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VSWR of Electrical Cables

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About the author

Stefan Burger received his engineering degree from the Offenburg University of Applied Science in 1986. He remained as a research associate at the university until 1990. He then transferred to the research and development department of Endress + Hauser in Maulburg.

Until 2001, he was involved in the development of level measuring devices based on RADAR. Among other things, he was responsible for the support of the RADAR modules as well as the development of antennas and pressure-resistant RF components.

From 2001 to 2011, he worked on filters and duplexers for base stations as well as SAW filters at Panasonic Electronic Devices in Lüneburg. He was responsible for the "Lifetime and Power Durability" simulation.

In 2012, he founded his own company, Delta Gamma Consultant (www.delta-gamma.com), in Hampton, Australia. Since 2014, he has been working as an exclusive consultant in the area of RF and measurement technology for el-spec GmbH in Geretsried, Germany.

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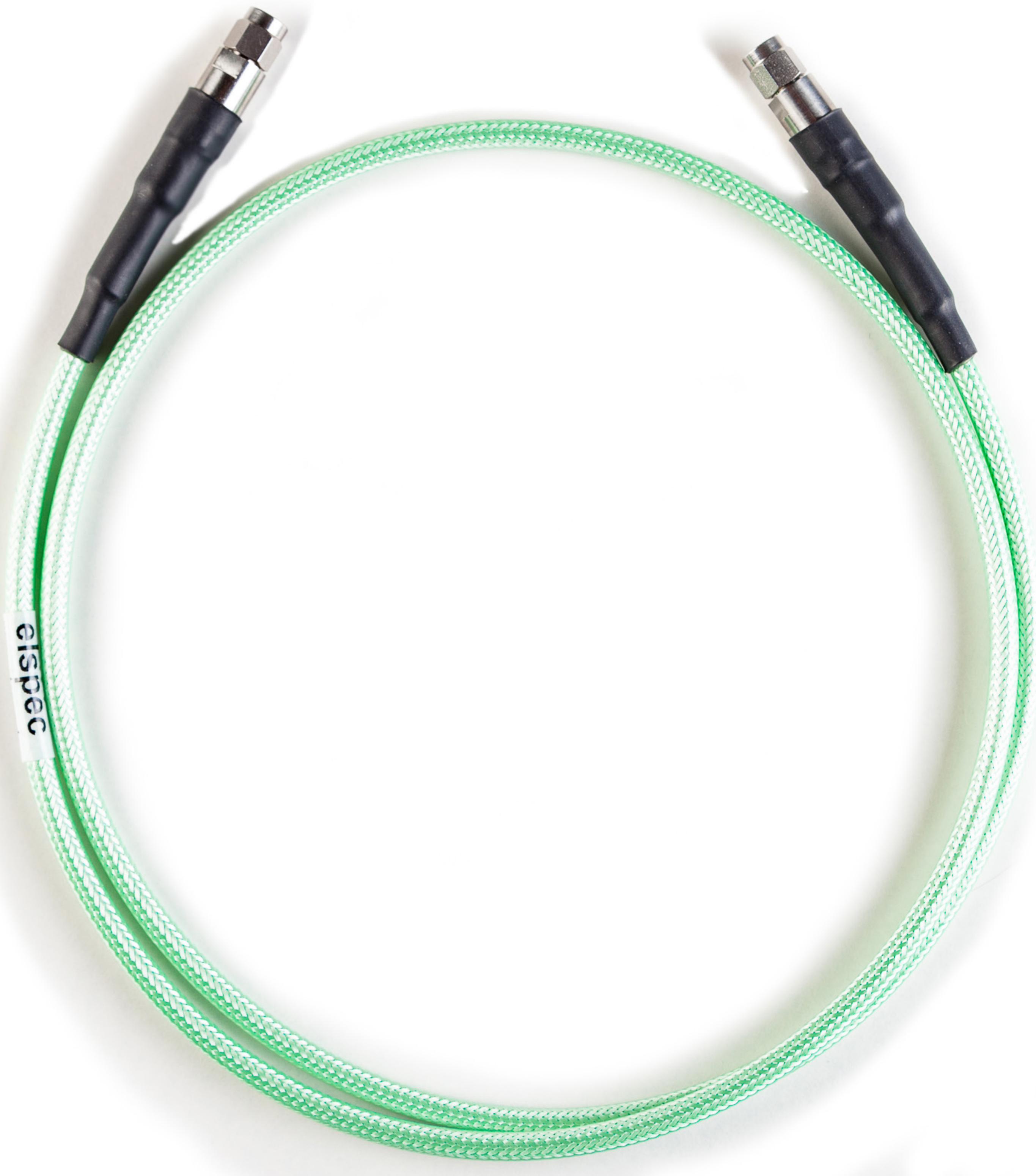
Content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Introduction

