Radiocommunication Study Groups

Received: 8 April 2013

Reference: Recommendation ITU-R BS.1615 and Report ITU-R BS.2144

Subject: Question ITU-R 60/6

Document 6A/228-E
9 April 2013
English only

Russian Federation

MEASUREMENTS OF DRM COVERAGE AREA IN THE MEDIUM-FREQUENCY BAND IN THE DAY-TIME, NIGHT-TIME AND IN THE FADING ZONE

Introduction

Results of the DRM system implementation studies during several years were presented in Report ITU-R BS.2144 (2009) and Recommendation ITU-R BS.1615 (2011).

These documents played an important role in the practical implementation of DRM broadcasting. At the same time the progress achieved recently in this field also needs to be reflected. Therefore it is reasonable to update and supplement this material based on new studies. The proposed contribution could be used for this purpose, bearing in mind that a new chapter of the Report on the DRM operation in the multibeam environment or in SFN could be compiled on its basis.

Measured data, presented in this contribution, provide estimated minimum field strength, signal-to-noise ratio (SNR), percentage of decoded audio frames and other parameters which provide required DRM reception quality in the medium-frequency (MF) band over moderately rugged terrain including urban and rural areas in night-time and day-time, as well as in the fading zone.

1 Test objectives

– Study of the DRM signal reception in the MF band in the urban and rural areas.

– Determination of the reliable reception area for DRM signal.

– Study on the possibility of DRM signal reception over the ground-wave and sky-wave paths and in the fading zone.

– Measurements of DRM signal parameters in the reception areas (field strength, signal-to-noise ratio, percentage of decoded audio frames).

The main test objective was determination of the more accurate DRM signal parameters for planning of DRM networks in the medium-frequency band in similar geophysical environments.

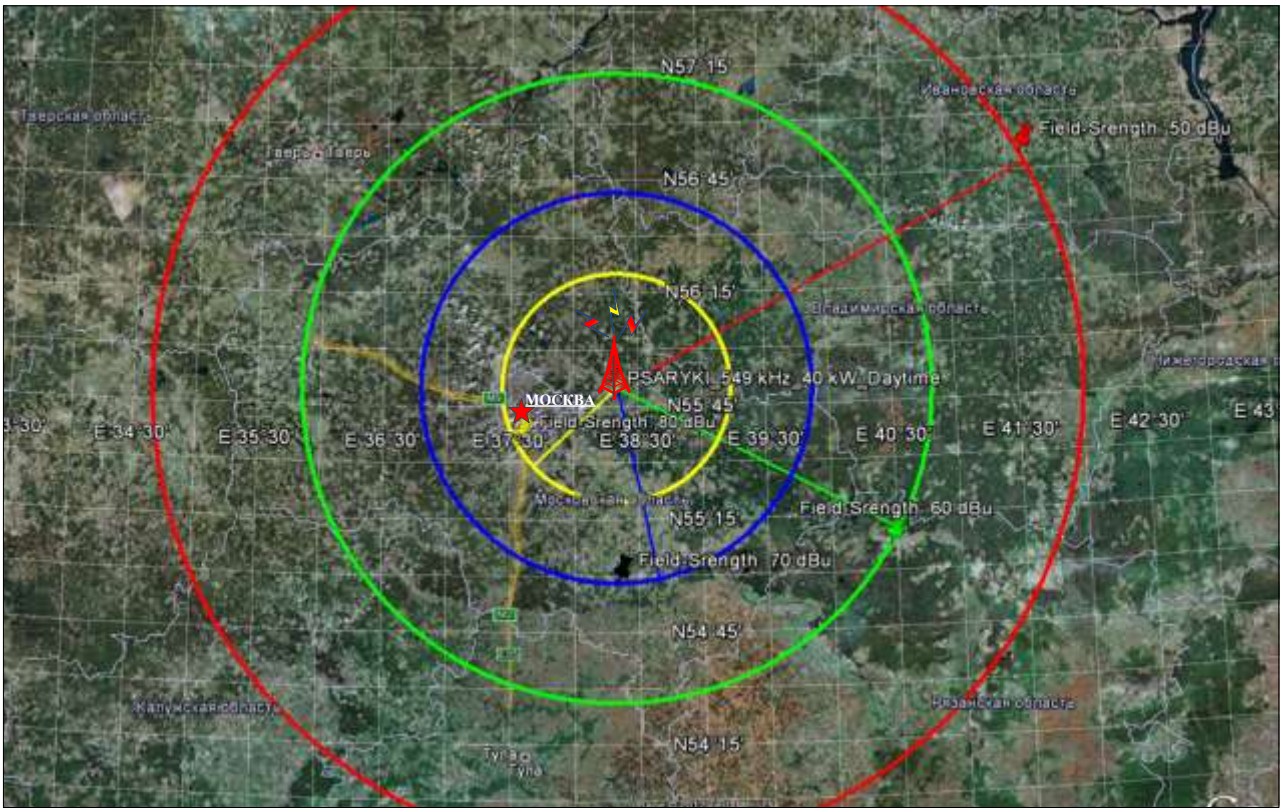
2 Test conditions

The medium wave DRM transmitter was installed at the radio broadcasting centre approximately 40 km from the centre of Moscow. Locations of the transmitter and the fixed measuring site, as well as paths for mobile measurements are shown in Figure 2. Configuration and technical characteristics of the transmitting equipment are shown in Table 1. Configuration of the receiving equipment is shown in Table 2.

