COMPATIBILITY BETWEEN RADIO COMMUNICATIONS SERVICES AND POWER LINE COMMUNICATION SYSTEMS

A position paper prepared by the RSGB EMC Committee for the PLC Workshop in Brussels, 5-Mar-2001

1. INTRODUCTION

The Radio Society of Great Britain (RSGB) represents the interests of some 60,000 licensed radio amateurs in the UK and also a large number of short wave listeners. The RSGB is a member of the International Amateur Radio Union (IARU) which represents the interests of radio amateurs internationally. This paper has been prepared in response to proposals for power line telecommunications (PLT) systems particularly in the range 1.6 - 30MHz.

2. BACKGROUND

The principle of using radio frequency communication via electrical power distribution wiring is not new but previously, the frequencies used have been below those used for broadcasting, i.e. below 150 kHz in Europe where there is a Long Wave broadcast band and below 450 kHz in other regions where there is no Long Wave broadcasting. If such frequencies are used for data communications, the maximum data rate that can be achieved is limited due the limited bandwidth available. This has led to pressure to introduce PLT systems that operate above 150 kHz, particularly in the range 1.6 - 30 MHz.

The proposed use of frequencies above 150 kHz for PLT challenges the fundamental purpose of EMC standards, namely to protect radio services from interference from non-radio sources. Such sources include unintentional signals generated by equipment such as switch-mode power supplies and also intentional signals generated by wire line communication systems.

3. POWER LINE TELECOMMUNICATION (PLT) SYSTEMS

In principle, PLT is no different to television, sound and/or interactive multimedia signals distributed via a cable network and for which radiated emissions are controlled by existing standards.

The current commercial proposals for PLT require considerable transmission bandwidth. ***Unless the mains cables are suitably screened, terminated and filtered, signals cannot be confined to power distribution cables alone and will be radiated by all connected wiring.*** Unless existing limits such as those for cable TV networks are applied, such emissions have the capacity to interfere with other radio services nearby. There is also a possible cumulative effect of many such emissions over considerable distances.

The HF (short wave) radio spectrum is a valuable commodity, supporting vital ‘Safety of Life’, local and world-wide broadcast and commercial communication services as well as the amateur radio service. If PLT is permitted to operate without adequate protection of radio services, much of the HF spectrum would become unusable.

There are a number of important new developments that will ensure continued use of the HF spectrum. These involve the replacement of conventional forms of modulation by new digital techniques that are optimised for the propagation characteristics of an HF radio path. These include a new digital broadcasting standard, Digital Radio Mondiale (DRM) that has been developed for high quality international HF broadcasting as well as national MF broadcasting. Other services such as military communications are using digital modulation techniques to provide reliable and secure long distance communications. A common factor to all such digital communication systems is that although they are resistant to interference from narrow band interfering carriers, they are susceptible to interference from broad-band noise-like interfering sources such as PLT.

In the case of 'in house' PLT systems that provide communication between equipment within the home, RF is injected into house wiring and it is not feasible to prevent it from radiating. In the case of 'access' systems which provide communication between homes and equipment outside the home, RF will also be radiated by house wiring and street lamps unless suitable RF filters are fitted at numerous locations. The widespread use of such filters is unlikely to be practical or cost-effective.

4 RADIO INTERFERENCE POTENTIAL

It is the RSGB's contention that PLT on HF frequencies is a cabled distribution system that should be covered by the requirements prEN 50083-8. Even if low signalling powers are employed it is believed that HF PLT will be incapable of meeting the emission or immunity requirements necessary to avoid interference to and from other services. There is a high probability that wide band emissions from PLT systems in the HF spectrum from connected domestic wiring would exceed levels allowing radio and telecommunications apparatus to operate as intended, contrary to UK Statutory Instrument 1992 - No.2372, Part 1, Section 5, Clause 4.

