Chapter 8 – EMC ANALYSIS METHODS

As mentioned in Section 6.1, the Task Group has for various reasons chosen to focus on cumulative effects in the far field.

8.1 CUMULATIVE EFFECTS MODELLING METHODS IN THE FAR FIELD (SKY WAVE)

In this section a comprehensive methodology is proposed to predict the cumulative effect at any particular receiver location. Given accurate knowledge of all relevant input parameters, the methodology would give accurate predictions.

It is well established and easy to explain (see e.g., [55],[84],[3, Annex 7]) that the cumulative effect from a large number of unintentional radiators (e.g., PLT installations), as received at a sensitive receiver site, can be written:

$$p_{Cum}(f,t) = \iint_{x,y} \frac{g_{RX}(x,y,f)}{L(x,y,f,t)} p_{TX}(f) D_A(x,y) \eta_{PEN}(x,y) \eta_{USAGE}(t) dA \qquad (8\text{-}1)$$

- $p_{Cum}(f,t)$ is the total received power spectral density [W/Hz], at frequency *f* and time instant *t*.
- The integral is done over an area with geographical coordinates (*x, y*).
- The integral (summation) is performed incoherently, i.e., on a power basis rather than on an amplitude basis. This corresponds to the emitted signals not being coherent with each other. Coherent sources could cause a higher total power if they add in phase.
- $g_{RX}(x,y,f)$ is the receiver antenna directivity in the direction (azimuth and elevation) of signals originating from a transmitter at point (*x, y*). It is important to use directivity rather than gain, in order to be able to compare easily the result to established background noise levels.
- $L(x,y,f,t)$ is the basic transmission loss from point (*x, y*) to the sensitive receiver site (see Chapter 6). For each frequency it varies with time (as function of solar activity and time of day and year). We propose to use the median transmission loss "LOSS" as predicted by ICEPAC, which gives a prediction of the cumulative PLT noise under *median* propagation conditions for the given input parameters. Note that this proposal contrasts with some previous works on cumulative effect prediction (e.g., [55],[84] and [3, Annex 7]), where a simple reflection model is used to predict ionospheric propagation loss (see also Section 6.2.1).
- Note that ICEPAC can estimate $L(x,y,f,t)/g_{RX}(x,y,f)$ directly, if given the receiver antenna diagram, which in this case should be normalized by the antenna efficiency to give antenna directivity rather than gain. In the absence of knowledge of receiver antenna, an isotropic antenna can be assumed, $g_{RX}(x,y,f)=1$.
- $p_{TX}(f)$ is the average EIRP spectral density [W/Hz] of a single PLT installation (see Chapter 7).
- $D_A(x,y)$ is the population density (persons per unit area). Such demographic data (actual numbers from 2005 and predicted numbers for 2010 and 2015) can be downloaded free of charge from the database "Gridded population of the world" [72]. It is recommended to download "Population Grid" data, which contains the number of people in each grid square, at a grid

resolution of 0.25 degrees. These data implicitly take into account the different areas of grid squares at different latitudes (and that some grid squares have smaller land areas since they contain partly sea), and hence contain $D_A(x,y)dA$ directly.

- $\eta_{PEN}(x,y)$ is the market penetration (PLT installations per capita).
- $\eta_{USAGE}(t)$ is the duty cycle; the average fraction of time each PLT installation is transmitting. This will be different for different times of day and week; for home installations it is likely to be larger when people are not at work. When considering In-House PLT systems, the market penetration would refer to the number of modems installed, while the duty cycle be averaged over the number of modems (and hence will not exceed 50%, considering that there always will be at least one modem listening to a transmitting modem).
- There will undoubtedly be large uncertainties in any kind of estimates of $\eta_{PEN}(x,y)$ and $\eta_{USAGE}(t)$, since this kind of market information is difficult to obtain access to and hard to predict into the future.

To estimate the potential of cumulative effect problems at a sensitive receiver site, the Task Group recommends the following methodology:

1) Download and import population density data $D_A(x,y)dA$.
2) Estimate $\eta_{PEN}(x,y)$ based on available market information.
3) Select a number of representative operating frequencies, times of day and year, sunspot numbers and levels of geomagnetic activity. For each combination of these, do the remaining points.
4) Run ICEPAC (ICEAREA_INV) to obtain median values of $L(x,y,f,t)/g_{RX}(x,y,f)$.
5) Estimate values of $p_{TX}(f)$ and $\eta_{USAGE}(t)$, based on available information.
6) Evaluate the integral numerically.
7) Compare the result with the background noise level (see Chapter 2, or use knowledge of noise levels at specific receiver site).

8.1.1 "Cumulative PLT Tool"

When implementing the methodology described above, one soon runs into the problem that the user interface of ICEAREA INVERSE only allows sweeping over 9 different combinations of input parameters, which makes it cumbersome to perform comprehensive analyses. The number of input parameters is five (month, time of day, sunspot number, geomagnetic Q index and frequency), such that the total number of parameter combinations easily exceeds 1000, even with a modest number of alternatives for each parameter.

To overcome this problem, the Task Group has developed a MATLAB-based tool "Cumulative PLT Tool" which will bypass the ICEAREA INVERSE user interface and rather call the program directly in batch mode for an arbitrarily large number of parameter combinations, by modifying the input files before issuing the DOS command to call the program without user interface. Note that the ICEPAC user interface also does include the option of starting a batch job, but that requires manual pre-configuration of input files.

For each parameter combination, Cumulative PLT Tool will perform items 1, 4, 6 and 7 in the methodology outlined above, and save the resulting cumulative PLT noise level to a text file which can easily be opened in Excel, MATLAB, or any other program for post-processing and display. The text file will also contain

existing ITU-R noise levels and the Absolute Protection Requirement proposed in Section 2.4. The Absolute Protection Requirement of –15 dBμV/m per 9 kHz bandwidth is converted to dBm/Hz using equations (2-4) and (2-3b), which are frequency-dependent.

Also, under certain rare circumstances it turns out that ICEPAC predicts path losses smaller than 30 dB from certain regions to the receiver site. This is clearly unphysical and is likely to be due to some flaw in ICEPAC. Cumulative PLT Tool will discard any ICEPAC runs which predict the path loss to any region to be smaller than 50 dB, and tag the predicted cumulative PLT noise level as NaN (Not a Number) to indicate missing data. In the examples described below, this occurred at 107 out of a total of 7992 ICEPAC runs.

Before running the tool, ICEAREA INVERSE should be run once in order to define receiver location and transmitter location grid, and set up the input files (which the tool will later modify) accordingly. The transmitter location grid must be a Latitude/Longitude grid with 0.25 degrees resolution in both directions (see Section 6.2.3), and the result should be saved in the "`default\`" subdirectory.

Due to time constraints, the tool is equipped with a text-based user interface rather than a graphical user interface (GUI). Also, $p_{TX}(f)$, $\eta_{PEN}(x,y)$ and $\eta_{USAGE}(t)$ are constant input parameters, such that variation in these parameters over frequency, location and time is not implemented.

8.1.2 Cumulative PLT Tool – Instructions on Use

IMPORTANT: Software files for the Cumulative PLT Tool have been made available with this report – they can be found in the folder named "TR-IST-050-Cumulative-Tool-Software-Files".

The user interface of the tool is intended to be reasonably self-explanatory. For an example on how to use the tool, see Section 8.2 below.

