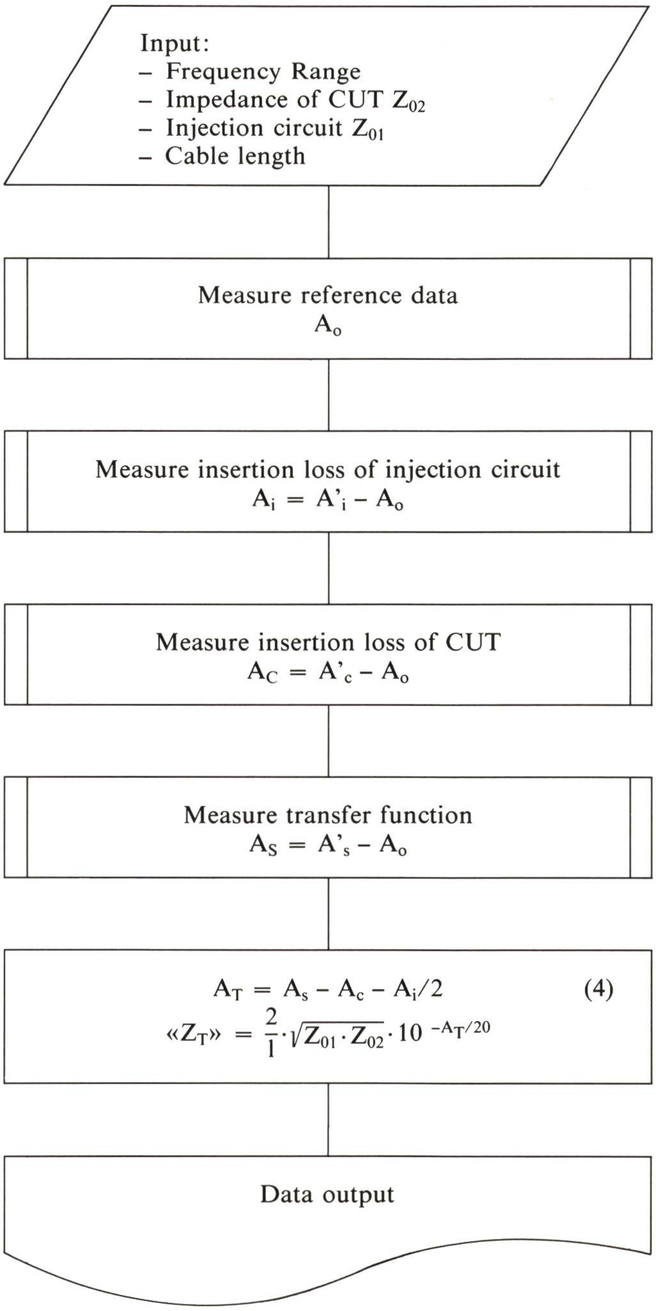


Fig. 9
Preparation of cables under test (CUT)
E Contact (soldering, crimping, etc.) between screen of CUT and additional shielding tubes
S Opening in jacket of CUT for above contact
h, l See section 4

According to figure 5, the output of the generator *G* is connected to the input of the receiver *f* to establish a level reference. Next, terminal *C* is connected to the generator and terminal *D* to the receiver to measure and store insertion loss data of the injection circuit. The CUT is then connected to the receiver as shown in figure 5 and the terminal *B* is connected to the generator. For this calibration step, a suitable attenuation value is switched in to allow for the necessary dynamic range on the receiver. Finally, terminal *C* respectively *D* is connected to the generator to measure either near end or far end transfer function. Terminal *B*, *C* and *D* must be terminated with the appropriate impedance. Terminal *A* and *B* should be additionally shielded when measuring low transfer impedance values.

