

**Discussion Paper (Ref. N0. WBS/PAB/UK/RA/TWG/003C)****UK RA Technical Working Group on VDSL & PLT****Evaluation of the Screening Efficiency at HF of Low Voltage Electricity Distribution Cables with a Concentric Metallic Sheath by the Application of Surface Transfer Impedance Methods**

Paul A Brown, White Box Solutions, UK

**1 Introduction and Background**

Digital Power Line (DPL) is a Power Line Telecommunication (PLT) system, originally developed by NOR.WEB DPL Ltd, which permits, broadband, digital signals to be transmitted over Low Voltage Electricity Distribution Networks (LVEDNs). Data rates in the order of 1 Mb/s are achieved when the baseband signals are modulated onto high frequency (HF) carriers, preferable in a number of discrete frequency bands typically: PLT1 which extends from 2.2MHz to 3.5 MHz and PLT2 which extends from 4.2 MHz to 5.8 MHz.

LVEDNs were not designed to carry HF signals and therefore some means of determining the radiation efficiency of such infrastructure is necessary. This paper overviews earlier work which investigated measurement methods for determining the screening properties and/or radiation efficiency of a typical UK LVEDN service cable [1] and compares this with the screening properties of radio frequency (RF) coaxial cable.

UK LVEDN architecture utilises metallic sheath type cables and as such it is assumed that we might treat these as semi-screened coaxial cables for the purpose of further analysis.

**2 Surface Transfer Impedance (STI)**

The radiation efficiency of cable screens may be described by the parameter 'coupling impedance' or 'surface transfer impedance' [2]. This relates the induced current flowing on one side of a screen to the longitudinal voltage appearing on the other side. The lower the STI, the more effective the screening properties. Previous work has illustrated that the characteristic impedance ( $Z_0$ ) of typical UK LVEDN cables is in the order of 10 to 15 Ohm [3]. For the purposes of this paper the  $Z_0$  figure was confirmed, independently, by utilising a Vector Network Analyser (VNA) and a sample of BICC service cable [4], which gave a value for the service cable  $Z_0$  of 10 Ohm.

A practical method of measuring STI is shown in Figure 3.1. The cable under test has the centre conductor and screen shorted together at one end. This short is connected to a series resistor with a value equal to the  $Z_0$  of the cable under test.

Ideally, in this measurement configuration one end of the cable under test is fed by a signal generator with a source impedance equal to that of the  $Z_0$  of the cable under test. The opposite end of the cable under test is connected to

a voltmeter of input impedance equal to the  $Z_0$  of the cable under test. For a cable with a perfect screen the voltmeter will read zero.

### **3 Measurement Method and Equipment**

An experimental method was used as a basis for the cable measurements [5]. The measurement equipment consisted of a Hewlett Packard Vector Network Analyser Type 8753D configured as a swept signal source and detector. The instrument was set up to sweep frequencies from 100 kHz to 30 MHz. The input-port terminal impedance and the output-port source impedance are both 50 Ohm.

First a 1 metre length of conventional, screened, coaxial cable was prepared with one end joined to a BNC 50 ohm plug. The other end had the screening joined to the centre conductor and to a 50 Ohm series resistor. A piece of aluminium sheet was bent into an L shape and this was fitted with a BNC female/female bulkhead adapter and a socket. The series resistor was soldered to the socket and the plug to the adapter. Finally the analyser was set up for  $S_{21}$  measurements, with port 1 to the socket and port 2 to the adapter.

BS7870 type LVEDN service cable was then tested against RG58 type RF coaxial cable.

#### **LVEDN Service Cable type BS7870**

This type of service cable consists of a 6mm solid aluminium centre conductor surrounded by red polymer type insulation. This polymer insulated centre conductor is surrounded by 28 copper wires, in a concentric format and covered with a protective black, outer, polymer sheath. In order to provide a short circuit for test purposes the cable core was drilled out and tapped for a M3 screw and a conductive disc was attached via a solder tag to the core. A 12 Ohm resistor was soldered to the tag and the copper wires were soldered around the edge of the disc.

The plug end core was also drilled and tapped for M3 and a short length of M3 brass rod was inserted and this centrally drilled with a 1mm hole. The central spill of a BNC panel plug was soldered into this hole. The copper wires were soldered around the edge of the plug.

