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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE (CISPR)

Subcommittee A: Radio Interference Measurements and Statistical Methods

Working Group 2: EMC measurement techniques and techniques for developing limits

Optimising radiated field testing with switched-impedance chamber (FAR) exit filters

1) OVERVIEW

It is proposed to perform emission and immunity testing (on an OATS, in a conventional chamber, and in a FAR) under ***two*** sets of cable conditions, firstly with very ***low*** common-mode impedance where each cable exits from the test chamber, and secondly with very ***high*** impedance at this point. The worst-case results will then be recorded as the formal test figures. The change of exit impedance will have the effect of drastically altering the resonant frequencies of each cable, as may be seen by comparing Figures 1 and 2. This will lead to the following advantages:

* Automatic worst-case cable layout selection, so reducing the inconsistencies now experienced due to human judgement. This will be particularly important for immunity testing where there is often no way by which the worst layout for susceptibility can be chosen.
* Elimination of the ambiguities and inconsistencies in existing standards and test practices, which often do not even specify the common-mode exit impedance. This is especially problematic for unshielded data and communication cables.
* The existing over-test of power cable emission at frequencies below 100MHz, (due to the usual low chamber/OATS exit impedance compared with practical use) is maintained, so preserving consistency of test results.
* In a FAR, where the fully-anechoic chamber walls make it difficult to define a conductive boundary to the limited test volume, this approach allows the switched connection of cables to each other and to a small reference plate, once again allowing automatic worst-case cable layout selection to match the conventional OATS situation.

2) RECOMMENDATIONS

The paragraphs below set out the details of this proposal and describe switched-impedance exit filters covering all types of cable that will function adequately even if made with wide tolerances. It is recommended that such filters be made and used by interested parties to gain experience prior to inclusion in standards.

3) BACKGROUND

The proposed use of a fully-anechoic room (FAR) for emission testing has thrown a spotlight onto cable emissions. It is difficult to create an environment without a groundplane in which the antenna behaviour of cables might match those (eg, on an OATS) where there is a groundplane. A number of authors (Refs. 1, 2, 5) have pointed out that earthing a power cable at a groundplane leads to an over-emphasis on low-frequency emission from the cable or that a high exit impedance reduces such emission, and that a FAR with moderate (about 150 ohms) exit impedance might be a better match to the real world (Ref. 3) - but the established usage of conventional test facilities and their operating practice is a very serious consideration. A relevant question is "Does the FAR project seek a theoretically optimum test set-up, or one that best replicates existing test methods". So far as its FAR application is concerned, this proposal aims to help the FAR replicate existing methods.

The present proposal uses the switched cable decoupler (SCD) technique introduced in CISPRA/WG1/(Alexander)00-2 and Ref. 4, but performs the switching ***at the test enclosure exit***. This avoids need of fibre-optic coupling to an SCD (switched coupler device) adjacent to the EUT as was previously proposed.

It is generally accepted that an EUT cable may be regarded as having a common-mode impedance of 150 ohms (Ref. 5), but accurate assessment or replication of this impedance is avoided in the present proposal by switching the exit impedance from substantially less than 150 ohms - say below 40 ohms - to substantially more - say more than 600 ohms. These impedances may be obtained in various ways as described under the heading "Switched-impedance exit filter design".

It should be noted that emission from cables can lead to cancellation or addition as may be seen in the charts of Ref. 4. Cancellation can cause very deep nulls over narrow frequency bands, whereas addition results in modest increases over wider frequency ranges. Therefore, whilst it is a convenient use of words to say that the objective of optimising cable emission it to secure the maximum emission/susceptibility, it is actually more important to ***avoid the minimum*** case. Use should be made of this in the treatment of multi-cable EUT situations: see section 7 below.

4) SWITCHED- IMPEDANCE EXIT FILTER DESIGN

Figure 3 shows a test set up for an EUT together with a switchable exit filter for a three-core unshielded power cable of which one core is grounded. The presence of this ground wire, and the acceptability of decoupling capacitors from the phase and neutral wires to ground, makes it very easy to connect a switch to change the common-mode impedance into a network that is very similar to the usual power filter network.

