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BUDAPEST

The use of propagation prediction programs for the purpose of detection of PMR devices

Balog Károly[1]

Abstract:

In these days, both the licensed and license-free PMR radio technology is going through massive paradigm shift as formerly seen at mobile phone technologies. In fact, the new types of digital PMR systems today show a significant relevance in practice. Since these devices can completely bypass the traditional telecommunications infrastructure, their detection and control is only possible by communication intelligence.
In this article I present the results of simulation experiments carried out with a radio propagation prediction program, built upon the theoretical basis I summarized in my previous article. I examine the operation of the selected program and its applicability in communication intelligence, which helps optimize the installation site in practice.

Keywords: PMR, digital PMR, simulation, RF propagation prediction programs

Absztrakt:

Napjainkban az engedélyhez kötött és engedély nélkül is üzemeltethető PMR rádiótechnológia a mobiltelefonoknál már megtapasztalt paradigmaváltáson megy keresztül. Az újfajta digitális PMR rendszerek napjainkra jelentős elterjedtséget mutatnak a gyakorlatban. Mivel ezek az eszközök a hagyományos távközlési infrastruktúrákat kikerülhetik, felderítésük, ellenőrzésük adott esetben kizárólag a rádiófelderítés eszközrendszerével történhet. Cikkemben egy rádiófrekvenciás terjedés becslő programmal elvégzett szimulációs-kísérleteim eredményeit mutatom be, az előző cikkemben[2] összefoglalt elméleti alapokra építkezve. A kiválasztott program működését és alkalmazhatóságát vizsgálom a polgári rádiófelderítés támogatásában, amely a települési hely optimalizálását segíti elő a gyakorlatban.

Kulcsaszavak: PMR, digitális PMR, szimuláció, RF terjedésbecslő programok

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[2] Balog Károly: Térinformatika alkalmazása a PMR eszközök rádiófelderítésében, Nemzetbiztonsági Szemle 2016/1. szám

1. Introduction

The focus of my research – within the field of signal intelligence – is the communication intelligence by national security agencies, and I especially deal with the problem of the detection of license free or illegally used PMR devices. In our days it is without doubt that geographic information programs or systems (GIS) are necessary for the proper fulfilment of communication intelligence by national security agencies. Therefore the question occurs in a different way, namely which programs or systems have extra capabilities or technical novelties, and how much they are worth spending on in light of the compatibility with the existing devices or systems. In the first part of this article, I examined the applicability of GIS system devices concerning the planning and fulfilling of signal intelligence, then I scrutinised the relevant theories, propagation models, and scientific considerations. In this article – based upon the previous one, without a description of fundamental terms – I present the results of the simulation experiments carried out by a chosen RF propagation prediction program. I examined the effects of the environment and the parameters of the intelligence devices on the intelligence capabilities of PMR devices. I especially focused on the optimization of the installation site and determining of operating range.

2. Selection of the program, and advantages of the cloud based GIS system

The application of cloud based graphical databases and map softwares (Google Earth, OpenStreetMap etc.) – mentioned in my previous article – have become widespread in practice because the maps themselves cost the most in the case of GIS systems. Due to this fact, numerous applications – even professional ones – are used, reducing the cost with significant amount. However, in this case permanent on-line availability is required, which is not considered an extreme requirement, thanks to the opportunities of info communication nowadays. Moreoever, these systems can usually be used off-line (with downloading map sheets in advance) as well but some precognitions are necessary therefore.

The second great advantage of these maps – beyond being quasi free of charge – is compatibility. They support open-source data exchange format (for examples KML[3]), and standardized interchange format of building data (for examples COLLADA[4]). This makes it possible for the outcome results are applicable

[3] *KML: Keyhole Markup Language – Google xml based open source data exchange format*

[4] *COLLADA: quasi-standard exchange format of vector based digital 3D (building) models*

in other systems, or the measuring results to be visualised through it, which is an active cooperation with these two systems.

In my previous article I divided the feasible tasks of the communication intelligence activity supported by GIS into two parts. One of them was the preparational and planning-, the other one was operational phase. This causes significant differences in the fulfilling of tasks and applied GIS programmes as well. In this article I merely scrutinise the tasks of planning for which we can apply radio frequency propagation prediction programs, used in the civil life as well. The cloud-based systems have more benefits compared to the others and therefore they can provide advantages during their application, due to the aforementioned reasons. If the program has a mobile and a desktop version, we can reach the operational data prepared in the office from the field, or the instant preparation is possible during an operational action even by using a mobile phone.

Such special cloud based GIS systems are available in different format and scales, not just for the planning software, but for the intelligence supporting special defence software as well. The advantages of the combined application of these models are presented in the figure 1. That is to say, the usage of integrated applications in different platforms; a support system for complex intelligence, analysis and operation implementation exploiting the cloud based storage, content management and sharing.

Because of this, for the simulations I looked for a reasonable priced cloud based program which supports operation planning, and contains basic functions which can be necessary for the planning of intelligence of PMR devices.

For the fulfilment of the task, in the case of narrowband signals – beside the simple building geometry – empiric and semi-empiric models are used in practice. The application of deterministic models is necessary because of the increasing complexity of building geometry, and the characterization of wideband and time variant of the radio channel. According to the literature[5], in the case of digital PMR – because of the narrowband signs – the scale of acceptable delay spread on radio channel (because of the multipath propagation) is between 50-100 µs, while in the case of GSM this figure is only 16 µs, though a faster movement- and data transfer speed is associated there to. This figure represents the sensibility of the relevant system to distortions caused by multipath propagation (bit error). From the aforementioned data, we can see that the digital PMR-s are less sensible to the effects of the multipath propagation than the GSM system. Still the experience shows that the high buildings have significant shadowing effect, especially in the case of detection of low transmission power devices. That was the reason why I chose a program which is able to take into account individually the deterministic effect of 3D objects, higher buildings, or shadowing

[5] *Hans-Peter A. Ketterling: Introduction to Digital Professional Mobile Radio. Artec House, 2004. (p. 18.)*

landmarks with the assistance of semi-empiric models based upon empiric propagation.

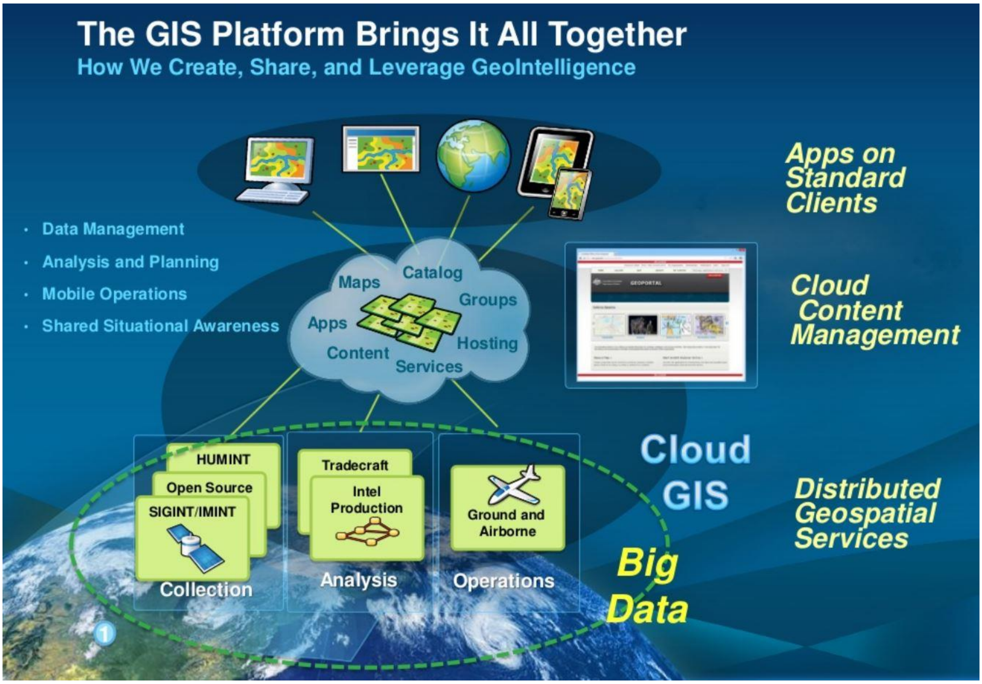


Figure 1*.* Advantages of application of the cloud based GIS[6]

The program – which I tested and satisfied the above mentioned criteria – was a commercially available could-based SaaS[7] solution, the ClouldRF application made by the English Farrant Consulting Ltd. Below I present the program itself and the fulfilment of the simulation tests carried out by the program.

