Development Department Report
05/10/2001

The radiated emissions characteristics of typical in-house PLT LAN installations

Input for the Radiocommunications Agency TWG

DOCUMENT NUMBER	**DDR 206-1**		
ISSUE	**1.0**	**Author/s**	**SR**
DATE	**05/10/01**	**Approved by**	**PS**
STATUS	**RELEASED**	**Authorised by**	**PS**
CIRCULATION	**PUBLIC**	**Signature**	

Development Department Report
05/10/2001

Revision History

Version	**Reason for Change**
1.0	Original version.

Development Department Report
05/10/2001

INPUT FOR THE RADIOCOMMUNICATIONS AGENCY TWG......1

1. ABBREVIATIONS......4

2. REFERENCES......4

3. NEAR FIELD MEASUREMENTS......5

3.1 INTRODUCTION......5
3.2 MEASUREMENT PROCEDURE......5
3.3 MEASUREMENT RESULTS......9
3.3.1 Combined 3 meter measurement data – adjusted for an injected level of 75 dBuV......9
3.3.2 Combined 10 meter measurement data – adjusted for an injected level of 75 dBuV......10
3.3.3 Combined 30 meter measurement data – adjusted for an injected level of 75 dBuV......11

4. FAR FIELD MEASUREMENTS......12

4.1 INTRODUCTION......12
4.2 MEASUREMENT PROCEDURE......12
4.3 MEASUREMENT LOCATION......12
4.4 RADIATED EMISSIONS MEASUREMENT RESULTS......13
4.4.1 Spot frequency measurements at 14 MHz......13
4.4.2 Spot frequency measurements at 21 MHz......14
4.4.3 Spot frequency measurements at 28 MHz......15

5. SUMMARY......16

5.1 NEAR FIELD......16
5.2 FAR FIELD......16

1. Abbreviations

CISPR	International Special Committee On Radio Interference.
CW	Constant Wave.
EMC	Electromagnetic Compatibility.
FCC	Federal Communications Commission.
HF	High Frequency.
LAN	Local Area Network.
MAC	Media Access Control.
OFDM	Orthogonal Frequency Division Multiplex.
PLT	Power Line Telecommunications.

2. References

CIPSR 11: 1997	Limits and methods of measurement of radio disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment.
CISPR 22: 1997	Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement.
CISPR16-1: 1999	Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus.
FCC title 47 CFR rule part 15	Radio Frequency Devices.
MPT 1570	Radiation Limits and Measurement Standard.
(February 2000 edition)	Electromagnetic radiation from telecommunications systems operating over material substances in the frequency range 9 kHz to 300 MHz.

3. Near field measurements

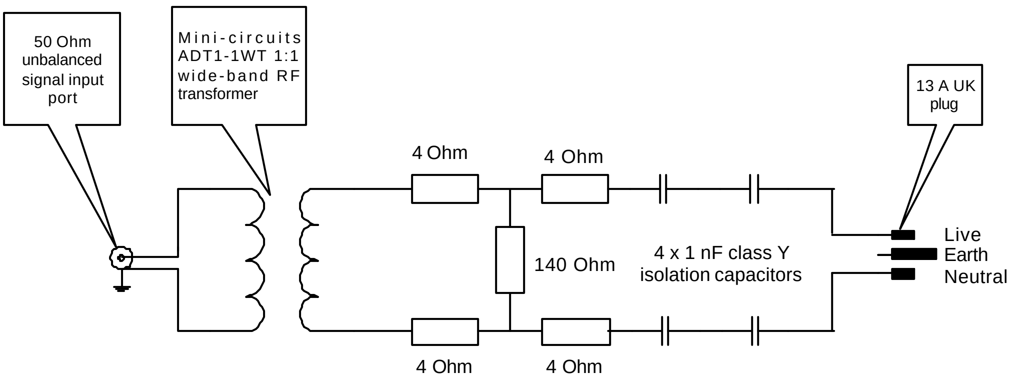
3.1 Introduction

A number of in-house PLT LAN technologies are currently being developed with modulation techniques which include narrowband carriers, spread spectrum and OFDM. In view of the variety of in-house PLT LAN technologies available, it was decided to implement a generic measurement program rather than to measure the radiated emissions profile of a single technology. The results of the generic measurement program provide an understanding of the relationship between injected signal level and radiated emissions level which in turn enables the radiated emissions profile of any in-house PLT LAN technology to be predicted providing the conducted emissions profile is known.

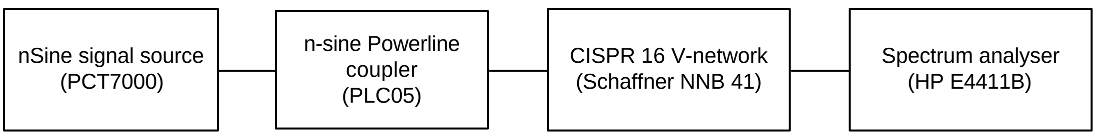
Measurements were carried out in a number of typical UK homes by Radio Frequency Investigation Ltd. RFI is an independent EMC and radio approvals test laboratory based in the UK and is well respected within the international EMC community.

