DRM for Local Coverage in the 11 m band – Predictions and Measurements

F. Maier, I. Peña*, P. Angueira*, A. Tissen, A. Waal

Institute for Communications Technologies,
Leibniz University of Hanover
Appelstr.9A, 30167 Hanover, Germany

* Department of Electronics & Telecommunications
Bilbao Faculty of Engineering (University of the Basque Country, UPV/EHU)
Alameda Urkijo s/n. 48013 Bilbao. Spain

Abstract

This paper presents the results of a DRM local broadcasting field trial in Hanover/Germany at 26.045 MHz. Stationary cluster measurements and mobile measurements along radial routes were carried out during the measurement campaign. A further focus is field strength measurements at different antenna heights which leaded to signal breakdown at a height of 4.50 m in previous measurements. Finally, comparisons between empirical and simulated field strengths are conducted considering the prediction model of the ITU-R P.1546 recommendation which could be adapted to the 11 m band to develop a new planning tool for the corresponding digital local services.

INTRODUCTION

Digital Radio Mondiale (DRM) is one of the worldwide digital radio standards accepted by the ITU. The DRM standard has configurations (Modes A, B, C) suitable for frequencies up to 30 MHz and an additional Mode E (DRM+) for frequencies up to band III.

A majority of the studies and planning procedures have focussed on short wave propagation. The ITU reference recommendations have also summarized results for Medium Wave and Short wave bands [1].

The 11 m shortwave band from 25.67 – 26.10 MHz has been traditionally used for long distance broadcasting by means of the sky wave propagation. However, this frequency band has nowadays very little activity, mainly due to the propagation dependency on daytime and sunspot numbers. Bearing in mind an optimized use of the spectrum resources, local radio services could lead to a better use of the 26 MHz band by means of the line-of-sight propagation. To do this, new planning tools must be developed and measurements have to be carried out in order to proof the prediction results.

Measurement campaigns in the 11 m band in Nuremberg [2] and Mexico DC [3] showed that the minimum required field strength is strongly dependent on the surrounding noise level and often a higher level of field strength is needed for proper reception than given in ITU-R BS. 1615 [1]. This paper will continue those studies providing more empirical data in order to refine planning models.

Another aspect analyzed during this test was the receiver antenna height dependence. Results from a previous field trial in 2006 showed signal breakdowns of more than 10 dB at a height of 4.50 m.

HANNOVER FIELD TRIAL DESCRIPTION

The field trial presented in this paper was carried out using DRM modes A and B. The DRM signal was broadcasted with a 64 QAM modulation scheme, a bandwidth of 10 kHz, a long interleaver and UEP (Unequal Error Protection) with protection level (PL) 0 (code rate = 0.5) for part A and PL 1 (code rate = 0.6) for part B was used which leads to data rates up to 26.5 kbps. In mode B UEP with PL 1 (code rate = 0.6) for part A and PL 2 (code rate = 0.71) for part B with data rates up to 24.7 kbps and for one trial PL 0 (code rate = 0.5) for part A and PL 1 (code rate = 0.6) for part B with data rates up to 21 kbps was used.

The transmitter was located on top of the roof of the University of Hanover, Appelstr.9A, The resulting antenna height was 70 m above ground level. The modulator was a Thomson Skywave 2000 that provided an ERP of 80 W. The DRM spectrum was delivered at a channel center frequency of 26.045 MHz.

Two different transmitting antennas were used during this experiment; a GP27 ground plane antenna and a newly developed ground plane antenna from Thomson. Both antennas showed nearly the same results. The results in this paper correspond to the data set obtained with GP27 as some more measurements were made with this antenna. Figure 1 shows the position of both antennas. The diagram shows also the position of the system used in a previous DRM trial on 2006 [4]. The roof superstructure in the middle has a height of 2.70 m, the antenna is mounted at 3.30 m.

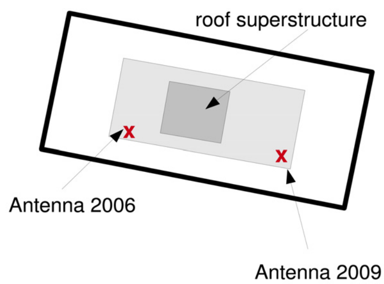

Figure 1: Antenna positions.