Expected field strength for different distances from the transmitter (Fig. 1) in the day-time, required for the preliminary determination of the service area, was calculated using software «LFMFPLOT», (software product of MICRODATA company). The Earth conductivity was assumed to be 3 mS/m and dielectric permittivity of 10.

FIGURE1

Calculated contours of the ground-wave field strength



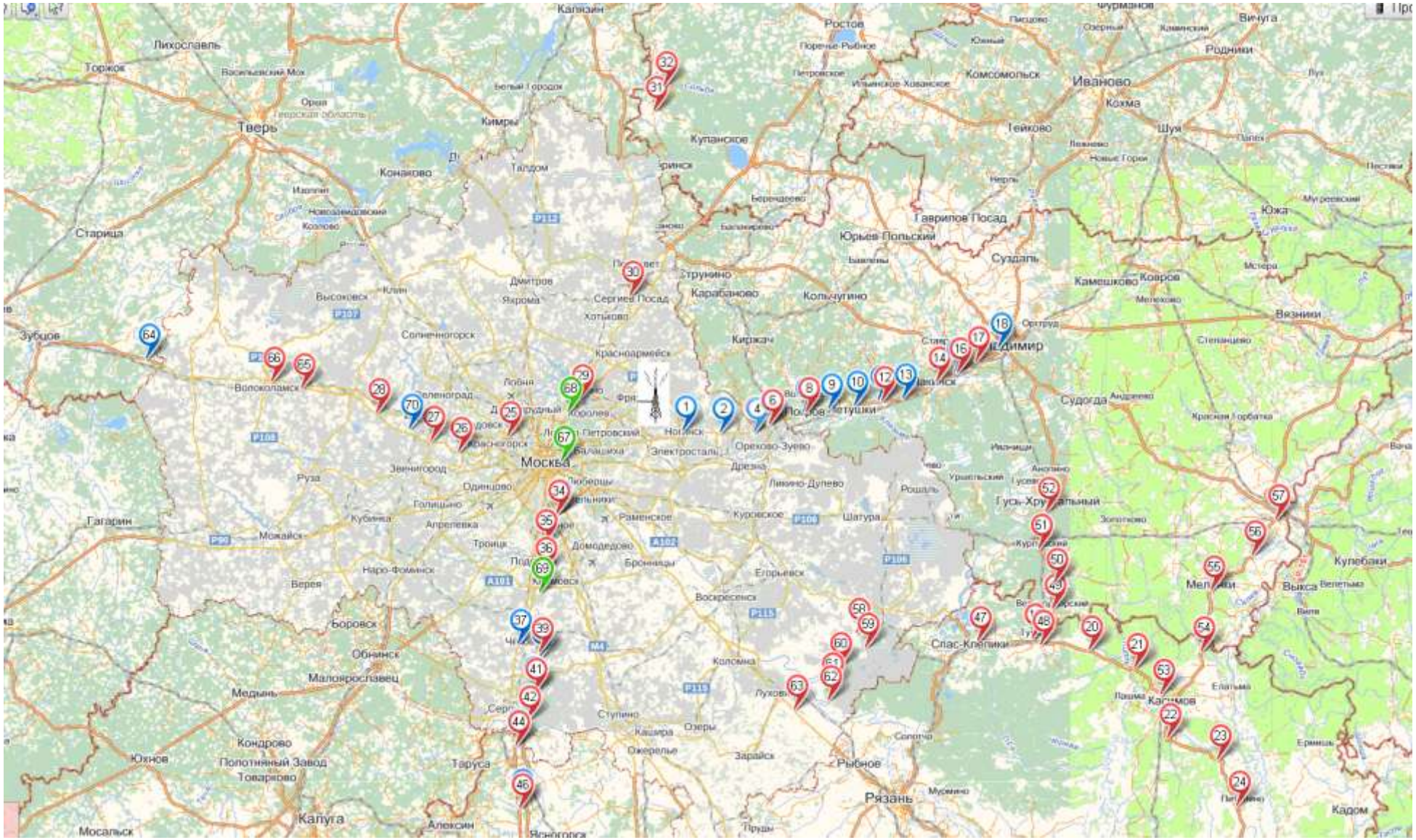
Calculated data: **240 km (50 dBu); 150 km (60 dBu)**
100 km (70 dBu); 60 km (80 dBu)

Figure 1 shows that the predicted ground-wave field strength in day-time is 80 dBuV/m at distance of 60 km (urban reception is possible); 70 dBuV/m at 100 km (guaranteed reception in rural area); 60 dBuV/m at 150 km (reliable reception not at all locations and unguaranteed 98% decoding throughout a year); 50 dBuV/m at 240 km (reception at separate “quiet” locations and without guaranteed 98% decoding throughout the year). In the North-West direction at the edge of the service area, co-channel interference from the transmitter (549 kHz, located at 625 km) is possible.