The programming sequence for the measuring equipment (if a controller is used) should allow to store the data taken in the steps listed above. Following calculations and routines are used for the test set-ups, described in this paper:



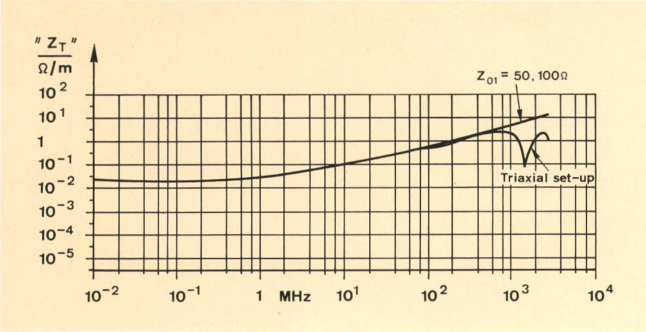


Fig. 10
Transfer impedance measurements for RG 58 C/U cable

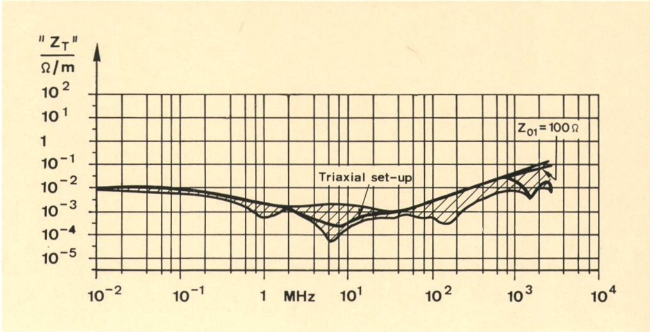


Fig. 11
Transfer impedance measurements for RG 223/U cable. The envelope is the result of the measurements with the 50 Ω wire injection set-up taken at 120° apart around the circumference of cable

By calculating A_T as given in equation (4), correction can be made for the losses in the circuits with a good approximation. Equation (3.3-6a) in [6] shows full expression. Z_T is placed between string quotes because the formula is only valid if the capacitive coupling is negligible ($Z_F \ll Z_T$) and $f < f_c$. For all cables tested $Z_F \ll Z_T$ is met, for this reason the frequency responses are similar to that in figure 3. The condition $f < f_c$ is usually not met at the upper frequencies. Nevertheless, the above formula is used. The string quotes indicate that for $f > f_c$ not the true Z_T is displayed but a quantity proportional to T.

$$«Z_T» = 2 \cdot \sqrt{Z_{01} Z_{02}} \cdot \frac{Z}{l}$$

6 Results

The following cable types have been tested in the triaxial *and* 50/100 Ω wire injection set-up with one exception. No triaxial measurements have been made with SA 07272 cable. It was impossible to make a good electrical contact with the foil screen. This cable has only been tested as an assembly with the special connectors provided for this cable.

RG 58 C/U	50 Ω single braid
RG 174/U	50 Ω single braid
RG 213/U	50 Ω single braid
RG 214/U	50 Ω double braid
RG 216/U	75 Ω double braid
RG 223/U	50 Ω double braid
PTT 6012	75 Ω double braid
Sucoflex 104	50 Ω microwave cable
Sucoflex 106	50 Ω microwave cable
Ethernet	50 Ω four screens
SA 07272	50 Ω foil screen CATV cable.

The results are given for the cables:
RG 58 C/U
RG 223 U
Sucoflex 104
SA 07272.

Only new cable samples (with one exception) have been used from standard production runs. The Sucoflex 104 cable was used as a standard laboratory cable before these screening measurements have been performed.

Figures 10 to *13* show the measurement results for every cable type using the three different set-ups. The noise floor of the equipment is held at least 10 dB below the lowest measured data. The agreement is very good among the data of the three methods.

61 Discussion of the test results

During the test series, the following observations have been made:

- Several double braided cables have been found with varying transfer impedance over circumference. On *figure 14* one example of a RG 223/U cable is shown. Three different positions are plotted. With the triaxial set-up, apparently an average value of the transfer impedance is measured (fig. 12). *Three* measurements with the injection wire *120°* shifted around the circumference gives sufficient security to measure the worst case condition even for 'cigarette' wrap foil braid cables. The effect on the RG 223/U cable is not yet fully understood but the most erratic curve was measured at the location of the cable designation print.
- With the wire injection set-up, good control of the characteristic impedance Z_{01} is achieved. The matching can be controlled during assembly with the aid of a time domain reflectometer. Reflection factors smaller than 0.2 (at an equivalent frequency of 1 GHz) give generally good results for Z_T up to serveral GHz.
- The use of the wire injection circuit with a wire insulation dielectric similar to the dielectric insulation mate-

