Paper

New SEAMCAT Propagation Models: Irregular Terrain Model and ITU-R P. 1546-4

Dariusz Więcek and Dariusz Wypiór

National Institute of Telecommunications, Wrocław, Poland

Abstract—Implementation of the ITU-R P.1546-4 and ITM propagation models for SEAMCAT prepared and developed in the National Institute of Telecommunications Poland is presented. Results of our research encompasses methodology, implementation and verification of plug-ins into the SEAMCAT software are shown.

Keywords*—*electromagnetic compatibility, interferences, propagation, SEAMCAT, spectrum engineering.

1. Introduction

Electromagnetic compatibility analyses of wireless systems have important role in process of radio network planning, optimization and frequency availability checking. Greater than ever number of wireless transmission devices work on the same or adjacent radio channels, what leads to necessity of using dedicated computer software carrying out computer calculations and analysis of EM compatibility aspects in very similar conditions as it is in real world. Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) is one of the most advanced and most popular tools in Europe. The SEAMCAT software is generally developed jointly within countries belong to the European Conference of Postal and Telecommunications Administrations (CEPT) under the framework of European Communication Office (ECO). The application is developed by SEAMCAT Technical Group (STG). It is freely distributed software developed on the base of open-source license and provides opportunities for creating scenarios in which radio systems are tested for quantitative and statistic probabilities of interferences. The significant impact on obtained results have different propagation methods dedicated for different propagation conditions. In SEAMCAT besides using a few in-built methods [1] there are also methods developed by user as propagation plug-ins. In this work, the ITU-R Recommendation P.1546-4 and Irregular Terrain Model (ITM) propagation models implementation are presented. The latter one is also called as Longley-Rice method. Those methods were official attached to SEAMCAT software after their successful verification made by ECO's experts and are now available on the SEAMCAT web pages [2].

2. Electromagnetic Compatibility of Radio Systems

Accordingly to the rapid increasing of radio systems working on the same or adjacent frequency channels, in the same or neighboring geographical areas risk of mutual harmful interferences can occur. It is consequence of the propagation of radio waves in all directions, crossing the borderlines and overlapping the same radio spectrum by different radio systems. As a result, receiver receives wanted as well as many interfering signals having various characteristic of electric field strength levels. It often leads to the situations where despite of sufficient wanted signal levels (exceeding the required minimum signal level threshold) in same location or in some time conditions the correct reception is not possible due to interferences.

In order to minimize this effect computer-aided EMC analyses are required before introducing new wireless system to guarantee minimization of the interferences probabilities. In this way, we can obtain an assessment of mutual interferences probabilities depending on varying parameters of individual transmitters (localization, transmitter antenna characteristic, frequency, signal character). Those analyses give guarantee of sufficient EM compatibility and prevent from the occurrence of interferences even at the stage of the preparation or evaluation possibility of allocations frequency bands by administration, international regulators bodies or telecommunications operators. It can be done by defining specific conditions, e.g., territorial separations or specific requirements of radio emissions (e.g., emission masks, receiver selectivity, maximum transmitter highs).

In order to get accurate information what emission parameters should be used or where transmitters ought to be localized, we need to develop new computer-assisted tools corresponding to increasing amount of new radio system and networks and their technical parameters. Also country administration can use such kind of software during multilateral international coordination agreements concerning frequency allotments and assignments. For the purpose of analysis the basic knowledge of input parameters, propagation models, technical aspects of receivers and transmitter stations are required. Also proper methodology of computing in dedicated software is important. In case of congestion of radio spectrum, when we need to use electromagnetic spectrum as efficient as never before, continuous researches lead to implementation of improved propagation methods are important. In such situation undertaken work aimed at SEAMCAT development is to be very helpful.

3. SEAMCAT Methodology

Creating an appropriate scenario is the base of conducting desired calculation (simulation) in the SEAMCAT application. Each from those scenarios has to contain one victim link and at least one interfering link. In Fig. 1 relation among various types of radio links are presented. Wanted transmitter (Wt) and victim receiver (Vr) are included in victim link. Besides, there could be any amount of interfering links which contains interfering transmitter (It) and wanted receiver (Wr). Arrows present the directions of radio paths, for which appropriate attenuation of signal levels are computed.

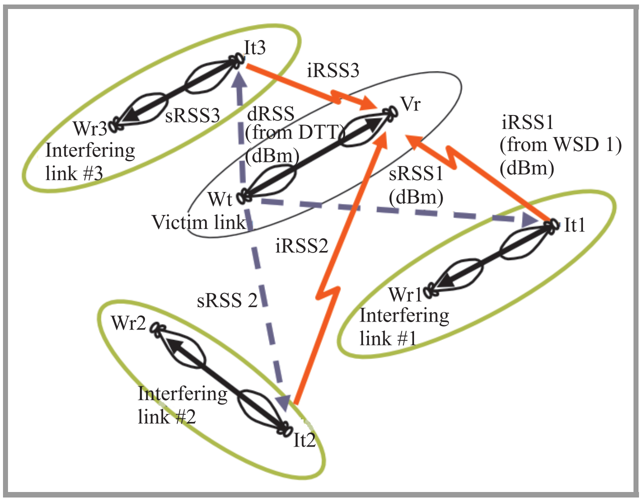

Fig. 1. Signal relations among various types of links [3].

Each of them is described by series of values presenting system parameters, spatial location information and propagation models. SEAMCAT works in Monte Carlo methodology, what means that many events are generated and results return with same statistics. Users have right to choose the number of simulation event. In every scenario, there is a possibility of changing input parameters (particularly station localization, frequency, emission power etc.) according to a pattern set by users. Moreover, in each of the event levels of signals are computed. We can get following results:

- desired received signal strength (dRSS),
- interference received signal strength (iRSS),
- sensing received signal strength (sRSS); it is used only by cognitive radio systems features.

