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Site-specific Radio Propagation Prediction Software:
Wireless InSite Prediction Models Overview

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Abstract — **Wireless InSite is site-specific radio propagation software for the analysis and design of wireless systems for communication, networking, sensors and numerous other applications. It provides efficient and accurate prediction propagation models and channel characteristics in complex urban, indoor, rural and mixed path environments and includes high-fidelity and real time options. This paper presents an overview of standard and real-time versions of propagation models. The results for urban prediction scenario in the city centre of Banja Luka, using Full 3D propagation model, is described, as well.**

Key words — Wireless InSite; Propagation models; Urban Scenario; Propagation Prediction Software;

I. INTRODUCTION

In recent years, there has been a large increase in the usage of devices emitting electromagnetic radiation. This influences almost every aspect of day-to-day living. Especially, public systems of mobile telephony became common-place communication technology around the world [1]. This wireless technology relies upon an extensive network of fixed antennas or base stations, exchanging information by means of radio frequency (RF) signals. About two millions base stations exist worldwide and the number is increasing significantly with the introduction of fourth generation technology devices and also on planning and developing the fifth generation of it. While the benefits to society of such technologies are accepted, significant public and media concern continues to be expressed about increases in EMF exposure of people and potential-related adverse effects on health. The key to addressing anticipated public and media concern about potential adverse health effects is foresight in respect of carrying out, co-ordinating and sharing knowledge of relevant multidisciplinary scientific research [1], [2]. The first step for estimating the exposure levels are so-called "*ad hoc*" measurements, which are referred to a specific time (usually 1–2 h) and date [1]. On the other hand, the notion of continuous measurement of EM radiation levels on a basis of 24 hours is more appealing to the concerned public. Namely, due to the fact that the radio-frequency range is active 24 hours a day, the monitoring process must cover the same period of time, as well. Only under such conditions, the full image on using of the observed frequency ranges can be acquired. This is due to the fact that the recorded values can be directly compared to the public exposure limits (reference levels-safety values), which are set by the relevant organizations, such as ICNIRP [3] and local governmental authorities. Also, a successful submission of European Union countries to the European Co-operation in Science and Technology (COST) programme was done in order to support an Action entitled "Emerging EMF Technologies: Health Risk Management" [2], [4], which facilitates identifying how existing technologies change and what potential health consequences might arise. Regarding estimation of electric field strength values, it can be performed the most precise prediction of the temporal and spatial distribution of EM field using prediction propagation software [1], [2], [5].

II. WIRELESS INSITE

Wireless InSite is a powerful electromagnetic modeling tool for predicting the effects of buildings and terrain on the propagation of electromagnetic waves [5]. It predicts how the locations of the transmitters and receivers within an urban area affect signal strength. Wireless InSite models the physical characteristics of the rough terrain and urban building features, performs the electromagnetic calculations and then evaluates the signal propagation characteristics. The virtual building and terrain environment is either constructed using Wireless InSite's editing tools or imported from a number of popular file formats, such as DXF, Shapefile, DTED, DEM and USGS [1], [5]. Transmitter and receiver locations can be specified using Wireless InSite's powerful site-defining tools or imported from an external data file. Separate calculations for portions of the overall area may be specified by defining study areas. The calculations are made 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 reflections from feature faces, diffractions around objects and transmissions through features. Wireless InSite uses advanced high-frequency electromagnetic methods to provide accurate results over a frequency range from approximately 50 MHz to 100 GHz [5]. The effects of each interaction along a rays' path to the receiver are evaluated to determine the rays' electric field. At each receiver location, contributions from arriving ray paths are combined and evaluated to determine predicted quantities such as electric and magnetic field strength, received power, interference measures, path loss, delay spread, direction of arrival, impulse response, electric field vs. time, electric field vs. frequency, and power delay profile. Wireless InSite 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. Wireless InSite is also capable of playing movies of time-domain *E*-field and *H*-field evolution. For other types of data, Wireless InSite provides an advanced plotting system. Overlays of data allow quick comparison to imported measurements or even previous Wireless InSite calculations. All output files produced by Wireless InSite are in a readable ASCII format. Also, Wireless InSite offers standard and real-time versions of propagation models [5].

