INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

Document 6E/274-E
30 September 2005
English only

Received: 29 September 2005

Subject: Question ITU-R 60/6

Digital Radio Mondiale (DRM)

DIGITAL RADIO MONDIALE DRM LOCAL COVERAGE USING THE 26 MHz BROADCASTING BAND

Abstract

This document reports on a carefully designed set of fixed and mobile reception tests in Mexico City on the DRM (Digital Radio Mondiale) system at a frequency in the uppermost shortwave broadcasting band – around 26 MHz – for local broadcasting. The testing was done during July 2005. These were not operational tests; that is, neither the transmitter antenna, nor antenna location, nor transmitter power were designed for real broadcast operations. However, from the test results, as documented throughout the report, the characteristic of an operational broadcasting station to cover a densely populated city as Mexico DF can be determined.

CONTENTS

1 Motivation

The 26 MHz broadcasting band is traditionally used for long distance transmission through ionospheric propagation. Due to the need of high ionization of the ionosphere, this type of propagation is used mainly in the high activity periods of the solar cycle of approximately 11 years. However, using a “line of sight” propagation, the 26 MHz broadcasting band can be used for local coverage. The local broadcast on the 26 MHz band could be on all day and all year, allowing a greater use of this band.

This report summarizes the results of tests made in Mexico City with the DRM (Digital Radio Mondiale) system in the 26 MHz broadcasting band for local coverage. This measurement campaign was carried out by DRM with the collaboration of Radio Educación, Radio Ibero, RIZ Transmitters and the Signal Processing and Radiocommunications Research Group at the University of the Basque Country. Deutsche Welle and TDF (Télédiffusion de France) contributed with measurement equipments.

2 Objectives

This study was defined to calculate the field strength needed in a city for DRM transmission on the 26 MHz broadcasting band. The minimun field strength needed is calculated for different DRM modulation modes and for different environments. The minimum SNR (Signal to Noise Ratio) and minimum field strength has been analyzed separately. Due to the different characteristics, mobile and fixed measurements has been analysed separately.

- Calculate, based on field measurements, the minimum field strength needed.
- Calculate the minimum SNR needed for each DRM transmission mode.
- Obtain the coverage area of the used transmitter, and extrapolate the theoretical coverage of higher powers.
- Analyze the influence of the environment on the reception quality.

3 The DRM System tested

The DRM signal was broadcasted from the transmitter station that Radio Ibero has in Santa Fe (Mexico City). Santa Fe is located 16 kilometers in the south-west direction from Mexico City Center and currently is a location to broadcast regular FM analogue emissions. A summary of the transmission centre features can be found in 1 and Figure 1. Figure 2 shows photos of the antenna and the transmitter.

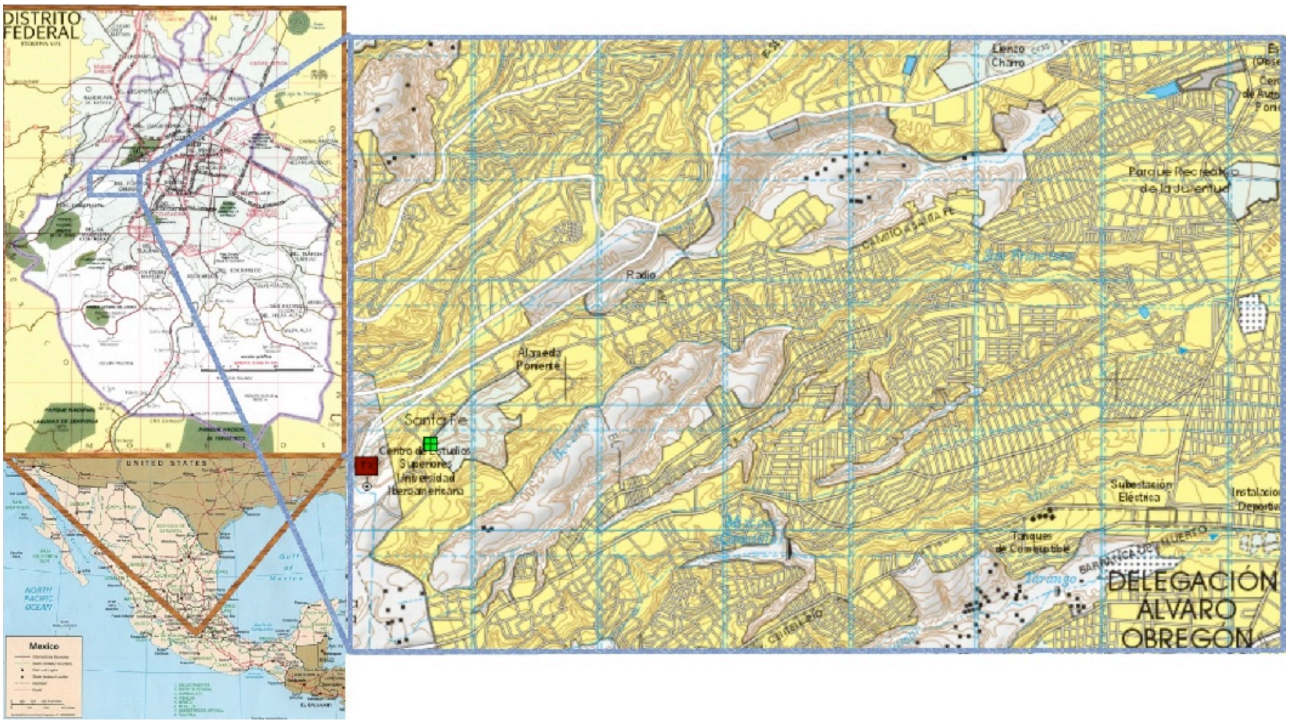
TABLE 1

Transmission Centre Features

Transmission Centre	**Radio Ibero (Santa Fe, México DF)**
Broadcaster	Radio Educación
Transmission centre coordinates	99º 15.920’ W ; 19º 22.071’ N
Frequency	25.620 kHz
Bandwidth	20 kHz
Radiating System	3 Element Yagi-Uda Antenna

FIGURE 1

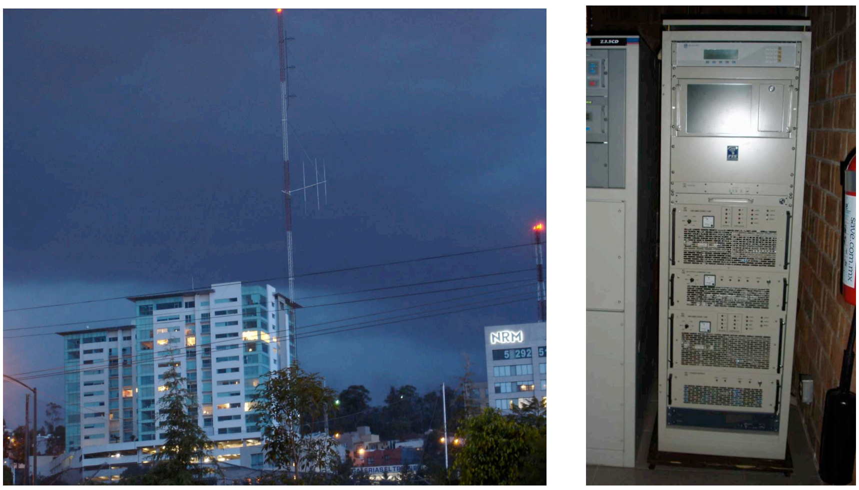
Transmission Centre Location



The radiating infrastructure is based on a 3 element Yagi-Uda antenna (YAGI-3EL-V) with has a maximum gain of approximately 7 dB in the 45º North-East direction. The DRM Compact Audio Solution – 2kW transmitter of RIZ Transmitters was installed and adjusted to fulfill radiation spectrum mask requirements of the ITU-R Recommendation 1615 **[2]**. The DRM output average power was 200 W.

FIGURE 2

Antenna and transmitter in Radio Ibero



The DRM standard **[1]** provides several configurable transmission parameters that allow many different DRM transmission modes, with different robustness against noise, multipath and interference. The more robust the mode is, the less maximum subjective audio quality can be achieved due to a lower useful bit rate available. In order to evaluate the influence of each parameter, the modes in Table 2 were chosen for the tests.

TABLE 2

Tested DRM Modes

Name in Document	Bandwidth (kHz)	OFDM	MSC	SDC	Code rate	Interleaver	Bite rate (kbps)
20K_A/64/16/0.6	20	A	64QAM	16QAM	0.6	Long (L)	54.98
18K_A/64/16/0.6	18	A	64QAM	16QAM	0.6	Long (L)	48.64
18K_B/64/16/0.6	18	B	64QAM	16QAM	0.6	Long (L)	38.18
20K_B/16/4/0.5	20	B	16QAM	4QAM	0.5	Long (L)	23.82
18K_B/16/4/0.5	18	B	16QAM	4QAM	0.5	Long (L)	21.20
10K_B/16/4/0.5	10	B	16QAM	4QAM	0.5	Long (L)	11.64

The first column of Table 2 is a reference code included for the sake of briefness when referring to a combination of parameters in the rest of this document. The DRM modes in Table 2 are ordered from less to more robust as can be deduced from the corresponding useful bit rate which decreases from the top to the bottom of the table.

During the system testing, a problem with some parts of the measurement system when working with the 20 kHz modes was detected. Although, the receiver indeed worked with 20 kHz bandwidth, the measured values were influenced by the measurement system problem. For this reason, equivalent modes with 18 kHz bandwidth were considered because they were free of errors and it is possible to compare their results easily.

Nevertheless, taking into account that 26 MHz band channels have 10 kHz wideband, it is common to use 20 kHz (or 10 kHz) modes instead the 18 kHz tested modes because they provide a little more bite rate.

A broader explanation of the number of carriers, guard interval, protection and interleaving algorithms, as well as the Main Service Channel (MSC) and the Service Description Channel (SDC) modulations is out of the scope of this document and can be found in detail in **[1]**.

4 Tests performed and purpose for each one of them

Most of the measurement campaign was devoted to measuring selected routes in different environments, repeating those routes for different DRM modes. For each route two types of measurements were obtained, fixed locations and mobile measurements. These routes (Routes 1 to 4 from Table 3) were chosen to determine the specific propagation characteristics in each type of environment. Those environments are “Dense Urban”, “Opened Residential” ”Typical Mexican” and “Low Dense Industrial”.

Besides, because of the coverage area was more limited than expected, route 6 was added. Although the route was farther from the transmitter, it presented less terrain obstacles for signal propagation (as it will be explained in section 6.2.1). Route 5 was selected for finding “line-of-sight” measurements area close to transmitter. As that area was very small, only 2 points and one single mode were measured.

TABLE 3

Measurement Routes

Denomination	Environment	Area	Approximated. Distance from transmitter
Route 1	Typical Mexican	Benito Juárez	11.5 km
Route 2	Dense Urban	Reforma Polanco	10 km
Route 3	Low Dense Industrial	Azcapotzalco	15 km
Route 4	Opened Residential	Chapultepec – Sport City	9.5 - 17 km
Route 5	Dense Urban	Santa Fe	2 km
Route 6	Typical Mexican	Aragón-La Villa	20 km

In total, 60 fixed locations and more than 600km in movement were measured.

Brief description of the environments:

- "*Typical Mexican*" is an urban environment with wide streets and little high houses, usually 2 floors.
- *"Dense Urban"* is an area with very high buildings.
- *"Opened Residential"* we consider in this case very little built or open areas such as parks. In this case two different areas were selected: the wood of Chapultepec and the Sport City. Between them there was a large distance.
- *"Low Dense Industrial"* is an industrial area with no heavy industry.

In these measurements several programs were used for evaluating the quality that DRM system can offer. That is why modes of 10 kHz and 20 kHz bandwidth were used.

For determining the possibility of different programs simulcast transmission in the same channel, Radio Educación prepared different programs with different languages. Tests were done in a fixed position, in a place with a perfect reception. That was the way of testing the quality that DRM system provides for each coder, as a function of the data speed used for each codification.

