DRM 20 kHz Simulcast Field Trials in the Medium Wave Band in Mexico D.F.

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Abstract—**This paper presents the results obtained from the first extensive field trials of Medium Wave DRM (Digital Radio Mondiale) simulcast, which were carried out in Mexico D.F.. The transmitted signal was composed of a 10 kHz bandwidth AM part at 1060 kHz and an adjacent 10 kHz bandwidth DRM part at 1070 kHz broadcasting the same audio contents and with a theoretically calculated back-off ratio of 16 dB at transmission.**

The results in this paper will be accompanied by a thorough description of the transmission network set up and also with the measurement system and measurement techniques. The data processing techniques are also included to give a meaningful interpretation of the final results. The conclusions of this work have focused on threshold values for AM and DRM correct reception, simulcast time variability, mutual analogue – digital SNR degradation and reception impairment analysis. The overall result of this work is a high reliability of the AM and DRM services in the difficult Medium Wave reception environments of Mexico D.F.

Index Terms— AM, DRM, Field Trials, Medium wave, Simulcast and Static Reception

I. Introduction

Digital Radio Mondiale (DRM) is the only non proprietary standard for digital radio broadcasting below 30 MHz [1]. It provides much higher audio quality than AM with the same bandwidth and less transmission power. After the initial definition, lab testing and standardization process [2] [3], numerous field trials were carried out in both, the Short Wave (SW) and the Medium Wave (MW) band.

Daytime Medium Wave DRM reception was intensively analyzed after the measurements of the extensive field trials carried out in Spain in 2004 [4]. The results obtained were very useful to clarify aspects such as the influence of transmission configuration parameters, the signal thresholds for correct reception and time variability [5]. The next step in the practical deployment of DRM technology has focused on the techniques to be applied to provide a smooth analogue to digital transition period for broadcasters. The least dramatic scenario is based upon a transitory period of AM and DRM coexistence services, preserving as much as possible the present analogue infrastructure, coverage and reception quality.

II. Objectives

The main objective of this paper is to assess the system reliability and to obtain the quasi error free, QEF, threshold levels of the DRM simulcast mode 1 [3] in the MW band. The results apply for daytime propagation when the MW signal is mainly propagated by means of the ground wave [6]. The system was tested in a very difficult radio reception environment such as the city of Mexico D.F.

Five studies have been carried out:

- Reliability analysis of both the AM and the DRM services of the ground wave propagated simulcast signal.
- Calculation of minimum usable SNR and field strength levels of the DRM part of the simulcast signal and comparison with ITU recommendations (mainly based on simulations and lab tests) [2].
- Analysis of the DRM signal's time variability in order to characterize its behavior near the threshold values.
- Evaluation and quantification, if any, of the mutual influence (QoS degradation) of the analogue and the digital parts when using the proposed simulcast configuration.
- Carry out a first approach study to mobile reception characterization and provide the mobile coverage radius achieved with the transmitted power.

III. Spectrum Occupancy Implications of Simulcast

There are 9 modes defined in the DRM standard [3] which define different bandwidths for the analog and the digital part of the simulcast signal.

The simulcast modes whose total bandwidth is that of a single AM channel, i.e. 9 or 10 kHz depending on the considered ITU region [7], have been traditionally called Single Channel Simulcast (SCS) modes. Those modes provide a DRM bandwidth which is limited to 4.5 or 5 kHz. This reduction has a direct reduction also in the available audio bitrate. On the other hand, Multi Channel Simulcast (MCS) modes [3] assign 9 or 10 kHz to the DRM digital part, at the cost that the total MCS bandwidth should be at least 18 kHz. This configuration and its regulatory implications should be analyzed by regulators. In Region 2, the channel bandwidth for AM broadcasting is usually 30 kHz [8] which allows the insertion of a MCS simulcast signal as the one shown in the block diagram of Figure 1.

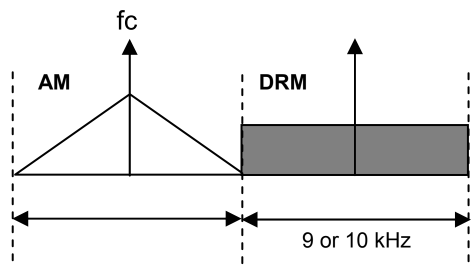

Fig. 1. DRM simulcast mode 1 signal block diagram

In any case, both options SCS and MCS, and others that types should grant the same AM coverage area for the existing services.

This is a challenge considering low selectivity AM receivers and requires anyway a certain protection ratio between both parts of the simulcast [9]. Theoretical calculus according to recommendation ITU-R 559-1 pointed out the need for a DRM back-off ratio of around 16 dB with respect to the AM carrier of the simulcast. This value was tested with laboratory setups and the results were not concluding at all[10]. The results presented in this paper come from the first extensive trial to provide planning values in the field for future simulcast networks.

IV. Measurement Campaign

A large MW DRM simulcast measurement daytime campaign was carried out in Mexico D.F. downtown. The electromagnetic noise sources density, wire and cable installation techniques over the streets along with building and urban elements density made this city a very difficult radio reception environment for a MW signal and a perfect candidate for testing a new system [6]. This section describes the transmission and reception system with an overview of the measurement campaign.

A. Transmission System

A DRM 20-kHz simulcast signal configured in mode 1 was broadcasted from the transmitter station that Radio Educación owns in Iztapalapa which is about 13 km away from the centre of the city of Mexico.

A summary of the transmission centre and simulcast signal features is shown in Table I.

