



## MEDIUM WAVE DRM FIELD TRIALS IN BRAZIL - DAYTIME RESULTS

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**Abstract:** The Digital Radio Mondiale (DRM) system broadcasts audio in the frequency band below 174 MHz [1]. In this experiment, designed to evaluate the DRM system performance in urban areas in Brazil, a hybrid signal composed of an analog AM signal and a digital DRM signal, with the same content, were broadcasted in diurnal and nocturnal transmissions. This paper describes the experimental setup and presents initial results of medium wave propagation measurements campaigns that are being carried out in Brazil. The experiment is part of a series of field trials that are being conducted by the Brazilian Government to evaluate the performance of DRM standard, which includes campaigns at MW, HF and VHF frequency bands in the cities of São Paulo, Rio de Janeiro and Belo Horizonte. The results of São Paulo campaign with Radio Cultura AM are presented in this article.

**Keywords:** DRM system, AM broadcast, digital radio, medium wave, OFDM

### 1. INTRODUCTION

The Brazilian Government is performing trials to support the process of choosing the Brazilian standard for digital radio broadcasting. The DRM (Digital Radio Mondiale) standard is adopted in Europe for digital audio broadcasting in AM bands (LW, MW and SW) and bands I/II FM [1]. The trials are composed by field tests carried out in AM band (Medium Waves) to obtain the performance evaluation and the coverage area. The measurements were performed with mobile unit of Inmetro in São Paulo in regions ranging from rural to dense urban. The results were obtained at pre-planned locations and the DRM transmitter module was installed at Radio Cultura AM station (1200 kHz).

### 2. OBJECTIVES

In this work the DRM system was tested in simulcast mode by transmitting audio using the existing analog AM signal and inserting the digital signal in the adjacent band, resulting in a simulcast transmission. The tests in São Paulo lasted four weeks broadcasting the usual programming of Radio Cultura AM. The DRM system employs OFDM modulation, with multiple carriers using four robustness modes according to propagation conditions (ground wave, sky wave, multipath impairments and Doppler spread). The

parameters of carrier spacing, symbol duration and guard interval are set according the robustness mode [1].

The objective of the field tests is the evaluation of digital audio quality through objective analysis, the obtention of digital coverage area, the field intensity threshold, the signal-to-noise ratio threshold and the analog coverage area of Radio Cultura AM for comparison purposes with digital coverage area. The transmission in two modulations (16QAM and 64QAM) allowed the evaluation of two robustness situations, where 16QAM is the more robustness mode. The more robust is the setting, the lower the bit rate available for audio and data transmission, which implies in lower audio quality.

### 2. METHODOLOGY

#### A. Transmission System

The transmissions in these trials were performed by a Medium Wave transmitter station at South-East of São Paulo, Brazil, in simulcast mode. The DRM signal was transmitted on the adjacent channel (1210 kHz) of the analog AM signal. The transmitter characteristics are shown in Table I.

TABLE I-Transmitter characteristics

Transmission center	Guarapiranga (São Paulo, BR)
Broadcaster	Padre Anchieta Foundation
Coordinates	23°40'37,16''S / 46°42'53,64''N
Frequency (AM-DRM)	1200 – 1210 kHz
Transmitted Power (Day/Night)	50/20 kW
Radiating System	70 m vertical monopole antenna

The DRM spectral bandwidth can be chosen among six values (from 4,5 kHz to 20 kHz). The choice of this spectral occupancy was due primarily to the bandwidth of Brazilian AM channelization, 10 kHz, so that the digital signal occupied the adjacent channel to analog AM channel. To overcome the problem of interference of the DRM signal in the host AM, the DRM signal was modified in amplitude by spectral shaping technique, decreasing the DRM signal strength in the vicinity of the AM signal to cause less interference to AM receivers. Although the DRM signal is degraded by about 2 dB due to the shaping, it allows reducing the protection ratio to 12 dB (the typical protection ratio for DRM in MW is 16 dB). The DRM signal strength

can be increased in 4 dB, providing an overall improvement in DRM signal reception of approximately 2 dB.