They form the basis for further interference probabilities calculations. The probability of interferences occurring p_I Eq. (1) accordingly to the signal-to-interference ratio (C/I) criterion for single event and form single interfering link is the conditional probability, where $sens_{RX}$ is the receiver sensitivity.

$$p_I = 1 - P\left(\frac{dRSS}{iRSS} > \frac{C}{I}\middle| dRSS > sens_{RX}\right) \qquad (1)$$

It is important that SEAMCAT does not give opportunity to use digital elevation/terrain map (DEM/DTM) and all calculation are carried out over a flat terrain, what comes from the fact that the application is to be especially used by government administrations in the work of establishing general rules of coordination, legislative and policy governing the use of radio spectrum on national and international levels. Such simulations are enough detailed for the purposes because it is usually established as worst-case situations from interference point of view.

Besides standard settings of radio networks, there is also possibility of conducting simulation for some predefined radio systems such as CDMA or LTE. What is more, at present STG is working on the introduction of appropriate solutions, which will take part in cognitive radio EMC analyses. Now users have possibility to do only some simple calculation with cognitive radio features, which are still being discussed and developed within ECO forum.

4. Propagation Models

4.1. General

The proper received signal strength prediction is based on using correct propagation models, which are properly chosen, i.e., depends on the type of system or feature of terrain where wireless systems works. During implementation we have analyzed a few methods, focusing on those, which are especially used to calculation over land areas and frequencies in the range 100 MHz till 3 GHz basically. Generally, propagation methods are divided into:

- point-to-area methods,
- point-to-point methods.

It is worth mentioning that first group of methods is used generally for larger areas and general estimations. The result is estimated based on general propagation rules, particular earlier measurements statistics and more or less accurate statistical terrain math descriptions. The latter group of methods contains greater number of input parameters and use sophisticated math dependencies for various physics phenomena and weather conditions (diffraction, scatter, rain cell, vapour attenuation etc.) but usually required detailed DEM/DTM maps and is basically used at detailed network planning stage.

4.2. ITM Propagation Model

Irregular terrain model (ITM) was developed in the 60's of the XX century in the USA for designing and planning analogue broadcast terrestrial television systems [4]. Later, it has been extended to work in wider frequency range for other systems types. Our implementation into SEAMCAT works as point-to-area method. The average height of profile between receiver and transmitter is described statistically by irregularity terrain parameter. Calculations are conducting for 3 propagation mechanism: line-of-sight, diffraction and scatter. That fragmentation has been made due to the dominant physical phenomena. Furthermore, ITM method contains some empirical dependence. It is very interesting model because of wide frequency range (VHF, UHF, SHF) and wide series of parameters allowing detailed parameterizations listed below.

- System parameters:
  - frequency,
  - height of antenna masts,
  - distance,
  - polarization.
- Terrain parameters:
  - irregular terrain parameter,
  - conductivity of ground,
  - relative permittivity,
  - surface refractivity
  - radio climate.
- Deployment parameters:
  - siting criteria.
- Statistical parameters:
  - percentage of localization,
  - percentage of time,
  - confidence level,
  - mode of variability,
  - signal standard deviation.

ITM model has following limitation:

- frequency: 20 MHz – 20 GHz,
- distance: 1 – 2000 km,
- height of antenna: 0.5 – 3000 m.

Input parameters presented above are treated as quantitative and qualitative parameters. Accordingly, i.e., the first are height of antenna, frequency etc., and the latter there are radio climate, siting criteria etc. In implementation seven radio climate zones are included: equatorial, continental subtropical, maritime subtropical, desert, continental temperate, maritime temperate over land and maritime temperate over the sea. Irregularity parameter dh is given in meters and it is assumed that for a flat terrain is equal 0 m, for plains $dh = 30$ m, for hills $dh = 90$ m, for mountains $dh = 200$ m and rugged mountains $dh = 500$ m. Conductivity of ground, relative permittivity have also such assumption. It is suggested to use following values of conductivity of ground σ, and relative permittivity εr:

- σ = 0.005 S/m, εr = 15 for average ground,
- σ = 0.001 S/m, εr = 4 for poor ground,
- σ = 0.02 S/m, εr = 25 for good ground,
- σ = 0.01 S/m, εr = 81 for fresh water,
- σ = 5 S/m, εr = 81 for sea water.

Surface refractivity depends on a climate zone. Siting criteria is a qualitative description of the care with terminals sites is chosen to improved communications. Percentage of time and localization determine the fraction of time or localization where the attenuation will not exceed the certain value. Confidence level is qualitative parameters describing other variables. For instance, if it is 50% of time, 70% of localization, and confidence levels equal to 90% it means that: in 90% of cases (situations) there will be at least 70% of the locations where the attenuation will not exceed certain value for at least 50% of the time [5]. There are also four mode of variability (single, individual, mobile, broadcast).

4.3. ITU-R P.1546-4 Propagation Model

ITU-R P.1546-4 Recommendation [6] offers field-strength predictions in point-to-area mode for terrestrial services over land and sea in the frequency range 30 MHz to 3 GHz. The method based on series statistically prepared measured field strength values (e.g., values for 50% time and 50% locations) presented as curves included into the Recommendation and widely used for broadcast, land mobile services as well as other wireless systems in this frequency range. Results of statistically prepared measurements data (median, 10% of time, 1% of time exceeding wanted value) in mean temperate climatic conditions obtained for land, cold and warm sea are tabulated and included into the Recommendation. Curves are divided into land and see (cold and warm) respectively and represent the following data:

- frequency (f),
- height of transmitting/base antenna (h),
- time percentage (t),
- distance (d).

Due to lack of ability of using DEM/DTM in SEAMCAT, as mentioned earlier, the discussed implementation of the model omitted sea path calculation and detailed terrain corrections. In this way in our implementation the percentage of sea path length over a profile is not used.