To start using the tool, do the following:

1) Run ICEAREA INVERSE once in order to set up the receiver location and transmitter location grid:
   a) Start ICEAREA INVERSE
   b) Push "`Receiver`" to select receiver location
   c) Push "`Plot Center`", → "`Set to receiver`", and select the X-range and Y-range for the transmitter grid. Ensure that the X-range and Y-range covers the same number of degrees.
   d) Push "`Grid`", select Grid Type = "`1 Lat/Lon`", and select the grid size such that each grid cell is 0.25 x 0.25 degrees; e.g., if X-range and Y-range cover 70 x 70 degrees, select a grid size of 281 x 281.
   e) Select "`Run`" →"`Map only`" in order to see the extent of the transmitter grid.
   f) Set up "`Coefficients`" and "`System parameters`", e.g., as suggested in Section 6.2.3 (Coefficients = URSI88, Min. angle = 0.1 deg, multipath power tolerance = 10 dB, maximum tolerable time delay = 15 ms).
   g) Select transmitter and receiver antennas (e.g., default/isotrope).
   h) Ensure that there is only one parameter combination under "`Groups`" (the actual parameter values here are irrelevant).
   i) Select "`Run`" → "`Calculate`" → "`Save/Calculate/Screen`"

j) When prompted for input file name, go to the subfolder named "`default`" and enter a meaningful file name.

k) The program should now perform calculations and produce a plot on the screen.

l) Close the program and all windows it has generated. The files generated by the program will be used by the Cumulative PLT Tool.

2) Start MATLAB, go to the installation folder and enter "`cumulative_plt_tool`" in order to start the tool. Follow the on-screen instructions.

a) The input procedures are intended to be relatively failsafe; in case of unexpected inputs the tool should repeat the question.

b) The options of the text-based user interface are illustrated in Figure 8.2.1-1.

c) When prompted to select population data file, note that, e.g., the file name glp05ag15.bil corresponds to population data from 2005, and glp10ag15.bil to 2010 (the middle digits of the file name denotes year).

d) Be aware that large amounts of processing time and hard disk space may be required if running a large number of parameter combinations.

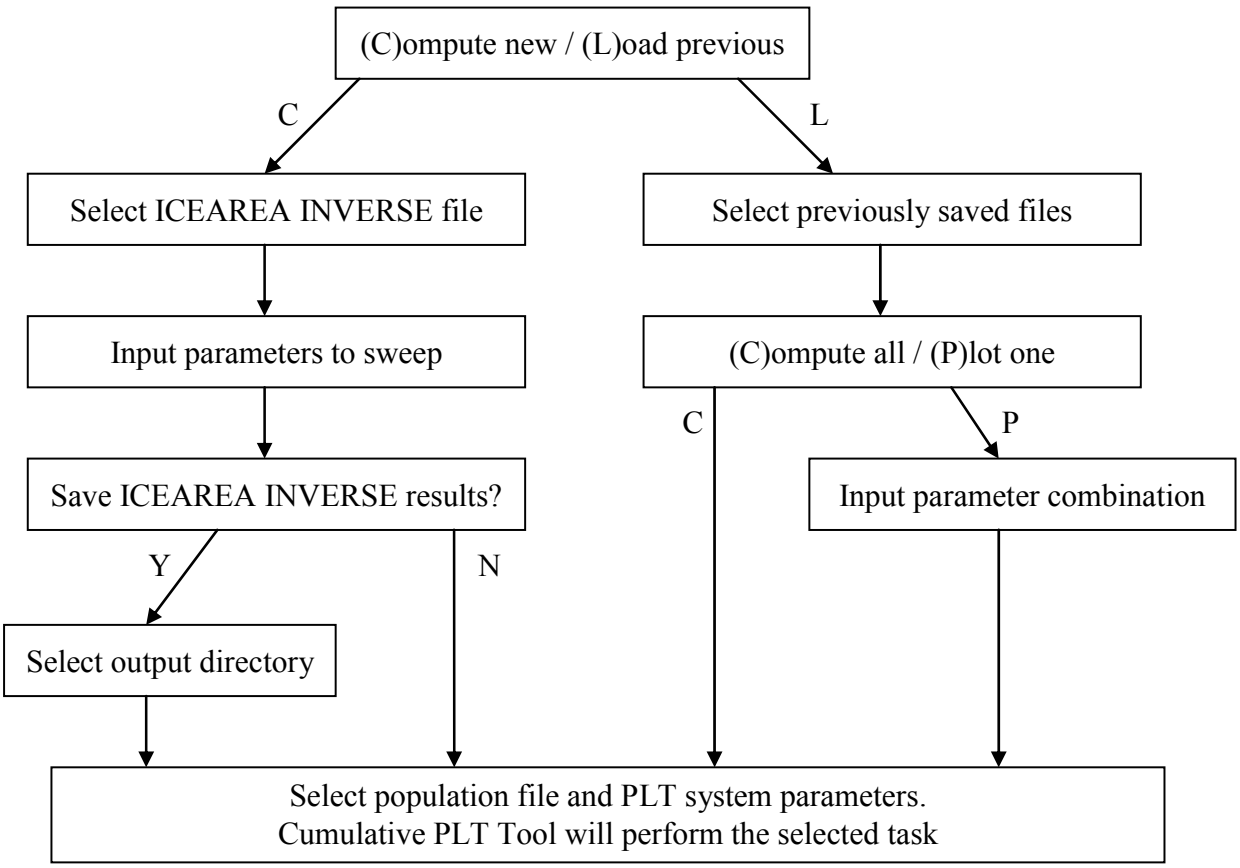

Figure 8.1.2-1: Flow Chart of the Available Options in the User Interface of Cumulative PLT Tool.

The tool has three different modes of operation:

1) "`Compute new`": The tool will go through a number of parameter combinations and do the following for each parameter combination:
   a) Call ICEAREA INVERSE.
   b) Store the result file generated by ICEAREA INVERSE for later use (optional).
   c) Estimate the cumulative PLT noise level and compare with ITU-R noise curves and with the Absolute Protection Requirement of Section 2.4.
   d) Write the resulting numbers to a text file.

2) "`Load previous / Compute all`": The tool will go through files previously generated by ICEAREA INVERSE under mode 1 and do the following for each file:
   a) Load ICEAREA INVERSE result file into memory.
   b) Estimate the cumulative PLT noise level and compare with ITU-R noise curves with the Absolute Protection Requirement of Section 2.4.
   c) Write the resulting numbers to a text file.

3) "`Load previous / Plot one`": The tool will prompt the user to select one of the previously computed parameter combinations and produce the type of figure/map shown in Figures. 8.2.1-2 and 8.2.2-2.

The following files are produced when running the tool:

1) "`xxx_summary.txt`": Text file containing the estimated cumulative PLT noise level compared to background noise curves for each parameter combination.
2) "`xxx_swept_parameters.mat`": MATLAB data file containing information on which parameter combinations were simulated (to be used in the "Load previous" modes).
3) (Optional) "`xxx_00001.ig1`", "`xxx_00002.ig1`", and so on: Results generated by ICEAREA INVERSE. One file per parameter combination.

8.1.3 Improvement Potentials Regarding Cumulative PLT Tool

Due to time constraints, Cumulative PLT Tool is equipped with a text-based user interface rather than a graphical user interface (GUI). Also, $p_{TX}(f)$, $\eta_{PEN}(x,y)$ and $\eta_{USAGE}(t)$ are constant input parameters, such that variation in these parameters over frequency, location and time is not implemented.

In case it should be required to improve the tool to address these shortcomings, a short overview of what would be required is given here:

- Equipping the tool with a GUI:
  In addition to designing the GUI, a substantial rewrite of the program would be required, since the text-based user interface has been implemented as an integrated part of the program.
- Allowing $p_{TX}(f)$ to vary with frequency:
  A procedure should be implemented to import the EIRP at each of the frequencies to be simulated, and store in a MATLAB vector `EIRP` containing one value per frequency. A counter `Freq_index` should be included, and the statement
  `EIRP_per_capita = EIRP(Freq_index) + marketfactor;`
  should be placed in the inner loop of the program.

