Interaction of Cable-Sense with LAN signalling

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Abstract:

Cable-Sense was premised on the requirement to be able to trace LAN cabling and identify properties such as whether a cable is disconnected at the 'far end'. The equipment uses transducers to create a differential signal across pairs of an unshielded twisted pair cable which then propagates and can be used for a variety of purposes. In principle, such a superimposed signal will have no effect on the differential LAN signalling and this paper has been written to investigate this claim on practical systems. It is concluded that the Cable-Sense equipment has no discernable deleterious effect on the electrical, mechanical or thermal performance of the LAN cabling.

1. Introduction

The background theory and operational details of the Cable-Sense equipment can be found in references [1] [2]. Essentially a differential signal is introduced between the pairs of a four (twisted) pair cable using a pair of antennas closely coupled to the outer sheathing of the UTP cable. The test signal can then propagate down the pair-to-pair channels that exist within the internal structure of UTP cable. Such a signal can then be used to trace cabling or reflectometry used to identify such things as unterminated cabling. The motivation for doing this was to provide equipment that can help in reducing unnecessary costs and LAN system down-time caused by:

1. Identifying active/inactive ports in a switch that have been filled so as to reduce the amount of unnecessary hardware purchased and power consumed by removing unused switch ports.
2. Improving network documentation, which is often poorly maintained following patching activities.

The basic system is illustrated in Figure 1. Which shows the transducers clipped on to UTP cabling.

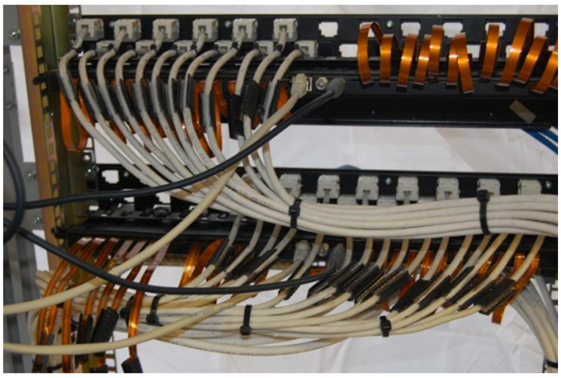


Figure 1 Installed cable sense equipment

Figure 2 shows the transducers which couple the test signal into the cabling, being differential across two pairs.

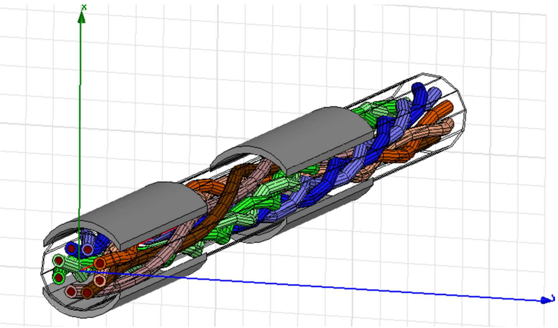


Figure 2 model of cable sense showing two pairs of transducers (antennas) (from [1])

The equipment generates a swept frequency signal over the range 30 MHz to 110 MHz. As this is within the pass band of LAN signalling, the effect that this test equipment may have on the data signalling, itself, was investigated.

Cable-Sense was designed as a reflectometry based measurement system and, while it was designed to also monitor the level of cable activity, there is no provision for 'sniffing' data and therefore no security issues associated with the equipment.

The rest of this paper discusses the tests used, the reasons for these particular tests being adopted, the results and the conclusions to be drawn from these tests.

2. Tests for interaction

The signal impressed on the cabling using the Cable-Sense equipment is monotonic and sweeps over a frequency range of 30 MHz to 110 MHz in 0.2 MHz steps, taking typically 40ms to complete the sweep (effectively 250 µs per step).

The nature of structured cabling means that interference is filtered out leaving differential mode signals and any noise contribution derived from common mode which has been converted to differential mode. Clearly, one of the main concerns for whether the Cable-Sense equipment has any effect on the system to which it is connected must be to what level are differential signals generated by the presence of the test equipment.

The Cable-Sense equipment actually couples from the transducers to the cable by electric field coupling. Essentially, an electric field is set up between two pairs of cables, as indicated in Figure 3.