The calculation of field-strength values from curves is based on interpolation/extrapolation algorithm. The more input parameters, which have not fit into exact tabulated field

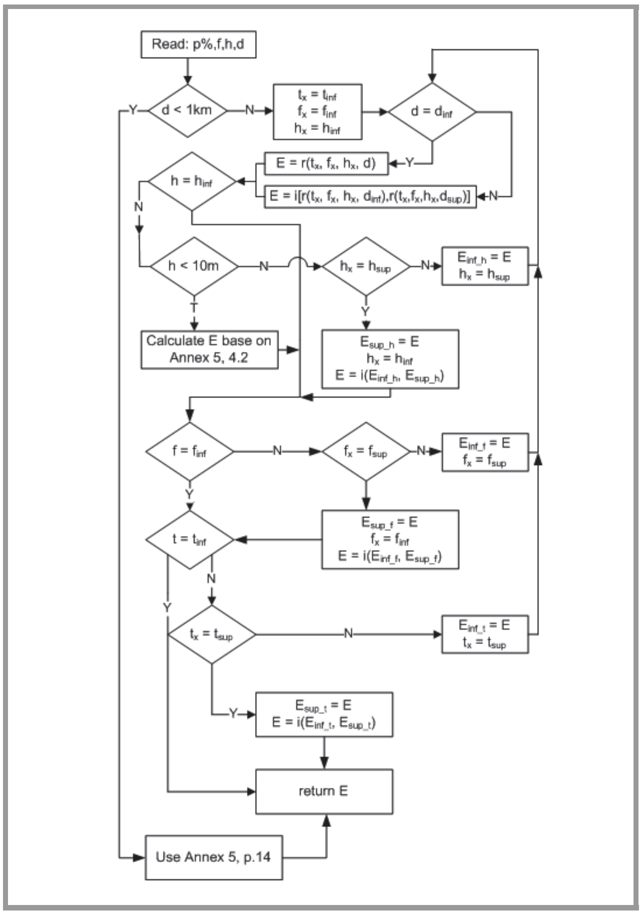

Fig. 2. The interpolation of field-strength value algorithm.

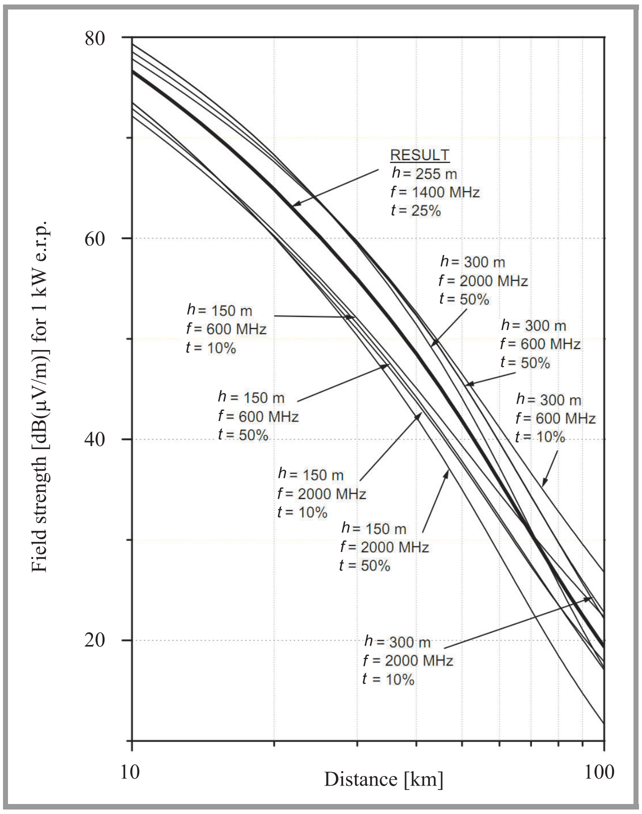

Fig. 3. The sample of quadruple interpolation.

strength values, the more interpolation operations have to be done. In the worst case, if none of those parameters are in direct tabulated form algorithm should perform 15-interpolation. The algorithm for solving the described problem was prepared (Fig. 2). The purpose of it is computing expected field-strength value exceeded at 50% of location within area of 500×500 m. The additional exceptions, as path with distance less the 1 km or transmitting antenna height less then 10 m, are also included. For those cases, the Recommendation introduced additional prediction methods.

Inf and *sup* indexes in algorithm's block boxes denote respectively the nearest tabulation value less then inputted and the nearest tabulation value greater then inputted. Function i is discussed interpolation function and function r read field-strength value from curves. A sample obtained result of the foregoing procedure is presented in Fig. 3, where following parameters were used: f = 1400 MHz, h = 225 m, t = 25%, distance 10 – 100 km (step 1 km),

In this case, four parameters have not exact corresponding value in the appropriate tabulated data and should be interpolated. The algorithm was implemented and all necessity actions and the results for the example were returned. Figure 3 shows the result and also all data, read directly from tables, which are used for interpolation calculations.