- Allowing $\eta_{USAGE}(t)$ to vary with time of day (and possibly with time of year):
  Implementation of this would follow the lines of implementing frequency variation as described above, but be slightly more complicated.
- Allowing $\eta_{PEN}(x, y)$ to vary with geographical location:
  In this regard, the most cumbersome challenge would be how to specify the variation in market penetration as function of location, e.g., based on maps combined with information on different penetration in different countries or regions. Once the market penetration is stored in a MATLAB array `penetration` covering the same area as the ICEAREA INVERSE results with of 0.25 x 0.25 degrees grid resolution, the information could be incorporated by changing the second last line in the subfunction `cumulative_integral.m` to `product = loss_used.*pop_used.*penetration;` and remove any current reference to `penetration` in the main program.
- Reducing storage requirements:
  Replacing the text files produced by ICEAREA INVERSE by binary files, and retaining only the estimated path loss (disregarding all other estimated parameters), would significantly reduce the disk storage requirements.

8.2 CALCULATION OF HF RADIO NOISE FROM PLT/xDSL SYSTEMS

In this section, we present examples where Cumulative PLT Tool is used to evaluate the interference potential at hypothetical sensitive receiver locations. The locations were selected on the basis that they should be cities (for easy reference) with lots of nearby countryside (where sensitive receiver sites might be located, and where comparison with "quiet rural" noise curves is natural). Any correspondence with real-world sensitive receiver sites is purely coincidental.

8.2.1 Receiver Location in Bodø, Norway

In this first example, the hypothetical receiver location is Bodø, Norway. The analysis is performed under the following assumptions:

- Average EIRP per PLT installation is $p_{TX} = -80$ dBm/Hz (e.g., –50 dBm/Hz HomePlug modems and equivalent antenna gain from wiring of –30 dBi. Please refer to Chapter 7, Section 7.5).
- Market penetration is $\eta_{PEN} = 0.05$ PLT modems per capita.
- Duty cycle of each modem is $\eta_{USAGE} = 0.3$.
- The transmitter location grid used extends from –20 to 50 degrees longitude and 10 to 80 degrees latitude, and PLT modems outside this area are disregarded.
- No knowledge of receiver antenna characteristics is assumed, hence an isotropic receiver antenna is used in the analysis.
- Population data predictions from 2010 is used.

Cumulative PLT Tool is run as follows:

```
-------------------------------------------------------------------------
Cumulative PLT Tool
Roald Otnes, Norwegian Defence Research Establishment (FFI), October 2006
NATO RTO IST-050/RTG-022 on HF Interference, Procedures and Tools
-------------------------------------------------------------------------

This program will estimate the cumulative effects from PLT,
based on ICEPAC sky wave path loss predictions and population data
from "Gridded population of the world" (gpwv3) database

The program has been tested on MATLAB versions 6.5 and 7.1,
and with ICEPAC version 05.0119WW

Please run ICEAREA INVERSE one time as normal to set up all parameters, before
running this program to sweep some of the parameters.
ICEAREA INVERSE will then be called (batch mode) for all chosen parameter combinations.

Use of text-based interface:
-----------------------------
Enter will provide default parameters.
Use MATLAB syntax for the parameters to be swept.
Be aware that using default values for all swept parameters will take very long time to
run.
Ctrl-C in MATLAB window to abort.
Do NOT close down the ICEPAC window that pops up; that will make Windows confused.

ICEAREA INVERSE batch calculation: (C)ompute new or (L)oad previous? c
ICEPAC installation directory [c:\itshfbc\]:
ICEPACfile =
BODO_ISO
Swept months [2:2:12]: 2:2:12
Swept UTCs [0:4:20]: 0:4:20
Swept SSNs [50 100 200]: [50 100 200]
Swept Qs [0 5]: [0 5]
Swept freqs [2 4 8 16 24]: [2 4 8 12 16 20 24]
Total number of ICEAREA INVERSE runs planned: 1512
Save ICEAREA INVERSE results for later use (disk space required: 20267.1 MB). [Y]/N? y
Output directory [.\ICEPAC\]: .\temp\
----------------------------------
EIRP per PLT modem (dBm/Hz) [-80]:
Market penetration (PLT modems per capita) [0.05]:
Duty cycle (fraction of time each PLT modem is transmitting) [0.3]:
Market factor (penetration * duty cycle): -18.2 dB
EIRP per capita: -98.2 dBm/Hz
----------------------------------
Results will be saved to file .\temp\BODO_ISO_summary.txt

Month: 2 / UTC: 0 / SSN: 50 / Q: 0 / Freq: 2.00
Modifying ICEAREA INVERSE input files
copy c:\itshfbc\run\temp1.txt c:\itshfbc\run\iceareax.da1
 1 file(s) copied.
copy c:\itshfbc\run\temp2.txt c:\itshfbc\area_inv\default\BODO_ISO.ice
 1 file(s) copied.
c:\itshfbc\bin_win\ICEPACw.exe c:\itshfbc\ INV CALC default\BODO_ISO.ice
copy c:\itshfbc\area_inv\default\BODO_ISO.ig1 .\temp\BODO_ISO_00001.ig1
 1 file(s) copied.

Integral of population / loss over entire area: -32.5 dB
Received PLT noise: -130.8 dBm/Hz

Atmospheric noise lower limit: -159.7 dBm/Hz
Man-made, rural: -115.0 dBm/Hz
```

```
Man-made, quiet rural: -129.0 dBm/Hz
Absolute protection requirement: -139.1 dBm/Hz
----------------------------------
and so on for 1511 other parameter combinations...
```

The MATLAB text dump presented above starts with documentation and usage explanation, followed by user input of parameters and brief reports from individual ICEPAC runs. Above is only shown the first of 1512 runs (for 6*6*3*2*7 parameter combinations), for which the estimated PLT noise happened to be close to the ITU-R value for man-made noise at this frequency (2 MHz) in quiet rural locations. The 1512 ICEPAC runs with the 281 x 281 grid used here took a total of about 22 hours on a standard desktop computer which was new in January 2006, and filled 20 GB of disk space when the detailed ICEPAC results were saved (optional) for later use.

As the input value "`EIRP per PLT modem`" is bandwidth normalized and given in units of dBm/Hz, the resulting estimate of the cumulative PLT noise is also given in units of dBm/Hz.

The results are saved to a tabulator-separated text file, one line per ICEPAC run, starting like this (in case of discarded ICEPAC runs, the number in the "`PLT noise`" column will be replaced by "`NaN`"):

```
BODO [ISOTROPE ], 2010 population data, EIRP = -98.2 dBm/Hz per capita
Month   UTC     SSN     Q       Freq    PLT noise Atm (low) Rural Quiet rural Abs. prot. req.
2       0       50      0       2.000   -130.80  -159.65 -114.99      -129.01        -139.06
2       0       50      0       4.000   -132.92  -152.37 -123.18      -137.62        -145.08
2       0       50      0       8.000   -139.34  -146.21 -131.36      -146.23        -151.10
2       0       50      0       12.000  -160.30  -151.36 -136.15      -151.26        -154.63
2       0       50      0       16.000  -193.54  -160.64 -139.55      -154.84        -157.12
2       0       50      0       20.000  -215.27  -174.00 -142.19      -157.61        -159.06
2       0       50      0       24.000  -217.12  -187.36 -144.34      -159.87        -160.65
2       0       50      5       2.000   -128.02  -159.65 -114.99      -129.01        -139.06
2       0       50      5       4.000   -133.04  -152.37 -123.18      -137.62        -145.08
2       0       50      5       8.000   -140.58  -146.21 -131.36      -146.23        -151.10...
```

This file can be opened in Excel or MATLAB or any other program for further post-processing and display. A simple example is given in Figure 8.2.1-1, where for each frequency is shown the spread in estimated PLT noise (for combinations of the 4 remaining parameters). Using MATLAB to count the number of measured values above and below the red line in this example, it is found that 45% of the estimated median PLT noise levels exceed the median quiet rural man-made noise level (7% at 2 MHz, 31% at 4 MHz, 62% at 8 MHz, 75% at 12 MHz, 65% at 16 MHz, 48% at 20 MHz and 29% at 24 MHz), see also Figures 8.2.3-1 and 8.2.3-2. **Note that these percentages will be highly influenced by assumptions on transmitter EIRP, PLT market penetration and duty cycle.** A change in any of these parameters will shift all estimated cumulative PLT noise levels up or down by the corresponding number of dBs.