3.2 Measurement procedure

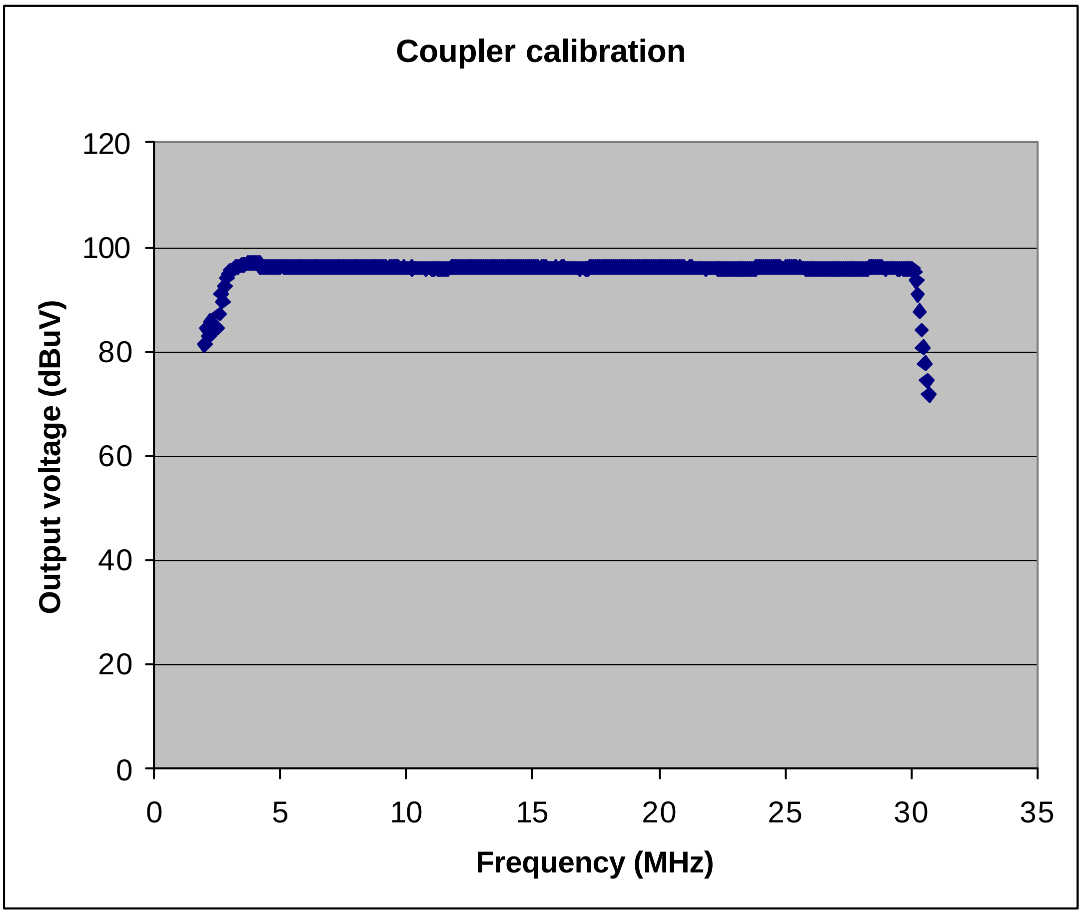
A signal generator with a 50 Ohm output impedance was used to provide a CW (un-modulated) signal that was injected into the power network via a broadband coupler. A Psion Workabout was used to control the signal source in order to generate synthesised sweeps. The broadband coupler was designed to inject the input signal differentially between live and neutral and to provide a differential injection impedance of 50 Ohms.