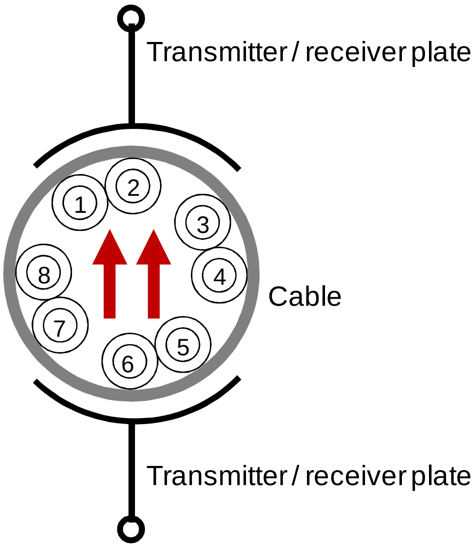


Figure 3 Coupling to cables (from [2]). 1 – 8 represent wires within the cable and labelled shows the electric field developed largely between pairs 1-2 and 5-6, but with a small component between pairs 3-4 and 7-8

This is clearly not what is considered to be 'common mode' signalling which would develop coherently across one or more pair(s) with a return path through an external route. Here, the out-going and return currents are largely balanced within the cable. Never-the-less, it is reasonable to assume that asymmetries and unbalances in the system could give rise to small mis-balances in the current flows, which could covert by normal means to differential mode signals. Similarly, a reasonable assumption is that such asymmetries and unbalances could lead to differential mode signals being induced in individual pairs. This observation leads to the questions

1. To what extent does the cable sense signalling appear in the cable to which it is connected?
2. What influence does the presence of the Cable-Sense equipment have on the channel performance (whether signalling or simply through being attached to the cable)

These questions were addressed by

1. Measure received (differential) power where the Cable-Sense equipment was signalling
2. Compare the pair return loss and near-end cross-talk with the Cable-Sense equipment disconnected, connected but not signalling and connected and signalling.

Other issues that were also considered were:

3. Estimating the power usage for the Cable-Sense equipment.
4. Considering how intrusive or potentially (mechanically) damaging the installed Cable-Sense equipment might be.

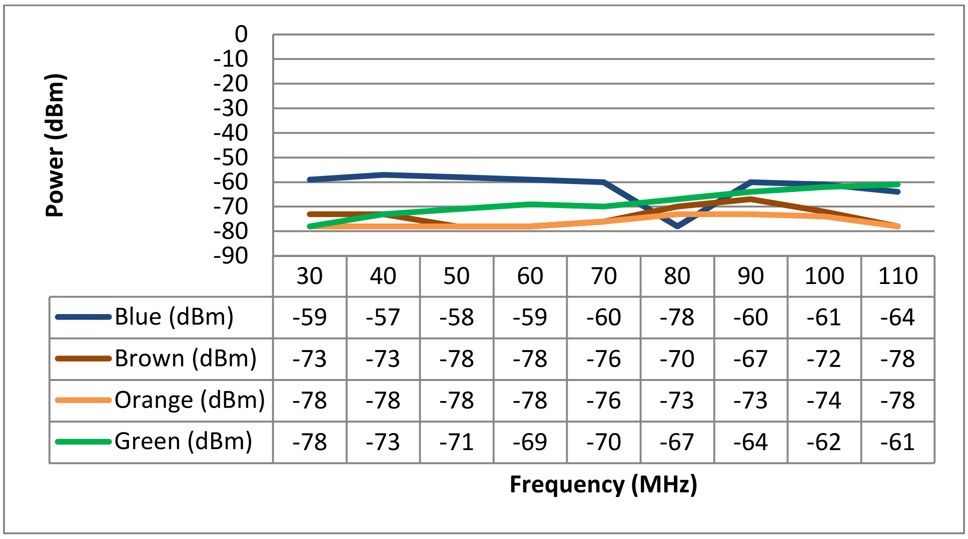
4.1. Differential power measurement

Two lengths of Category 5e LAN cable were used to test the differential power coupled to individual pairs. The cables were 20 m and 80 m long. The experiment set up so that the Cable-Sense equipment was signalling with the near or far end of the cable connected to a spectrum analyzer using approximately 1.2 m of patch cable and appropriate baluns. The other end of the cable was terminated in the cable characteristic impedance.

The measurement losses were of the order of 7 dB. The received power at the near end with the far end terminated is shown in Figure 4 and the received power at the far end with the near end terminated is shown in Figure 5. This is for the 20 m cable.