### B. Reception System

The DRM measurements were performed using a fully prepared vehicle configured to work in the field. The mobile laboratory of Inmetro unit can easily be adapted to include different kinds of reception equipments and antennas to perform all sorts of experiments at various frequencies and communications systems.

The main equipments used in the experiment are a professional DRM receiver and a spectrum analyzer. Data from the spectrum analyzer were recorded by dedicated software, together with location information and time provided by GPS. This time information is used to generate control files that store all the parameters recorded along the measurement path at a rate of 400 ms. Three commercial analog audio receivers were also used to receive the analog audio.

### C. DRM characteristics

The OFDM transmission modes in DRM system are subdivided in four categories (A to D), concerning robustness [1]. The modes differ in the carrier separation, symbol duration and guard interval. Mode A is the least robust and was employed during diurnal tests. The 64QAM modulation was used for real stereo audio, which has a higher bit rate. A more robust modulation (16QAM) transmits stereo parametric audio.

Table II shows the parameters adopted for daytime period. The acronym Band/Mod/CR/BR corresponds to bandwidth, modulation, code rate and bit rate respectively.

TABLE III-Daytime DRM characteristics

OFDM Mode	Band/Mod/CR/BR	Interleaving	Audio
A	10kHz/64QAM/0,6/26,6	Long	Stereo
A	10kHz/16QAM/0,62/18,4	Long	Param st

The DRM transmission super frame consists of three channels: the Main Service Channel (MSC), the Fast Access Channel (FAC), and the Service Description Channel (SDC). The MSC contains the audio and the data for the services holding most of the transmission capacity of the DRM signal. The FAC provides information on the channel width and other such parameters and also provides service selection information to allow for fast scanning. The SDC gives information on how to decode the MSC, how to find alternative sources of the same data, and gives the attributes of the services within the multiplex. It can include links to analog simulcast services.

### D. Measurements methodology

The coverage area of the AM service is determined by a fixed value of field strength, which determines the service contour. In this area, the signal reception occurs without noticeable interruptions or losses.

To achieve the coverage area of the digital system under test, the procedure adopted was to measure the signal strength along several routes, with the AM station site as reference.

Measurements were performed in two types of routes: 6 radial routes, to analyze signal behavior with distance to the transmitter and define the coverage area; and 5 local routes to evaluate the effect of different reception environments on DRM signal reception. Figure 1 shows the orientation of the routes and localization of measurement sites. The blue line represents the daytime protected contour where the field intensity is 2 mV/m (AM service area of Radio Cultura).

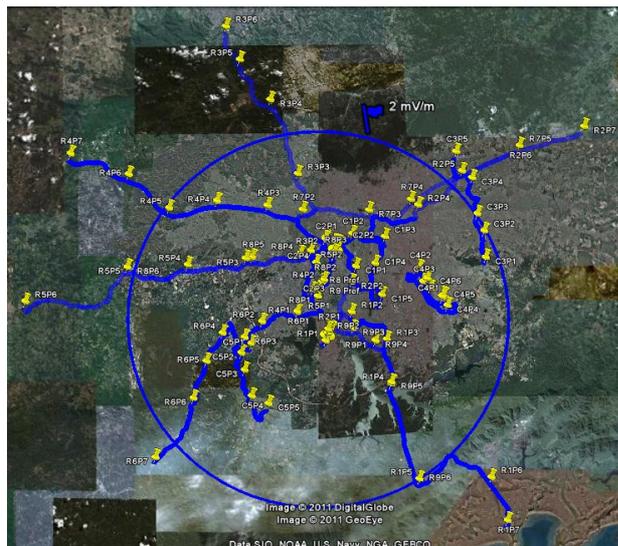


Figure 1: Measurement routes and sites for Radio Cultura trials

The measurement procedure begins with the registration at the reference point for verification and comparison with previous measurements at the same place. Each DRM frame has 400 ms and the measurement at each fixed point lasts 3 minutes. The measurements are: the simulcast signal and the digital audio recordings by the DRM receiver; the recording of analog audio by commercial receivers, the spectrum recording by spectrum analyzer, photos of the environment and the registration of occurrences (heavy traffic, dense vegetation, tunnel, power lines, bridges and any other obstacles). The measurements refer to DRM signal received in two modulations (16QAM and 64QAM), recording the electric field intensity, signal to noise ratio, audio quality, synchronism, integrity of the recovered audio frames, Doppler shift, delay, GPS, hour and date.