4.1 Emissions

PLT using HF is a cable distributed system but mains power distribution cables were designed for 50Hz power distribution and not as HF transmission lines. Without substantial screening, shielding and filtering to prevent emissions, particularly from domestic wiring, substantial levels of pollution will occur to the short wave radio spectrum against which no mitigating measures can be applied. If HF PLT becomes operational, large portions of the HF radio spectrum will become unusable, an unacceptable position. *An important part of the role of each country's PTT is to protect radio frequencies from pollution from 'non radio' sources including emissions from cable communication systems.*

Because of the two different HF propagation modes (ground wave and sky wave), there is a possibility of interference being caused to radio services at distances of tens or hundreds of kilometres due to the cumulative effect of a large number of PLT systems. Little protection is likely to be achieved by leaving 'exclusion zones' around commercial or other 'sensitive receiving areas' as these may still suffer unwanted interference, perhaps even more so than the amateur service, by virtue of the high gain and/or directional receiving antennas that may be in use. The cumulative effect of emissions from a large number of PLT sources could also cause interference to airborne users of HF when flying over built-up areas.

Mobile HF users such as the military may find reception totally blanketed by high level emissions from nearby buildings. It is impossible to predict the location of a mobile HF station and of course only simple transmitting and receiving antennas are feasible.

Data transmitted using a PLT system would need to be encrypted if interception by other users on the same power network is to be avoided. The system may also suffer interruption or degradation of service by the operation of local transmitting stations. As PLT 'access' systems use a shared communication medium, they would also be susceptible to a deliberate 'denial of service' attack by other users.

As shown in 4.2 below, the level of the composite PLT transmitted waveform could be of the order of several volts RMS. This is high enough to cause non linear mains loads to generate spurious signals such as harmonics and intermodulation products in the HF band or at VHF and above. Such a phenomenon is known and has been observed near Medium Frequency (MF) broadcast transmitters where HF intermodulation products are generated in the mains distribution network.

4.2 Immunity

The immunity levels of the PLT equipment are likely to be compromised by legitimate transmissions such as amateur radio which may have power levels up to 26 dBW on adjacent frequencies. It will be difficult if not impossible to implement mitigating measures in such cases. International Standard IEC 1000-2-5 : Electromagnetic Compatibility (EMC) - Part 2 Environment - Section 5 : Classification of Electromagnetic Environments, quotes RF field strengths of up to 10V/m in an urban environment where there are no amateur radio transmitting stations within 20m. Amateur transmissions in the HF band will be picked up by the radio amateurs' own and neighbouring house wiring and RF power may be fed back into the mains distribution network.

A precedent has already been set in the UK. In the 1980s, Rediffusion Ltd distributed television and sound by means of a cabled distribution system on a 5.5 MHz HF carrier system. Although tightly controlled and with carefully balanced transmission lines and terminal equipment input circuits, system emissions were such that it was quite feasible to receive useable television signals without actually being connected to the system. The system suffered from poor immunity to local amateur and some broadcast and commercial transmissions, many of which were using quite moderate power. Systems had to be re-routed or cable apparatus replaced by conventional equipment when local interference problems could not be resolved. This option is not open to PLT systems, it is not feasible to disconnect a consumer from the power line. There is every possibility that a transmitting station could be installed in an area served by PLT. It is difficult to see how the resulting interference and system immunity problems could be solved.

As stated in 6.2 below, the radio frequency power spectral density required for a practical PLT system is of the order of -40 dBm/Hz. This is equivalent to -0.5 dBm in 9 kHz, which is approximately 50 dB higher than the conducted emission limit permitted by EMC standards such as EN 55022 (B). If a PLT signal occupies a broad bandwidth, such as 1 MHz for example, the total power could be +20 dBm. In 50 Ω this is equivalent to 127 dB(μV) or 2.23 volts rms. This exceeds the conducted ***immunity*** test level for domestic appliances and is within 3 dB of the generic conducted immunity limit, EN 50082-1.

5. LEGISLATION

Member states of the EC are bound by the EC EMC Directive 89/336/EEC, which requires them to implement measures relating to apparatus which is liable to cause electromagnetic disturbance and to apparatus the performance of which is liable to be affected by such disturbance. In the UK, this Directive is implemented by -

Statutory Instrument - 1992 No. 2372, ELECTROMAGNETIC COMPATIBILITY
The Electromagnetic Compatibility Regulations.