The receiving antenna was the Rhode & Schwarz HE 010 monopole on a ground plane mounted on the roof of a car was used. The DRM signal was mixed down by a DRT1 module, and sampled by a M-Audio Fast Track

Pro USB sound card by a DReaM DRM receiver. Field strength was measured with a Rhode & Schwarz ESCE measuring receiver and a FSH-6 spectrum analyzer (stationary measurements). Height measurements were made with a cage aerial (Schwarzbeck BBA 9106).

Mobile measurements

Mobile measurements were made on radial routes from to the west (B441) and to the northwest (B6) along distances between 2 and 18 km from the transmitter. Field strength, audio quality and the calculated SNR were measured for robustness mode A and B. In mode A tests were run with PL 0/1, in mode B one test run was made with PL 0/1, the others with PL 1/2. Figure 2 shows the routes with the field strengths which did not show a difference between mode A and B.

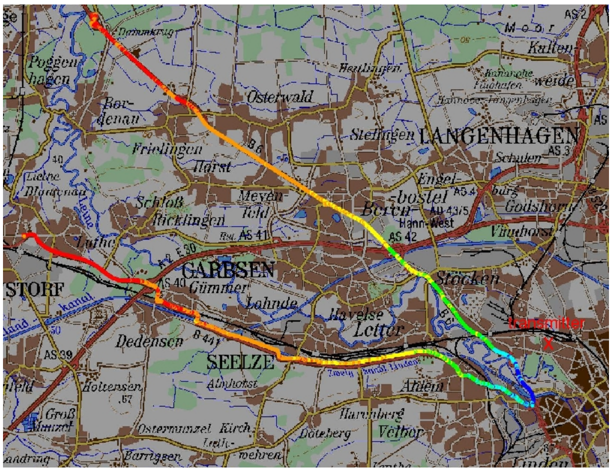

Figure 2: Field strength along two of the radials (higher values on blue and lower values on red).

The following figures (3 to 7) show field strength values (dBµV/m), correctly decoded audio frames (% of the received frames) and SNR values (dB). Figures show the obvious dependencies of the audio quality on SNR and field strength. In [3] the reception was considered correct when the percentage of correct decoded audio frames was equal or higher than 98%. This criterion will also be used here. However; results show that the intersection between correct reception and absence of reception is quite clear and the percentage of correct decoded audio frames drops very fast. The dropouts at shorter distances mostly occurred while passing under bridges.

Figure 3 and 4 show the test runs on the B441 in mode A with a data rate of 26.5 kbps and mode B with a data rate of 24.7 kbps. In mode A reception is possible up to distances of about 11 km, in mode B up to nearly 12 km. Field strength at the dropout distance is around 40 dBµV/m with an SNR of about 16 dB.

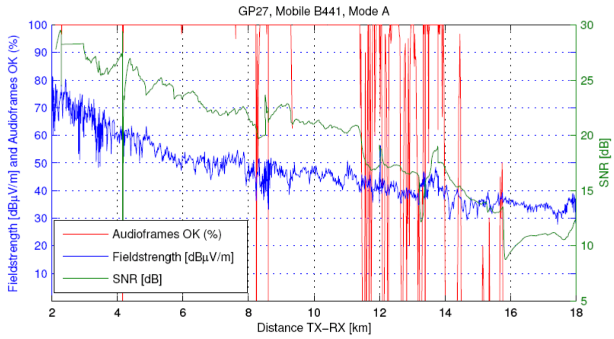

Figure 3: Mobile measurement on the B441 in mode A.

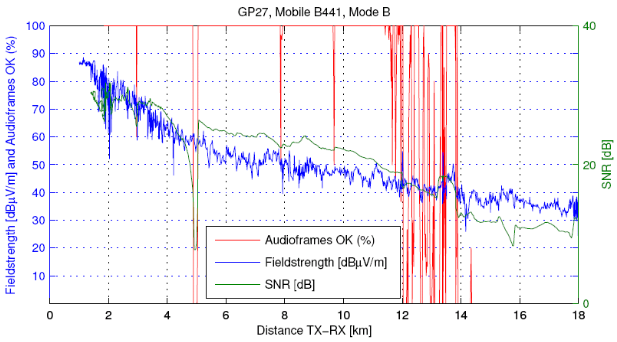

Figure 4: Mobile measurement on the B441 in mode B.