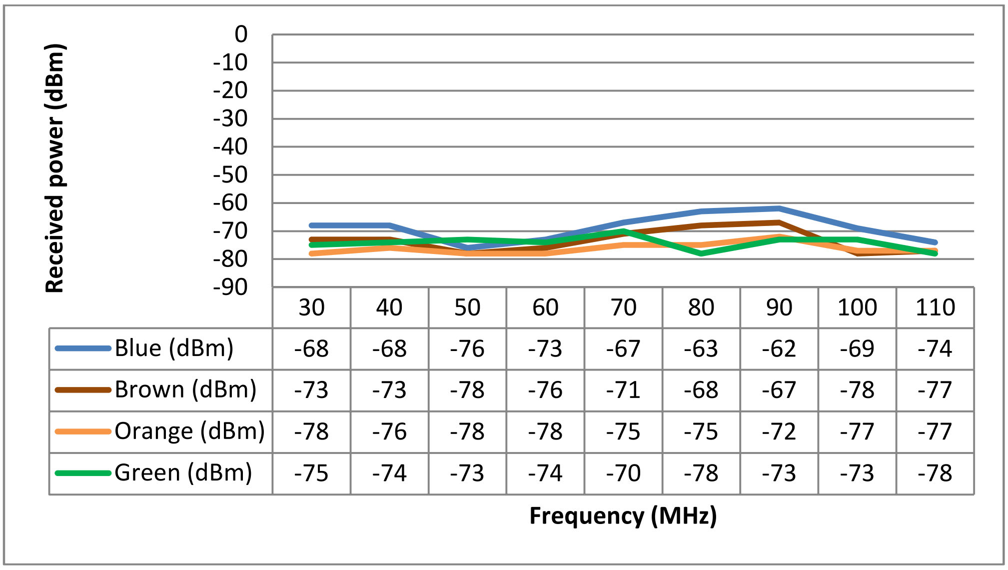
These figures represent the general peak envelope. In detail, the received power spectrum consisted of discrete frequency components, separated by 200 kHz superposed on a slowly varying resonant structure resulting from the length of the cable.

The measurement noise floor was -78 dBm and measurement repeatability was no more than 1 dBm. The near end measurement with the far end unterminated is shown in Figure 6 – only the Blue pair, the worst of the pairs, is shown.



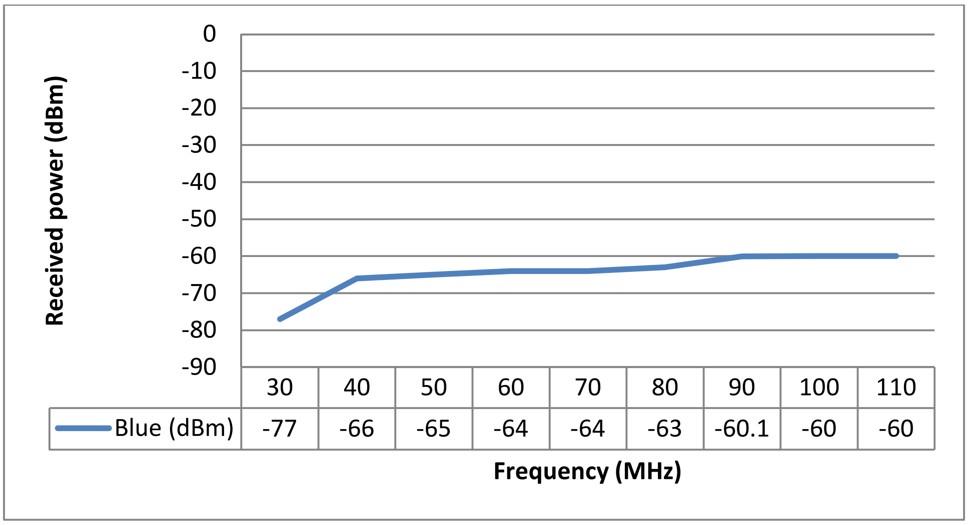
	30	40	50	60	70	80	90	100	110
Blue (dBm)	-59	-57	-58	-59	-60	-78	-60	-61	-64
Brown (dBm)	-73	-73	-78	-78	-76	-70	-67	-72	-78
Orange (dBm)	-78	-78	-78	-78	-76	-73	-73	-74	-78
Green (dBm)	-78	-73	-71	-69	-70	-67	-64	-62	-61

Figure 4 Power converted to differential mode from Cable-Sense equipment for a 20m terminated cable, measured at the 'near end'.



