SPACEWIRE CABLE CHARACTERISATION

Session: 7. SpaceWire Test and Verification

Long Paper

Martin Suess

European Space Technology Centre, PO Box 299, 2200 AG Noordwijk ZH, The Netherlands

Steve Parkes, Paul Crawford

Space Technology Centre, University of Dundee, Dundee, DD1 4HN, Scotland, UK

E-mail: martin.suess(at)esa.int, sparkes(at)computing.dundee.ac.uk, psc(at)sat.dundee.ac.uk

ABSTRACT

The SpaceWire physical layer comprising twisted pair cables and micro-miniature D-type connectors is specified in detail in the SpaceWire standard ECSS-E-50-12A. In some cases the physical layer defined in the standard is not fulfilling all requirements of a specific application. The cables as defied in the standard are quite rigid and not handy for use in the laboratory and for SpaceWire connections over very long distances (>10 m) cables with lower loss are required. For this purpose cables with stronger gauge as well as different types of connectors have been proposed. In order to be able to assess the consequences of these modifications a test setup for SpaceWire cable and connector characterisation has been developed and a set of performance parameters to be measured have been defined. The testing uses a Vector Network Analyser (VNA) and a set of specially developed interface boards to measure S-parameters. From these S-parameters the performance figures for return loss, insertion loss, near- and far-end crosstalk can be derived. The paper describes the different test setups and how the performance figures are obtained from the measurements.

1 SPACEWIRE CABLE SPECIFICATION

The SpaceWire cable and connector is specified in the SpaceWire standard [1] in the chapters 5.2 and 5.3. For the cable a detailed specification of the construction is provided in the standard (Figure 1). It specifies the diameter of the twisted pair conductors and of the wires in the braided shields, the materials used for the filler and the protective sheath etc. as well as the physical properties of the resulting cable like diameter, bent radius, mass and colour.

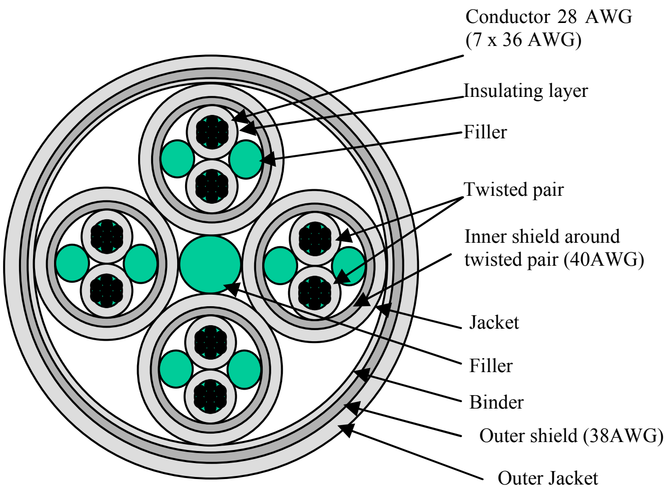

Figure 1: Section though a SpaceWire cable

While such a detailed specification ensures that any cable constructed accordingly will fulfil the performance requirements and directly provides mass, diameter and bent radius figures for the system engineering this kind of specification does not leave room for further improvements or other specifically adapted cable solutions.

In terms of electrical requirements only the characteristic differential impedance (100±6 Ω), the DC resistance of the inner conductors (≤ 256 Ω/m) and the skew between the differential signal pairs (≤ 0.1 ns/m) are specified. The performance in terms of insertion loss over frequencies and cross talk between the twisted pairs is only specified implicitly by the detailed requirements on the construction of the cable.

One objective of the test setup described here is to get a complete electrical characterisation of the SpaceWire compliant cables.

2 S-PARAMETER DEFINITION

Scattering or S-parameters can completely characterise linear networks with respect to their electrical behaviour as a function of frequency. They are commonly used when describing and designing RF and microwave components and systems. Today they are measured with the help of a VNA up to frequencies beyond 100 GHz.