III. STANDARD VERSION PROPAGATION MODELS

Wireless InSite Standard deals with the high-fidelity propagation models based on ray-tracing, finite difference time domain and empirical techniques. Site-specific models can provide detailed predictions including *E* and *H* fields, received power and propagation loss and gain. Signal and channel characteristic outputs include delay spread, direction of arrival and departure and mean time of arrival. Options include detailed urban (indoor and outdoor) and longer-range propagation over rough terrain. More details can be found in [5].

A. X3D (multithreaded and GPU accelerated)

The X3D Ray model is Remcom's first ray-based model to use GPU (*Graphics Processing Unit*) acceleration to reduce calculation time. It is a 3D propagation model, so there are no restrictions on geometry shape or transmitter/receiver height. The model includes effects from reflections, diffractions, transmissions and atmospheric absorption. Applications include urban, indoor and indoor-outdoor propagation scenarios. An example of X3D propagation model is shown in Fig. 1.

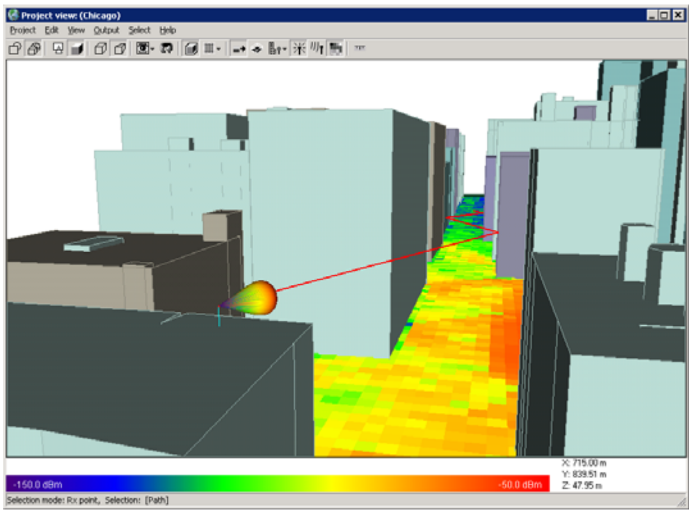

Figure 1. Example of X3D propagation model

B. Full 3D

Remcom's Full 3D model is a general propagation model that can be applied to urban, indoor and indoor-outdoor propagation. The model can handle arbitrary geometry and transmitter/receivers at any height. Users have the option of performing the ray tracing with the shooting and bouncing ray (SBR) method or Eigenray, which is based on the method of images. The model includes effects from reflections, diffractions and transmissions. An example of Full 3D propagation model is shown in Fig. 2.

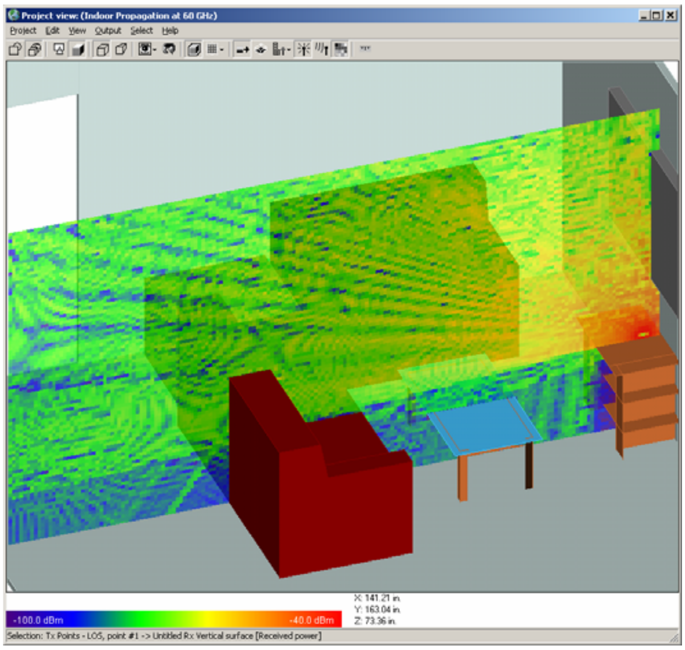

Figure 2. Example of Full 3D propagation model

C. Urban Canyon Ray Model (2D)

The Urban Canyon models are intended for high-rise urban environments where the transmitting and receiving antennas are located close to the ground relative to the building heights. Energy that diffracts over the rooftops of buildings is assumed to be negligible. Urban Canyon includes propagation effects from reflections and diffractions. An example of Urban Canyon Ray (2D) propagation model is shown in Fig. 3.