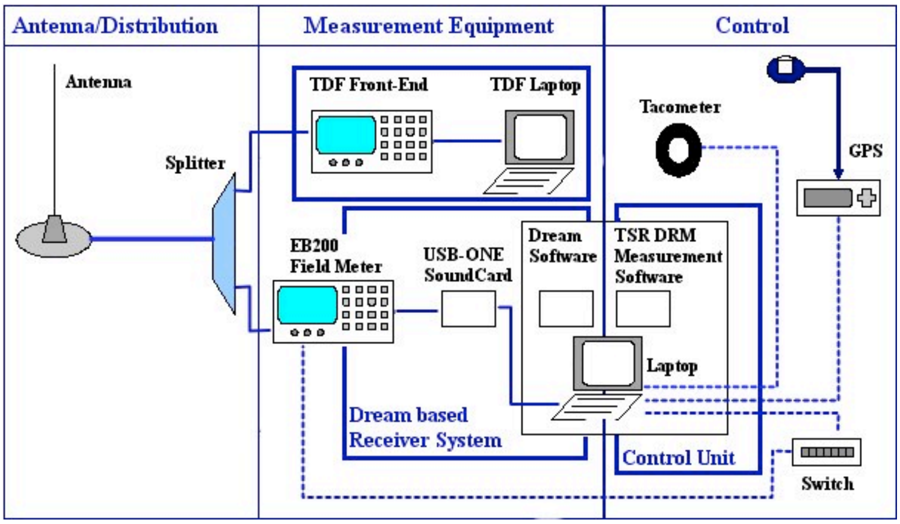
Radioelectric noise due to human activity (voltage lines, car motors, voltage transformation plants and electronic equipment in general) gets greater every day. For that reason, noise measurements were done in the city, with the transmitter switched off at the transmission frequency.

5 Tests setup

The measurement vehicle was equipped as shown in Figure 3, where three sections are distinguished: The acquisition and distribution system, the measurement system and the control system.

FIGURE 3

Measurement System



The acquisition system was composed of the fully characterized short monopole active antenna R&S HE010 mounted on top of the van with a specific ground plane. The signal received by the antenna was properly distributed to both TDF DRM Receiver Front-End and R&S EB200 Field Meter.

The TDF Receiver was integrated by the TDF Receiver Front-End and the TDF DRM software. This setup was used for specific trials, apart from being used to compare reception results with Dream based Receiver System.

The Dream based Receiver System was composed of R&S EB200 Field Meter, a Media USB-ONE sound card and a laptop running a modified version of GPL-ed DReaM software. R&S EB200 Field Meter, apart from field measuring, was capable of down converting an RF signal to a IF channel, making it suitable for the analog input of the 24 bit USB-ONE professional soundcard, which sampled the signal into a PC running a modified version of GPL-ed DReaM software DRM Radio demodulator over a GNU/Linux platform.

The second measurement block was made up of the R&S EB200 Field Meter to measure the RF field strength in the DRM signal bandwidth.

The control system was based on the same laptop computer, running a control software over a GNU/Linux platform which had the tasks of configuring and controlling the rest of the equipment, calculating some on-the-run statistics. Ancillary data were ordinate the time/position/trip measuring provided by a GPS receiver and a tachometer.

A set of DRM signal parameters and ancillary data was captured by the measurement system and was conveniently stored in plain text format files. These base parameters were stored for each tested mode, over each whole route for mobile measurements or over a fifteen minutes interval at each static selected location. A statistical analysis window of one minute was considered for fixed reception measurements. The on-the-run statistics were stored in one plain text file for each of the measurements performed.

TABLE 4

Measured Parameters

Provider	Type	Parameter	Fs
Dream based receiver system & TDF Front-End	RF	Delay spread	400 ms
		Doppler spread	
	IF	QAM constellation measurements	
	Baseband	Corrupted audio frames distribution	
Field strength meter	RF	Field strength	400 ms
GPS receiver	Ancillary data	Time	1s
		GPS positioning	
		Speed	

This measurement parameters table shows in brief the measurements done by the different parts of the system.

As well as the base parameters and the calculated statistics, the IF sampled input signal, was stored in binary files. The received DRM IQ samples of the whole measurement campaign were thus stored for any subsequent processing.

6 Tests results

6.1 Transmission reliability

The objective of this section is to determinate the minimum signal levels required for receiving correctly the DRM signal. For that purpose, fixed locations measurements have been analyzed. The results presented here are statistics consequential of 15 minutes measurement intervals. These results are compared with the values given by ITU for analogues AM signals **[3]**.

To determine the successfulness of a transmission circuit, a parameter called AudioQ is used. This parameter measures the **objective** audio quality and it is defined as follows:

$$AudioQ(\%) = \frac{Number\ of\ audio\ frames\ received\ without\ error}{Total\ number\ of\ audio\ frames} \cdot 100$$

It is, therefore, the percentage of time with received perfect audio. A successfully transmission is considered if the parameter value is above 98%. Therefore 98% AudioQ value is considered the threshold that assures a perfect **subjective** audio reception for a “non-professional” listener. This is a conservative limit according to the subjective perception of the engineers who have performed these tests. This is so because many of the poorly received audio frames do not convert to subjective listening defects. Besides, the fact that these engineers can be considered as trained listeners reinforces the previous affirmation about the definition of good audio quality for “non-professional” listeners. That 98% implies that there are 1.2 seconds of erroneous frames accumulated in one interval of 1 minute. This is the reference value for assessing excellent **subjective** audio quality considered for the different tests performed by DRM consortium.

6.1.1 Results of 18K_B/16/4/0.5 mode

In this section results obtained from the 18K_B/16/4/0.5 mode are described. The transmission rate of this mode is 21.20 kbps, which allows for example, an audio transmission coded with parametric stereo.

This is the mode more robust among all ones used for these tests. The obtained results for this mode can be easily extrapolated to the mode with 20 kHz bandwidth, which provides a little more binary rate and is the proper mode along with the 10 kHz mode for being used in the 26 MHz broadcasting band.

Table 5 shows the results of the 18K_B/16/4/0.5 mode. As observed on that table, the mean value of all the measured points is more than 98% value. Besides, more quality than that threshold is obtained for 19 out of 24 points. For the 5 points with AudioQ lower than 98%, 3 of them have more quality than 97%, so that those points provide a value very close to the minimum one. Taking into account that the transmission power is very low (200watts), the obtained results are really quite good.

TABLE 5

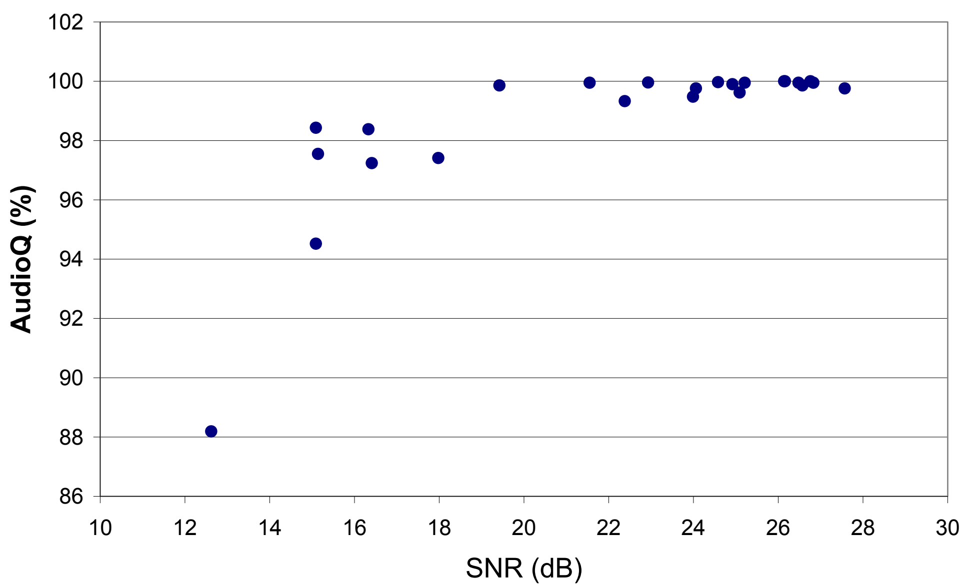
Results of 18K_B/16/4/0.5 mode (21.14kbps)

Mean AudioQ	98.71%
Number of points where AudioQ > 98%	19
Number of total measured points	24
Minimum signal to noise ratio	18 dB
Minimum field strength	37 dBµV/m

Figure 4 shows the observed results relative to the signal to noise ratio.

FIGURE 4

SNR of 18K_B/16/4/0.5 mode



It can be observed that points with more than 18 dB of signal to noise ratio provide correct reception. According to these data, the signal to noise ratio necessary to receive properly with this mode is 18dB. Considering a SNR of 18 dB, there is a measurement point with a quality of 97.41 %, so that it is the most critical point of all the measured ones. This is the point number 7 of the route 4 and it is a point with especial negative conditions as seen more ahead.

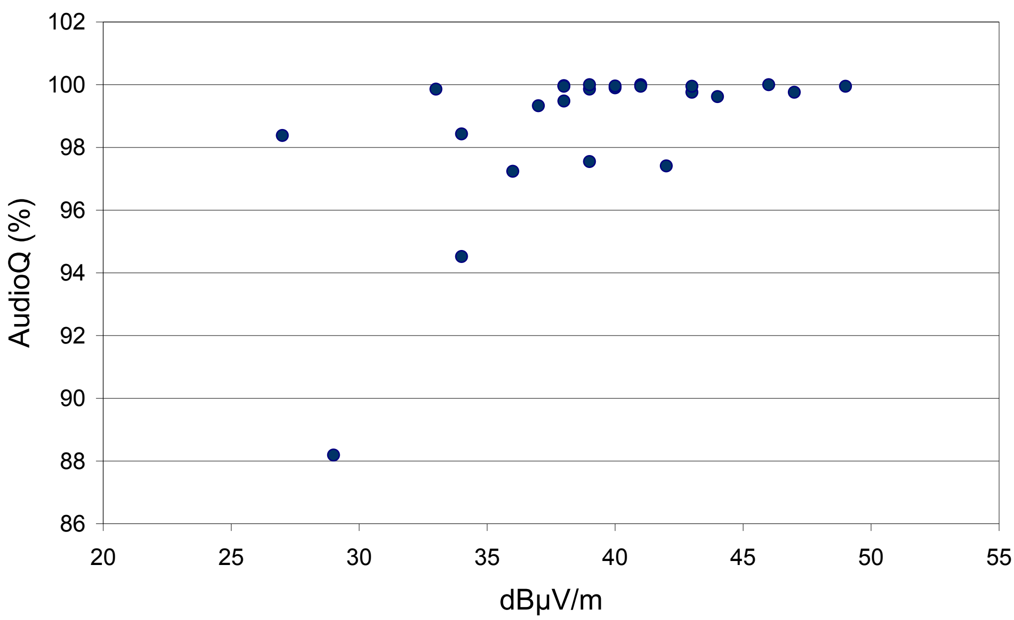
Although the measurement conditions defined for AM and DRM are different, if we compare both results, the values are clearly favorable for DRM system. The C/N ratio (Carrier to Noise Ratio, an equivalent parameter to SNR for DRM but in this case for AM) necessary for an AM transmission is 36.5 dB **[3]**. For a DRM transmission considering the 18K_B/16/4/0.5 mode the minimum SNR value is 18 dB, that is, 18.5 dB lower than the AM value.

ITU does not provide SNR values for DRM channels of 18 kHz but the best approximation is the estimated values for channels of 10 kHz. Thus, according to ITU **[2]** the minimum estimated signal to noise ratio for HF channels is between 14.6 dB and 18 dB. Although results are very similar to those ones given by ITU, it should be remarked that considered propagation channels are different. While ITU simulates ionospheric propagation channels, these tests consider tropospheric propagation (surface wave plus line of sight).