The SNR estimation is based on the Modulation Error Ratio (MER), which is a measure of signal quality, provided by the MSC data. It reflects any deterioration in the signal that arrives at the receiver decision circuit and not only the deterioration caused by noise. Thus, this quantity provides an indication of the ability of the receiver to correctly decode the signal.

## 3. RESULTS

The results presented here are related to measurements of electric field strength, signal-to-noise ratio and audio

quality of DRM signal in MW band and analog coverage area from the first campaign at São Paulo.

*Field strength measurements:* The analysis considered the median field strength measured at each fixed point. Results of the 49 field strength measurements along the six daytime measurements routes are shown in Figure 2. These figures also show the field strength predicted by the method in ITU-R Rec. P.368-9 [2], which is applied for this frequency band. The predictions consider a ground conductivity of 1 mS/m, obtained from Rec. ITU-R P. 832-2 [3].

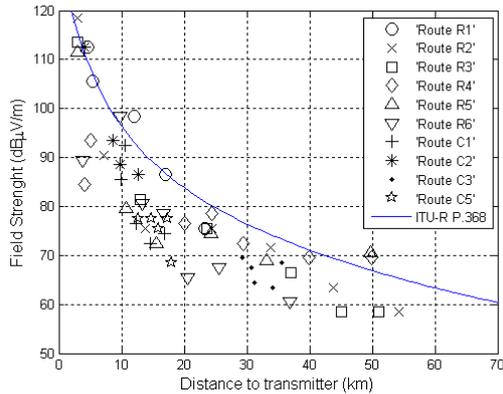


Figure 2: Received field strength (daytime)

The received field strengths are very similar for the two modulations (16 QAM and 64 QAM), as expected. The predictions of ITU-R Rec. P.368-9 overestimated the received field at daytime. The observed differences between measured and predicted values are due to the fact that the prediction model does not consider the irregularities of the terrain and urban settlement.

*Audio quality measurements:* The evaluation of the digital signal is made through the behavior of the parameter AQ (audio quality), which gives the percentage of audio frames correctly decoded. An AQ factor of 98% or better is required for good reception [6]. The estimation of digital signal coverage is obtained from the percentage of measured points where  $AQ \geq 98\%$ , which features good audio reception without distortion.

The measured audio quality achieved at each diurnal measurement point is indicated in Figure 3, for the 16 QAM signal. Good reception of the 16 QAM signal required field strengths above 60 dBµV/m and reached up to 24,5 km. The white line in Figure 3 indicates this distance from the transmitter. Inside this area, 89% of the measured points had  $AQ \geq 98\%$  and 3% had  $90\% \leq AQ < 98\%$ . For the 64 QAM case good reception required field strength above 63 dBµV/m and the coverage reached up to 23 km. Inside this area 79% of measured points had  $AQ \geq 98\%$ .

The transition of values of AQ between 98% and 90% is shown in 16QAM case. There are few cases and the boundary between good and bad reception is clearly seen. Bad reception within these areas occurred due to the presence of vegetation of parks, concrete structures, power lines and heavy traffic.

