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Comparative study of Radio Mobile and ICS Telecom propagation prediction models for DVB-T

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***Abstract*—In this paper, a comparative study between the results of a measurement campaign conducted in northern Greece and simulations performed with Radio Mobile and ICS Telecom radio planning tools is performed. The DVB-T coverage of a transmitting station located near the city of Thessaloniki is estimated using three empirical propagation models (NTIA-ITS Longley Rice, ITU-R P.1546 and Okumura-Hata-Davidson) and one deterministic model (ITU-R 525/526). The best results in terms of minimum average error and standard deviation are obtained using the deterministic model and the NTIA-ITS Longley Rice empirical model. In order to improve the results, the tuning options available in the ICS Telecom software are used on the Okumura-Hata-Davidson model, leading to a significant increase in accuracy.**

Keywords—DVB-T; measurement campaign; ICS Telecom; Radio Mobile; propagation model; radio coverage

I. Introduction

As the transition from the analog to the digital TV and radio broadcasting is almost complete across Europe, an accurate radio planning procedure becomes a necessity in order to optimize the quality of the received signal over wide areas and minimize the interferences with other communication systems.

In order to evaluate the coverage that can be obtained from a certain broadcasting station, various propagation models can be used in order to predict path loss and received signal power.

There are several options of software tools available for calculating the radio coverage. In this paper three different solutions were used in order to simulate the path loss and estimate the received signal level. ICS Telecom [1] is a commercial modeling platform for telecommunication network planning and for frequency spectrum management. It focuses on the network design needs for commercial operators, spectrum regulators, equipment manufactures and consultants. Among several types of radio systems, it can also handle broadcast (analog and digital TV and radio; simulcast and multicast). A multitude of radio propagation models are available in ICS Telecom, including the four models that were used in the current paper.

Radio Mobile [2] is a freeware software tool used to predict the performance of a radio system. It is dedicated to amateur radio and humanitarian use. The radio propagation model that is used by Radio Mobile is the NTIA-ITS Longley Rice model.

In order to implement the other two empirical propagation models that were analyzed (ITU-R P.1546 and Okumura-Hata-Davidson) the Matlab [3] environment was used.

The paper is organized as follows. In Section II a theoretical review of the different propagation models that were used to calculate the radio coverage for the broadcasting DVB-T station is made. Section III contains a description of the locations and equipment that was used during the measurement campaign [4-6], alongside their setup parameters. An analysis of the simulation results obtained with the different software tools described above is performed, highlighting the correlation between the simulated and the measured signal levels in case of different propagation models. Section IV concludes the paper and presents future research directions.

II. Relevant Propagation Models

The propagation of radio waves can suffer different path changes due to the several external environmental factors. For example a flat, dry, desert environment exhibits different propagation characteristics than a hilly, wet, jungle environment. Another important factor to be taken into consideration is the level of population of the area: an urban area, which is densely populated, presents different propagation characteristics than a rural area. Even in the same environment but under different weather conditions changes may occur. Therefore, it is difficult to precisely characterize the propagation of radio waves. Thus, in the radio network planning tools (e.g. ICS Telecom, Radio Mobile), available on the market, propagation models are used to model the environment.

A radio propagation model is an empirical mathematical formulation that tries to characterize the path loss of a radio wave. These models were created from the extensive observation of different scenarios, in different environments. Nevertheless, these models are not precise and many differences can be encountered. In the next paragraphs we present the most common propagation models that one can find in ICS Telecom and Radio Mobile. These models are used in Section III for simulation purposes.

A. The Okumura-Hata-Davidson Model

This model brings up different modifications to the Okumura-Hata [7] model. The modified model covers a broader range of input parameters and distances.

