Chapter 9 – CONCLUSIONS AND RECOMMENDATIONS

Over its mandated three-year work programme, the RTG accomplished the specified tasks with diligence, dedication, professionalism and competence. In many areas, it investigated and produced a product that exceeded specific requirements.

Naturally, a work of this complexity cannot be reduced to a few simple point-form highlights. The entire Report ought to be consulted for full benefit.

In the following paragraphs, a few salient findings are presented.

9.1 CONCLUSIONS

a) The cumulative noise field strength due to the PLT emissions may have a possible detrimental effect upon military HF radio communications and COMINT systems. This is particularly the case if In-House PLT systems should become widely popular. However, it should be noted here that the determination of the nature and the severity of any possible detrimental effect upon the military systems was outside the RTG's expertise and ToR.

b) The HF noise level in the vicinity of PLT installations has been considered in numerous other studies. One study concludes that interference from PLT to a station receiving low-level signals is likely at distances up to 460 m from a single Access PLT installation using overhead power lines. On the other hand, in sensitive receiver sites, the user generally can be assumed to have control over the vicinities, such that a protection radius of up to 1 km, without PLT installations, can be employed. In this case, the cumulative effect of long-distance propagation from a large number of PLT installations may be a more serious problem that requires careful consideration. Therefore, the RTG chose to focus on this less-studied problem.

c) PLT rather than xDSL will cause the most problems regarding HF interference because:

- PLT devices and the power lines that carry PLT signals have the potential to act as unintentional radiators. The amount of radiation depends on the symmetry of the network at radio frequencies. Symmetry is related to the difference in impedances between conductors and ground, where perfect symmetry corresponds to equal impedances. PLT lines have poorer symmetry than xDSL lines, and will also exhibit impedance discontinuities. Any impedance discontinuity in a transmission line, which may arise from a PLT coupling device, a transformer, a branch or a change in the direction of the line, may produce radiation directly or by reflections of signals forming standing waves that are radiated from the conductors. Even if the RF energy is injected into one of two or more conductors, the remaining wires generally act as parasitic radiators and, therefore, the lines can act as an array of antenna elements at certain frequencies. Radiation may come from one or more point radiators corresponding to the coupling devices, as well as one or more power lines.
- A great number of PLT In-House systems (e.g., HomePlug) are expected to be deployed. Such products are readily available on the market and can be installed by anyone, with no verification of the quality of the installation.
- VDSL variants covering the whole HF range are still in the definition phase. Eventual implementation of these systems has not been in sufficient numbers to raise potential interference issues, in the time frame of this RTG. The other versions of xDSL have no documented HF interference-causing problems, therefore the RTG chose to focus on PLT as a noise source.

d) ITU-R P.372-8 noise curves (based on measurements carried out in the 1970s) are still valid in Europe. Recent measurements carried out in Germany and Great Britain indicated that there is no remarkable difference between these measurements, specifically no increase of the ambient noise in quiet rural zones within the last 30 years.

e) Based on these measurement results, the cumulative interference field strengths far away from telecommunication networks should not be higher than **–15 dBµV/m** (9 kHz bandwidth) across the entire HF-range, if no measurable increase in minimum noise levels is to be tolerated. The RTG refers to this criterion as the **Absolute Protection Requirement**. It should be noted that this value is in the range of 10 to 1 dB below the ITU-R P.372-8 Quiet Rural noise curve, which are median values, across the HF band.

f) A survey of available information indicated that OFDM is the modulation of choice for PLT and xDSL systems.

g) Similarly, from the same sources, the maximum injected PSD is given as –50 dBm/Hz for PLT.

h) On the subject of emission limits, FCC in the U.S.A. updated CFR 47 Part 15 Rules to address Access BPL systems. In Europe, the work is still on-going, and in the interim, for cases involving complaints, NB30 is to be used.

i) The quantity of interest when considering cumulative effects in the far-field is the EIRP (equivalent (or effective) isotropic radiated power) per unit bandwidth caused by each signal source, in units of dBm/Hz, at different frequencies. The radiation pattern might also be of interest in some cases, but when summing up many different sources with different wiring geometries over a wide area, it is reasonable to approximate the average radiation pattern as isotropic (in elevation as well as in azimuth).

j) Cumulative PLT noise simulations were carried out at several hypothetical sensitive receiver locations, using the Cumulative PLT Tool developed by the RTG. For each receiver location and frequency, the percentage of parameter combinations was computed where the estimated PLT noise level is above the quiet rural level, above quiet rural +6 dB, and above the rural noise level (all these noise curves represent median values, and the cumulative PLT noise levels are estimated from median propagation loss per parameter combination). The results indicated the following:

   - High probability of PLT to cause increased noise levels at sensitive receiver sites given the projected market penetration.
   - It should be kept in mind that the percentages are highly influenced by assumptions on transmitter EIRP, PLT market penetration and duty cycle.