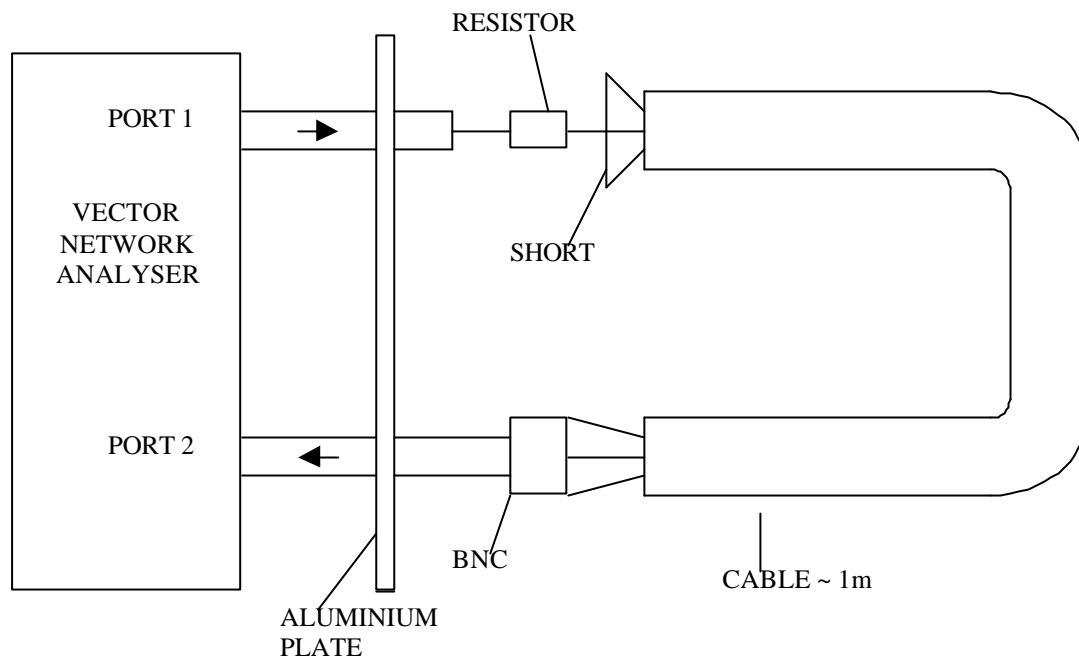
Two 50/12.5 Ohm transformers were used to match the analyser impedance to the cable. Figure 4.1 below shows the  $S_{21}$  results for this type of cable.

#### **RG58 RF Coax Cable**

This is a 50 Ohm single screened cable. The conductor and screening are of tinned copper. The shorted end was connected to a series 50 Ohm resistor. No matching transformers were used.

$S_{21}$  measurements were made.

Figure 4.2 below shows the  $S_{21}$  results for this type of cable.



**Figure 3-1 Measurement Configuration**

#### 4 Test Results

The graphical results obtained from the analyser are shown below. The DPL system centre frequencies for PLT1 and PLT2 transmissions are 2.9 MHz and 5.1 MHz respectively. The table shows the values obtained at these frequencies.

Cable Type	Frequency	Attenuation
BS7870	2.9 MHz	49 dB
BS7870	5.1 MHz	44 dB
RG58	2.9 MHz	61 dB
RG58	5.1 MHz	59 dB