Figure 5 and 6 shows the test runs on the B6 with PL 0/1 and PL 1/2. Here the DRM decoding again fails at field strengths below 40 dBµV/m and an SNR of 16 dB. This occurs at a distance of around 14 km.

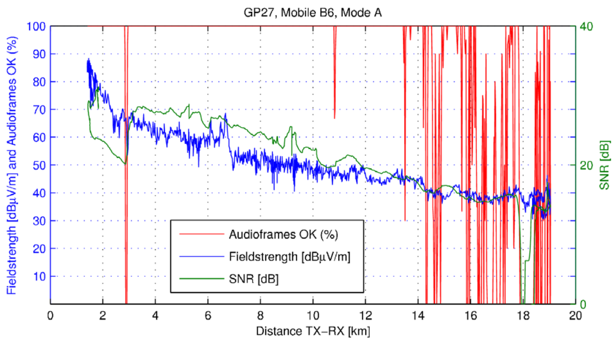

Figure 5: Mobile measurement on the B6 in mode A.

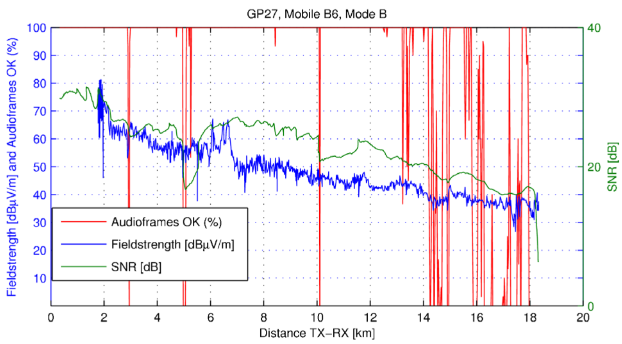

Figure 6: Mobile measurement on the B6 in mode B.

The difference between the field strength levels are probably due to the roof superstructure beside the transmitting aerial which has shadowing effects in the direction of the B441.

Figure 7 shows the test run on the B6 with the same protection level as mode A. Due to the more robust modulation with more sub carrier spacing and a guard interval of 5.33 ms instead of 2.66 ms data rate decreases here to 21 kbps. In return, reception is possible here down to field strength less than 40 dBµV/m. This enhances the coverage up to nearly 16 km.

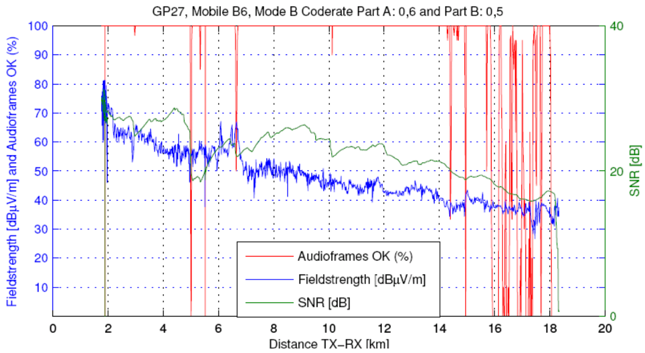

Figure 7: Mobile measurement on the B6 in mode B, with PL 0/1.

Stationary measurements

The stationary measurements where carried out in clusters. A cluster was defined as a distance of 10 λ x 10λ, which equals an area of 110 x 110 m at the 11 m band. The distance between the measuring points was planned to be around 0.8-0.9 λ (10 m). If the first 5 measurements did not differ more than 5 dB there was no need for further measurements. If they did, 11 measurements had to be made. Figure 8 shows the clusters located around the transmitter in distances of multiples of 2 km. The results are found in the following section in figure 11 along with the predicted values for comparison.