The transmission equipment consisted of an AM-DRM DMOD 2 [11] exciter manufactured by Continental Electronics and Transradio. The exciter was connected to a Harris DX50 transmitter which provided a total output power up to 50 kW. Field trials were carried out using an AM experimental configuration since "Radio Educacion" regular AM emission features 100 kW power.

TABLE I
TRANSMITTER FEATURES

Transmission Centre	Iztapalapa (Mexico D.F.)
Broadcaster	Radio Educación
Coordinates	19º 21' 50.40" N 99º 01' 37.75" W
Frequency (AM-DRM)	1060 – 1070 kHz
Bandwidth (AM–DRM)	10 – 10 kHz
Transmitted Power (AM-DRM)	48.78 – 1.22 kW
Radiating System	134.1 m high tower braced antenna

The mentioned transmitter output was produced according to the DRM simulcast mode 1. In this simulcast configuration the DRM signal is located at the upper side of the AM signal, using a 10 kHz frequency offset from the AM carrier as shown in the captured spectrum of Figure 2. The DRM part of the simulcast was broadcasted using a power ratio of 16 dB with respect to the analogue level. Accordingly power levels delivered by the radiating system were of 16.9 dBkW for AM and 0.9 dBkW for DRM. This ratio was established to maintain a negligible perturbation of the analogue signal by the digital one according to [2].

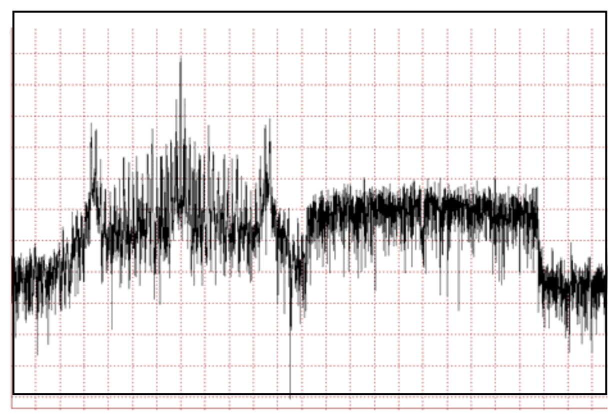

Fig. 2. DRM simulcast mode 1 signal spectrum with a whole bandwidth of 20 kHz.

As regards the digital part, the DRM standard [3] provides several configurable transmission parameters that allow many different signal broadcast modes with different robustness against noise, multipath or interference. The parameters used in this trial are summarized in Table II

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TABLE II
DRM SIGNAL FEATURES

Bandwidth	**MSC Modulation**	**SDC Modulation**	**Bitrate (kbps)**
10 kHz	*64 QAM*	*16 QAM*	*22.1*
Redundancy	**Interleaving**	**AM-DRM power ratio**	**Applications**
0,5	*Long*	*16 dB*	*MW daytime*

For the sake of briefness this parameter configuration will be referred as 10K_A_64_16_05_L in the rest of the paper.

"Radio Educacion" regular programming was used as base band source audio information for both AM and DRM in order to evaluate the subjective audio quality of both during the simulcast trials.

B. Reception System

The system was made up by four modules: signal acquisition and distribution, measurement, control and commercial reception module. A measurement vehicle was equipped with the three first modules as shown in Figure 3. This measurement setup is similar to others that have been explained in detail in [4] [12] [13].

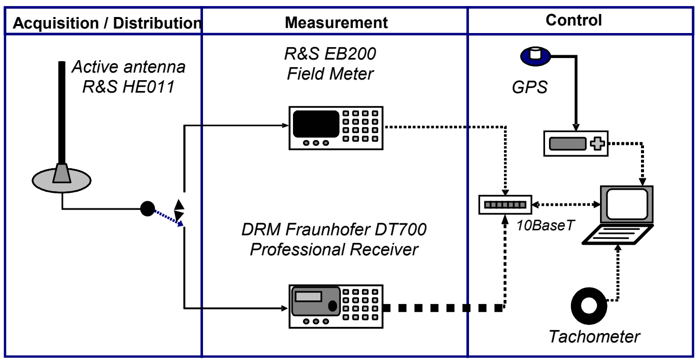


Fig. 3. Receiving system modules and used equipment set.

The system included a fully characterized short monopole active antenna R&S HE011 [14], a Fraunhofer DT700 professional DRM monitoring receiver [15] and a R&S EB200 field meter [16] The DRM and AM signal demodulation and measurement was provided by the DT700 receiver while radio electric noise was measured using the EB200.

The measurement system captured a set of simulcast signal parameters and auxiliary data which is summarized Table III. Measurements were captured every 400 ms, that is, every DRM frame, during a minimum of 3 minutes in each static location, and they were conveniently stored in plain text format files. In case of mobile reception, these basic parameters were stored over each complete route.

TABLE III
MEASURED PARAMETERS

Supplier	*Type*	*Parameter*	*Signal*
DT700 Receiver	RF	Field Strength	AM-DRM
		SNR	DRM
		Delay Spread	DRM
		Doppler Spread	DRM
	IF	IQ Signal	AM-DRM
	Base Band	Audio frames CRC	DRM
EB200 Field Meter	RF	Field strength	Noise

The fourth module (commercial reception not shown in Figure 3) was used to assess the audio quality of the simulcast analogue service. AM subjective audio quality depends highly on the demodulation features of the receiver [17], and the type and shape of intermediate frequency filters has a direct effect on the signal to noise ratio (SNR) of demodulated base band audio. Commercial receivers show quite a wide variety of responses, even among models from the same manufacturer. Thus, different receivers were used to assess the AM signal subjective audio quality. Four different commercial receivers were used at every location to evaluate subjectively the AM reception: a: Sony ICF SW10 and Grundig MiniWorld PE as mid range receivers, Sony CFDS400 as high end receiver, and Panasonic RQ-CR07V as representative of lower priced market segments. The subjective AM quality was evaluated for 3 minutes at each static location and along one of the mobile routes. In addition, after the trials, the IQ files captured in the field have allowed to assess the AM subjective audio quality at the laboratory.