The formulas for the model are [3]:

$$PL_{OHD} = PL_{Hata} + A(h_1, d_{km}) - S_1(d_{km}) - S_2(h_1, d_{km}) - S_3(f_{MHz}) - S_4(f_{MHz}, d_{km}) \quad (1)$$

Where,

$$PL_{Hata} = 69.55 + 26.16\log f_{MHz} - 13.82\lg h_1 - a(h_2) + (44.9 - 6.55\lg h_1)\cdot \log d_{km} \quad (2)$$

and $a(h_2)$ is the correction factor for the mobile antenna height defined as:

$$a(h_2) = \begin{cases} (1.1\lg f_{MHz} - 0.7)\cdot h_2 - 1.56\lg f_{MHz} + 0.8, \\ \text{for medium/small city, quasi - open/open area} \\ 8.29(\lg(1.54\cdot h_2))^2 - 1.1, \\ \text{for large city and } f_c \le 300MHz \\ 3.2(\lg(11.75\cdot h_2))^2 - 4.97, \\ \text{for large city and } f_c > 300MHz \end{cases} \quad (3)$$

The other parameters are defined as follows:

$$A(h_1, d_{km}) = \begin{cases} 0, d_{km} < 20 \\ 0.62137(d_{km} - 20)\left[0.5 + 0.15\lg\left(\frac{h_1}{121.92}\right)\right], \\ 20 < d_{km} < 300 \end{cases} \quad (4)$$

$$S_1(d_{km}) = \begin{cases} 0, d_{km} < 64.38 \\ 0.174(d_{km} - 64.38), 64.38 \le d_{km} < 300 \end{cases} \quad (5)$$

$$S_2(h_1, d_{km}) = 0.00784\left|\log\left(\frac{9.98}{d_{km}}\right)\right|(h_1 - 300), h_1 > 300m \quad (6)$$

$$S_3(f_{MHz}) = \frac{f_{MHz}}{250}\log\left(\frac{1500}{f_{MHz}}\right) \quad (7)$$

$$S_4(f_{MHz}, d_{km}) = \left[0.112\log\left(\frac{1500}{f_{MHz}}\right)\right](d_{km} - 64.38), d_{km} > 6439km \quad (8)$$

where f_{MHz} is the carrier frequency (30-1500MHz), h_1 is the base station antenna height HAAT (20-2500m), h_2 is the mobile station antenna height (1-10m), d_{km} is the transmission distance (1-300km), A and S_1 are factors that extend the distance to 300Km, S_2 is a correction factor for the height h_1 of the base station antenna extending the value of h_1 to 2500m, S_3 and S_4 are correction factors that extend the frequency to 1500MHz.

The field strength is calculated as:

$$E(dB\mu V/m) = ERP(dBW) - PL_{HD}(dB) + 20\log f_{MHz} + 109.35 \quad (9)$$

These modifications help to cover a boarder range of input parameters. For example it provides corrections for link distances up to 300km and an altitude of the transmitters up to 2500m. Also, it can be used only for frequencies between 150 MHz to 1500 MHz.

B. The ITU-R P.1546 Model

The ITU-R P.1546 model [8] is for point – to – area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz. It is based on the interpolation /extrapolation from empirically derived filed –strength curves as function of distance, antenna height, frequency and percentage time. It implies the following conditions:

- The propagation curves represent field strength values for 1 kW effective radiated power as functions of various parameters. The measurements that the values are based on were made in areas with two seasons climate and can differ very much if made under other climate conditions.
- The maximum field strengths can be obtained under specific conditions
- The effective height of base station antenna is considered above the average terrain height (between distances of 3 to 15 km)
- The effective height of the mobile station antenna is considered above the ground, which is the representative height of the ground around the mobile station antenna. The minimum value of the representative height of ground cover is 10 m.
- Non-symmetrical model (i.e. Loss T->R ≠ Loss R->T).

C. The ITU-R 525/526 Model

This model implies no offset for standard free space attenuation which is described in ITU – R 525 recommendation.

The Free Space loss is calculated from the formula [9]:

$$PL_{Free} = 32.44 + 20\log(f_{MHz}) + 20\log(d_{km}) \quad (10)$$

The diffraction term described in the ITU – R 526 recommendation can be selected in the diffraction geometry frame to get a full ITU model, without any subpath attenuation term [10]. This model is also a good one for modeling the environment for a DVB transmission if it is used with a diffraction model like the Deygout 94 method, that is available in ICS Telecom. The ITU-R 525/526 Deygout model takes into account three worst-cases intrusions into the Fresnel zone (Figure 1).

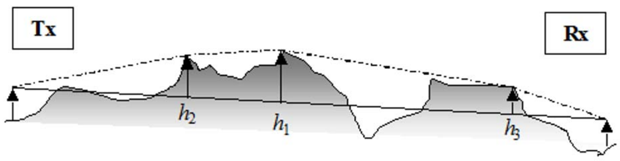

Fig. 1. The Fresnel intrusion for the ITU-R 525/526 Deygout mode.

