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Softwares for urban electromagnetic wave propagation modeling

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Abstract — **A few commercial softwares for computations of urban electromagnetic wave propagation have been considered and analyzed in this paper. The paper discusses the basic characteristics of several leading international softwares for wave propagation modeling with a focus on the urban environment. The basic principles of work, frequency range, used tools, possibilities and options for successful wave propagation prediction are given. All the necessary input data, the form in which they should be and all output and analysis options are enumerated as well. Three program predictions for Banja Luka city are given in this paper. The accent is put on Wireless InSite propagation software tool, as it was available most of the time. Finally, a brief comparison and analysis of softwares was made in some segments.**

Keywords — ***Software packages; Electromagnetic wave propagation; Urban environment.***

I. INTRODUCTION

Nowadays there are many of wave propagation calculation tools for planning of mobile wireless networks. All softwares are dealing with precise wave propagation calculations for urban scenarios described by a building database. Different software packages require somewhat different formats for the data. However, in all programs some kind of vector format is needed. Building's databases have been produced by GDi-Geographical Information System (GIS) Data for major Bosnia and Herzegovina cities. Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred to a digital medium through the use of a computer-aided design (CAD) program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of the traditional method of tracing the geographic form on a separate digitizing tablet (heads-down digitizing). GIS data represents real objects (such as roads, land use, elevation, trees, waterways, etc.) with digital data determining the mix. Real objects can be divided into two abstractions: discrete objects (e.g., a house) and continuous fields (such as rainfall amount, or elevations). Traditionally, there are two broad methods used to store data in a GIS for both kinds of abstractions mapping references: raster images and vectors. Points, lines, and polygons are the stuff of mapped location attribute references. However, adapting these data to various softwares is far from a trivial task. Although there are several standardized building data formats, e.g. DXF, Shape or ESRI Generate format, there seem to coexist various not fully compatible dialects of these among different producers. Adaptation of Banja Luka city's data has been made for three of the softwares and has implied data conversions that were successful only after consultations with the program manufacturers. We used a digital map of Banja Luka, in GK6 and UTM34 GISDATA projections, which are the combination of different height systems. GK6 is a projection officially used in BiH and the UTM projection is used at the global level and differs from the official projection of the ellipsoid on which are projections based. Digital orto-photos treated area is a satellite image resolution of 1 meter in Tiff format. 3D models of buildings include all the attributes of height (absolute height of the building, relative height of the building, height of the building). Data for buildings and facilities are provided in ESRI shape format, with the available terrain model resolution 20x20 m and 10 m height accuracy.

II. SOFTWARE PACKAGES

A. *Wireless InSite*

The program Wireless InSite (WI) is a powerful electro-magnetic modeling tool which applies physics-based propagation models to site-specific predictions in rural, urban and indoor environments, and for viewing and analyzing the predictions effects of buildings and terrain on propagation of electromagnetic waves. It is a product of Remcom company, USA [1]. Software can be licensed using either a software license file or a USB hardware key. This program predicts how the locations of the transmitters and receivers within an urban area affect signal strength, also models the physical characteristics of rough terrain and urban building features, performs the electromagnetic calculations, and then evaluates the signal propagation characteristics. With only a few steps it is possible to import data for buildings, foliage, floor plans and terrain, define the antennas, specify the transmitter and receiver locations, select the desired output, and run the calculations. The software [2] consists of three basic modules: urban, indoor and finally a rural module. The following propagation models are available: Full 3-D, X3D, Moving Window FDTD, Urban Canyon, Urban Canyon FDTD, Vertical Plane, and

Real Time version of COST-Hata, Freespace, Hata, OPAR, Triple Path Geodesic, VPUP, Walfish-Ikegami propagation models. The computations are ray based with reflections from ground (triangular pixels) as well as from building walls and roofs. Diffractions from corners and edges are calculated also. The software uses advanced high-frequency electromagnetic methods to provide accurate results over a frequency range from approximately 50 MHz to 40 GHz. Outside these ranges the program can still give answers but with degrading performance. The effects of each interaction along a ray's path to the receiver are evaluated to determine the resulting signal level. At each receiver location, rays are combined and evaluated to determine signal characteristics such as path loss, delay, delay spread, direction of arrival, and impulse response. Users can specify incoherent or coherent combination of the rays, allowing calculation of fast fade characteristics if desired. The ray paths themselves can be displayed for each transmitter/ receiver pair.