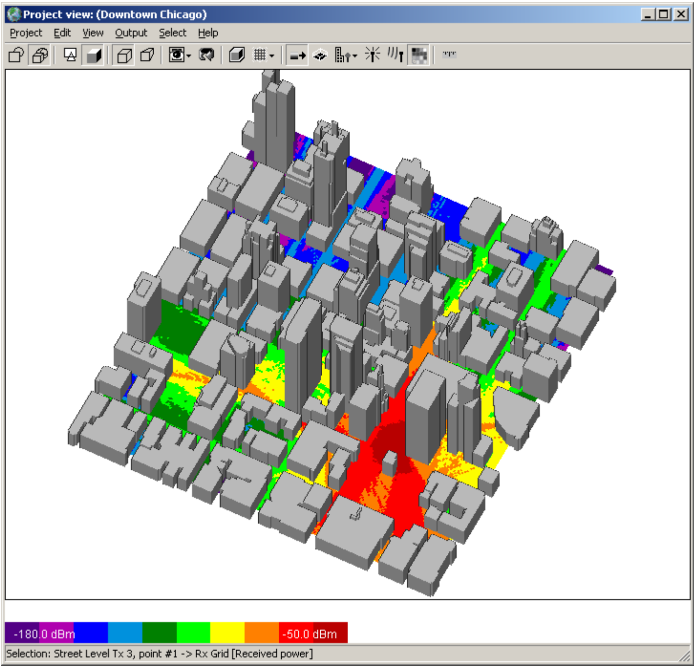

Figure 3. Example of Urban Canyon Ray (2D) propagation model

D. Vertical Plane Ray Model (2D)

The Vertical Plane is a 2D ray based model for predicting propagation over irregular terrain. The model only considers energy propagating in the vertical plane that contains the transmitter and receiving antennas. Vertical plane is well suited for propagation distances up to 20 km and includes effects from reflections and diffractions. An example of Vertical Plane Ray (2D) propagation model is shown in Fig. 4.

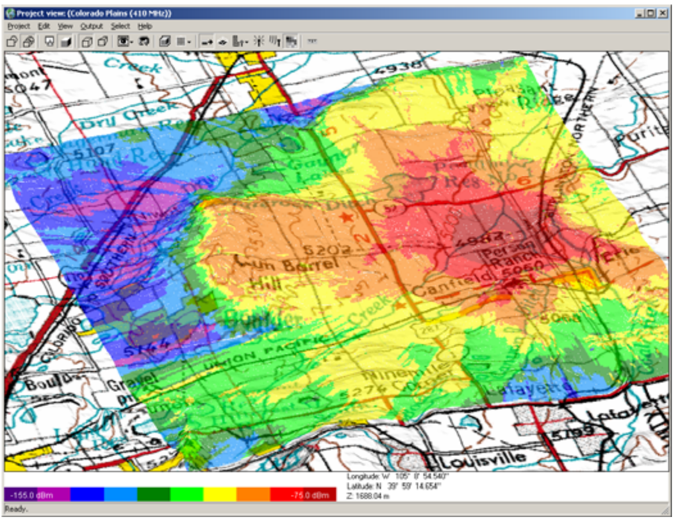

Figure 4. Example of Vertical Plane Ray propagation model

E. Moving Window FDTD (GPU accelerated)

The Moving Window FDTD model (MWFDTD) is based on the 2D FDTD (Finite Difference Time Domain) method and can model the propagation of radio waves over irregular terrains. MWFDTD is a full-wave model that includes all relevant physical processes associated with radio wave propagation in the 2D environment. An example of Moving Window FDTD propagation model is shown in Fig. 5.