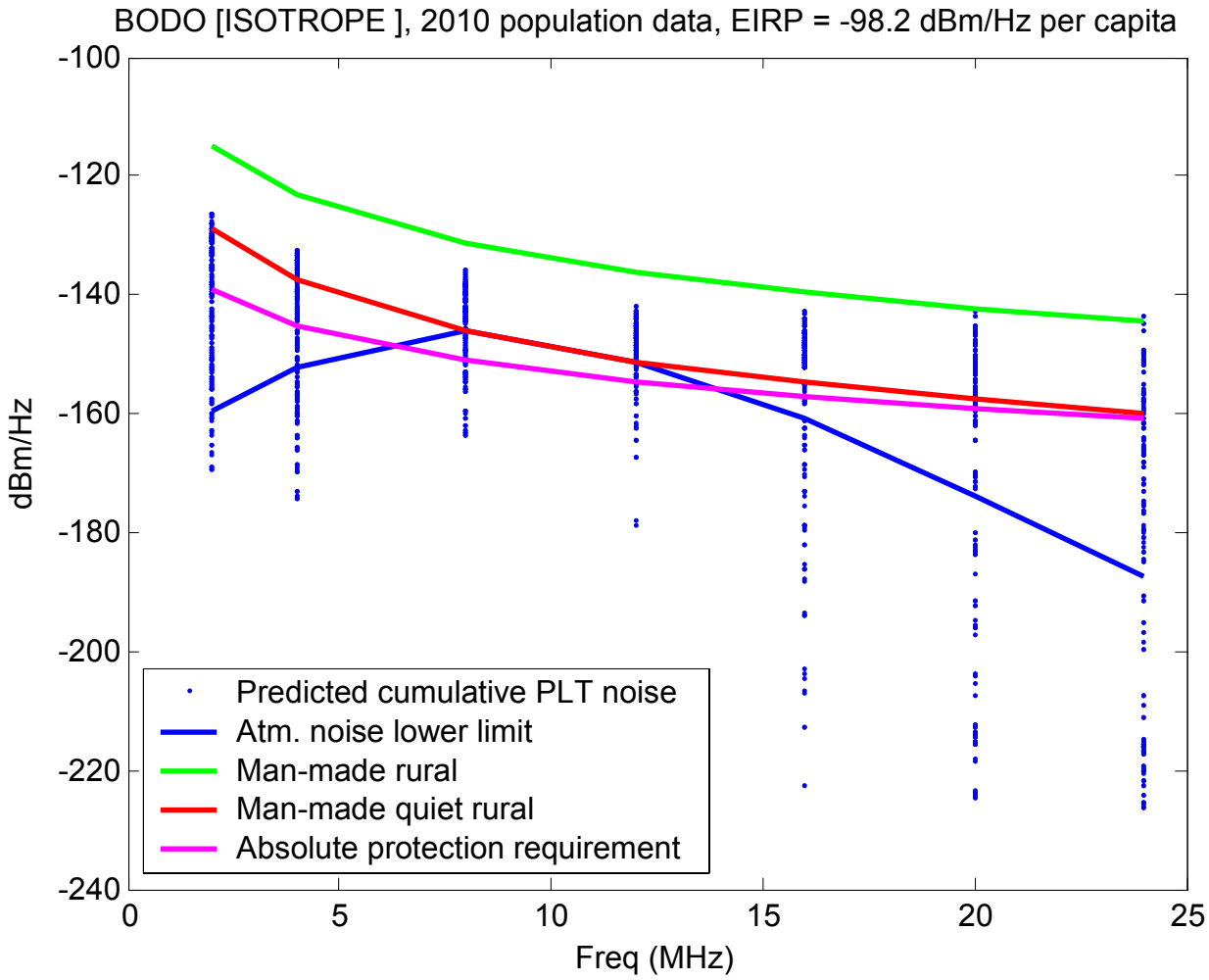

Figure 8.2.1-1: Predicted Cumulative PLT Noise Parameters, for example with Receiver in Bodø, Compared to Established Background Noise Levels.

Cumulative PLT Tool also provides the option of plotting "maps" illustrating the correspondence between ICEPAC path loss and population density. This requires that the detailed ICEPAC results have been saved to disk. An example for a case where the predicted PLT noise exceeds the median quiet rural man-made noise by more than 10 dB is shown in Figure 8.2.1-2 below.

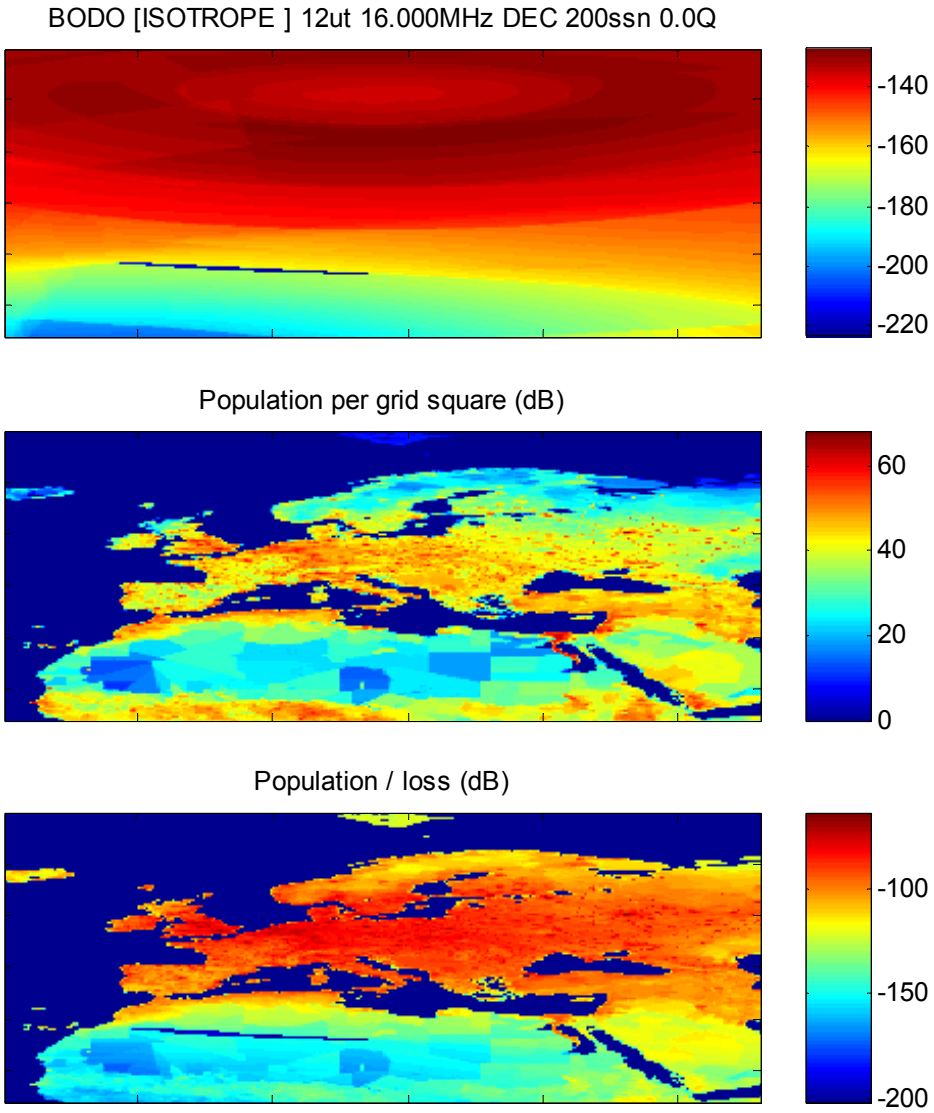

Figure 8.2.1-2: Upper Plot: Median Path Loss (dB) as Predicted by ICEPAC for a Certain Combination of Input Parameters with Receiver in Bodø; Middle Plot: Population per 0.25 x 0.25 Degrees Grid Square in dB (10*log$_{10}$(population)); Lower Plot: Product (dB-sum) of the Two above Plots.