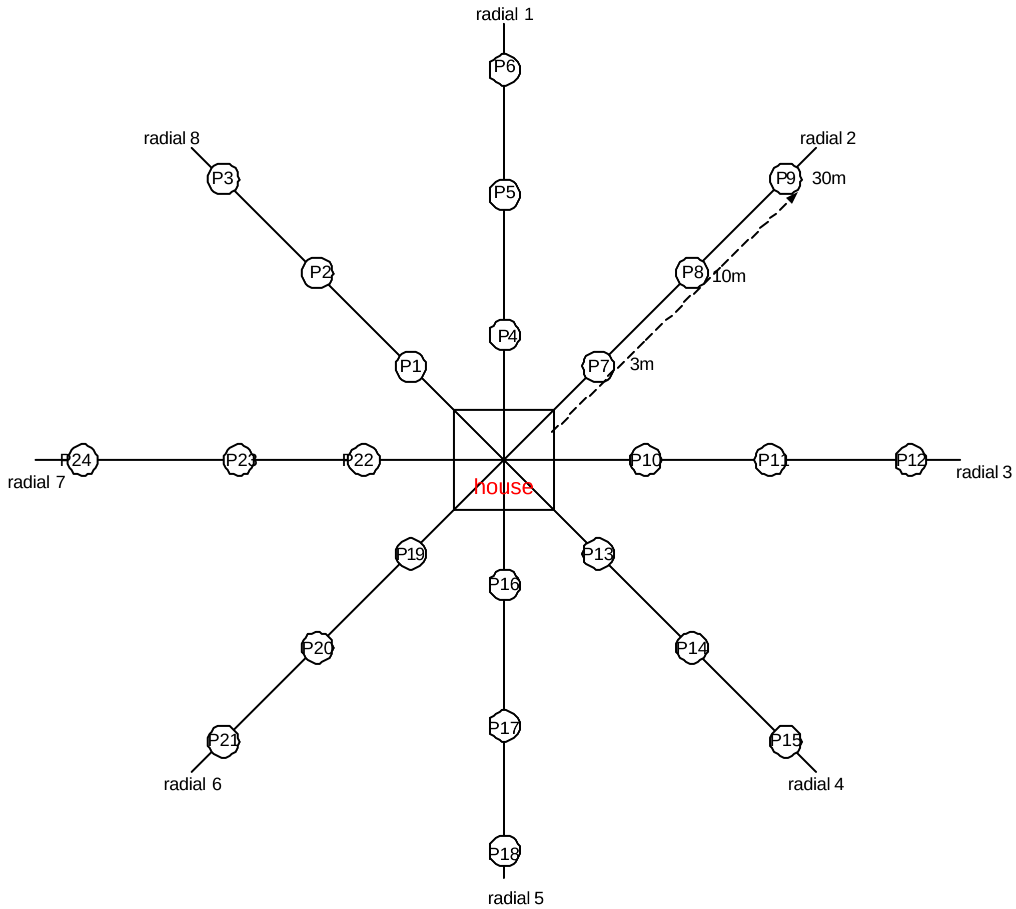
The signal generator and coupler were calibrated to produce an injected signal voltage of 96 dBuV when measured using a CISPR 16 50 Ohm / 50uH artificial mains V-network and spectrum analyser.



Due to the difficulty of differentiating PLT signals from background signals at 30 meters, an injected level of 96 dBuV was used to improve the visibility of the radiated emissions from the power network. Having made the measurements, the results were adjusted to provide an indication of the radiated field strength that would have been measured for an injected signal voltage of 75 dBuV.



A magnetic loop antenna and spectrum analyser was used to measure magnetic field strength. Where possible, measurements were made at 3, 10 and 30 meters on eight 45 degree radials.

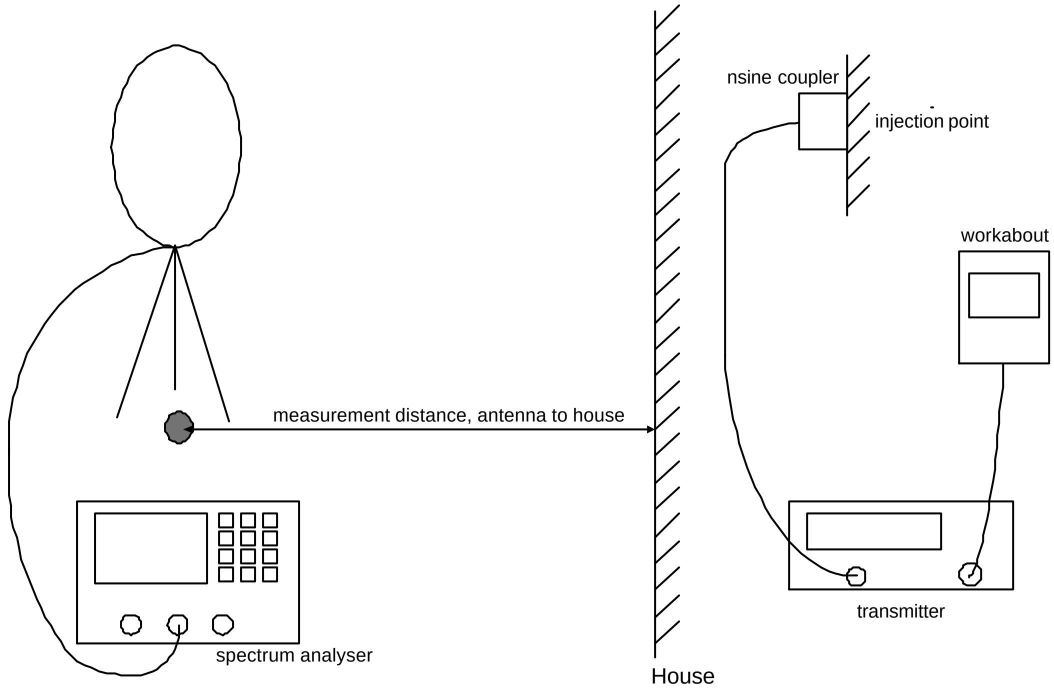


Magnetic field strength was converted to equivalent electric field strength by adding 51.5 dB[1].