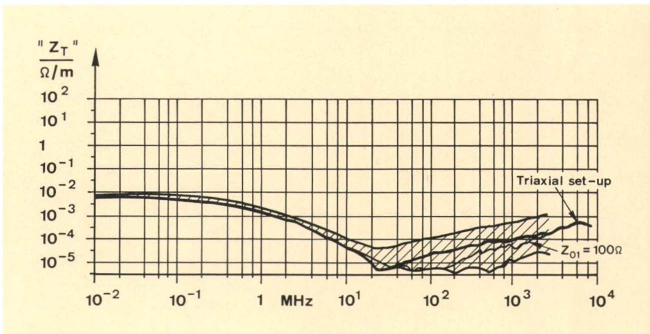


Fig. 12
Transfer impedance measurements for Sucoflex 104 cable. The envelope is the result of the measurements with the 50 Ω wire injection set-up taken at 120° apart around the circumference of cable. Before these measurements, this cable was used several months as a standard laboratory cable

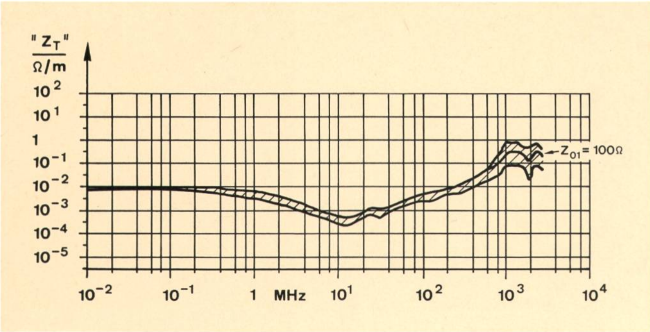


Fig. 13
Transfer impedance measurements for SA 07272 cable. The envelope is the result of three measurements with the 50 Ω wire injection set-up taken at 120° apart around the circumference of cable. Worst screening values found along the seam of foil screen

rial of the CUT provides close matching of the phase velocities in both primary and secondary systems. Therefore, direct Z_T measurements up to 3 GHz are achievable, i.e. 'Z_T' has the correct Z_T value.

- On the RG 58 C/U and RG 223/U cable, test lengths of 0.5, 1, 2 m have been compared with wire injection only. On *figure 15*, Z_T results of the RG 58 C/U show practically the same values for the different measurements as long as $f < f_c$, according to section 21. The shift of f_c to lower frequencies is to be noted, when using longer cables, according to equation (21-2). Similar experiments on CUTs with several isolated screens have not yet been made, see [6], section 3, 4, 5.
- Some strange measurement results are mainly caused by contact resistance problems with the triaxial circuit at low frequencies (below 0.1 MHz)
- The measurement limits of very low transfer impedance values has been exploited. Below frequencies of 100 kHz, two main limitations of the dynamic range have been found:

1. Most receiver systems (spectrum analyzer, network analyzer) have limited sensitivity toward 0 Hz due to local oscillator noise.
2. Uncontrolled currents in earth loops cause residual transfer impedance values (section 23). With a complete set-up (generator, spectrum analyzer, screened room, wire injection circuit) following residual Z_{Tres} values have been found:

$$\begin{aligned} 10\,\text{kHz}\ Z_{Tres} &= 3 \cdot 10^{-4}\Omega\,\text{m} \\ 100\,\text{kHz}\ Z_{Tres} &= 1 \cdot 10^{-5}\Omega\,\text{m} \\ >1\,\text{MHz}\ Z_{Tres} &= <3 \cdot 10^{-7}\Omega/\text{m}. \end{aligned}$$

A semi rigid cable, additionally screened with an iron tube (21/17 mm diameter) has been used as CUT for this sensitivity evaluation.

These earth loop problems may easily be avoided according to the proposals of section 23.

7 Conclusions

The comparative test program as described was based on the triaxial set-up as a reference measurement standard.

The deviation between the wire injection and triaxial test results are within ± 6 dB, typically ± 4 dB. The ± 6 dB corresponds to the typical accuracy of cable screening tests.

As postulated in section 22 and confirmed by the tests, the only significant difference between wire injection and triaxial circuit is that a local transfer impedance (on the circumference of the CUT) is measured with the wire injection set-up. In case of a totally unknown CUT, it is best to take at least three measurements at 120° apart around the circumference of the CUT. The wire injection set-up simulates very closely a practical installation case and the test results represent the practical worst case condition. In contrast, the triaxial set-up test results represent a more or less averaged condition.