According to the calculations, radial directions for measurements were chosen to be East, West, North, South and South-East from the transmitter, as well as South-East direction to assess field strength place-to-place variations at the distances 110 km, 150 km and 220 km from the transmitter. As a fixed reception site the following sites were equipped: Moscow City site (megalopolis area), Mytishchi site (suburban town of Moscow – urban area) and radio receiving centre at 30 km from the Moscow City border (rural area).

Locations of receive measurement positions are shown on the map in Figure 2. Data were measured in the daytime (red marks) and in the night-time (blue marks) in the radial directions from the transmitter (East, West, North, South and South-East) and in the South-East direction at 110 km, 150 km and 220 km from the transmitter, as well as in the fixed receive positions (green marks). Some marks of night-time and daytime measurements at the same position are overlapped.

FIGURE 2 – **The map of receive measurement positions**



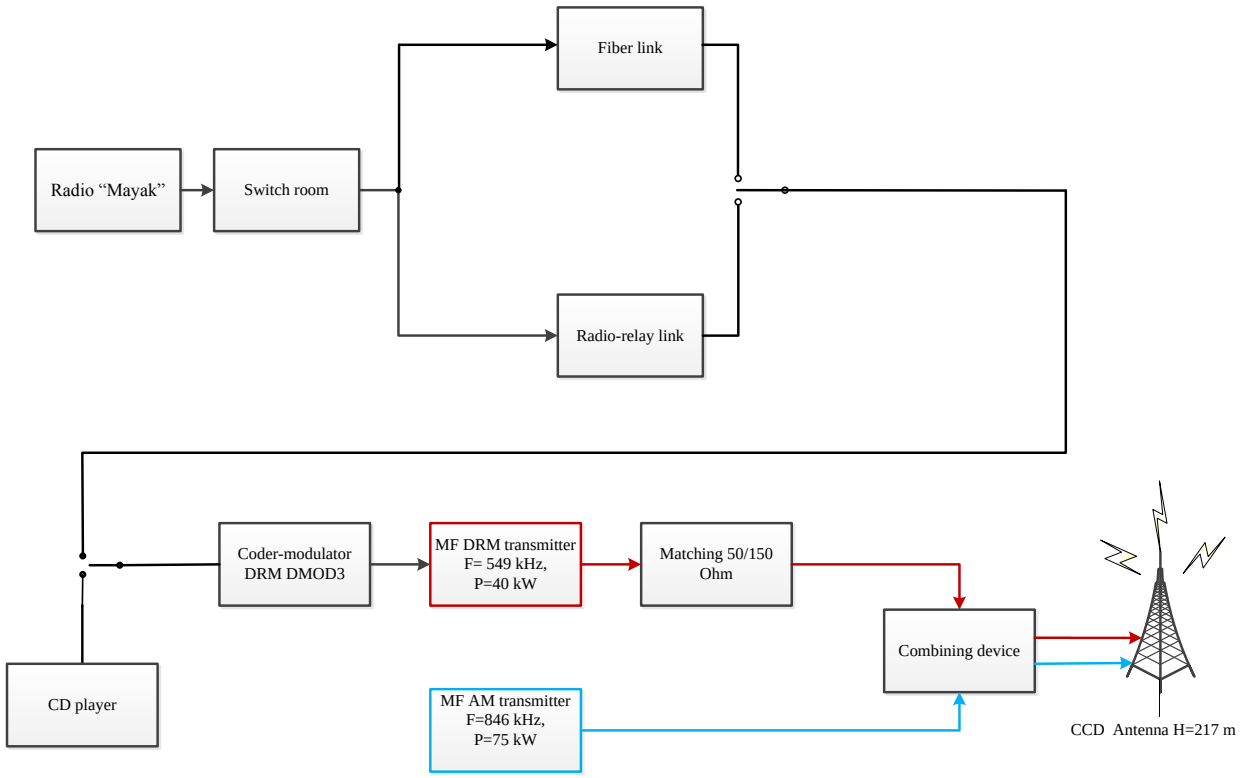
3 Configuration and technical characteristics of the transmitting equipment

TABLE 1

Transmitter	MF, DRM, P = 40kW (Figure 3)
Coordinates of Radio broadcasting centre	55.50.10N; 38.20.35E
Sound signal source	"Mayak" radio programme, CD player
Frequency	549 kHz
Bandwidth	9 kHz
Antenna system	Antenna mast with controlled current distribution (CCD), Antenna height=217 m (Figure 4)
Auxillary equipment	
CD player	Set of test CDs (tone signals, selection of musical samples with different frequency spectrum and dynamic range)
Sound processor	ORBAN 2200 FM (stereo)

FIGURE 3

Block diagram of the transmitting equipment



1 Configuration of the receiving equipment

TABLE 2

Fixed measuring equipment	Mobile measuring equipment
Fraunhofer DRM Monitoring Receiver DT700	Fraunhofer DRM Monitoring Receiver DT700
Notebook + appropriate software (Dream, Neutrik Audio Test & Service System A1)	Notebook + appropriate software (Dream, Neutrik Audio Test & Service System A1)
SMV-6.5 Set of calibrated antennas Antenna installation height 1.5 m from the ground level	SMV-6.5 Set of calibrated antennas Antenna installation height 1.5 m from the ground level
Consumer receivers: Himalaya, Richardson	Consumer receivers: Himalaya, Richardson, Roberts