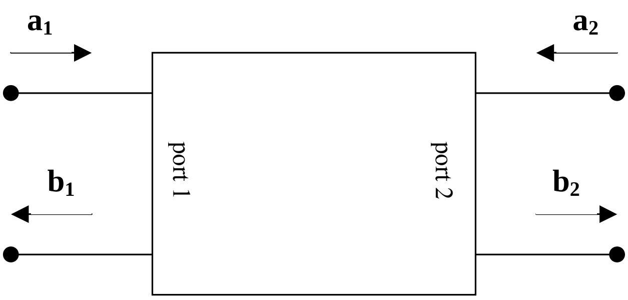

Figure 2: 2-port network with incident and reflected power waves

A 2-port linear network can be described with the complex scattering matrix containing 4 S-parameters which are calculated from the incident and reflected power waves which are measured by the VNA.

$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \cdot \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \qquad (1)$$

S_{11} and S_{22} are commonly called return loss while S_{12} and S_{21} are usually named insertion loss for passive networks.

3 Electrical Performance Parameters

The need for the electrical characterisation of twisted pair cables is not unique for SpaceWire. Twisted pair cables are widely used in computer networks in offices like Ethernet. The characterisation of this type of cables is specified in two IEC standard documents [2] and [3]. The most important electrical measurements defined in the standards are Return Loss, Insertion Loss, Near-end Crosstalk (NEXT) and Far-end Crosstalk (FEXT). All these electrical characteristic is measured as a function of frequency with the use of an VNA. One difficulty when using a VNA for this type of measurements is to go from the single ended configuration of the VNA to the balanced configuration needed for the twisted pairs. This is achieved by using baluns (balanced to unbalanced RF transformers) which have a sufficient high bandwidth for the measurements. The test setup for these measurements as defined in [2] and [3] is described in the following.

3.1 Return Loss

The return loss is the ratio of power delivered to power reflected at the input port of the cable assembly, when the far end is terminated with its nominal characteristic impedance.

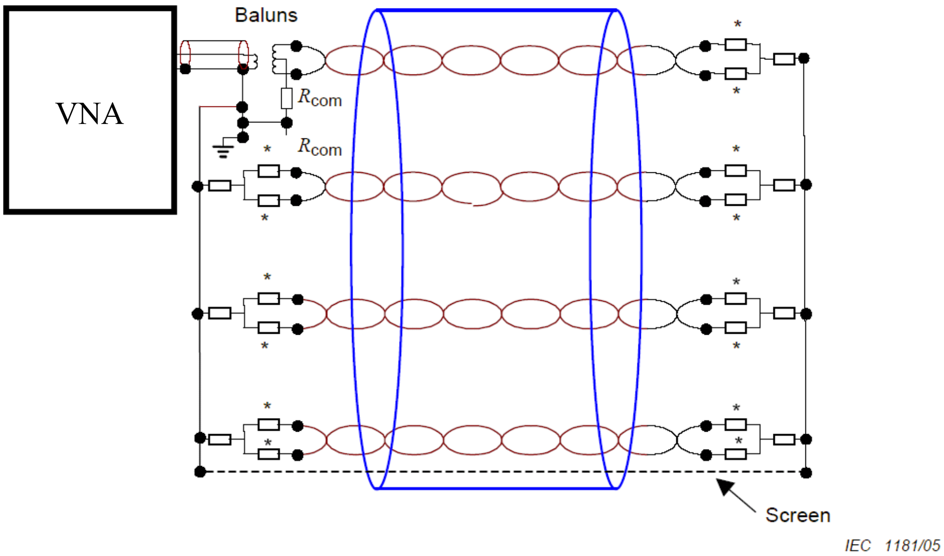

Figure 3: Return Loss test configuration according to ICE 61935-1

The return loss measured S_{11} can be directly translated into a measurement of the differential impedance Z_c of the cable and its termination.

$$|S_{11}| = 20\log_{10}\left|\frac{100\,\Omega - Z_c}{100\,\Omega + Z_c}\right| \tag{2}$$

This test setup could also be used to determine the quality of a SpaceWire receiver termination in SpaceWire equipment.

3.2 Insertion Loss

Insertion loss is measured by determining the signal loss of the cabling element under test, relative to the signal loss of a short connection between the test ports of the Vector Network Analyser.

