Comparison of Longley-Rice, ITM and ITWOM propagation models for DTV and FM Broadcasting

Stylianos Kasampalis, Pavlos I. Lazaridis, Zaharias D. Zaharis, Aristotelis Bizopoulos, Spiridon Zettas and John Cosmas, *Senior Member IEEE*.

Abstract— **With the rapid deployment of digital TV, there is an increasing need for accurate point-to-area prediction tools. There is a great deal of propagation models for coverage prediction of DTV. Some of them are pure empirical models, and others are mixed, empirical-analytical models, based on measurement campaigns and electromagnetic theory. The aim of this paper is to compare accurate measurements taken by a Rohde & Schwarz FSH-3 portable spectrum analyzer and precision antennas (biconical and log-periodic), with simulation results derived from coverage prediction models, like the NTIA-ITS Longley-Rice model, the ITM (Irregular Terrain Model) using the 3-arc-second SRTM (Satellite Radar Topography Mission) data that is available freely, and the newer ITWOM (Irregular Terrain with Obstructions Model) model which combines equations from ITU-R P.1546 model with Beer's law and Snell's law. Furthermore, measurements for analog FM broadcasting are compared to predictions from the above mentioned models.**

Keywords—**DVB-T, NTIA-ITS, Longley-Rice, ITM, ITWOM, SRTM, ITU-R P.1546, FM.**

I. INTRODUCTION

In order to take full advantage of DTV services and characteristics and to obtain a satisfactory coverage, measurement campaigns are required, as well as field trials, comparing simulation and laboratory results with measurements. The scope of this research, is to provide coverage prediction maps for DTV and FM radio services, in the region of Thessaloniki – Greece, and to validate simulation results with field measurements. It is well known that the coverage of a transmitter can only be obtained by extensive measurement campaigns. However, on-site measurements are inconvenient, because they cost in time and money. Therefore, the use of a prediction model becomes absolutely necessary. There is a vast number of prediction models, like: Egli, Longley-Rice, Okumura-Hata, COST 231, Lee, Bullington, the ITU model P.1546-3, [1], and others. The literature on this subject is huge, [2-3]. From all the above models, Longley-Rice is by far the most widely used. There are commercial software programs for coverage prediction based on the above mentioned propagation models, but they are expensive and the use of their demonstration versions is very restricted. Fortunately, there are some excellent freeware programs, such as: Radio Mobile (Windows based software) and SPLAT! (Linux based software). Both of them are based on the NTIA's original Longley-Rice Technical Note 101 (TN101), [4].

The Radio Mobile program, [5-7], (Radio Propagation and Virtual Mapping Freeware is based on the Longley-Rice Model-ITM and uses the 3-arc-second Satellite Radar Terrain Mission SRTM maps, [8]. Radio Mobile performs a wide range of simulations, it is user friendly, and can be used instead of the very expensive commercial applications giving satisfactory simulation results.

The SPLAT!, [9], program (an RF **S**ignal **P**ropagation, **L**oss, **A**nd **T**errain analysis tool) for the spectrum between 20MHz and 20GHz is an excellent open-source, Linux based program. For Windows users, there are two versions, freely available, [10-11]. SPLAT! is also based on the Longley-Rice Model-ITM and uses SRTM maps.

In the latest version of SPLAT! ITM is replaced by the ITWOM, [12-13]. The ITWOM involves empirical data from ITU-R P.1546 as well as Beer's law and Snell's law and promises greater accuracy over the older ITM, [13]. An optimization method for tuning the parameters of ITU-R P.1546 was recently proposed, [16].

II. MEASUREMENTS AND COMPARISONS

In order to measure the field strength from DVB-T and FM transmitters, a measurement campaign was carried out in Thessaloniki, located in the north of Greece. The measurement equipment consists of a Rohde & Schwarz FSH-3 portable spectrum analyzer, factory calibrated with ± 0.7dB accuracy, two high-precision calibrated biconical antennas by Schwarzbeck, SBA 9113 (500MHz - 3GHz) and BBVU 9135 (30MHz - 1000MHz), a log-periodic precision calibrated Schwarzbeck antenna USLP 9143 (0.25 – 6 GHz), factory calibrated with ± 1.0dB accuracy, and low-loss cable Suhner GX-07272-D, 1.8 meters long with N-type connectors. In our study, for the calculated values of the field-strength we employ the Radio Mobile software (Windows) with ITM, the SPLAT! for Windows software (splat-1.2.3-win32) with ITM, and the open-source SPLAT! v.1.4.0 with ITWOM (Linux - Ubuntu 12.10).