	30	40	50	60	70	80	90	100	110
Blue (dBm)	-68	-68	-76	-73	-67	-63	-62	-69	-74
Brown (dBm)	-73	-73	-78	-76	-71	-68	-67	-78	-77
Orange (dBm)	-78	-76	-78	-78	-75	-75	-72	-77	-77
Green (dBm)	-75	-74	-73	-74	-70	-78	-73	-73	-78

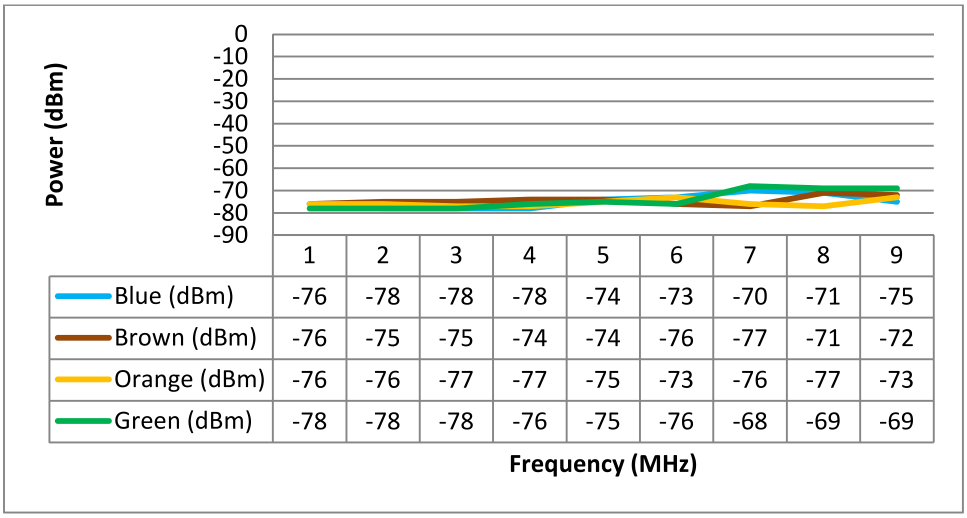
Figure 5 Power converted to differential mode from Cable-Sense equipment for a 20m terminated cable, measured at the 'near end'.



	30	40	50	60	70	80	90	100	110
Blue (dBm)	-77	-66	-65	-64	-64	-63	-60.1	-60	-60

Figure 6 Power converted to differential mode from Cable-Sense equipment for a 20m unterminated cable, measured at the 'near end'.

The effect on the near-end measurement with the far end terminated when 80m of cable was used is shown in Figure 7. The corresponding far-end measurement is not shown as the values were generally at the noise floor (the highest values were -76.2 dBm for the orange pair at 100.6 MHz.



	1	2	3	4	5	6	7	8	9
Blue (dBm)	-76	-78	-78	-78	-74	-73	-70	-71	-75
Brown (dBm)	-76	-75	-75	-74	-74	-76	-77	-71	-72
Orange (dBm)	-76	-76	-77	-77	-75	-73	-76	-77	-73
Green (dBm)	-78	-78	-78	-76	-75	-76	-68	-69	-69

Figure 7 Power converted to differential mode from Cable-Sense equipment for an 80m terminated cable, measured at the 'near end'.

The immediate question to consider, having noted that the maximum power at the far end of the cable in the 20m case was actually -61 dBm measured on the Blue pair at 88 MHz, is how close is this to the minimum acceptable signal power for transceiver equipment. A signalling voltage of approx 0.5 V represents a power of approximately -26 dBm, if losses on a 20 m Category 5 cable are approximately -6 dB, maximum, then the approximate received power is approximately -32 dBm. If it can be assumed that the receive equipment has a minimum SNR of approximately 18 dB then the Cable-Sense equipment did not exceed the resulting system noise floor of -56 dB, even allowing for measurement system losses. A similar exercise shows that the effect of the Cable-Sense equipment on the near-end measurements is similarly well above the system noise floor.