Part 1, Section 5 (Protection Requirements), Clause 4 of the Statutory Instrument states -

> *(4) Without prejudice to the generality of paragraph (2)(a), the electromagnetic disturbance generated by relevant apparatus shall -*
>
> *(a) not exceed a level allowing radio and telecommunications apparatus to operate as intended; and*
>
> *(b) be such as not to hinder the use of apparatus of any of the descriptions listed in Schedule 3 hereto (being descriptions listed in the illustrative list of the principal protection requirements in Annex III of the EMC Directive) where that apparatus has an adequate level of immunity in its usual electromagnetic environment so as to allow its unhindered operation taking into account the levels of electromagnetic disturbance generated by relevant apparatus complying with applicable EMC standards.*

The above regulations impose general requirements that ***all*** systems must meet in addition to complying with any applicable standards. It is our considered opinion that proposals for cabled PLT in the HF spectrum are in direct contravention of the European EMC Directive 89/336/EEC and UK Statutory Instrument 1992 No. 2372.

A PLT system is such that emissions cannot be confined to the mains cable network and will be radiated to the HF spectrum in the frequency bands used by the system. Such emissions are not a requirement of the system operation but a function of the practical inability to engineer PLT systems to the standards necessary to prevent unwanted emissions. Spurious signals are also likely to be generated on other radio frequencies by imperfections in equipment connected to the same distribution network.

6. APPLICABLE STANDARDS

6.1 Existing standards

It should be noted that compliance with a Standard does not of itself confer immunity from legal obligations.

> BS EN 50065-1 + AMD.3. 1996 CENELEC. GENERAL REQUIREMENTS. SIGNALLING ON LOW VOLTAGE INSTALLATIONS 3KHZ - 148.5KHZ - ELECTROMAGNETIC INTERFERENCE.

> EN 50083-8 : 2000 CENELEC. CABLED DISTRIBUTION SYSTEMS FOR TELEVISION, SOUND AND INTERACTIVE MULTIMEDIA SIGNALS - PART 8: ELECTROMAGNETIC COMPATIBILITY FOR INSTALLATIONS.

EN 50083-8 is a new European Standard that covers the frequency range 0.3 MHz - 3.0 GHz and cross references to numerous 'Normative references' (other related CENELEC or IEC standards) quoting them where appropriate throughout the text. It further recognises in Section 1, Scope, the risk of interference to other radio services from cabled distribution systems -

> *"To minimise the risk of interference to other radio services caused by possible radiation from a cabled distribution system and to limit the possible penetration of external signals which may interfere with the operation of a system, it is necessary not only to use equipment which satisfies the requirement regarding limits of radiation and of immunity to external fields but also to ensure the integrity of all cable connections on each item of active or passive cabled distribution system equipment."*

The standard further lays down the maximum allowed radiation levels together with methods of measurement. Annex A (informative) additionally makes specific reference to the Radiocommunications Agency standard MPT 1520 which remains valid instead of the European Standard until removed. Existing emission standards for cable TV networks are based on single carrier modulation techniques such as VSB. Consequently, emissions may approach the limit only at a relatively small number of vision carrier frequencies. ***The same limit is not appropriate for multi-carrier modulation where a large number of sub-carriers could all approach the limit.***

> MPT 1520 - RADIOCOMMUNICATIONS AGENCY: RADIATION LIMITS AND MEASUREMENT STANDARD; ELECTROMAGNETIC RADIATION FROM CABLED DISTRIBUTION SYSTEMS OPERATING IN THE FREQUENCY RANGE 300 KHZ - 30 MHZ; JULY 1984 (REVISED 1989).

MPT 1520 is similar in scope to prEN 50083-8 and specifies radiation limits from cabled distribution systems in the frequency range 300 kHz - 30 MHz. The maximum interfering field strength permitted at 10 metres distance from a complete system in the 2190.5kHz to 30 MHz range is 20 dB(μV/m).