### 4.1 Measurement for LVEDN Service Cable

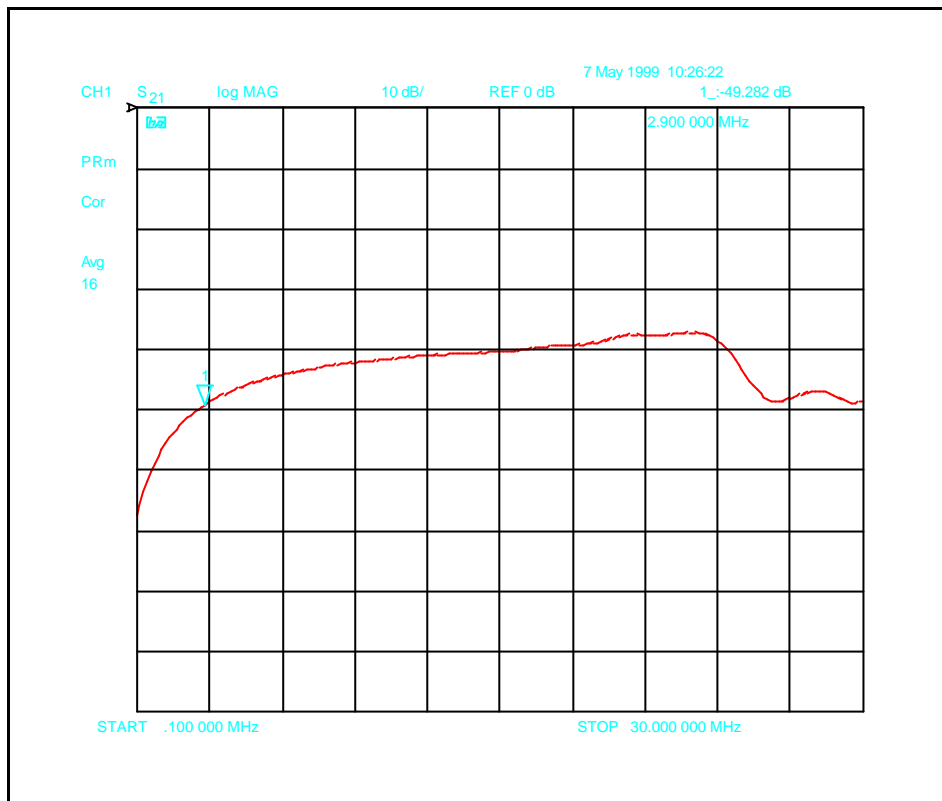


Figure 4-1 BS7870 Cable

### 4.2 Measurements for Coaxial Cable

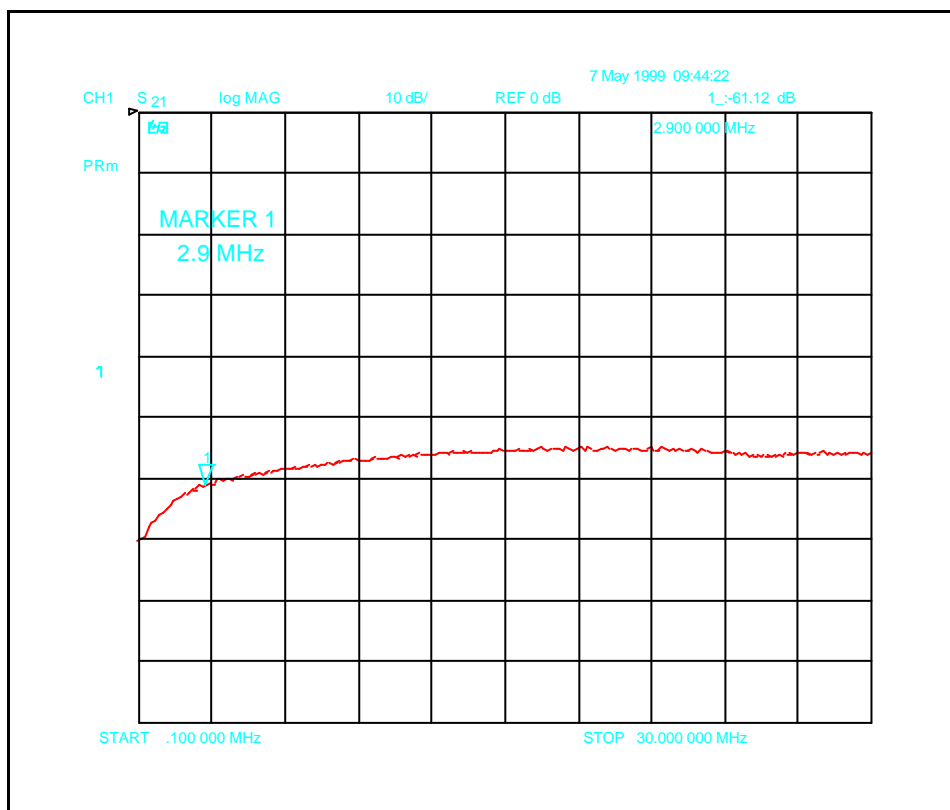


Figure 4-2 RG58 Coax

## 5 Conclusions and Further Work

The BS7870 service cable had 28 outer conductors, which gave around 46dB of screening in the frequency range of interest.

The RG58 coaxial cable gave an attenuation of around 60dB in the frequency range of interest.

From the results it can be seen that the screening efficiency of the LVEDN service cable is within approximately 14 dB of that of the RF coaxial cable. In practice the service cable's screening efficiency will vary at joint positions and at the service cable termination(s) where the screening conductors will be disorientated about the central conductor.

The service cable should, for most of its length, be buried at 0.5m below ground.

Non-intrusive, in-situ, measurements [6][7][8] of the radiation efficiencies of composite sections of typical UK, underground, LVEDNs might be undertaken in order to obtain further information as to their screening and/or radiation efficiencies when excited at HF.

## 6 References

- [1] P L Stevens, 'Surface Transfer Impedance Test Results', Corning Communications, 17<sup>th</sup> May 1999.
- [2] BICC Electric Cables Handbook.
- [3] D Fenton and P Brown, 'UK Electricity Distribution Network Cable Characteristics - Discussion Paper for UK RA TWG on VDSL & PLT', White Box Solutions, 21<sup>st</sup> June 2001.
- [4] BICC LVEDN Service Cable to British Standard No. BS7870.
- [5] Jasper Goedbloed, 'Electromagnetic Compatibility', Prentice Hall.
- [6] D M W Reed, A G Burr and P A Brown, ' HF Broadcast Interference on LV Mains Distribution Networks', Proceedings of ISPLC1998, Soka University, Japan, 1998.
- [7] OFCOM, Switzerland and ASCOM, Switzerland, 'Measured Skywave Radiation Characteristics of Low Voltage Distribution Networks Excited by PLC Systems Transmitting in the HF-Band (FAFIRA Report No. 2)', CEPT/ERC PT SE35, London, 22-23 Jan 2001.
- [8] OFCOM, Switzerland and ASCOM, Switzerland, 'Measured Groundwave Radiation Characteristics of Low Voltage Electricity Distribution Networks Excited by PLC Systems Transmitting in the HF-Band (FAFIRA Report No. 5)', CEPT/ERC PT SE35, London, 22-23 January 2001