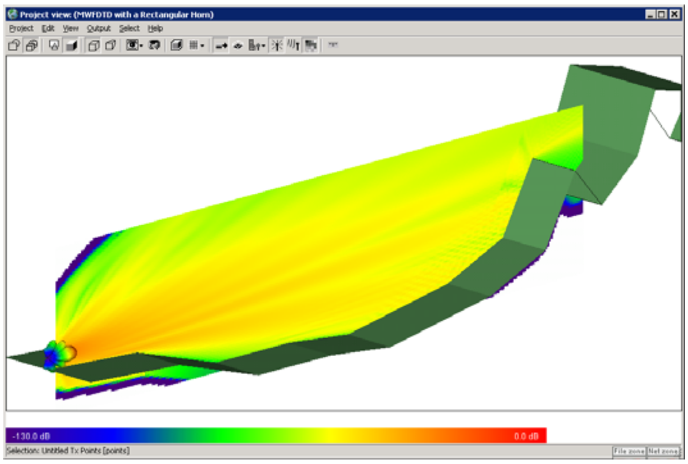

Figure 5. Example of Moving Window FDTD propagation model

F. Urban Canyon FDTD

The Urban Canyon FDTD model (UCFDTD) is intended for high-rise urban environments where the transmitting and receiving antennas are located close to the ground relative to the building heights. Energy that diffracts over the rooftops of buildings is assumed to be negligible. UCFDTD is a full wave model includes all relevant effects associated with propagation in a 2D environment. An example of Urban Canyon FDTD propagation model is shown in Fig. 6.

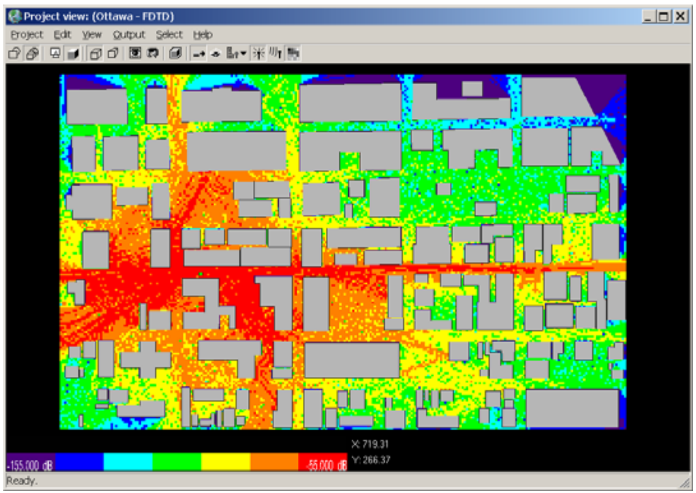

Figure 6. Example of Urban Canyon FDTD propagation model

IV. REAL TIME VERSION PROPAGATION MODELS

Wireless InSite Real Time deals with the propagation models intended to balance fidelity and speed, providing site-specific urban propagation models, but with rapid calculation capability. Models provide estimates at a tiny fraction of the run time, calculating point-to-point links in less than a millisecond. More details can be found in [5].

A. Vertical Plane Urban Propagation

Vertical Plane Urban Propagation (VPUP) is a deterministic model designed to rapidly calculate propagation in urban scenarios. When line of sight exists between the transmitter and receiver, the free space path loss is returned.