   The percentage of parameter combinations was also computed where the estimated PLT noise level is above the Absolute Protection Requirement. Again, the probability of the cumulative effect of PLT exceeding the Absolute Protection Requirement is predicted to be relatively large for all frequencies and receiver locations simulated.

9.2 RECOMMENDATIONS

a) Absolute Protection Requirement outlined in Section 2.4: Should NATO decide that no increase in minimum noise levels are to be tolerated, then the application of this criterion is recommended by the RTG (Note that ITU-R P.372-8 noise curves are for median values, while this requirement reflects minimum values).

b) From the RTG's perspective, it is highly desirable that the regulatory limits on PLT emissions be harmonised throughout the NATO countries, for the following reasons:

- Emissions from wire-line communications travel long distances and past international boundaries, therefore, differences in emission limits introduce additional difficulties to the interference assessment and mitigation functions.
- Different emission levels, thus different PLT-induced increases in ambient noise levels, have the potential to affect interoperability within NATO:
  - Directly in the immediate vicinity of the wire-lines; as well as
  - Far away from mass-deployed telecommunication networks by cumulative interference.
- Therefore it is necessary to find worldwide harmonized standards covering EMC aspects of wire-line telecommunication networks including their in-house extensions. These standards should ensure that broadband wire-line telecommunications will not degrade HF radio reception.

The RTG recognizes that NATO, by itself, has no regulatory authority over the emission limits. Therefore, it is recommended that NATO seek the implementation of the above-mentioned goal by working together with the national and international regulatory authorities.

c) Measurement techniques presented in Chapter 5 be considered the most appropriate procedure whenever measurement of PLT emissions is found necessary.

d) For propagation prediction requirements, RTG recommends the use of ICEPAC for sky wave propagation prediction with parameter settings as described in Section 6.2.3, and the use of GRWAVE (augmented by Millington's method when necessary) for ground wave propagation prediction.

e) The antenna gain of a wire-line transmission system is defined as the ratio between EIRP and injected power. Based on a comprehensive review of the available information, the RTG recommends the following values:

- –30 dBi for In-House systems;
- –15 dBi for overhead Access systems; and
- –50 dBi for underground Access systems.

It should be recognized that there are uncertainties in these numbers of the order of ±5 to ±10 dB due to statistical spread. Furthermore, in the case of overhead Access system power lines, at resonant frequencies the antenna gain may be higher by 10 to 13 dB.

f) CMRR/LCL values are generally measured as the ratio between the DM and CM voltages *at the injection point*. This may not be a representative measurement with respect to radiation, since impedance mismatches and standing waves can cause large variations in the CM current along the line.

g) For measurement of radiation caused by impedance discontinuities occurring with In-House systems, the RTG recommends the use of a magnetic loop antenna and the EIRP obtained from the electric field expression (7-2).

h) In modelling the emissions from an overhead Access PLT line, the PLT wires can be modelled as a successive set of dipoles, assuming that the standing waves present are the dominant emission source. As to the dipole type, both half-wavelength and one-wavelength dipoles are suitable; however, the half-wavelength has the wider half-power beamwidth (78 degrees vs. 48 degrees), therefore it is preferable (the wider the beamwidth, the smoother the pattern overlap). The RTG recommends the following:

- Given the PLT geometry, the cylindrical coordinate system is more practical rather than the spherical coordinate system generally used in electromagnetics.

- In the vicinity of a PLT, up to 200 metres, the use of the expression for the exact solution of a dipole, which is valid at any distance in both near-field and far-field.
- Again, in the vicinity of the PLT, the proper determination of the conversion factor with distance requires that the reflected field from the ground be also taken into consideration. The two-ray method using the exact solution expression is the best technique for such an assessment.
- Beyond 200 metres, the single-ray technique using the far-field approximation expression is suitable.

i) In the computation of cumulative effects of PLT transmissions, the RTG recommends that these be computed always using a source defined in terms of EIRP rather than in terms of electric field strength. The EIRP values, if not available, could be obtained from the electric field strength calculated with the appropriate expression (exact or far-field) of the selected PLT dipole model.

j) The distance conversion factor is a composite of the results obtained from two-ray (PLT vicinity) and single-ray (further away) techniques. The RTG recommends the distance conversion factors listed in Table 7.4.3.1-6.

k) A direct comparison of measured and theoretical results for distance conversion factor is not recommended due to the many uncertainties involved in the various measurement techniques, instruments, positional (locational) variables, and so on. Nevertheless, it is observed that both sets of results show a commonality of values, and similar variation with frequency and distance.

l) In the assessment/prediction of PLT cumulative noise level by sky wave at a particular receiver site of interest (sensitive or otherwise), the RTG strongly recommends the use of the Cumulative PLT Tool (CPT) developed in the course of its work.

m) Recognizing that certain improvements to the CPT would provide more user flexibility and ease of use, the RTG recommends that the proposed CPT improvements listed in the Report be followed through by NATO.

n) RTA is urged to consider forming a further RTG to deal with the VDSL impact on HF spectrum, if this is found necessary.