> IEC 61000-2-5 : ELECTROMAGNETIC COMPATIBILITY (EMC) - PART 2 : ENVIRONMENT - SECTION 5: CLASSIFICATION OF ELECTROMAGNETIC ENVIRONMENTS.

Table 5.2.1 lists 'Sources and range of disturbance degrees for radiated oscillatory disturbances'. For amateur frequencies this may reach 10V/m in a residential , urban environment (Table A.2).

> IEC 61000-3-8 - (1997-08) ELECTROMAGNETIC COMPATIBILITY (EMC) - PART 3: LIMITS - SECTION 8: SIGNALLING ON LOW-VOLTAGE ELECTRICAL INSTALLATIONS - EMISSION LEVELS, FREQUENCY BANDS AND ELECTROMAGNETIC DISTURBANCE LEVELS.

IEC 61000-3-8 (1997) applies to mains signalling in the 3kHz to 525kHz range and specifies disturbance limits in the frequency range 3kHz up to 400GHz.

EN 50065-1 applies to mains signalling at frequencies up to 148.5 kHz.

FEDERAL COMMUNICATIONS COMMISSION, CODE OF FEDERAL REGULATIONS, TITLE 47, TELECOMMUNICATIONS, PART 15, RADIO FREQUENCY DEVICES

Although not applicable in Europe, US FCC 47CFR Part 15.3 defines a 'Current-Carrier system' as:

> *"A system, or part of a system, that transmits radio frequency energy by conduction over the electric power lines. A carrier current system can be designed such that the signals are received by conduction directly from connection to the electric power lines (unintentional radiator) or the signals are received over-the-air due to radiation of the radio frequency signals from the electric power lines (intentional radiator)."*

Part 15.3 defines an 'Unintentional Radiator' as:

> *"A device that intentionally generates radio frequency energy for use within the device, or that sends radio frequency signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction."*

.***The FCC rules that allow 'current carrier devices' were intended only for narrow band systems and originally date from the early 1950s***.

Part 15, Section 15.209 (1st October 1999 edition) defines a radiated field strength limit of 30 µV/m at 30 m. This is equivalent to 29.5 dB(µV/m) at 30 m or 39.5 dB(µV/m) at 10 m.

The FCC rules state the operators of Part 15 devices must ensure that they do not cause harmful interference to radio services. The operator of a radio frequency device is required to cease operating the device upon notification by an FCC representative that the device is causing harmful interference. Operation is not allowed to resume until the condition causing the harmful interference has been corrected. This contrasts with the situation that would exist in Europe if a harmonised European standard were introduced for PLT.

6.2 Standards Under Development

A draft CENELEC document on PLT, prES 59013 was circulated for comment in December 2000 but was withdrawn and a revised January 2001 version was circulated. This also included extracts from the ETSI SRD as informative Annexes which would not be included in the published document.

ETSI is developing a System Reference Document (SRD) for PLT. The draft includes specifications for radiated emission limits that are claimed to protect radio services against interference from PLT. These limits are 50 dB(µV/m) in the range 1.6 - 30 MHz, measured at 10 m. There is an option to implement 'notches' which reduce the Power Spectral Density (PSD) by 20 dB in specified amateur radio bands The radiated emission limit would therefore be 30 dB(µV/m) in all amateur bands, except for part of the UK '160 metre' amateur band. Only the 1.81 - 1.85 MHz section is listed as a range to be 'notched', whereas the UK band allocation is 1.81 - 2.0 MHz.

A similar proposal is contained in CENELEC SC205A (Sec)75, 'Proposal for a CENELEC ES: Power Line Communication on Low Voltage Installations in the frequency range 1.6MHz - 30MHz - Radiation and Power Spectral Density Levels'. In the CENELEC proposal, the depth of the 'notches' for the amateur bands follow a sloping characteristic that is claimed to follow NB30 limits for protection of radio services. The document does not give any details of NB30 which is the German RegTP Nutzungbestimmung (Usage Provision) NB 30. The NB30 limits are numerically equal to the RegTP 322MV05 limits [1]. ***The 322MV05 limits are measured at 3m distance whereas in the SC205A (Sec)75 proposal, the measurement distance for outdoor devices is 10 m.*** Hence the SC205A (Sec)75 proposed limit is effectively 10 dB higher than the 322MV05 limit.