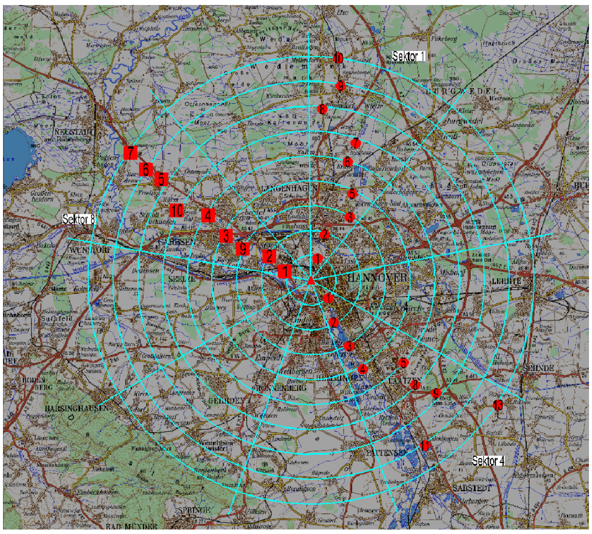

Figure 8: Stationary measurement clusters (Source: Niedersächsischen Vermessungs- und Katasterverwaltung).

ITU-R P.1546 PREDICTION RESULTS

A study to determine the applicability of the ITU-R P.1546 Recommendation prediction method for DRM network planning in the 26 MHz band is presented in this section.

This model is defined to obtain field strength predictions for the VHF and UHF bands. However, it can be considered as a possible planning tool for DRM local services on the 11 m band since the tropospheric wave is the main propagation mechanism in this case. The algorithm provides the field strength level applying and interpolation/extrapolation process and different correction factors to the field strength values of several empirical curves given for a set of frequency, distance, transmission antenna effective height and time variability percentage nominal values [5]. Following subsections include a comparison analysis of the prediction error for the reception locations and routes of the field trials previously described.

Prediction Error for Stationary Measurement Locations

A software tool that implements the algorithm of ITU-R P.1546 Recommendation was developed to obtain the simulated field strength values for the stationary measurement locations of the field trials. Table 1 includes the values of the input parameters related to these predictions.

Table 1. Input data

PARAMETER	VALUE	PARAMETER	VALUE
Frequency (MHz)	26.045	Type of profile	Land
Transmission power (W)	100	Time variability (%)	50
Max. gain of Tx antenna (dBi)	2.15	Location variability (%)	50
Transmitter loss (dB)	1	Type of system	Digital Narrow Band
Tx antenna height (m)	70	Climate correction	Considered
Rx antenna height (m)	1.5	Urban/Suburban paths correction	Considered

In addition to the previous data, plain text format files with the transmitter-receiver terrain profile samples and the definition of the latitude, longitude, azimuth and elevation transmission antenna gains and type of environment was needed for estimating the field strength at each reception location.The prediction error was calculated as the difference between the simulated field strength values given by the method and the measured levels during the field trials (Ep-Em). The distribution of its absolute value was obtained in order to analyze the reliability of the ITU-R P.1546 model.

Figure 9 shows that the absolute error prediction was lower or equal to 6 dB at 20 out of 27 locations, and 13 of those locations belong to the 0 to 3 dB interval. Therefore, the method provides quite good results for the reception area where field trials took place in Hanover.

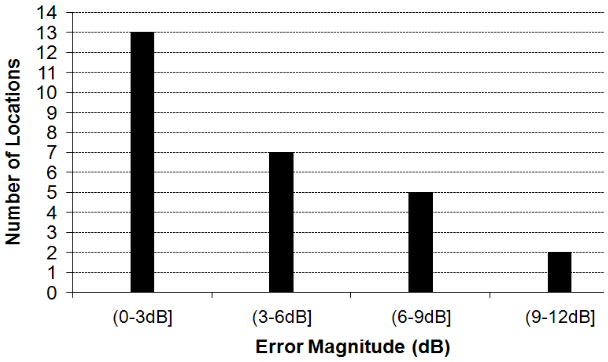

Figure 9. Prediction error distribution

Nevertheless, there were some locations where the error is higher than 9 dB. In order to find an explanation to these results, the magnitude and sign of the prediction errors was analyzed, as shown in Figure 10. The values have been classified according to the measurement sector (measurement geographical areas) of the field trials (sectors 1, 4 and 8) and different symbols have been used to represent the reception environment at each location (urban, rural and dense urban) as defined by the ITU-R P.1546 recommendation. A positive error value means that the predicted field strength value is higher than the measured one, the case of an optimistic prediction, and vice versa.