In order to complete all measured and stored information, a detailed description of the reception environment and some photographs were taken at each location. The presence of power lines, buildings, heavy traffic and of other man made noise sources was annotated on the description files annexed to the measurements.

C. Planning

The measurements were distributed to cover several reception conditions which are representative of a crowded big city. Five reception environments were distinguished within the city of Mexico D.F.:

- Open Residential (OR): Open areas with few buildings like parks. Two different areas have been chosen very far from each other.
- Industrial (I): Light industry areas.
- Typical Mexican No Dense (TMND): Areas with wide streets and low buildings, up to 2-storey.
- Typical Mexican Dense (TMD): Areas with 3 to 6-storey buildings and narrower streets than the No Dense Mexican environment
- Urban (U): Areas with very high buildings, usually more than 7-storey buildings.

Most of the measurement campaign took place along nine routes (a route is composed by static and mobile measurements).Static reception was evaluated at 35 locations while mobile reception was tested along the stretches between the mentioned 35 locations. The coverage limit study required some additional measurement locations not included in the nine mentioned routes. Measurement routes and locations are depicted in Figure 4.

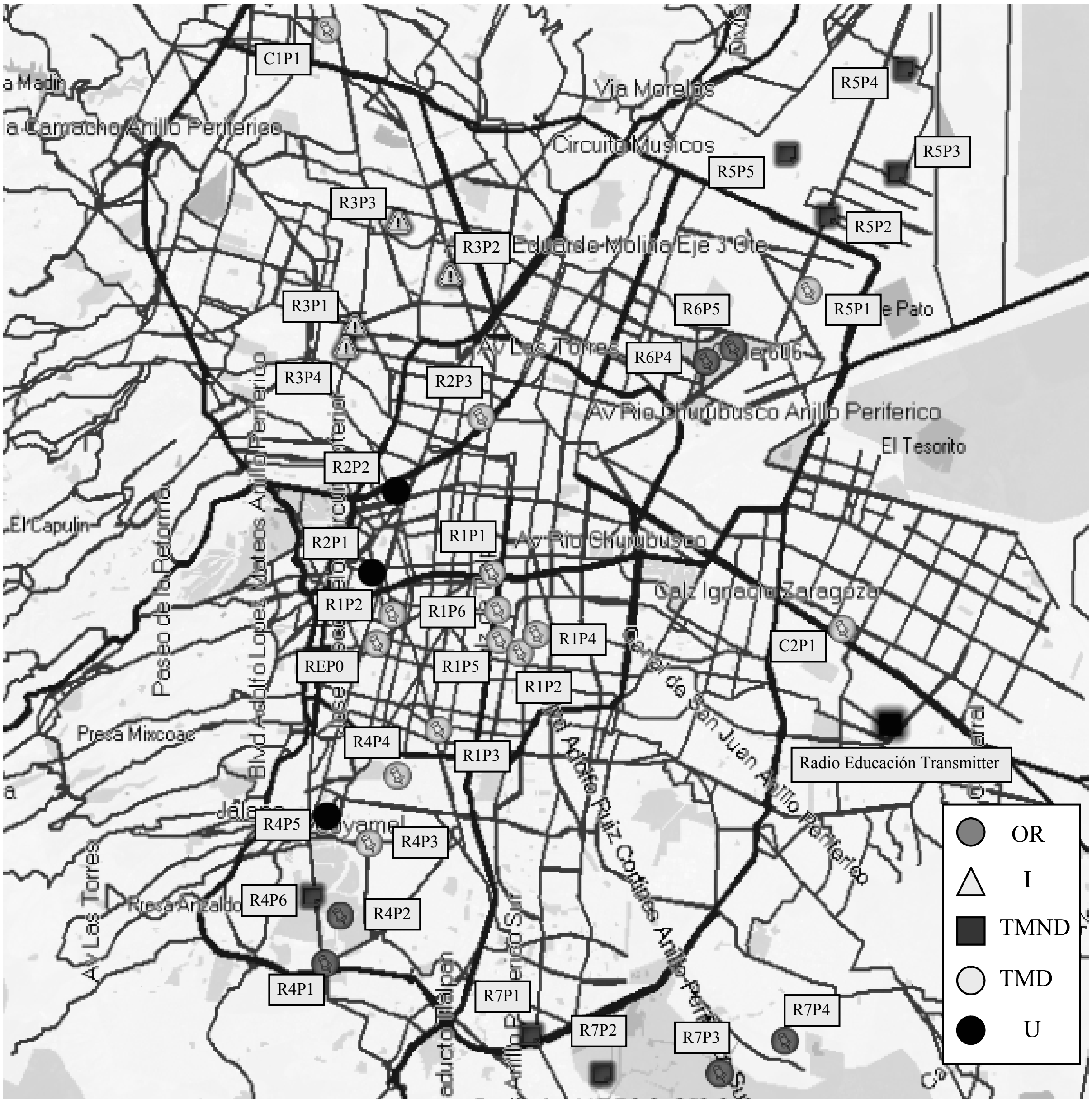


Fig. 4. Measurement campaign geographical layout in Mexico D.F.