3. Presentation of CloudRF program

The CloudRF program[8] is a commercially available cloud based GIS program which greatly builds upon open-source elements. The program can be used for planning of radio-frequency propagation and its main advantage is the flexibility. It has a desktop thin client HTML5 base web-interface and a Keyhole Radio An-

[6] *John Day (ESRI India), GIS as a Platform For Special Forces, Geo Intelligence India (Geospatial-Force Multiplier for Modern Warefare) New Delhi, India, 2013. 06. 13-14. http://www.slideshare.net/EsriIndia/gis-as-a-platform-for-special-forces (2014. 12. 05.)*

[7] *SaaS: Software as a Service*

[8] *CloudRF Online radio planning, https://cloudrf.com/ (2016. 05. 31)*

droid application. In addition, after downloading a special Google layer (Keyhole Radio KML) it is able to connect to the interface of the Goggle Earth Pro program, where we can plan interactively. The functionality of user interfaces are nearly the same (with minor differences) thus I present the configuration options based on the print-screen images of the web interface shown in the figure 2. and I will adress the differences on the concerning interfaces further on.

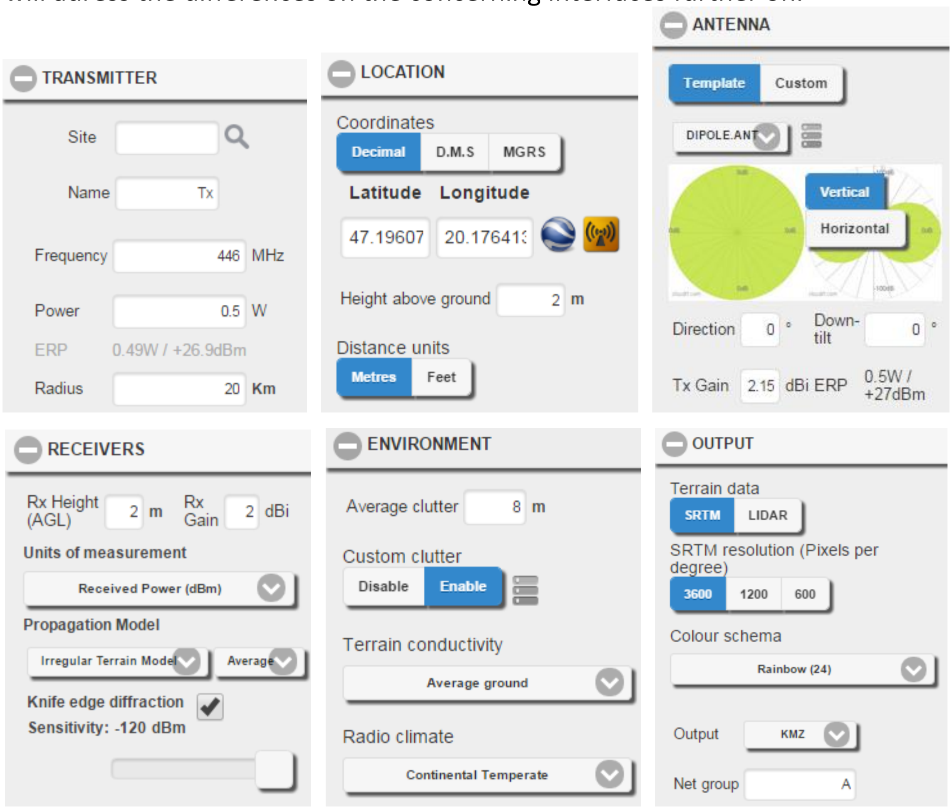
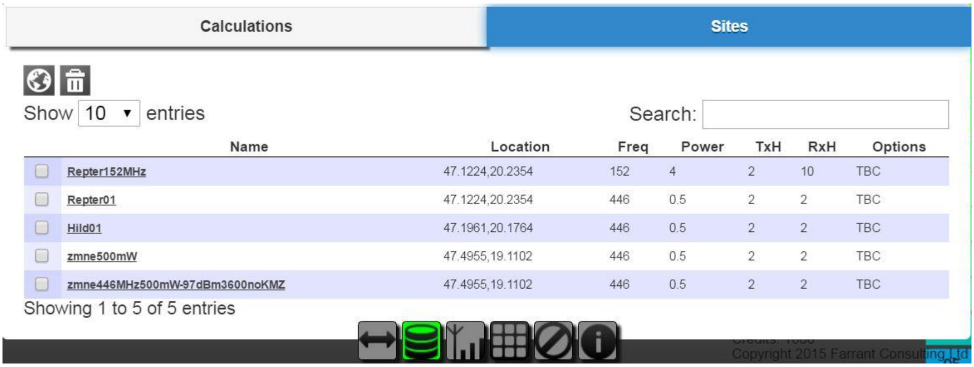


Figure 2. CloudRF web-client interface menu (print-screen from the program, made by the author)

Under the "**Transmitter**" menu we can set up the frequency of the transmitter (20 MHz-100 GHz), the transmitter power (10mW-5MW) and the radius of simulation calculation (max 300 km). In the Site and Name field we can search the previously saved parameters of the transmitters or we can load and save these data there from the cloud. In the figure 3. we can see the list of the saved transmitters, which can be displayed by the "Archive" icon lighting with green. There is an opportunity to delete the saved transmitters (dustbin icon) or the reloading of the parameters of transmitters (earth icon) as well.


Calculations | Sites

Show 10 entries | Search:

Name	Location	Freq	Power	TxH	RxH	Options
Repter152MHz	47.1224,20.2354	152	4	2	10	TBC
Repter01	47.1224,20.2354	446	0.5	2	2	TBC
Hild01	47.1961,20.1764	446	0.5	2	2	TBC
zmne500mW	47.4955,19.1102	446	0.5	2	2	TBC
zmne446MHz500mW-97dBm3600noKMZ	47.4955,19.1102	446	0.5	2	2	TBC

Showing 1 to 5 of 5 entries

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Figure 3. Web interface archive data, list of the saved transmitters (print-screen, made by the author)

Under the "**Location**" menu the coordinate of the transmitter can be set up in three different formats, beyond the two traditional ones, in the format of NATO used MGRS[9] as well. Moreover it is possible on the map in an interactive manner. If we click to the Google Earth icon the set up coordinate will be synchronized on the Keyhole Radio layer. By clicking on the little yellow transmitter icon, we can turn on or off a sign on the web interface which shows the place of the transmitter (with the same icon format) on the map. The height of the transmitting antenna above the ground and its measure unit can be set up here as well.

Under the "**Antenna**" menu the type of the transmitter antenna and its other data can be set up. We can choose from predetermined types (224 pieces) but there is opportunity to set up and upload the radiation pattern of our own 3D antenna (setting up the direction, antenna down-tilt, front to back ratio). In addition, the polarization of the antenna can be decided (vertical or horizontal), finally the antenna gain (Tx Gain) can be set up in dBi (0-50). The set up gain automatically changes the value of the radiated power (ERP[10]) under the antenna and transmitter menu as well. If we manipulate this value we can take into consideration the other gains and losses existing in the system for examples cable losses.