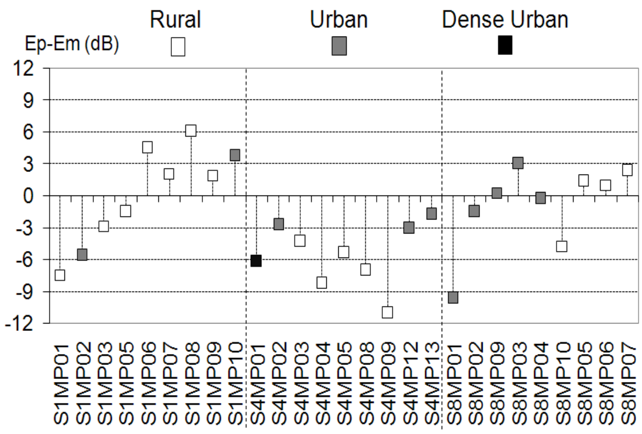

Figure 10. Prediction error values

There is not a clear error tendency as a function of the reception environment. However, positive and negative errors have been obtained for the locations of sectors 1 and 8 while all the predictions of sector 4 are pessimistic. This result is emphasized in Figure 10. Figure 11 shows the curves of the measured and predicted field strength values for each sector. The curves of sector 1 and 8 fit quite well, but in the case of sector 4 the prediction is lower than the measurement. Table 2 includes the prediction error statistics for the total set of the measurement locations and for each measurement sector.

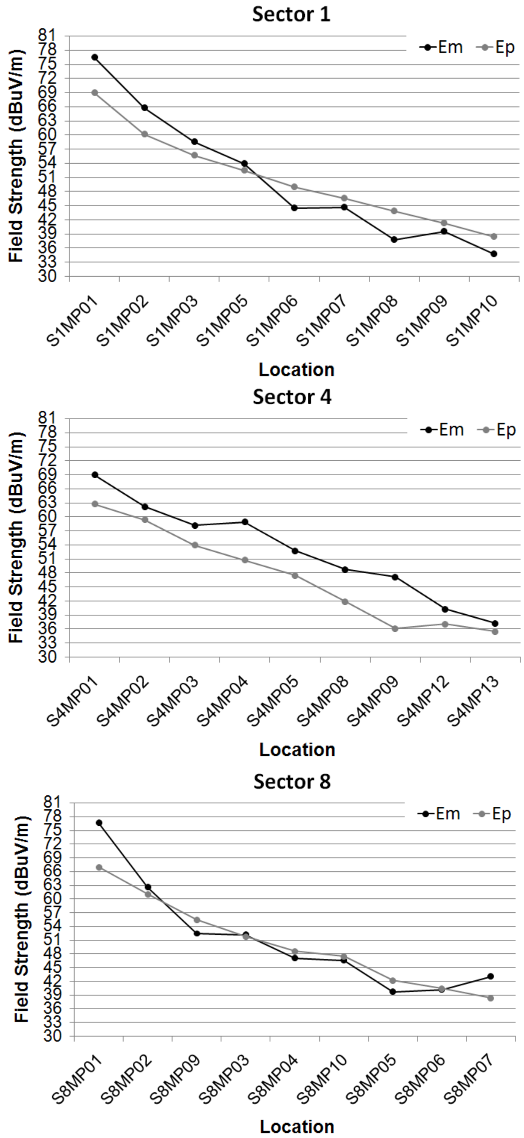

Figure 11. Ep and Em values for each sector

Columns have been ordered so the mean value of the prediction error is decreasing according to the sector. It can be seen that the error is close to 0 dB for sectors 1 and 8 and approximately – 6 dB for sector 4.

Table 2. Prediction error statistics

Statistic	Total	S1	S8	S4
Mean Value (dB)	-2.12	0.08	-0.93	-5.50
Median Value (dB)	-1.77	1.86	0.24	-5.32
Standard Deviation (dB)	4.53	4.71	4.01	2.93

An explanation of the pessimistic behaviour of the method for sector 4 can be found analyzing the mean values of the effective transmitting antenna height (h1) and the terrain clearance (TCA) obtained for each measurement sector. Both parameters are defined in the ITU-R P.1546 Recommendation to consider the terrain topography [5]. Table 3 shows that sector 4 presents a lower mean value of h1 than sectors 1 and 8 while TCA mean values are similar. This means that corrections due to the TCA of the same order of magnitude are applied to the predicted values for all the measurement locations. However, the predictions at locations of sector 4 are more pessimistic because the corresponding h1 values are lower in this sector.