4.4. Practical Implementation

SEAMCAT offers possibility to use plug-in propagation models. Each of them has to be written in Java programming language, compiled and put into SEAMCAT home directory. The template for plug-ins development with some basic code containing sample class is able to download from the official online user manual [2]. Users are able to make optional changes in that code adequacy to their needs. Propagation plug-in activity can be illustrated as a "black box" (Fig. 4). On its input, the basic system parameters are

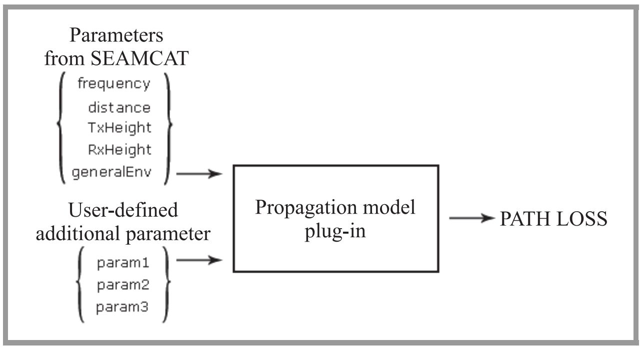

Fig. 4. Propagation plug-in treated as "black box".

introduced – reading directly from the workspace. What is more, every user has ability to introducing up to 3 additional user-defined optional parameters. The radio path loss is designated after each event and returned to workspace as preliminary value of dRSS, iRSS or sRSS depending on which signal attenuation was computed.

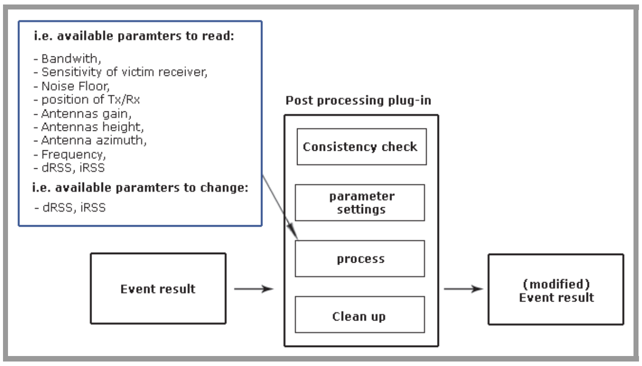

Fig. 5. Postprocessing plug-in treated as "black box".

In case of implementation the ITM propagation plug-in some problems were occurred. They were connected mainly to maximum 3 user-define parameters, which developer may use. That issue was solved by using second type of plug-in, which SEAMCAT offers namely postprocessing plug-in. It allows performing operations for various parameters, both input and output as instance dRSS (Fig. 5). Through this extension postprocessing plug-in is treated in our solution as a configuration panel for all additional input parameters. Presented solution is not the best because by changing at least one input parameter it can be introduced an incorrect result in first event – all parameters shall be set after first event. However, it can be omitted if simulation event number is very large or in case, when first one event simulation will be made, which will be treated as a pre-configuration simulation. After that manipulation, the event in second simulation will be correct.

5. Tests

5.1. ITM Model

During testing phase many simulations were conducted for various input parameters and type of terrain as well as radio climates. They aimed to verifying obtained results and source code correctness. Results, for certain input parameters (Table 1), derived from our implementation was compared with results from ITM – Irregular Terrain Model 1.5.5 software (Fig. 6). A very good correlation of both applications was received. Details can be found in the PBZ Report [7]. Other sample results are presented in Figs. 7 and 8. Test workspace was configured in all simulation in the same way (Table 1). All radio system works on the frequency 900 MHz, the heights of transmitter and receiver antennas have respectively 100 m and 10 m. In the particular calculation, input parameters have been changed to those presented in Figs. 7 and 8. Furthermore, for radio climate changing surface refractivity was also varied and set on 280, 301, 320 respectively for desert, continental temperate, maritime temperate over land radio climate.

Table 1
Input values for ITM model test

Parameter	Value	Units
Frequency	900	MHz
Transmitting antenna height	100	m
Receiving antenna height	10	m
Surface refractivity	301	N-units
Terrain irregularity parameter *dh*	90	m
Conductivity of ground	0.005	S/m
Relative permittivity	15	
Antenna polarization	Horizontal	
Siting criteria	Random	
Radio climate zone	Continental temperate	
Percentage of time	50	%
Percentage of localization	50	%
Confidence level	90	%
Mode of variability	Broadcast	
Standard deviation	0	dB

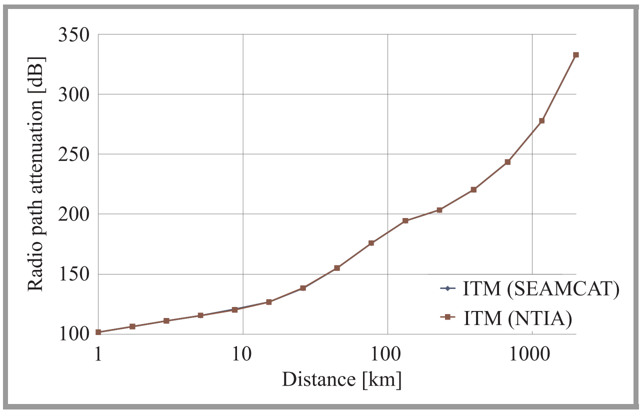

Fig. 6. Radio path attenuation against distance for comparison of ITM model applications.

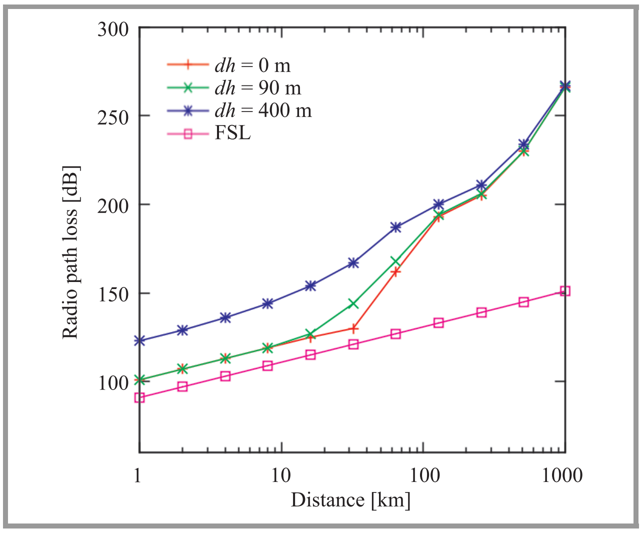

Fig. 7. Results of radio path loss for various irregular terrain parameters *dh*.

