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Novel Tracing Algorithm vs Remcom Wireless InSite

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Abstract—**Results of comparison between a popular commercial software for radio wave propagation modeling versus prototype implementation of a novel algorithm proposed by the author of this paper is discussed. It is shown that both algorithms lead to very similar results while the new one is faster by a few orders of magnitude.**

Keywords—**Ray Tracing, radio wave propagation modelling.**

I. Introduction

THIS paper presents early results of new tracing algorithm (*Gotszald*). Like other ray based algorithms it could be applied to wide range of applications: radio wave propagation modeling, computer graphics, sound propagation, heat propagation and more. We concentrate here on the wave propagation modeling for wires communication systems. However we can envisage also application of the new algorithm for other applications like object localization, military purposes and other scientific research. This contribution describes a fully functional software implementation of the new algorithm developed by the author. The software is supposed to perform the tasks of modeling radio wave propagation in urban environment and others. The specific focus of this his paper is a comparison of the results obtained with the new algorithms against the results obtained with the newest release of popular commercial solution: Remcom Wireless InSite 2.6.3, Full 3D Ray Tracing, Shooting and Bouncing Ray (*Remcom*).

It was verified that the proposed algorithm overcomes very important limitations of any ray based method like maximum number of interactions in path or multithreading. It also keeps strong fidelity of geometry on larger environment models when finding exact paths. The crucial thing is that it significantly reduces simulation time. Simulation time reduction is the main reason why the ray based methods replace Finite Difference Time Domain for indoor and outdoor scenarios.

II. Model description

Two ray based propagation models from high-frequency class were considered in this paper: *Gotszald* and *Remcom*. Both were designed on the basis of well known Geometrical Optics (GO) and Uniform Geometrical Theory of Diffraction (UTD) [2] which is the extension of Geometrical Theory of Diffraction (GTD) [1]. However models of these implementations are not exactly the same because they use a different modifications to the UTD.

Gotszald implements UTD extensions from Luebbers papers [3], [5], [6], [7] and practical tips from Kubacki [11], Morawski and Gwarek [12]. Tracing algorithm was designed by *Gotszald* and has not been published yet.

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TABLE I
Assumptions of Gotszald and Remcom

	Gotszald	Remcom
model	UTD, full 3D Ray Tracing	UTD, full 3D Ray Tracing
obstacles	any shape	any shape
interactions	unlimited	3, 30
multithreading	unlimited	one per transmitter
exact paths	yes	no

Remcom also implements UTD extensions from Luebbers papers [3], [5], [6], [7] and modified dependencies of Burnside [4] and Balanis [8]. Tracing algorithm was developed by Schuster and Luebbers [9], [10]. Additional information could be found in reference manual [13] and website [14]. *Remcom* company does not reveal exact details.

In case of *Remcom* maximum combined number of reflections and transmissions cannot exceed 30, maximum number of diffractions is 3, but the 2nd diffraction is currently restricted to edges coplanar with the 1st diffraction, and the 3rd to edges coplanar with the 2nd diffraction. Multithreading is limited by maximum number of threads that cannot exceed number of transmitters. It is unlikely that any ray will pass exactly through a receiver point so there are no exact ray paths. To compensate that, an arbitrary collection surface is constructed around the receiver. Rays that pass through this surface are used to construct the specific paths.

Gotszald handles unlimited number of interactions in ray's path i.e. reflections, transmissions and diffractions. Number of threads is not limited by the algorithm. It always constructs exact ray paths from any transmitter to any receiver.

The summary of the properties of mentioned solutions are presented in Table I.

III. Simulations

Several different scenarios has been taken into consideration. All of them were modeled on square terrain covered by grid of receivers and with different configuration of buildings. Simulations were processed on exactly the same hardware and operation system conditions (Intel Xeon X5550, Microsoft Windows XP Professional x64) for both: *Gotszald* and *Remcom*. They run separately and were allowed to consume all system resources.

Below is the explanation how simulation settings have been chosen. Both mentioned solutions require arbitrary parameter of *path loss threshold* measured in dB. It means that ray paths are traced until they have enough energy. This is very common condition which allows to determine how far simulation should go. However *Remcom* is limited about maximum number of interactions in ray paths while new proposed algorithm does not have such limitation. In order to make fair comparison simulations settings have been cut off accordingly to *Remcoms* limits, especially maximum number of diffractions. Value of *path loss threshold* has been set properly to ensure that the longest paths are equal for both solutions in all scenarios. Simulation settings are as follows.