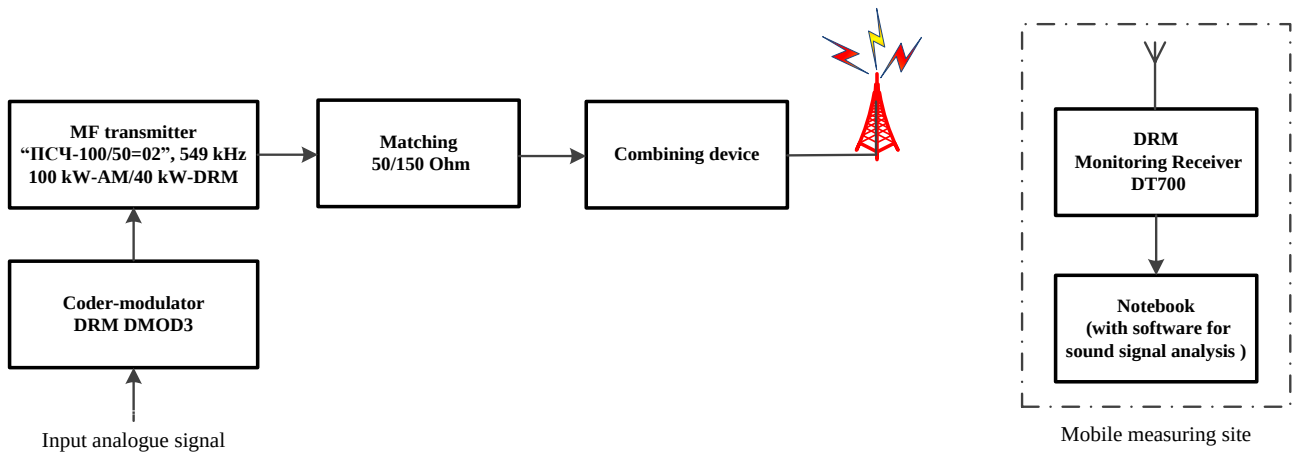
5 Methodology of field strength measurement

During the measurement, the transmitter was switched to the corresponding transmission mode (DRM or AM) without modulation by sound signal and with nominal radiated power.

Signal field strength at the reception position was measured using Fraunhofer Monitoring Receiver DT700 and the calibrated measurement antenna of magnetic type according to the block diagram shown in Figure 4.

FIGURE 4

Block diagram for measurement of field strength and parameters of the transmitted signal (Mobile measuring site)



Description of measurements:

a) the measuring antenna was located at the distance of two to three metres from the automobile and other reflecting metal objects. Measurements were not allowed close to electric power lines;

b) connecting cable between the measuring antenna and the Fraunhofer Receiver DT700 had characteristic impedance of 50 Ohm;

c) Fraunhofer Receiver DT700 performed relevant measurements at every measurement position;

d) field strength levels were read from the display of the Fraunhofer Receiver DT700.

Field strength was calculated using the following formula:

$$E\ [dBuV/m] = U\ [dBuV] + K\ [dB/m]$$

where:

U[dBuV] is the voltage level measured by the Fraunhofer Receiver DT700;

K = XX [dB/m] is the conversion (transformation) coefficient for the measurement antenna, which is derived from the calibration curves for the specified operating frequency.

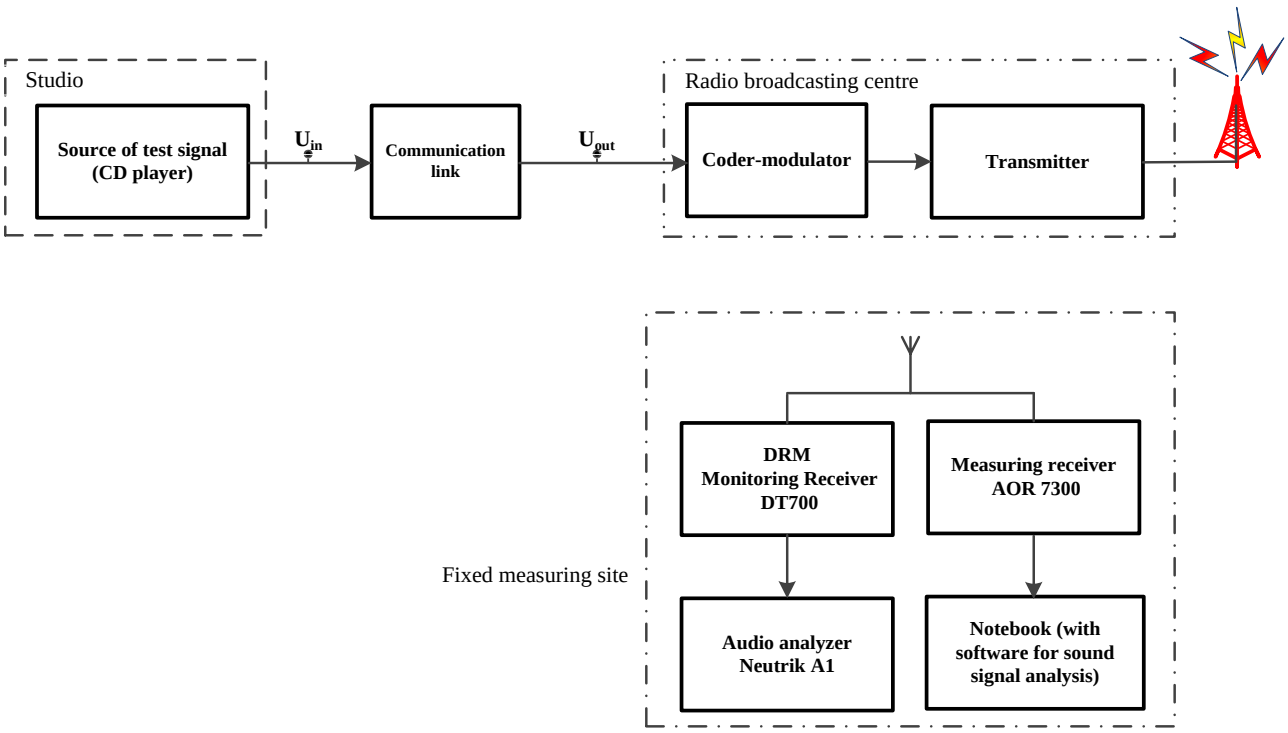
Signal-to-noise ratio (SNR) for the received DRM signal was measured simultaneously with the field strength measurement.