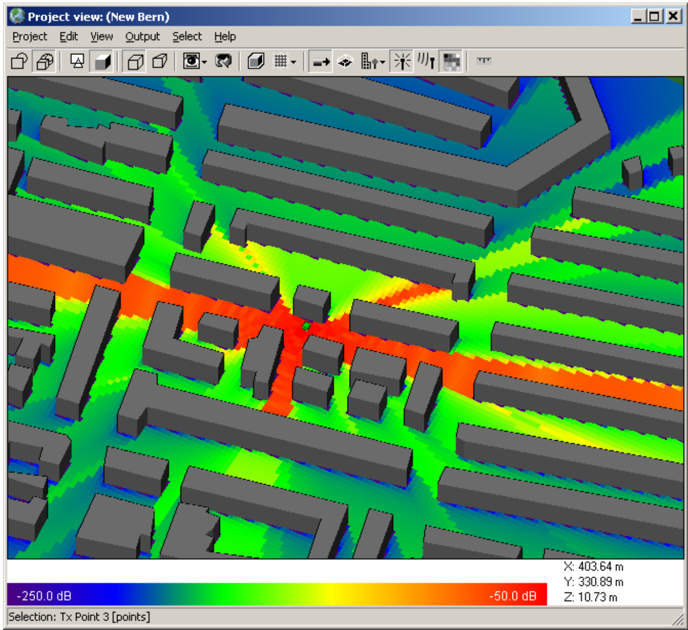

Figure 7. Example of Vertical Plane Urban propagation model

For transmitters and receivers separated by buildings, the path loss is determined by considering energy that diffracts over the actual detailed urban profile. An example of Vertical Plane Urban propagation model is shown in Fig. 7.

B. *Triple Path Geodesic*

Triple Path Geodesic is a deterministic model designed to enhance the VPUP predictions for urban environments. When building geometry obscures the line of sight between the transmitter and receiver, the model calculates the contributions from energy traveling around the sides of the buildings and over the rooftops. Point to point calculations are typically on the order of milliseconds. An example of Triple Path Geodesic propagation model is shown in Fig. 8.

Figure 8. Example of Triple Path Geodesic propagation model

C. *Wall Count*

The Wall Count model is the Wireless InSite Real Time method for indoor calculation.

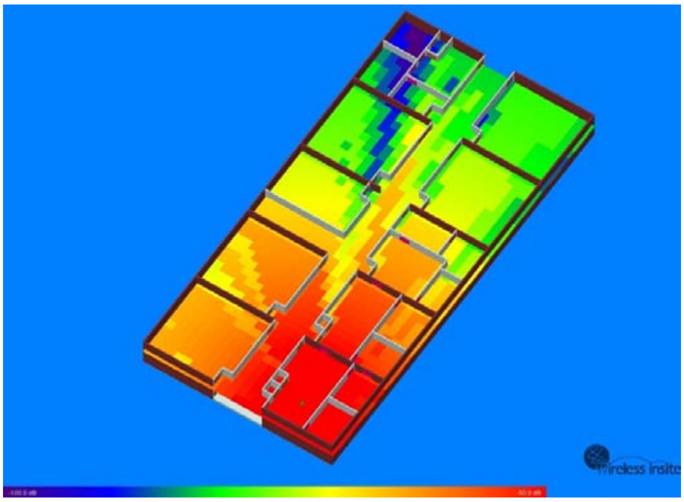

Figure 9. Example of Wall Count propagation model

Direct rays are constructed between the transmitter and the receiver, and every wall intersected in the indoor geometry is counted. Each intersection adds an additional 3 dB of loss to free space path loss. An example of Wall Count propagation model is shown in Fig. 9.

D. *Walfisch-Ikegami*

Walfisch-Ikegami is a deterministic empirical model useful in predictions where the dominant energy is contributed by diffractions over rooftops. An example of Walfisch-Ikegami propagation model is shown in Fig. 10.