A Point-to-Point analysis for Public Greek DTV ERT, Channel 56 (754MHz) is presented in Table I. Errors between FSH-3 measurements and ITM model (Radio Mobile & SPLAT! for Windows), with average error and standard deviation, are shown in the Table II.

TABLE I

A POINT-TO-POINT ANALYSIS FOR PUBLIC GREEK DTV ERT, CH56 -754MHz.

No.	DVB-T Measurements Points CH56 - 754MHz LAT: 40.597648 LONG: 23.0997993	LAT LONG	E(dBμV/m)			
			FSH-3 Measure-ments	ITM Radio Mobile (Windows)	ITM SPLAT! (Windows)	ITWOM SPLAT! v1.4.0 (LINUX)
1	PROFITIS ELIAS (7Km/313degs)	40.640411 23.039927	101.6	96.4	99.0	93.8
2	THESSALONIKI (12,3Km/279degs)	40.615822 22.955735	95.9	97.0	93.9	92.8
3	LAKE VOLVI (14,3Km/31degs)	40.707102 23.188914	98.9	97.0	92.7	89.5
4	PEREA (16,7Km/236degs)	40.513489 22.937471	96.7	95.8	91.3	88.4
5	METHONI (47Km/252degs)	40.469402 22.574711	84.0	84.0	81.7	63.1
6	KORINOS (52Km/232degs)	40.307130 22.618620	82.3	84.3	80.6	60.6
7	BORDER EVZONI (68,8Km/321degs)	41.081410 22.588160	65.3	73.8	77.4	58.0
8	SOUMELA (86Km/256degs)	40.410086 22.116606	75.6	77.2	76.0	56.4
9	LOUTRAKI (107Km/293degs)	40.966160 21.923630	75.8	77.8	72.8	53.3
10	POLIKASTRO (69Km/320degs)	41.081190 22.588360	71.9	73.9	77.4	58.0

TABLE II

ERRORS BETWEEN FSH-3 MEASUREMENTS AND ITM MODEL (RADIO MOBILE & SPLAT! FOR WINDOWS), WITH AVERAGE ERROR AND STANDARD DEVIATION

No.	DVB-T Measurements Points CH56 - 754MHz	E(dBμV/m)			Errors (dB)	
		FSH-3	ITM Radio Mobile	ITM SPLAT! For Windows	FSH-3 & Radio Mobile	FSH-3 & SPLAT! ITM
1	PROFITIS ELIAS	101.6	96.4	99.0	-5.2	-2.6
2	THESSSALONIKI	95.9	97.0	93.9	1.1	-2.0
3	LAKE VOLVI	98.9	97.0	92.7	-1.9	-6.2
4	PEREA	96.7	95.8	91.3	-0.9	-5.4
5	METHONI	84.0	84.0	81.7	0.0	-2.3
6	KORINOS	82.3	84.3	80.6	2.0	-1.7
7	BORDER EVZONI	65.3	73.8	77.4	8.5	12.1
8	SOUMELA	75.6	77.2	76.0	1.6	0.4
9	LOUTRAKI	75.8	77.8	72.8	2.0	-3.0
10	POLIKASTRO	71.9	73.9	77.4	2.0	5.5
Average					0.9	-0.5
Standard Deviation					3.5	5.5

Errors between measurements (FSH-3) and simulations (ITM model from Radio Mobile & SPLAT!), are shown in the bar graph below in Fig. 1.