Section 6 of CENELEC SC205A (Sec)75 quotes coupling factors of about 50 (dB(µV/m)-dBm) for PLC outdoor devices and about 60 (dB(µV/m)-dBm) for PLC indoor devices in the middle of rooms, where the measurement distance would be less than 3m. These results are said to be derived from measurements by the PLCforum but no further details are given. There is a large discrepancy between these PLCforum results and

the results of a comprehensive study performed by the Technical University of Dresden [2]. In section 8.1.8 of the TU Dresden report, the field strength resulting from injecting 105 dB(μV) was found to be 77 (dB(μV/m) from 500 kHz - 5MHz at a distance of 3 - 5 m. This corresponds to a coupling factor of 79 (dB(μV/m)-dBm) compared to a figure of 60 (dB(μV/m)-dBm) quoted in CENELEC SC205A (Sec)75 for indoor measurements.

Fig 3 of CENELEC SC205A (Sec)75 shows a coupling network for measurement of PSD but there is no indication of the loss in the coupling network nor whether any correction is made for this loss.

Section 1 of CENELEC SC205A (Sec)75 states that operation of a PLC system would be subject to conditions that no harmful interference is caused to any radio service. Nevertheless, there is no definition of 'harmful interference'. The RSGB EMC Committee considers that a radiated emission level of 30 dB(μV/m) for broad band signals in amateur bands is absolutely unacceptable and that such a level would cause 'harmful interference'. The level required to avoid such interference is very much lower and may not be achievable by a practical PLT system.

Fig 1 shows the proposed radiated limits from the draft ETSI PLT SRD and CENELEC SC205A (Sec)75 in relation to background noise levels at frequencies up to 30 MHz.

Tests by the RSGB EMC Committee have shown that the background noise levels in the HF band is lower than is generally realised. In particular, it is understood that the levels in ITU-R report PI 372/6 are based on measurements made in the USA and are higher than the man-made noise levels in the UK and elsewhere in Europe. A possible reason for the difference is that LV electricity distribution in the US uses predominantly overhead wiring whereas UK LV distribution wiring is predominantly underground. Some RSGB EMC Committee background noise level measurements are shown in Fig. 1. It is therefore considered that intentional broad band emissions from PLT in amateur bands should not exceed 0 dB(μV/m) in 9 kHz bandwidth at a distance of 10 m.