Measurement locations are depicted using different shapes that identify different reception environments as shown in the legend. The nomenclature used for location names consists on a letter ‘R’ if the point belonged to a route, followed by the number of the route, or a letter ‘C’ if the point corresponded to a coverage specific measurement. After this, the location name includes a letter ‘P’ followed by a number that indicates the position of the location within its route or the measurement chronological order within the coverage measurements

Three locations of the routes were selected to perform tests that were specific to DRM signal so the analogue part of the simulcast was measured in 32 of the planned 35 locations.

I. RESULTS

The results have been organized following the structure proposed in the “Objectives” Section.

A. Simulcast AM Results: Reliability and Thresholds

Two parameters are analyzed in this subsection: the subjective evaluation of the AM service by means of commercial receivers and the received AM field strength.

The evaluation of the AM reception quality was done by a subjective evaluation process. The possible disturbances on AM part of simulcast mode 1 caused by the presence of the DRM part, were analyzed subjectively using the commercial receiver set described in previous sections. The results obtained using different AM commercial receivers were very similar for the whole receiver set.

The degradation of AM subjective audio quality was evaluated following ITU-R BS.1284 recommendation [18] criterion. The signal quality was graded in a 1 to 5 scale corresponding to Bad and Excellent quality grades respectively. Considering that grade 4 stands for “noticeable but not annoying”, only grades 5 and 4 were considered as **correct** reception. On the other hand, locations with grades 3, 2 or 1 (slightly annoying degradation and lower grades) were considered as spots out of the coverage area. The latter have been useful to determine the field strength threshold for a correct reception of the simulcast AM service within the service area of the experimental network.

Subjective audio quality evaluations were made by Radio Educación staff with the broadcast engineers who carried out the measurements. Both groups can be considered as expert listeners. As a consequence, the assessments were more pessimistic than the ones from an average listener. Table IV shows AM subjective audio quality general results.

TABLE IV
AM QUALITY RESULTS

Measured Mode	*AM part*
Total number of measured locations	32
Number of locations w/ audio quality grade ≥ 4	27
Locations with correct reception (%)	84.4

Almost 90% of the static locations had a correct (Grades 4 and 5) AM reception quality. It is also noticeable that not a single complaint on the reduction of the perceived AM quality were received by the Customer Service of “Radio Educacion”.

The median value of the field strength values measured at each location were been considered for analysis. Figure 4 presents the AM field strength values are depicted versus the distance to the transmitter. Locations are classified according to reception environment. Incorrect reception points, where the AM subjective quality was not acceptable are marked using a grey ellipse in the figure.

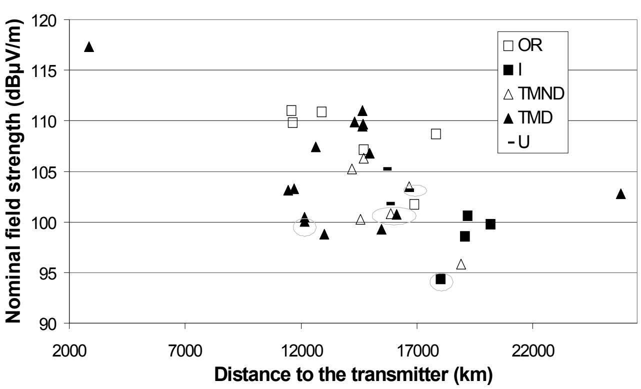


Fig. 5. AM field strength vs distance to the Tx. Static reception

The graph shows that, as expected [6], Open Residential had higher field strength values than locations of the rest of environments. It is also remarkable that a field strength variation of up to 15 was observed among locations with similar distances to the transmitter, but in different reception environments within the city.

The incorrect reception location, with the highest nominal field strength has been chosen as the field strength level threshold for correct reception. This value was 103 dBµV/m. This figure is much higher than ITU-R BS.703 [19] recommended value for MW daytime reception which is 60 dBµV/m.

It should be noted that the floor noise considered by the ITU-R is much lower than the actual noise of Mexico D.F. In fact, `previous MW experiments carried out in Madrid (Spain) in 2004 showed that, in the best case, noise levels were 10 dB higher than the ones considered by ITU-R. Mexico D.F. proved to have even higher levels of man made noise than Madrid [6].

B. *Simulcast DRM Results: Reliability and Thresholds*

The DRM simulcast digital service reliability in static reception was analyzed using the AudioQ parameter. This parameter is the rate of correctly received DRM audio frames with respect to the total amount of received frames. If this figure is at least a 98% the location is considered as a QEF reception point. Previous tests have shown that a 2% of incorrect audio frames are not perceived as audio dropouts by an average listener [20].

Table V shows the results for the DRM part. More than 90% of the considered static locations were covered by the simulcast DRM service.

TABLE V
DRM QUALITY RESULTS

Measured Mode	*10K_A_64_16_L_0.5*
Total number of measured locations	35
Number of locations w/ AudioQ ≥ 98%	32
Correctly received locations (%)	91.4

With respect to the simulcast DRM signal level, the measured field strength median value of each location versus the distance of the location to the transmitter is depicted in Figure 6. The depicted points are classified according to reception environment. Locations where AudioQ was lower than 98% are marked with a grey ellipse.