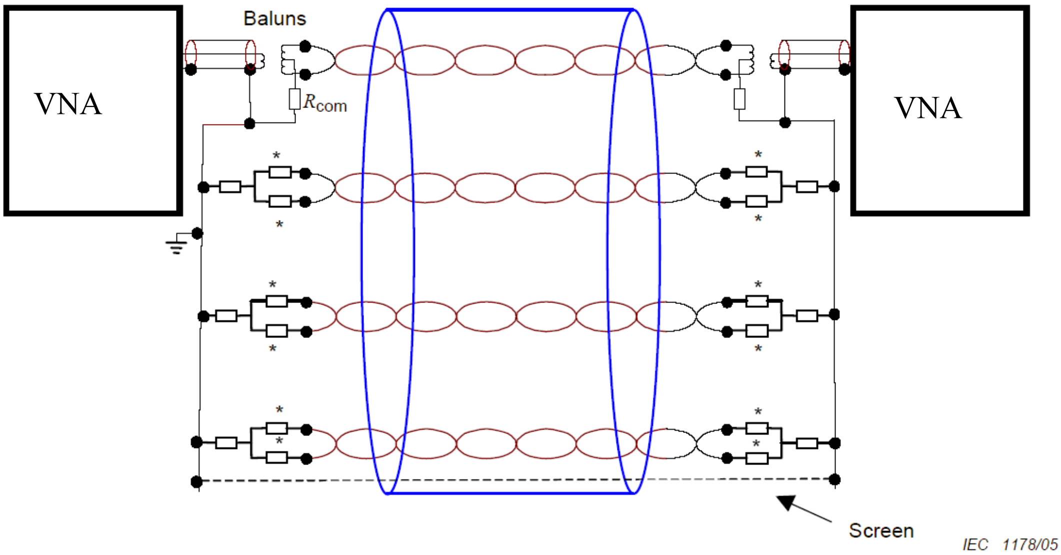

Figure 4: Insertion Loss test configuration according to ICE 61935-1

Each of the twisted pair cables is measured subsequently while the other twisted pairs are terminated at both sides with the reference impedance.

The same insertion loss measurement S_{12} can be used to determine the skew between the data and strobe lines. For this the phase of the complex scattering parameter S_{12} is unwrapped and compared with the phase in the S_{12} of the second twisted pair. A skew between the two twisted pairs will show up as an additional linear phase component as a function of frequency.

3.3 Near-end Crosstalk (NEXT)

The objective of this test is to determine the coupling between a transmitted signal applied at the near end of one twisted pair to the received signal at the near end of a different twisted pair.

NEXT is measured by applying the signal at the near end of one twisted pair and measuring the coupled signal S_{12} at the near end of a different twisted pair. The coupling between the transmitting twisted pairs and the receiving twisted pairs which is of particular interest requires two times four separate measurements.

All cables need to be terminated with a connector at the far end with matched loads at each pair. Pairs that are not used in the measurement shall have terminations at the near end as well.

The over all influence of the transmitters on the receivers of the near end is described by the Power Sum NEXT (PSNEXT) which can be calculated but summing up the linear values (not dB) of the measured pair to pair NEXT.

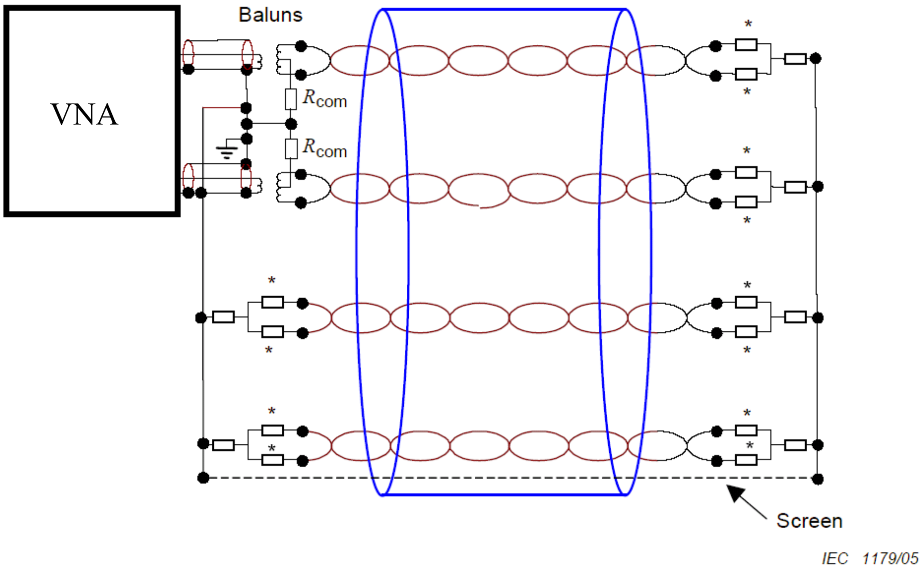

Figure 5: Near-end Crosstalk test configuration according to ICE 61935-1

3.4 FAR-END CROSSTALK (FEXT)

The objective of this test is to determine the coupling between a signal applied at the near end of one wire pair to the signal received at the far end on a different wire pair by measuring the insertion loss S_{12} between the two twisted pairs at different ends.

