López, S.; de la Vega, D.; Angulo, I.; Guerra, D.; Angueira, P.; Arrinda, A.; Ordiales, J.L.: 'Comparative study of field strength prediction methods in medium wave band', Electronics Letters, 2008, 44, (22), p. 1286-1288, DOI: 10.1049/el:20082492, IET Digital Library, https://digital-library.theiet.org/content/journals/10.1049/el_20082492.

A comparative study of the field strength prediction methods in the MW band

S. López, D. de la Vega, I. Angulo, D. Guerra, P. Angueira, A. Arrinda, J. L. Ordiales

The recently developed digital radio systems for the MW band require accurate field strength prediction algorithms for coverage estimation. This paper presents a comparison of the estimation accuracy provided by the most relevant field strength prediction methods employed for ground-wave propagation at this band. Moreover, a field strength prediction method recently developed by the authors, has been also considered in the analysis. Empirical values from measurement campaigns carried out in three different broadcasting networks have been used to analyse the accuracy of the prediction methods. The comparison between the predicted and the measured values allows an objective evaluation of the estimation accuracy of each method under different reception conditions. The proposed method provides the most accurate results on field strength predictions, and consequently, it is a suitable method for the coverage estimation of the new digital radio systems.

Introduction: Digital services require higher coverage percentages than those used for analogue services, due to their abrupt degradation when the field strength level is near the threshold value for good reception [1]. The planning of the new digital radio services needs accurate prediction algorithms in order to verify the above-mentioned higher coverage percentages. Existing prediction algorithms for field strength predictions in the MW band were developed some decades ago for analogue radio services [2], [3]. Nowadays, it is necessary to evaluate the accuracy of these algorithms by comparing the predicted values with empirical data in different reception conditions. The use of precise measurement systems and detailed altimetry maps allows a thorough analysis of these methods. A new prediction method for ground-wave propagation, recently developed by the authors, is also included in this study, and their results are compared to the empirical data.

This paper presents a comparative study of the accuracy of field strength estimations provided by these prediction algorithms for ground-wave propagation in the MW band.

Empirical Data: Empirical data from measurement campaigns carried out using three different Digital Radio Mondiale experimental transmissions have been used in the comparison. The development of the field trials (transmitter network, measurement equipment and reception environments) is described in detail in [4], [5], [6]. The transmission frequencies used in the trials were 1359 kHz, 810 kHz and 1260 kHz, respectively, and the coverage areas are located in Spain, Macedonia and Greece. A proper selection of reception points from these extensive measurement campaigns was realized, considering the following criteria. The selected points must be located in rural areas, at distances within a range between 15 km and 100 km from the transmitter, in order to avoid an additional attenuation due to the urban environment reception [3] and to the Earth curvature [2], respectively. Moreover, reception points located near important radio noise sources were not considered. As a result, a group of 847 reception points with different characteristics in their path profile (different ground electrical properties and different degrees of obstruction) were selected.

At each reception point, the field strength local mean value was calculated, in order to avoid local fast variations, not considered by the prediction methods. In the assessment of the local mean values, the Generalized Lee Method [7], [8], and 10164 instantaneous field strength values were employed. This amount of instantaneous values allowed a precision of ±1 dB in the calculation of the local mean values, with a degree of certainty of 90% [7], which ensures the accuracy of the empirical data.

Analysis: The five field strength prediction methods for ground-wave propagation in the MW band considered in the study are briefly described below.

Rotheram [9] developed a prediction method where the field strength values are obtained as a function of the ground electrical properties, the transmission frequency and the distance to the transmitter. The influence of the Earth curvature and the atmosphere refractivity are also considered [3]. Derived from this method, several prediction curves were defined, as a function of the mentioned parameters. This method only considers homogeneous paths (constant values of ground electrical properties, conductivity and permittivity, along the path). This method is recommended by the ITU-R for homogeneous paths, and a set of representative curves can be found in the Rec. ITU-R P 368-9 [10]. The application of this method requires the selection of the representative conductivity and permittivity values for the broadcasted area. Hence, for the field trials in Spain, values of wet land (σ = 10 mS/m and ε_r = 30) were used, according to Rec. ITU-R P.368-9 [10]; and for the reception points located in Macedonia and Greece, values of medium dry ground [10] were used (σ = 1 mS/m and ε_r = 15). Selected values agree with the average of the conductivity values provided by the ITU-R Atlas of Conductivity [11] for each area. the areas in each measurement campaign.

