

Transfer Impedance and Shielding Effectiveness of a Belden 8669 Overbraid Shielded Cable Compared to RG58 and RG214 from 0.25MHz to 12GHz

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14-01-2004

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1) Cable shielding effectiveness

The two main methods of determining the shielding of cables and connectors are shielding effectiveness (S.E.) and transfer impedance.

Shielding effectiveness is defined as the ratio of electric field or magnetic field strength at a point before and after placement of a shield. For a cable this is typically defined as the voltage or current induced into the center conductors/s of the cable, by the field, with and without the shield in place. A number of disadvantages exist in the measurement and characterization of shielding effectiveness and these include:

- a) Shielding effectiveness is not an “intrinsic electromagnetic parameter” which means that its measurement is dependent on the test set up.
- b) No unique definition of S.E. exists
- c) No method exists for independent calibration.

However data from the shielding effectiveness measurements described here show a remarkably good correlation to the shielding effectiveness derived from the transfer impedance, over the frequency range where the cable is electrically long and the frequency range where the transfer admittance predominates (100MHz to 1000MHz) Shelkunoff showed that Surface Transfer Impedance, described in section 3, is by contrast an Intrinsic Electromagnetic Parameter and its measurement is independent of test set up. This means that any test method may be used to determine the transfer impedance and the test results should be comparable with data obtained on the same cable in a different test set up.

The disadvantages of the transfer impedance test is the upper frequency limit and the fact that it does not measure effectively coupling to the cable via transfer admittance. In most set ups the connection between the shield of the cable and the driveline is 0Ω and this maximizes the transfer impedance coupling and minimizes the transfer admittance coupling. Many consider the transfer impedance the most important factor and this is true at low frequency, but not necessarily true at high frequency. The upper frequency for most coaxial and triaxial cable test set ups is 100MHz, although 1GHz is achievable. The

method used to obtain the data described in this test is the IEC 96-1 and is useable up to 1GHz, and theoretically beyond. However the limit we have achieved is 1GHz.

The cable transfer impedance test induces a current directly into the Cable Under Test (CUT) which is part of the test fixture. The predominant form of coupling is porpoising and magnetic field penetration through the apertures, although some coupling of the E field occurs due to the transfer admittance of the cable.