Materials

earth: conductivity: 0.02 S/m, relative permittivity: 20
concrete: conductivity: 0.015 S/m, relative permittivity: 7
air (vacuum)

Waveform

sinusoid
carrier frequency: 1 GHz
effective bandwidth: 10 Hz
phase: 0

Antenna

isotropic
maximum gain: 0 dBi
polarization: horizontal
temperature: 293 K
receiver threshold: -250 dBm
transmission line loss: 0 dB

Transmitter

input power: 1 W
location for scenario 1: (200, 200, 30) m
location for scenario 2: (160, 135, 40) m
location for scenario 3: (200, 200, 30) m
location for scenario 4: (205, 215, 30) m
location for scenario 5: (225, 190, 75) m
location for scenario 6: (225, 190, 75) m

Receivers

type: grid
geometry: [(0, 0, 1), (400, 400, 1)] m
spacing: 4 m
use bounding box: yes
bounding box length: auto
noise figure: 3 dB
collection surface radius: auto

Requested output

received power

Study area

propagation model: Full 3D
ray spacing: auto
ray tracing method: Shooting and Bouncing Ray (SBR)
plane wave ray spacing: auto
sum complex electric fields: none
ray tracing acceleration: auto

Maximum number of reflections and diffractions

scenario 1: 1, 0
scenario 2: 2, 1
scenario 3: 1, 1
scenario 4: 3, 2
scenario 5: 4, 2
scenario 6: 4, 3

Path loss threshold

scenario 1: - 85 dB
scenario 2: - 120 dB
scenario 3: - 120 dB
scenario 4: - 110 dB
scenario 5: - 100 dB
scenario 6: - 103 dB

Terrain

shape of square
materials: air (above), earth (below)
geometry: [(0, 0, 0), (400, 400, 0)] m

Buildings

materials: air (outside), concrete (inside)
placed on terrain (earth)
geometry: depends on simulation scenario

A. Scenario 1

Scenario 1 is shown in Fig. 1. This is the simplest scenario from all presented. Transmitter antenna is located in the middle of flat terrain, thirty meters above the ground, marked by green point. Locations of receivers are represented by red grid. There are no buildings. Results are shown in Fig. 7 - 8. Simulation time: Gotszald 0.9 s, Remcom 5 s.

B. Scenario 2

Scenario 2 is shown in Fig. 2. There is only one building on gray color. Building geometry given as min. and max. vertex in Cartesian coordinates in meters: [(190, 210, 0), (230, 250, 20)]. Transmitter antenna is located next to the building and higher than its roof. Results are shown in Fig. 9 - 10. Simulation time: Gotszald 1.7 s, Remcom 22 s.

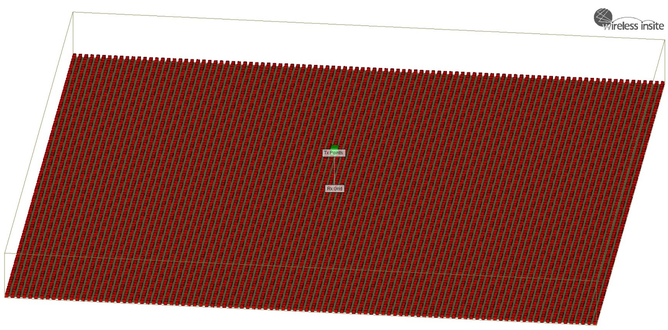

Fig. 1. Remcom Wireless InSite - Project View: scenario 1. Transmitter (green point) above square terrain covered by grid of receivers (red points).

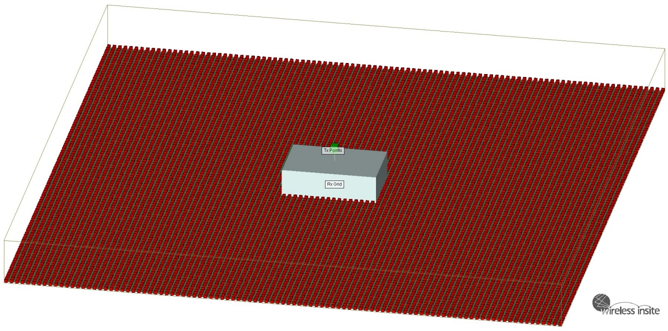

Fig. 2. Remcom Wireless InSite - Project View: scenario 2. Transmitter (green point) next to concrete building (gray). Square terrain covered by grid of receivers (red points).

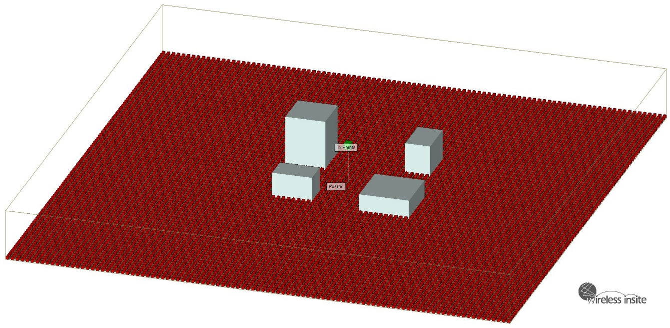

Fig. 4. Remcom Wireless InSite - Project View: scenario 4. Transmitter (green point) between four concrete buildings (gray). Square terrain covered by grid of receivers (red points).