D. The Longley Rice Model

The NTIA-ITS Longley Rice model, also known as the ITM (Irregular Terrain Model) coverage prediction model [11], is a widely accepted one and was adopted by the FCC as a standard and is used for frequencies from 20MHz-20GHz, antenna heights from 0.5-3000m and distances from 200-5000m. In ICS telecom the model is implemented using the NTIA point-to-point (P2P) approach, as the information provided by the freely available SRTM maps that were used is accurate enough. The main parameters of the model are: frequency; effective radiated power; antenna height; polarization; surface refractivity; permittivity; conductivity; climate zone; earth effective curvature; surface transfer impedance of the ground; situation variability and time variability. These parameters can be changed in ICS Telecom in order to have a more accurate prediction.

The model is used to predict the attenuation of the radio signal as a function of distance and is also used to predict other losses due to refraction and terrain obstacles.

III. Comparative Analysis of the Simulations and Measurements

The measurements and the simulations were performed for a DVB-T broadcasting network located in the northern part of Greece. The transmitter station (ERT Hortiatis Transmitter Center, Greek Public TV) is located 12 km away from the city of Thessaloniki (LAT:40.597648 LONG:23.0997993), at an altitude of 846m above the sea level. The frequency of the transmitted signal was 490 MHz (Channel 23 UHF) and the transmit power of the analyzed broadcasting station was of 1600W (32dBW), ERP = 42dBW [4].

The transmitter station uses three bays of 4 broadcasting UHF panel antennas having azimuth values of 15, 195 and 285 degrees. The antennas are placed on a tower at a height of 80m above ground. The net antenna gain is 10dBd.

The measurements have been performed in 9 locations around the transmission site, as it can be seen in Table I [2]. In order to perform the simulations, a 3-arc-second resolution SRTM map was imported in ICS Telecom. The map, containing the locations of the broadcasting station and of the nine measurement points can be seen in Fig. 2.

TABLE I. Measurement Locations

Location	Latitude	Longitude
1.PROFITIS ELIAS	40.640411	23.039927
2.THESSALONIKI	40.615822	22.955735
3. LAKE VOLVI	40.707102	23.188914
4. PEREA	40.513489	22.937471
5. METHONI	40.469402	22.574711
6. KORINOS	40.307130	22.618620
7. BORDER EVZONI	41.081190	22.588360
8. SOUMELA	40.410086	22.116606
9. LOUTRAKI	40.966160	21.923630

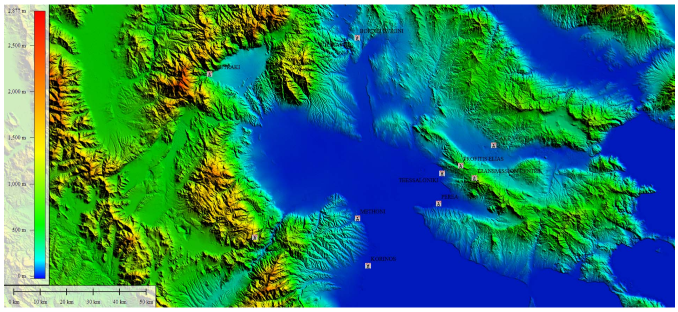

Fig. 2. SRTM 3-arc-second resolution map that was used for simulations in both Radio Mobile and ICS Telecom.

In order to estimate the coverage provided by the Hortiatis broadcasting station over a wide area, covering several hundreds of square kilometers, several propagation models were used: Longley Rice, ITU-R P.1546, ITU-R 525/526 and Okumura-Hata-Davidson. The models were chosen based on the broadcasting frequency that is used (490 MHz) and on the characteristics of the terrain.

The results of the measurements that were performed in the nine locations described before and of the simulations performed with the Radio Mobile and ICS Telecom radio planning environments and Matlab implementations of ITU-R P.1546 and Hata-Davidson models [4] are presented in Table II.

In Figures 4, 5, 6 and 7 the graphical representations of the coverages obtained for the Longley-Rice, ITU-R P.1546, Okumura-Hata-Davidson and ITU-R 525/526 propagation models using ICS Telecom are given.