In general, high predicted PLT noise levels correspond to cases where there is low path loss from densely populated regions.

The maps in Figure 8.2.1-2 are generated using Cumulative PLT Tool in the following fashion:

```
ICEAREA INVERSE batch calculation: (C)ompute new or (L)oad previous? l
ICEPACfile =
BODO_ISO
(C)ompute cumulative PLT noise for all files, or (P)lot One? p
Select month, one of (2 4 6 8 10 12): 12
Select UTC, one of (0 4 8 12 16 20): 12
Select SSN, one of (50 100 200): 200
Select Q, one of (0 5): 0
Select Freq, one of (2 4 8 12 16 20 24): 16
----------------------------------
```

```
EIRP per PLT modem (dBm/Hz) [-80]:
Market penetration (PLT modems per capita) [0.05]:
Duty cycle (fraction of time each PLT modem is transmitting) [0.3]:
Market factor (penetration * duty cycle): -18.2 dB
EIRP per capita: -98.2 dBm/Hz
-----------------------------------
Month: 12 / UTC: 12 / SSN: 200 / Q: 0 / Freq: 16.00

Integral of population / loss over entire area: -44.5 dB
Received PLT noise: -142.7 dBm/Hz

Atmospheric noise lower limit: -160.6 dBm/Hz
Man-made, rural: -139.6 dBm/Hz
Man-made, quiet rural: -154.8 dBm/Hz
Absolute protection requirement: -157.1 dBm/Hz
----------------------------------
```

8.2.2 Receiver Location in Winnipeg, Canada

In the second example, the hypothetical receiver location is in Winnipeg, Canada. The analysis is performed under the same assumptions as above, except that the transmitter location grid used extends from –125 to –65 degrees longitude and 0 to 60 degrees latitude. In this example, details on usage of Cumulative PLT Tool are not included, as it is similar to the previous example.

Compared to the previous example, we increased the number of frequencies probed from 7 to 9, and the number of hours probed from 6 (every fourth hour) to 12 (every second hour). The result from the same post-processing method as used for Figure 8.2.1-1 is shown in Figure 8.2.2-1. In this example, 52% of the estimated median PLT noise levels exceed the median quiet rural man-made noise level (14% at 2 MHz, 46% at 4 MHz, 57% at 6 MHz, 65% at 8 MHz, 73% at 10 MHz, 77% at 12 MHz, 65% at 16 MHz, 41% at 20 MHz and 27% at 24 MHz), see also Figures 8.2.3-1 and 8.2.3-2. Note that also in this example, these percentages will be highly influenced by assumptions on transmitter EIRP, PLT market penetration and duty cycle.

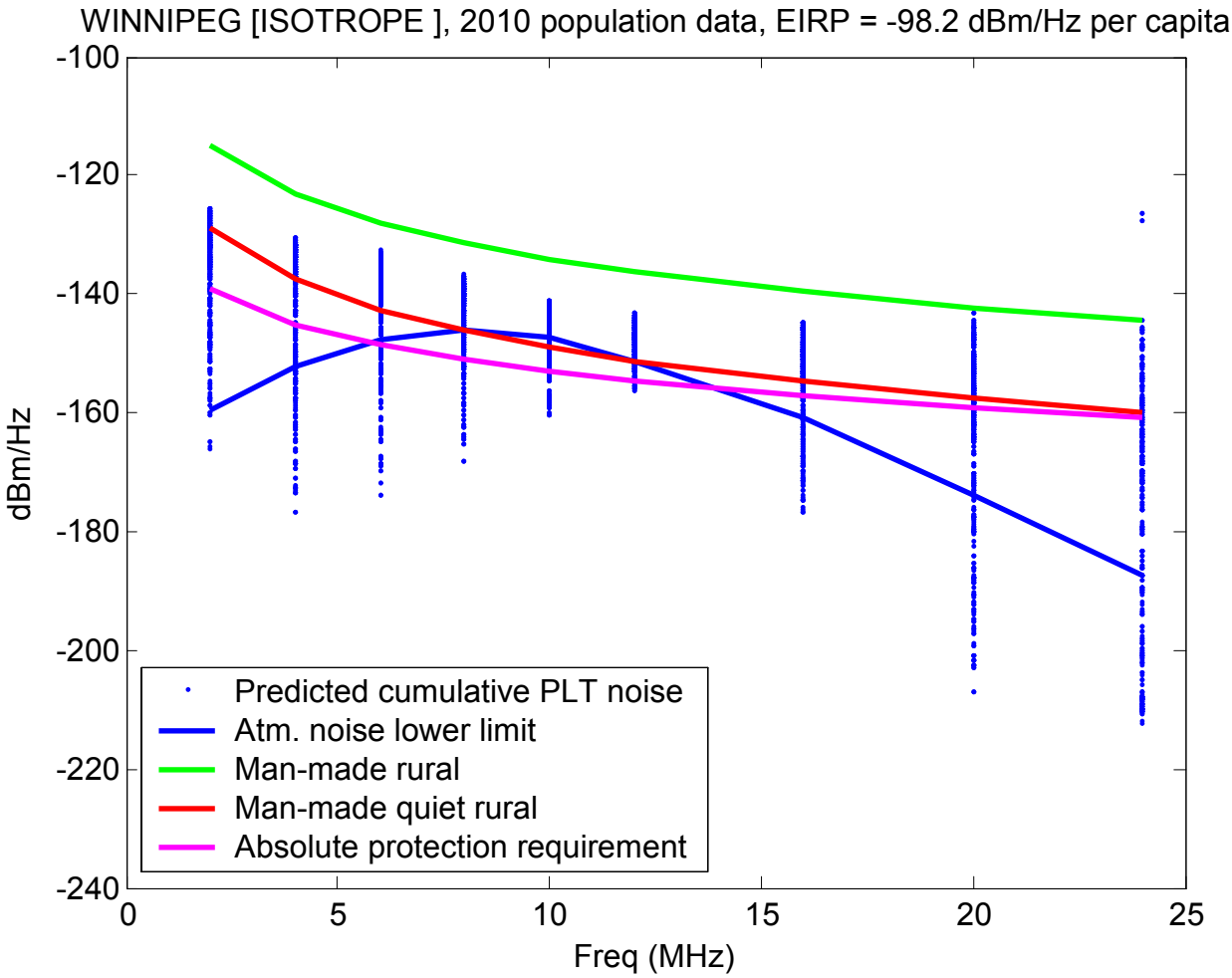

Figure 8.2.2-1: Predicted Cumulative PLT Noise Parameters, for example with Receiver in Winnipeg, Compared to Established Background Noise Levels.

In Figure 8.2.2-2 is shown an illustrating map of the same type as Figure 8.2.1-2, for a case where the predicted PLT noise is –136.8 dBm/Hz while the median quiet rural noise level is –146.2 dBm/Hz.