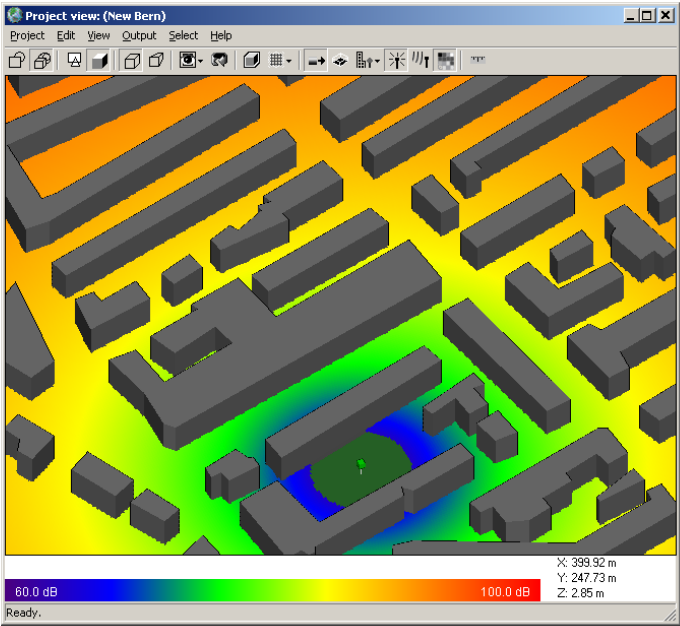

Figure 10. Example of Walfisch-Ikegami propagation model

E. *Opnet Path Attenuation Routine*

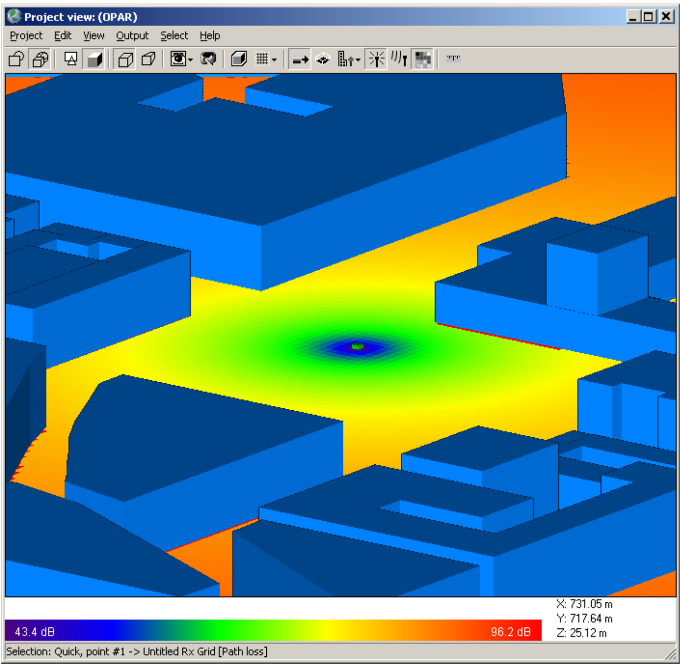

Figure 11. Example of Opnet Path Attenuation Routine propagation model

OPNET Path Attenuation Routine (OPAR) is a deterministic urban path loss algorithm that uses the building depth between the transmitting and receiving antennas to enhance attenuation predictions. An example of Opnet Path Attenuation Routine propagation model is shown in Fig. 11.

F. Hata

Hata is a non-deterministic empirical model which takes frequency, transmitting antenna height, receiving antenna height and the distance from the transmitting to the receiving antenna into account for urban propagation. These parameters are used to predict field strength using an equation derived from measurements.