Under the "**Receiver**" menu we can set up the height and the gain of the receiver antenna, one of the nine predetermined propagation model applied for simulation, plus we can choose from three methods in each model: conservative, average or optimistic computational method. The specification of the predetermined propagation models is available on the homepage of the software[11]. For the purpose of universal application of the program, the predetermined

[9] *MGRS: Military Grid Reference System*

[10] *ERP: Effective Radiated Power*

[11] *CloudRF Propagation Models: https://cloudrf.com/propagation%20models (2016. 05. 31)*

propagation models cover the wide range of wireless methods. From the fitting types, the semi-empiric ITM [12] 7.0 model and its advanced version the ITWOM[13]3.0 (which has the most effective obstruction handling function) are the most proper model for the detection of PMR devices. The ITM is basically a Longley-Rice model which was developed by the NIST[14] USA in the sixties and it is applicable from handheld PMR devices to the microwave systems, from 20 MHz to 20GHz. The model is able to calculate on the average height of ground clutter and the effect of diffraction propagation. But in the case of the new types of communication systems where the average heights of the antennas are often on a very low level, this model counts quite incorrectly, especially regarding the shadow effect of the buildings being close to the antenna. That was the reason why the enhancement of the model was decided in 2008. In the new model, the Radiative Transfer Engine (RTE) – which takes into consideration the principles of wave optic – is used for computing more correctly the effect of close clutters to diffraction and refection in the case of lower antenna height[15]. The accuracy of the new advanced model was confirmed by the direct measurements which were conducted by experts [16].

The output data of the result of the simulation and the units of measurement can be set up as well: the received performance in dBm, path losses in dB, received field strength in DbμV/m or in BER[17]%. We can take into consideration – by ticking the diffraction – the knife-edge diffraction of the obstructions which penetrates into the Fresnel zone of connection (this is default in ITM models) and we can set up the sensitivity of the used (intelligence) receiver in a scale which is between 20 and120 dBm.

Under the “**Environment**” menu we can define the average clutter of terrain obstacles or special man-made custom clutter which can be saved in KML files

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[12] *ITM: Irregular Terrain Model*

[13] *ITWOM: Irregular Terrain Model with Obstruction*

[14] *National Institute of Standards and Technology (USA)*

[15] *Sid Shumate: Deterministic Equations for Computer Approximation of ITU-R P.1546-2, International Symposium on Advanced Radio Technologies, ClimDiff 2008 and The Working Party Meetings for ITU-R WP 3J, 3K, 3L and 3M hosted by National Institute of Standards and Technology, At Hotel Boulderado, Boulder, Colorado June 2 - 4, 2008. http://www.its.bldrdoc.gov/isart/art08/slides08/shu_s-08.pdf (2016. 05. 31.)*

[16] *Stylianos Kasampalis, Pavlos I. Lazaridis, Zaharis D. Zaharis, Aristotelis Bizopoulos, Spiridon Zettas, John Cosmas: Comparison of Longley-Rice, ITM and ITWOM propagation models for DTV and FM Broadcasting, Conference Paper, June 2013, 16th International Symposium on Wireless Personal Multimedia Communications (WPMC 2013), At Atlantic City, NJ, USA www.researchgate.net/profile/Pavlos_Lazaridis/publication/250615289_Comparison_of_Longley-Rice_ITM_and_ITWOM_propagation_models_for_DTV_and_FM_broadcasting*

[17] *BER: Bit Error Rate*

and for the computing we can upload these data to the cloud. Afterwards I will present the method of the uploading, which carries out on a special uploading homepage. Terrain conductivity (9 predefined measure unit for examples: city, highland, water, forest, wet ground etc). Finally we can set up the type of the climate (continental in our country).

Under the "**Output**" menu we can set up which elevation model should be used by the program. In the case of the newest model, besides the three different resolution elevation model of SRTM[18] (operate upon DEM databases), there is an opportunity to choose and apply the LIDAR[19] based elevation model. In my previous article I presented in detail the LIDAR based ground imaging, nowadays the relevant ground can be imaged in the most accurate manner with this method. But only certain areas of England and London are available in the program. The setting up of resolution of DEM databases significantly influences the computing speed during the simulation proceeding. Most of the simulations which I carried out – even with the best 3600 (approximately 30 m resolution) – took 80 seconds, which can be evaluated quasi real time. This result fell down to few seconds when I reduced the resolution. Obviously, for the LIDAR based computing – which provides 2 m accuracy to the propagation model – more computing time is necessary. Due to the fact that the system is a cloud based system the resource for the computing is provided by the server of the program, not by our own computer, thus the speed rate depends on the current workload of the server and the set up parameters.

Because of the cloud based operation, the program uses its own on-line databases for the computing, so we do not have to have or storage DEM databases in our computer.

The results of our computing will be stored so they will be available and we can reach them easily from any interfaces (figure 4). The result can be download in KMZ[20] file which is visualisable by a Google Earth program, plus we can export the results to the own format of geographic information programs, such as QGIS, MAPINFO and ESRI ARCGIS, as Gtiff or SHP files. There are some other opportunities: we can see the results on the map on-line through a URL link and we can share them with others, or naturally, we can embed them into a HTML website as a final option.

Like the saved transmitters, there is an opportunity to delete the measurement results by picking them one-by-one or to upload them into the map in groups or individually. We can handle the uploaded maps by clicking to the layers icon being on the right upper corner shown in the figure 5. Then we can set

[18] SRTM: Shuttle Radar Topology Mission - Space mission established to produce NASA's open digital elevation database (DEM – Digital Elevation Model)

[19] LIDAR: Light Detection and Ranging – imaging process operating on the principle of light detection and distance measurement

[20] KMZ: Is a compressed zip file which contains for example: icons, 3D objects, etc.

up the visualisation format of the maps on the top of the pull-down list (surface, satellite or LIDAR visualisation). We can delete the downloaded maps of the layer list with the crossed circle icon which is bottom of the screen.

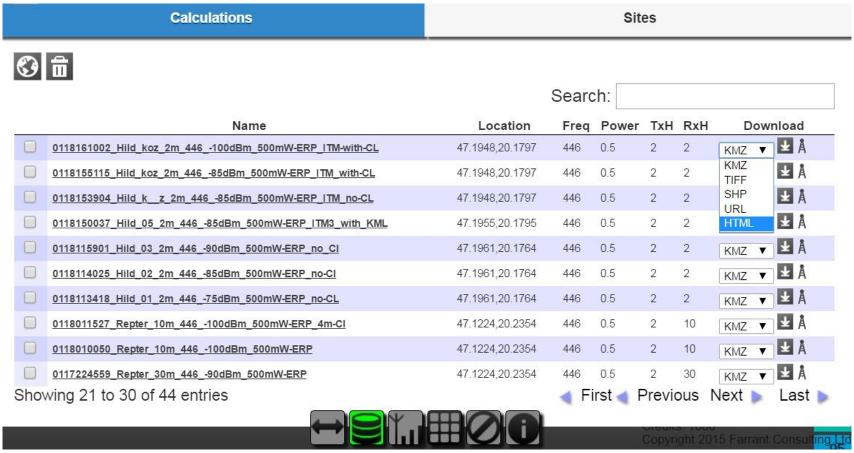


Figure 4. Interface archive data, saved simulations (print-screen, made by the author)