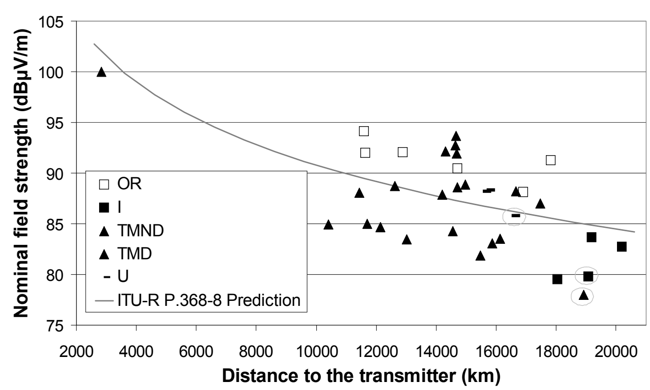


Fig. 6. DRM field strength vs distance to the Tx. Static reception

The graph shows higher values in Open Residential locations as observed in Figure 5. The field strength nominal value at two of the three incorrect reception locations is higher than the value of some QEF reception locations, so the lack of signal level was not the only cause of reception failure. Radio electric noise and the reception antenna obstruction by large vehicles passing by the measurement van were other important causes.

The calculation of the field strength and SNR threshold was carried out with data from the three locations with incorrect reception. The data captured every 400-ms at each location was used.

The methodology for calculating the field strength threshold is illustrated in Figure 7 with an example.

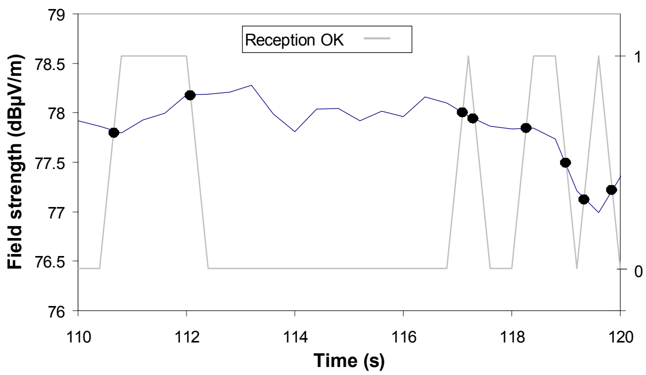


Fig. 7. DRM field strength vs time at location R5P4 (fragment)

In the graph field strength is depicted in black and the correct reception flags every 400 ms frame intervals are depicted in grey. Whenever the DRM reception provided audio frames with correct CRC the grey line is up, otherwise is down. This correct reception criterion does not allow any erroneous frame so the calculated threshold is even more restrictive than the one based on 98% of AudioQ [4].

The black dots show the field strength value measured at the transition from correct to incorrect or vice versa. The mean value of these transition field strength values has been considered the field strength threshold for each of the three locations. Finally the most restrictive value given by the three mean ones has been chosen as the field strength threshold. This value is **85.9 dBµV/m**, which is approximately 16 dB lower than the calculated simulcast AM threshold but it is much higher than the ITU recommended threshold [2] for the same DRM signal configuration which is 38.6 dBµV/m

The same procedure has been applied to calculate the minimum SNR and a threshold value of **16.6 dB** has been obtained. This value is a bit higher than the ITU recommended threshold which is 14.7 dB for the same DRM signal configuration. Both SNR threshold values are quite similar while the field strength ones are noteworthy different. This fact confirms the statement of the *Simulcast AM Results* subsection: man made noise of Mexico D.F. is much higher than the one considered in the calculi of the ITU recommendation.

C. Analysis of the potential DRM impairments due to the AM part

Locations with incorrect DRM reception were analyzed in order to investigate the AM signal influence on the reception quality of the digital part. When analyzing the presence of the adjacent AM part of the simulcast into the DRM quality there were three incorrect reception locations: R3P4, R4P5 and R5P4. The causes of failure are detailed for each location in the following paragraphs.

Figure8 represents field strength, SNR (upper part of the graph) and the correct data frames reception flag (lower part of the graph) measured at the location R3P4. Incorrect reception at this location was due to the low received field strength level, which was close to the system threshold. Also, this location had very high signal time variability and very high electric noise level, both factors were associated to the presence of trolley buses.

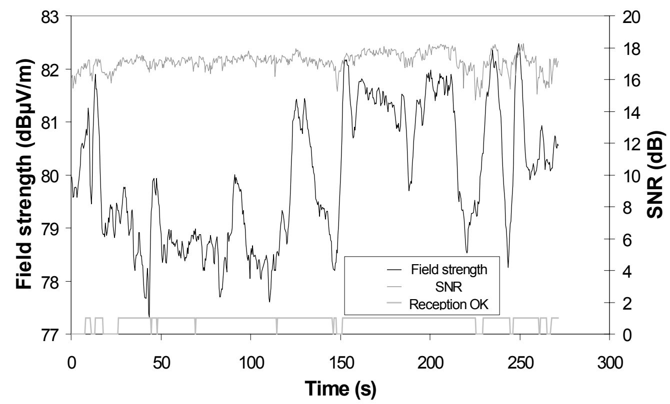
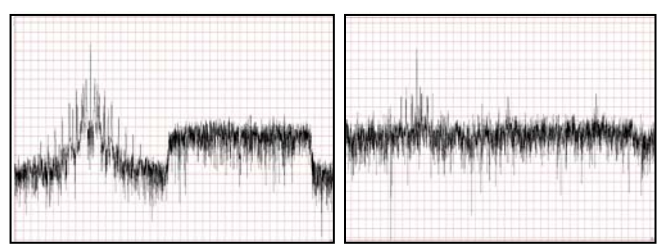


Fig. 8. R3P4 field strength, SNR and correct reception flag vs. time

R4P5 location presented extremely high field strength median value for an incorrect reception location. When analyzing the spectrum captured at this location, there was a high power radio electric noise source as shown in Figure 9. Whenever a trolley bus passed by close to the measurement van, the noise level increased dramatically.