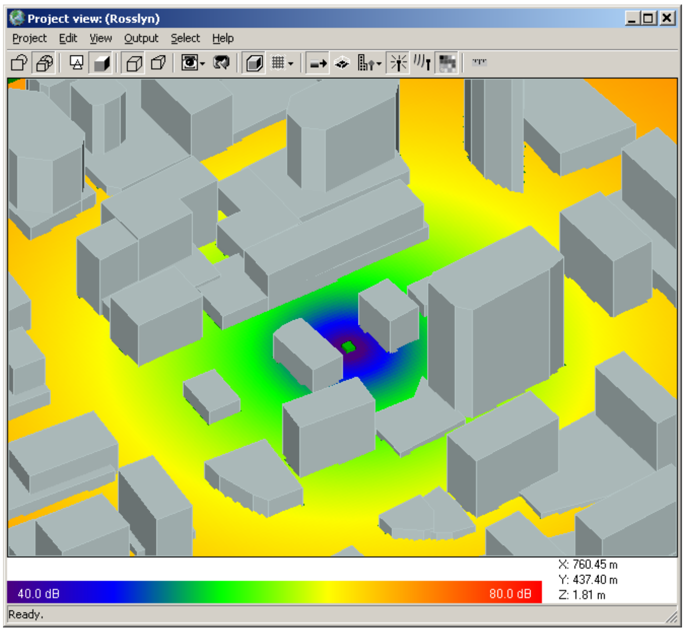

Figure 12. Example of Hata propagation model

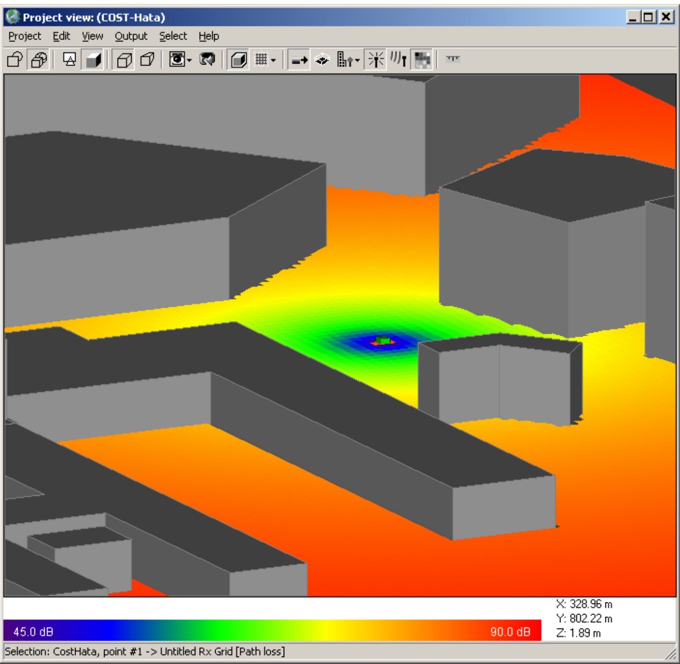

Figure 13. Example of Cost-Hata propagation model

In addition to the standard Hata results, free space attenuation is used in line of sight situations. Hata is valid for frequencies between 30 MHz and 1500 MHz. An example of Hata propagation model is shown in Fig. 12.

G. Cost-Hata

COST-Hata is an extension to the Hata model for frequencies between 1500 MHz and 2000 MHz. An example of Cost-Hata propagation model is shown in Fig. 13.

H. Free Space

The Free Space model returns the free space path loss between a transmitter and receiver based on distance and frequency. An example of Free Space propagation model is shown in Fig. 14.

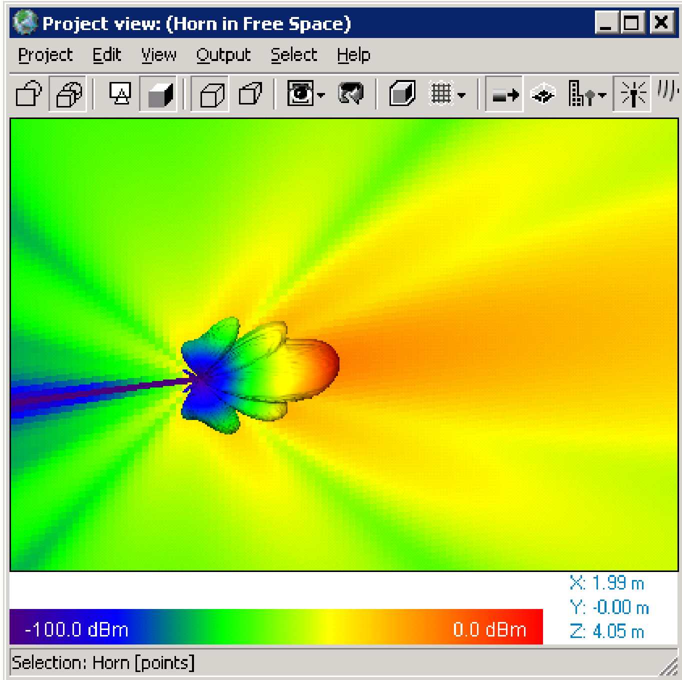

Figure 14. Example of Free Space propagation model

V. Results of Propagation Prediction for Urban Scenario in the Banja Luka City Centre

For quality and reliable propagation prediction of electromagnetic field spatial distribution it is necessary to posses [1]: High-quality prediction and simulation software; Databases to store the location and technical details of all transmitters and antennas; Digital maps that contain terrain heights at locations with a resolution good enough and a map that shows land use (e.g. urban, rural etc.) as the terrain height map of the observed area; Appropriate computer hardware capacity. Due to the lack of the space in this paper, only a prediction for limited region (city centre of Banja Luka) and GSM 900 MHz signal has been shown, using available digital map [6]. All necessary software adjustments are given in [1], [2]. The program has created a real 2D orthographic projection (Fig. 15) and 3D perspective projection (Fig. 16) of the total electric field strength spatial distribution at 900 MHz.