A prediction method which considers sections of different conductivity and permittivity values along the path between transmitter and receiver (mixed paths) was developed by Millington [12]. This method is also recommended by the ITU-R [10].

The two above-mentioned methods are focused on the frequency and the electrical properties of the ground, and do not take into account the influence of the terrain irregularities. Two methods that consider this aspect have been also included in this study, and are described below.

The National Telecommunications and Information Administration of USA (NTIA) developed a prediction method which considers mixed paths and smoothly varying rough surfaces in the path profile [13]. This method is based on the integral equation described by Hufford [14].

Moreover, the British Broadcasting Corporation (BBC) developed a prediction method which also considers mixed paths and irregularities in the path profile [14]. This method is based on the compensation theorem, which provides an attenuation value recursively obtained at each point of the path between the transmitter and the receiver.

Finally, the UPV-EHU method, recently developed by the authors, considers the ground electrical properties and the path profile irregularities in the estimations. This method calculates the field strength at a specific reception point using the prediction curves provided by the Rec. ITU-R 368-9 [10] for homogeneous paths, by using a weighted conductivity value. This conductivity value is obtained for each reception point as the average conductivity value along the path, weighted with the length of every conductivity section. The method includes an attenuation function that estimates the field strength attenuation due to the path profile irregularities [16]. The attenuation due to the irregular terrain was demonstrated to be a function of both the height of the obstacle and the distance between the obstacle and the receiver location [16], [17].

Field strength values were obtained using the five prediction methods described above for the set of reception points selected from the measurement campaigns, and compared to the empirical values.

Results: The difference between the empirical and the predicted values was assessed at each reception point, using the field strength prediction methods described in the previous section. In order to make an objective comparison of the methods, some statistical parameters of these differences were calculated: the mean error, the standard deviation of the error values and the percentage of the reception points where the absolute error was lower than 4 dB [18]. Table 1 shows the results obtained in this comparison. As it can be observed, the UPV-EHU is the prediction method which provides the most accurate estimations, achieving the lowest mean error value and the highest percentage of occurrences with an error lower than 4 dB. The Millington method also provides precise results.

In order to make an in-depth analysis, the path profile of each reception point was obtained and the terrain irregularities analysed. The reception points were classified according to the possible obstruction of their path profile into two groups: reception points with no obstructions in the path profile (reception in line-of-sight) and reception points with obstructions caused by the terrain irregularities. The results of this analysis are shown in Table 2.

The UPV-EHU and Millington methods provide the best accuracy in the predictions for the reception points in line-of-sight with the transmitter. Nevertheless, when the reception points obstructed by the terrain irregularities are considered separately, the UPV-EHU clearly provides the most accurate predictions. The reason can be that the Millington method does not consider the influence of the terrain irregularities in the estimations, while the UPV-EHU method includes an empirical attenuation function that calculates the attenuation of different degrees of obstruction of the irregular terrain.

Conclusion: This paper analyses the accuracy of the most relevant prediction methods for ground-wave propagation in the MW band, for its possible use in the planning of digital radio services. Four of the selected methods were used in the planning of analogue radio services (two of them are recommended by the ITU-R).

Moreover, a semi-empirical method recently developed by the authors has been also included in the analysis.

The analysis has used empirical data from three measurement campaigns in different coverage areas. A detailed selection of 847 reception points in different reception conditions was realized. In these points, the field strength local mean values were calculated from the instantaneous field strength values registered in the measurement campaigns. The reception points were classified according to the obstruction of the terrain irregularities in the path profile. The difference between the measured and the predicted values with the observed methods was assessed at each reception point, and the set of values was statistically analysed.

The UPV-EHU method provides similar prediction accuracy than Millington method for non obstructed reception points, but it clearly provides the most precise results when the reception points are obstructed by the irregular terrain. The UPV-EHU method is proposed as a suitable field strength prediction method for the planning of digital radio services.

References

[1] International Telecommunication Union, “Document 6E/54-E. Digital broadcasting at frequencies below 30 MHz. MF and HF field – test report summary. Final system performance report for IST-RADIATE 1999-20113 for ITU,” Feb. 2004.

[2] B. Hall, M.P.M., Barclay, L.W., “Radiowave Propagation,” IEE Electromagnetic Waves Series 30, Ed. Peter Peregrinus, 1989.

[3] L. W. Barclay, “Propagation of Radiowaves – 2nd Edition”, The Institution of Electrical Engineers, 2003.