Figure 5 depicts obtained results relative to the field strength received. All points with more than 36 dBμV/m have a perfect audio quality, except 2 points with quality slightly lower than 98%. One of those points is the 7th point of the 4th route, that is the same problematic point that the one in the previous figure. The other point is the 6th point of the 2nd route, which will be analyzed later.

FIGURE 5

Field strength values of 18K_B/16/4/0.5 mode

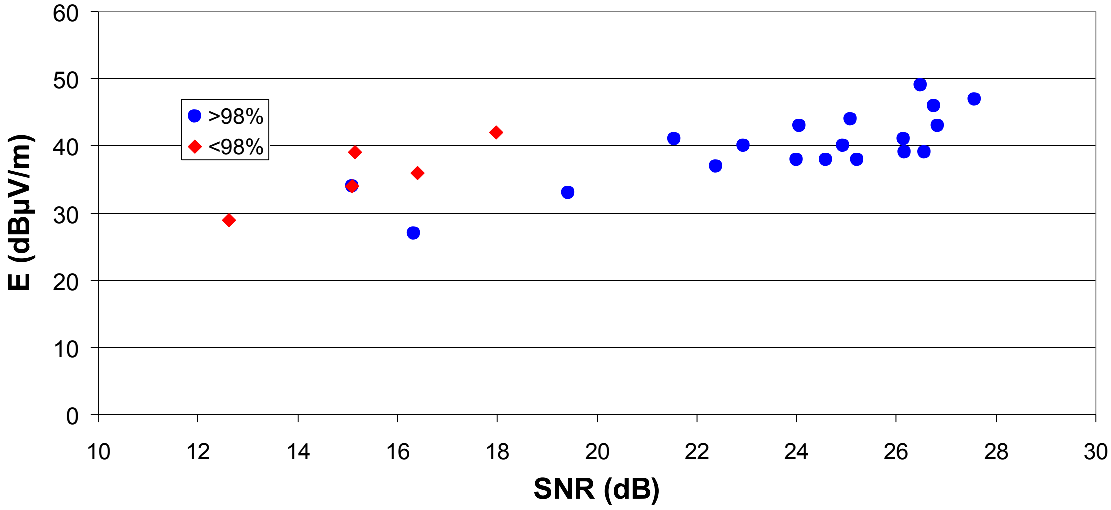


Comparing these data with the ITU ones, the minimum field strength value necessary for receiving an AM transmission without noise is 40dBμV/m [3]. Considering the DRM 18K_B/16/4/0.5 mode, that value is 37dBμV/m, 3dB lower than the AM value. This difference is caused by the external noise, which is significant in urban areas. But this noise also is applied to AM signal, so the 40dBμV/m value should not be considered with urban areas.

Figure 6 presents these data in another way, being able to observe clearly the minimum SNR required value.

FIGURE 6

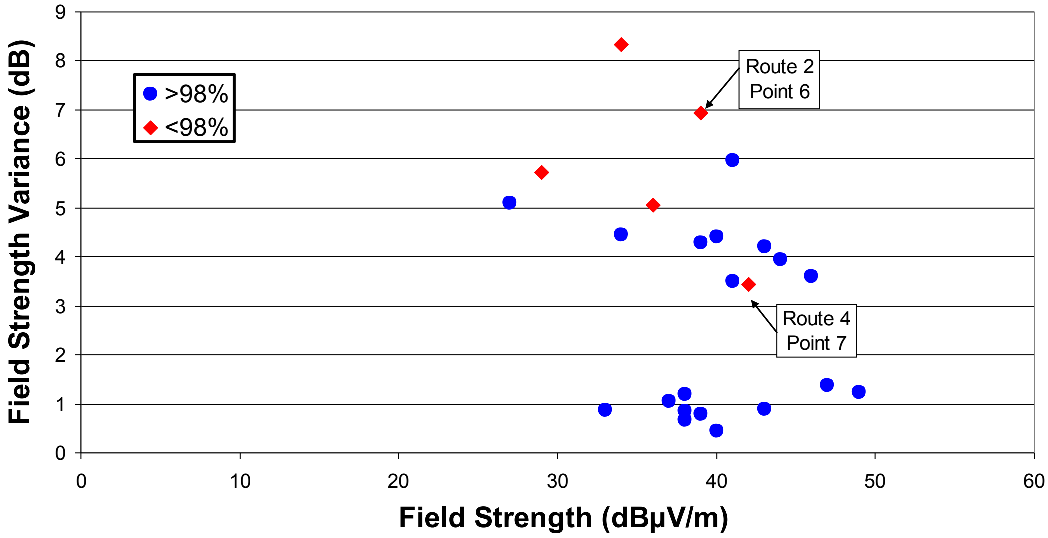
Field strength and SNR of 18K_B/16/4/0.5 mode



During the measurements, it was appreciated that the received field strength level varied considerably. Figure 7 shows how the signal variation also has a negative effect over the received signal quality.

FIGURE 7

Field strength and variance of 18K_B/16/4/0.5 mode



As expected, the variability of the received signal level has a detrimental effect on the reception reliability, however and except for the point 7 of the route 4, the reception is perfect with variances up to 5 dBµV/m. This gives an idea of this DRM mode robustness. We can also observe that point 6 of route 2 (problematic point considered before) presents great variability.

This high variability seems to be due to the traffic and also to the airplanes flying above Mexico City towards the airport. The traffic, profuse anywhere of the city, is also a source to radioelectric noise. To analyze its influence on the DRM signal reception, locations with constant or intense traffic (referenced as locations with traffic in this paper) have been separated from those with sporadic or null traffic (referenced as locations with no traffic). Table 6 shows the results of that analysis.

TABLE 6

Reception with and without traffic for 18K_B/16/4/0.5 mode

	Total	**Locations without traffic**	**Locations with traffic**
Mean AudioQ	98.71%	99.60%	98.18%
Number of points where AudioQ > 98%	19	9	10
Number of total measured points	24	9	15
Minimum signal to noise ratio	18 dB	< 15 dB	18 dB
Minimum field strength	37 dBμV/m	-	37 dBμV/m

It is evident that traffic has high influence, as demonstrated by the fact that in all the locations without traffic the reception is perfect, and all problematic locations are those with traffic. Due to a perfect reception in all locations without traffic, neither the minimum signal to noise ratio nor the minimum field strength value can be calculated with accuracy, but it is possible to obtain the minimum SNR and field strength measured in perfect conditions of reception. These values are 15 dB of SNR and 27 dBμV/m of field strength, both quite lower than the global values. Section 6.3.2 includes a more exhaustive analysis of the traffic influence.

In 5 out of 24 measured locations, the reception was lower than the minimum threshold of 98%. To analyze what happened in those points, the previous figures and the measured noise in each location will be taken into account. Before starting the measurement of 15 minutes for each point, some measurements on the adjacent channels were performed for determining the noise level. Noise is measured as power at receiver entry. Considering that the base noise is approximately -8 dBμV/m, Table 7 shows that all problematic locations have a high noise level.

TABLE 7

Points where reception has not been right with mode 18K_B/16/4/0.5

	Field strength (dBμV/m)	**Variance (dB)**	**Noise Level (dBμV)**	**Problem**
Point 2 - Route 1	34	8.33	-4.5	Low and variable signal
Point 4 - Route 1	36	5.05	-0.5	High noise
Point 6 - Route 2	39	6.93	0	High noise
Point 7 - Route 4	42	3.44	5.5	High noise
Point 1 - Route 6	29	5.73	-2	Low signal and High noise (low SNR)

Again, the point 7 of route 4 is considered apart because it is an especially problematic location. This point is close to the airport and a transmission centre, in a road with dense traffic. Figure 8 is a photo of the place.

FIGURE 8

Point 7 of route 4

This is the location where the measured noise power was the highest one (5.5 dBμV). Even in this case, a subjective audio quality of 97.41 %, value very close to the minimum threshold, was obtained.

Taking into account all these data, it can be deduced that 18K_B/16/4/0.5 mode is a robust transmission mode and clearly advantageous in comparison with the traditional analogue AM transmission. The transmission rate allowed with this mode is 21.20 kbps, enough for broadcasting a program with AAC coder and parametric stereo, so that the quality will be better than AM sound quality. In spite of having tested this mode, the mode that should be used in the 26 MHz broadcasting band is that one with 20 kHz bandwidth. Therefore, the quality even coded with parametric stereo would be slightly higher. As mentioned before, obtained data can be extrapolated with small error to that mode.

6.1.2 Results of other modes of transmission

18K_B/16/4/0.5 mode has been the most tested one, but also there are tests with three different modes, two of them with 18 kHz bandwidth and a higher binary rate but less protected and the third one like 18K_B/16/4/0.5 mode but with 10 kHz bandwidth, and therefore with less binary rate. In the following tables obtained results are detailed for the different modes. Sometimes the number of analyzed points is not very high so the results should be considered an approximation (marked with asterisk (*)) or it is impossible to give any result.

TABLE 8

10K_B/16/4/0.5 (11.64kbps) mode results

Mean AudioQ	95.75 %
Number of points where AudioQ>98%	5
Number of total measured points	7
Minimum signal to noise ratio	16-17 dB
Minimum field strength	38 dBµV/m *

TABLE 9

18K_B/64/16/0.6 (38.18 kbps) mode results

Mean AudioQ	88.24%
Number of points where AudioQ>98%	3
Number of total measured points	8
Minimum signal to noise ratio	22 dB
Minimum field strength	>43 dBµV/m *

TABLE 10

18K_A/64/16/0.6 (54.98 kbps) mode results

Mean AudioQ	93.08%
Number of points where AudioQ>98%	2
Number of total measured points	6
Minimum signal to noise ratio	-
Minimum field strength	-

Minimum field strength required for appropriate reception with the mode 10K_B/16/4/0.5 is slightly higher than the value needed for the mode 18K_B/16/4/0.5, although in theory it should be slightly lower. Probably, the reason is that the value was obtained with few samples. On the other hand, the minimum SNR value is close to the measured value for the 18K_B/16/4/0.5 mode, which is logic because they should be very similar.

Modes 18K_B/64/16/0.6 and 18K_A/64/16/0.6 need higher power levels to cover Mexico City. The results from Tables 9 and 10 show that, apart from other problems that could exist, the required power is not enough. Considering the minimum SNR of the 18K_B/64/16/0.6 mode, it can be deduced that an increment of 4 dB with respect to the 18K_B/16/4/0.5 mode, is necessary for an appropriate reception (difference in the signal to noise ratio). The minimum SNR values given by the ITU for HF channels and B/64/16/0.6 mode of 10 kHz bandwidth [2] are between 22.7 and 25.4 dB, which are higher than the ones obtained here. It could be because ITU estimated channels are deduced by simulating ionosphere propagation and not for a city, like in our case. Also, it is remarkable that the difference between both modes (4dB) is slightly lower than the one given by the ITU, that is, among 5.3 and 5.5dB depending on the estimated channel.

It is also clear that for using the 18K_A/64/16/0.6 mode, which allows high data transmission rate, the power level necessary should be greater than the one used for these tests.

Tables 11 to 13 detach these data in locations with and without traffic, so that the importance of the traffic in the DRM signal reception can be observed.

TABLE 11

Reception with and without traffic for 10K_B/16/4/0.5 mode

	Total	Points without traffic	Points with traffic
Mean AudioQ	95.75 %	99.18 %	93.18 %
Number of points where AudioQ>98%	5	3	2
Number of total measured points	7	3	4

TABLE 12

Reception with and without traffic for 18K_B/64/16/0.6 mode

	Total	Points without traffic	Points with traffic
Mean AudioQ	88.24 %	99.36 %	84.54 %
Number of points where AudioQ>98%	3	2	1
Number of total measured points	8	2	6

TABLE 13

Reception with and without traffic for 18K_A/64/16/0.6 mode

	Total	Points without traffic	Points with traffic
Mean AudioQ	93.08 %	90.54 %	98.15 %
Number of points where AudioQ>98%	2	1	1
Number of total measured points	6	4	2

In spite of having few data, the signal to noise ratio of the 18K_B/64/16/0.6 mode is around 22 dB for environments without traffic and around 24-25 dB for environments with traffic. The power increment required for the 18K_B/64/16/0.6 mode to cover an area with traffic is similar to the previously commented increment for the 18_B/16/4/0.5 mode.