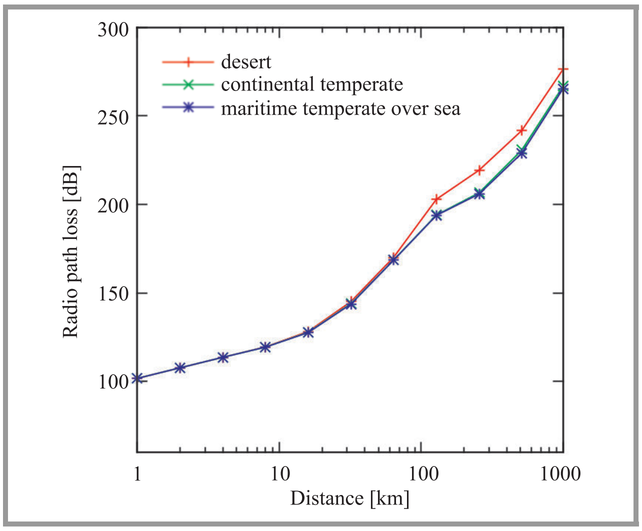

Fig. 8. Results of radio path loss for various radio climates.

5.2. ITU-R P.1546-4

The test procedure was oriented on correct radio path loss returning in dependencies on various input parameters. Obtained results were compared firstly to the version P.1546-1

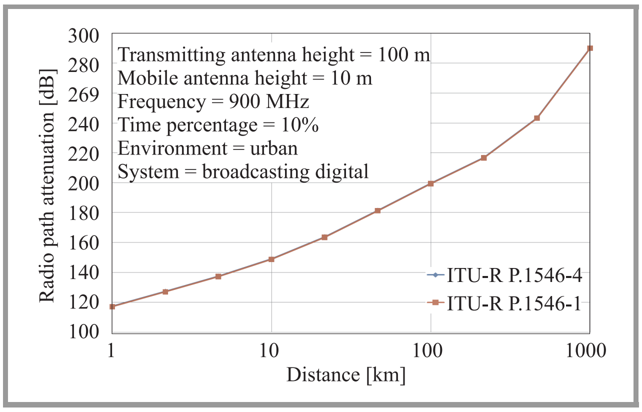

Fig. 9. Radio path attenuation against distance for P.1546-1 and P.1546-4.

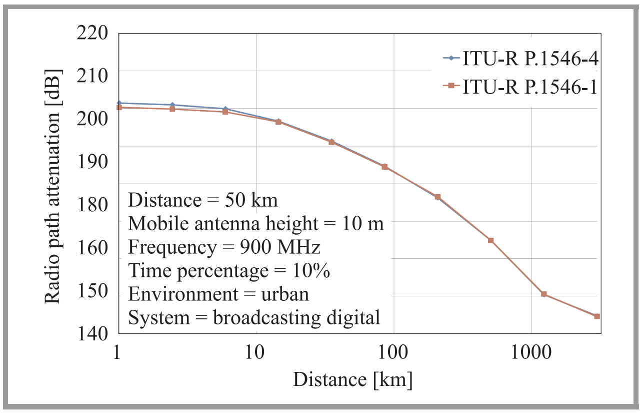

Fig. 10. Radio path attenuation against transmitting antenna height for P.1546-1 and P.1546-4.

from previous version of SEAMCAT. Some sample results are shown in Figs. 9–12.

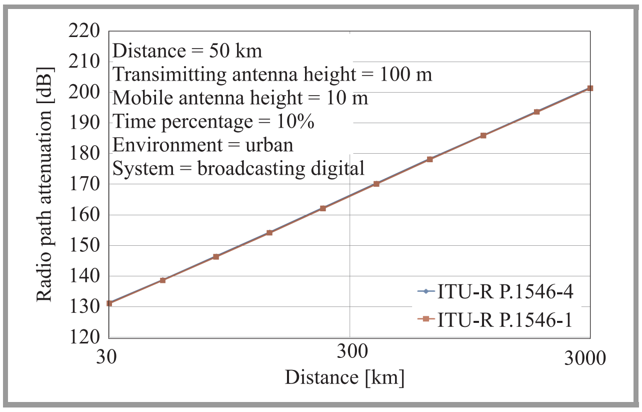

Fig. 11. Radio path attenuation against frequency for P.1546-1 and P.1546-4.

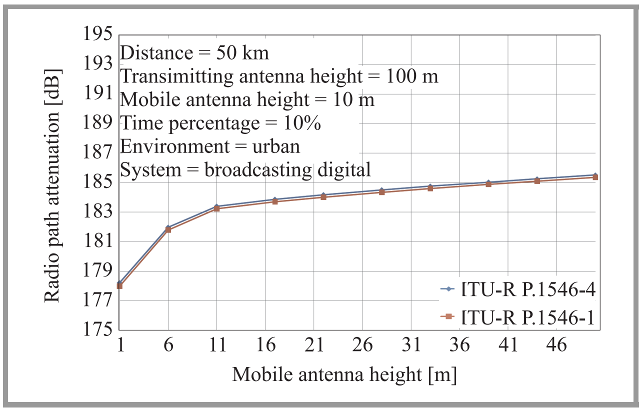

Fig. 12. Radio path attenuation against percent of time for P.1546-1 and P.1546-4.

The result obtained from comparison of both models confirmed proper implementation of the P.1546-4. It is worth to note that in P.1546-4 interpolation between tabulated points taken from curves is used while the implementation of recommendation P.1546-1 in SEAMCAT computes the curves from some equations for certain coefficients, but both methods should generate the same value for single case calculations of basic variables (e.g., distance, frequency, transmitting antenna high) as it is shown above in Figs. 9–12.

