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EVALUATION OF PREDICTION ACCURACY FOR THE LONGLEY-RICE MODEL IN THE FM AND TV BANDS

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***Abstract*- Accurate geographical coverage predictions maps for FM and TV are needed for channel and frequency allocations and in order to avoid unwanted interferences. The Longley-Rice model has been used for this purpose over the last four decades and still being used almost exclusively by the FCC in the United States. In this work a comparison is presented between the relative accuracy of this model in the VHF-FM and UHF-TV frequency bands. Simulations were made with accurate and up to date input data (antenna height, location, gain, transmit power, etc.) for the FM-TV stations provided by the ERT S.A. public broadcaster in the region of Thessaloniki – Greece. Finally, the calculated – simulated results were confronted to field measurements using a Rohde & Schwarz FSH3 portable spectrum analyzer and high precision calibrated biconical and log-periodic antennas, and the errors between predictions and measurements were statistically analyzed in the two frequency bands. It has been found in this study that the Longley-Rice model, in general, overestimates field-strength values, but this overestimation is much higher in the VHF – FM radio band (88-108 MHz) than in the UHF-TV band (470-790 MHz).**

***Index terms*—VHF-UHF measurements, field-strength, FM-TV coverage prediction, Longley-Rice, biconical antenna, log-periodic antenna, spectrum analyzer.**

1. INTRODUCTION

The Longley-Rice model originally used for the planning of analogue TV broadcasting and channel allocation in the US in the 1960s, is still being used to date, [1]. In fact, it is the method of choice in the United States, and almost exclusively used in FCC (Federal Communications Commission) calculations. The FCC's Office of Engineering and Technology (OET) has recently released an updated version of the model to calculate TV station coverage and potential interference in an attempt to repack the TV stations coverage areas. The analogue switch-off is now a reality in many European countries and in the United States, but the question of accurate coverage prediction is still open. Digital TV (DTV) makes the demand for accurate coverage prediction more important as operators of digital TV stations must ensure that their transmissions do not cause interference to other stations or to mobile telephony operators in nearby frequency channels (digital dividend). All these issues make the accurate coverage prediction and DTV transmitter distribution critical facts for the proper deployment of digital terrestrial television, [1-10]. Furthermore, the accurate prediction of FM radio coverage is also very important to FM broadcasters in order to impose them the correct maximum ERP (Effective Radiating Power) and to avoid long-distance (DX) interferences between stations using the same frequencies.

In order to correctly evaluate the accuracy of a propagation model, and more specifically in this case, of the Longley-Rice model, extensive field measurements are required, and their confrontation to simulation results obtained by the propagation model, [1-4]. This is exactly the scope of this study, i.e. to compare accurate field-strength measurements with simulation results in the Thessaloniki-Greece area and evaluate the precision of the propagation model in various circumstances. Also in [4] some comparisons between measurements and the Longley-Rice model have been presented in the case of UHF DVB-T and, in a limited number of points, FM broadcasting. In this study, the coverage prediction maps and field-strength calculations were produced by the Radio Mobile software, [10] using the classic Longley – Rice ITM (Irregular Terrain Model), [1]. Therefore, in first place, an introduction of the propagation model and the required inputs will be made. Consequently, the measurements equipment and their precision will be described, followed by Tables comparing measured to simulated results, their statistical analysis, and, finally, the conclusions about the relative accuracy of the Longley-Rice model in the VHF-FM radio band and in the UHF-TV band.

2. PROPAGATION MODEL AND SOFTWARE

2.1 The Longley – Rice Propagation Model

The Longley–Rice model is a radio propagation model for predicting the attenuation of radio signals for a telecommunication link in the frequency range of 20 MHz to 20 GHz. The Longley-Rice model is also known as the Irregular Terrain Model (ITM) because it takes into account the terrain elevation and irregularities, (hills, mountains, etc.). It was created for the needs of frequency planning in television broadcasting in the United States in the 1960s and 1970s, and was extensively used for preparing the tables of channel allocations for VHF/UHF broadcasting. The Longley-Rice model has two calculation modes: a mode for predictions over an area and a mode for point-to-point link predictions. Like all other propagation models (e.g. ITU-R P.1546-4, [5-7]), the Longley-Rice model requires the input of certain general parameters needed for the propagation calculations. These are: the operating frequency, the length of the path, the polarization of antennas (the model considers that both antennas, transmit and receive, have the same polarization, vertical or horizontal), the heights of the antennas, the refractivity of the atmosphere, the effective earth curvature, the conductivity of the soil, the relative permittivity or dielectric constant of the ground and the climatic conditions. These parameters are sufficient for the calculation of the free-space loss, the ground reflection coefficients, the Fresnel parameters of knife-edge diffraction and thus the total electrical field strength.