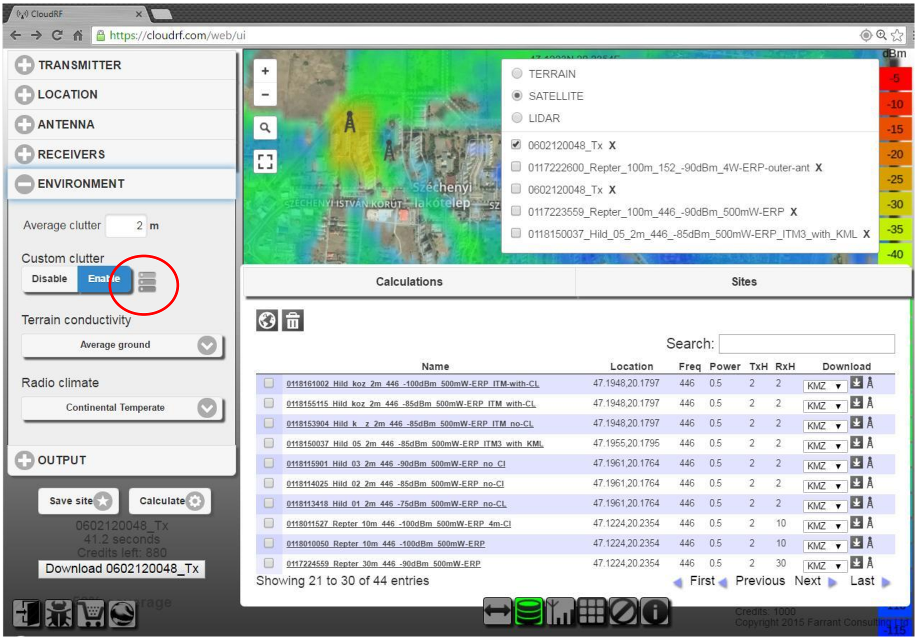


Figure 5. Web interface saved data visualization (print-screen, made by the author)

If we click to the horizontal double-headed arrow icon below the screen, we can examined visibility between two points on the map (between the transmitter and the receiver by default), as the figure 6. shows this. We can see the parameters of the transmitter and the receiver, and the strength of the received signal in the set up measurement unit. The height difference between the two points and the character of the ground between the points are also shown, and the Fresnel zone is visualised as well. The propagation between the two points is modified by the obstacles of natural terrain and man-made objects with which the program calculate during the determining of the received signal.

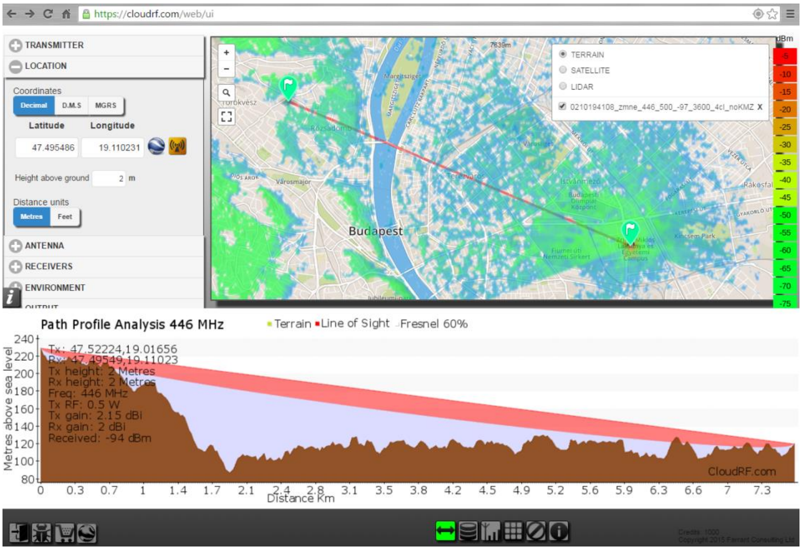


Figure 6. Web interface, propagation profile visualisation (print-screen, made by the author)

The program can be tested for free of charge with restricted capabilities for seven days, so it is definitely recommended to test the paid version. For this purpose there are three different solutions[21]: purchase of the normal, the professional or the credit based version. The website helps us to find the proper solution for us with online price calculation. The first two versions are purchasable for 30 days for the price of 8 or 30 €, to the third version 1000 credit can be purchased for 8 € per unit. In the last case we can use the program until the credit runs out but maximum for one year. Each version has cloud based storage opportunity: the normal version contains 1 GB, the professional version contains 5 GB storage, but for the credit based version we have to buy that. Our data can be stored in this way 1 or 2 years without buying a new subscription. In my opinion it is worth buying the professional version because this contains the ITWOM

[21] *CloudRF, Pricing Plans, https://cloudrf.com/plans (2016. 05. 31.)*

propagation model – besides the credit based version – which provides the best results in the case of PMR proximity simulations. In the following I will present my results and experience of the simulations carried out by the program.

4. Presentation of simulations carried out by the CloudRF program

Preparation of the simulation, definition of building data

During the simulations I wanted to examine the capabilities of the program and to discover its potential to fulfil the appointed tasks. This was the facilitation of the installation site selection and its examination during the preparation for the intelligence of PMR devices. My purpose was that to compare the capabilities of the built-in ITM and ITWOM propagation model which are the two most proper propagation models for the examination of the RF propagation, especially by focusing on the different receiver sensitivity, height of the receiver antennas, and different terrain obstacles. The propagation can be characterized effectively with the support of the empiric element of the built-in ITM model in the case of open spaces or between low buildings in the suburb, if we take into consideration the three resolution DEM elevation databases and average clutter of terrain obstacles on the ground.

However I wanted to examine the capabilities of the program in an urban environment. I was wondering how high row-buildings can influence the receiving of an average 500mW PMR radio device, which is located into these high buildings (this is a typical situation in an average urban environment). For this purpose I had to prepare the models of the buildings in the immediate surroundings. A prepared these data series in the software of Google Earth Pro. In the figure 7. a typical area with high buildings can be seen with ten- and four-storey buildings having the height of 35 and 17 meters and with flat roof buildings having the height of 5 and 10 meters.

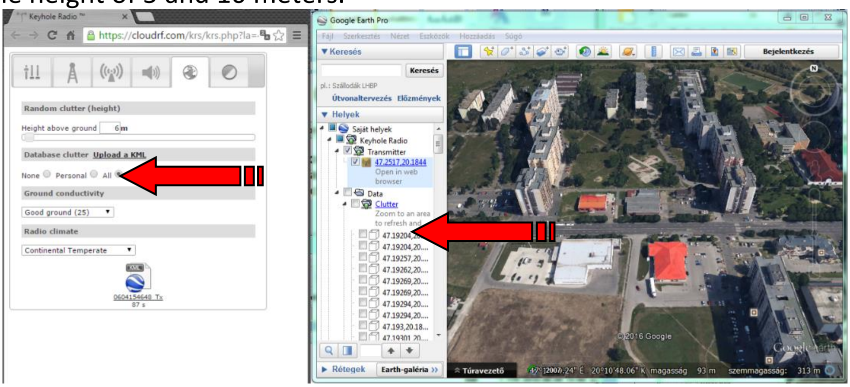


Figure 7. Area of the measurement and the "custom clutter" set up on the Keyhole Radio (print-screen, made by the author)

The original 3D building models of the Google are quite detailed and they are textured with the photos of the buildings as well but unfortunately they are not available directly from the program so I prepared the geometric approximation of these.

Around the area of the transmitter, there are four pieces of four-storey buildings having the height of 17 meters, and three pieces of ten-storey building having the height of 35 metres, two detached houses, and four pieces of flat roof buildings having the height of 5-10metres. I registered all of them as polygons characterized by their corner points and their layouts relative to the ground (figure 8.). I designed the row-buildings separately (under the menu of adding, polygon) and saved them one-by-one in KLM format. Then I uploaded the files into the storage of the cloud which was available from the website of the CloudRF under the menu of “Environment – Custom clutter” (figure 5., red circle) or clicking to the upload KML icon of the Keyhole Radio signed with red arrow which can be seen in figure 7. on the left side. In both cases we will reach the uploading page of the program which can be seen in figure 9., and there we can see the data series of two uploaded models on the right side. The uploaded data can be collectively enabled and disabled during computing on the web page (figure 5.), but from the interface of Keyhole Radio the certain uploaded files can be separately enabled (figure 7., red arrow on the right side) under the menu of the “Data – Clutter” of the transmitter. But in this case the simulation hase to be run from the interface of the Keyhole Radio and we have to select the “Personal” icon under the “Database clutter” (figure 7., on the left side) in order to consider the clutters, which are selected on the list on the right side.