Simultaneously with these measurements, an additional auditory monitoring was performed to reveal short-time loss of the received sound signal.

Signal parameters in fixed reception positions were measured according to the block diagram shown in Figure 5.

FIGURE 5

Block diagram for measurement of field strength and signal parameters (Fixed measuring site)



6 Measurement of coverage areas for DRM and AM broadcasting

6.1 Measurements in the day-time

Measurement results for the field strength and SNR in the day-time are shown in Figure 8. Legend in the figure: E – East, N – North, S – South, W – West, SE – South-East. Threshold values for a surface wave are also shown for 100% decoding in the 64QAM(3), 64QAM(0) and 16QAM(0) modes.

Figures 6 and 7 show threshold values as “Better than VHF-FM”, “Close to VHF-FM” and “Close to AM”. These threshold values were chosen based on the conditions that:

– data rate with 64QAM (3) is 34 680 kbit/s, so the playback bandwidth is 16 700 Hz, that is “Better than VHF-FM”;

– data rate with 64QAM (0) is 22 060 kbit/s, so the playback bandwidth is 12 700 Hz, that is “Close to VHF-FM”;

– data rate with 61QAM (0) is 10 980 kbit/s, so the playback bandwidth is 2 800 Hz, that is “Close to AM”.

Based on the measurement results for the field strength, it is possible to select the most appropriate values of effective specific conductivity and dielectric permittivity of the Earth surface for the current season, that is 1.5 mS/m and 20, accordingly (red curve in Fig. 8). For the 64QAM(3) mode, 100% decoding of the audio signal was possible at the distances 120 to 180 km from the transmitter (depending on the direction). In the North and West directions this distance corresponded to the minimum, i.e. 120 km, which can be explained by the following reasons:

– co-channel interference from the transmitter located in the area of St. Petersburg;