When measuring pre-assembled coaxial cables with the network analyzer, it is important to understand that the matching read-out on the analyzer results from the superposition of the signals reflected by the connectors on both ends of the cable.

The dB (short for decibel) is a unit we constantly encounter carrying out such procedures. Let's have a quick look at the „decibel" and how the calculation using it works: the Bel (that is the original designation) presents power relationships on a logarithmic scale. Since the Bel is somewhat cumbersome to use, a tenth of a Bel was adopted as a more conducive unit. Thus the deci-„Bel" (dB) has established itself as the common measure.:

$$p = 10 \cdot \log\left(\frac{P_1}{P_2}\right)[dB] \qquad [1]$$

The power can be represented by the voltage, as well:

$$P = \frac{U^2}{R} \qquad [2]$$

$$p = 10 \cdot \log\left(\frac{U_1^2}{R} \cdot \frac{R}{U_2^2}\right) = 10 \cdot \log\left(\frac{U_1}{U_2}\right)^2 = 20 \cdot \log\left(\frac{U_1}{U_2}\right) \qquad [3]$$

The return loss is the ratio of reflected power to the input power. Consequently, if - for a given connector - a maximum return-loss (RL) is specified, we may calculate the voltage of the corresponding signal to:

$$V = V_{ref} \cdot 10^{\frac{RL}{20}} \qquad [4]$$

The signal carrying this voltage is (as an ac signal) also characterized by a phase. This phase depends on the properties of the connector and changes along the line according to the following equation:

$$\phi = \frac{2 \cdot \pi \cdot l \cdot \sqrt{\epsilon_r} \cdot f}{c} \qquad [5]$$

wherein c stands for the speed of light: 299 792 458 m/s. l represent the length of the line.

Clearly, the phase changes with increasing frequency, i.e. the signal reflected by the second connector superimposes with the signal reflected by the first connector with a phase changing with frequency. The phases of the two signals may change in the same direction, or they may change in opposite directions. This is shown symbolically in Fig. 1 where the arrows represent signals of differente voltages (the length of the respective arrow) and different phases (the direction of the respective arrow). With regard to reflected power, in the worst case that may present itself, the red and the black arrows superimpose towards the blue pointer, and in the best case they superimpose towards the green pointer.