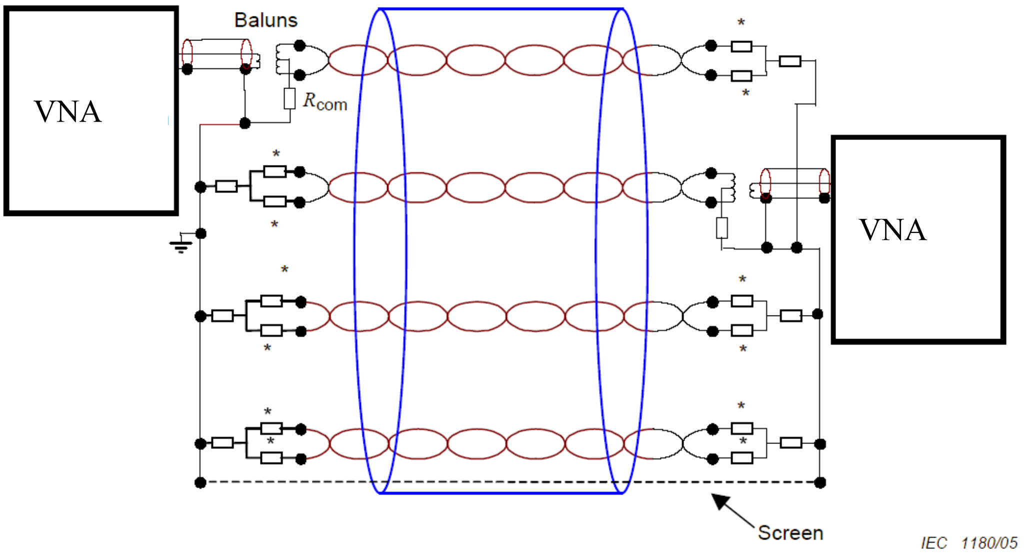

Figure 6: Far-end Crosstalk test configuration according to ICE 61935-1

FEXT is measured by applying the signal to the near end of one wire pair and measuring the coupled signal at the far end of a different wire pair. The coupling between the data and the strobe lines which is of particular interest requires two times two separate measurements.

4 SPACEWIRE TEST CONNECTOR BOARD

In order to be able to perform the tests discussed previously on SpaceWire cables a special test connector board has been designed. It allows to connect the VNA with SMA connectors on one side and to interface the SpaceWire cable via a microminiature D-type socket on the other side. The two different structures described in the following have been integrated on this PCB in order to perform the measurement by using two different measurement techniques. A comparison of the results will be used to get an estimate of the measurement accuracy and to select the best measurement technique for the future. Four identical test connector boards of this type have been built.

5.1 BALUN DRIVEN TEST CONNECTOR

This test connector is in line with the measurement setup described in [2] and [3].

The balun driven connector allows for a conventional 2-port VNA use, as each of the SpaceWire differential pairs are driven from single-ended 50Ω SMA connectors via a 1:2 impedance ratio balun. The centre tap of each of the baluns is terminated for common mode AC signals by a 51Ω resistor and a π–section RC low-pass filter Figure 7.

The baluns used (Mini-Circuits TX-2-5-1) are specified as having a –2dB bandwidth of 30-1100MHz in a 75Ω system and have shown a very similar performance in the 50Ω system used for the tests here.

When used to test the match (return loss) of real SpaceWire receiver in normal operation it is important that the LVDS line receivers are biased to the nominal 1.2V potential. For this purpose a RC low-pass filter and a jumper link to an on-board regulated supply have been implemented. This is not needed for testing passive devices.

In order to investigate the impact of a DC disconnection of the outer shield of the SpaceWire cable on the crosstalk performance, the chassis support bracket is mounted on a small section of copper plane which is connected to the PCB’s ground plane via two capacitors for some AC grounding at all times and by a set of 4 paralleled jumpers which can be used to break up the DC connection.