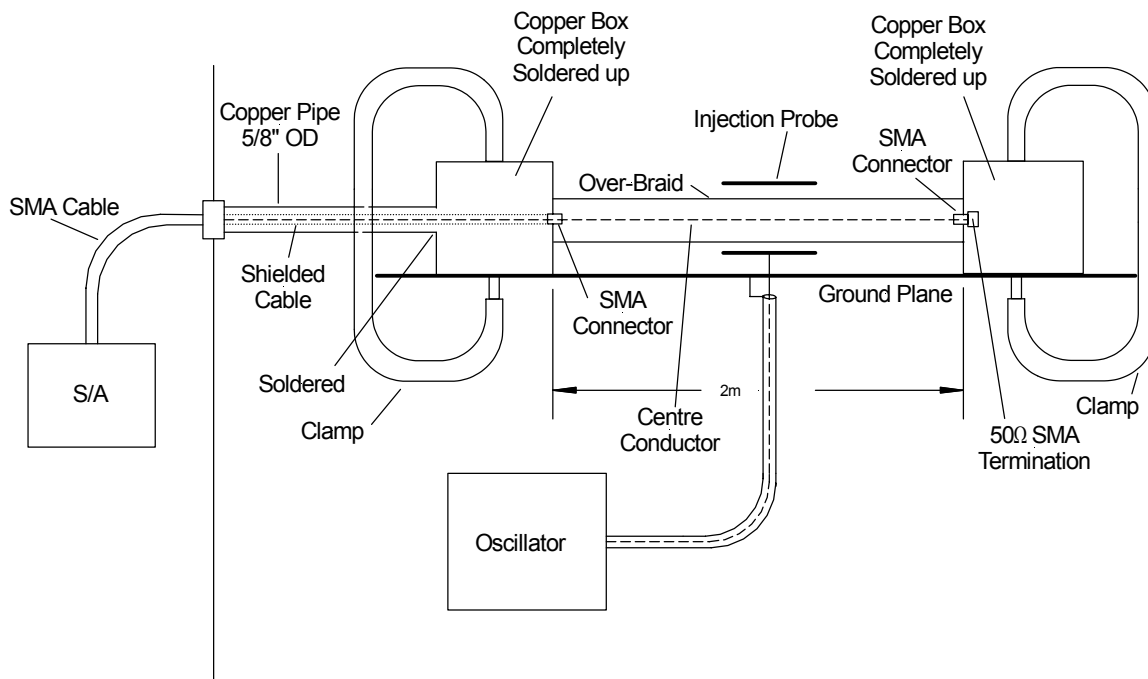
1.1 Shielding effectiveness test method

The test method described in reference 1 uses a capacitive injection probe to create a high electric field between the probe and the cable. This capacitive injection more realistically simulates a high level E-field incident vertically on the cable and the source would typically be from a high gain antenna and somewhat localized. The test method maximizes aperture coupling through the cable transfer admittance and at the same time sets up a current down the length of the cable which ensures both transfer impedance coupling, through the magnetic field aperture coupling and porpoising coupling. Although the test set up is not standardized we have achieved reproducible results using the same type of shielded cable and injection probe in a number of tests.

As the shielding effectiveness test compares the induced levels with and without the shield and is made with the cable electrically long, i.e. multiple wavelengths long, the measurement is virtually independent of cable length.

At 12GHz the probe movement required was only 3mm to maximize the coupling. Also at numerous locations down the length of the cable a maxima was seen. This shows that the probe was setting up a resonant cable current regardless of where the injection occurred and also that the coupling via the transfer admittance was independent of cable location.

Cable Shield-Braid Shielding Effectiveness Test Set Up 0.1GHz - 12GHz



Braid SE.skf

Figure 1.1 Basic shielding effectiveness set up

1.2 Shielding effectiveness test results

The shielding effectiveness of the Belden 8669 shield braid was measured, as well as an RG58 and a RG214 shielded coaxial cable under an R&D program.

During all the shielding effectiveness tests the Belden braid when pulled tight had no visible apertures and so at least 96% optical coverage was achieved. To test the importance of magnetic field (transfer impedance) and electric field (transfer admittance) aperture coupling the braid on the Belden cable was relaxed somewhat so that small apertures became visible. The shielding effectiveness test was performed again at the highest frequency of 12GHz and the shielding effectiveness reduced by 10dB from 25dB to 15dB.

Table 1.1 and Figure 1.2 shows the shielding effectiveness from 8-12GHz and how this is derived.

Figure 1.3 shows the shielding effectiveness measurements from 100MHz to 12GHz on the Belden 8669 braid, an RG58 single braid coaxial cable and an RG214 double braid shielded cable. As expected the RG214 shows the highest shielding effectiveness, although even this double braid shielded cable only achieved a S.E. of 31dB at 12GHz.

The RG58 had the lowest shielding effectiveness at most frequencies and consistently lower than the RG214, again as expected. Some anomaly was present in the test set up at 6GHz and so a plot of the trends with the 6GHz measurement omitted is shown in Figure 1.4. The test results are comparable to the results first obtained in reference 1 using the identical injection probe. On repeating the tests they were reproducible to at least 6dB, with the height of the cable above the ground and the tightness of the braid over the centre conductor as the most critical variables.

Shielding Effectiveness Measurements

Frequency	Shielded Cable	Unshielded Cable	Shielding Effectiveness	Noise Floor
GHz	dBuV	dBuV	dB	dBuV
8	42.5	76	33.5	-7
10	41.7	69	27.3	-6.6
12	34	59	25	-2.7