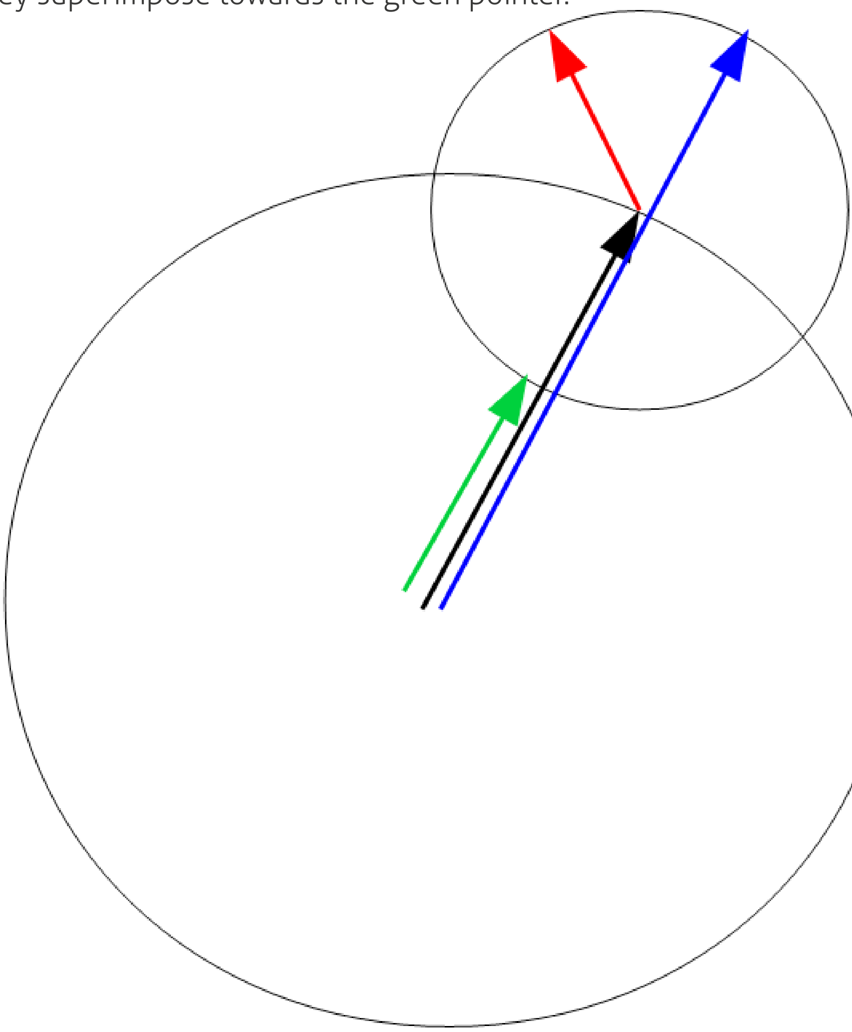

Fig. 1: Superposition of signals with different phase (and different voltage)

Let‘s assume that the cable has a plug on both sides with a return loss of -20 dB. What is the minimum return loss to be measured here?:

$$U_1 = U_2 = 1V \cdot 10^{\frac{-20}{20}} = 0.1V \quad [6]$$

In the worst case, the voltages of the two signals add up to 0,2 V.

$$RL = 20 \cdot \log\left(\frac{0.2V}{1V}\right) = -14.0dB \quad [7]$$

If we find a matching of -20 dB at one end and a matching of -30dB at the other end of the cable, how large would the return loss be?

$$U_1 = 1V \cdot 10^{\frac{-20}{20}} = 0.1V \quad [8]$$

$$U_2 = 1V \cdot 10^{\frac{-30}{20}} = 0.0316V \quad [9]$$

$$RL = 20 \cdot \log\left(\frac{0.1316V}{1V}\right) = -17.6dB \quad [10]$$

If we want to achieve a matching of the cable of -25 dB, which matching must then the connector at least achieve?

$$U = 1V \cdot 10^{\frac{-25}{20}} = 0.0562V \quad [11]$$

$$RL = 20 \cdot \log\left(\frac{0.0562V}{2 \cdot 1V}\right) = -31.0dB \quad [12]$$

However the previous elaborations ignored the attenuation of the line itself. The return-wave caused by the second connector is attenuated as it runs along the line and improves the situation because the signal becomes smaller.

Considering a line attenuation of e.g. 6 dB, and a matching at both connectors of -20 dB, we obtain a worst-case-value of:

$$U_1 = 1V \cdot 10^{\frac{-20}{20}} = 0.1V \qquad [13]$$

$$U_2 = 1V \cdot 10^{\frac{-26}{20}} = 0.05V \qquad [14]$$

$$RL = 20 \cdot \log\left(\frac{0.15V}{1V}\right) = -16.5dB \qquad [15]$$

The 6-dB-line-attenuation improve the matching by 2.5 dB.

However, this can also lead to misinterpretations, e. g. if you want to monitor the matching of an antenna over a long cable. Apparently, the antenna is still within the tolerance range, whereas in reality, as in our example, the values are worse by 2.5 dB, which is outside the tolerance range.

Imprint

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