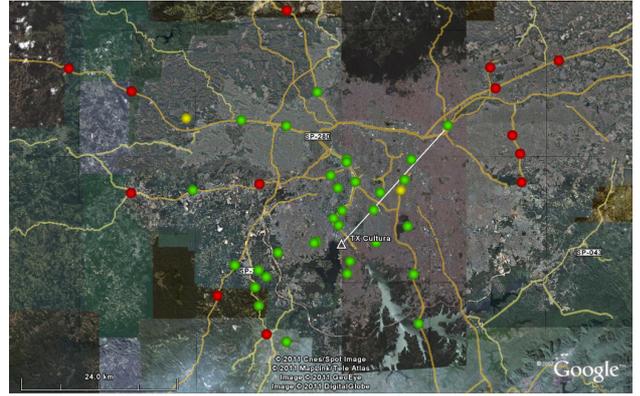


Figure 3: Classification of parameter AQ (16QAM daytime)

*SNR measurements:* The SNR thresholds were obtained from fixed point measurements in diurnal period. This analysis verifies the relation between the median values of field strength and signal to noise ratio of each fixed point of radial and circular routes, ranked by the value of AQ. Figure 4 and Figure 5 show graphically the behavior of values, which clearly reflects the separation of AQ values below and above 98%. For 16QAM mode transmission the interval of AQ between 98% and 90% (which does not occur in 64QAM mode) marked a transition range of signal to noise ratio where there were two cases ( $AQ = 94.4\%$  and  $90.7\%$ ). Overall values of  $AQ < 90\%$  were zero excepting two ( $AQ = 87.6\%$  and  $75\%$ ). In 16QAM mode the signal to noise ratio threshold is approximately 14.2 dB and in 64QAM mode the value that the signal to noise ratio threshold is 19.0 dB.

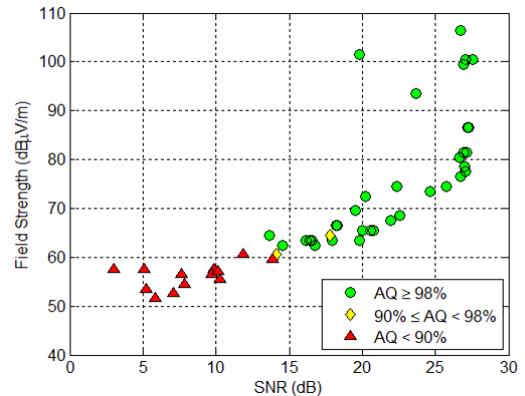


Figure 4: Field strength vs SNR (16 QAM)

The comparison with the reference values of Rec. ITU BS 1615 [4] that meet the BER ( $10^{-4}$ ) requirements are presented in Table III. In diurnal cases (A3) the measured values were higher than ITU values. The acronym Mod/Rob/Spec/CR refers to modulation, robustness mode, spectral occupancy and code rate.

TABLE IIIII - Comparison of SNR measured and ITU

Mod/Rob/Spec/CR	S/N req ITU (dB)	S/N meas (dB)
16QAM/A3/0.62	10,9	14,2
64QAM/A3/0.6	15,8	19,0

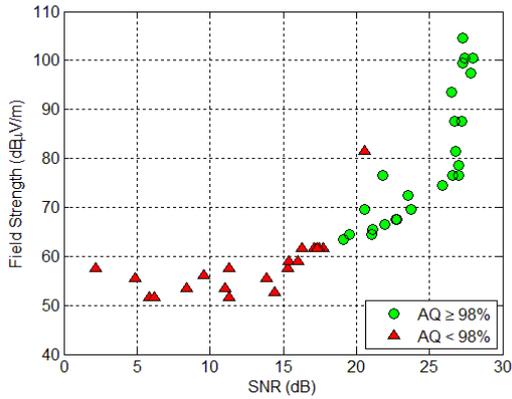


Figure 5: Field strength vs SNR (64 QAM)

*Subjective evaluation of analog system:* The audio quality of the AM received signal involves evaluation of listeners following the guidelines of Recommendation ITU-R. BS 1284 [4]. Grades rank from 5 (excellent quality) to 1 (bad quality). For the purpose of this work, the term “Good reception” refers to the grades from 5 to 3 inclusive, “Poor reception” refers to grades between 3 and 2 and “Bad reception” refers to grades equal to 2 or minor. Figure 6 shows the measured field strength with distance according to the subjective assessment of analog audio. Figure 7 shows this information on a map.