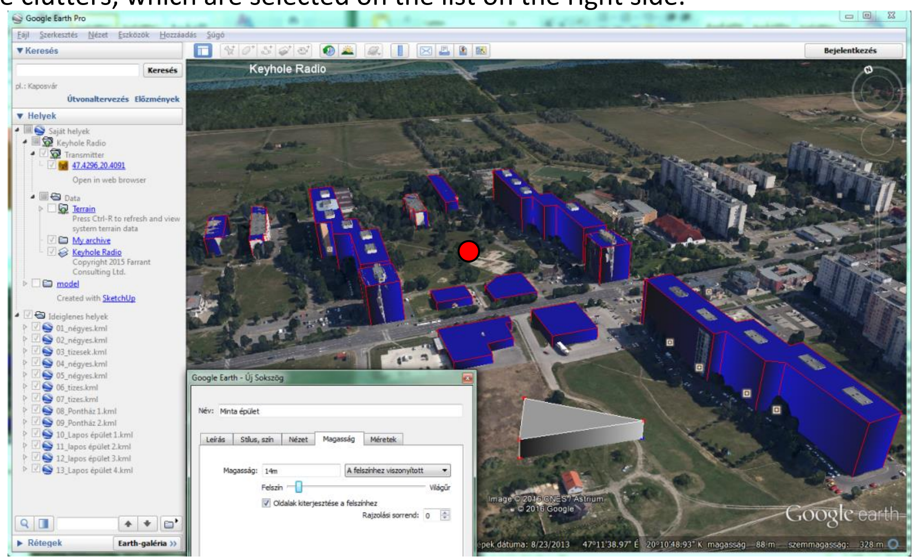


Figure 8. Models of the buildings prepared by myself with Google Earth Pro program and the location of the transmitter (print-screen, made by the author)

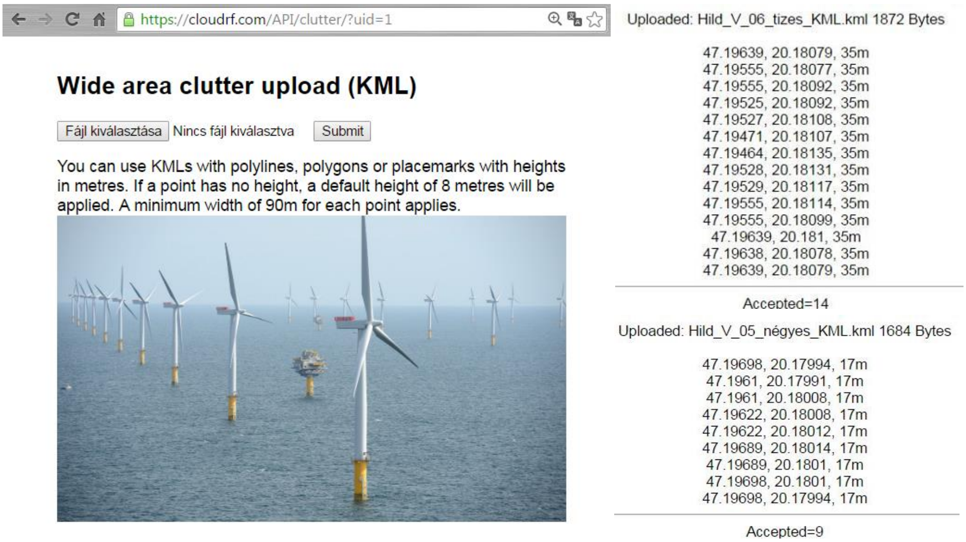


Figure 9. Uploading page of CloudRF KML clutter and the data of one ten- and one four-storey row of buildings, accepted after uploading (print-screen, made by the author)

This means that the web interface is not able to handle the files separately, therefore if we would liked to handle separately the uploaded buildings or objects data or to check their existence during the computing, we definitely have to use the Keyhole Radio interface. But I recommend the use of web interface for the examination of the propagation model because this interface is less complicated is this case.

Simulation carried out in urban environment without building database

First, I examined the results without the buildings which were prepared based upon elevation data of DEM databases and the selected 6 meters high average clutter[22]. I used the following simulation parameters: 2 meters high transmitter antenna (shown red dot on figure 8.), 2 meters high receiver antenna, 446 MHz frequency, 500 mW ERP transmitter power with dipole antenna 2,15 dBi transmitter and 2 dBi receiver antenna gain, -100dBm receiver sensitivity. The simulations carried out by the former ITM and the newer ITWOM models provided the following results.

In the figure 10., it is clearly visible that the ITWOM model overestimates the propagation without the buildings data and in the case of setting up 6 metres high clutters it defines 88% coverage in 10 km radius circle. If we reduce the distance to 5 km, the coverage will increase to 91%.

[22] *Is the height of average terrain obstructions (small buildings, trees, cars, people, etc.) in the field, above geometric height of the ground (DEM value in the given point) .*

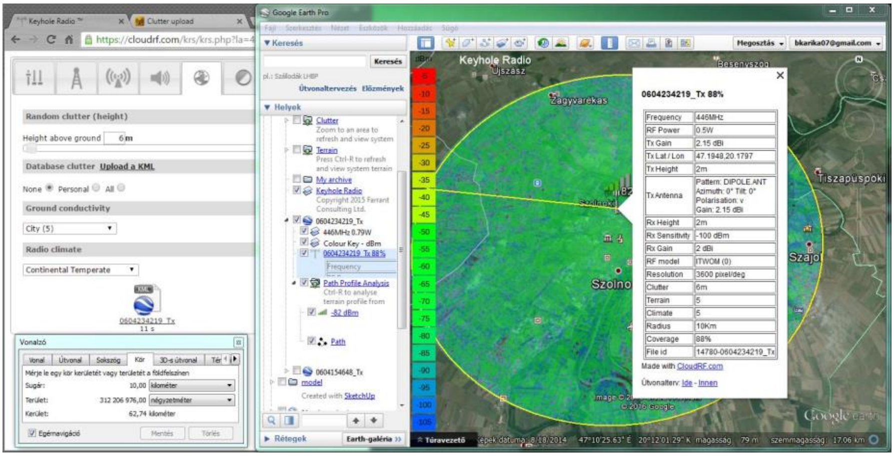


Figure 10. -100 dBm ITWOM model without buildings, 88% coverage in 10 km radius (print-screen made by the author)

If we use the same parameters with the ITM models we will receive more pessimistic but in my opinion more realistic results (figure 11.). In the case of 10 km radius circle and 6 meters high clutter we will receive 6% coverage even if we apply an optimistic setting up (figure 12./a). Taking into consideration these results and drawing a circle by a ruler in the Google Earth based there on, we can reach about over 70% coverage if the distance is 2 km. This hypothesis was confirmed by the measurement, when I reduced the distance to 2 km, the result was 79% (figure 12./b). This method can be used in practice for examples for the determination of the distance's signal detection range in the case of flat surface with low terrain obstacles.