The virtual building and terrain environment is either constructed using WI's editing tools or imported from a number of popular formats(DXF, Shapefile, DTED, and USGS). Users can specify transmitter and receiver locations with WI's powerful site-defining tools or they can import them from an external data file. These areas of urban and terrain features may be large. Also, users may specify separate calculations for portions of the overall area by defining Study Areas. Wireless InSite makes these calculations by shooting rays from the transmitters and propagating them through the defined environment. These rays interact with environmental features and make their way to receivers. Interactions include reflection of the ground or of the building face surface, diffraction of the building edge or transmission through the wall. WI presents results in a number of ways. It provides visual representation of some results, such as transmitter coverage areas and power distributions, placing these visually within the modeled environment. The software is also capable of playing movies of time-domain E-field evolution. For other types of data, WI provides an advanced plotting system. Overlays of data allow quick comparison to imported measurements or even previous calculations. The program allows many Output and Analysis files. WI also offers a possibility of real time (RT) overview. With the RT module, WI users have a choice between two options: high fidelity results very quickly, or extremely high fidelity results with a physics-based model. Regarding this, using software package WI, we have performed precise prediction of the temporal and spatial distribution of electromagnetic field at wide downtown area of Banja Luka. In order to achieve the desired goal, we used a digital map of the city, which covers approximately 10km^2, provided by GisData Effective Solutions, Zagreb - Croatia has been used. The digital map is made in the UTM projection, but as these formats could not be imported in WI, they had to be converted into appropriate formats like DXF, Shape file, DTED, and USGS. Terrain model has been created manually through the software option for creating a new terrain.

WI has modeled the physical characteristics of the building urban area, carried electromagnetic calculations, and estimated propagation characteristics of the signal defined. Data and parameters that should be imported and configured to perform the simulation refer to the following: City and terrain features, Study area(s), Transmitters, Receivers, Materials, Antennas, Waveforms, Requested output and Output.

Structures of Banja Luka city have been imported in DXF file format. Total number of covered structures is 8243. Building material is concrete and the material assigned to the ground surface is asphalt. Terrain model has been created manually through the software option for creating a new terrain. The size and location of a study area have been specified automatically in order to include the entire region defined by the terrain and building features. The selected propagation model is Full 3D, which is the most complex from the viewpoint of computation time. This model places no restriction on object shape and includes transmission through surfaces. The selected raytracing method is SBR (Shot-and-Bounce Ray). Ray paths are traced without regard for the location of specific field points. Rays are first traced from the source points. Some of them that hit building walls would be reflected specularily and would continue to be traced up to the maximum number of reflections. For the particular application, rays are stopped when they hit the study area boundary. WI combines the ray paths, which follow nearly the same path through environment, with the phase. It then adds the powers of all the correllated groups.

Base stations (BS) have been created by combining a total of 134 transmitter (Tx) points. Forty seven base stations have been created on the observed area from the data submitted by the three operators: M:tel, HT Eronet and BH Telecom. Most of the base stations have three sectors, which have been created as three different Tx points, with the difference in orientation of about 120 degrees. Antenna radiation pattern has been assigned specifically for each transmitter. Transmitters have been located in virtual space using latitude and longitude. Input power has been set to the value determined by taking into account the antenna and Equivalent Isotropic Radiated Power, EIRP, of each sector. Receivers have been created in the form of a grid, which allows a large area to be easily covered. It is important to determine spacing between receiver (Rx) points. This value affects the "grid resolution" and quality of results. The geometrically defined directional antenna beam is used by transmitters. These data have been inserted from antennas datasheet: Vertical half-power beamwidth takes values from 6.5° to 10°. Horizontal half-power beamwidth has been set to be 65°. Vertical and Horizontal first null beamwidth have been set to 180°. Maximum antenna gain takes values from 15.5 to 18 dBi, depending on the specific antenna. Receiver treshold has been set to -100 dBm which determines which the individual ray paths to be ignored when evaluating the power at an Rx point.