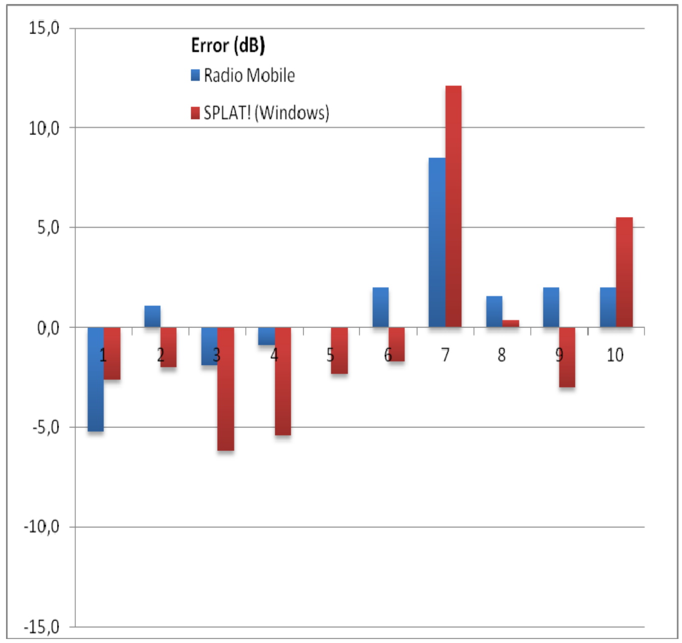

Fig.1. Errors between measurements (FSH-3) and simulations with ITM model (Radio Mobile & SPLAT! for Windows).

The No. 2, 4, 5, 7, 9, and 10 simulations results are better for Radio Mobile than those of SPLAT! for windows, and No. 1, 6, and 8 simulation results are better for SPLAT! (ITM) than those of Radio Mobile. The main conclusion for the above measurement points is that Radio Mobile gives overall better simulation results with lower standard deviation (S.D. = 3.5 dB) than SPLAT! for Windows (S.D. = 5.5 dB), though both software use the same propagation model, i.e. ITM.

The sample standard deviation was calculated between measured path loss values and those predicted by Radio Mobile and SPLAT! using the following commonly used equation with Bessel's correction :

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu)^2}$$

where :

N: number of measured data points (N=10)

x_i: Error between predicted and measured field-strength (dB) for data point i

μ: Average value of difference (dB)

All the antennas of the FM radio and TV stations are located on Hortiatis mountain nearby the city of Thessaloniki.

Differences between FSH-3 measurements, SPLAT! for Windows with ITM and SPLAT! v 1.4.0 for Linux with ITWOM, with average error and standard deviation, are shown in Table III. Errors between measurements (FSH-3) and simulations (SPLAT!-ITM & SPLAT!-ITWOM), are shown in the bar graph below, Fig. 2.

As we can see from the above measurements and simulation results, SPLAT! v1.4.0 with ITWOM gives worse simulation results than SPLAT! for Windows and Radio Mobile.

Additionally, in distances bigger than 40Km the simulation results are much worse. Most probably, SPLAT! with ITWOM overestimates the attenuation by obstacles and this is currently under investigation.

TABLE III

ERRORS BETWEEN FSH-3 MEASUREMENTS, SPLAT! FOR WINDOWS WITH ITM AND SPLAT! V 1.4.0 FOR LINUX WITH ITWOM, WITH AVERAGE ERROR AND STANDARD DEVIATION

No.	DVB-T Measurements Points CH56 - 754MHz	E(dBμV/m)			Errors (dB)	
		FSH-3	ITM SPLAT! For Windows	ITWOM SPLAT! v1.4.0 LINUX	FSH-3 & SPLAT! For Windows	FSH-3 & SPLAT! ITWOM v1.4.0 LINUX
1	PROFITIS ELIAS	101.6	99.0	93.8	-2.6	-7.8
2	THESSSALONIKI	95.9	93.9	92.8	-2.0	-3.1
3	LAKE VOLVI	98.9	92.7	89.5	-6.2	-9.4
4	PEREA	96.7	91.3	88.4	-5.4	-8.3
5	METHONI	84.0	81.7	63.1	-2.3	-20.9
6	KORINOS	82.3	80.6	60.6	-1.7	-21.7
7	BORDER EVZONI	65.3	77.4	58.0	12.1	-7.3
8	SOUMELA	75.6	76.0	56.4	0.4	-19.2
9	LOUTRAKI	75.8	72.8	53.3	-3.0	-22.5
10	POLIKASTRO	71.9	77.4	58.0	5.5	13.9
Average					-0.5	-13.4
Standard Deviation					5.5	7.1