2.2 The Radio Mobile software

The Longley – Rice model is implemented within the Radio Mobile software. Radio Mobile is a freeware able to calculate a wireless coverage map and point-to-point propagation loss, [10].

The program obtains data for the terrain elevation from databases that are freely accessible through the internet. The main database is the STRM (Shuttle Radar Topography Mission) with a resolution of approximately 90 metres for Europe and a much better resolution for the US.

3. MEASUREMENTS-SIMULATIONS RESULTS

The basic idea of this study is to compare simulated results with measurements at 11 points around the broadcasting site and at varying distances and angles. The measurements points are chosen in order to be representative of all kinds of propagation conditions from short to long distance and from Line-Of-Sight (LOS) unobstructed to severely obstructed. The signal-strength measurements were performed during the second half of 2012, and before the analogue TV switch-off of the Hortiatis mountain broadcasting site, that is serving the region of the city of Thessaloniki in northern Greece. The analogue TV stations were used in this study because their signal strength was much higher than the corresponding DTV signals (due to much higher ERP), and so the measurements results are more accurate.

Table 1

A POINT-TO-POINT ANALYSIS FOR GREEK PUBLIC ANALOGUE TV ET-3, CH27 (519.25 MHz). COMPARISON BETWEEN MEASUREMENTS & THE LONGLEY-RICE MODEL

No.	Analogue TV Measurements Points CH27- 519.25 MHz LAT: 40.597648 LONG: 23.099793	LAT.	LONG.	R&S FSH-3 Measure-ments	Longley-Rice	Error (dB)
1	KOURI-642m (5.2km/319degs)	40.632814	23.058840	116.9	114.9	-2.0
2	CARREFOUR-90m (15.2km/307)	40.680266	22.956606	91.8	88.6	-3.2
3	SHOLARI-225m (17.5km/207degs)	40.457970	23.004350	102.9	107.6	+4.7
4	TEI-2m (25.6km/285degs)	40.655267	22.805703	101.5	105.1	+3.6
5	PROHOMA-64m (43km/303degs)	40.809070	22.673190	66.9	64.4	-2.5
6	METHONI-30m (47km/252degs)	40.469402	22.574711	97.4	104.7	+7.3
7	KORINOS-1m (52km/232degs)	40.307130	22.618620	91.3	92.8	+1.5
8	EVZONI-114m (69km/321degs)	41.081410	22.588160	72.4	87.1	+14.7
9	VERIA-305m (75km/259degs)	40.467249	22.225950	67.3	59.2	-8.1
10	PLATAMONAS-2m(78km/213degs)	40.008522	22.598672	83.3	94.1	+10.8
11	LOUTRAKI-354m (107Km/293degs)	40.966160	21.923630	84.6	87.5	+2.9

Average error = +2.7 dB

Standard deviation = 6.6 dB

Table 2

A POINT-TO-POINT ANALYSIS FOR GREEK PUBLIC FM RADIO, ERT-102.0 MHz. COMPARISON BETWEEN MEASUREMENTS & THE LONGLEY-RICE MODEL

No.	FM Radio Measurements Points 102.0 MHz LAT: 40.597648 LONG: 23.099793	LAT.	LONG.	R&S FSH-3 Measure-ments	Longley-Rice	Error (dB)
1	KOURI-642m (5.2km/319degs)	40.632814	23.058840	108.8	110.0	+1.2
2	CARREFOUR-90m (15.2km/307)	40.680266	22.956606	76.3	83.6	+7.3
3	SHOLARI-225m (17.5km/207degs)	40.457970	23.004350	98.8	96.9	-1.9
4	TEI-2m (25.6km/285degs)	40.655267	22.805703	87.7	92.8	+5.1
5	PROHOMA-64m (43km/303degs)	40.809070	22.673190	56.1	67.7	+11.6
6	METHONI-30m (47km/252degs)	40.469402	22.574711	96.7	91.7	-5.0
7	KORINOS-1m (52km/232degs)	40.307130	22.618620	71.9	81.5	+9.6
8	EVZONI-114m (69km/321degs)	41.081410	22.588160	63.0	76.3	+13.3
9	VERIA-305m (75km/259degs)	40.467249	22.225950	63.2	68.5	+5.3
10	PLATAMONAS-2m (78km/213degs)	40.008522	22.598672	72.1	82.1	+10.0
11	LOUTRAKI-354m (107Km/293degs)	40.966160	21.923630	65.7	76.7	+11.0

Average error = +6.1 dB

Standard deviation = 5.9 dB

In Tables 1 and 2, the simulations and measurements results for 11 different locations in the region around the city of Thessaloniki are presented. In all cases the broadcasting site was at the Hortiatis mountain antenna park, and more specifically the ERT S.A. public broadcaster's antenna tower (N 40.597648–E 23.099793), around 13 km south-east of Thessaloniki city centre at an altitude of 868m. Both TV and FM stations transmit from an antenna tower that has a height of 80m.