Table 1.1 Braid shielding effectiveness from 8 –12GHz

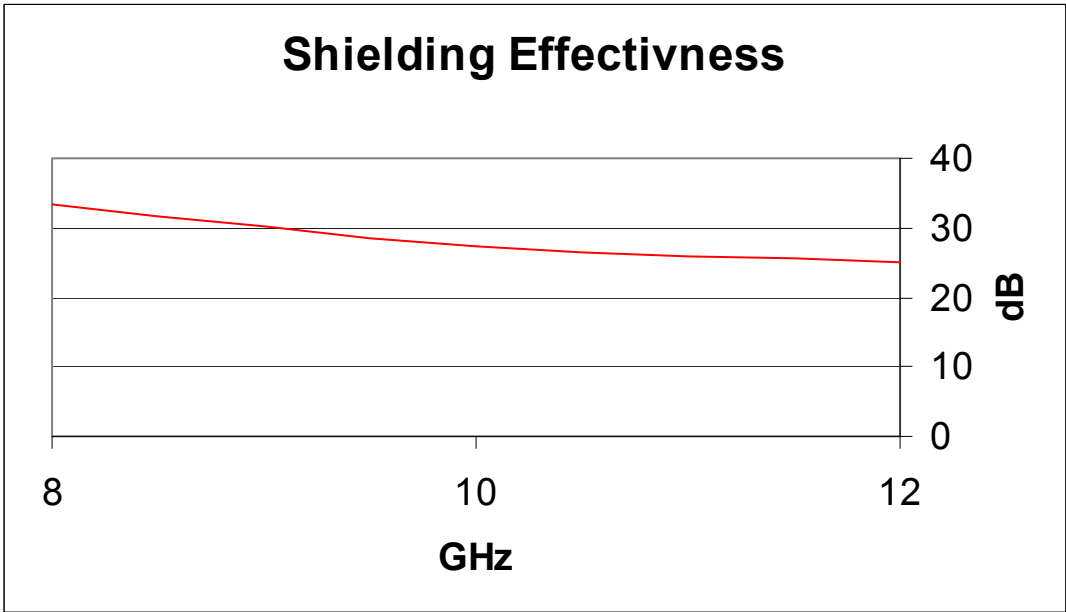
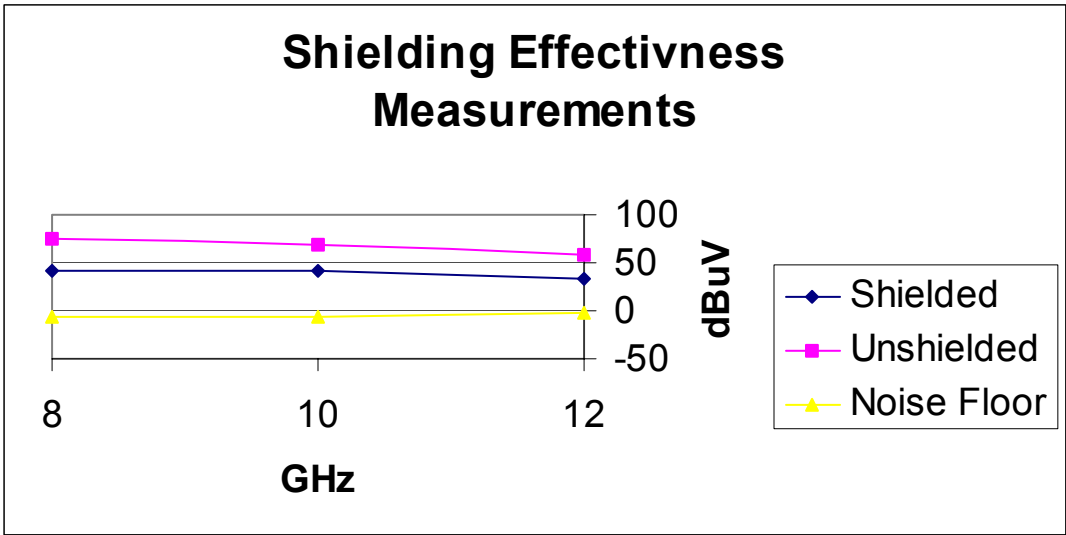


Figure 1.2 Shielding effectiveness measurements from 8 to 12GHz on the Belden 8669 braid shielded cable.