C. Scenario 3

Scenario 3 is shown in Fig. 3. There is only one building with geometry: [(166, 178, 0), (234, 222, 20)]. Transmitter antenna is located exactly in the middle of the concrete building, ten meters above its roof. Results are shown in Fig. 11 - 12. Simulation time: Gotszald 4.8 s, Remcom 24 s.

D. Scenario 4

Scenario 4 is shown in Fig. 4. This is the example of scenario where results from both considered solutions differ the most. Transmitter antenna is located between four concrete buildings. Only one building is higher than antenna, three buildings are lower. Geometry of the buildings : [(230, 162, 0), (270, 202, 15)], [(150, 230, 0), (182, 262, 40)], [(242, 242, 0), (262, 274, 25)], [(158, 170, 0), (190, 190, 20)]. Results are shown in Fig. 13 - 14. Simulation time: Gotszald 7.7 s, Remcom 9 min. 43 s.

E. Scenario 5

Scenario 5 is shown in Fig. 5. There are eighteen concrete buildings with geometry: [(30, 50, 0), (58, 78, 10)], [(36, 130, 0), (66, 194, 15)], [(50, 250, 0), (86, 310, 20)], [(58, 350, 0), (78, 370, 10)], [(90, 118, 0), (118, 178, 20)], [(106, 58, 0), (174, 90, 10)], [(122, 362, 0), (142, 382, 10)], [(130, 234, 0), (178, 270, 30)], [(130, 298, 0), (190, 330, 25)], [(142, 118, 0), (170, 178, 15)], [(222, 170, 0), (250, 198, 50)], [(230, 90, 0), (258, 122, 35)], [(242, 250, 0), (290, 290, 20)], [(258, 326, 0), (330, 350, 15)], [(290, 138, 0), (310, 198, 20)], [(298, 70, 0), (350, 94, 12)], [(322, 242, 0), (362, 270, 12)], [(350, 162, 0), (370, 198, 10)]. Transmitter antenna is located on the roof of the highest building. Results are shown in Fig. 15 - 16. Simulation time: Gotszald 9.5 s, Remcom 20 min. 8 s.

F. Scenario 6

Model of scenario 6 is the same as scenario 5 (Fig. 5) except that settings were modified to get more diffracted rays: *path loss threshold* lower by 3 dB. Results are shown in Fig. 17 - 18. Simulation time: Gotszald 12.6 s, Remcom 46 min. 42 s.

TABLE II
SIMULATION TIMES OF EACH SCENARIO.

	Gotszald [s]	Remcom [s]	Gotszald to Remcom
scenario 1	0.9	5	6 x faster
scenario 2	1.7	22	13 x faster
scenario 3	4.8	24	5 x faster
scenario 4	7.7	583	76 x faster
scenario 5	9.5	1208	127 x faster
scenario 6	12.6	2802	222 x faster

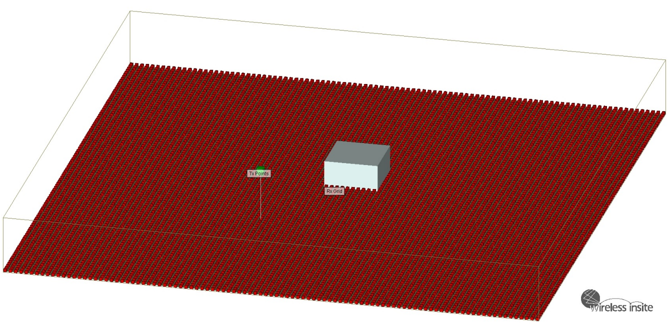

Fig. 3. Remcom Wireless InSite - Project View: scenario 3. Transmitter (green point) above concrete building (gray). Square terrain covered by grid of receivers (red points).

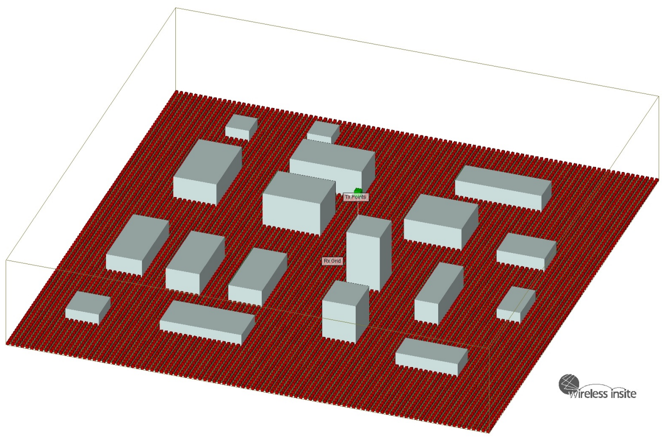

Fig. 5. Remcom Wireless InSite - Project View: scenario 5 and 6. Transmitter (green point) between eighteen concrete buildings (grey). Square terrain covered by grid of receivers (red points).