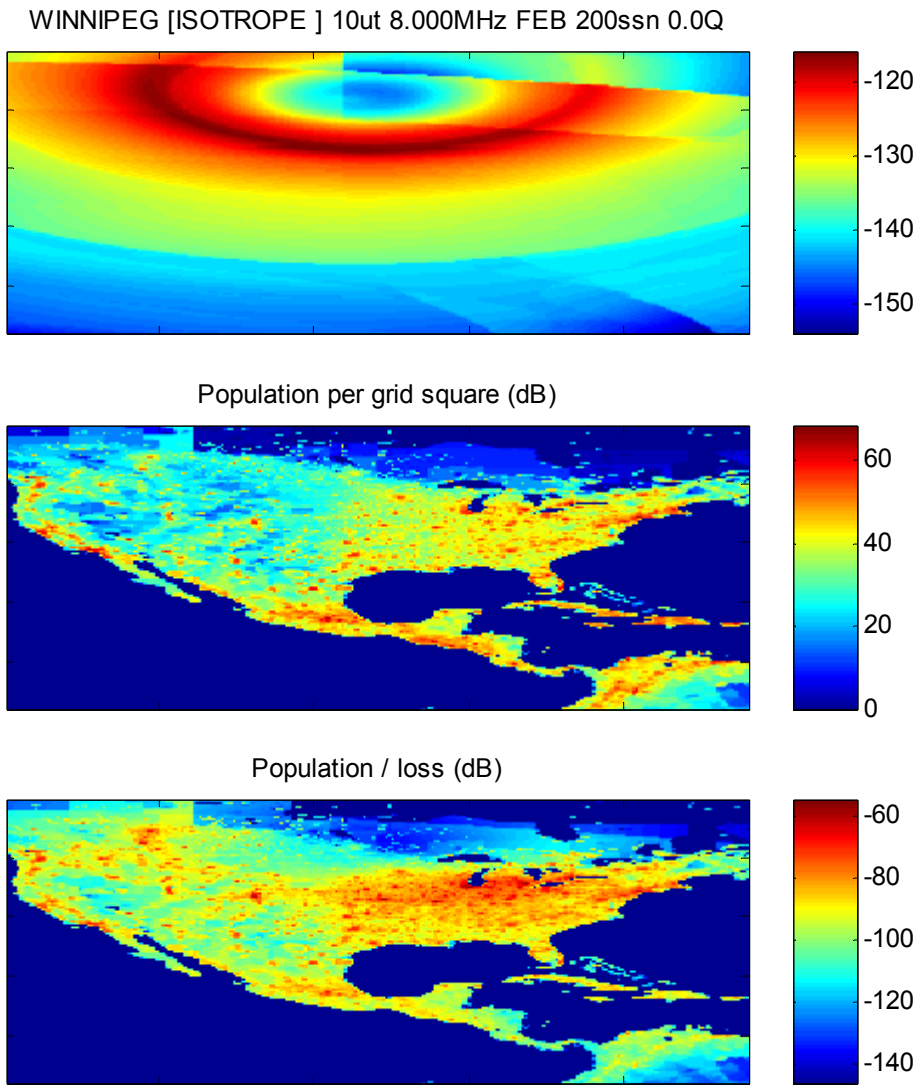

Figure 8.2.2-2: Upper Plot: Median Path Loss (dB) as Predicted by ICEPAC for a Certain Combination of Input Parameters with Receiver in Winnipeg; Middle Plot: Population per 0.25 x 0.25 Degrees Grid Square in dB (10*log$_{10}$(population)); Lower Plot: Product (dB-sum) of the Two above Plots.

The striking point of these two examples is the similarity of the results (given the same assumptions on input parameters) despite the disparate geographical locations, as seen by comparing Figures 8.2.1-1 and 8.2.2-1. The one thing these two locations have in common are that they are so far North that there are no heavily populated regions nearby, except for the city itself.

8.2.3 Other Receiver Locations

We repeated the procedure outlined above for two more receiver locations. The receiver locations (including the two locations previously described in detail) are summarized in Table 8.2.3-1.

Table 8.2.3-1: Receiver Locations used in Simulations

Location name	Transmitter grid area (lat/long)	Total # parameter combinations	# failed ICEPAC runs	Frequencies simulated (MHz)
Bodø, Norway	10N-80N / 20W-50E	1512	8	2,4,8,12,16,20,24
Winnipeg, Canada	0-60N / 125W-65W	3888	29	2,4,6,8,10,12,16,20,24
Augsburg, Germany	0-70N / 15W-55E	1080	14	2,4,8,16,24
Jacksonville, NC, USA	35S-55N / 125-35W	1512	56	2,4,8,12,16,20,24

We retain the same assumptions as previously, repeated here:

- Average EIRP per PLT installation is $p_{TX} = -80$ dBm/Hz (e.g., –50 dBm/Hz HomePlug modems and equivalent antenna gain from wiring of –30 dBi. Please refer to Chapter 7, Section 7.5).
- Market penetration is $\eta_{PEN} = 0.05$ PLT modems per capita.
- Duty cycle of each modem is $\eta_{USAGE} = 0.3$.
- PLT modems outside the transmitter location grid area are disregarded.
- No knowledge of receiver antenna characteristics is assumed, hence an isotropic receiver antenna is used in the analysis.
- Population data predictions from 2010 is used.

For each receiver location and frequency, we computed the percentage of parameter combinations 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 are summarized in Figure 8.2.3-1. It should be kept in mind that the percentages are highly influenced by assumptions on transmitter EIRP, PLT market penetration and duty cycle.