Using Belden 336x#34 (.02 Sq MM) TIN CU Braid 1/2" I.D. Tubular

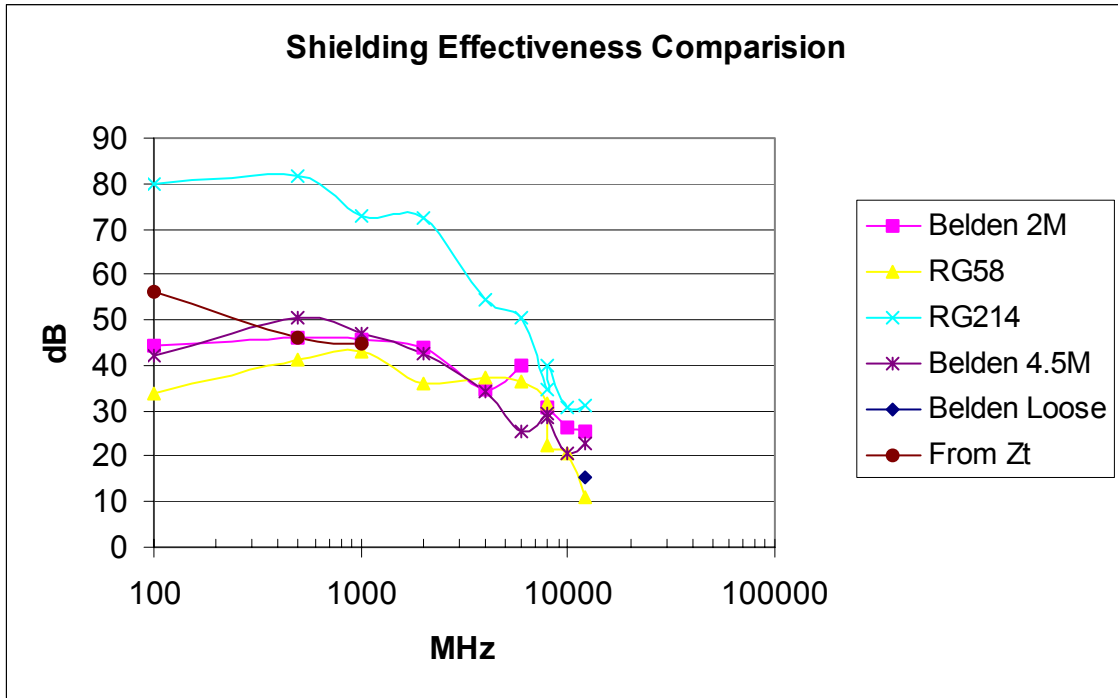


Figure 1.3 Shielding effectiveness data on a 2m and 4.5m long Belden 8669 shielded cable, and RG58 and RG214 coaxial cables.

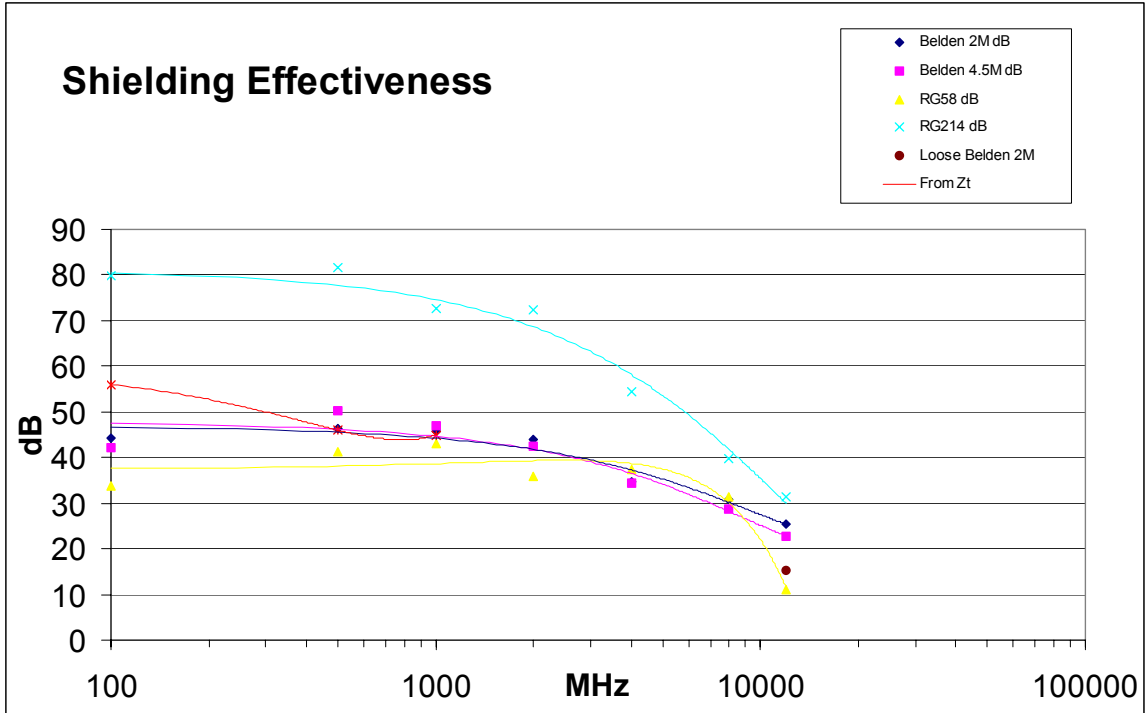


Figure 1.4 Shielding effectiveness trend with the measurement at 6GHz omitted and compared to Z_t derived S.E.