IV. Conclusions

The paper presents early results of prototype implementation of the authors tracing algorithm. Here is the summary of the properties of the new algorithm:

- It traces all possible path combinations under energy criteria.
- It has very strong geometrical accuracy and provides exact paths.
- It considers unlimited number of interactions in ray path.
- It has very low computational complexity.
- It appears to be the fastest full 3D ray tracing algorithm.
- It opens way for unlimited multithreading implementations.

In the paper the authors new algorithm has been compared against a well know algorithm implemented in a commercial software by *Remcom*. Both algorithms are based on UTD model of electromagnetic field. However they are not the same because they use different modifications or extensions to UTD. To compare the practical applicability of both algorithms we need to consider the following criteria:

A. Functionality

Remcom tracing algorithm has serious functionality limitations. For example it cannot handle five diffracted rays in path and is unable to use multi core processing for single transmitter scenarios. These are very common problems for any ray based tracing algorithm, especially when searching for exact paths. Algorithm proposed by the author of this paper has succeeded to overcome these functionality limitations.

B. Speed

The algorithm presented here by the author is faster by a factor of 10 for smaller scenarios and by a factor exceeding 100 for bigger scenarios. Simulation times for each presented scenario are shown in Table II and Fig. 6.

C. Applicability to large scenarios

Considered simulation scenarios calculated by both algorithms have been matched with the limitations of the *Remcoms* software. The author looks forward to comparison of more complicated scenarios including much longer ray paths and more influence of diffraction. In such cases more efficiency gains with respect to the presently available commercial solutions are expected.

D. Accuracy

It is shown that both algorithms lead to very similar results. The results are slightly different in some scenarios since they use slightly different theoretical model of diffraction. It is difficult to judge which of the algorithms is more accurate since we typically do not have reliable reference data. One of the aims of this paper is to encourage interested individual researchers and companies to arrange tests of accuracy of the authors solution against other simulations or measured reference date.

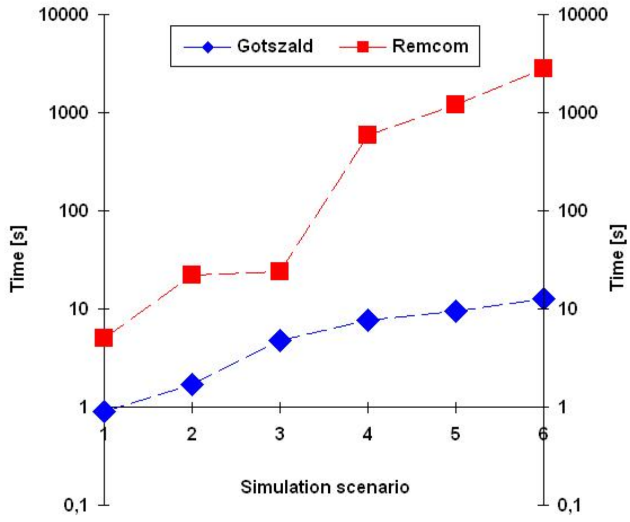

Fig. 6. Simulation times of each scenario on logarithmic scale.

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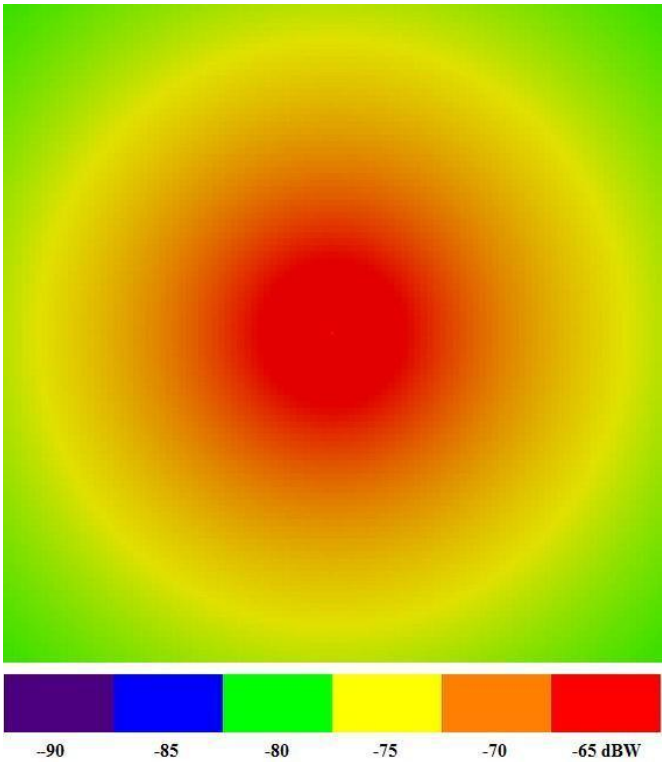