4.2. Return Loss Measurement

In order to test whether the presence of the Cable-Sense equipment had any effect on the channel performance, in particular, affecting the localised impedance where the transducers were clipped on, cable return loss was measured. Figure 8 shows a typical comparative return loss with the equipment running, turned off and with it unclipped. The tests were performed with a commercial hand-held tester (Fluke Omniscanner). The results show differences well within expected measurement repeatability.

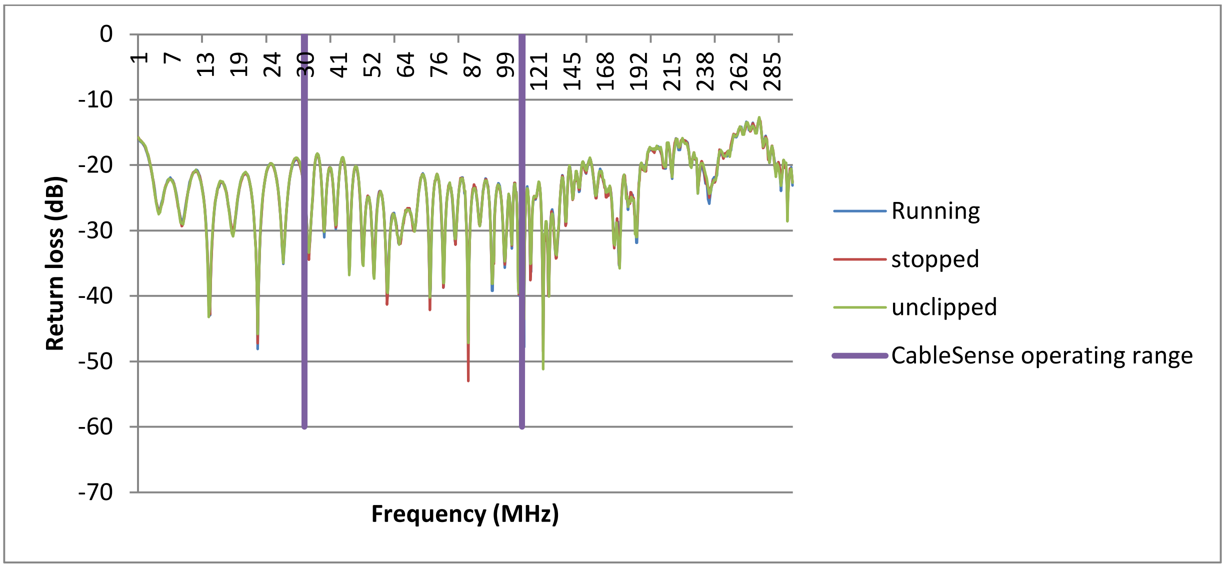


Figure 8 Return loss comparisons, with and without Cable-Sense equipment.

4.3. Near End Cross Talk

The near end cross talk was also measured using the same equipment as with the return loss measurements to test whether the presence of the transducers degraded Cross Talk. The results for coupling between pairs 12 and 36 are presented in Figure 9. Only one cross talk result is shown as this is typical of all possible combinations. Again, the results show no greater differences than would be expected from measurement repeatability.

4.4. Power Considerations

One of the objectives for introducing the Cable-Sense equipment in the first place was to reduce power consumption at switches through identification and removal of unnecessarily connected cables. This is, of course, nullified if the test equipment, itself, draws excessive current, dissipating large amounts of power. A test system was measured and, with a 9V supply the Cable-Sense quiescent current for a full system of 24 transducers was 1.28 A. It drew 1.7A when sweeping, resulting in a maximum power requirement of 15.3 W, reducing to under 12 watts when not actively sweeping.

The nature of the system design and implementation makes the Cable-Sense equipment highly unlikely to have any impact on Power over Ethernet systems, or vice versa.

4.5. Mechanical Considerations

One final area of possible concern was whether the Cable-Sense equipment could give rise to issues of, for example, excessive strain on the cabling. It should be noted that, at the time of writing, further improvements were being made on the method of attaching the transducers. Clearly, the transducers need to make intimate contact with the outer sheathing but visual inspection of the sheathing following removal of the transducers showed minimal impression. Certainly there was insufficient cable compression to cause any performance degradation of the channel performance. Similarly, there was very little force on the cable exerted by the transducers and their connection to the scanner unit.