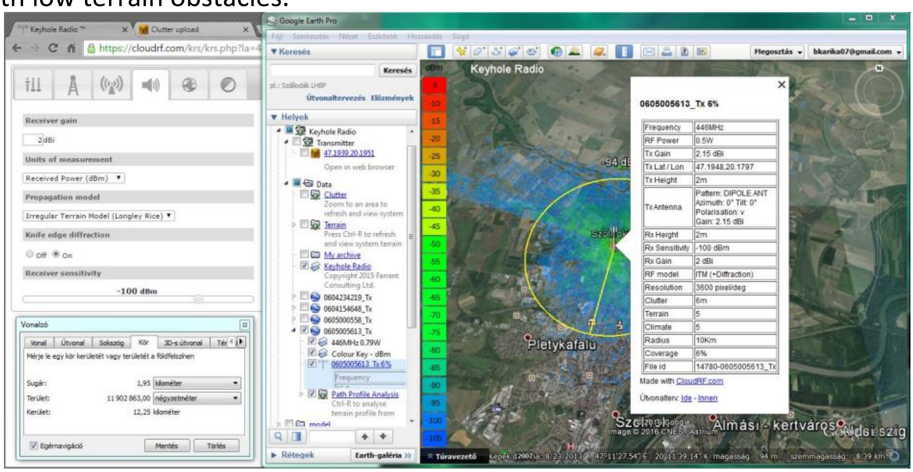
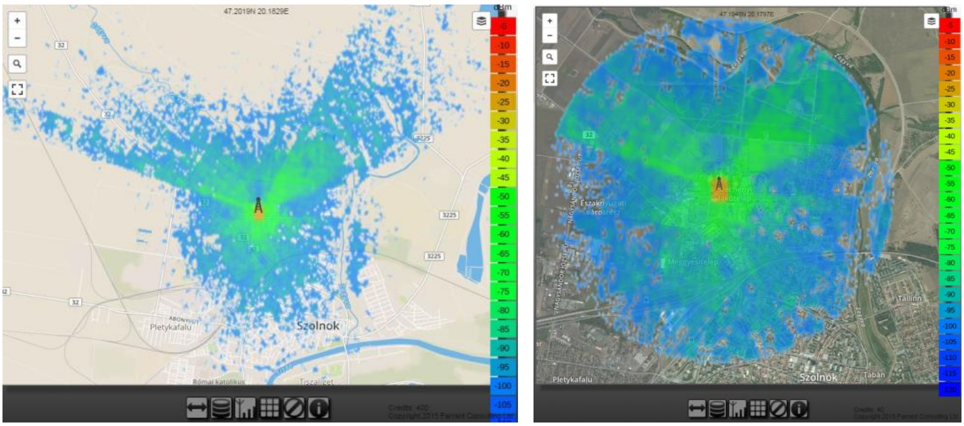


Figure 11. -100dBm ITW model without buildings, 6% coverage 10km radius (print-screen made by the author)



a, -100 dBm, ITM, 10km, 6% b, -100 dBm, ITM, 2 km, 79%

Figure 12.-100dBm, ITM model without buildings, coverage 10 and 2 km (print screen, made by the author)

Simulation carried out in urban environment with buildings

Let us examine the same situation (with the same receiver parameters and environmental data) with the two models considering the KML buildings data which I prepared and uploaded to the website.

First I carried out the simulations with the ITWOM model. The coverage with buildings provided more realistic figures in the case of 10 km radius, this result was only 42% as we can see in the figure 13. Later on I expanded the buildings with the highest object of Szolnok which was a high-rise having the height of 76 metres which reduced the coverage only with 2% to 40% in the 10 km radius.

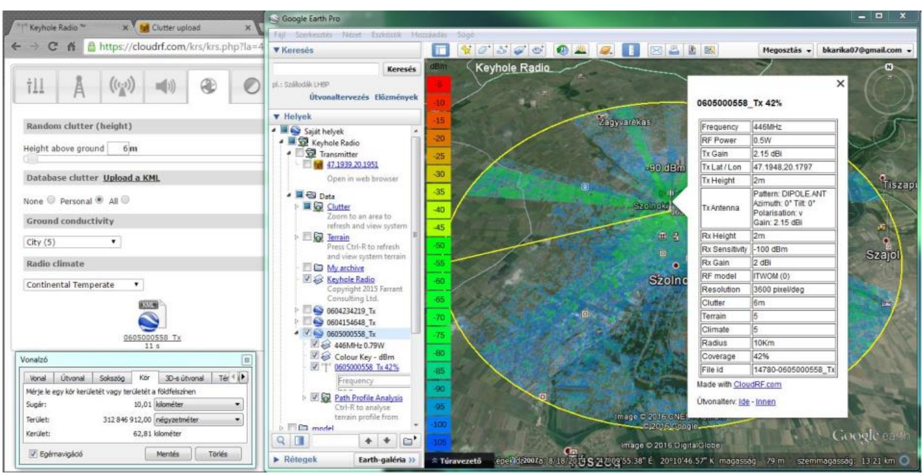


Figure 13. -100dBm with buildings 42% coverage 10km radius (print screen, made by the author)

This result proved that the proper imaging of the close area to the transmitter is more relevant from the view of propagation accuracy than some single but high objects in the distance. Even if they are very high – in the present case the high-rise was 76 metres high – they have less influence because of the distance.

Then I reduced the measurement area of the simulation from 10 km to 5 km radius where the coverage was 64% with the effect of the high-rise. This is shown in figure 14.

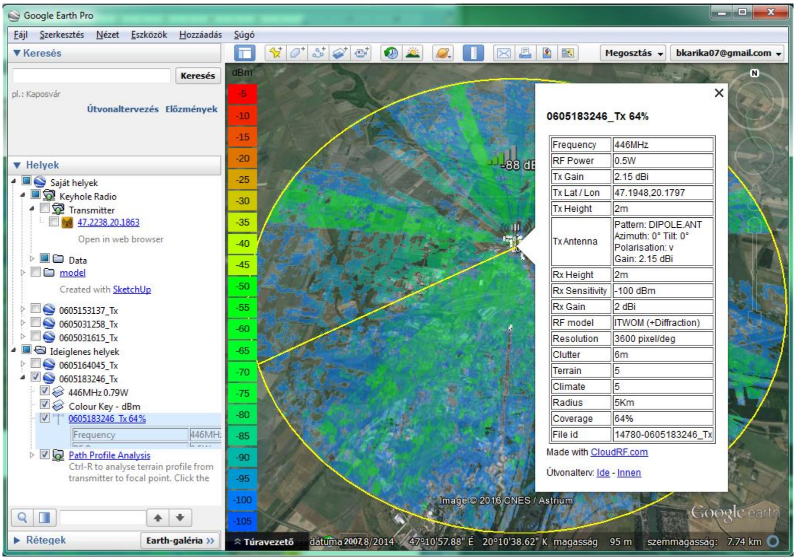
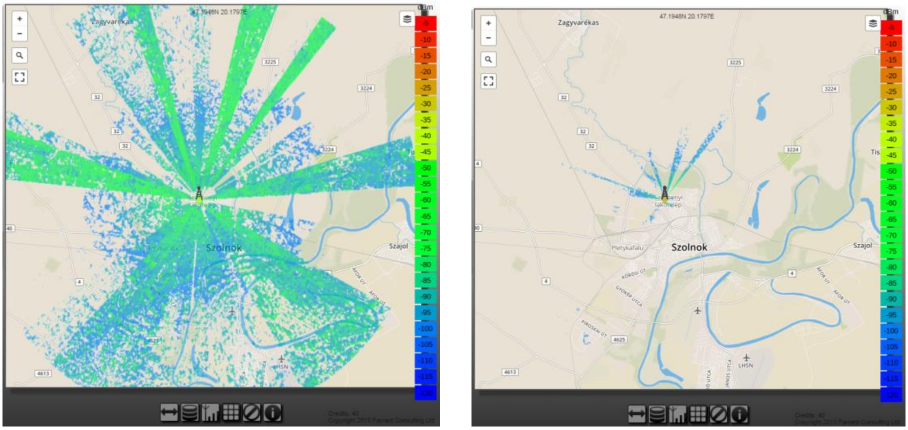