Fig. 7. Scenario 1, Gotszald

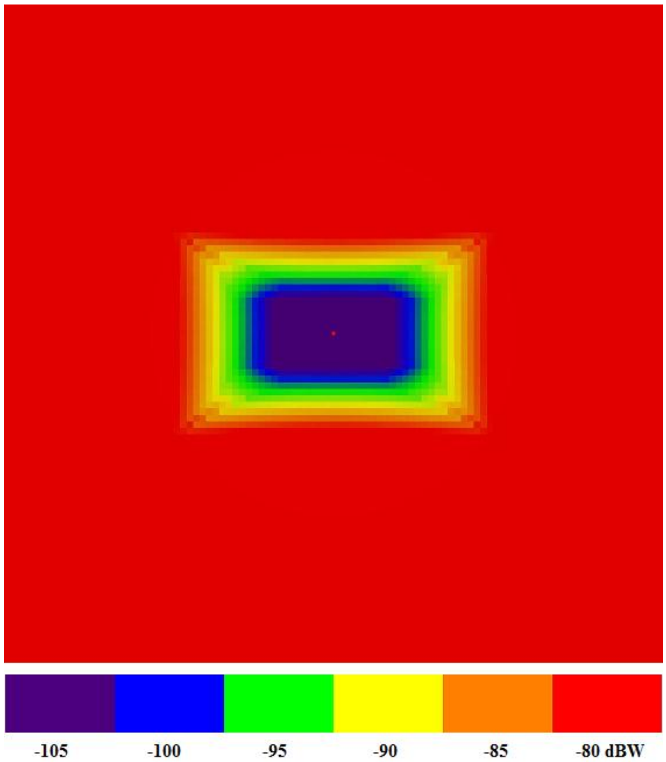

Fig. 9. Scenario 2, Gotszald

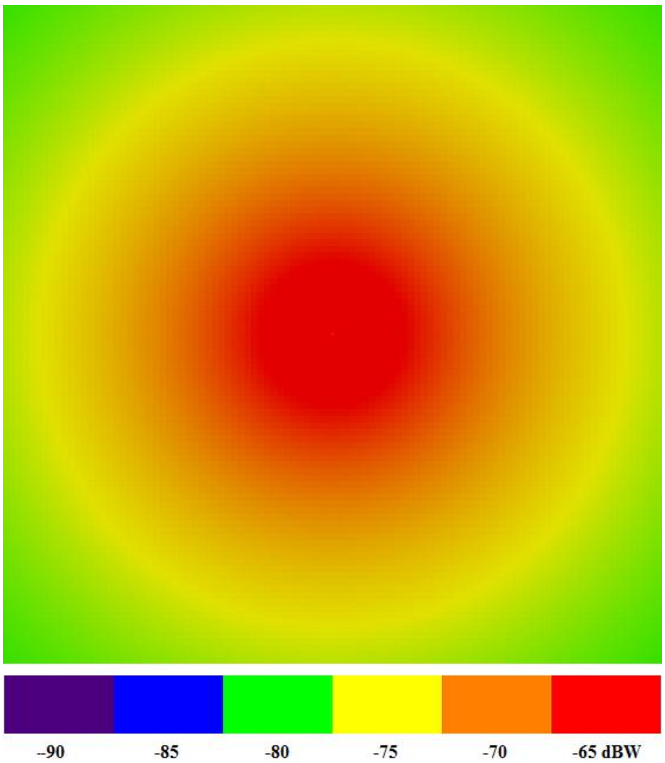

Fig. 8. Scenario 1, Remcom

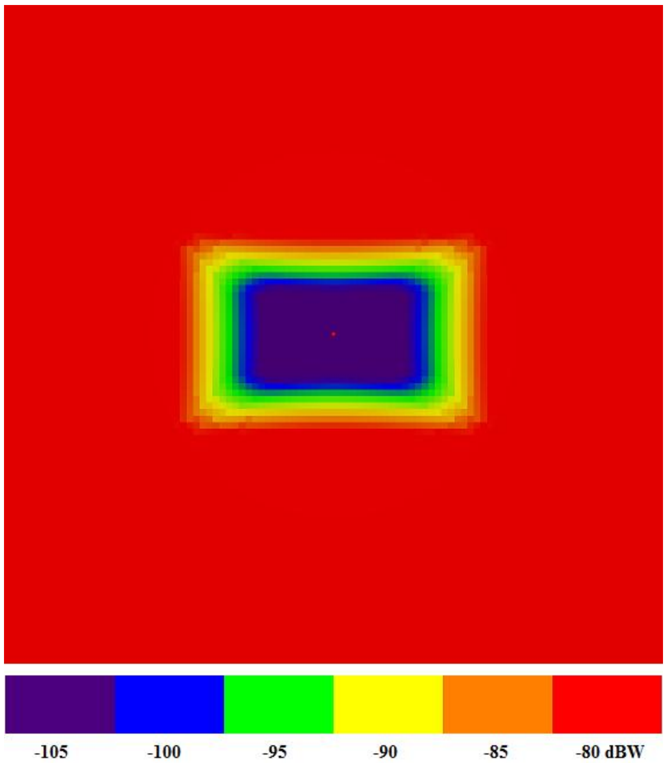