[1] The conversion factor of 51.5 dB is based on the electromagnetic wave impedance of free space. Whilst it is technically incorrect to use this conversion factor in the near field, it is used by convention:

$$20 * \log(120p) = 51.5dB$$

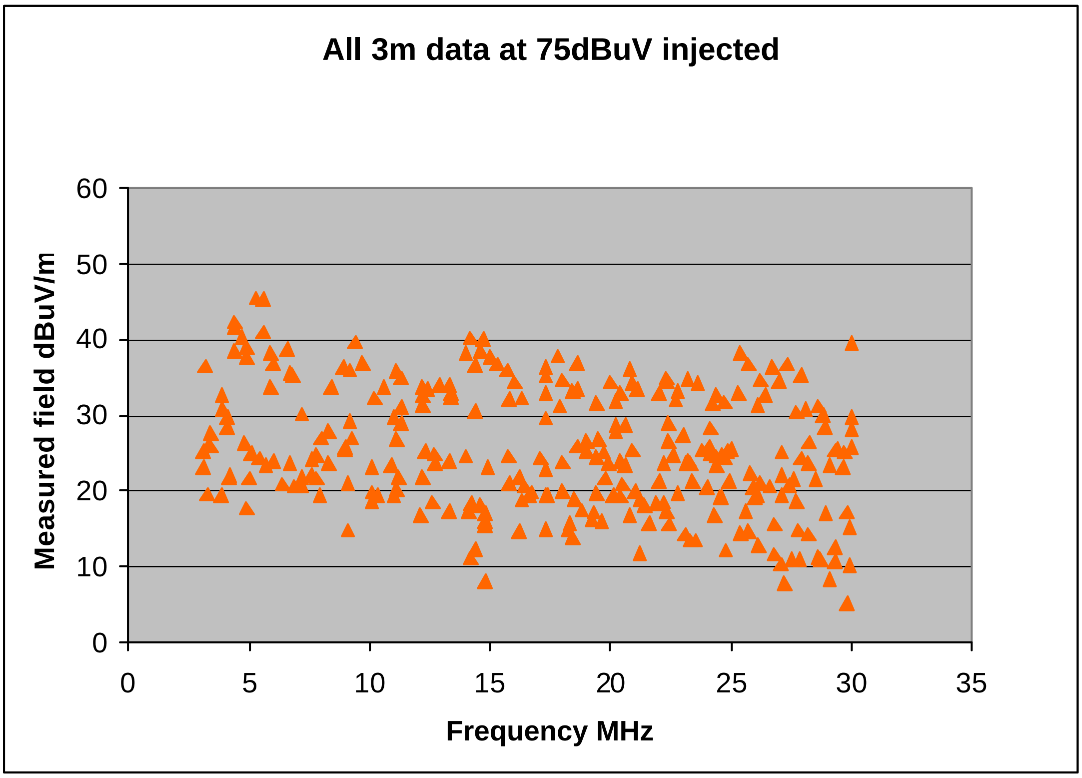
These measurements were carried out for two signal injection points in each home. The injection points were chosen to be as far apart as possible in order to energise as much of the house wiring as possible.