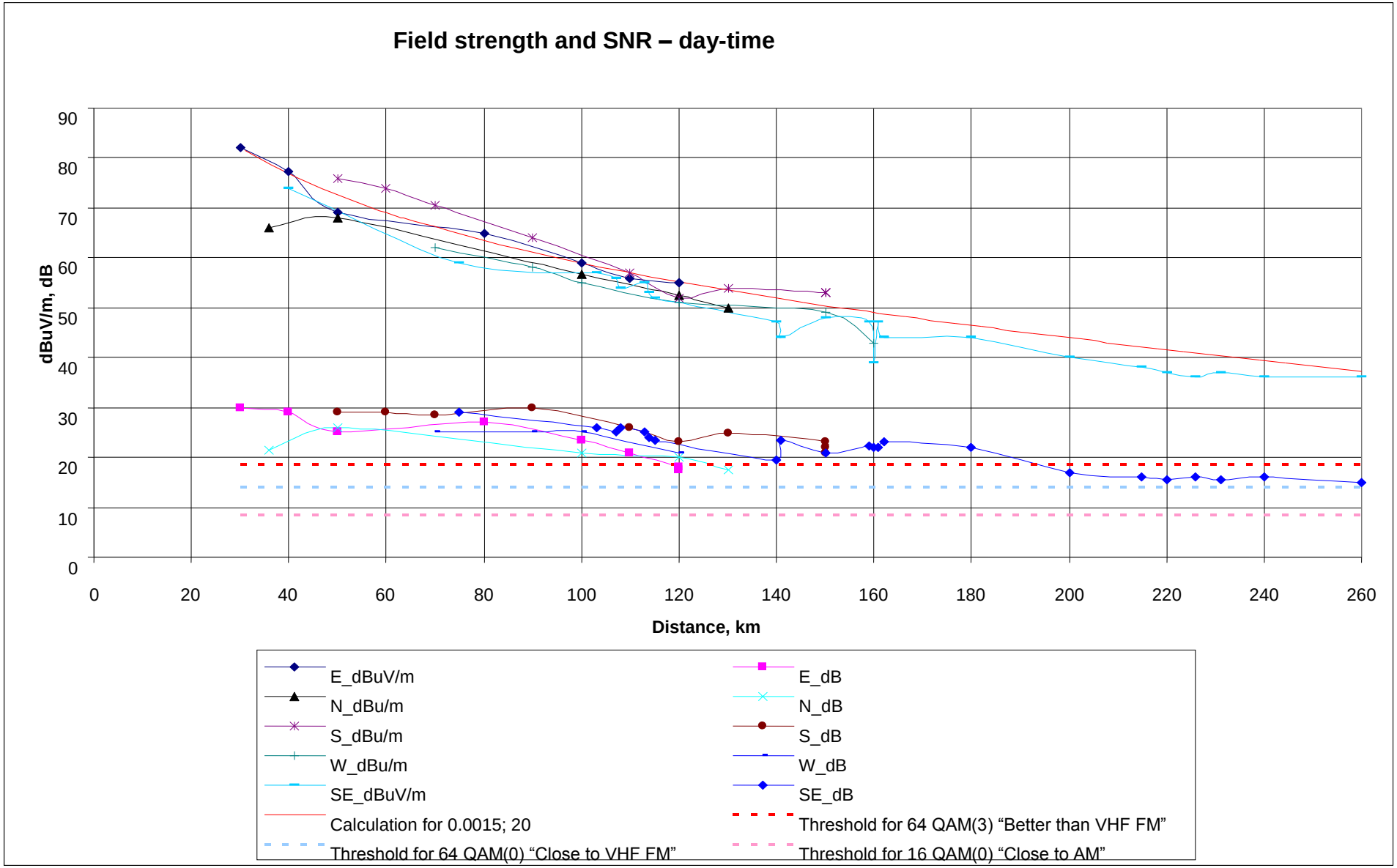
– field strength attenuation along the path over Moscow (West) or over the Klinsko-Dmitrovskaya Gryada (North).

100% decoding in this mode was observed in the South direction at the distance of up to 150 km and in the South-East direction at the distance of up to 180 km.

Measurements in positions 47, 48, 49, 50, 51, 52 (see Fig. 2) located at the distance from 140 to 160 km from the transmitter at the length of 84 km in the South-East direction demonstrated reliable decoding in the 64QAM(3) mode with variation of field strength up to 8dB from place to place.

In the 64QAM(0) mode, 100% decoding of the audio signal in the South-East direction was observed at the distance of up to 260 km from the transmitter, positions 22, 23, 24 (see Fig. 2). Measurements in positions 53, 54, 55, 56, 57 (see Fig. 2) located at the distance of 220 km in the South-East direction demonstrated reliable decoding in the 64QAM(0) mode with insignificant variations of the field strength from place to place.

FIGURE 6 – **Field strength and SNR in the day-time**



In the AM mode, radius of the service area was 75 to 90 km (SNR = 26 dB with 30% modulation). At the distance of 160 km from the transmitter, SNR = 13.4 dB in the AM mode.

Thus, the service area in the DRM 64QAM(3) mode (quality “better than VHF FM stereo”) is 4 times larger than in the AM mode, with DRM transmitter power twice as little.

The service area in the DRM 64QAM(0) mode (quality “close to VHF FM”) is 9 times larger than in the AM mode, with DRM transmitter power twice as little.

6.2 Measurements in the night-time and in the fading zone

Measurement results for the field strength and the SNR in the night-time are shown in Figure 9. Legend in the figure: E – East, S – South, W – West. Threshold values are also shown for 100% decoding for the combination of the ground wave and the ionospheric wave in the 64QAM(3), 64QAM(0) and 16QAM(0) modes, as well as calculated curves for field strength of the surface wave (red colour) and the ionospheric wave (green colour). Field strength of the ionospheric wave is calculated according to [3].

In the 64QAM(3) mode, 100% decoding of the audio signal was possible at the distance of 70 to 80 km from the transmitter (depending on the direction) with the surface wave prevaled.

Reliable reception of the skywave was observed at distances greater than 200 km in the 64QAM(0) mode.

In the AM mode at the distance of 150 km from the transmitter, SNR was 8 to 12 dB with aurally noticeable fading.

The fading zone existed at distances from 80 to 120 km for the given transmitter with the given antenna at the frequency of 549 kHz, and reception in this zone was studied in more detail.

One of the study objectives was the practical assessment of the preference between two interference immunity modes, "A" or “B”, for use in the fading zone in the night-time. The relevance of this objective can be shown by means of the following arguments.

It is known that the DRM standard [1] recommended use of interference immunity mode “B” with the duration of the guard time of 5.33 ms (“A” mode uses 2.66 ms) in the MF band in the night-time. The propagation channel model for this case (channel No.2, combination of the ground wave and ionospheric wave) comprises two beams with the propagation delay of only 1 ms.

SNR required for decoding in the propagation channel model No.2 in the “B” mode is somewhat higher than in the “A” mode.