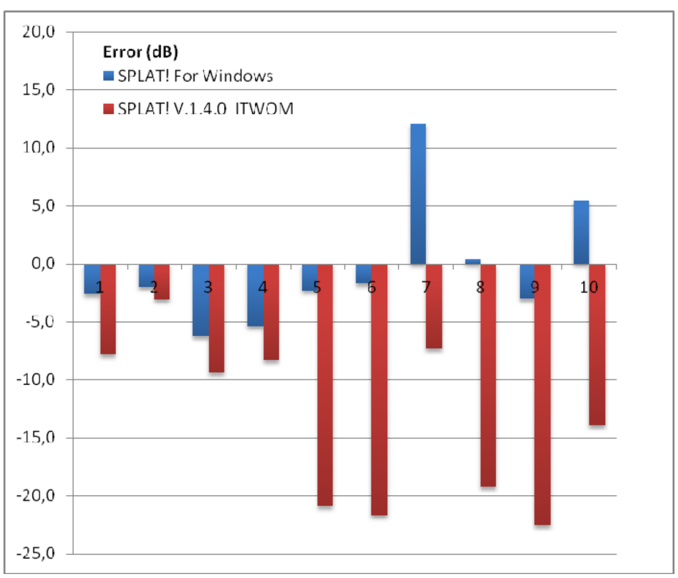

Fig. 2. Errors between measurements (FSH-3) and simulations SPLAT!-ITM & SPLAT!-ITWOM.

A coverage map produced by Radio Mobile with ITM for Greek public DTV ERT, Channel 56 (754MHz), is shown in Fig. 3. The transmitting antenna coordinates are N 40.597648 - E 23.099793, the transmit power is 1.25 kW rms), the antenna type is a 4 bay-3 directions UHF panel array, each panel having an 11 dBd gain for a total gain minus cable losses of 10 dBd, the average antenna height is 70 m, and the azimuth is 285degs. A coverage map produced by SPLAT! for the Greek public DTV, ERT CH56 (754MHz), is shown in Fig. 4.

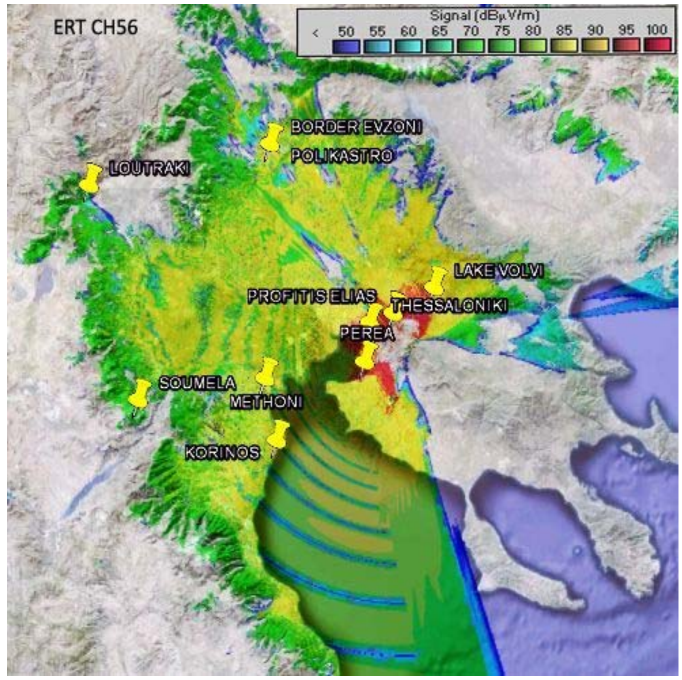

Fig. 3. Coverage map produced by Radio Mobile with ITM for ERT Ch 56. Use of 3 directions UHF panel array antenna.