The results show that at short distances from the transmitter, around 10 km, there are points with poor reception, which by definition occur where the noise becomes a nuisance for the hearing. This situation persists until about 30 km existing, however, places where reception is considered good. This alternation of qualities of reception is probably due to variations in terrain profile between the measurement point and the transmitter, which ultimately reduce the quality of audio received when the noise becomes louder. As the measurements were done along radial routes, the AM signal with “Good reception” reached from 3 km to 12 km, and there was a radial where this situation occurred at 25 km and 33 km. Also it happened in a circular route located at 15 km. AM signal with “Poor reception” reached distances from 13 km to 30 km. Many shadow regions were found, featuring a discontinuous coverage, even though the field strengths satisfy the boundary value of daytime protected contour 2 mV / m or 66 dBμ / m, which occurs at 31.7 km according to the prediction model. Concerning field strength intensity, there are values above 64 dBμV/m up to the distance of 33 km. From the set of 58 points, 33% were categorized as “Good reception”, 26% as “Poor reception” and 41% as “Bad reception”.

*Comparison between analog and digital systems:* The digital coverage area in 16QAM and 64QAM modes are fairly similar to the analog coverage, as they reached 24,5 km and 23 km respectively, and the analog coverage ranged from 3 km to 12 km, and in isolated sites at 15km, 25km and 33km. However, the digital coverage presented good reception up to 24,5 km and 23 km, while analog coverage presented many shadow regions.

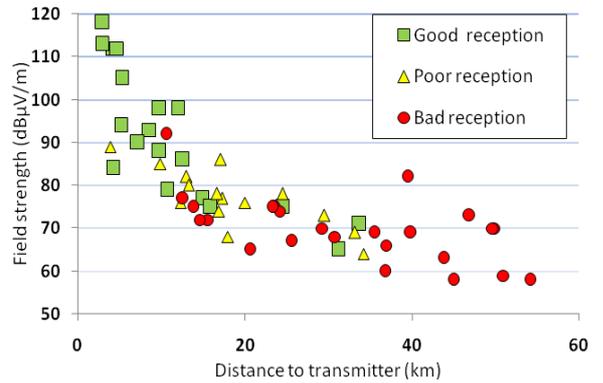


Figure 6: Diurnal AM field strength vs. distance

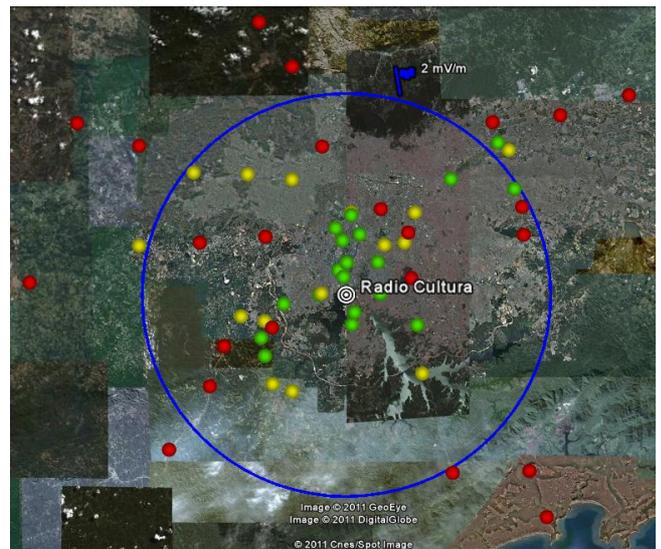


Figure 7: Subjective evaluation of AM audio of Radio Cultura

A comparison between AQ parameter of digital signal and the grades of subjective assessment of analog system of each measurement point employed an equalization of the classification terms. The criteria was “Good reception” to  $AQ \geq 98\%$  and “Bad reception” to  $AQ < 98\%$ . In analog case “Good reception” refers to grades between 5 and 3 inclusive and “Bad reception” refers to grades below 3.

Table IV presents the number of measured points and the comparison of audio quality in digital and analog measurements for 16QAM case, and Table V corresponds to 64QAM case. The tables also present the results for measured points inside the diurnal protected service contour of 2 mV/m (66dBμV/m). For both cases it can be seen that there were more points with better digital reception.