Figure 14. -100dBm with buildings + high-rise 64% coverage 5km radius (print screen, made by the author)

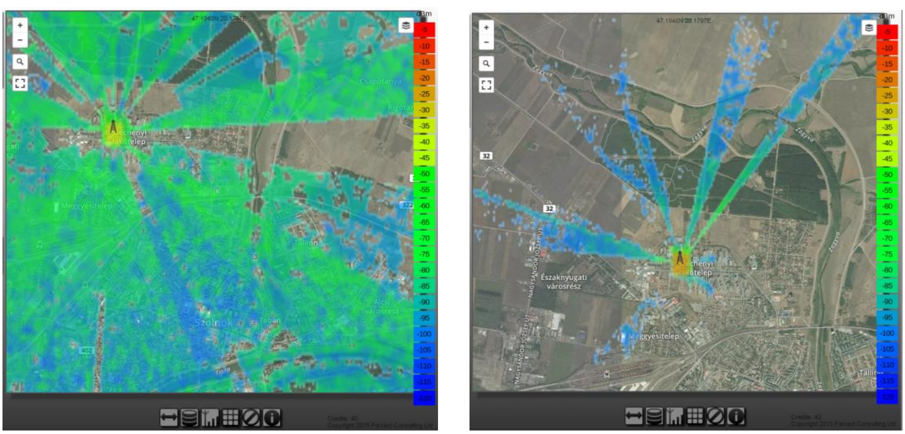
After that, I carried out the coverage computing involved the buildings by the ITM model and compared the received results with the results of ITWOM model.

After scrutinizing the results – from the near and from the further distance - of the simulations, we can find that the ITWOM model counted more correctly the effect of the high buildings close to the transmitter then the former ITM model, but in my opinion it again overestimated the distance in this situation. In the pictures of comparison we can see next to each other the area of the proportional (figure 15.) and the transmitter close data (figure 16.) of the two simulations. The results we received with the ITM simulation are more pessimistic again than what we reached with the new model. With the same parameters we can received 5% coverage in 10 km radius comparing to the 42% of ITWOM model. The ITM model is quite inaccurate in near field because the buildings located to south from the transmitter are not able to shadow to that extent that we can see in the figure 16./b. According to this picture very low level of energy can reach this area.



a, ITWOT, -100 dBm, 10km, 42% b, ITM, -100 dBm, 10 km, 5%

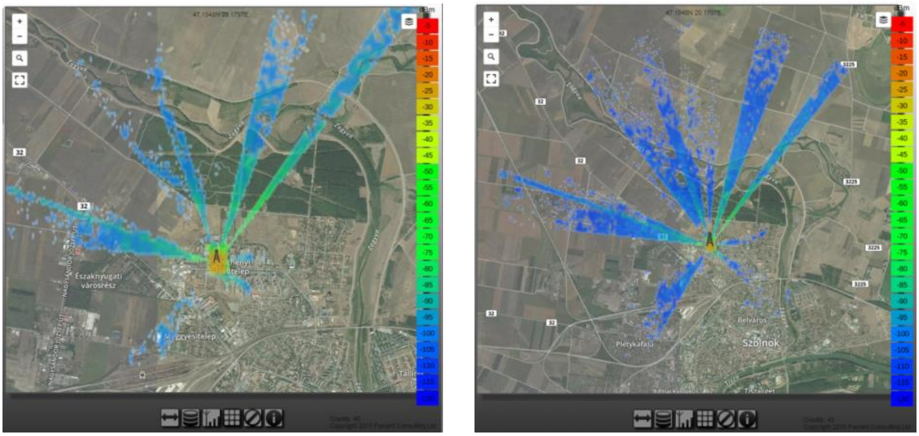
Figure 15. proportional comparison of ITWOM and ITM simulation
(print screen, made by the author)



a, ITWOT magnified b, ITM magnified

Figure 16. Comparison of simulations of the models in near field
(print screen, made by the author)

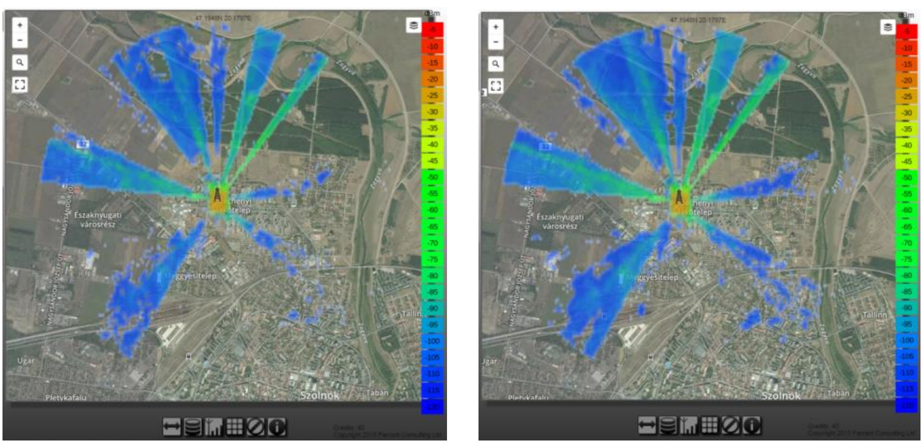
Testing the ITM model, if we set up the receiver sensitivity more sensitive – by increasing it to - 110 dBm – the results start to get better but the coverage is still on a very low level: 5 km 12%, and 2 km only 35% (figure 17./b, 18./a,). If we intend to continue to increase the results properly we can do that by setting the receiver antenna in a higher position or applying a directional antenna (increasing the antenna gain). When using a directional antenna we have to have detailed knowledge concerning the location of the target device for setting up the direction of the antenna. The antenna lifting is also problematic, one of the problems is the operational reason (losing the mobility with fix installation site), the other is that if we keep the mobility we have to face physical (antenna mast) and operational (concealment) obstacles as well. Further I will concentrate on the examination of the effects of antenna lifting.



a, ITM, -100dBm, 10km, 5% b, ITM, -110dBm, 5km, 12%

Figure 17. The effect of the increase of the threshold of the receiver (print screen, made by the author)

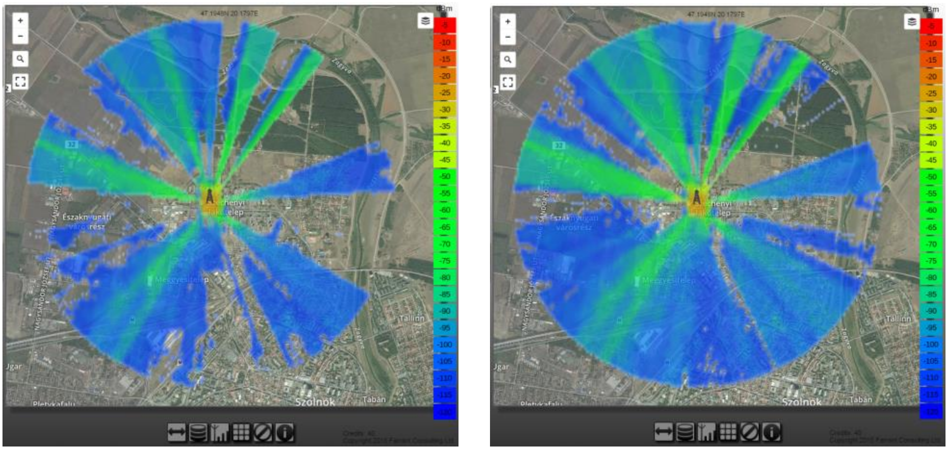
First I lifted the height of the receiver antenna to 5 meter (semi-mobile circumstance) then to 17 and finally to 35 meter which heights were the same as the four- or ten-storey buildings had nearby (stationer circumstance). The results can be seen in figure 18. When the height of the antenna was 2 meter the coverage was 35 % in 2 km radius, but when the height of the antenna was 5 meters the coverage reached the 41%.