6.1.3 Environment effects in DRM signal

The kind of environment where the receiver is placed is a very important factor in the reception of any radioelectric service. In order to study the environment effect on DRM system, several routes were considered in different kinds of environments. Tables 14, 15 and 16 show results of 18K_B/16/4/0.5 mode, divided by routes and including the median values of power measurements in all the points and the mean values of quality and SNR. Since there were no measurements of 18K_B/16/4/0.5 mode on the route 3, described values were obtained with the 20K_B/16/4/0.5 mode. Received power and noise results are not influenced by this difference but SNR and objective audio quality (AudioQ) data cannot be taken into account.

The term “field variability” is defined as the median value of the field strength variance of each point. It is a statistic that shows if received signal is very or little variable.

TABLE 14

Power statistics divided by environment types

	Environment Type	Mean distance to the transmitter (km)	Field (dBµV/m)	Field variability (dB)
Route1	Typical Mexican	11.5	37	4.63
Route2	Dense Urban	10	39.5	4.00
Route3	Low Dense Industrial	15	35	2.87
Route4	Opened Residential	9.5 - 17	40.5	2.20
Route6	Typical Mexican	20	37	1.19

The value of the received field strength is not very related to the distance to the transmitter. This was an expected result because the field strength must be more influenced by orography, since propagation is by "line of sight" wave. The difference between route 1 and 6 is the clearest case, both areas have the same environment. Route 6 is placed 20 km away from the transmitter and route 1 only 11.5 km, however, in both areas the received field strength value is similar because route 1 is in a shadow area (see section 6.2). As expected, the variability in open areas is also low.

TABLE 15

Noise statistics divided by environment types

	Environment Type	Noise (dBµV)
Route1	Typical Mexican	-3.5
Route2	Dense Urban	-3.75
Route3	Low Dense Industrial	-6
Route4	Opened Residential	-7
Route6	Typical Mexican	-5

The radioelectric noise generated in a city is one of the most important factors. As expected, noise in open areas (route 3) is lower than in the other ones, and the obtained value is more influenced by the noise of measuring equipments that by the external noise. It should be remarked also that noise in industrial areas is lower than in urban ones. This is because in industrial areas there is less traffic and probably less interferences from transmitters.

TABLE 16

Audio and SNR statistics divided environment types

	Environment Type	Mean distance to the transmitter (km)	SNR (dB)	AudioQ (%)
Route1	Typical Mexican	11.5	20.24	98.25
Route2	Dense Urban	10	25.07	99.30
Route4	Low Dense Industrial	9.5 - 17	26.15	99.95
Route6	Opened Residential	20	22.38	97.32

Reception in opened residential environment is practically perfect (99.95%) and presents the highest value of signal to noise ratio. Results of other noisy areas are very good as considered in routes 1 and 2, where, in addition to high noise levels the variability of the received signal is very great due to reflections in buildings and vehicles in movement. In spite of this, the audio qualities are over the threshold for correct reception.

It can be also observed that in a dense urban environment the reception is better than in the typical Mexican, which does not seem to be logic. About the factors that can differentiate both environments it can be said that traffic is similar in both of them. Mexico DF has dense traffic in practically the whole city, so it seems not to influence on the reception. Noise level in both areas is also similar. Statistics for route 6 are influenced by a location with a very bad reception. Without this location, the mean “AudioQ” would be 99.6 %.

6.2 Coverage area

6.2.1 Environment overview

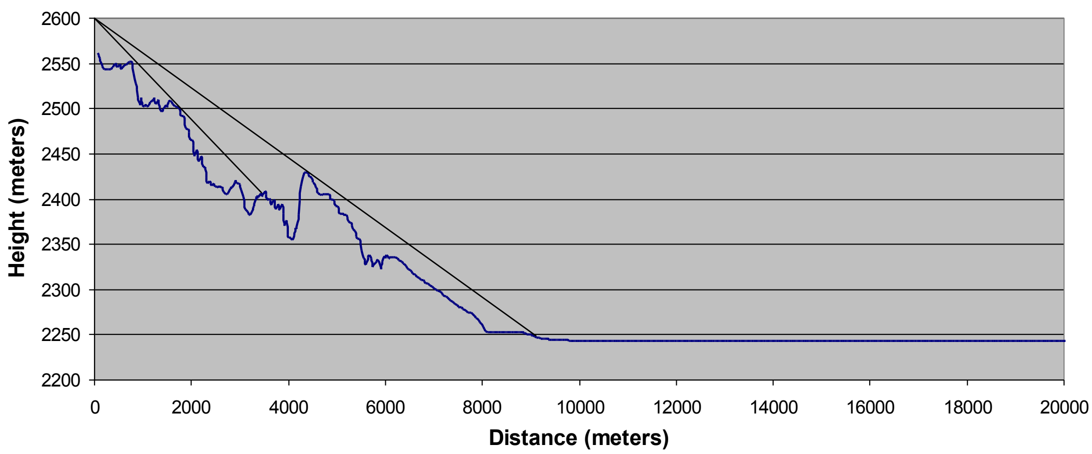
Before analyzing the measured data and the resulting coverage, in this section an environment overview is presented with the aim of making more understandable the obtained results. This overview considers both, the location of the transmitter and reception environment.

As stated before, the transmitter was located in a properly equipped Radio Ibero facility in Santa Fé (Mexico City). The transmitting antenna was installed at 40 meter height in a tower available at this facility (almost 350 meters above the Mexico City center as it can be seen in Figure 1). Although it ought to be said that this location was the best available for both the transmitter and the antenna, due to the sharp orography of the terrain, in some points Fresnel ellipsoid was obstructed, fully or partially.

This leads to some points being in shadow areas, thought being near the transmitter. Nevertheless, due to the robustness and multipath characteristics of the DRM system, reception has been possible even in some of this shadow points. In order to be able to take the most from the DRM system in those critical zones, the most robust mode available for a 18 kHz bandwidth has been used, as presented before in section 3.

FIGURE 9

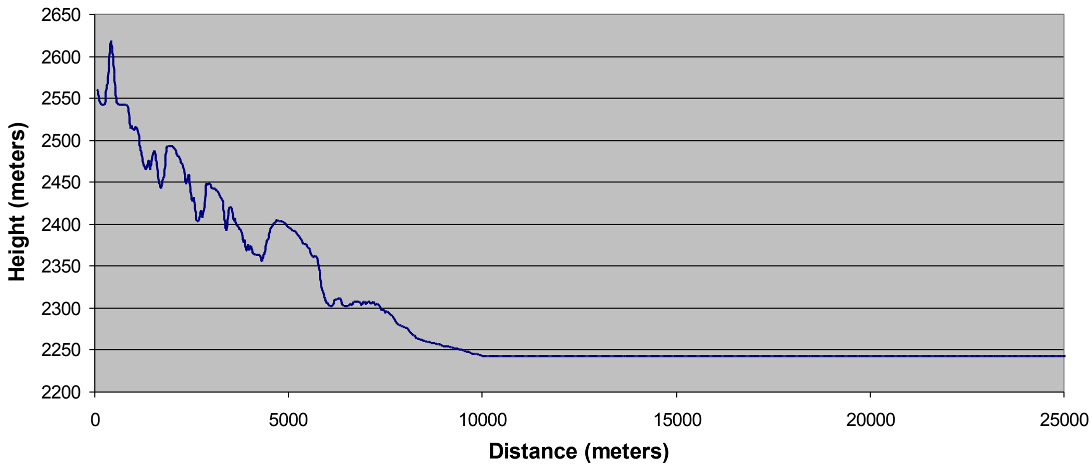
Terrain profile from Transmitter in 45º North-East direction



In Figures 9 and 10, terrain profiles starting in the transmitter site and directed in the 45 and 60 degrees North-East directions have been depicted. Though, as it can be seen in the figure, line-of-sight obstruction exists in the 45 degrees direction, it must be said that it is the direction with less Fresnel ellipsoid obstruction that could be radiated from the transmitter site. As it can be seen, in the 60 degrees direction the sharp orography clearly obstructs line of sight.

FIGURE 10

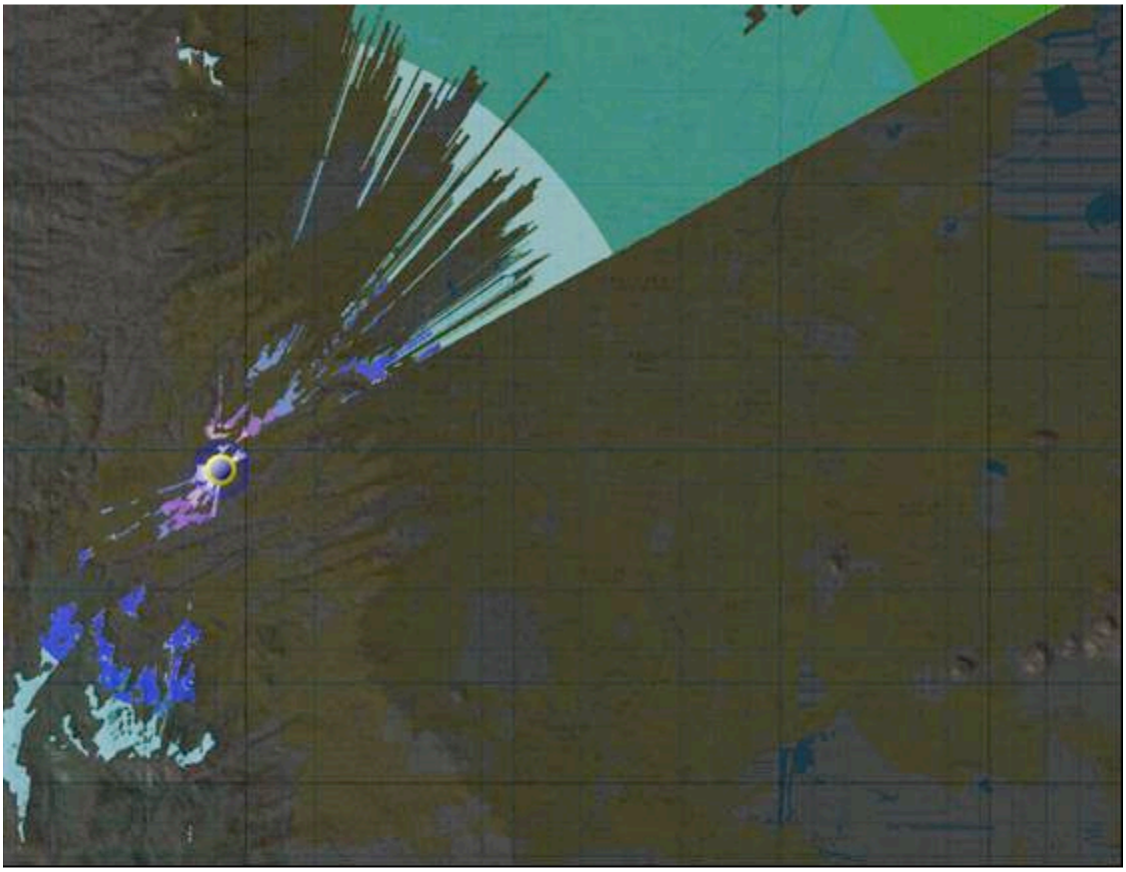
Terrain profile from Transmitter in 60º North-East direction



Assuming that only line of sight propagation exists, a simulation has been done using a Digital Elevation Model (DEM) of Mexico City. The coverage map that resulted from this simulation has been depicted in the Figure 11.