Fig. 10. Scenario 2, Remcom

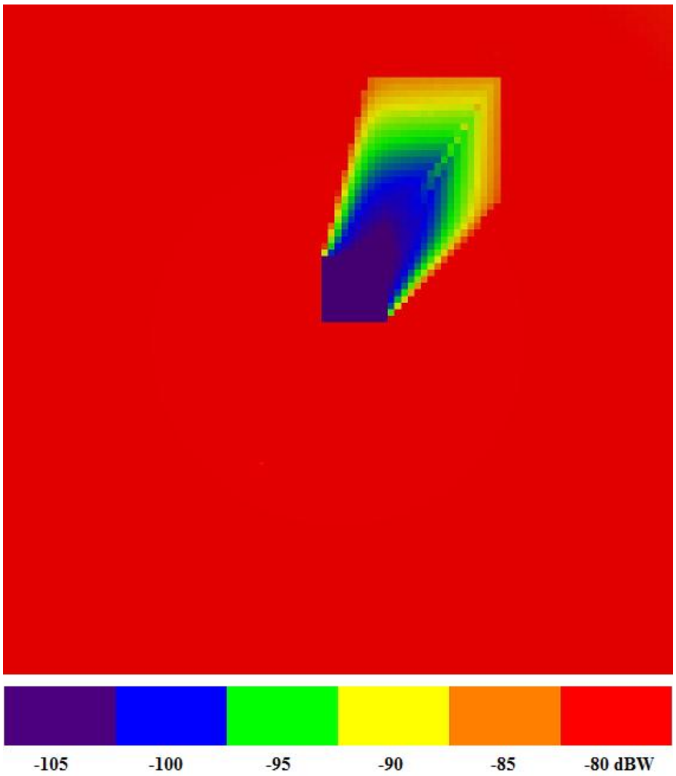

Fig. 11. Scenario 3, Gotszald

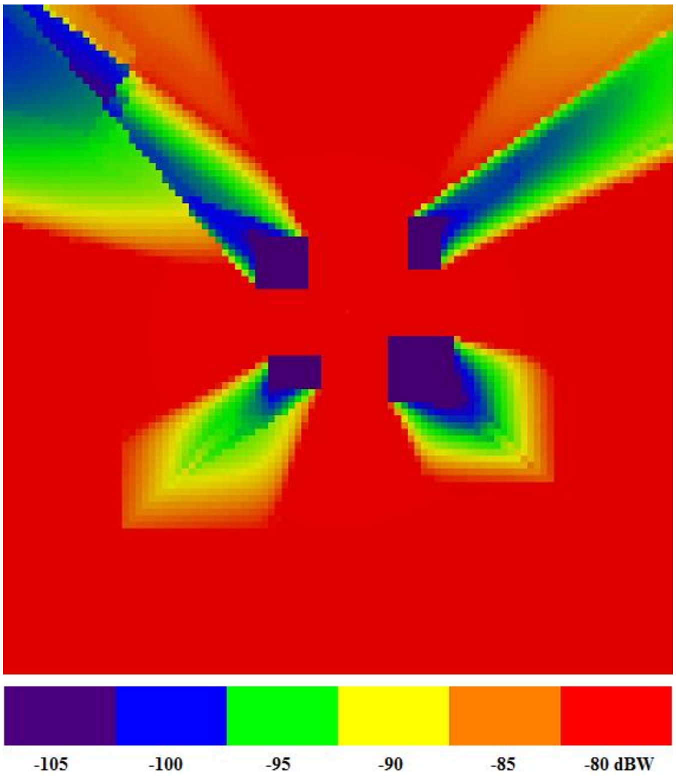

Fig. 13. Scenario 4, Gotszald