The second tests phase led to calculations of results for some group of input parameters (like time percentage, environment in vicinity of receiver etc). The workspace, during tests, was configured default as follow:

– frequency:	900 MHz
– transmitting antenna height:	100 m
– receiving antenna height:	10 m
– environment:	urban
– time percentage:	50%
– area:	500 × 500 m
– number of event:	20 000.

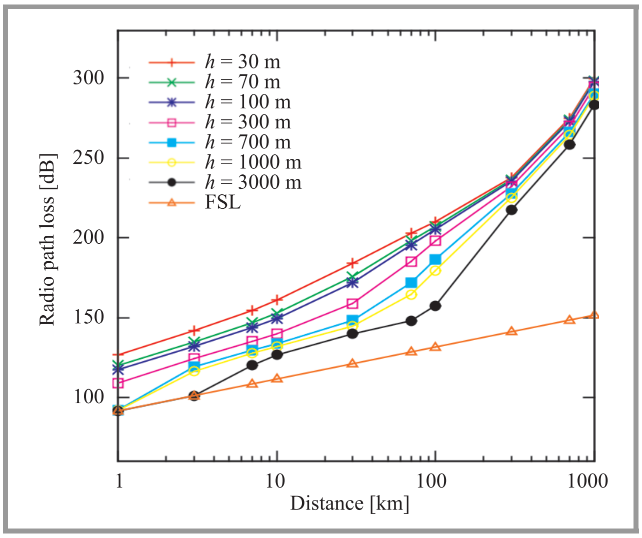

Fig. 13. Radio path loss for various transmitting/base station antenna heights *h*.

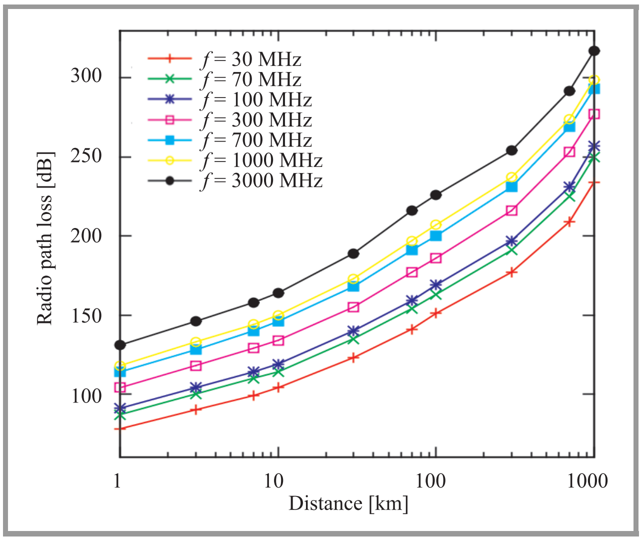

Fig. 14. Radio path loss for various frequencies *f*.

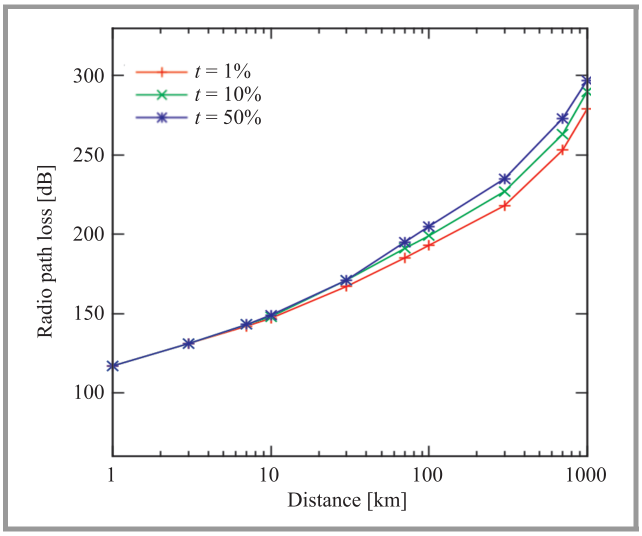

Fig. 15. Radio path loss for various time percentages *t*.

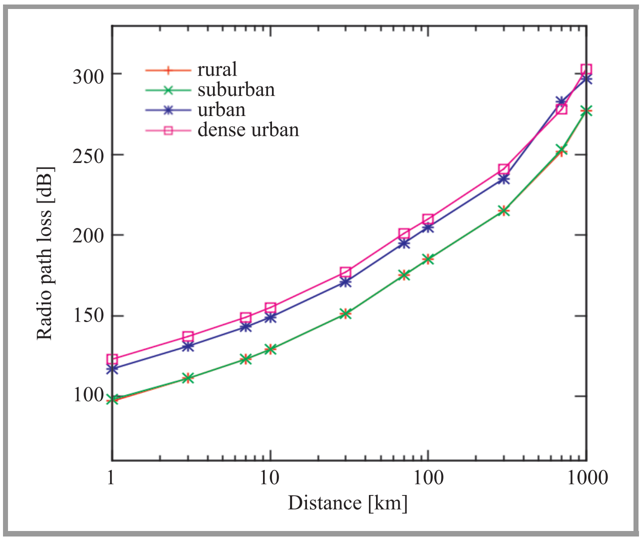

Fig. 16. Radio path loss for various clutter types.