FIGURE 11

Line-of-sight simulation using DEM of Mexico City



As it can be seen in the simulation, most of the zones in the first 10 km from the transmitter, in the direction of the transmitting Antenna (45º), are in line-of-sight shadow. This will cause that points more than 10 Km away from the transmitter could get more power level than points in the first 10 km from the transmitter. Nevertheless, this does not mean that coverage of those first 10 km would not be possible, due to the existence of ground wave propagation in the proximities of the transmission, and due to DRM capability of using multipath propagation, this will only require more power to cover some of those zones than the power that would be necessary to cover 10 km in orographically more suited conditions. In should be also noted that the beamwidth of the transmitting antenna is 120º aiming at 45º, therefore the simulation is not influenced by the antenna.

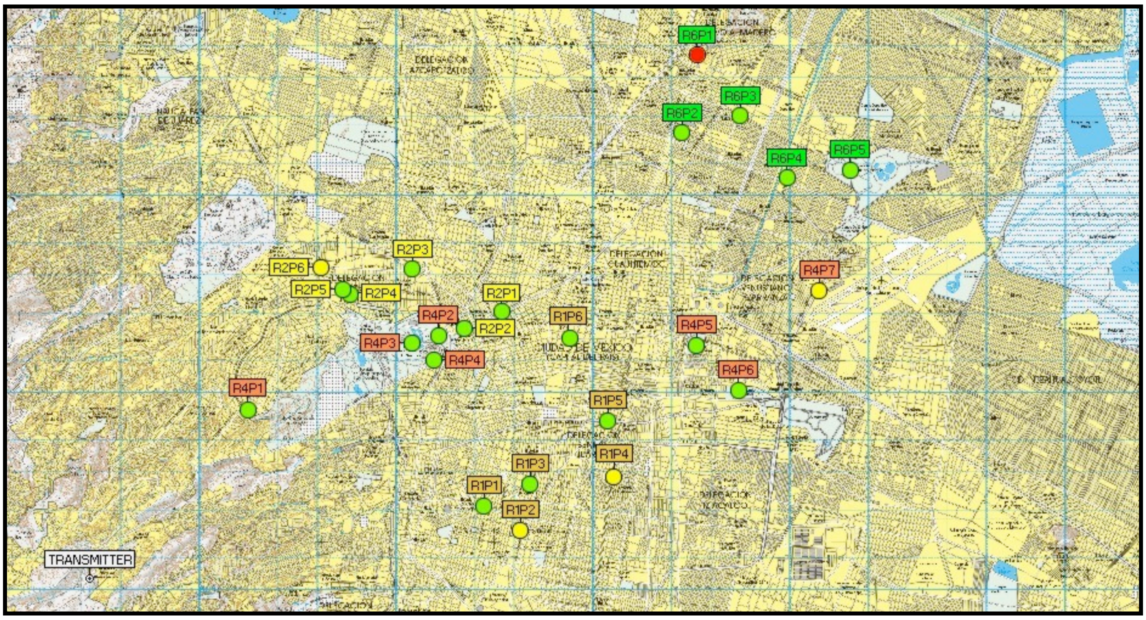
Apart from the orography, there are other factors that affect reception, those include buildings in the urban area, interferers and noise. Interferers and noise has been explained in section 6.3. The effect of the planes over Mexican City urban area when approximating to land in Mexico International Airport is also remarkable as explained in section 6.3.3.

6.2.2 Fixed Point Coverage

Several DRM modes have been tested in Mexico City, being the most satisfying for the environment described in section 6.2.1 and the available power the one with 18 KHz bandwidth, B mode, using MSC 16 QAM and SDC 4 QAM and protection redundancy of 0.5. The fixed points measurements done for this mode have being depicted in the map of the Figure 12. The criteria used for the location colors is green for the points that comply with the AudioQ greater than 98 %, yellow for the points with an AudioQ greater than 90% but less than 98% and red for points with AudioQ less than 90%.

FIGURE 12

Fixed point coverage for 18 kHz B/16/4/0.5



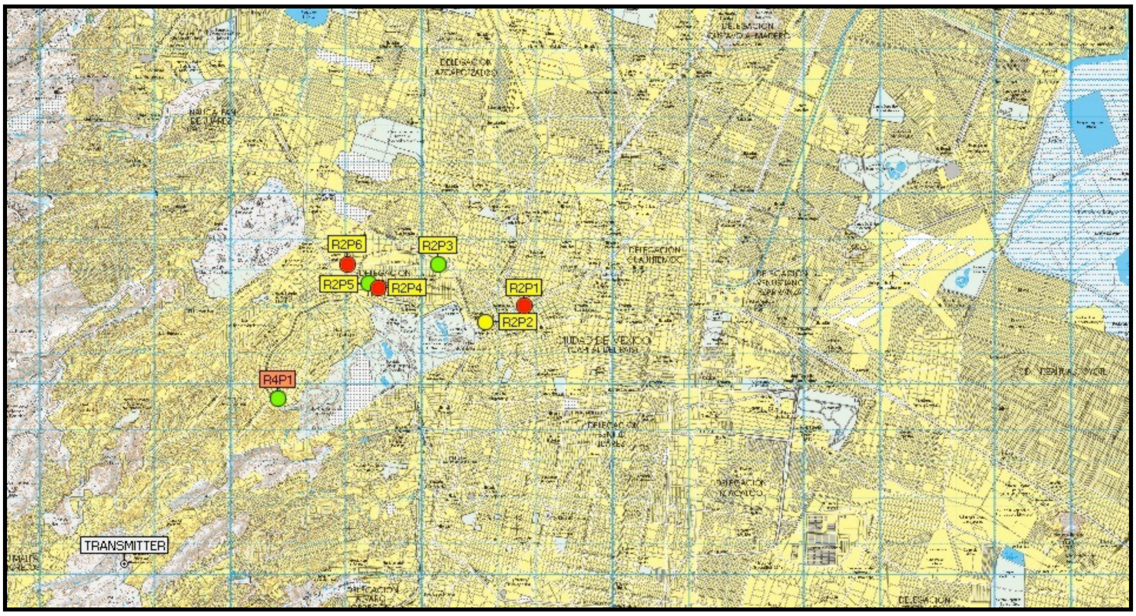
As it can be seen, and taking into account the considerations on the Fresnel ellipsoid obstruction as function of the 45º direction stated before, for this mode, it could be said that the coverage for a 200 Watts DRM transmitter is about 15 km.

Only three out of 18 tested points in a 15 km coverage area don't comply with the tight 98% AudioQ criteria. Nevertheless, those three points comply with an AudioQ of 97%. This reduced AudioQ causes have been studied in 6.1.1 and it is resumed in Table 7.

Other modes has also been considered, for mode B/64/16/0.6, with the same 200 Watts power, the coverage has been severally reduced as it can be seen in Figure 13.

FIGURE 13

Fixed point coverage for 18 kHz B/64/16/0.6

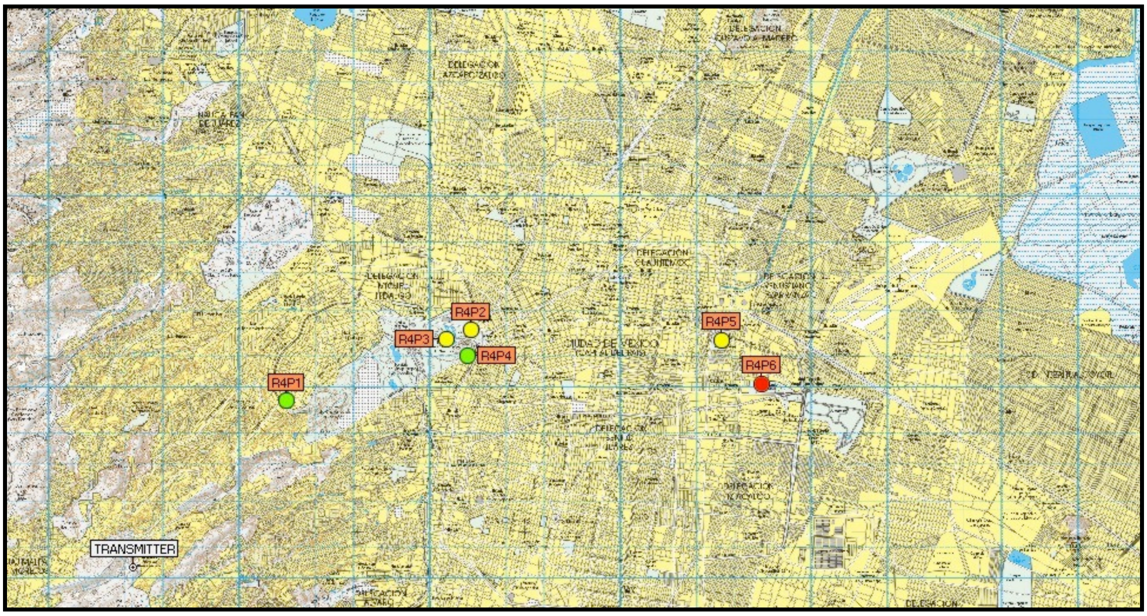


This reduced coverage using this mode is mainly caused by the reduced power levels available in the first 10 Km zone due to orography as explained in section 6.2.1.

Finally, mode 18K A/64/16/0.6 has been tested as well, giving the map depicted in Figure 14.

FIGURE 14

Fixed point coverage for 18 kHz A/64/16/0.6



As for the former mode, this reduced coverage is also caused by the reduced power levels available in the first 10 Km zone due to orography as explained in section 6.2.1.

6.2.3 Mobile coverage

The DRM system has also been tested for mobile reception. This mobile reception was analyzed by means of mobile measurements along six different routes in Mexico City. For comparison purposes the mobile measurements were close to locations where the fixed reception was also tested.

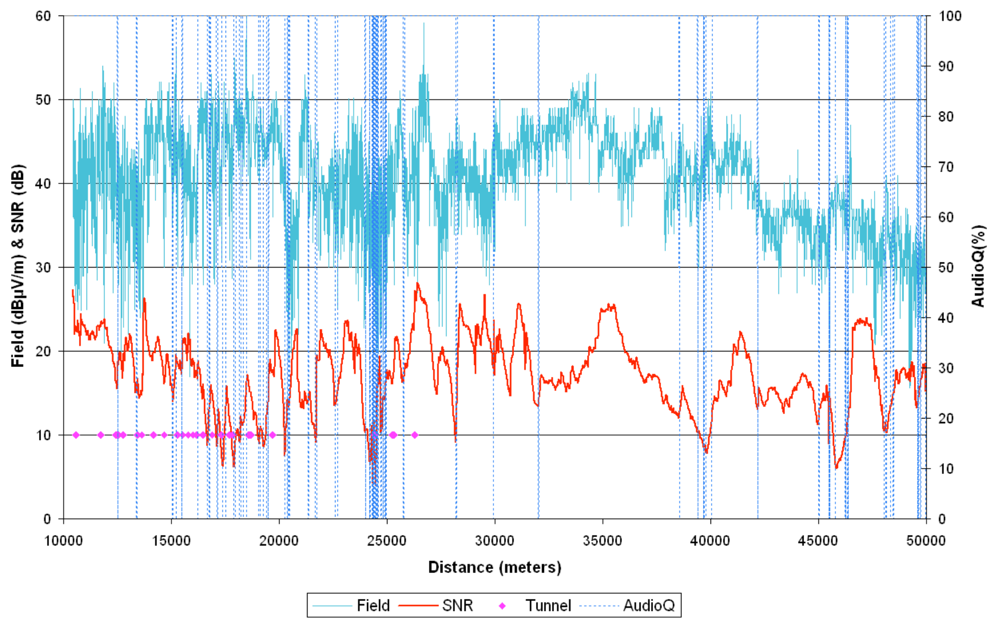
One additional mobile test was performed along a quasi-radial direction from the transmitter to have information about the coverage of the transmitter. This radial route is route is formed by two different sections. The first one consisted on driving along the road called “Viaducto” and the second section along the Texcoco highway. The viaduct is a wide road two lanes each sense that crosses Mexico City in the west-east direction. It should be noted that the whole route has dense traffic.