The TV antenna UHF panels are located at the top of the tower at an average height of 70m on the tower while the VHF-FM panels are below them at an average height of around 50m on the same tower. The TV antenna system is a 6 bay – 3 directions UHF panel arrangement in horizontal polarization with a net gain of 14 dBd (after cable losses have been subtracted). The FM antenna system is a 6 bay – 3 directions FM panel arrangement in mixed (horizontal-vertical) polarizations with a net gain of 5 dBd in each polarization. Both antenna's main lobe is at an azimuth of 285^{o} towards the city centre. The TV transmitter has a power of 10 kW and an ERP of 54 dBW (250 kW), and the FM transmitter has a power of 20 kW and an ERP of 48 dBW (63 kW).

The simulation results are compared with highly accurate field measurements in Table 1 for TV and Table 2 for FM radio. 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.

The sample standard deviation was calculated between measured field-strength values and those predicted by the Longley-Rice model 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=11)

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

μ: Average value of error (dB)

In all presented simulations the antenna height was varied from 0.5m to 2.5 m and the value where the signal is maximum was held. The measurements with the spectrum analyzer were made with the MAX-HOLD option on and a corresponding change in the height of the receiving antenna, between 0.5 and 2.5 m from the ground, in order to have a correct correspondence between measurements and simulations procedures. This option is the simplest and fastest to implement, and it is also similar to the approach of a user moving his antenna trying to maximize his received FM-TV signal.

For the above results, we took into account the operating frequencies, the transmission power P (kW), the Effective Radiated Power (ERP), the height of the antenna mast (m) and the type and gain of the transmitting antenna system (dBd or dBi).

Minimum signal levels according for satisfactory coverage of analogue TV and average signal levels for DVB-T, and FM Stereo are shown in Table 3.

Table 3. MINIMUM SIGNAL LEVELS FOR SATISFACTORY RECEPTION

Analogue UHF-TV	70	dBμV/m
Digital UHF-TV, DVB-T	47	dBμV/m
FM STEREO	54	dBμV/m

4. COVERAGE MAPS

Coverage maps were created using the "Single Polar Coverage" option of the software with 0.01^{o} step size and with the correct antenna radiation pattern, as interpolated from the antenna manufacturer's data, and with an azimuth of 285^{o}, thus directed to the city centre. The 'Cartesian Coverage' option was not used because it was found to result in inaccuracies depending on the software version utilized.

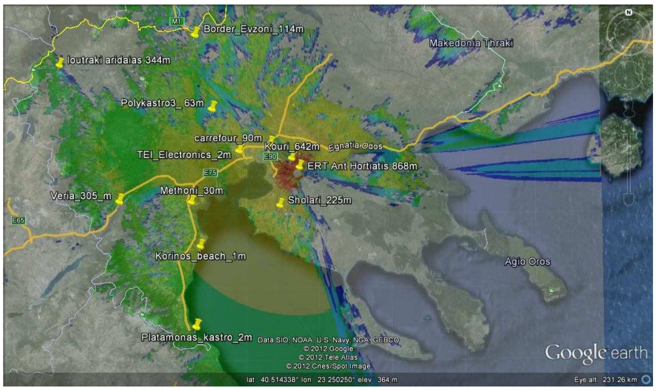

Fig. 1. ET-3 TV station coverage map (for a receiving antenna height of 10m) from the Longley-Rice model along with the 11 measurements points.

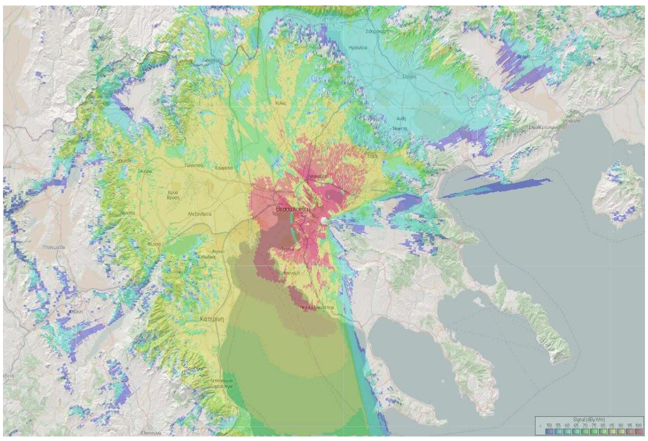

Fig. 2. Coverage map of ERT FM Station 102 MHz, from Hortiatis mountain) for a receiving antenna height of 10m.