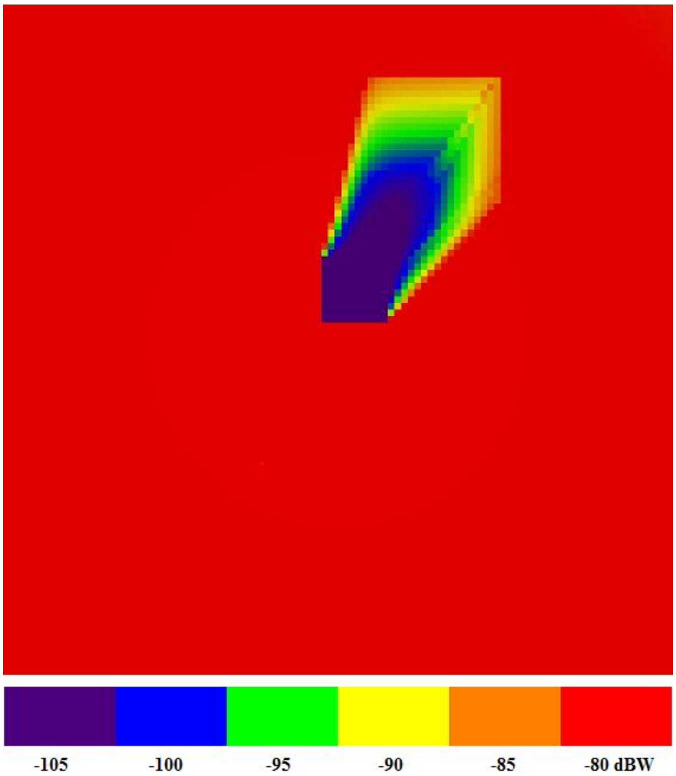

Fig. 12. Scenario 3, Remcom

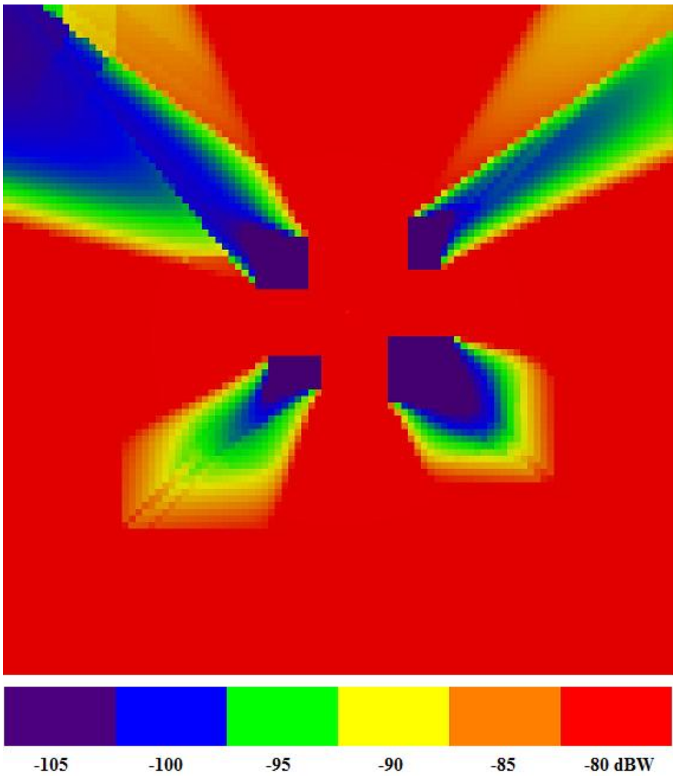

Fig. 14. Scenario 4, Remcom

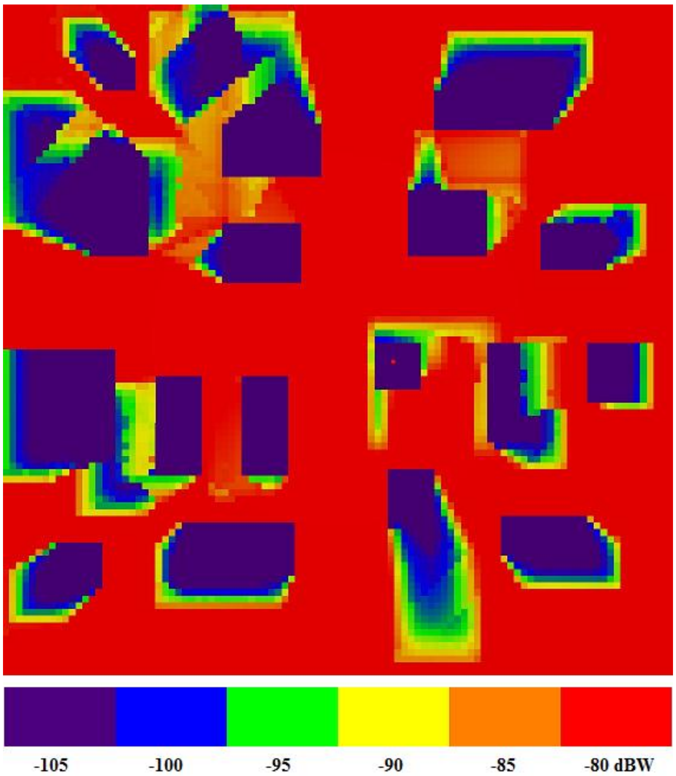

Fig. 15. Scenario 5, Gotszald