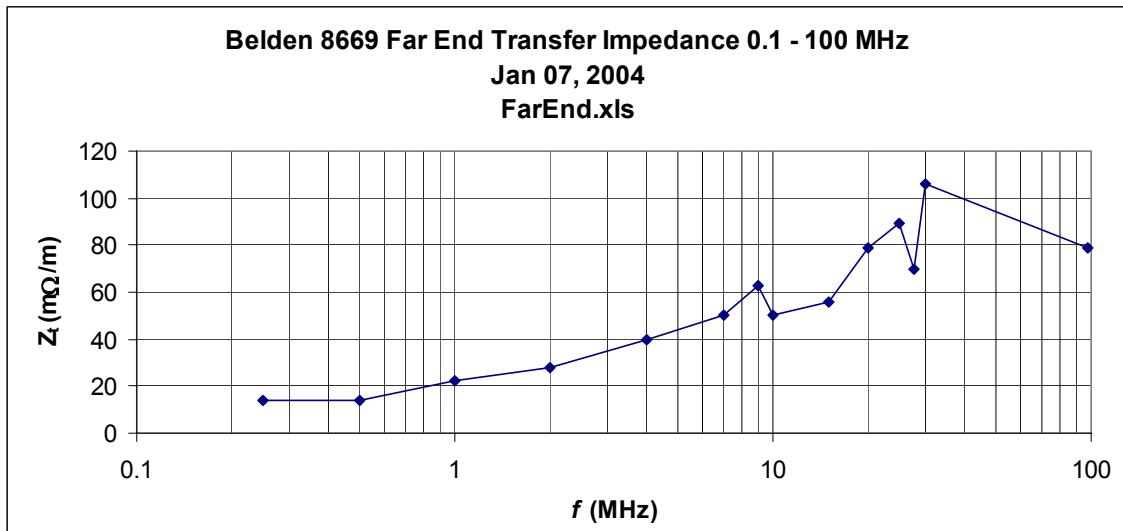


Figure 1.5 Belden 8669 braid shielded cable Far End Transfer Impedance 0.25MHz to 100MHz

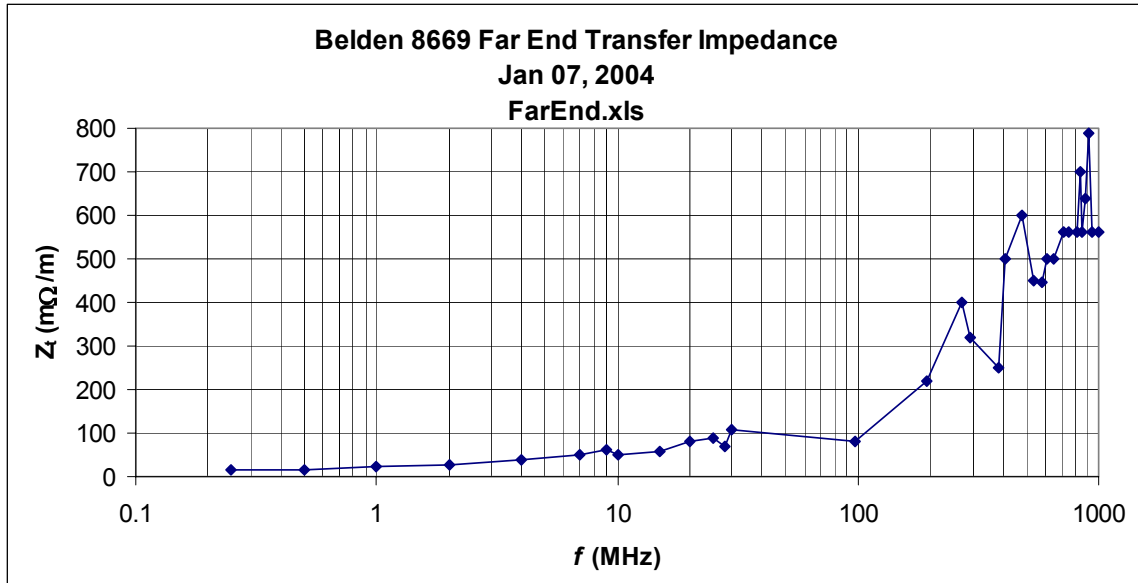


Figure 1.6 Belden 8669 braid shielded cable Far End Transfer Impedance 100MHz to 1000MHz

The shielding effectiveness test was made with a 50Ω load at each end of the cable and so it is possible to predict the shielding effectiveness from the transfer impedance using:

$$\text{S.E. (dB)} = 20 \log (2 \times 50 / Z_t)$$

This predicted shielding effectiveness from Z_t and the measured S.E. above 100MHz are compared in Table 1.2.

f(MHz)	Shielding effectiveness derived from Z_t (dB) (2m length)	Shielding effectiveness from measurement (dB) 2m length
0.25	71	-
0.5	71	-
1.0	67	-
10.0	58	-
20.0	56	-
30.0	53	-
100/97.4	56	44
194	47	45
271	48	45
500/478	44	46
900	42	46
1000	43	46

Table 1.2 Shielding effectiveness from the transfer impedance measurement and compared to the S.E. measurement.

Considering that the two test methods are radically different, it can be seen that above 100MHz, when the cable becomes electrically long, and especially between 271MHz and 1000MHz, that the correlation between the two methods is incredibly close.