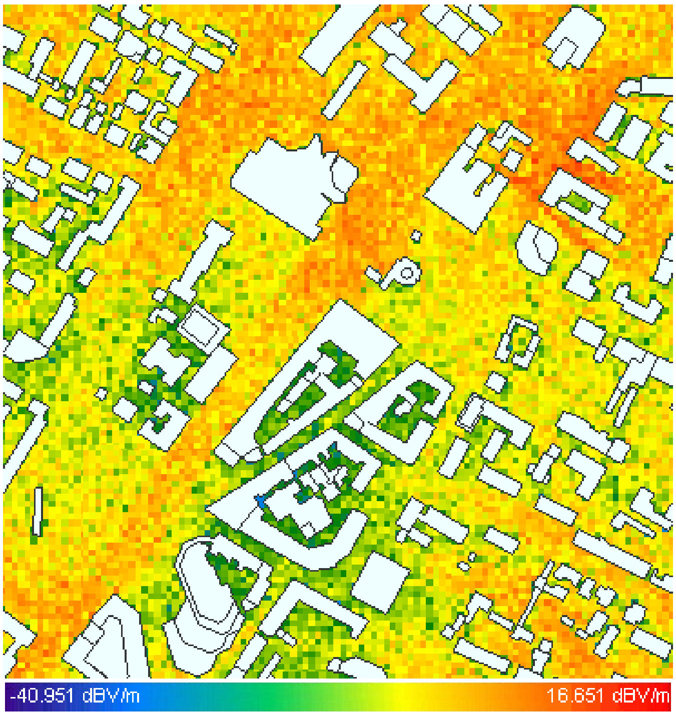

Figure 15. 2D orthographic view of GSM 900 MHz field distribution

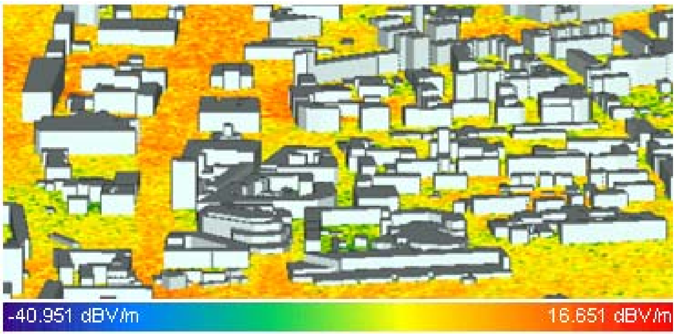

Figure 16. 3D perspective view of GSM 900 MHz field distribution

The selected propagation model is Full 3D, which is the most complex from the viewpoint of computation time [1], [2], [5]. This model places no restriction on object shape and includes transmission through surfaces. The selected ray-tracing 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 specularly 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. In practice, the situation is different because of additional number of artificial and natural sources of radiation. So, the prediction results of electromagnetic field distribution deviates from the actual distribution due to variations in the building dimensions, coordinates and base station data [1], [2].

VI. CONCLUSION

Wireless InSite is a suite of ray-tracing models and high-fidelity EM solvers for the analysis of site-specific radio propagation and wireless communication systems available through a common user interface. The software provides efficient and accurate predictions of EM propagation and communication channel characteristics in complex urban, indoor, rural and mixed path environments. Wireless InSite's physics-based propagation models are able to predict the paths by which energy travels from the transmitting to the receiving antenna. The graphical interface makes it easy to view and interpret these results. Finally, all the values obtained by Wireless InSite in this paper were far below safety limits for general population perscribed by [3], [7]-[10].

LITERATURE

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