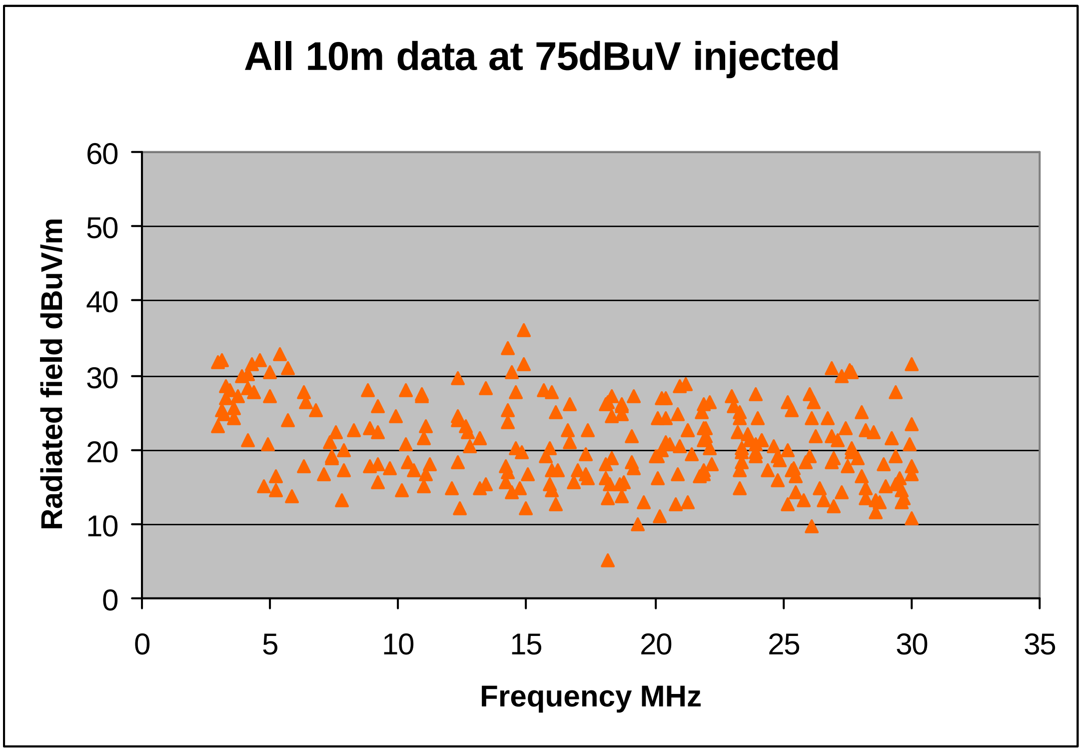
3.3 Measurement results

The following results have been adjusted to provide an indication of the radiated field strength that would have been measured for an injected signal voltage of 75 dBuV.

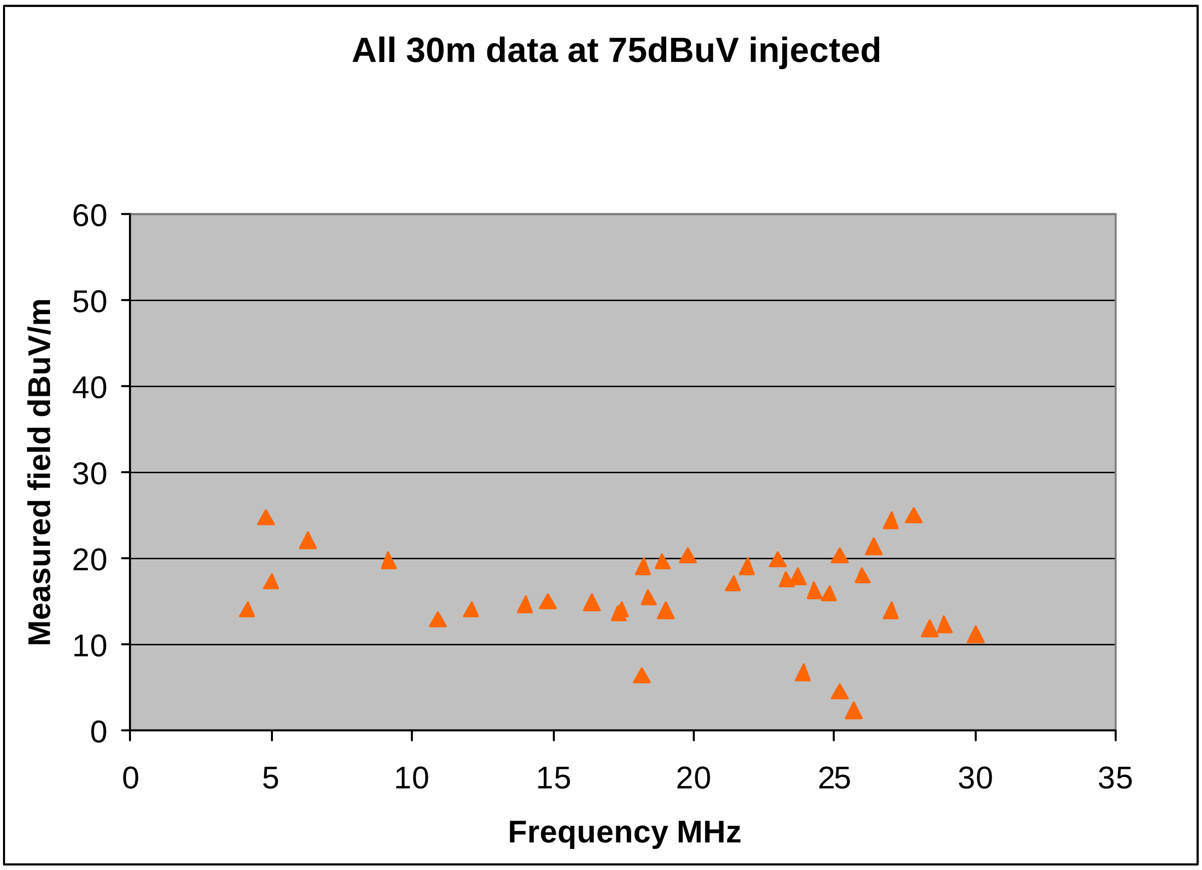
3.3.1 Combined 3 meter measurement data – adjusted for an injected level of 75 dBuV