In the figure the heavy dashed line represents the conductive test enclosure - or a plate below the EUT in a FAR. The antenna or other field coupling means are omitted for clarity. A single three-core unshielded cable from the EUT is lead through the chamber boundary wall and a series element comprising choke coils in each core provide a high common-mode impedance to radio-frequency signals flowing upon the cable inside the chamber, so ensuring a ***current minimum*** at this point. However, the ground conductor and two filter capacitors are linked so that closure of the switch results in a very low common-mode impedance at radio-frequencies. There will then be a current **maximum** at the chamber boundary. This will lead to the different resonance conditions already shown in Figures 2 and 1 respectively.

It is not necessary for the choke coils to offer an inductive impedance: Indeed to provide a high impedance over a wide frequency range a substantially resistive choke action such as may be achieved with a suitable ferrite core may be preferred. They might be arranged as a single common-mode choke as in the following example.

Figure 4 shows an example of a switched filter for a coaxial or multicore **shielded** cable. The desired high series impedance is provided by a common-mode choke which may take the form of several ferrite sleeves. Alternatively a length of the cable may be wound into an air-cored choke coil, or the cable may be passed through an "absorbing clamp". The impedance switch is directly connected to the cable shield and - in this example - utilises the contact of an electromechanical relay whose coil is energised by a remote control**.** To minimise RF leakage though the chamber wall the relay coil circuit includes a decoupling lead-through capacitor together with a ground return.

In the case of unshielded cables carrying high-speed data it is not possible to access the cable in common-mode using capacitors as was shown in Figure 3 since these would produce unacceptable differential mode loading or impedance discontinuity. In such a situation they may be replaced by the distributed capacitance of a length of shielded cable outside the test enclosure as shown in Figure 5. In this arrangement the shielded section tends to act as a resonant coaxial stub whose end nearest the "associated equipment" is open circuit. To prevent this from reflecting a high impedance in series with the switch it may be desirable to ensure adequate resistive loss in the shielded section by providing a lossy dielectric or by inserting resistors in series with the shield at intermediate points along its length. Alternatively, since tests on Cat 5 FTP data cable have shown that the coaxial cable formed with all the 8 conductors in parallel as the inner, and the foil shield as the outer, has a characteristic impedance of about 15 ohms, and a 70 metre length has sufficient inherent loss at 30MHz to limit the SWR with the far end open circuit to about 2.6:1, which limits the maximum impedance in series with the switch to the desired 40 ohms. A further alternative would be to construct a lossy line using conductive gasket material developed from that described in Ref. 3.

Figure 5 also shows how the switch may be implemented by using a PIN diode which is biased by a dc potential supplied by the remote control. The 2.2 kilohm resistor prevents the remote control circuit from reducing unduly the impedance of the diode switch when this is "open", and defines the diode current when it is closed. If the output of the remote control is held negative by 24 volts with respect to ground then the PIN diode is reverse biased and presents an impedance of some 0.3 pF so that the "switch" is effectively open. If on the other hand the output of remote control is held positive with respect to ground then the PIN diode conducts and assumes a low resistance so that the "switch" is effectively closed. This PIN diode switch has the advantage of very fast operation but the disadvantage of limited voltage- and current-handling capability. It may therefore be preferred for emission testing, whilst the electromechanical relay may be the better choice for immunity testing.

In describing the filter construction for three different classes of cable, three different ways of switching have been described. These three ways are not specific to the applications shown, and may be used in other combinations.

5) TIMING

It is possible to perform a complete scan in each switch position (or combination of switch positions for a multi-cable EUT). In this case a manual switch or electromechanical relay is quite adequate.

However, the PIN diode is very fast and so advantage may be taken of the peak or quasi-peak detector in a measuring receiver to record the worst-case during a single frequency sweep as described in Ref. 4. Using the quasi-peak detector according to IEC standard CISPR16 each switch state or each combination of switch states needs to be maintained for approximately 2 milliseconds to enable the measuring receiver to register the strength of the emitted field under those conditions. A pattern of 2 mS "on" and a rather longer "off" period gives a spectrum-analyser display in which the two states may be easily distinguished.

Such fast switching might lead to incorrect response to certain pulsed emission signals: further work on this would be useful.