Waveform in WI allows adjustment of parameters that describe the signal radiated from the transmitting antenna. Selected parameter that describe the signal radiated from the transmitting antenna is a Gaussian waveform. Carrier frequencies are 900 and 1800 MHz. The prediction has been made in a resolution of 5x5m, which generates the 105684 Rx points. Each Rx point has been uniquely numbered so the first one is in the lower left corner of the map and the second one is to the right from the first, and so on. In this way, the program has made a real 2D and 3D orthographic and perspective projection of the total power and electric field (EF) strength. Due to a lack of space in this paper, in Fig.1 and Fig.2 are given only partial 2D and 3D color orthographic views of spatial distribution of electric field strength, in the frequency bands 900MHz and 1800 MHz respectively.

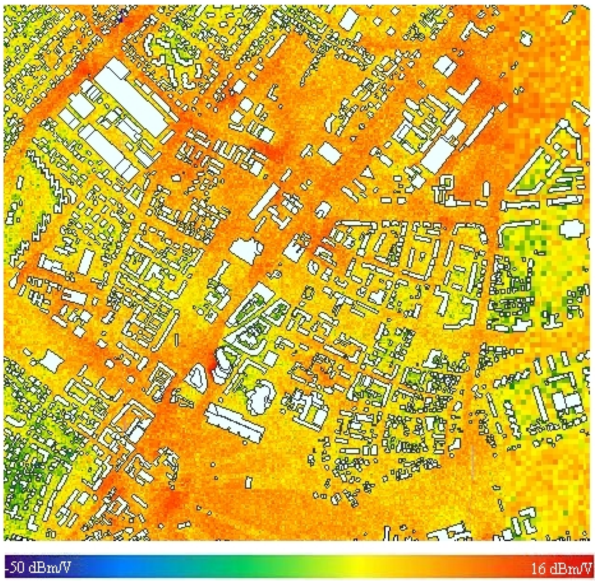

Fig 1. 3D Electric field strength at frequency 1800 MHz, 5mx5m

Fig. 2. 2D Electric field strength at frequency 900 MHz, 5m x 5m

For the same reason here are, from possible 105684 Rx points, only the highest five levels of EF total magnitude at 900 MHz (Table 1.) and 1800 MHz (Table 2).

B. *ASSET3G*

ASSET3G is a recognized trademark of AIRCOM International Ltd. from England [3]. ASSET3G is a network planning and analysis tool containing a complete range of functionality for the design and simulation of GSM, PCS, AMPS, TDMA, TACS, TETRA, UMTS, W-CDMA, CDMA 2000, HDR, TD-SCDMA and WiMAX networks. Its functionality includes hierarchical network planning, propagation modeling, service definition, analysis arrays, neighbor list definition, automatic frequency planning, CW data analysis, detailed reporting and simulation of network performance.

TABLE I. FIVE THE HIGHEST EF STRENGTH LEVELS, 900 MHZ

Rx	X(m)	Y(m)	Z(m)	Dist(m)	Mag(V/m)
1569	1860	1740	233.62	431.42	2.2223
1085	1440	1200	233.62	262.05	2.0951
1671	1620	1860	233.62	479.33	1.2725
767	1440	840	233.62	574.35	1.2617
1246	1560	1380	233.62	76.91	1.2388

TABLE II. FIVE THE HIGHEST EF STRENGTH LEVELS, 1800 MHZ

Rx	X(m)	Y(m)	Z(m)	Dist(m)	Mag(V/m)
1569	1860	1740	233.62	431.42	2.2223
1085	1440	1200	233.62	262.05	2.0951
1671	1620	1860	233.62	479.33	1.2725
767	1440	840	233.62	574.35	1.2617
1246	1560	1380	233.62	76.91	1.2388

ASSET3G is the market-leading radio network design product that includes comprehensive planning/ optimization and automation capabilities. ASSET has been engineered to facilitate the most demanding needs of today's and tomorrow's multi-vendor, multi-operator, multitechnology mobile networks. As part of the ENTERPRISE (the core-common user interface) suite, ASSET3G [4] benefits from the common Site Database window and Map View window, but adds an extensive range of many specific functionalities. The following list describes some ENTERPRISE functionalities used by ASSET3G: Equipment and Antenna Databases; Height Profile window; Site Reporting; Applying and Committing data; Global Commit All; Refresh All; Restoring data from the Wastebasket; Array Manager; Global Editor; Templates. The menu options that are specific to ASSET3G: File menu, View menu, Database menu, Equipment menu, Configuration menu, Arrays menu, Tools menu, Reports menu, Help menu. Using the Global Editor, which is common to all ENTERPRISE products, it is possible to make global changes to 2g, UMTS and CDMA network elements (Cell Site, Antenna, Installation, UMTS Antennas, UMTS Cell Power, CDMA BS Antennas parameters etc...) These propagation model types are supplied and supported in the ENTERPRISE suite: a) Standard Macrocell (1, 2, 3); b) SUI model and c) Microcell.