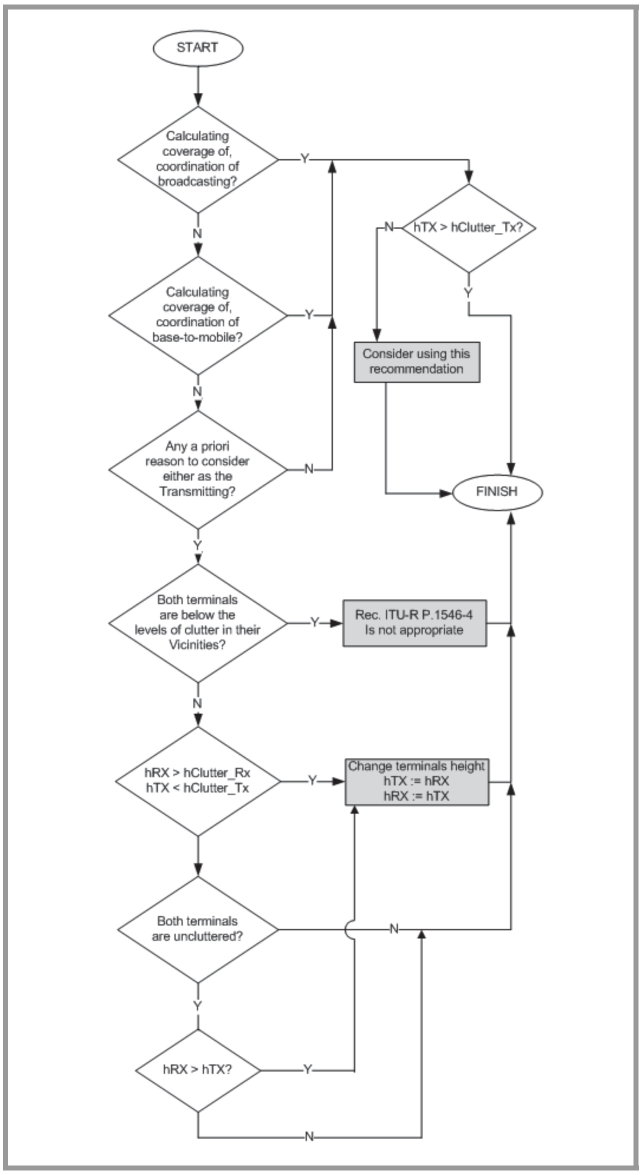

Fig. 17. The terminal designation algorithm.

Results which are presented (Figs. 13–16) were obtained by changing parameters accordingly to those written in figures.
Additionally ITU-R P.1546-4 Recommendation has introduced *the terminal designations* in Annex 5 Paragraph 1.1. In any cases where there are not *a priori* reason to consider terminal as transmitting/base, and user is aware this paragraph can be omitted. This way, all results shown earlier omitted that outlines. Algorithm (Fig. 17) presented step-by-step procedure how the application of the procedure ought to be use. It is important to use them, because of lack of reversible with respect to designations of transmitting and receiver station and in view of wording from Recommendation "It is primarily intended for use with broadcasting and mobile services where the transmitter/base antenna is above the level of local clutter" [6].

6. Application Example

Some analyses using developed implementation of new SEAMCAT propagation methods were conducted during the validating test stage. Below some examples of the results are presented.

6.1. The Influence of BS PMR into DVB-T

Typical example of analysis which can be carrying on into SEAMCAT software is impact of one wireless system into another, working in the same or adjacent frequency bands. Below modified scenarios taken from the ECC Report 104 [8] were used. Influence of BS PMR on DVB-T receivers were analysed there. DVB-T receivers work on channel 21. The values of the system setting are present in Table 2 and Table 3.

Table 2
DVB-T parameters

Height of TV transmitting antenna	100 m
Height of TV receiving antenna	10 m
EIRP	43 dBW
Bandwidth	8 MHz
TV channel	21 (470–478 MHz)
RX sensitivity	–79 dBm

Table 3
PMR parameters

Height of BS antenna	30 m
Height of MS antenna	1.5 m
EIRP	22 dBm
Bandwidth	12,5 kHz
Centre frequency	469.99375 MHz

The digital television receivers were at distance 30 km from transmitting antenna (DVB-T). Mobile base station of PMR was located in random distances from television receiver, but no further than 10 km. In the presented results there are probabilities of the interferences. The unwanted and blocking signals calculation models used in SEAMCAT were taken into account.

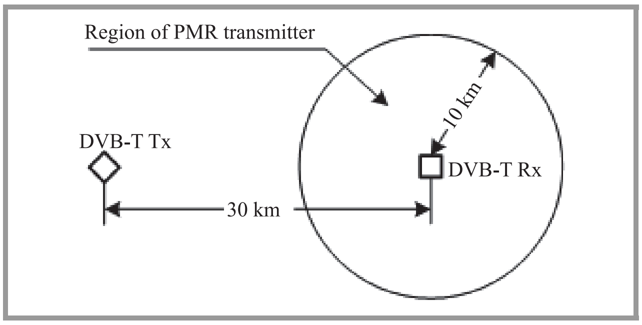

Fig. 18. Location of transmitters and receivers in analysis scenario.

The radio path loss between DVB-T transmitter and receiver was computed by ITM method. Input parameters are presented in Table 4. The signal attenuations between PMR base stations and DVB-T receivers were calculated by using Extended-Hata propagation model. Probabilities of interferences were computed for modification of individual parameters of ITM method. In this simulation 100 000 events were taken into account.

Table 4
Probability of interferences for different terrain irregularity parameters

Terrain irregularity parameter	Interference probability
0 m	0.03%
90 m	0.1%
200 m	0.2%
450 m	1.38%

As we can observe, the higher terrain irregularity parameter value the less signal level at receiver input is, what resulting in decreasing of the signal to noise plus interference ratio C/(N+I) and corresponding probability of interference. In Table 5 results for different radio climate zones are also shown. The terrain irregularity parameter was set to 250 m. In this simulation 500 000 events were used.

Table 5
Probability of interferences for different terrain radio climate zones

Radio climate zone	Interference probability
Equatorial	0.26%
Continental subtropical	0.29%
Maritime subtropical	0.24%
Desert	0.32%
Continental temperate	0.30%
Maritime temperate over land	0.28%

It can be noticed that in such propagation zones where additional propagation effects occurs (and better propagation conditions are), higher useful signal levels at the same distances exist and then interference probability decrease (e.g., maritime versus land).