A much broader coverage area is predicted by the Longley-Rice model for the FM station transmitting from the same tower as the TV station. However, this prediction seems overly optimistic and could be misleading in the case of long-range (DX) interference studies. It should be noted that the colours in the two figures above do not correspond to the same field-strength values. Thus, the figures are just indicative of the general coverage area in the two cases.

5. DISCUSSION

Comparing the point measurements made with the spectrum analyzer and the simulation results, it is seen that the simulation is very near to the measured results (to within 2 dB) in the very short distance and unobstructed Line-of-Sight (LOS) point 1 for both FM and TV stations and similarly at point 2 that is also unobstructed LOS but at a larger distance. In these cases the free-space propagation model is applicable. Points 4, 6, 7, 10, 11 are, progressively, longer distance but fairly unobstructed LOS points. At these points it is seen that the Longley-Rice model clearly overestimates field-strength in the FM case, and this cannot be due to the calculation of diffraction losses. Most probably, this is due to the much stronger reflection of lower frequency FM radio signals leading to destructive vector addition at the measurement points, after a certain distance.

It also is clearly seen by the statistical analysis of the results presented in the Tables above that the Longley-Rice model overestimates, in general, the measured field-strength (positive average values). However, the overestimation is much bigger for the lower frequencies of the VHF-FM band (much bigger average values of error than in the UHF-TV band). The standard deviation values are slightly higher in the UHF-TV band, most probably due to the higher diffraction losses in this case.

6. CONCLUSIONS

The measurements and simulation results using the Longley-Rice propagation model indicate that, when there is no significant obstruction of the Fresnel ellipsoid in the propagation path the model, that in this case is reduced to essentially the simple free-space propagation model, accurately predicts the field-strength values, at least at relatively short distances. As the distance increases, the accuracy gradually gets worse, especially for points 10 and 11, where an overestimation of the order of 10 dB by the model in the FM band shows the shortcomings of the free-space model for long distances at lower VHF frequencies. A 2-ray model with a break-point distance depending upon the antenna heights would be preferable in this case. On the other hand, for propagation paths with large obstructions of the Fresnel ellipsoid leading to substantial attenuations of the order of 15 – 30 dB (measurement points 2, 5, and 8) the Longley-Rice model seems again to underestimate the obstruction loss in the vast majority of cases (and mainly in the FM long distance cases). Consequently, there is a need for correcting the model, especially in the large-distance (DX) mode, and in the coverage limit zone, because as it is, its behaviour is overly optimistic and particularly in the FM band where, even in the absence of obstructions and in longer distances, the calculated values can be 10 dB higher than the measured field-strength values.

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7. REFERENCES

[1] P. L. Rice, A. G. Longley, K. A. Norton, and A. P. Barsis, “Transmission loss predictions for tropospheric communications circuits,” Technical Note 101, U.S. Dept. of Commerce NTIA-ITS, 1967.

[2] ‘A survey of wireless path loss prediction and coverage mapping methods’, by C. Phillips, D. Sicker, and D. Grunwald, IEEE Communications, Surveys, Tutorials, vol. 15, 1, pp. 255-270, 2013.

[3] ‘Comparison of UHF measurements with the propagation model of Recommendation ITU-R P.1546’, the Radiocommunications Agency Netherlands, 2010.

[4] ‘Comparison of Longley-Rice, ITM and ITWOM propagation models for DTV and FM broadcasting’, S. Kasampalis, P.I. Lazaridis, Z.D. Zaharis, A. Bizopoulos, S. Zettas, and J. Cosmas, GWS-2013 conference, Atlantic City, NJ, USA, June 2013.

[5] ITU-R Recommendation P.1546-4 (10/2009), ‘Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz’.

[6] ITU-R Report BT.2137, ‘Coverage prediction methods and planning software for digital terrestrial television broadcasting (DTTB) networks’, 2008.

[7] ‘New SEAMCAT Propagation Models: Irregular Terrain Model and ITU-R P. 1546-4’, Dariusz Więcek and Dariusz Wypior, National Institute of Telecommunications, Wrocław, Poland, Journal of Telecommunications and Information Technology, 3/2011, pp. 131-140.

[8] BBC R&D White Paper WHP 048, ’UK planning model for digital terrestrial television coverage’, P.G. Brown, K. Tsioumparakis, M. Jordan, and A. Chong, Sept. 2002.

[9] ‘Accurate coverage prediction and optimization for digital broadcasting’, Bachir Belloul and Simon Saunders, EBU technical review, April 2004.

[10] Radio Mobile software, http://www.cplus.org/rmw.