[4] D. Guerra, G. Prieto, I. Fernández, J. M. Matías, P. Angueira and J. L. Ordiales, “ Medium Wave DRM Field Test Results in Urban and Rural Environments,” IEEE Transactions Broadcasting, Vol. 55, pp. 431-438, Dec. 2005.

[5] F.Held and A. Giefer, “Macedonian DRM Test on Medium-Wave”, DRM Document TC SE300,private communication, Nov. 2004.

[6] U. Gil, D. Guerra, L. del Almo, J. Masdeu, “DRM field trials for urban coverage planning in Spain”. EBU technical review – 2008 –Q2.

[7] D. de la Vega, S. López, J. M. Matías, U. Gil. M. M. Vélez and P. Angueira, “Generalization of Lee Method for the analysis of the signal variability,” IEEE Transactions on Vehicular Technology. Accepted for publication.

[8] D. de la Vega, S. López, U. Gil, J. M. Matías, D. Guerra, P. Angueira and J. L. Ordiales “Evaluation of the Lee Method for the analysis of long-term and short-term variations in the digital broadcasting services at the MW band,” 2008 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, April 2008.

[9] S. Rotheram, “Ground-wave propagation. Part 1. Theory for short distances,” IEE Proceedings F, Vol. 128, pp. 275-284, 1981.

[10] ITU-R Recommendation P.368-9, 2007. “Ground wave propagation curves for frequencies between 10kHz and 30MHz”.
[11] ITU-R Recommendation P.832-2, “World Atlas of Ground Conductivities,” July 1999.
[12] G. Millington, “Ground wave propagation over an inhomogeneous smooth Earth”, Proceedings IEE Part IV, Vol. 96, pp. 225-268, March 1949.
[13] R.H. Ott, “A new method for predicting HF Ground Wave attenuation over inhomogeneous, irregular terrain”, OT/ITS, Research Report 7, January 1971.
[14] G. A. Hufford, “An integral equation approach to the problem of wave propagation over an irregular surface,” Quart. Appl. Math, 9, 1952.
[15] G. D. Monteath, “BBC RD 1978/7. Computation of ground-wave attenuation over irregular and inhomogeneous ground at low and medium frequencies,” BBC Research Reports, March 1978.
[16] International Telecommunication Union, “ Document 3J/24 E Ground-wave propagation, Method for predicting the transmission loss mean value due to terrain irregularities on the propagation path," May 2008.
[17] D. de la Vega, S. López, D. Guerra, G. Prieto, M. M. Vélez and P. Angueira, “Analysis of the attenuation caused by orography influence in the Medium Wave Band,” IEEE 65th Vehicular Tech. Conference, April 2007, Dublin.
[18] International Telecommunication Union, “ITU-R Rec. SM.1447. Monitoring of the Radio Coverage of Land Mobile Networks to Verify Compliance with a Given Licence,” April 2000.

Authors’ affiliations:

S. López (susana@bips78.bi.ehu.es), D. de la Vega (david.delavega@ehu.es), I. Angulo, D. Guerra, P. Angueira, A. Arrinda, J. L. Ordiales (Department of Electronics and Telecommunications, University of the Basque Country UPV-EHU, Alda. Urquijo s/n, 48013 Bilbao, Spain).

Table captions:

Table 1 Difference between predicted and experimental field strength values, using the analysed prediction methods

Table 2 Difference between predicted and experimental field strength values, using the analysed prediction methods and considering the obstruction of the irregular terrain (LOS: reception points in line of sight with the transmitter, OBS: reception points obstructed by terrain irregularities)

Table 1

Prediction Methods	Homogeneous Path Method	Millington Method	NTIA Method	BBC Method	UPV/EHU Method
Mean error (dB)	6.71	5.54	6.12	5.87	4.05
Standard deviation (dB)	4.55	5.77	4.22	3.84	4.84
% Reception points |error|<4 dB	30.58	54.7	37.2	34.6	61.63

Table 2

Prediction methods	Homogeneous Path Method		Millington Method		NTIA Method		BBC Method		UPV/EHU Method	
Type of reception points	LOS	OBS	LOS	OBS	LOS	OBS	LOS	OBS	LOS	OBS
Mean error (dB)	5.54	7.98	6.55	5.15	3.80	7.43	6.86	5.31	3.8	4.31
Standard deviation (dB)	3.24	5.37	4.05	3.45	3.24	7.17	4.31	3.96	2.75	6.38
% Reception points |error|<4 dB	35.74	24.93	29	40.7	62.7	45.9	31	44	59.05	64.44