a) *Standard Macrocell model (1, 2, 3)*

The Macrocell model is general purpose model that accounts for the different elements of propagation in the wireless channel. It can be typically calibrated to less than 7dB standard deviation. It is recommended that Standard Macrocell model 3 is used because it is more accurate and models 1 and 2 have been retained for users who do not wish to upgrade and retune their models. It is recommended for usage in sites in environments where: The distance from the site is greater than approximately 500m; Base station antenna heights in the range of 15-200m; Receiver heights in the range of 1-10m. These Mapping Data needed**:** Terrain DTM height – raster data; Terrain clutter - raster data. Clutter and Height data should be of the same resolution(s). Although there is no minimum resolution, recommended pixel sizes for this data are between 20m and 200m. Standard ASSET3G Macrocell model most commonly used the Okumura-Hata prediction method. Fig. 3 shows the result of predicting the desired coverage area, with signal of 900 MHz BS mobile telephony performed by using the Okumura Hata method. BS is located on a Highbuilding in the downtown of Banjaluka. The Okumara propagation model is an empirical propagation model, based on extensive Okumura's measurements of wave propagation in the vicinity of Tokio. The Okumura model is given in the form of graphics and conditional equations.

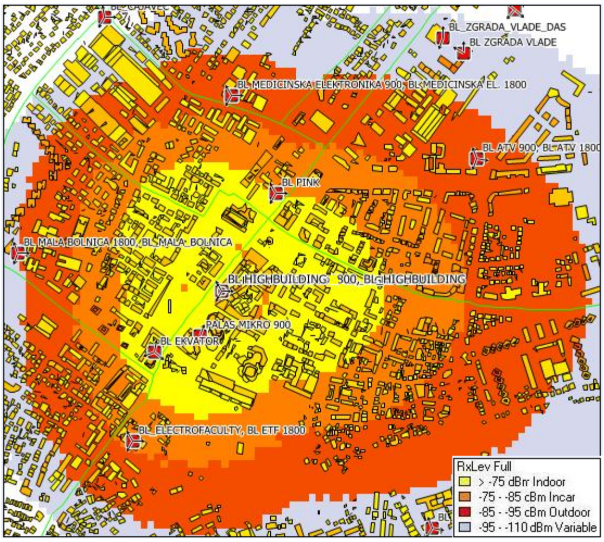

Fig. 3 Prediction by using the Okumura-Hata method

Hata has developed a mathematical formula, based on Okumura's measurements, to make the calculation of the field simpler. This Hata model was announced in the year 1980 and this is the most popular propagation model, from which are derived a variety of other models based on additional measurements and theoretical corrections.

b) Microcell model

Based on a pseudo ray-tracing technique. Calibrated typically to 8dB standard deviation. It is recommended for usage in: Sites found in urban environments; Propagation in the urban canyon environment; In-building coverage. These Mapping Data needed: Terrain DTM height – raster data; Terrain clutter - raster data; Building outlines - vector data Clutter and Height data should be of the same resolution(s) with a pixel size of between 1m and 5m. The prediction area is divided into pixels and path loss is calculated at each pixel center. The model calculates signal strength using vector data to a resolution of less than 1m. However, the final prediction array is limited to the resolution of the terrain height data. The model examines wave propagation in a horizontal direction assuming that the dominant method of RF propagation is down street 'canyons' bounded by buildings. Each section of the propagation path also incurs an additional clutter loss. This can be used to correct the street-based propagation formula for propagation over large open areas (such as large squares, parks) where the wave-guiding effects of street propagation are not present. The path loss is calculated by considering paths of direct and diffracted rays between the base site (source) and prediction point. Reflection and transmission at building walls is not considered in the current version of the model, nor is in-building coverage calculated. The model uses a combination of real and virtual sources to model wave propagation between two points. Real sources are positioned in the center of the prediction area and correspond to a physical base station. Virtual sources are positioned to model diffraction effects at vertical building edges, which are assumed to be infinitely tall. Two types of path loss model are used depending on whether the prediction point has line of sight (LOS) to the real source, or it only receives contributions from diffracted waves. As well as the macrocell and microcell propagation models that are supplied and supported by ENTERPRISE, these third party models can also be used: Volcano Models (Macrocell, Microcell, Minicell); WinProp; WaveSight. A number of Application Programming Interfaces (APIs) which enable to create custom propagation models are also available.