Digital bitrates available in the “A” mode are significantly higher than in the “B” mode. With 10 kHz bandwidth and 64QAM modulation, this allows quality of sound “close to VHF FM” (22.1 kbit/s) or “like VHF FM” (26.5 kbit/s) with code rates of 0.5 and 0.6. For these cases required SNRs at the receiving position are 14.9 dB and 16.3 dB accordingly.

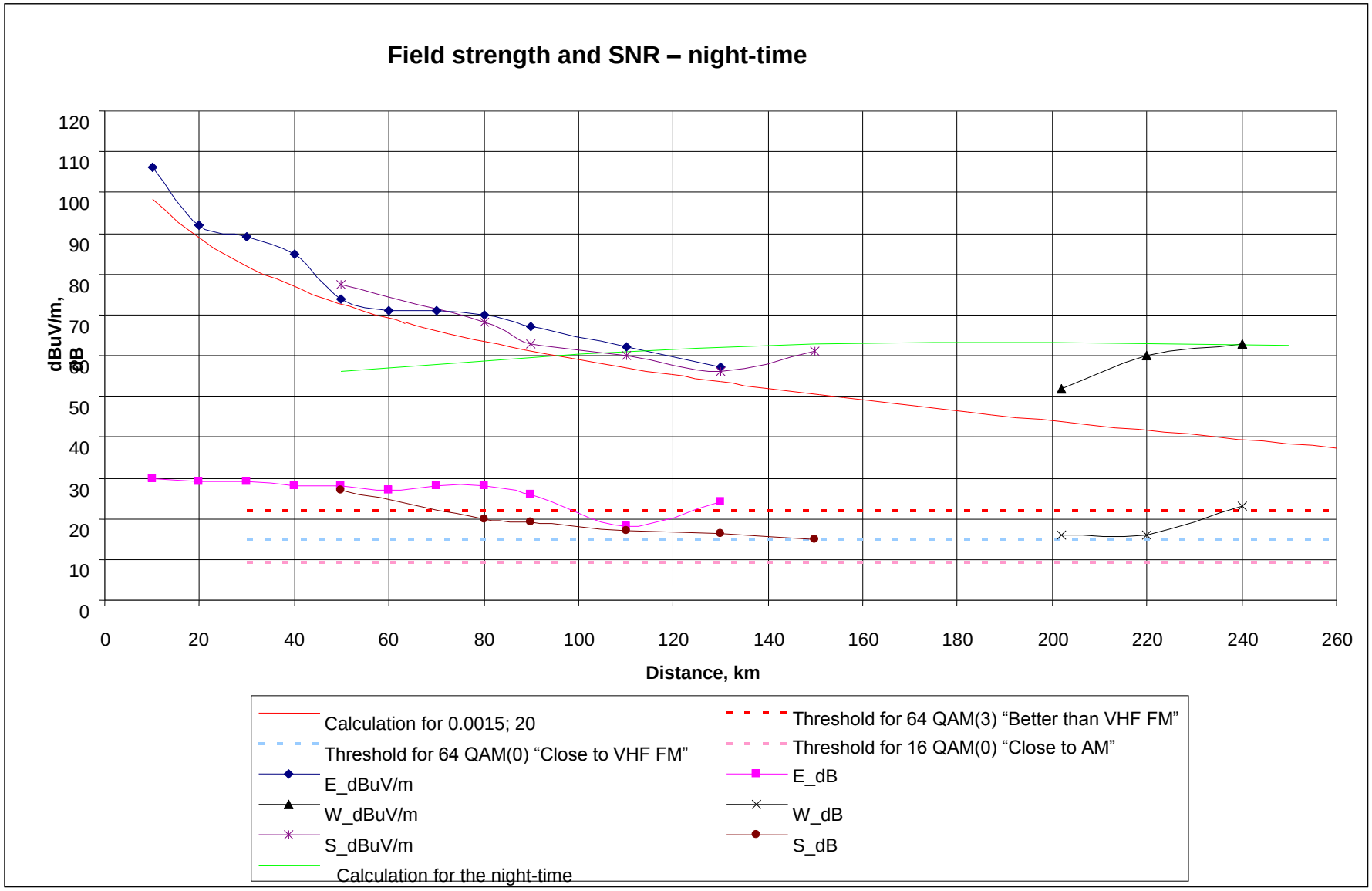
In the “B” mode, comparable quality of sound requires code rates of 0.6 (20.1 kbit/s) and 0.71 (24.7 kbit/s), and this needs SNRs of 16.9 dB and 19.7 dB at the receiving position, i.e. 2 to 3 dB higher than in the “A” mode.

Additionally, signal reception in the MF band in the night-time is generally complicated by the presence of co-channel interference from remote stations. In the presence of the co-channel interference, absolute protective ratio for the “A” mode with 10 kHz bandwidth and 64QAM(1) modulation is 6.7 dB, and for the “B” mode with similar parameters it equals 7.3 dB [4].

According to [4], at frequencies below 700 kHz and at distances of 100 to 200 km, arrival of waves having relevant intensity for decoding and delayed for more than 2 ms relative to the ground wave is not predicted. For this reason it can be suggested that using the interference immunity “A” mode in the above conditions with comparable quality of sound will be more power efficient than using the “B” mode.