7. Summary

SEAMCAT as an open-source licensing software delivers many additional manners to make its closer to user needs either by using plug-ins or editing the source code.

The ITU-R P. 1546-4 and ITM propagation models were implemented into official SEAMCAT application. Those are important methods both in Europe and in the USA. The enrichment of the software allows to extending SEAMCAT ability. It seems to be interesting to use ITM model because it allows introducing some quantitative values which describing details about terrain in case where no DEM/DTM maps in SEAMCAT are used. Such solution may lead to more detailed EMC calculations increasing spectrum efficiency in the areas where some special terrain obstruction exists and where no such detailed terrain descriptions were possible.

In the National Institute of Telecommunication Poland, the P.1546-4 method with digital terrain map reading ability for SEAMCAT have been also developed as an additional function however such method is not used in official SEAMCAT version. In such case the postprocessing plug-ins were used. It allows introducing coordinates information and attaches maps files and gives an opportunity to make calculation with very good precision between transmitters and receivers, as we can compute the exact great circle distances. It may be interesting for others to use such solution and it may be worth to extend SEAMCAT with such functionality.

In future, it could be expected that SEAMCAT developers offer ability of using more then three user-defined parameters for propagation plug-ins in order to offer usage of advanced many-parameters propagation models as it was in the case of ITM model.

These days where more and more different wireless systems are introduced in the same or adjacent frequency bands such open, powerful and flexible software for electromagnetic compatibility analysis is very useful on research, scientific or radio spectrum policy levels as well as for preparation the decisions about introducing new radio systems which should be well prepared after such detailed EMC analysis performed and proper results-evaluation.

Acknowledgment

The paper is prepared under Research Project entitled: "Next Generation Services and Networks – technical, application and market aspects" contracted by the Polish Ministry of Science and Higher Education (no. PBZ-MNiSW-02/II/2007), authors: J. Sobolewski, D. Więcek, J. Wroński, B. Gołębiowski, D. Niewiadomski, R. Strużak, and D. Wypiór.

References

[1] D. Więcek, B. Gołębiowski, J. Sobolewski, and D. Wypiór, "Opracowanie i oprogramowanie modułów aplikacji SEAMCAT do wykonywania symulacyjnych badań kompatybilności międzysystemowej", *Conference PBZ-MNiSW-02/II/2007*, Warszawa, Polska, 2010.

[2] www.seamcat.org

[3] SEAMCAT Handbook, January 2010, www.ero.dk/seamcat

[4] A. G. Longley, "Radio propagation in urban areas", OT Report 78-144, 1978.

[5] G. A. Huffor, A. G. Longley, W. A. Kissick, "A guide to the use of the ITS irregular terrain model in the area prediction mode", NTIA Report 82-100, 1982.

[6] "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz", ITU-R 1546-4, Geneva, 2009.

[7] J. Sobolewski, D. Więcek, J. Wroński, B. Gołębiowski, D. Niewiadomski, R. Strużak, and D. Wypiór, "Sprawozdanie merytoryczne nr 4 i nr 5 z realizacji części Projektu Badawczego Zamawianego Usługi i sieci teleinformatyczne następnej generacji – aspekty techniczne, aplikacyjne i rynkowe", IŁ PIB, O/Wrocław, 2011.

[8] "Compatibility between mobile radio systems operating in the range 450-470 MHz and digital video broadcasting – terrestrial (DVB-T). System operating in UHF TV channel 21 (470–478 MHz)", ECC Report 104, Amstelveen, June 2007.

Dariusz Więcek received the M.Sc. and Ph.D. degrees in Telecommunications Engineering from Wrocław University of Technology, in 1992 and 2006, respectively. He joined National Institute of Telecommunications Poland in 1993 where currently he is Head of Spectrum Engineering and Management Section. His research areas include radio systems networks planning and optimization, broadcasting systems, compatibility analysis of different radio systems, cognitive radio, opportunistic and white space radio, dynamic spectrum access and spectrum engineering and management on national and international (CEPT, ITU, WRC, IEEE) levels. He was involved in preparation of the digital broadcasting switchover strategy in Croatia and digital plans in Poland. Dr. Więcek is member of Management Committee COST IC0905 (TERRA – Techno-Economy and Regulatory Aspects of Cognitive Radio Systems). He manages many projects for companies from telecommunications industry sector. He was delegate of the Republic of Poland to the conferences: ITU WRC2007, ITU RRC06, ITU RRC04, ITU WRC2000, CEPT Chester97, CEPT Wiesbaden95. He is member of Section of Electromagnetic Compatibility of Electronic and Telecommunications Committee of the Polish Academy of Science (PAN), senior member of IEEE and v-Chair of Polish Chapter of the IEEE EMC Society. He takes part in reviewing and evaluation process of EU research projects. Dr. Więcek chaired organizing committees of the Wrocław International Symposium and Exhibition on EMC in years 2002 and 2004. He was published more than 40 scientific papers in journals and conference proceedings.

E-mail: D.Wiecek@il.wroc.pl
National Institute of Telecommunications
Swojczycka st 38
51-501 Wrocław, Poland

Dariusz Wypiór received the B.Sc. in Electronics and Telecommunications from Wrocław University of Technology, in 2010. Currently he is with the National Institute of Telecommunications Poland where he works as an research engineer in the Electromagnetic Compatibility Department, Spectrum Management and Engineering Section. His interests cover propagation modeling, radio networks planning, spectrum engineering and software development.

Email: D.Wypior@il.wroc.pl
National Institute of Telecommunications
Swojczycka st 38
51-501 Wrocław, Poland