(a) Without trolley buses (b) With trolley buses

Fig. 9. IQ frequency spectrum at location R4P5

The third location, R5P4 was affected by two factors. First, the field strength was quite low. In fact the SNR instantaneous values appear very close to the system threshold. The second factor, and in this case, the critical one, was the time variation caused by surrounding traffic, that made the quality parameters oscillate around the threshold and thus leading to an AudioQ of 38%, far below the acceptable limit.

D. Analysis of the potential AM impairments due to the DRM part

Following a similar analysis procedure, the possible impact from the DRM part on the AM quality was evaluated. The set of locations with no correct AM subjective (R1P1, R1P4, R5P3, R4P5 and R5P4) were processed and the failure cause at each case was identified.

The field strength measured at R1P1 and R5P3 R4P5 were close to the measured AM reception value. Additionally, identified man made noise sources (trains and power lines) caused SNR dropouts in the first two cases.

The locations called R4P5 and R1P4 did not provide AM correct reception due to the high power impulse radio electric noise source shown in Figure 12

Table VI summarizes the measured parameters of all the incorrectly received locations for both the AM and the DRM parts of the simulcast signal.

TABLE VI
FIELD STRENGTH, AM-DRM BACKOFF RATIO AND STANDARD DEVIATION OF SIMULCAST INCORRECT RECEPTION LOCATIONS

Point	***System Failure***	***Field strength (dBµV/m)***		***Measured Back-off ratio (dB)***	***σ (dB)***
		DRM	AM		
R1P1	AM	84.6	100.4	15.8	0.16
R1P4	AM	84.9	N/A	N/A	0.14
R5P3	AM	83.1	100.8	17.8	0.15
R5P4	Both	78.0	95.8	17.8	0.27
R3P4	DRM	79.8	98.6	18.8	1.26
R4P5	Both	85.8	103.1	17.4	0.94

The first column in Table VI is the location identifier, the second one shows the system which is failing at each location, next two columns show the received field strength and the last two ones the relative power back-off and the signal time variability. The AM-DRM back-off ratio is the difference between the median field strength value of the analogue part and the median field strength of the DRM part. Median values have been chosen instead of the values captured every 400 ms because field strength measurements of the AM and the DRM signals of the simulcast at each static location were consecutively but not simultaneously performed. Incorrect reception locations provided back-off ratios equal to or higher than the 16 dB theoretical back-off ratio configured at the transmitter.

As a conclusion, after analyzing the problematic locations it was concluded that presence of a DRM signal close to the analogue AM spectrum does not affect the analogue reception. This conclusion was based on a representative set of AM commercial receivers. The DRM part was not affected either.

The possible variation of the back-off ratio in the field and the possible impact on the system performance has been also considered. The summarized results are shown in Table VII.

TABLE VII
AM-DRM BACK-OFF RATIO

AM-DRM Back-Off Ratio	
Median Level (dB)	17.31
Standard Deviation (dB)	1.34
Maximum Value (dB)	18.79
Minimum Value (dB)	13.49

The measured back-off ratio values are close to 17 dB with a standard deviation which is less than 1.5 dB. This value is coherent with the theoretical transmission back-off ratio set up at the transmitter (16 dB). In addition a minimum value of 13.49 provided both good DRM and AM service reception. This result reinforced the lack of influence of the DRM part into the analogue reception quality: the presence of the DRM part does not degrade the AM part evaluated with commercial receivers when using DRM simulcast mode 1.

E. Simulcast DRM Time Variability

The received field strength time variability in the MW band is an important parameter in order to make realistic planning for a 99% of the time [5]. Ground wave propagated MW signals are very stable in rural areas so this factor might be dismissed in those environments. Nevertheless, in the case of a digital signal in urban environments, when the field strength level is close to the correct reception threshold value, a signal level drop can cause service dropouts as shown in the example of Figure 10.

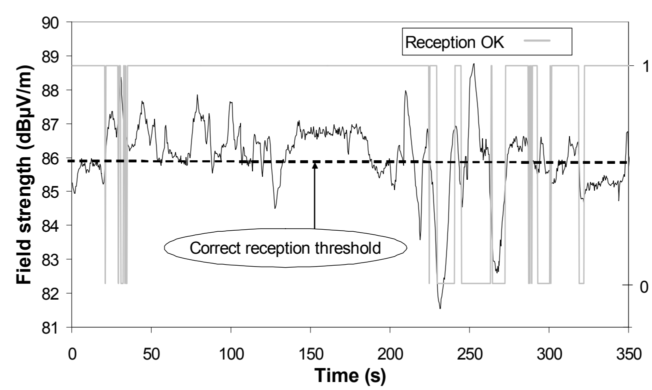


Fig. 10. R4P5 location field strength and correct reception flag vs time

A first evaluation of time variability can be carried out using standard deviation and the threshold exceeded 99% of time.

Ground wave propagated signals time variability in static reception depends on the presence of different mobile obstacles in the vicinity of the propagation path [5]. As expected, the higher density of urban elements the selected environment has, the more variable the received DRM signal is.

For planning purposes the difference between the field strength median value (E_{50}) and the value exceeded 99% of the time (E_{99}) is preferred. The mean values of the five reception environments considered are exposed in Table VIII.