Finally, the scanner unit fits within a normal rack unit and any such retro-fit activity will have little to no impact on the quality of terminations on the cables.

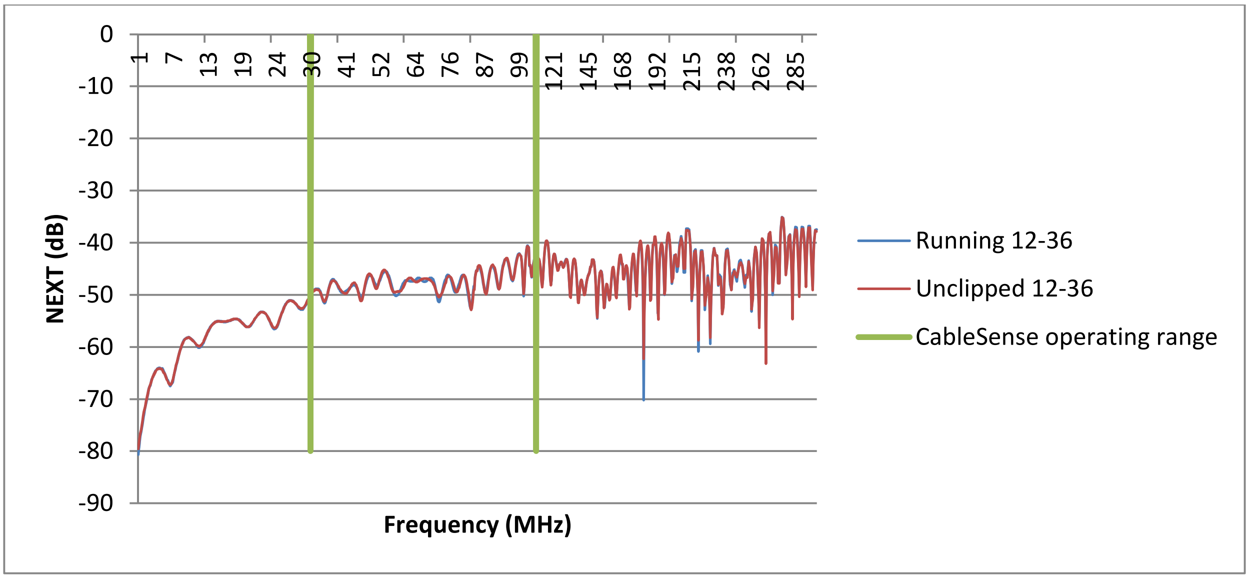


Figure 9 Near End Cross Talk between pairs 12 and 36 with and without the Cable-Sense equipment

5. Conclusions

This white paper set out to consider whether the Cable-Sense equipment could impact on the system that it is intended to measure. This impact could be electrical, mechanical or through excessive thermal contribution. A series of tests were undertaken in order to test these hypotheses.

The first issue was whether the signalling used by the Cable-Sense equipment could convert to differential signalling coupling to the data path itself. This was shown not to be the case, with the differentially converted signal having a high probability of being below the system threshold.

The second issue was whether the presence of the cable sense equipment itself, including the transducers, could affect the localised impedance (resulting in degraded return loss) or whether it could act as an 'agent' to degrade cross talk. Results showed that this was not the case.

Mechanical issues were visually assessed and thermal issues considered through power consumption. It was observed that the Cable-Sense equipment was 'minimally invasive' and would not have a discernable impact on PoE systems. There is no evidence that PoE can be affected.

The overall conclusion is that no evidence could be found to support an hypothesis that the Cable-Sense equipment could interfere or degrade the LAN signalling on the system to which it is connected. Similarly, there is no evidence of security issues associated with Cable-Sense: in particular there is no way of getting data into or out of the cabling and coupled with the very low conversion to differential mode, means that network security and network throughput will not be affected.

References

[1] Sriram Dorai, "Electromagentic Modeling of UTP Cables for Non-Contact Measurements," University of Manchester, Manchester, PhD Thesis 2009.

[2] Anthony Peyton and John Kelly, "Apparatuses and methods for coupling a signal to and/or from a cable," WO 2010/109211 A1, September 30, 2010.

Author Biography: Dr Alistair Duffy is Reader in Electromagnetics at De Montfort University, Leicester, UK. He has published approximately 200 papers and articles and is currently on the Boards of Directors of the IEEE EMC Society and the IWCS.