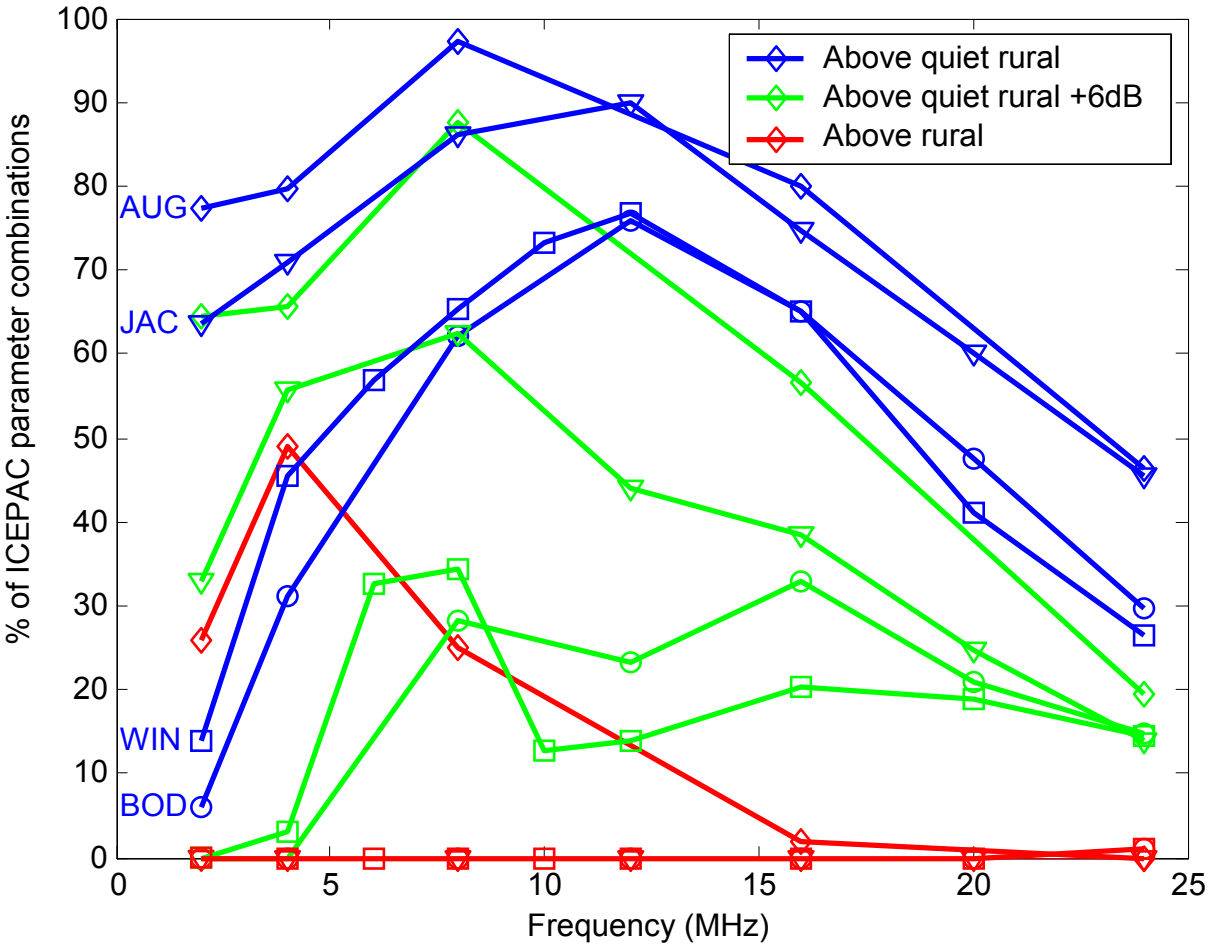

Figure 8.2.3-1: Percentage of Environmental Parameter Combinations where Estimated Cumulative PLT Noise Exceeds Different Noise Curves. Different receiver locations are denoted by different markers and annotated on the left-hand side (BODø, WINnipeg, AUGsburg, JACksonville).

From Figure 8.2.3-1 we note that while the simulated cumulative effect of PLT is similar for the Northern locations of Bodø and Winnipeg, the problem is predicted to be larger in Augsburg in central Europe: With the chosen assumptions on PLT systems, 97% of the parameter combinations at 8 MHz exceed the median quiet rural noise curve, and 49 % of the parameter combinations at 4 MHz even exceed the median rural noise curve. The result for Jacksonville on the US East Coast is between Augsburg and the Northern sites.

In Figure 8.2.3-2 we computed the percentage of parameter combinations where the estimated PLT noise level is above the Absolute Protection Requirement of Section 2.4. It should be kept in mind that the percentages are highly influenced by assumptions on transmitter EIRP, PLT market penetration and duty cycle. Note that with the chosen assumptions on these values, 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.

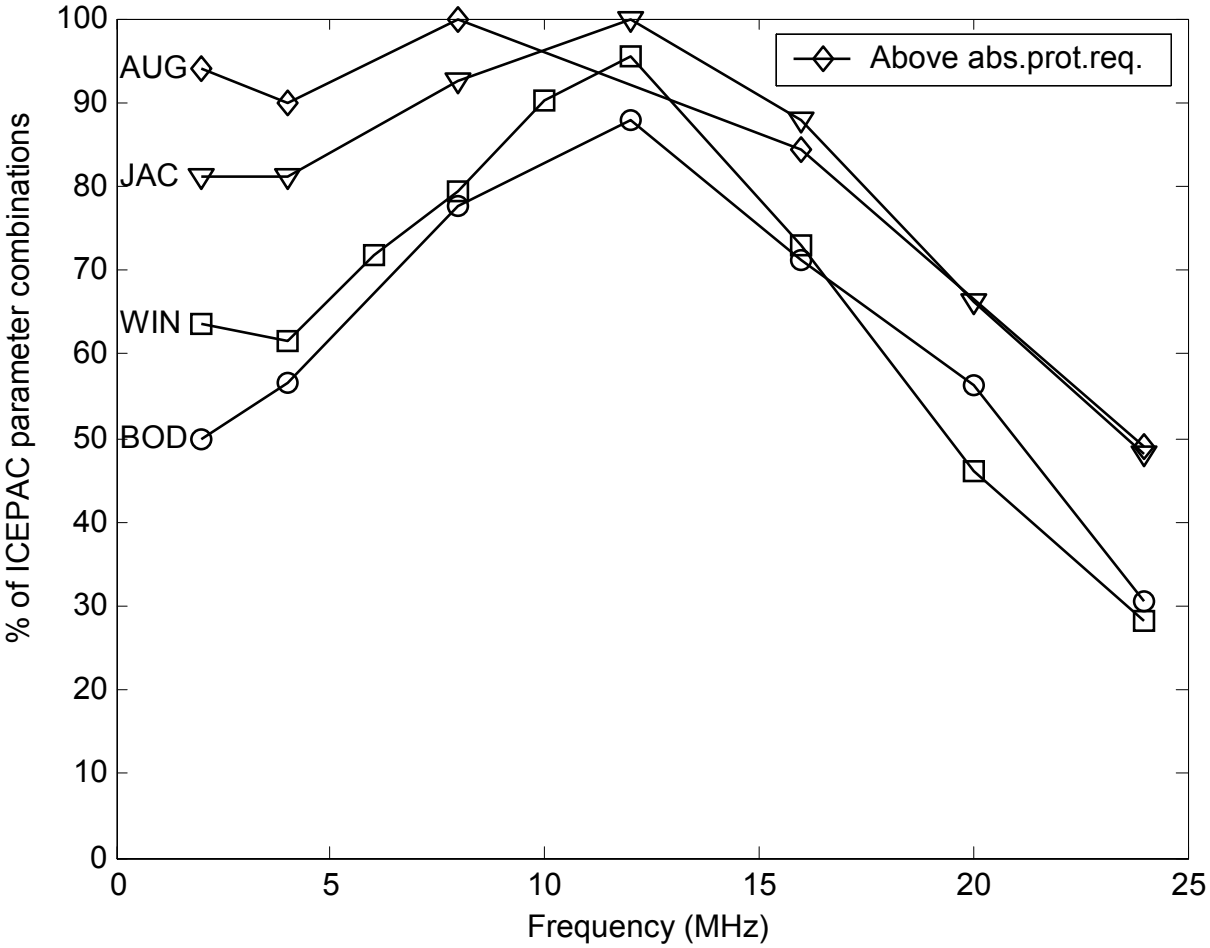

Figure 8.2.3-2: Percentage of Environmental Parameter Combinations where Estimated Cumulative PLT Noise Exceeds the Absolute Protection Requirement of Section 2.4. Different receiver locations are denoted by different markers and annotated on the left-hand side (BODø, WINnipeg, AUGsburg, JACksonville).

For completeness, we show plots of the same type as Figure 8.2.1-1 and 8.2.2-1 also for the two last examples, Augsburg and Jacksonville where the results are in dB units. These are shown in Figures 8.2.3-3 and 8.2.3-4.