As agreed by the IEC SC 46A/WG 1 (screening effectiveness of RF-cables) more comparative measurements in other laboratories will be performed to verify the overall measurement accuracy of the new transmission type wire injection circuit.

Nevertheless, the following conclusions can already be made:

The *transmission type wire injection set-up* has the following advantages:

- Very broad bandwidth (<10 kHz up to 3 GHz and more) without the need of readjusting any part of the set-up (no change of feeding phase necessary, see [2])
- Inexpensive test set-up
- Easy preparation of CUT and injection circuit

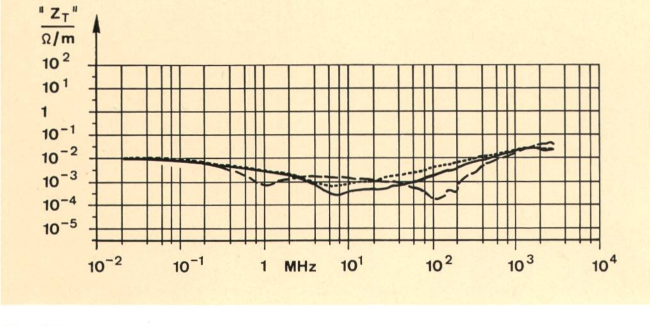


Fig. 14
RG 223/U measured at three different positions 120° apart around circumference of cable. 50 Ω wire injection set-up used

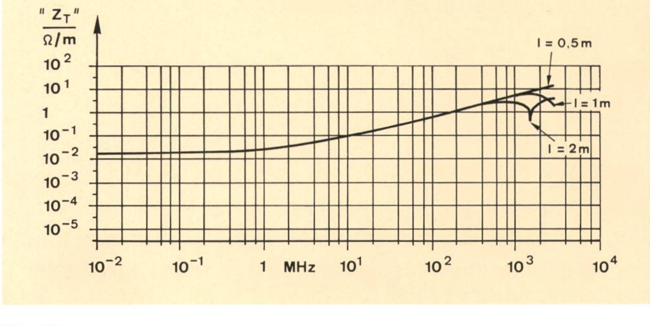


Fig. 15
Three different cable lenghts of RG 58 C/U. 50 Ω wire injection set-up used

- Open, flexible structure of the injection circuit allows moving and bending of CUT during measurements
- Simple control of the impedance Z_{01} and better match of the phase velocities
- The insertion loss of the wire injection circuit is easily measurable
- Free choice of length of CUT
- Backward and forward transfer function measurements without significantly altering the set-up or the CUT
- Cable assemblies can be measured in the same way.

The complete report with more detailed results can be obtained from the PTT's Directorate of Research and Development, CH-3030 Berne.

Addresses of the authors: B. Eicher, C. Staeger and B. Szentkuti c/o Directorate of Research and Development of Swiss PTT, CH-3030 Berne. H. Fahrni c/o Autophon AG, CH-4501 Solothurn.

References

[1] *Staeger C.* and *Bolinger W.* Screening effectiveness of coaxial connectors and measuring methods at high frequency and microwave. Techn. Mitt. PTT, Berne 59 (1981) 9, p. 374.

[2] *Eicher B.* and *Staeger C.* Extremely broadband RF-connector and cable screening measurements (up to 150 dB screening attenuation) for frequencies of 1 kHz to 10 GHz, proceedings of the 15th European Microwave Conference. Paris, pp 887-894, 1985.

[3] *Fowler E. P.* On the interference immunity of coaxial cables. IEEE, Eurocon 1971, B11-3.

[4] *Fowler E. P.* Screening measurements in the time domain and their conversion into the frequency domain. Journal IERE, Vol. 55, pp. 127-132, April 1985.

[5] *Fowler E. P.* Private communications and numerous documents in IEC SC 46A/WG 1 (screening effectiveness of RF-cables).

[6] *Halme L. K.* and *Szentkuti B.* The background for electromagnetic screening measurements of cylindrical screens. Techn. Mitt. PTT, Berne 66 (1988) 3, p. 105-105.

[7] IEC SC 46A(Secr)141: specification for superscreened cables, IEC 96-Y, Part 1: General requirements and test methods.