**TABLE IV-Comparison of 16QAM and analog system**

Modulation 16QAM	Total	Inside 2 mV/m (31,7 km)
Measurements in fixed points	49	42
Points where $AQ \geq 98\%$	34 (69%)	34 (81%)
Analog signal with "Good reception"	19 (39%)	18 (43%)
Coverage comparison		
Digital and analog "Good Reception"	17	17
Only digital "Good" reception"	16	16
Only analog "Good reception"	2	1
Digital and analog "Bad Reception"	13	7

**TABLE V - Comparison of 64QAM and analog system**

Modulation 64QAM	Total	Inside 2 mV/m (31,7 km)
Measurements in fixed points	44	37
Points where $AQ \geq 98\%$	24 (55%)	24 (65%)
Analog signal with "Good reception"	19 (43%)	18 (49%)
Coverage comparison		
Digital and analog "Good Reception"	13	13
Only digital "Good reception"	10	10
Only analog "Good reception"	6	5
Digital and analog "Bad Reception"	14	8

#### 4. DISCUSSIONS

Concerning the measured values of field strength the results indicate that, for this environment, Rec. ITU-R P.328-9 overestimates the measured field during daytime. São Paulo is a very densely urbanized with several skyscrapers and this may be the reason for the additional attenuation. Another reason can be the use of fixed parameters of conductivity and permittivity of ground as input to the model, according to information available on the soil conductivity map of the region of São Paulo. The soil conductivity varies along the terrain according to the soil type and its composition. The permittivity depends on the degree of humidity of the soil.

The daytime SNR measurements are higher than the ITU recommended thresholds, indicating that man made noise of São Paulo is much higher than the one considered in the calculus of ITU. Another reason may be the degradation due to the spectral shaping of about 2dB.

For a 50 kW maximum transmitter power, the range for digital good reception was around 24.5 km for 16 QAM modulation and 23 km for 64 QAM modulation. Better quality of audio was obtained for the digital case in comparison with the simulcast AM signal with the same content. Although the reception range was about the same in both cases, the analog signal coverage presented shadow regions that were not present in the digital transmission. The use of spectral shaping allowed good reception of both digital and analog systems in simulcast transmission.

#### 5. CONCLUSIONS

This paper presented the results of the first medium wave DRM measurement campaign in Brazil, which were

carried out in São Paulo. The objective was to evaluate the performance of the system to provide technical basis for the choice of radio digital Brazilian standard.

The measurements were performed for two modes of DRM signal configurations (16QAM and 64QAM). In daytime period it was employed the configuration of ground wave propagation. The mode 16QAM presented a more robust behavior in the presence of reception impairments such as noise and power lines.

Results of the parameter SNR, which is relevant for system planning, showed that ITU values are optimistic compared to the measured ones due to intrinsic characteristics of propagation of the urban environment of São Paulo. Such observations reinforce the necessity of characterization of different environments through measurement campaigns, which allow adequate system planning.

As expected for digital systems, the trials showed a better quality of audio for the DRM digital signal compared to the audio of AM signal in the same coverage area. The comparison between the results of analog and digital system in these trials presented more sites with good audio quality reception.

The experiments underway in Brazil also include trials in MW (daytime and nighttime periods), in VHF band II and 26 MHz band in two different regions. The analysis of the data collected in these trials, as well as the mobile test results, is still being performed and will soon be available.

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#### REFERENCES

- [1] ETSI ES 201 980: "Digital Radio Mondiale (DRM); System Specification", v3.1.1.2009
- [2] Recommendation ITU-R P.368-9, "Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz"
- [3] Recommendation ITU-R P.832-2, "World atlas of ground conductivities"
- [4] Recommendation ITU-R BS 1615, "Planning parameters" for digital sound broadcast at frequencies below 30 MHz
- [5] Recommendation ITU-R BS 1284-1, "General methods for the subjective assessment of sound quality", 2003
- [6] ITU-R Document 6E/403-E, Digital Radio Mondiale (DRM): MW Simulcast Tests in Mexico D.F., August 2006.