c) SUI model

The SUI (Stanford University Interim) model is one of the recommended models for the purpose of analyzing fixed wireless broadband communication networks such as WiMax at frequencies below 11GHz. It is recommended for usage in:Cells with radius < 10km; Can be used for various terrain and tree density types; Base station antenna heights in the range of 15 - 40m; Directional antennas (2-10m) at the CPE receiver, installed on or below rooftops or windows These Mapping Data are needed:Terrain DTM height – raster data; Terrain clutter - raster data. Clutter and Height data should be of the same resolution(s). Although there is no minimum resolution, recommended pixel sizes for this data are between 20m and 200m.

C. TEMS^{TM} Cell Planner

TEMS^{TM} CellPlanner [5] is an advanced, a graphical PC-based application for designing, rollout, implementing, and optimizing mobile radio networks developed by Ascom and Ericsson (Sweden). It assists designers and projectants in performing complex tasks, including network dimensioning, traffic planning, site configuration, frequency planning, and network optimization. TEMS CellPlanner Universal provides a flexible system configuration and an efficient working environment. Operators can choose stand-alone configuration for quick and easy planning in the field; no database installation is required. Choosing network configuration allows multiple users, as part of a team, to share network data and simultaneously plan a common network. This team approach is regulated by a unique system of security features for safe and secure handling of data. TEMS Cell Planner Universal ensures that the results of calculations are accurate and realistic data, tested in practice. New services and technologies can be planned even before they hit the market. Ericsson CellPlanner Universal supports GSM/GPRS/EDGE, WCDMA with HSPA/EUL and MBMS, WiMAX and LTE technologies and provides superior planning and optimization capabilities to save time and money during network deployment of 2G, 2.5G, 2.75, 3G, WiMAX, and LTE networks. TEMS CellPlanner Universal supports several propagation models. It uses the 9999 model, which is Ericsson's implementation of the Okumura-Hata model with empirical corrections. The Fig. 4 given ortographic view of signal coverage of 900MHz BS, located on a Highbuilding in the downtown of Banjaluka, obtained with the prediction by TEMS Cell Planner 9999 model (program version: 8.1.0.304).

It also uses the half-screen model to generate path loss above rooftops, and the Recursive Microcell Model for calculating the propagation between the buildings. The Urban Model is an advanced 3D propagation model that has been designed for determining wave propagation in an urban environment. The Walfisch-Ikegami RF Model is a