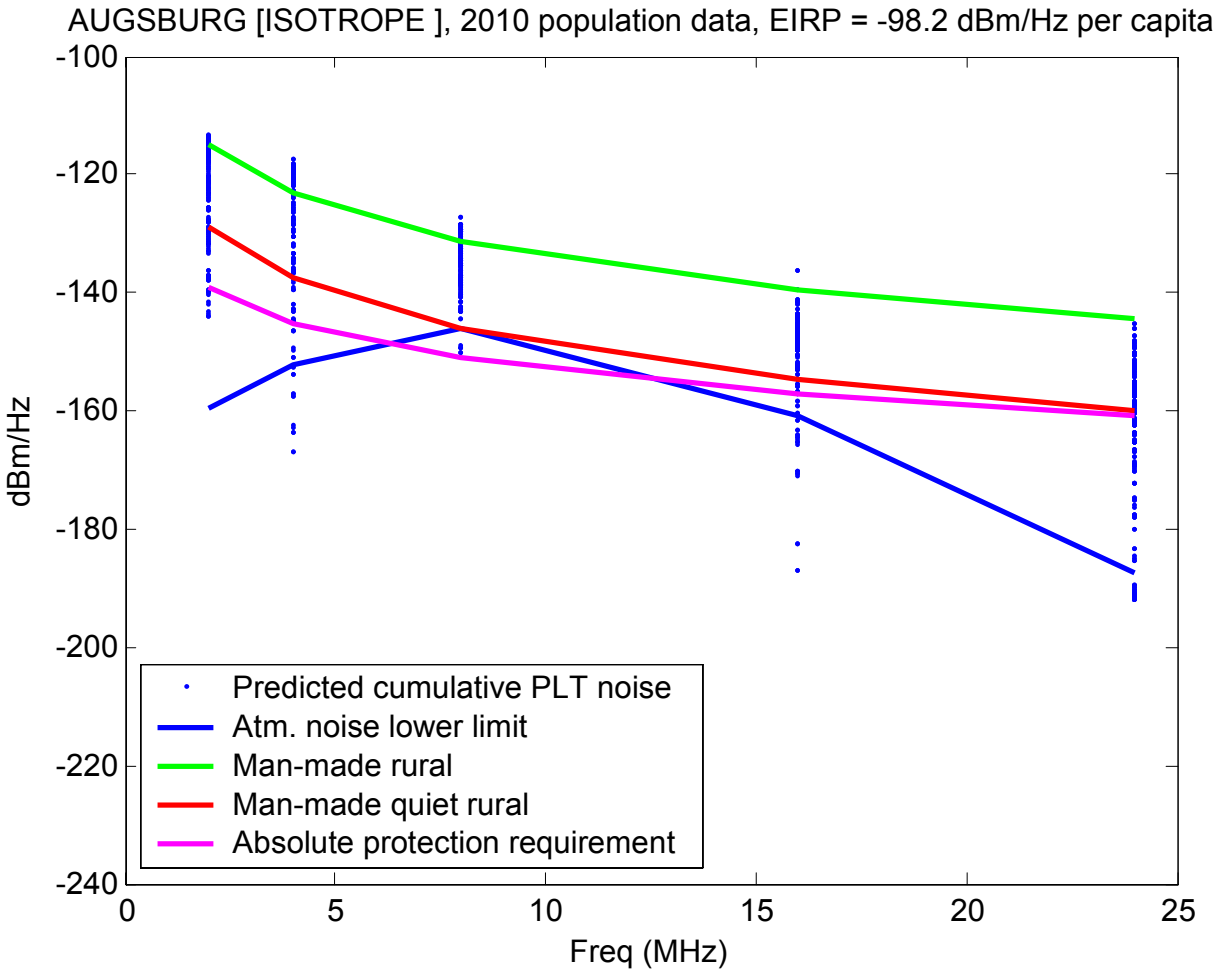

Figure 8.2.3-3: Predicted Cumulative PLT Noise Parameters, for example with Receiver in Augsburg, Compared to Established Background Noise Levels.

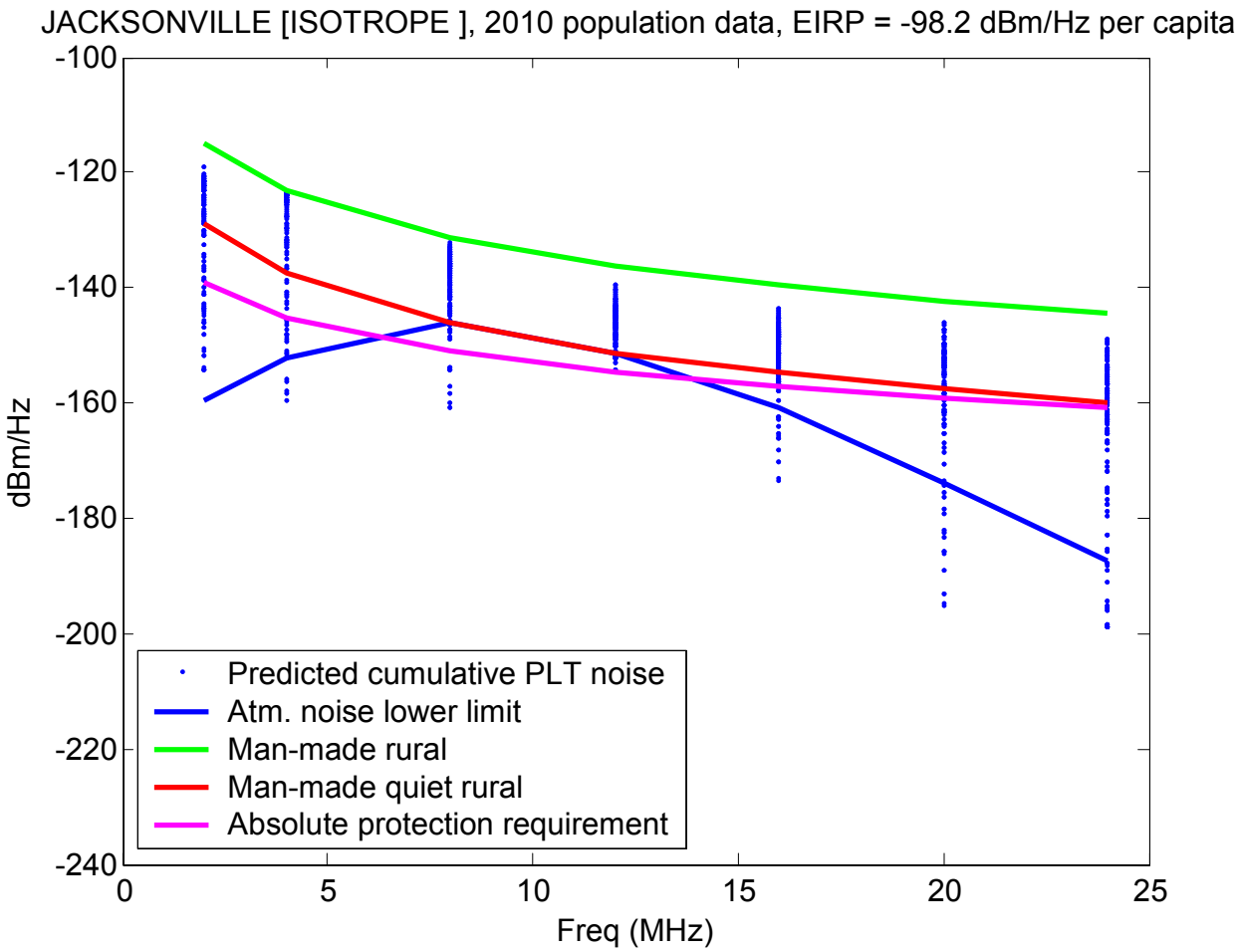

Figure 8.2.3-4: Predicted Cumulative PLT Noise Parameters, for example with Receiver in Jacksonville, Compared to Established Background Noise Levels.

Reference [101] also estimates the cumulative effect over different combinations of environmental parameters. The underlying assumptions are not directly comparable with those made above. However, both results show a similarity in that, the predicted cumulative PLT noise level for some of the parameter combinations are predicted to be above and some below the background noise level.

8.3 CUMULATIVE EFFECTS BY GROUND WAVE

The Task Group has not investigated cumulative effects of PLT by ground wave, but notes that other authors have found a protection region of 1500 m around sensitive receiver sites being sufficient in this regard [100].

8.4 CURRENT PLT MARKET PENETRATION INFORMATION

Market information is generally difficult to obtain access to and hard to predict into the future, since vendors do not disseminate this information readily, and the technology is still in development.

An attempt to predict the market development for PLT is given in [38], which predicts that by 2010 there will be between 2.5 and 5 million Access PLT (BPL) subscribers in USA. This corresponds to a market penetration of 0.9 – 1.7 % of the population.

In Germany, the number of HomePlug devices “on the market” in February 2005 was 300000, and in February 2006 it was 800000 [77]. This information was given to the Task Group from the German BITKOM (industry) via the German Ministry of Commerce. The population in Germany is 82 million, thus the HomePlug market penetration as of February 2006 is 0.01 modems per capita.

As of April 2006, Intellon had sold 10 million HomePlug chipsets worldwide and shipped 5 million of those [78]. Intellon is one of the three major vendors of PLT chipsets; the other two are DS2 and Panasonic.