The viaduct mobile measurement has been done using the 10 kHz B/16/4/0.5 DRM mode. In the Figure 15, the field strength, SNR and AudioQ are represented along with tunnel location.

The most remarkable conclusion from the measurements along this radial route is the absence of dropouts at the first 10 kilometers. The first and second audio dropouts appear at 12.4 km and 13.3 km. Those audio dropouts are caused by tunnels. Third audio dropout appears at 15 km and is caused by a long tunnel (thought not marked in map) and interferences of a nearby communication tower. Before 16.5 km another three drop-outs occur due to tunnels. From 16.5 km to 20 km there are several dropouts not caused by tunnels.

FIGURE 15

Viaduct 10 kHz B/16/4/0.5



It should also be noted that there are not audio dropouts in most tunnels. An interesting additional conclusion is the good coverage obtained at distances up to 45 km. This second section of the route can be considered as semiurban environment and being the noise level lower, the SNR values during the Texcoco section are above the 20 dB threshold and thus providing a reasonable coverage exception made for tunnels.

As mentioned before, the transmitter power used in this measurement campaign was low (200 W) and consequently the received field strength was low too. The figure suggests that an increase of about 5-6 dB would increase the mobile coverage until 20 km (tunnels included). An increase up to 2-6 kW would provide an error free coverage up to 40 km. Some uncovered spots as long tunnels would remain, but those locations would not be covered with analogue services either.

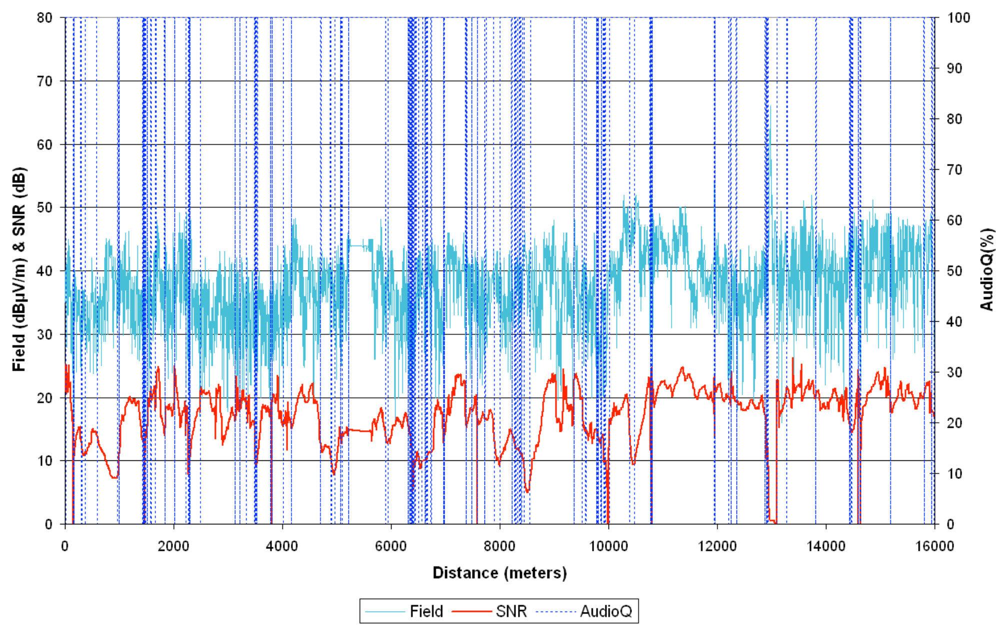
The remaining six routes represent the different urban environments available in Mexico City as described before in section 4. Before analyzing each environment, it should be stated that the mobile coverage inside the Mexico City was not satisfactory. This statement should be clarified as follows. As mentioned all through out this document, the transmitter used in the tests was a very low power transmitter and the objective of the tests was not to ensure the DRM coverage for the whole Mexico DF. Mobile reception has shown as a summary of the modes and routes tested that the received SNR was too low due to both low power of the transmitter and the high noise levels within the coverage area. Again, an increase of about 10 dB would have provided a good mobile coverage for modes B/16/4/0.5.

Mobile reception in typical Mexican environment

Route 1 represents a typical Mexican environment as described before in section 4. The measurement graph is the one of the Figure 16.

FIGURE 16

Route 1 18 kHz B/16/4/0.5



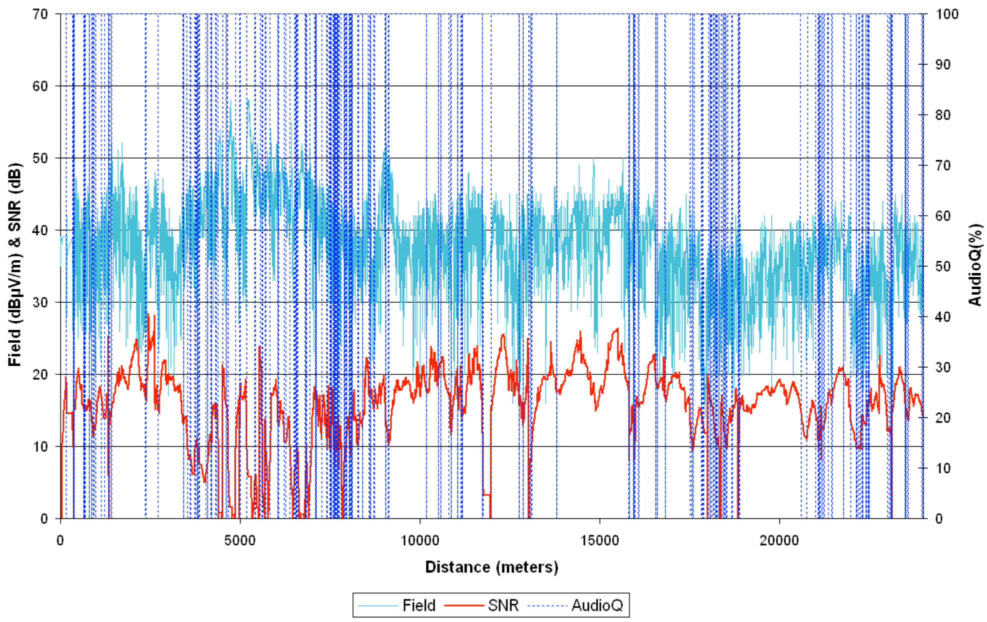
This mobile test was affected by both noise and low received field strength. This latter parameter was smaller than the one received along the viaduct and noise was also 4 dB higher. Assuming a SNR 20 dB threshold from the static reception tests, it can be clearly said that most of this area is uncovered. Most SNR values from Figure 16 would be above the threshold provided a 2 kW transmitter is installed. Except for spots at 9, 10, 13 and 15 km, where tunnels and interferers make the reception unfeasible for any digital or analogue services in this frequency band.

Another example of Typical Mexican environment as described before in section 4 is shown by results of the route 6. The measurement graph is the one of the Figure 17.

This mobile measurement route is more affected by noise and interference than the route 1. Around the fifth kilometer there is a complete fading of the SNR value being the received field strength quite high if compared with the median value along this entire route. Again, those levels of interference and noise would lead to the absence of radioelectric services (either analogue or digital) at this spot.

FIGURE 17

Route 6 18 kHz B/16/4/0.5

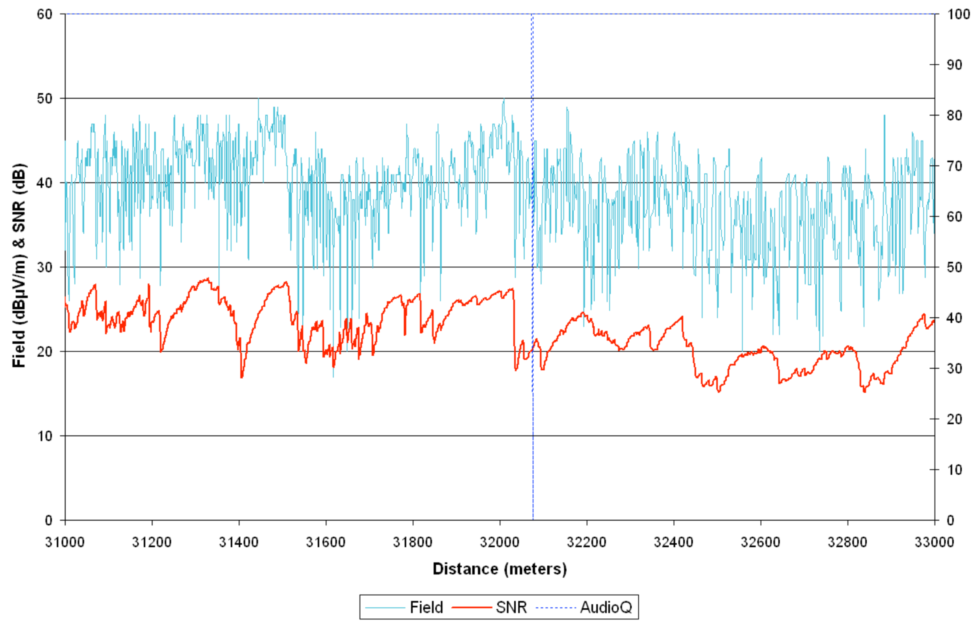


Mobile reception in open residential environment

Route 4 represents an open residential environment as described before in section 4. The measurement graph is the one of the Figure 18.

FIGURE 18

Route 4 18 kHz B/16/4/0.5



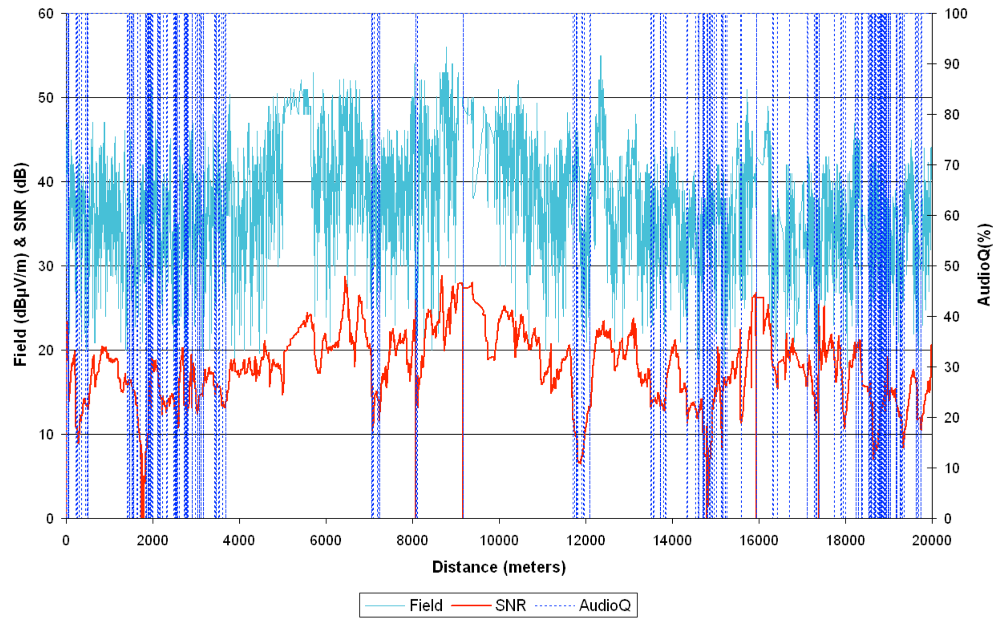
In the route 4, the received field strength has been similar to route 1 and, thought the noise level is about 4 dB lower as stated before in Table 15, this route is received alike the route 1.

Mobile reception in urban dense environment

Route 2 represents an urban dense environment as described before in section 4. The measurement graph is the one of the Figure 19.