TABLE VIII
MEAN VALUES OF THE DIFFERENCE BETWEEN MEDIAN AND 99% OF TIME THRESHOLD IN DIFFERENT ENVIRONMENTS

Environment	E_{50}-E_{99} *(Mean Values)*
Open Residential	0.29
No Dense Typical Mexican	0.62
Dense Typical Mexican	1.59
Industrial	2.06
Urban	2.15

Urban and Industrial environments showed the highest values due to the presence of heavy traffic (cars and trucks). However, Typical Mexican Dense environment also had heavy car traffic as well as public transport vehicles, such as trolley buses. The traffic was very sparse in Open Residential environments while it was moderate in the so called Typical Mexican No Dense. In order to analyze this time variation behavior following a scheme that could be applied to planning tools, the locations were divided into three traffic density categories: scarce, medium and heavy.

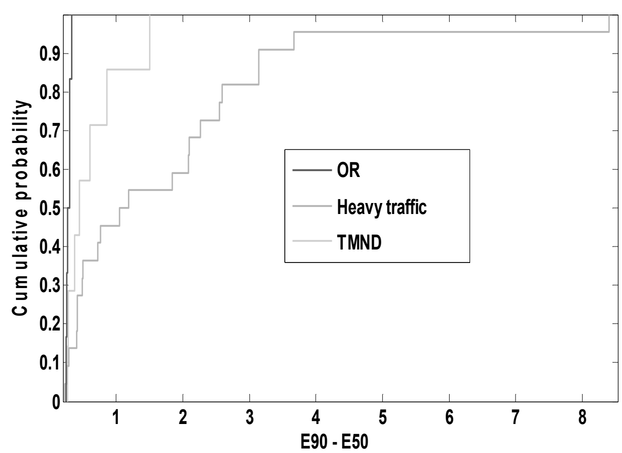


Fig. 11. Difference between median value and 99% CDF

The cumulative distribution function (CDF) of the difference values between the field strength median value and the field strength exceeded 99% of time is depicted in Figure 11. Three different curves are shown, each one representing the CDF associated to each of the three considered reception environment categories.

The graph shows that correction factors for 90% of the cases of the above mentioned three categories are 0.35, 1.52 and 3.16 dB for scarce, medium and heavy traffic environments respectively.

These results have been compared with the ones obtained from MW DRM daytime measurement campaign carried out in downtown and the surroundings of Madrid (Spain) in the year 2004 [4]. Spanish rural environment presented similar time variability to Open Residential environment of Mexico D.F. However, Suburban environment had lower time variability than Typical Mexican Non Dense environment and heavy traffic category in Mexico presents considerably higher signal time variability than urban environment in Madrid. Mexico D.F. is a much more difficult environment than Madrid for MW ground wave propagation. In terms of time variability, the signal behavior is affected by a higher number of urban elements like trolley buses and big vehicles in Mexico D.F.

F. Mobile Reception

This subsection discusses the QoS of the tested simulcast configuration for mobile reception. The mobile reception characterization required smaller time slots for calculating the percentage of correctly received audio frames than the static reception, where the time frame calculation was based on the whole 3 minute interval. In the case of mobile reception, the audio frames percentage time interval the length of a DRM transmission frame itself, that is, 400 ms. One DRM frame is composed of ten audio subframes in mode 10K_A_64_16_L_0.5 so the 98% of AudioQ is no longer an accurate correct reception threshold. Thus a DRM transmission frame has been considered as correct when containing ten CRC correct audio subframes, that is, when featuring perfect reception or 100% of AudioQ. Even for mobile reception, this is a restrictive condition in most of the cases. However, with lower percentages, there is a risk of overestimating the received quality.

A mobile radial route from the transmitter was selected for this analysis. The received field strength, SNR and audio dropouts are shown in Figure 12. Three different areas can be distinguished along this radial route. The first one, up to 17 km from the transmitter, is an urban area where some field strength deep drops, due to bridges, tunnels and severe traffic impairments, caused sporadic DRM reception failures The second one, from 18 to 23 km from the transmitter, is a suburban-rural area out of Mexico downtown with less reception impairments than the first one and better DRM reception. Finally, from 25 km on, the route joined the main Mexico highway where the signal dropped below the necessary threshold. The heavy traffic made even more difficult the correct system behavior.

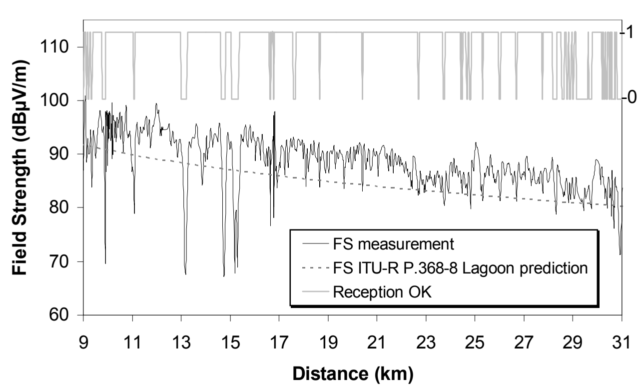


Fig. 12. Field strength and correct reception flag vs. distance

After these results, it can be stated that the simulcast DRM 1.22 kW MW broadcasted service provided in Mexico D.F. a coverage radius of around 25 km for mobile reception. Simulcast AM reception, which was assessed by means of the receivers of the commercial reception module, showed a very similar behavior to the quality observed for the DRM part. In both cases, urban obstacles and man made noise sources were the main reception impairments. Those impairments were not linked to the system (analogue or digital) and will be always present at any radio system working in the Medium Wave.