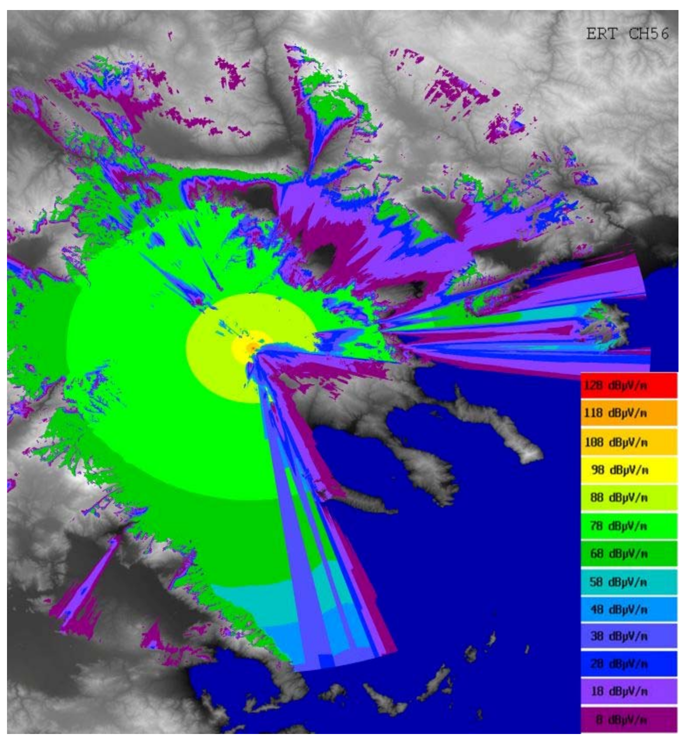

Fig. 4. Coverage map produced by SPLAT! for Windows for ERT Ch 56.

A coverage map produced by SPLAT! v.1.4.0 with ITWOM is shown in Fig. 5. Because SPLAT! v.1.4.0 works only with Linux, Ubuntu 12.10, [14], was used to produce the coverage map. For the simulation purposes, an omni transmitting antenna has been used.

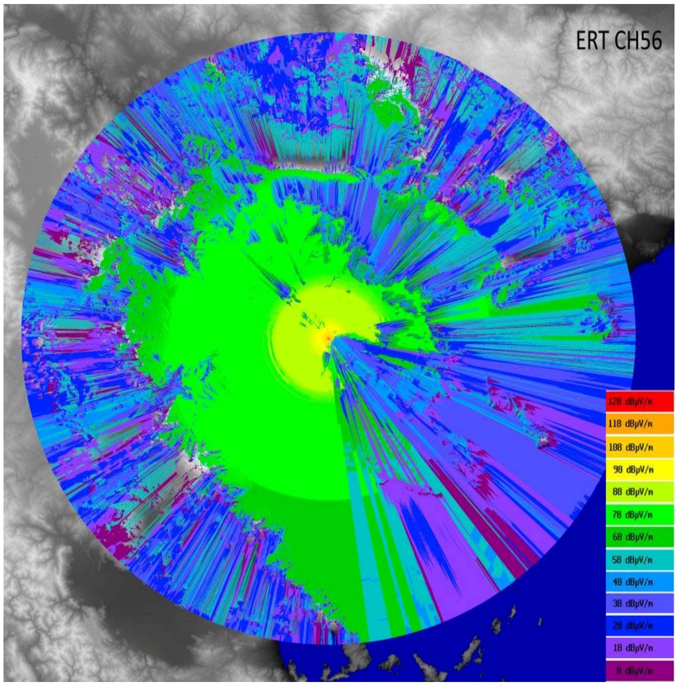

Fig. 5. Coverage map produced by SPLAT! with ITWOM model for ERT CH-56.

All measurements were made by varying the receiving antenna from 0.5 meters to 2.5 meters height and keeping the peak value. The simulation results produced by ITM & ITWOM model with Radio Mobile and SPLAT! used the same reception antenna heights, for an accurate comparison of results.

Although DAB (Digital Audio Broadcasting), was developed in the early nineties, it is still not in use in many countries, [17]. Recently, in February 2013 at Geneva, EBU released recommendation r138 for Digital Radio Distribution in Europe [18]. In Greece DAB is currently not in use, and all radio stations are still analog. There is, however, a necessity for measurements and predictions in radio broadcasting, especially in the VHF frequencies. Using the same equipment and software, as above for the DTV case, measurements were made for the Greek public FM radio station "ERA-102". This station is also located on Hortiatis Mountain, nearby the city of Thessaloniki. The coordinates are the same as before (same antenna tower), the transmit power is 20 kW, frequency is 102 MHz, the antenna type is 6 bays in 3 directions of FM panel antennas (dipoles in front of reflector) with a total gain minus cable losses of 5 dBd, the average antenna height is 50m, and the azimuth is 285degs.

A Point-to-Point analysis for the Greek public FM radio station "ERA102" is shown in Table IV. Errors between FSH-3 measurements and ITM model (Radio Mobile & SPLAT! for Windows), with average error and standard deviation, are shown in the Table V.