3.3.2 Combined 10 meter measurement data – adjusted for an injected level of 75 dBuV



3.3.3 Combined 30 meter measurement data – adjusted for an injected level of 75 dBuV



Note:

It was not possible to obtain as much measurement data at a measurement distance of 30 meters as it was at measurement distances of 3 and 10 meters. This was due to:

1. The topology of the test environment, which determines which of the desired measurement locations are accessible.
2. The high ambient signal levels in the HF band, which tend to obscure PLT emissions.

4. Far field measurements

4.1 Introduction

The data presented in this section shows that the field strength produced by a PLT installation can be expected to reduce by between 31 to 36 dB for every decade increase in distance (in the far field).

The data presented in this section relates to the radiated emissions profile of a typical house when stimulated by a single point source. A typical power line LAN would comprise many stations rather than a single station. However, the PLT MAC mechanism will ensure that only one station is able to transmit at any given time. The data presented in this section is therefore expected to be representative of the radiated emissions profile of a typical house equipped with a fully functioning PLT LAN system.

4.2 Measurement procedure

Spot frequency measurements were carried out by White Box Solutions on behalf of nSine Ltd.

These measurements were made in the 14, 21 and 28 MHz amateur bands by injecting a 10 dBm CW signal into the domestic LV wiring circuit using the coupler described above. Due to the difficulty of differentiating PLT signals from background signals, an injected level of 10 dBm was used to improve the visibility of the radiated emissions from the power network. Having made the measurements, the results were adjusted to provide an indication of the radiated field strength that would have been measured for an injected signal voltage of 60 dBuV. A CW signal source was used in order to maximize the value of the measured radiated field. The effect of the modulation and the packet structure employed by in-home PLT LAN systems would be to reduce the measured level of radiated emissions.

A multi-band ‘G’ whip antenna, attached to the roof of a four-wheel drive vehicle in conjunction with a sensitive, narrow band communications receiver were used to measure electric field strength.

A GPS receiver was used to determine the distance between the measurement antenna and the signal injection point.

4.3 Measurement Location

Spot frequency measurements were made at 14, 21 and 28 MHz at each of the following locations:

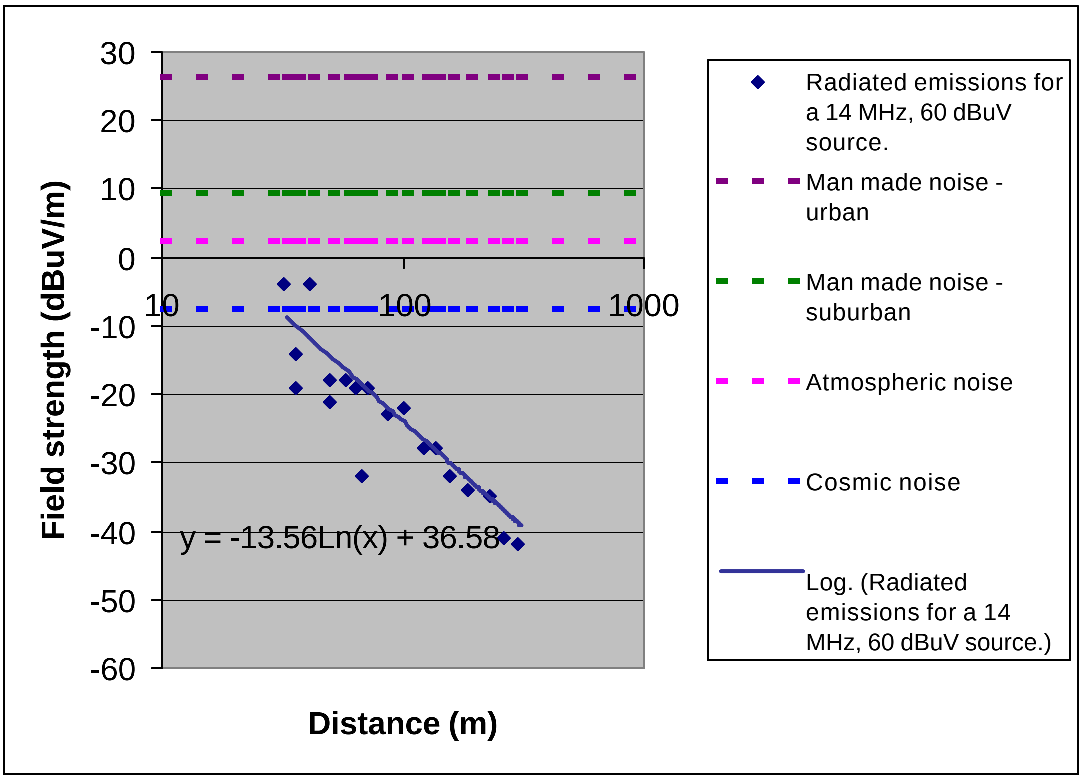
1. Lancaster University.
2. A typical suburban house located in Garstang, Lancashire.
3. A rural house located in Kendal, Cumbria.