It can be noticed that the most optimistic from the three propagation models considering the total surface of the area that can be covered with signal by the Hortiatis broadcasting station is the ITU-R P.1546 propagation model. However, by looking at the signal level values that were obtained as simulation results for the nine locations where the measurements were performed, it can be seen that the highest values are the typically the ones obtained using the ITU-R 525/526 propagation model.

TABLE II. MEASUREMENT AND SIMULATION RESULTS USING RADIO MOBILE, ICS TELECOM AND MATLAB ENVIRONMENTS

No.	DVB-T Measurements Points CH23- 490MHz LAT: 40.597648 LONG: 23.0997993	LAT LONG	E(dBμV/m)							
			Measurements	Longley-Rice Estimation		ITU-R P.1546 Estimation		Okumura-Hata-Davidson Estimation		ITU525/526
				Radio Mobile	ICS Telecom	Matlab	ICS Telecom	Matlab	ICS Telecom	ICS Telecom
1	PROFITIS ELIAS (7Km/313degs)	40.640411 23.039927	101.9	95.3	101	96.1	96	97.8	100	101
2	THESSALONIKI (12.3Km/279degs)	40.615822 22.955735	94.7	98.2	96	93.5	95	95.6	92	96
3	LAKE VOLVI (14.3Km/31degs)	40.707102 23.188914	98.2	97.0	95	95.8	91	94.2	90	95
4	PEREA (16.7Km/236degs)	40.513489 22.937471	98.2	94.8	93	94.4	89	93.1	88	93
5	METHONI (47Km/252degs)	40.469402 22.574711	89.1	82.4	85	84.2	83	72.9	83	85
6	KORINOS (52Km/232degs)	40.307130 22.618620	83.5	80.4	84	82.8	80	70.5	71	84
7	BORDER EVZONI (69Km/320degs)	41.081190 22.588360	71.9	72.4	60	55.3	55	73.7	68	77
8	SOUMELA (86Km/256degs)	40.410086 22.116606	77.9	77.9	79	71.5	74	80.2	61	79
9	LOUTRAKI (107Km/293degs)	40.966160 21.923630	77.3	74.7	78	43.0	66	78.3	53	77

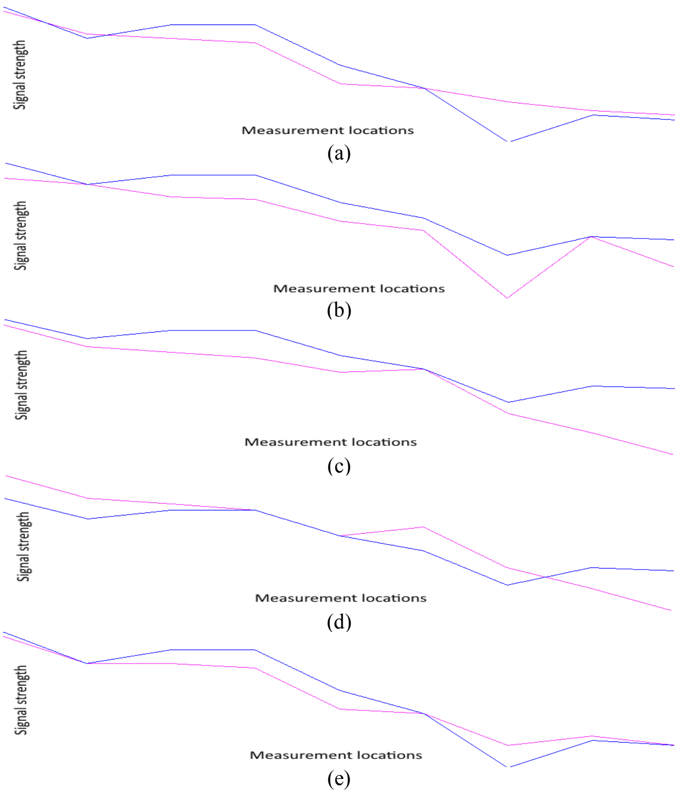

Fig. 3. Graphical representation of the differences between the measurement data (blue) and the simulated ones (magenta) for the nine locations in case of the models (a) Longley-Rice (b) ITU-R P.1546 (c) Okumura-Hata-Davidson (d) Okumura-Hata-Davidson after tuning (e) ITU 525/526.