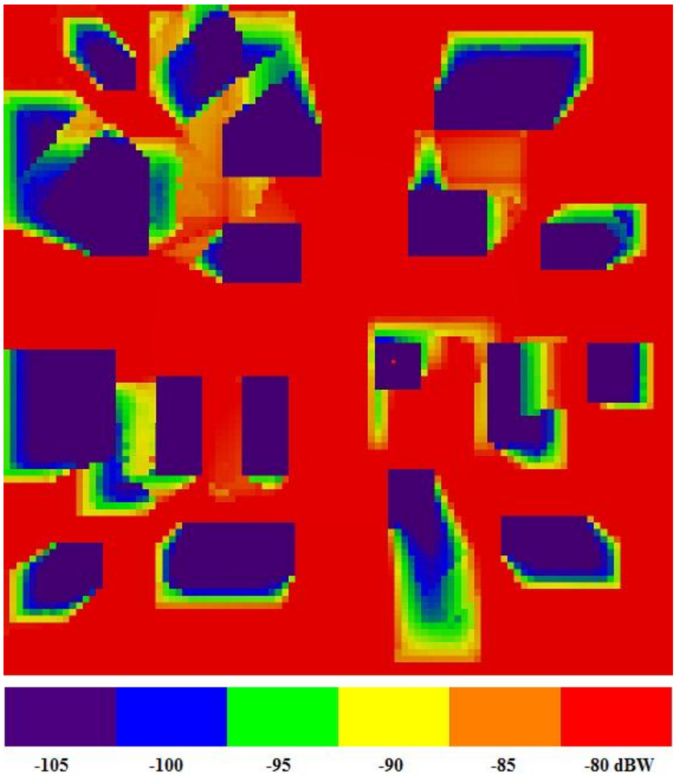

Fig. 17. Scenario 6, Gotszald

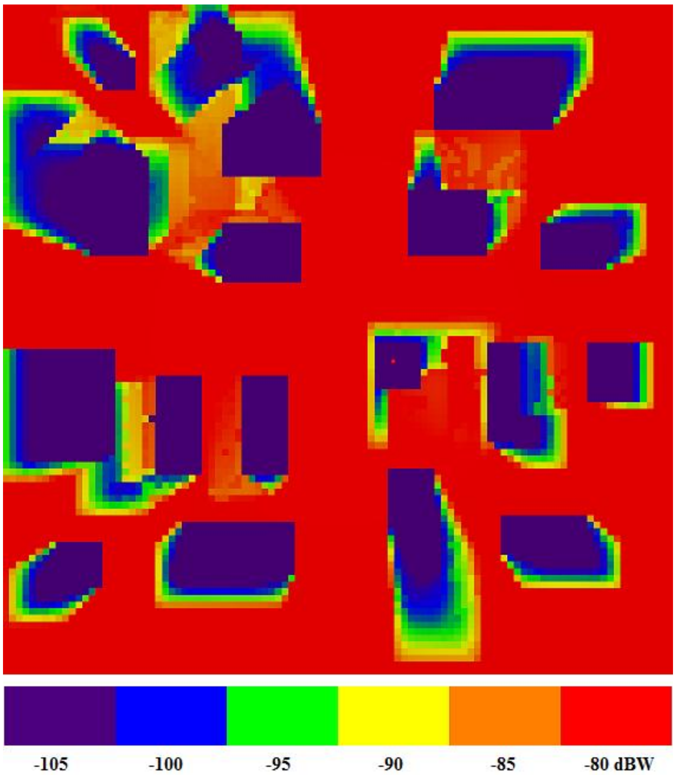

Fig. 16. Scenario 5, Remcom

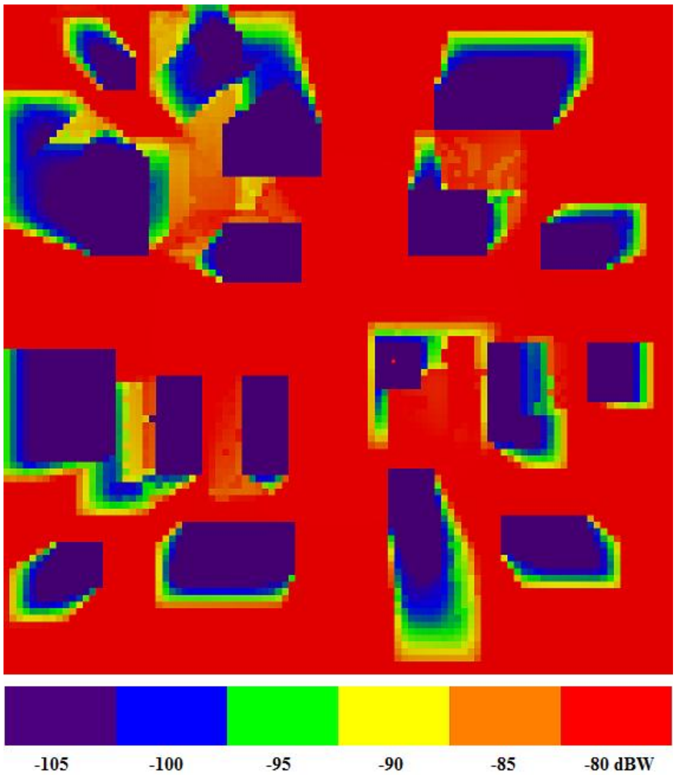

Fig. 18. Scenario 6, Remcom