6) EUTs WITH MANY CABLES

In the case of an EUT with two or more connecting cables leaving the test enclosure both positions of the switch associated with each cable must be explored in several, but not necessarily all, possible combinations so as to avoid any possibility of a null response, and get sufficiently near the worst-case electromagnetic coupling without excessive test time. Ref. 6 notes that with many cables connected to an EUT the impedance conditions are less important. There is scope for more work here, but tentatively it seems that since the low-impedance state gives more emission at low frequencies and enables current to flow in loops formed by two cables, the minimum test pattern should be to set one cable at a time into the high-impedance state. This could easily be achieved by a custom-built timer, counter, and state decoder.

7) TESTING IN FULLY ANECHOIC ROOMS

It was mentioned above that it is difficult to create an environment without a groundplane in which the antenna behaviour of cables might match those (eg, on an OATS) where there is a groundplane. In particular it must be said that adopting a high exit impedance in a FAR prevents RF current flow in the loop that might be formed by two cables connected to an EUT and grounded to the wall of an OATS. Therefore it is proposed that a small ground plane be provided as used for some of the measurements reported in Ref. 4. This would have the required number of switched exit filters mounted on it, as shown in Figure 6, and the filters switched as described above to allow current flow in each cable loop.

8) CONCLUSIONS

See paragraph 2.

9) REFERENCES

1) CISPR/A/WG2 project FAR/Convenor 5 March 1999, E Ristig.
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5) "On the relation between radiated and conducted RF emission tests", S B Worm, Philips Research, *13th International Zurich Symposium Feb 16-18, 1999.*
6) "Using ferrite clamps on the cables leaving the turntable", H Ryser, *CISPR/G/WG1 (Ryser) 96-1 (September 1996)*