FIGURE 19

Route 2 18 kHz B/16/4/0.5



In the first 15 km of the route 2, the received field strength has been slightly higher than route 1, being the noise level similar as stated before in Table 15. The dropouts within this first section occur due to low field strength levels that produce SNR values under the threshold. There is also a tunnel located approximately between the first and second kilometers of the section that makes unfeasible the reception of any radioelectric service in this frequency band. The second part of this it is affected by either a heavy interference or noise that produces reduced SNR areas.

6.2.4 Power and coverage

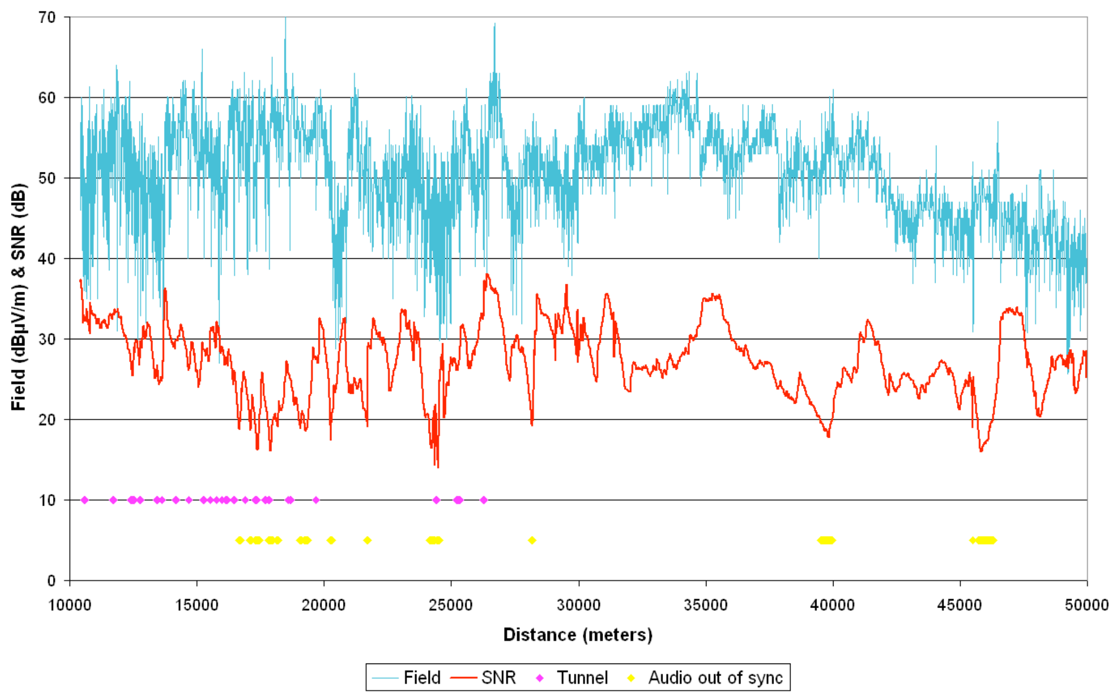
As it has been shown before, for this transmitter location and due to the Fresnel ellipsoid obstruction as stated in 6.2.1. Environment Overview, two zones have to be considered. A first zone, out of the line-of-sight area, which coverage would need a little more power than usual, and a second zone within the line-of-sight.

Taking into account that a minimum SNR of 20 dB is need to ensure a good mobile coverage, some mobile routes will be used in this section to extrapolate a relationship between power and mobile coverage.

The first mobile route to consider is the viaduct mobile measurement, which has been done using the 10 kHz B/16/4/0.5 DRM mode. This measurement as represented in Figure 20 would correspond to a transmitted power of 2 kW.

FIGURE 20

Viaduct 10 kHz B/16/4/0.5 with power extrapolated to 2 kW



The graph represents the estimated received field strength, SNR values and the expected audio dropouts if the transmitter was 10 dB higher (either with a better antenna location or a higher transmitter of 2 kW).

As it can be seen in the Figure 20, the audio dropouts that persist are mostly caused by long tunnels. At 20.2 km 21.5 km and there are also two unmarked tunnels. At 28 km there is a zone with low

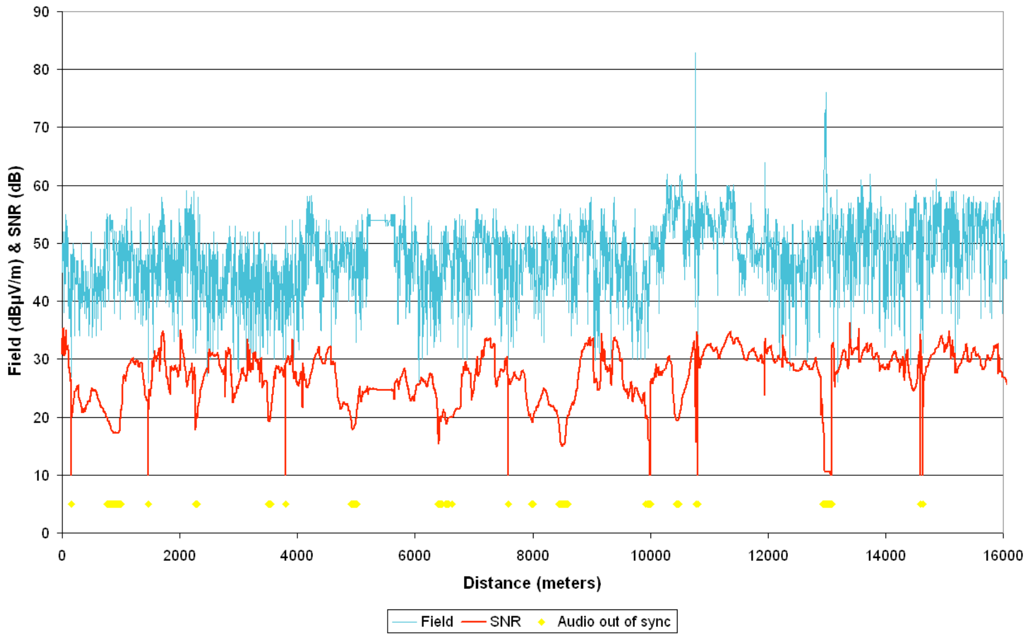
SNR caused by a high structure near the airport. At 39 km there is an unidentified strong interference. At 47 km the low SNR zone is caused by the structure of the toll of the highway.

As a conclusion, it can be said that with an increment of 10 dB in the transmitter power, the 93.35% of the whole route is covered. The last point of this route is 42 km away from the transmitter. If the power is increased by 15 dB, almost the 100% of the route will be covered, including places where analogue signals reach highly degraded or don't even reach.

With regard to the Typical Mexican environment of route 1 as described before in section 4 the measurement graph is the one of the Figure 21.

FIGURE 21

Route 1 18 kHz B/16/4/0.5 with power extrapolated to 2 kW

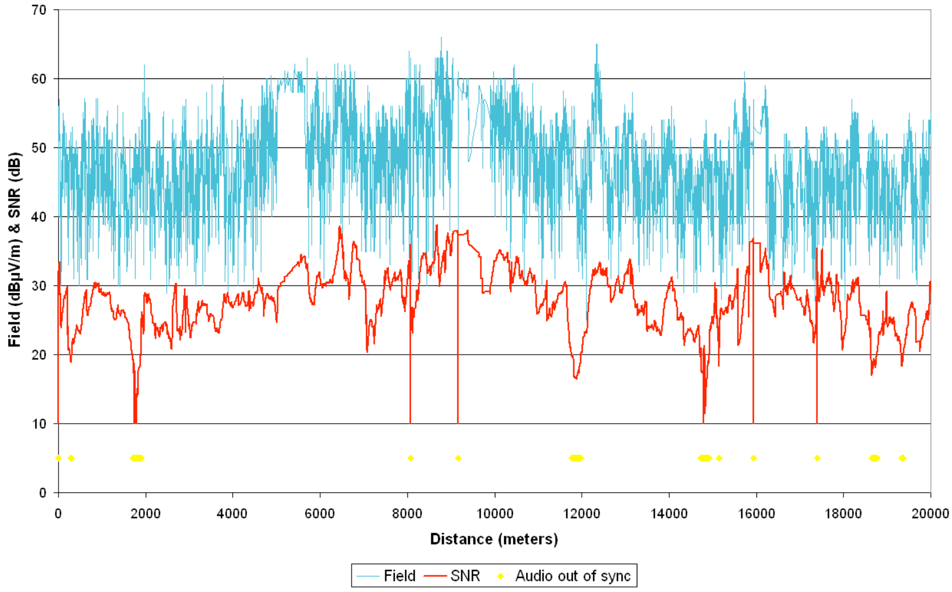


In the Figure 21, the field and SNR have been boosted by 10 dB, which would be the case if a 2 kW transmitter was to be used. As it can be seen coverage has been severely improved, from 28.87% to 90.87 % of the whole route. By boosting the signal by 15 dB, only special points would be out of coverage, where analogue signal would not be received either.

Finally, considering the measurements in dense urban environment of route 2, if the signal is boosted by 10 dB, the measurement graph would be as the one of the Figure 22.

FIGURE 22

Route 2 18 kHz B/16/4/0.5 with power extrapolated to 2 kW

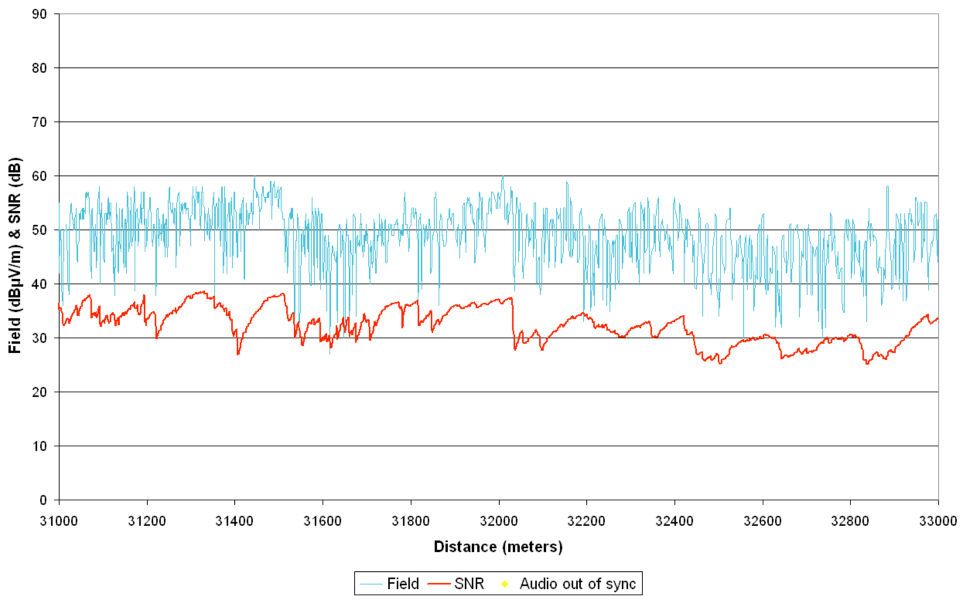


As in the route 1, in the first 20 km of this route, it can be seen coverage has been severely improved, from a former coverage of 23.03% reaching up to a 90.23 % coverage along the first 20 km. Nevertheless, due to heavy interference at the second part of the route, the coverage in the whole route after being boosted by 10 dB is reduced to 86.91 %. By boosting the signal by 15 dB, only special points would be out of coverage, where analogue signal would not be received either.

Finally, considering the measurements in dense urban environment of route 4, if the signal is boosted by 10 dB, the measurement graph would be as the one of the Figure 23.