4.4 Radiated emissions measurement results

Spot frequency measurements were made at various measurement distances for an injected signal level of 10 dBm. These measurements were performed by a class A amateur radio licence holder.

The following graphs illustrate the field strength that would have been measured for an injected signal level of 60 dBuV (which corresponds to the CISPR 22 quasi-peak class B limit between 5 MHz and 30 MHz):

4.4.1 Spot frequency measurements at 14 MHz



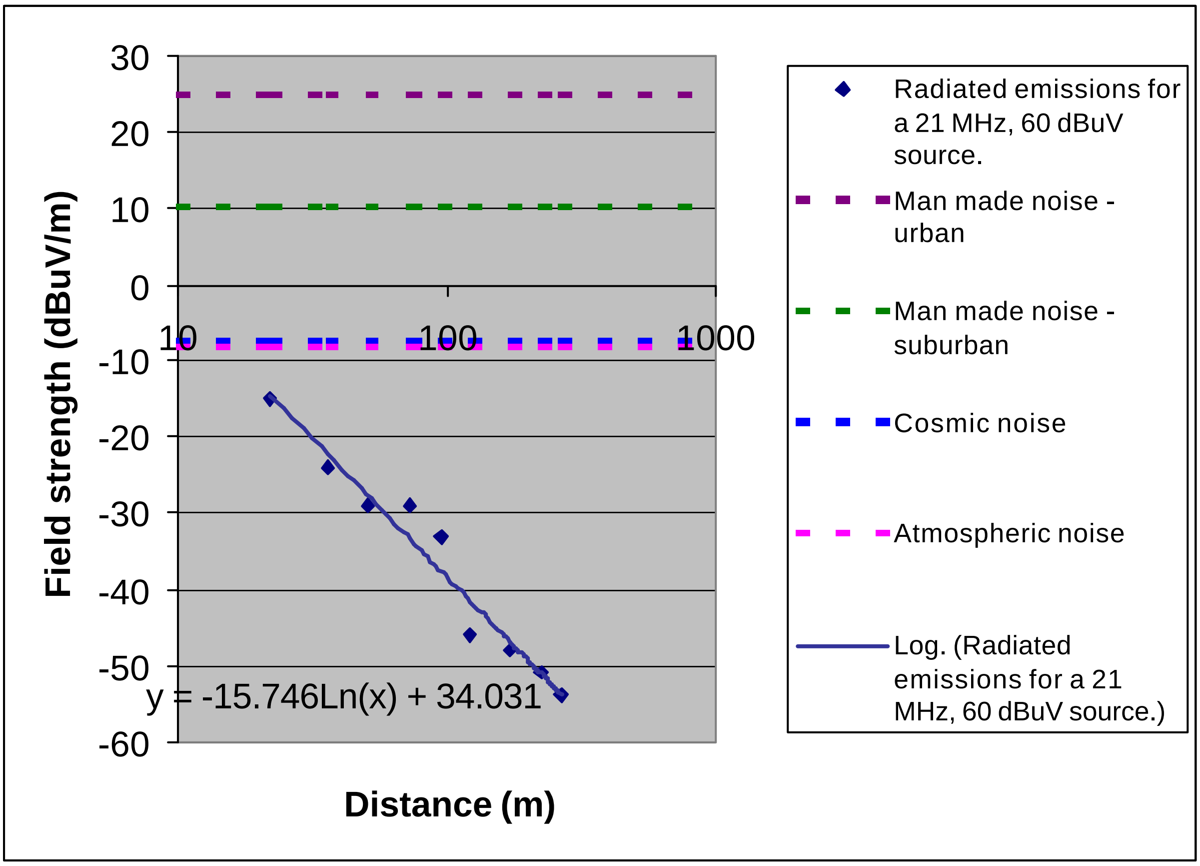
The relationship between distance and field strength can be expressed as follows:

$$E[dBuV/m] = 36.6 - 13.6 * Ln(d[m])$$

$$E[dBuV/m] = 36.6 - 13.6 * \frac{Log(d[m])}{\log(e)}$$

$$E[dBuV/m] = 36.6 - 31.2 * Log(d[m])$$

4.4.2 Spot frequency measurements at 21 MHz



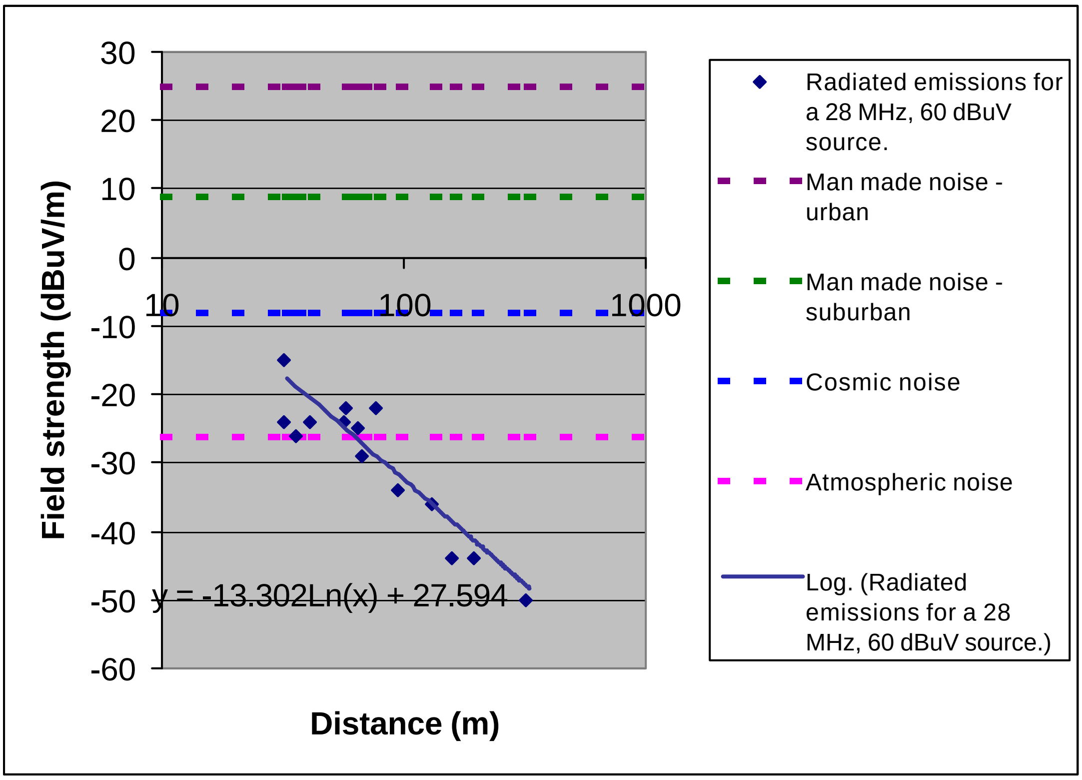
The relationship between distance and field strength can be expressed as follows:

$$E[dBuV/m] = 34.0 - 15.7 * Ln(d[m])$$

$$E[dBuV/m] = 34.0 - 15.7 * \frac{Log(d[m])}{\log(e)}$$

$$E[dBuV/m] = 34.0 - 36.2 * Log(d[m])$$

4.4.3 Spot frequency measurements at 28 MHz



The relationship between distance and field strength can be expressed as follows:

$$E[dBuV/m] = 27.6 - 13.3 * Ln(d[m])$$

$$E[dBuV/m] = 27.6 - 13.3 * \frac{Log(d[m])}{\log(e)}$$

$$E[dBuV/m] = 27.6 - 30.6 * Log(d[m])$$

5. Summary

5.1 Near field

The data presented in this section shows that the field strength produced by typical in-house PLT LAN installations using a differential injected signal voltage of 75 dBuV can be expected to be below the following values:

Measurement distance [m]	Field strength [dBuV/m]
3	40
10	30
30	20

Note:
It was not possible to obtain as much measurement data at a measurement distance of 30 meters as it was at measurement distances of 3 and 10 meters. This was due to:

1. The topology of the test environment, which determines which of the desired measurement locations are accessible.
2. The high ambient signal levels in the HF band, which tend to obscure PLT emissions.

5.2 Far field

The data presented in this section shows that the field strength produced by an in-house PLT LAN installation can be expected to reduce by between 31 to 36 dB for every decade increase in distance (in the far field). This data was obtained from suburban and rural measurement locations. The extrapolation factor in urban areas is likely to be somewhat higher and may approach the figure of 40 dB/decade, which is used by the FCC (part 15.31(2)).

Based on a reduction in field strength of 31 to 36 dB/decade, it would appear that ground wave cumulative interference is unlikely to be a problem. Any interference experienced by a victim receiver will most probably be attributable to a local source of interference rather than due to the cumulative effect of a number of installations.