Table 3. h1 and TCA values for each sector

Statistic	S1	S8	S4
Mean Value	h1 = 73.67 m TCA = -0.43 º	h1 = 73.36 m TCA = -0.36 º	h1 = 62.43 m TCA = 0.10 º
Standard Deviation	h1 = 0.96 m TCA = 0.71 º	h1 = 1.07 m TCA = 0.78 º	h1 = 8.25 m TCA = 1.17 º

A similar effect can be seen when comparing the mean error obtained from the Hanover measurements with the prediction errors in previous studies carried out from measurements in Brazil and Mexico [6]. These previous studies concluded that the slope of the terrain profiles of the Tx-Rx paths can influence the prediction error by means of the parameters h1 and TCA.

Table 4 includes the values of both parameters for the 3 reception areas: Hanover, Brazil and Mexico. All of them present similar TCA mean values but the effective transmitting antenna height (h1) is lower in Hanover. The transmitting antenna height above the ground level (hTx) was higher in this area: 70 m in Hanover, 55 m in Brazil and 40 m in Mexico.

Table 4. h1 and TCA values for different reception areas

Statistic	Hanover	Brazil	Mexico
Mean Value	h1 = 69.82 m TCA = -0.23 º	h1 = 215.32 m TCA = 0.03 º	h1 = 248.42 m TCA = 0.23 º
Standard Deviation	h1 = 7.07 m TCA = 0.90 º	h1 = 27.73 m TCA = 0.57 º	h1 = 46.64 m TCA = 1.40 º

The value of h1 is lower in Hanover because the profiles here are smoother than the ones in Brazil and Mexico. As a conclusion, the predictions are more pessimistic for this area as observed in Table 5.

Table 5. Prediction error for different reception areas

Area	Hanover	Brazil	Mexico
Mean Error (dB)	- 2.12	1.63	20.34

Along with the previous effect, the terrain irregularity (Δh) is another factor that has to be considered. This parameter is defined in [7] and allows the classification of the terrain as follows:

A. Water or very smooth plains $\Delta h = 0 - 5$ m
B. Smooth plains $\Delta h = 5 - 20$ m
C. Slightly rolling plains $\Delta h = 20 - 40$ m
D. Rolling plains $\Delta h = 40 - 80$ m
E. Hills $\Delta h = 80 - 150$ m
F. Mountains $\Delta h = 150 - 300$ m

According to this, the type of terrain that prevails in each measurement area is:

- Hanover Smooth Plains
- Brasilia Rolling Plains
- Mexico Mountains

The influence of the terrain irregularity on the prediction error can be observed when comparing the corresponding values for each measurement area, concluding that the error decreases when the irregularity is lower.

Finally, the effect of reception environment on the prediction error was analyzed. The ITU-R P.1546 model includes two correction factors that might be useful to consider the reception environment influence. The first one is the urban/suburban short path correction which was applied to all the measurement locations in Hanover. However, it did not influence the predictions significantly. The second one is the receiving antenna height correction (Ch2). The value of this correction depends on the representative height of ground cover around the receiving antenna location, R (m), which takes different values according to the reception environment. Table 6 shows the impact of this correction on the prediction error when applying different environment assumptions.

Table 6. Prediction error for different environments

Type of environment	Mean Value of the Prediction Error
Rural Environment	-1.83 dB
Urban Environment	-2.22 dB
Dense Urban Environment	-5.14 dB
Environment Combination	-2.12 dB

The first row of the table shows the mean value of the prediction error if all the locations are simulated according to a "Rural" environment scenario (R = 10 m.). The second and third rows provide the same simulation results for "Urban" (R = 20 m.) and "Dense Urban" (R = 30 m) environments. Finally, the last row, named "Environment Combination" shows the results when making an individual study of each location and trying to assign to each reception point, the category that better fits the reality, "Rural", "Urban" or "Dense Urban".