In Table III and Fig. 3 the differences that were obtained between the measurement data and the data obtained by means of simulations are presented. Two different metrics were used for each of the models, average error and standard deviation.

Regarding the correlation between the measurement results and the simulation results, the propagation model that offers a minimum average error is the ITU-R 525/526 deterministic model (average error of only 0.6 dB over the nine analyzed locations). For this model, the typical difference between the measurement results and the simulated ones is below 5 dB. From the empirical models, the best performance is obtained by the Longley Rice model, with average errors of only 2.2 dB (in case of the Radio Mobile implementation) and 2.4 dB (in case of the ICS Telecom implementation).

It can be also noticed that in case of the Okumura-Hata-Davidson model the differences between the measurement and the simulation results are increasing the longer the distance is between the transmitter and the analyzed receive location.

In order to improve the performances for the propagation models where the differences between the prediction and the measurements are significant, the ICS Telecom software offers tuning options, which can provide important improvements. In Fig. 3(c) the differences for the original Okumura-Hata-Davidson model are pictured (average error of 9.6 dB). In Fig. 3(d) the differences for the same model are given, but after the tuning, and the average error decreased to as low as 1.1 dB.

IV. CONCLUSION AND FUTURE WORK

The present paper presents a comparison between the results of a measurement campaign conducted in northern Greece and simulations performed using ICS Telecom, Radio Mobile and Matlab environments. The propagation models that were considered were three empirical ones (NTIA-ITS Longley Rice, ITU-R P.1546 and Okumura-Hata-Davidson) and a deterministic model (ITU-R 525/526). The performance of the models was evaluated in terms of average error and standard deviation for a number of 9 locations around the

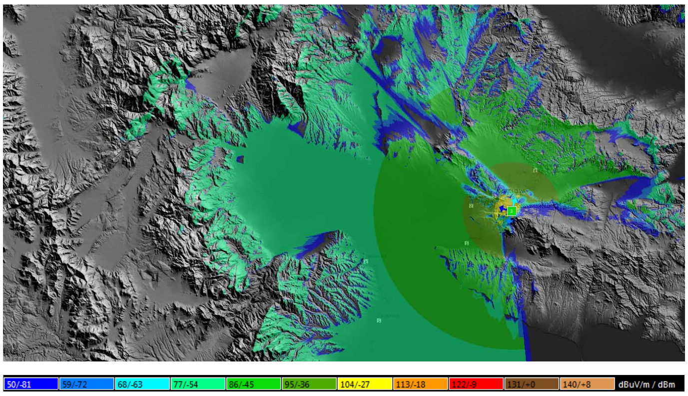

Fig. 4. DVB-T coverage of the analyzed area using the Longley-Rice propagation model using ICS Telecom.

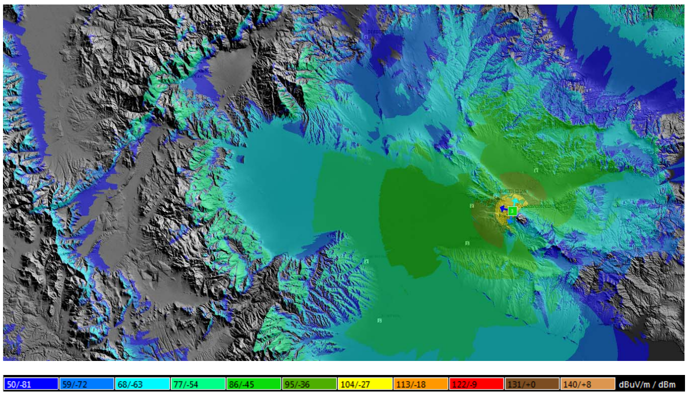

Fig. 5. DVB-T coverage of the analyzed area using the ITU-R P.1546 propagation model using ICS Telecom.