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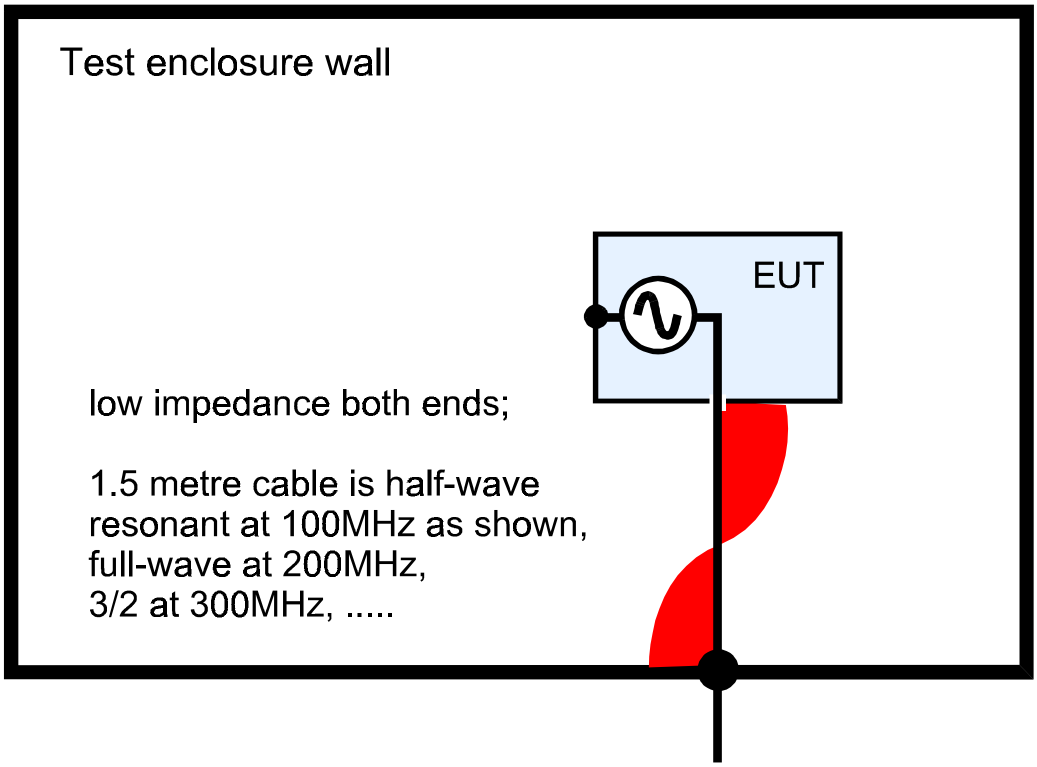