TABLE IV

A POINT-TO-POINT ANALYSIS FOR THE GREEK PUBLIC FM RADIO STATION "ERA102"

No.	ERA102 Measurements Points FM - 102MHz LAT: 40.597648 LONG: 23.0997993	LAT LONG	E(dBµV/m)			
			FSH-3 Measure-ments	ITM Radio Mobile (Windows)	ITM SPLAT! (Windows)	ITWOM SPLAT! v1.4.0 (LINUX)
1	KOURI (5.2Km/319degs)	40.632814 23.05884	108.8	110.0	100.8	96.6
2	METHONI (47Km/252degs)	40.469402 22.574711	96.7	91.7	94.0	76.1
3	KORINOS (52Km/232degs)	40.307130 22.618620	71.9	81.5	92.9	73.0
4	BORDER EVZONI (68.8Km/321degs)	41.081410 22.588160	63.0	76.3	88.8	70.3
5	LOUTRAKI (107Km/293degs)	40.966160 21.923630	65.7	76.7	82.7	65.8
6	POLIKASTRO (69Km/320degs)	41.081190 22.588360	56.1	67.7	88.8	70.3

TABLE V

ERRORS BETWEEN FSH-3 MEASUREMENTS AND ITM MODEL (RADIO MOBILE & SPLAT! FOR WINDOWS), WITH AVERAGE ERROR AND STANDARD DEVIATION

No.	DVB-T Measurements Points ERA102- 102MHz	E(dbµV/m)			Errors (dB)	
		FSH-3	ITM Radio Mobile	ITM SPLAT! For Windows	FSH-3 & Radio Mobile	FSH-3 & SPLAT! For Windows
1	KOURI	108.8	110.0	100.8	1.2	-8.0
2	METHONI	96.7	91.7	94.0	-5.0	-2.7
3	KORINOS	71.9	81.5	92.9	9.6	21.0
4	BORDER EVZONI	63.0	76.3	88.8	13.3	25.8
5	LOUTRAKI	65.7	76.7	82.7	11.0	17.0
6	POLIKASTRO	56.1	67.7	88.8	11.6	32.7
Average					7.0	14.3
Standard Deviation					7.2	16.2

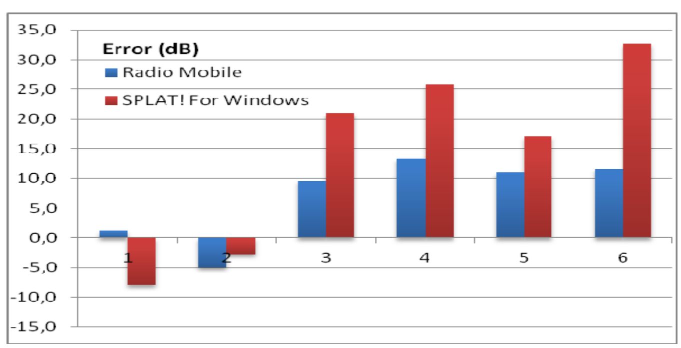

Fig.6. Errors between measurements FSH-3 and simulations ITM model, Radio Mobile & SPLAT!

Errors between measurements (FSH-3) and simulations (ITM model from Radio Mobile & SPLAT!), are shown in the bar graph below, Fig. 6. No. 1, 3, 4, 5, and 6 simulations results are better for Radio Mobile than these of SPLAT! for windows, and only No. 2, simulation result is better for

SPLAT! (ITM) than Radio Mobile. Consequently, Radio Mobile gives better simulation results with a lower standard deviation (S.D. = 7.2dB) than SPLAT! for Windows (S.D.= 16.2 dB), though both software use ITM for propagation modeling. It can be also seen in the FM case that the simulations results produced by SPLAT! for Windows are worse than Radio Mobile results, and getting worse as distance increases above around 40Km. The simulation results are, in general worse for VHF FM radio frequencies than those for UHF DVB-T frequencies.

Differences between FSH-3, SPLAT! for Windows with ITM and SPLAT! v 1.4.0 for Linux with ITWOM, with average error and standard deviation , are shown in Table VI. Errors between measurements (FSH-3) and simulations (SPLAT!-ITM & SPLAT!-ITWOM), are shown in the bar graph below, Fig. 7.