FIGURE 23

Route 4 18 kHz B/16/4/0.5 with power extrapolated to 2 kW



In the Figure 23, the field and SNR have also been boosted by 10 dB, reaching to a power of 2 kW. It can be seen coverage has been greatly improved, from a coverage of 51.26% reaching up to a coverage of the 94.43 %. By boosting the signal by 15 dB, only special points would be out of coverage, where analogue signal would not be received either. In the Table 17 coverage from a 200 Watts transmitter, along with coverage estimations for 2 kW and 6.3 kW are summarized.

TABLE 17

Estimated mobile coverage for different transmitter power levels

Route	Environment	Coverage (200 W)	Coverage (2 kW)	Coverage (6,3 kW)
Viaduct-Texcoco	Four lane road	Up to 15 Km (90%)	Up to 42 km (93 %)	More than 42 km (almost 100%)
ROUTE1	Typical Mexican	29 %	91 %	Almost 100%
ROUTE2	Dense urban	23 %	87 %	Almost 100%
ROUTE3	Open residential	51 %	94 %	Almost 100%
ROUTE4	Typical Mexican	21 %	87 %	Almost 100%

6.3 Noise, interference and traffic

6.3.1 Noise considerations

The sensibility of a standard receiver is according to the ITU 4.5 dBμV/m for 10 kHz bandwidth [2] or 9 dBμV/m for 30 kHz bandwidth. The received noise power in the whole measurement system (noise of all the reception and equipment control system elements) is close to -8 dBμV/m. Considering that the antenna K factor is 20 dB, the tests system sensibility is 12 dBμV/m, only 3dB more than the ITU reference system. To know the real noise that exists in Mexico City, tests have been performed with the transmitter switched off. A measured power level significantly greater than -8 dBμV/m is due to noise or interferences.

Figures 24 and 25 show the received power for two city routes. Route 1 is from the Radio Education offices (in Benito Juárez) to the transmission location in Radio Ibero (Santa Fe). Route 2 is from the transmitter station of Radio Educación (Iztapalapa) to Radio Education offices. In this second route a bandwidth of 9 kHz was considered, so that the base noise is about 5dB lower than the previously calculated data.

FIGURE 24

Measured power on route 1

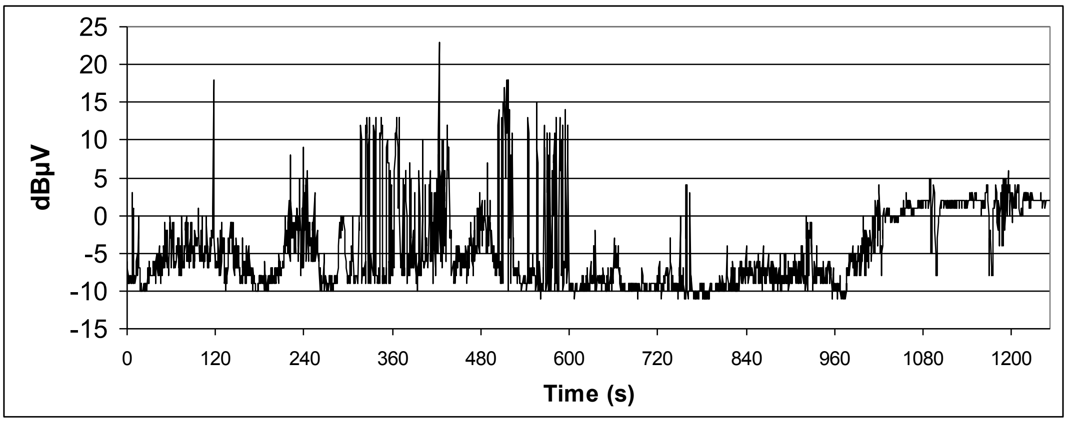
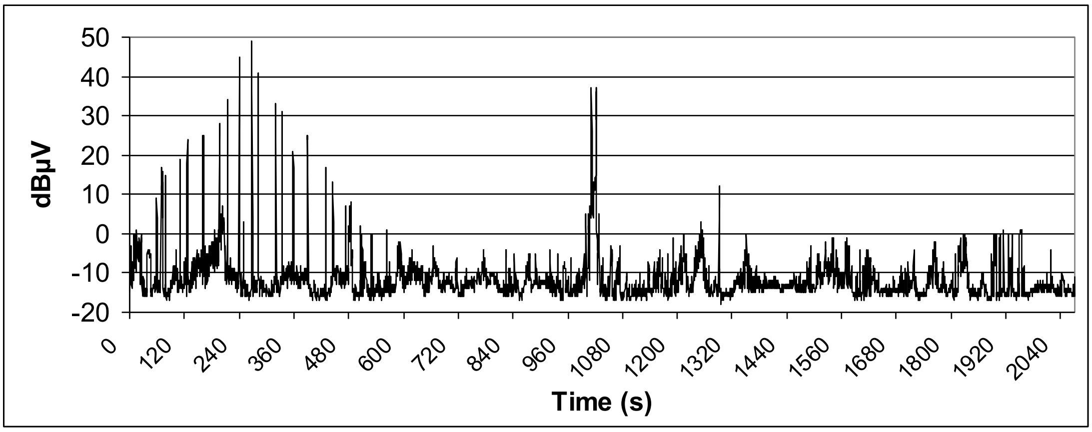


FIGURE 25

Measured power on route 2



In these figures we can observed that the noise level in Mexico City is very high. Very different elements can be the source of this noise and some of them have been identified. Among the main causes it should be remarked voltage transformation plants and traffic, especially trolleybuses and old cars. Sometimes received signal should not be considered noise, but interference. These interferences can be due to the proximity to a transmission station (AM or FM) or citizen band transmitters that would not fulfill the requirements about spectral width. High power peaks measured at first kilometers of the second route seem to be due to the approaching and moving away of an interference source.

In spite of the high noise levels the system worked very well, as shown on previous sections. But it is evident that the minimum required power for receiving DRM (or other broadcasting services) should be higher than these powers.

6.3.2 Traffic Influence

As mentioned above when analyzing the system reliability, reception locations where the traffic is dense near the receiver should be analyzed to obtain the real influence of this factor in the received quality. Several parameters have been studied to quantify the effect of the traffic: noise, received field strength time variability and multipath (Doppler spread and delay spread). This analysis has been performed with the measurements done with 18 KHz modes, Table 18 shows the values for the above enumerated four parameters.

TABLE 18

Traffic influence

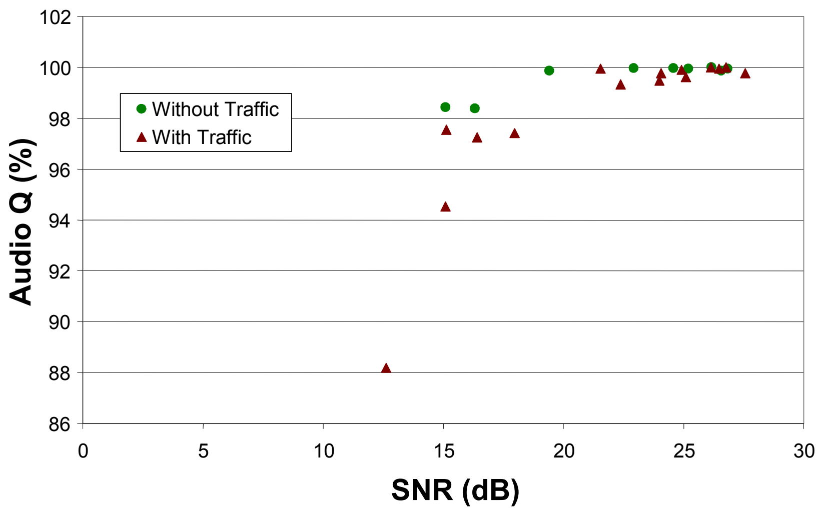
	without traffic	**with traffic**
Field strength variance (dB)	0,89	3,6
Noise (dBµV)	-7	-3,5
Delay median (ms)	3,93	2,53
Doppler median (Hz)	0,19	0,35

Traffic causes a significant variability of the received field strength. Being the wavelength related to the dimensions of the vehicles the reflections have an important contribution to the overall received field strength.

Vehicles in Mexico DF have been also observed as an important source of radioelectric noise. This noise is impulsive in its nature and having a higher effect on the VHF band [4], the impact cannot be neglected in HF. Figure 26 shows the received SNR and the audio quality in both traffic and “non-traffic” locations. Locations with traffic require higher SNR values to have a perfect reception. Nevertheless, the thresholds given in former sections have been calculated using the results of ALL the measurement locations so the traffic influence is already included in those thresholds.

FIGURE 26

Traffic influence in SNR and AudioQ, mode 18K_B/16/4/0.5



6.3.3 Airplane traffic over Mexico

At a few locations in Mexico DF, it was observed that the airplane approach maneuvers over the city caused dropouts of the received SNR. Figure 27 represents the received SNR and the triggered indication of an airplane made by technicians at the measurement campaign. Both parameters fit perfectly and so the dropouts in the SNR are clearly caused by planes at locations near the approach line of the airplane.

FIGURE 27

Airplane approach effect

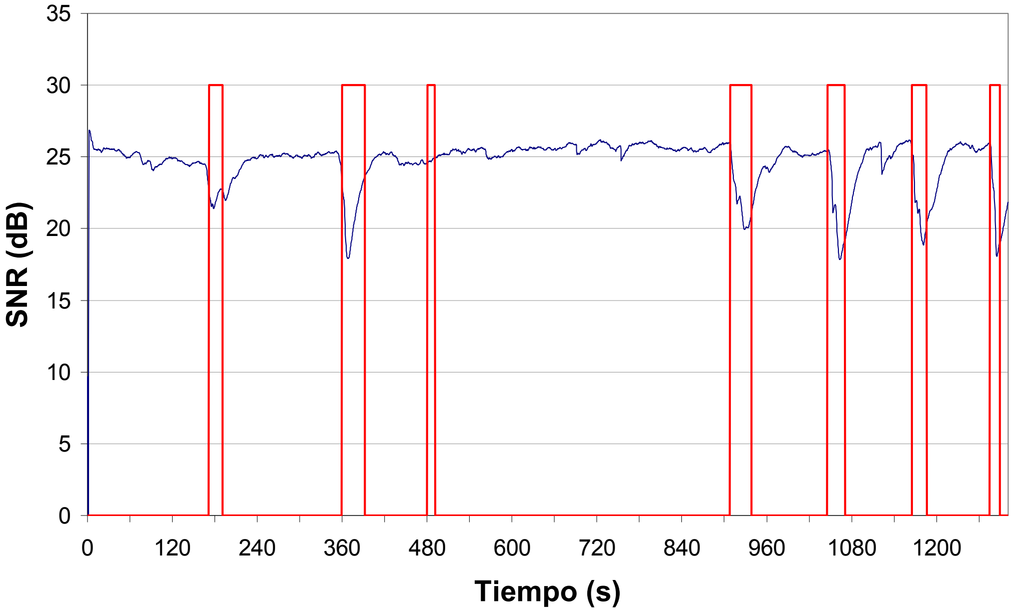


Figure 28 shows the approximate approach line that airplanes follow over Mexico D.F. The green point on the figure shows the location where SNR was measured. It should be also noted that this is the worst Doppler situation as the transmitter and the landing path are on the same radial.

FIGURE 28

Landing Path and measurement point

7 Acknowledgements

This document has been produced by the University of the Basque Country as the result of a cooperative effort made by the DRM consortium and Radio Educación. The experimental network has been set up by RIZ Transmitters. Several measurement equipments have been kindly provided by Deutsche Welle and TDF. Radio Ibero has participated with its personnel and his transmission centre at Santa Fe (Mexico D.F.).

8 References

[1] ETSI. ES 201 980 V2.1.1, DRM ETSI Standard. European Telecommunications Standards Institute. April 2004.

[2] Recommendation ITU-R BS.1615, “Planning parameters for digital sound broadcasting below 30 MHz”. 2003.

[3] ITU-R. Recommendation BS.703.”Characteristics of AM sound broadcasting reference receivers for planning purposes”. 1990.

[4] Recommendation ITU-R P.372-8 (04/03) Radio noise.