It can be concluded that the error is much lower when all the reception locations are considered dense urban but the difference is negligible between the rural and urban cases and the environment combination does not improve the prediction error.

Prediction Error for Mobile Measurements

This section presents a comparison study between the field strength level that was measured along the routes B441 and B6 and ITU-R P.1546 Recommendation predictions. The field strength curve for distances in the range from 2 to 18 km was calculated, considering a frequency f = 26.045 MHz, an effective radiated power ERP = 80 W, a receiving antenna height h2= 1.5 m and an effective transmitting antenna height h1= 69.82 m, the mean value of h1 obtained for the reception area. Also, an extra attenuation of 10 dB was added to the values of the simulation curve in order to include the topographical and environment corrections of the method. Figure 13 depicts the prediction curve and the measured field strength levels along the routes.

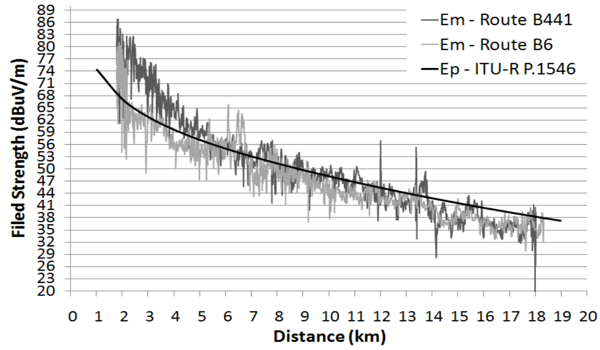

Figure 13. Ep and Em curves for B441 and B6 routes.

Both types of curves (Em and Ep) fit very well and this agrees with the results of the previous section where an absolute value of the mean prediction error lower than 3 dB was obtained for the stationary measurement locations.

MEASUREMENTS AT DIFFERENT RECEIVER ANTENNA HEIGHTS

The conducted measurements have shown that the signal breakdown at a receiver height of 4.50 m occurred due to coupling effects with the metal rod that was used. Therefore this time a fiber-plastic rod was used.

Calculations were made during the measuring phase in 2006 [4] with the ITU-R P.1546 Recommendation for the measuring locations in sector 1 and 4 for receiver antenna heights of 1.50 m and 10 m. They resulted in a height loss of approximately 10 dB for distances more than 6 km from the transmitter.

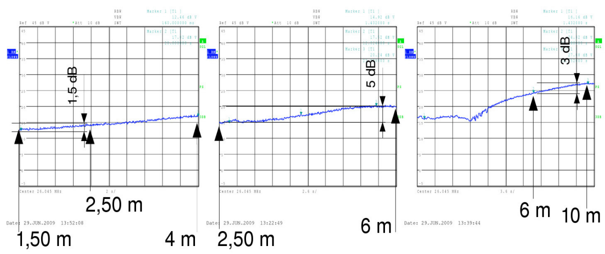

Figure 14. Height scan with the cage aerial

Figure 14 shows a height scan made with the cage antenna from 1.50 - 10 m at MP 6 in sector 1 at a distance of approximately 10 km from the transmitter. At this point the calculations show a height loss of 11.5 dB. The measured field strength difference of 9.5 dB between 1.50 m and 10 m corresponds quite well with the expected value.

CONCLUSIONS

Measurements have shown that the DRM in the 11m band with a 64-QAM modulation works down to an SNR of about 16 dB. Using Mode A or B did not make a big difference adopting the protection levels so, that the same bit rate is achieved. However, the measuring location Hanover lies in a quite flat area and has little dense urban areas. In bigger cities the situation can be different.

The accuracy of the ITU-R P.1546 prediction method has been studied by means of a comparison between measurement values from a field trial in the 11m band carried out in Hanover. The prediction error has been analyzed for 27 reception locations and 2 routes considering the influence of topographical and environment factors. The model provides accurate predictions for the reception area under study with a mean prediction error lower than 3 dB at stationary measurement locations. The empirical and simulated curves for the routes fit very well. In this case, the prediction and quasi radial routes show the major differences close to the transmitter. This might be a sign of certain presence of a ground wave component. This aspect is included in the studies being carried out by the authors of this paper.

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