TABLE VI
ERRORS BETWEEN FSH-3, SPLAT! FOR WINDOWS WITH ITM AND SPLAT! v 1.4.0 FOR LINUX WITH ITWOM, WITH AVERAGE ERROR AND STANDARD DEVIATION

No.	DVB-T Measurements Points ERA102- 102MHz	E(dbµV/m)			Errors (dB)	
		FSH-3	ITM SPLAT! For Windows	ITWOM SPLAT! v.1.4.0 Linux	FSH-3 & SPLAT! For Windows	FSH-3 & SPLAT! v.1.4.0 Linux
1	KOURI	108.8	100.8	96.6	-8.0	-12.2
2	METHONI	96.7	94.0	76.1	-2.7	-20.6
3	KORINOS	71.9	92.9	73.0	21.0	1.1
4	BORDER EVZONI	63.0	88.8	70.3	25.8	7.3
5	LOUTRAKI	65.7	82.7	65.8	17.0	0.1
6	POLIKASTRO	56.1	88.8	70.0	32.7	14.2
Average					14.3	-1.7
Standard Deviation					16.2	12.7

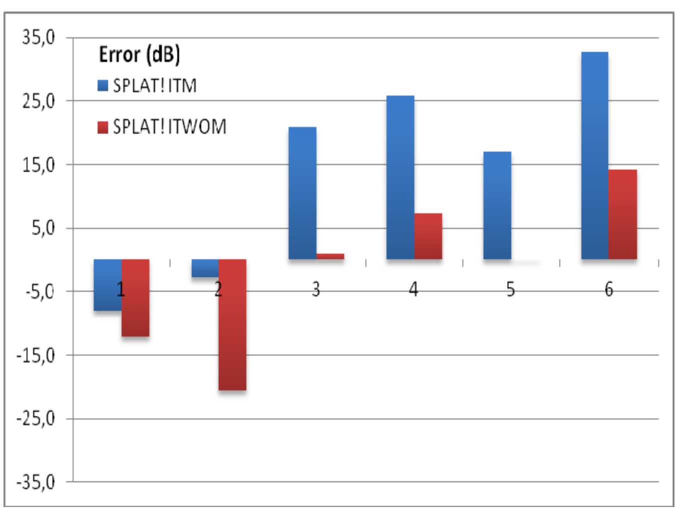

Fig.7. Errors between measurements FSH-3 and simulations SPLAT!-ITM & SPLAT!-ITWOM.

It can be noticed that simulation results for No. 3 4, 5, and 6 measurement points using SPLAT! with ITWOM are better than SPLAT! for Windows, which in turn gives better results for No. 1 and 2 measurement points. We observe that for frequencies in the VHF FM range, SPLAT! with ITWOM gives better simulation results than SPLAT! for Windows.

A coverage map produced by Radio Mobile (ITM Model) for Greek public FM radio "ERA-102" is shown in Fig. 8. A coverage map produced by SPLAT! for Windows (splat-1.2.3-win32) for the Greek Public FM Radio Station, "ERA-102" is shown in Fig. 9.

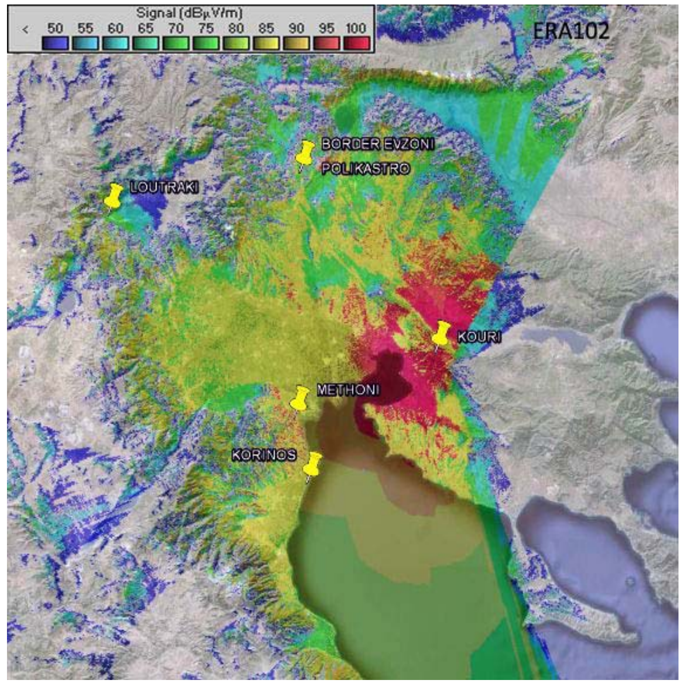

Fig. 8. Coverage map produced by Radio Mobile with ITM for "ERA-102" - FM radio station.