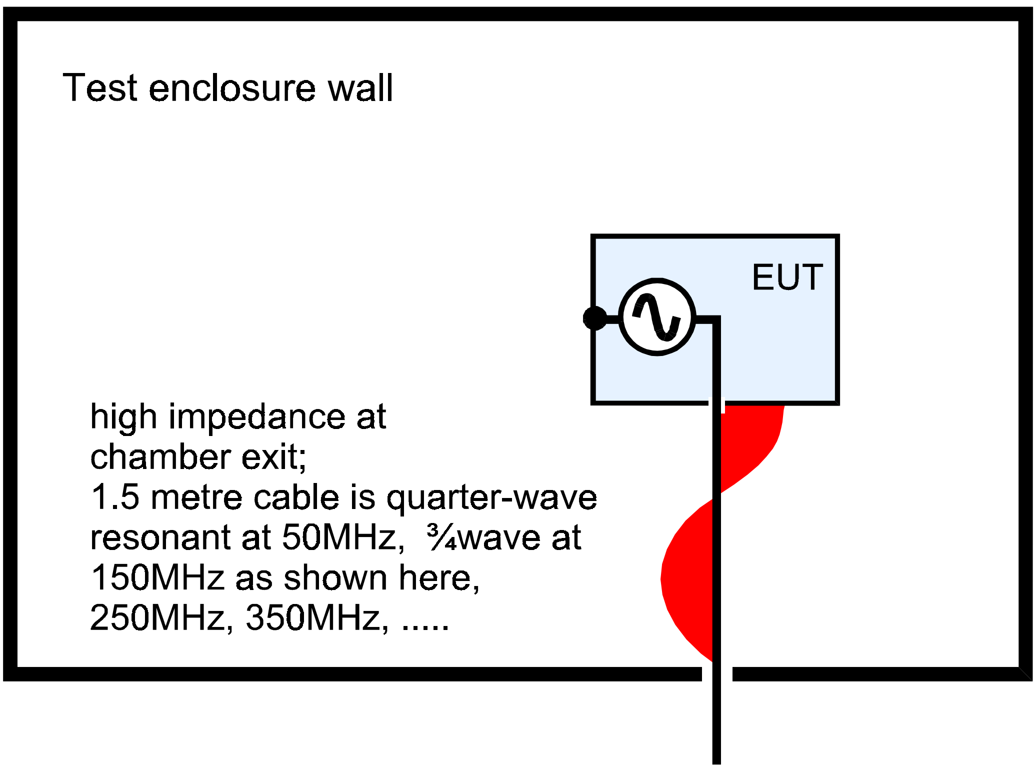
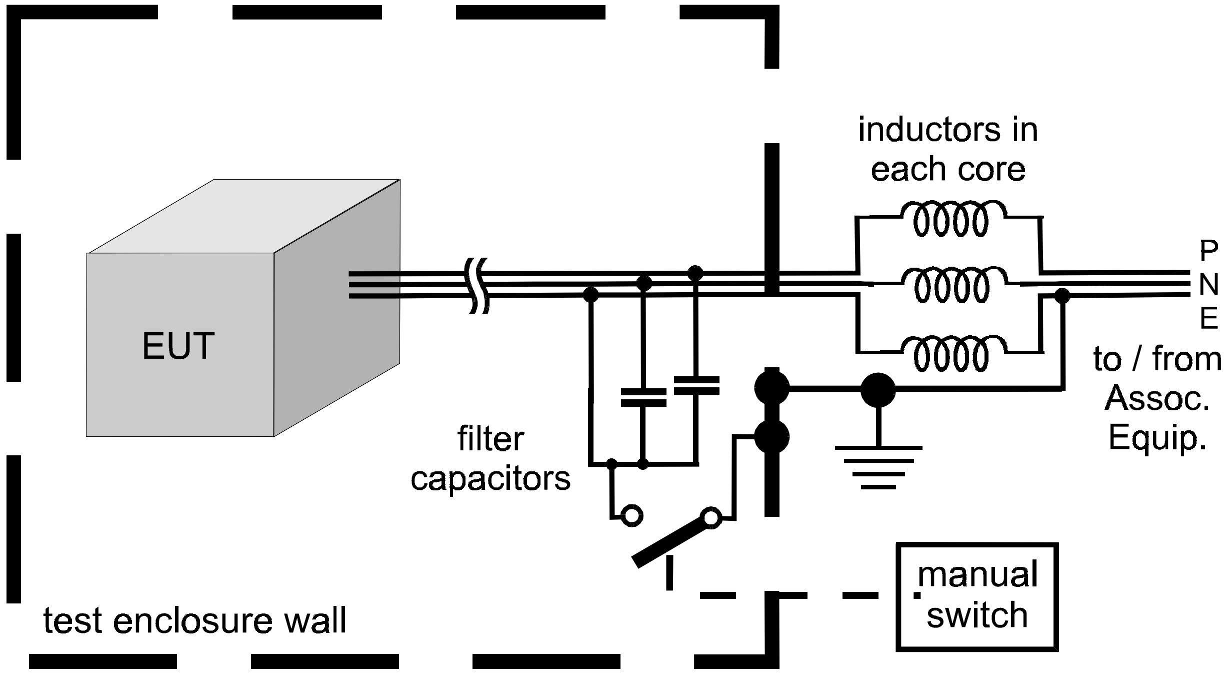