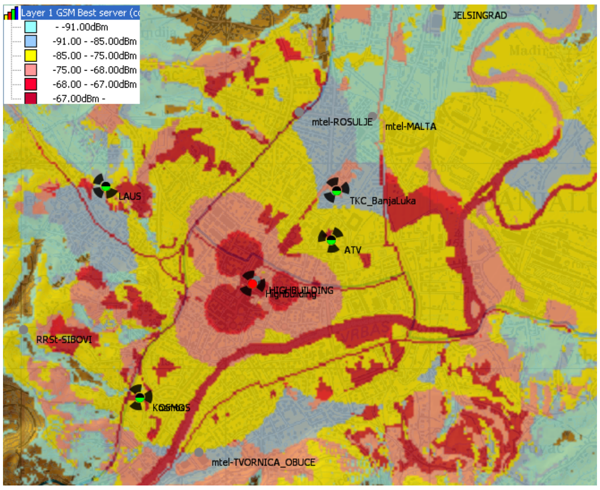

Fig.4. Ortographic view of signal coverage of BS Highbuilding

semi-deterministic model of the wave propagation process that takes place in urban environments outside the high-rise urban core. In addition, the traditional Okumura-Hata RF model for macrocell environment is also supported. Several import/ export formats are supported for maximum flexibility. Operators can export calculation results to MapInfo or use a generic export format to export information as text. Imported data can be edited and changed using Microsoft Excel. With puncturing it is possible to re-use collected measurement data. This measurement integration feature replaces predicted signal strength with measured signal strength values in all areas where a measurement has been made. This gives the user the ability to use both predicted and measured signal strength to improve the accuracy of path loss predictions. TEMS CellPlanner Universal includes the highly advanced GIS engine EriMap. It is an Ericsson-developed GIS engine especially designed for RF planning purposes. It is capable of displaying multiple layers of information with differing transparency of multiresolution and projection data. The optional Map Data Package assures that the geographical information being used is as accurate as possible. CellPlanner Universal is built on the latest Java platform and is designed for class-leading accuracy and speed in planning and optimization tasks.

D. WinProp

WinProp is a software produced by AWE Commu-nications, Gartringen, Germany [6]. WinProp software consists of three software tools: (a) *ProMan*, which performs network planning and wave propagation calculations; (b) *WallMan*, which generates building databases and (c) *Amam*, which produces and modifies antenna patterns.

We have looked at the ProMan and WallMan tools and the indoor and urban scenarios [7]. It is not possible to use a file generated in one of the tools in a different one using only the free trial version software, however, this is possible with the full license. It took some effort to get the ProMan started. The users manual is useful for finding specific information but is not so helpful when you start the software the first time. The information needed is spread over different places in the document. However, once the initial phase is passed, the use of the software is quite straightforward.

With the experience gained with the ProMan it was much easier to get started with the WallMan, since the software tools are organized in a similar way. The software supports .dxf files as input. Since the .dxf format is not fully standardized, this might cause trouble when importing files from other softwares. The .dxf file we used for the test generated a lot of error messages, but it seems to be functional. The height information in the source files was somehow lost, though. It is possible to look at the imported files in both 2D and 3D view but the database has to be restarted to see the 2D view. Below, we list the various prediction models in WinProp:

a) Rural scenarios: Okumura-Hata, Replacement Obstacles, Parabolic Equations

b) Urban Scenarios/ Requires 3D vector-oriented data of the buildings and can use topological databases for the urban area, if desired:

- Determienistic(Ray optical/Ray tracing and ray launching): Intelligent Rigorous 3D, Rigorous 3D (Standard), 2D vertical and horizontal plane;
- Empirical models: COST 231 (Walfisch-Ikegami model), Diffraction model(extended knife-edge- model)

c) Indoor scenarios (see Fig. 5.)/Requires 3d vector-oriented data of the walls of the buildings and their material:

- Deterministic: Dominant Paths, Rigorous 3D
- Deterministic/Ray optical (Ray tracing and ray launching): Intelligent Rigorous 3D, Rigorous 3D (Standard)
- Empirical models: COST 231 (multi wall model), Motley-Keenan.

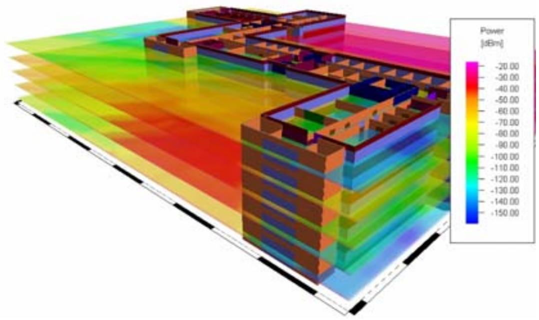

Fig. 5. Prediction of received Power with multiple layers

d) For vegetation objects: As an alternative to material parameters, two macroscopic parameters can be defined for vegetation objects: The first one, "Additional attenu-ation of pixels", refers to the prediction inside vege-tation. This parameter defines the number of dB by which the signal is predicted lower due to the presence of vegetation. The second parameter, "Additional attenuation if rays", defines the attenuation of strong rays passing beyond the vegetation.

E. Wave Sight

The WaveSight software for accurate wireless predictions is developed by WaveCall SA in Lausanne, Switzerland [8]. This is propagation model for TDMA, GSM, GPRS, HSDPA, CDMA, UMTS and WiMax planning and optimization of micro and macrocells. The program is ray based for accurate radio wave predictions and of so-called 2.5D type, i.e. propagation over roofs and around vertical, corners are computed separately in 2D calculations (Fig .6).