4.1 DIRECTLY DRIVEN TEST CONNECTOR

The baluns have been introduced to perform the transformation of the 50 Ω single ended interface of a conventional 2-port VNA to the 100 Ω differential line of the twisted pair cable Figure 7. Where a 4-port VNA is available the directly driven test connector can be used with a direct connection from one 50Ω SMA connectors to one pin in the SpaceWire connector. From the measurements not only the differential mode but also the common mode S-parameters can be calculated as well as the signal transitions between common and differential mode. This setup further avoids the maximum frequency limitations on the measurement introduced by the baluns.

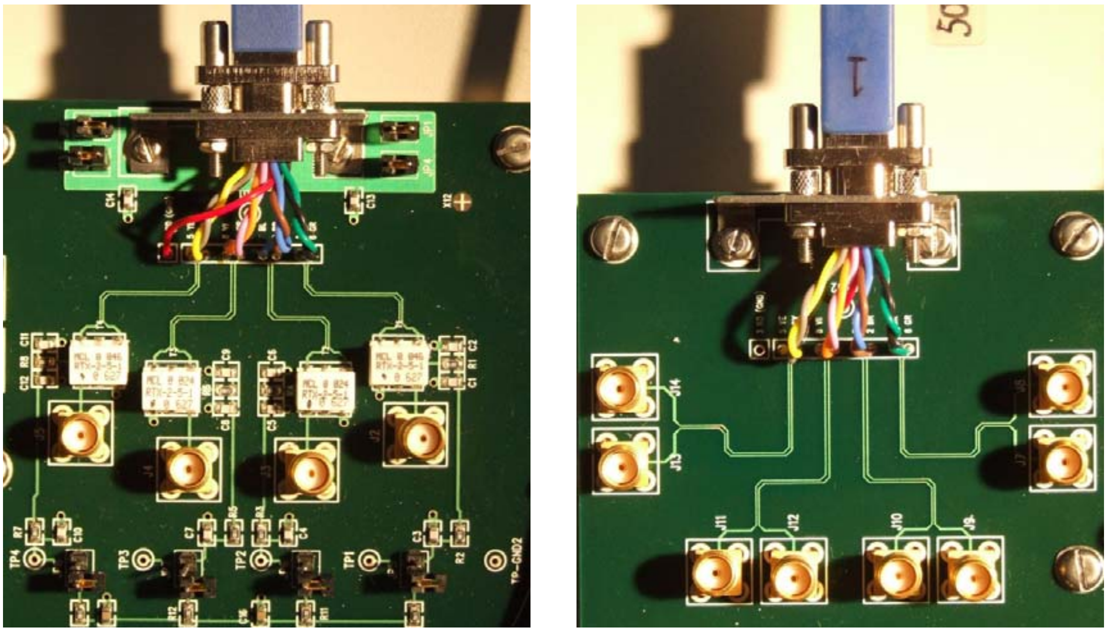

Figure 7: Balun driven test connector (left) and Directly driven test connector (right) as implemented on SpaceWire test connector board

5 CALIBRATION

A good calibration is always a crucial point for an accurate VNA measurement. This calibration has to be performed at the reference plane for measurement which is in this case the SpaceWire connector. For the micro-miniature D-type connector there is no standard calibration kit commercially available but the calibration standards have to be designed and self-built. A number of different calibration techniques like

Short/Open/Load/Through, Trough/Reflect/Line and adaptor removal will be tried out and compared to each other.

The test connector boards further contain some special structures which are intended to be used for calibration and its verification.

6 CONCLUSION

In the current standard the SpaceWire cable is specified by a detailed specification of its construction. Its electrical performance is only partially specified. Particularly no cross-coupling performance and insertion loss performance as a function of frequency is specified. A definition of electrical performance parameters to cover this gap in the specification and a technique to measure them has been described.

A characterisation of the specification-compliant SpaceWire cables with the presented performance parameters will allow it to be compared with other cable designs with respect to the electrical performance.

7 REFERENCES

[1] ECSS-E-50-12A, SpaceWire - Links, nodes, routers and networks

[2] IEC 61935-1, Testing of balanced communication cabling in accordance with ISO IEC 11801 Part1 Installed cabling

[3] IEC 61935-2, Testing of balanced communication cabling in accordance with ISO IEC 11801 Part2 Patch cords and work area cords