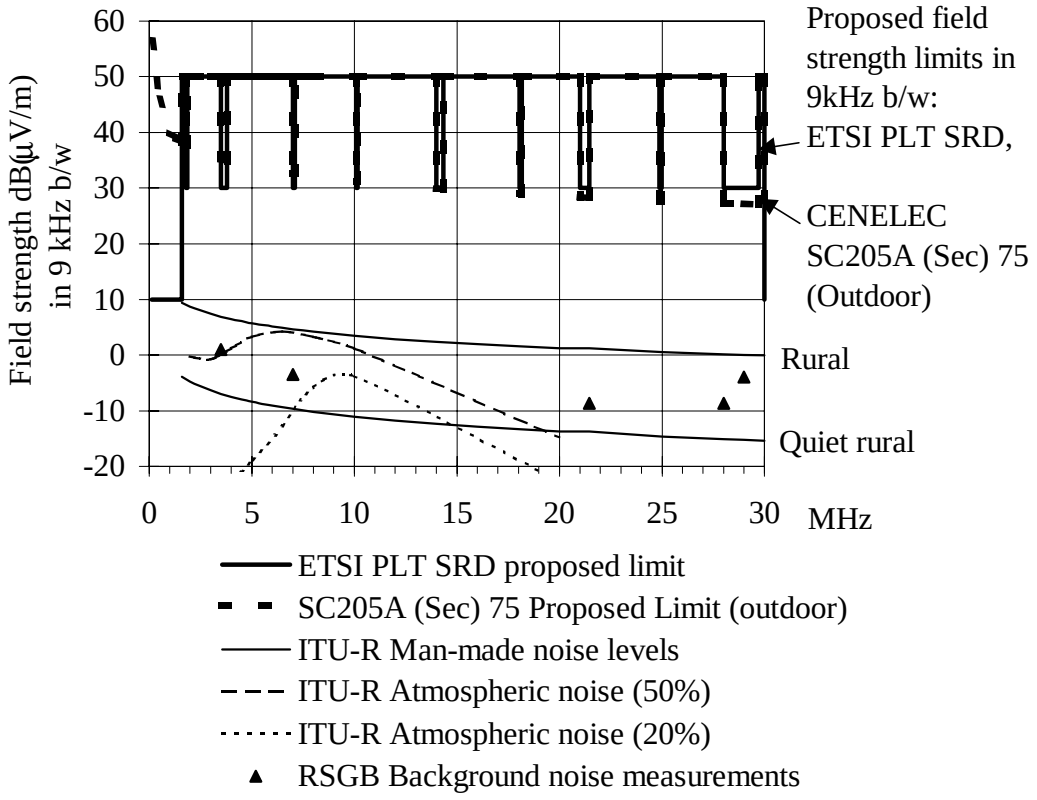

Fig 1. The proposed radiated limits from the draft ETSI PLT SRD and CENELEC SC205A (Sec)75 in relation to background noise levels at frequencies up to 30 MHz.

The draft ETSI PLT SRD also specifies a maximum PSD that PLT systems may transmit into the mains power network. This limit is -40 dBm/Hz outside the 'notches', which is equivalent to -0.5 dBm in 9 kHz bandwidth or 106.5 dB(μV) in 50 Ω. Fig 2 shows the proposed conducted emission levels in relation to the EN 55022 Class 'B' conducted emission limits.

Another ETSI document, TS 101867 includes information on the average 'noise floor' that may be expected on mains power distribution networks. This 'noise floor' has been converted to dB(μV) in 50 Ω in 9 kHz bandwidth and is also shown on Fig 2. The fact that this 'noise floor' falls by 20 dB from 1.6 - 30 MHz indicates that ***in practice, the conducted noise level on typical mains power distribution networks is far below the EN 55022 'B' limit over much of the HF band.***

This result is consistent with measurements of radiated emissions generated by typical electronic equipment such as switch-mode power supplies. Such emissions may be within a few dB of the EN 55022 'B' limit at frequencies below 1 - 2 MHz but are normally far below the EN 55022 Class 'B' limit in the higher parts of the HF band.