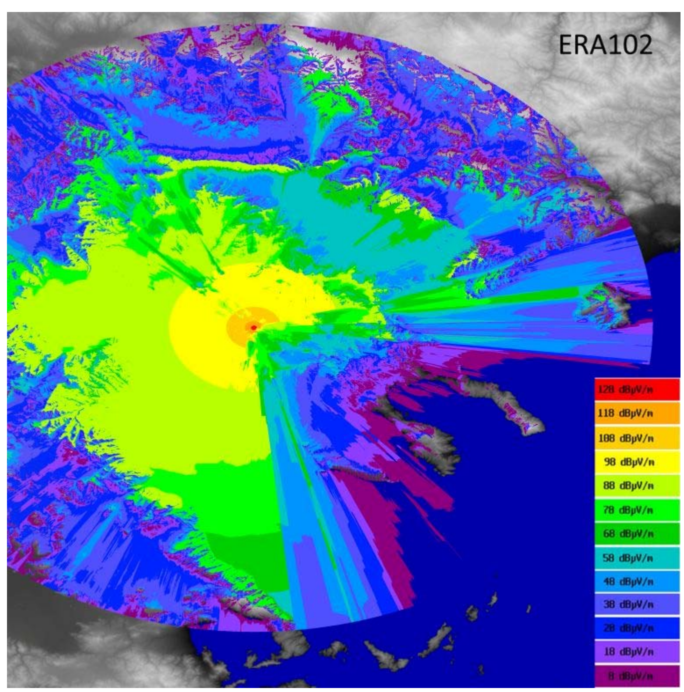

Fig. 9. Coverage map produced by SPLAT!-ITM (Windows), for "ERA-102".

A coverage map produced by SPLAT! v.1.4.0 with ITWOM for the same radio station is shown in Fig. 10.

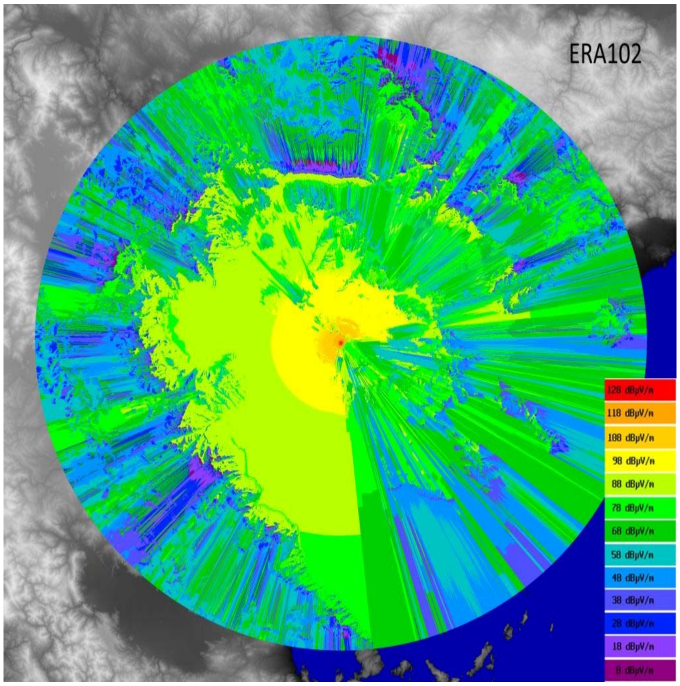

Fig. 10. Coverage map produced by SPLAT!-ITWOM (Linux), for FM radio station "ERA-102".

III. CONCLUSION

The Longley-Rice (ITM) model, that Radio Mobile and SPLAT!, use in conjunction with worldwide Shuttle Mission Satellite Radar 3-arc-second data (SRTM) produce, in some cases, big differences comparing with measurements results. The ITM does not work quite well in the line-of-sight mode and in the early diffraction range. Furthermore, the ITM does not use more detailed terrain information as other more sophisticated models do, [15]. The ITWOM propagation model was recently proposed, [13], claiming an improved accuracy over the ITM. However, early simulations and measurements results in point-to-point path analysis with ITWOM do not verify these claims. The ITWOM has a somewhat better accuracy for distances < 20Km, but very big differences for larger distances > 40Km. Of course, we were not able to use the more detailed 1/3-arc-second SRTM maps, because they are only available for the US territory.

ACKNOWLEDGMENT

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