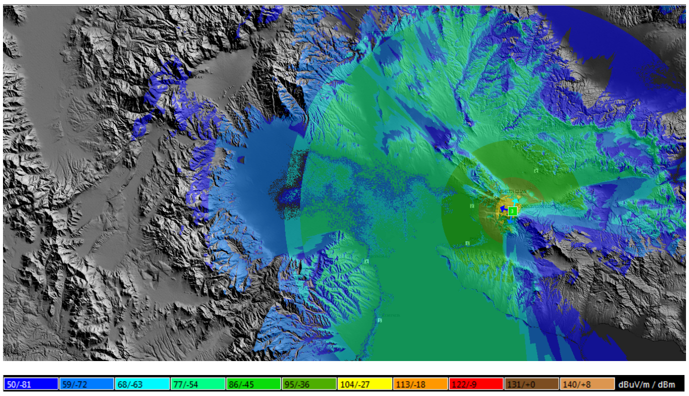

Fig. 6. DVB-T coverage of the analyzed area using the Okumura-Hata-Davidson propagation model using ICS Telecom.

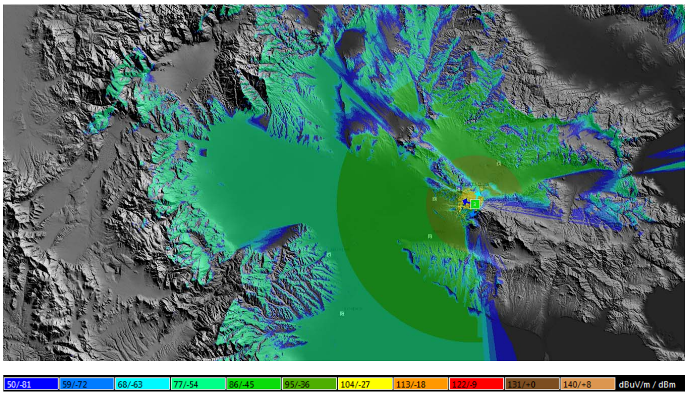

Fig. 7. DVB-T coverage of the analyzed area using the ITU-R 525/526 propagation model using ICS Telecom.

TABLE III. DIFFERENCES BETWEEN THE MEASUREMENTS AND THE SIMULATIONS RESULTS

No.	**DVB-T Measurements Points CH23- 490MHz LAT: 40.597648 LONG: 23.0997993**	**Performance metric**	**Errors Measurements vs Simulations (dB)**						
			Longley-Rice Estimation		**ITU-R P.1546 Estimation**		**Okumura-Hata-Davidson Estimation**		**ITU525/526**
			Radio Mobile	**ICS Telecom**	**Matlab**	**ICS Telecom**	**Matlab**	**ICS Telecom**	**ICS Telecom**
1	PROFITIS ELIAS (7Km/313degs)	Error	6.6	0.9	5.8	5.9	4.1	1.9	0.9
2	THESSALONIKI (12.3Km/279degs)	Error	-3.5	-1.3	1.2	-0.3	-0.9	2.7	-1.3
3	LAKE VOLVI (14.3Km/31degs)	Error	1.2	3.2	2.4	7.2	4	8.2	3.2
4	PEREA (16.7Km/236degs)	Error	3.4	5.2	3.8	9.2	5.1	10.2	5.2
5	METHONI (47Km/252degs)	Error	6.7	4.1	4.9	6.1	16.2	6.1	4.1
6	KORINOS (52Km/232degs)	Error	3.1	-0.5	0.7	3.5	13	12.5	-0.5
7	BORDER EVZONI (69Km/320degs)	Error	-0.5	11.9	16.6	16.9	-1.8	3.9	-5.1
8	SOUMELA (86Km/256degs)	Error	0.0	-1.1	6.4	3.9	-2.3	16.9	-1.1
9	LOUTRAKI (107Km/293degs)	Error	2.6	-0.7	34.3	11.3	-1	24.3	0.3
		Average error	**2.2**	**2.4**	**8.5**	**7.1**	**4.00**	**9.6**	**0.6**
		Standard deviation	**3.3**	**4.3**	**10.8**	**5.0**	**6.6**	**7.3**	**3.2**

broadcasting transmitter station. The best results were obtained by using the ITU 525/526 model (average error 0.6 dB and standard deviation 3.2 dB). The Longley Rice model implementations used in Radio Mobile and ICS Telecom have shown a similar and very good accuracy based on our statistical analysis. The ITU-R P.1546 and Okumura-Hata-Davidson models are much simpler but also less accurate.

Coverage analysis of other broadcasting transmitters in future studies will be very useful for a more complete assessment of the various propagation models and their implementations. Furthermore, simulations using more detailed maps (resolution of 1 arc second or less) will be made in order to evaluate the influence of the map resolution on the coverage predictions.

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