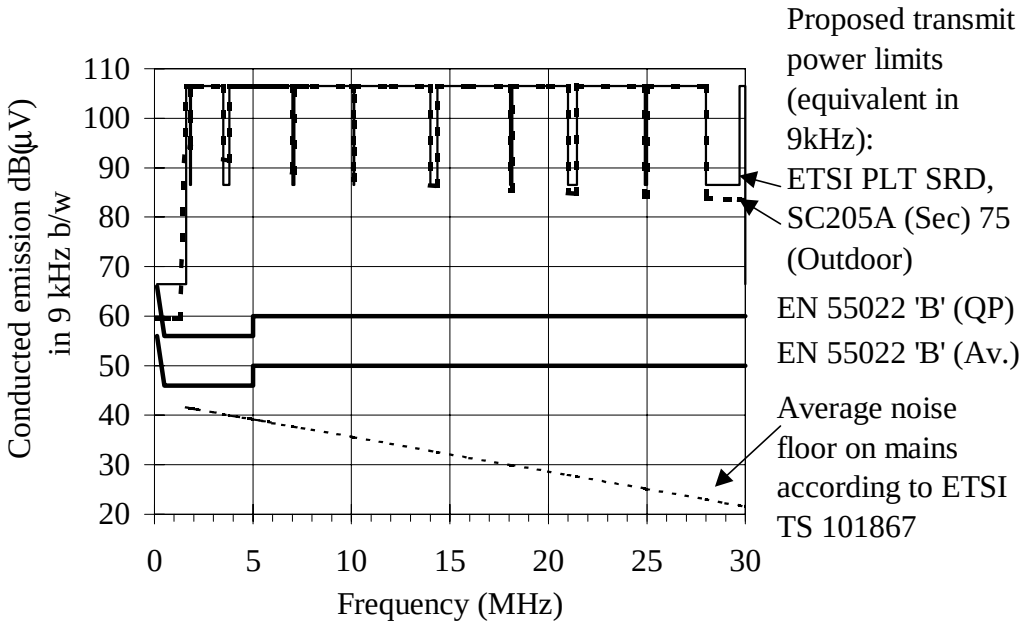

Fig 2. The proposed PLT transmit power limit from the ETSI PLT SRD and CENELEC SC205A (Sec) 75 in relation to EN 55022 Class 'B' conducted emission limits and background noise levels on mains power networks at frequencies up to 30 MHz.

The RSGB EMC Committee considers that intentional emissions such as PLT should be limited to a ***lower*** limit than the EN 55022 'B' limit for the following reasons:

- Limits such as the EN 55022 'B' limit are intended to protect radio services from interference due to unintentional emissions from randomly distributed items of equipment that are used intermittently. In practice, emissions from such equipment normally decrease with frequency and even if they are close to the limit at 0.5 MHz, they are normally ***well below*** the EN 55022 Class 'B' limit at 3 - 5 MHz and above.

- In PLT systems, the emission is intentional and is likely to be close to applicable limit. The emission may be produced continuously and there may be a high density of PLT systems in a given area.

- If PLT is subjected to a higher limit than EN 55022 Class 'B', there would then be pressure to relax the EN 55022 Class 'B' limits. If this were accepted, the existing noise floor level on mains wiring would be raised, preventing PLT from operating as intended and protection of the radio spectrum below 30 MHz would effectively be abandoned.

PLT is a cabled distribution system and should therefore be subject to limits that are no higher than those for other cable distribution systems such as cable television networks. Even the cable TV emission limits are

considered too high because they were not intended for broad band multi-carrier modulation techniques. It is therefore considered that intentional broad band emissions from PLT in amateur bands should not exceed 0 dB(μV/m) in 9 kHz bandwidth at a distance of 10 m.

7 SUMMARY

- Proposed PLT radiated emission levels are in direct contravention of the EC EMC Directive 89/336/EEC and UK Statutory Instrument 1992 No. 2372, The Electromagnetic Compatibility Regulations.
- PLT Emissions in the radio spectrum cannot be confined to the mains power distribution cables.
- Interference signals can be radiated over considerable distances, with the potential to affect vital 'Safety of Life' and other essential radio communications.
- The proposed system may suffer interruption or degradation due to insufficient immunity form interference from permitted radio transmitters.

8 RECOMMENDATION

The Radio Society of Great Britain raises a very robust objection to the current commercial proposals for PLT in the High Frequency spectrum. The Society will take all measures open to it to oppose the introduction of mains HF signalling. The RSGB considers that serious degradation of an important part of the HF spectrum is of far greater international importance than the short term commercial benefit of PLT.

The Radio Society of Great Britain recommends that all proposals for standards that would allow PLT to operate in the High Frequency spectrum be firmly rejected unless the signal levels are within the existing standards for mains conducted emissions or unless a specific frequency allocation is made for PLT that is compatible with radio services in the HF band.

9 REFERENCES

[1] RegTP (Regulierungsbehörde für Telekommunication und Post) Measurement Specification RegTP 322MV05. 'Radio Monitoring and Inspection Service Measurement Specification for Disturbance Field Measurements on Telecommunications Equipment and Lines in the Frequency Range from 9 kHz - 3 GHz'

[2] 'Abschlussbericht zur Power-Line Studie'. This is the final report dated 27-Jan-2000 on a comprehensive study of the EMC characteristics of low voltage mains distribution networks by the Technical University of Dresden (in German). It includes balance and coupling factors.
http://www.regtp.de/tech_reg_tele/start/in_06-03-02-03-00_m/index.html

The RSGB EMC Committee. 21 February 2001.