Two reflections and two diffractions at vertical corners are considered. Over roof top diffraction can account for up to 15 diffractions. Penetration into buildings can be calculated assuming a constant loss. Typical outputs generated by WaveSight are transmission loss, time of arival, impulse response and angle of arrival. Whether you are building a new 3G network, optimizing a 2G network or planning a public safety network or a municipal Wi-Fi system, Wavecall has the tools you need to see your actual radio coverage. The WaveSight uses UTD (Unified Theory of Diffraction) ray tracing and 3D building data bases to measure how radio signals bounce of the structures - providing the most accurate network coverage information available for both the microcell and macrocell layer.

F. Radiowave Propagation Simulator- RPS

Information on Radiowave Propagation Simulator is taken from Radioplan Gmbh Dresden Germany (9). RPS 5.2 simulates the interactions between radio transmissions and the physical features of the real world. RF field strength and coverage prediction maps generated by the simulator show the effects of placing antennas in selected physical locations. The software RPS 5.2 is ray based and developed mainly for outdoor and indoor propagation in micro and pico cells. It is a fully-featured radio propagation modeling tool that allows radio field strength prediction and channel determination in the micro and mm-wavelengths (300 MHz to 300 GHz) using built-in ray tracing and empirical prediction models. It is particularly suitable for modeling complicated indoor (in-site) environments, and has been used with great effects in recent projects in Asia and Europe. Besides two deterministic models two empirical models are implemented.

Fig. 6. A WaveSight 2D prediction in very urban area

III. DISCUSSION AND CONCLUSION

It is difficult to make direct comparisons between different programs without in depth study of the available information. The products differ regarding their price, the duration of the license, technical support and availability of source code. Does the GUI include geographic presentation of the area? What calculations can be done and to what extent can results be exported for direct use by other programs, e.g. Matlab? Can the program handle calculations with transitions between different environments in the propagation area? Various techniques to speed-up the computations are implemented, but these cannot be assessed without running the programs for the same scenarios. In addition, some of the considered programs are being further developed, while others may be stagnating. It is not obvious which of all the capabilities listed for the various softwares are essential for the intended application. If the need arises to use a software of this kind a careful specification of the essential requirements should be written. Only after that a renewed contact with the manufacturers should be established to enquire about the current status of their product. All softwares have been declared fast and accurate without specifying a particular values. Only, ASSET3G is stated to have standard deviation about 8dB, which is quite large. In future work we will be able to verify these findings. Each of the software has some advantages over the other. So Wireless InSite have simple menu that allows easy handling and faster transitions within the program. It also has options like no other programs such as: Real Time Overview, Overlays Data, Cumulative Probability Density. WI is also capable of playing movies of time-domain E-field evolution. ASSET3G has, at its disposal, a powerful database with the support of the common user interface ENTERPRISE suite. In ASSET3G these third party models can also be used: Volcano Models (Macrocell, Microcell, Minicell); WinProp; WaveSight and a number of application programming interfaces. Also, ASSET3G allows for each section of the propagation path to incurs an additional clutter loss for correcting the street-based propagation formula. Unforunately, reflection and transmission at building walls is not considered in the current version of the ASSET3G, nor is in-building coverage calculated. The users manual of WinProp is not so helpful when you start the software for the first time. The information needed is spread over different places in the document. Two macroscopic parameters can be defined for vegetation objects in the WinProp software. All programs are suitable for a wide frequency range, especially RPS (300MHz to 300GHz).

REFERENCES

[1] Remcom, PA, USA, http://raptor.remcom.com//remcom

[2] Wireless InSite User's Manual version 2.5, Remcom

[3] AIRCOM International Ltd, London, England http://www.aircom.co.uk, www.aircominternational.com

[4] ASSET3G User Reference Guide, version 5.2

[5] TEMS™ CellPlanner 8.1, Ericsson, Release Note, Ascom 25 June 2009 LZT 108 9841 R2C

[6] WinProp documentation. AWE Communications GmbH Gatringen,Germany, http://www.awecommunications.com

[7] Overview WP Software Suite, www.awe-communications.com

[8] WaveCall,SA in Lausanne,Switzerland, www.wavecall.com

[9] Radioplan GmbH, Germany, http://www.radioplan.com