Current in cable with common-mode ground at chamber exit
Figure 1

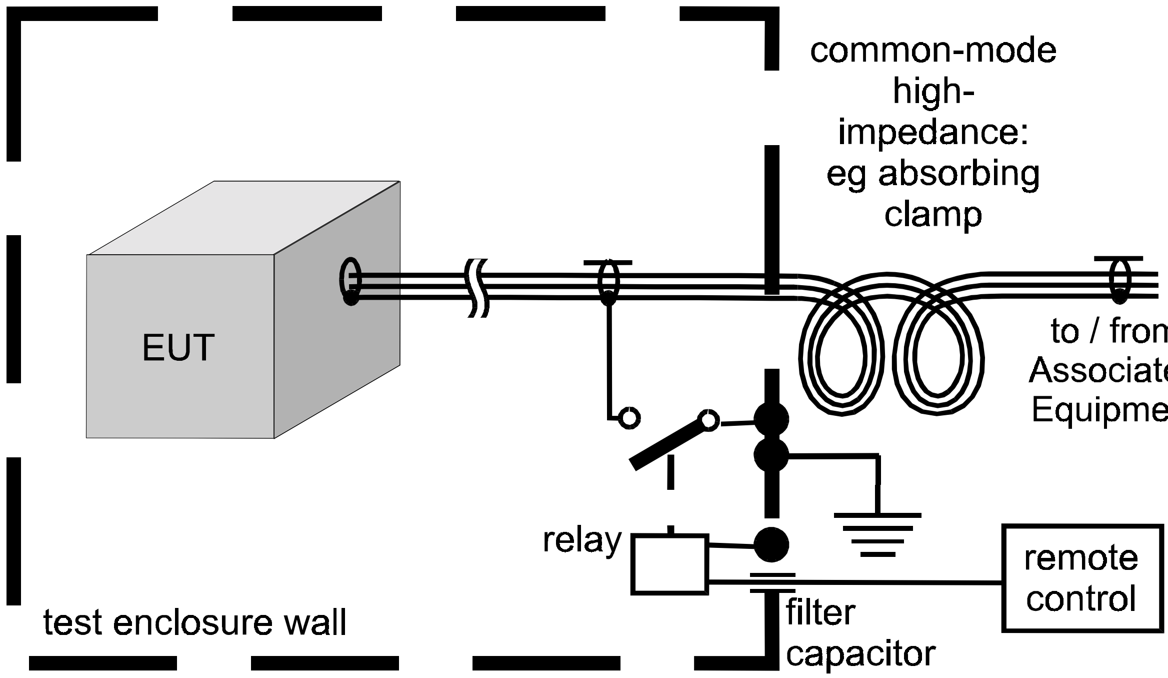


Current in cable with high common-mode impedance at exit
Figure 2



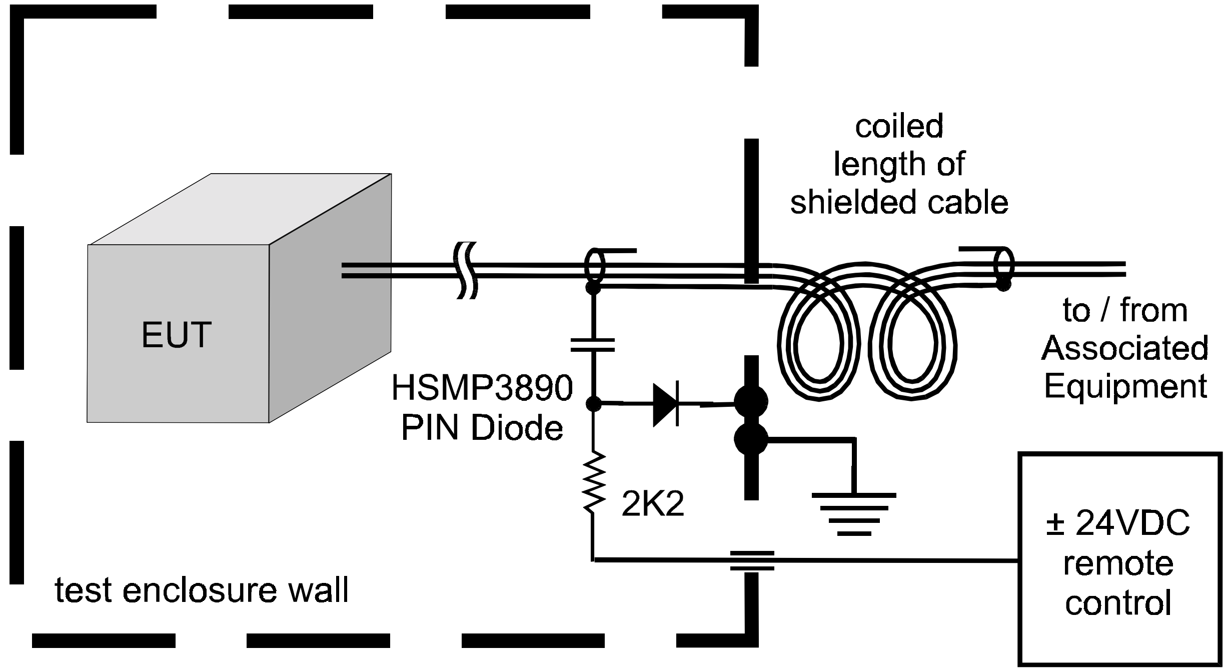
Switched network for a 3-core power cable

Figure 3



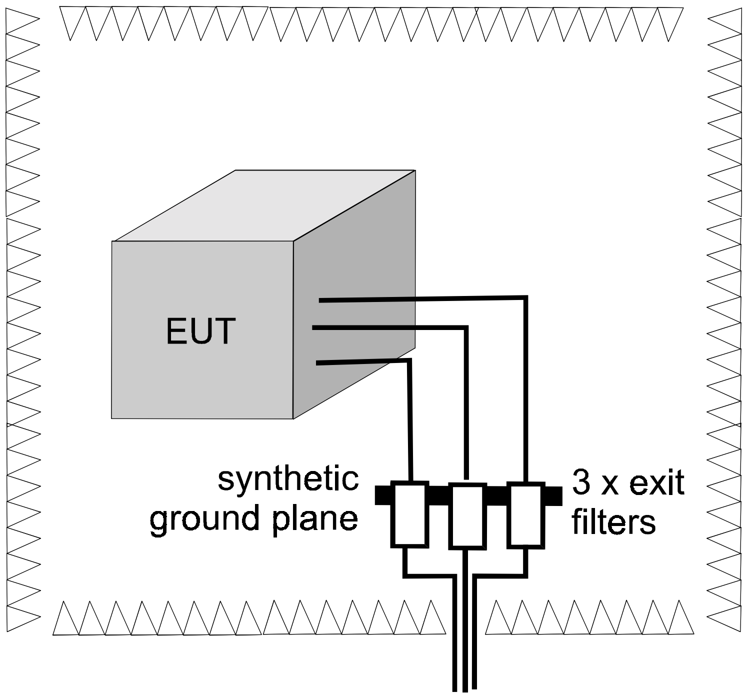
Switched network for a 2-core cable with shield

Figure 4



PIN diode switching network for a 2-core unshielded cable with shielded coupling section

Figure 5



Synthetic ground plane for multi-cable FAR testing

Figure 6