a, ITM, -110dBm, 2km, 2m rec. ant., 35% b, ITM, -110 dBm, 2km, 5m rec. ant., 41%

Figure 18. The effect of the lifting of the receiver antenna (print screen, made by the author)

If we want to increase the height of the antenna, it is possible by losing flexibility and if we choose a fix installation site, for examples: by setting up antennas on the top of buildings. We can check the results received that way in figure 19. The coverage was 63% when the receiver antenna was on 17 meters high, and this figure was 82% when the antenna was on 35 meter high in 2 km radius. The number of the uncovered zones and directions were radically decreased in that case.



a, ITM, -110dBm, 2km, 17m rec. ant., 63% b, ITM, -110 dBm, 2km, 35m rec. ant., 82%

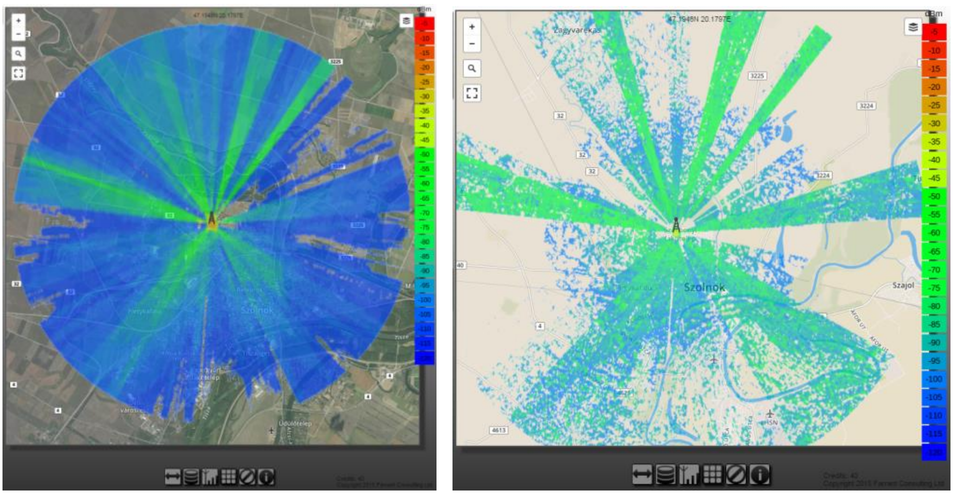
Figure 19. the effect the further lifting of the receiver antenna (print screen, made by the author)

If we continue to increase the height it is possible with special methods, for examples a remote controlled or wired payload installed on some aircraft (UAV or small airship hanging in one place or balloon) or a remote controlled device placed on the top of an extremely high tower or high-rise. The solution of the high-rise brings a new aspect to consider, which is distance, this distance from the target site was 2 km in our case, however, we can count with a significant increase thanks to height which is 76 meter. Let us increase the distance to 5 km and see the results. The 78% coverage which we can see in figure 20/a. speaks for itself. There are hardly any uncovered zones and it is clearly seen that the distance of the signal detection is far beyond the border of the illustrated 5 km zone.

There is a very similar situation to this in figure 6., where a 500 mW transmitter in Pest sends radio signals which are receivable from the side of Buda from 7 km distance because there is 100 meter difference in height and there is a direct physical line of sight. I had no intention to examine the other parameters of the receiver which can influence radio receiving (intermodulation distortion) or the effect of the physical radio environment, for example the effects of the close transmitters operating on the same or close frequency in a certain band. Obviously they provide different influences besides different traffic load of radio environment but the theoretical possibility of the receiving is given. Without calculation: a 500mW PMR with a -107 dBm sensitivity receiver in the case of direct line of sight (taking into consideration the free space loss) calculating with 20 dB fading margin, approximately provides 25 km propagation distance. This theoretical result can be confirmed in practice if there is LOS[23] and the radio environment is quasi sterile. In reality it is almost unachievable.

Comparison of ITM and ITWOM models

If we compare the improved results (with antenna lifting and increasing the sensitivity of the receiver antenna) of the ITM model to the results of ITWOM model (figure 15./a,) – see this in the figure 20. – we can declare that the main routes of the energy propagation (green beams with more energy) are similar to each other. There is a significant difference in the case of homogeneity of zones with lower signal (bluish shade), which do not have direct line of sight visibility (NLOS[24] case).



a, ITM, -110dBm, 5km, 76m rec. ant., 78% b, ITWOT, -100 dBm, 10km, 42%

Figure 20. The effect of the further lifting of the receiver antenna (print screen, made by the author)

The strength of estimation skills of ITWOM model is the more accurate calculation with NLOS energy covered zones, taking into consideration the diffraction or other principles of wave optic. It is obvious that this model is the better one for the combined use with building data and for defining the optimal inter-

[23] *LOS: Line of Sight – direct visibility between transmitter and receiver*

[24] *NLOS: Non Line of Sight – non direct visibility between transmitter and receiver*

ception direction. However in my opinion – in its present condition – it slightly overestimates the propagation distances. This can be corrected/calibrated by setting up of the sensitivity of the receiver (checked by measurements in practice) during the simulation for the purpose of receiving more accurate results. With this method the ITWOM program can be more applicable not just for defining the proper interception areas and directions but for defining the signal detection range more accurately. But the ITWOM model is under development so it is conceivable that the accuracy of implementation in the software will be corrected/calibrated.

The ITM model is the better one for defining the propagation circumstances in the case of relatively flat ground without bigger terrain obstacles but its accuracy is restricted in the case of combined counting with building data.

We can see in figure 20./b, that if the height of the receiver antenna is 2 meters, the target radio can be detected in a relatively wider range from south, taking into consideration the elements of mobility of both our own and the target radio. But if the concealment or the further distance is the relevant aspect, one of the north beams can be appropriate as well in the case of non moving target. In the case of moving target, main beams can vary.

5. Summarized findings

According to the literature and my experience, the transmitter power of an average PMR is between 27 and 40 dBm. I examined the propagation circumstances for the lowest figure that is 27 dBm transmitter power, for which I used two different propagation models namely the ITM and ITWOM and I used them first as an empiric model in an urban environment without buildings data, then as a semi-empiric model with buildings data created by myself.

After the analysis of the results of simulations I came to the conclusion that the calculations with buildings data provide more accurate results for preparation of near field communication intelligence than without these data.

The ITWOM model is definitely more appropriate for combined use with buildings data and for defining the optimal installation site and interception area/direction. In my opinion we can reach better results concerning the accuracy of the simulations if we check the results by measurements in practice and we calibrate the settings up of the model according to these.

In the case of mobile and ground intelligence devices a slight increase in the height of the antenna can only happen at the expense of concealment and mobility, or an even greater lifting can only be carried out by installing the antennas of stationary equipments on the top of high buildings, completely losing mobility with this solution.

The requirement that that the communication intelligence shall comply with the requirements of eavesdropping and accuracy is a basic expectation which can be a relatively achievable task with fixed installation systems if we select a proper installation site. In the case of ad-hoc field operational conditions we have to satisfy numerous other requirements which, however reduce technically and geo-informatically optimal RF visibility and accuracy. We have to consider the necessity of the proper camouflage or in an urban environment the rules for parking and traffic direction or that in the countryside the installation site shall be easily approachable on a good quality road.

The installation site - preventing deconspiration – cannot be closer than a certain distance to the place of transmitting. So if we want to keep in mind the operational aspects then the softwares similar to CloudRF can support our operational planning and fulfilling tasks on a significant level.

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