II. CONCLUSIONS

Simulcast DRM mode 1 using 20 kHz bandwidth at 1060 and 1070 kHz has been analyzed in depth in this paper. The system worked properly in a set of representative reception environments in a big, densely populated city (Mexico D.F.). Such type of urban dense environment showed to be very difficult for systems using the MW band.. Both, the AM analogue signal and the DRM digital signal of the simulcast configuration performed very well except for the presence of critical reception impairments: attenuation and noise. Both, the DRM and the AM parts of the simulcast were received correctly at 90% of the tested locations (35).

Bridges, tunnels and large vehicles passing by the receiver on the one hand, and power lines on the other hand were critical factors for simulcast reception. Trolley buses are large vehicles which also feature high impulsive electric noise levels. The DRM field strength threshold for correct reception was found to be 85.9 dBμV/m and 103 dBμV/m for AM.

Heavy traffic in general, implied high signal time variability, which was found as an additional critical factor for DRM reception in locations close to the fringe of the coverage area. DRM signal time variability was analyzed in different traffic density categories.

In order to cover the 90% of locations during 99% of time, a margin added to the median estimated value should be considered for planning purposes. The mean value of this parameter was 0.35 , 1.52 and 3.16 dB for scarce, medium and heavy traffic environments respectively. The latter two values are higher than the ones obtained previously from some DRM measurements carried out in the city of Madrid in 2004 [5].

After analyzing reception impairments, it has been concluded that the AM part of the simulcast does not interfere the digital part and in the opposite way, DRM does not interfere AM when both signals are transmitted with a certain back-off ratio. The transmitted simulcast backoff ratio between AM and DRM was 16 dB. This value showed to be enough to guarantee correct AM reception with different commercial receivers. This value also provided a good DRM reception in the coverage area, with no apparent degradation coming from the analogue part. In fact, lower backoff ratio values proved also to provide similar results. In any case, considering the protection of existing analogue audience a must for the analogue to transition period, the 16 dB value is recommended.

DRM mobile measurements were also analyzed and the obtained coverage area reached a distance of 23 km away from the transmitter (1.22 kW transmitted power).

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REFERENCES

[1] DRM official website. http://www.drm.org
[2] ITU-R, BS.1615 Recommendation, “Planning Parameters for Digital Sound Broadcasting at Frequencies below 30 MHz”. International Telecommunications Union. Radiocommunication Service. 2003.
[3] ETSI TS 201 980 V2.1.1., DRM ETSI. European Telecommunications Standard Institute. 2004.
[4] D. Guerra, G. Prieto et al., “Medium Wave DRM Field Test Results in Urban and Rural Environments”, IEEE Trans. Broadcast. , vol. 51. no. 4, pp. 431-438, Dec. 2005.
[5] D. Guerra, U. Gil et al., “Medium Wave DRM Field Strength Time Variation in Different Reception Environments”, IEEE Trans. Broadcast. , vol. 52. no. 4, pp. 483-490, Dec. 2006.
[6] N. DeMinco. “Ground Wave Analysis Model for MF Broadcast Systems”. NTIA Report 86-203. 1986.
[7] ITU-R Plan for MF Broadcasting in Regions 1 and 3 and LF Broadcasting in Region 1. Geneva, 1975 (GE75).
[8] Plan for MF Broadcasting in Region 2. Rio de Janeiro, 1981 (RJ81)
[9] Question ITU-R 217/10, ITU-R BS.1514 Recommendation, “Digital Sound Broadcasting in the Broadcasting Bands below 30 MHz. First Simulcast Field-Tests in MW”. France, March 2002.
[10] J. Gruson and J. B. Sauquet, “DRM Simulcast Transmission with DRM Shaping Report on a Field Test Experimentation”. DRM Consortium System Evaluation. Paris, 2004.
[11] TransRadio, “DMOD2 Product Brochure”. [Online] http://www.broadcast-transradio.com/DRM-Flyer.pdf
[12] J. M. Matías et al, “DRM (Digital Radio Mondiale) Local Coverage Tests Using the 26 MHz Broadcasting Band” IEEE Trans. Broadcast. , vol. 53 no. 1, pp. 59-68, March 2007.
[13] G. Prieto et al. “External Noise Measurements in the Medium Wave Band” IEEE Trans. Broadcast. , vol. 53 no. 2, pp. 553-559, June 2007.
[14] Rohde-Schwarz. Active Rod Antenna, HE011, “Manual”. 1998.
[15] Fraunhofer II DRM Monitoring Receiver DT700, “Data Sheet”. 2005.
[16] Rohde&Schwarz. MiniPort Receiver EB200, “Pocket Guide”. 2002.
[17] J. B. Sauquet, “Multiple Channel Simulcast”. DRM Consortium System Evaluation. Lisbon, Oct. 2003.
[18] ITU-R, BS.1284-1 Recommendation, “General Methods for the subjective assessment of sound quality”. International Telecommunications Union. Radiocommunication Service. 2003.
[19] ITU-R. BS 703 Recommendation, “Characteristics of AM Sound Broadcasting Reference Receivers for Planning Purposes”. International Telecommunications Union. Radiocommunication Service. 1990.
[20] I. Fernández et al., “Subjective Evaluation of the Reception Quality Thresholds for the Digital Radio Mondiale Broadcast Standard Abstract,” in Proceedings of the IEEE 56th Annual Broadcast Symposium, Washington D.C., September 27-29.