For practical verification of the above argumentation, measuring position was chosen at the distance of 97 km from the transmitter, where the field strengths of the surface wave and the ionospheric wave were about the same. This parity is verified by the fact that the depth of fading with AM signal was significant and reached 14 dB.

FIGURE 7 – **Field strength and SNR in the night-time**

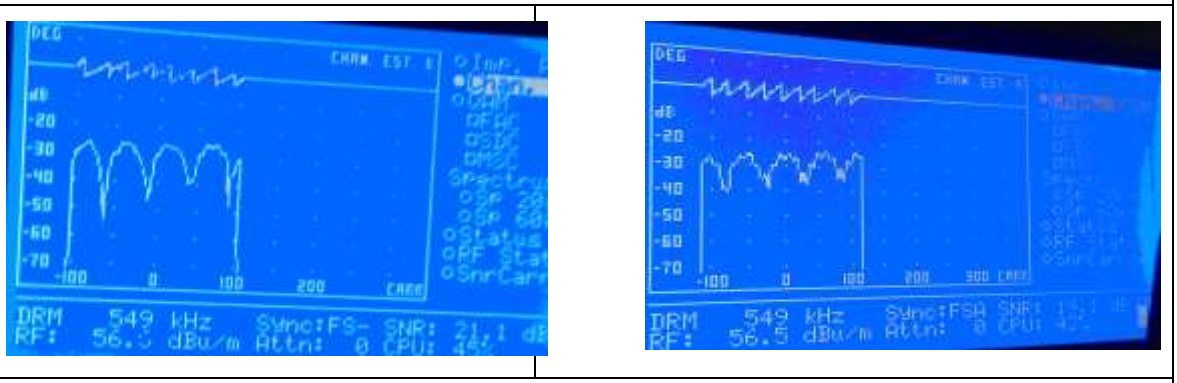


Illustrations of the DRM signal reception in the fading zone are shown in Figure 8. One of the illustrations for impulse response of the channel demonstrates equal surface and ionospheric waves with the delay of about 0.4 ms between them. The ionospheric wave is time-variant. Other waves with longer delays have significantly smaller strength. Image of transfer function of the channel, similarly to the “SNR spectrum”, resembles frequency-selective fading.

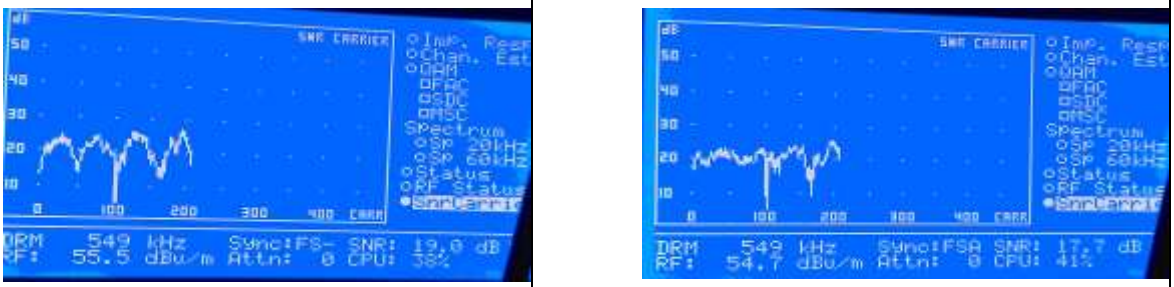
FIGURE 8

Illustrations for the reception of the DRM signal in the fading zone

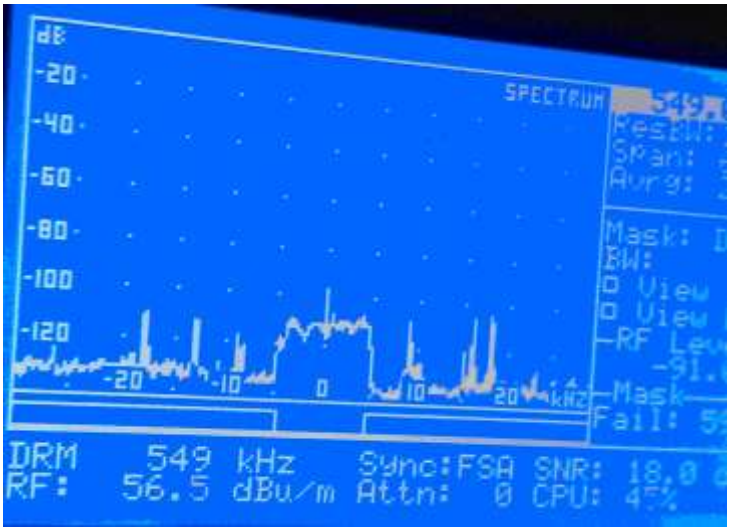
Examples of impulse response of the channel in the DRM mode



Examples of transfer function of the channel in the DRM mode



Examples of “SNR spectrum” – SNR values for subcarriers



Spectrum of input signal in the 60 kHz bandwidth

At the central frequency of the desired signal spectrum, interference is observed with field strength (measured in the absence of the wanted signal) equal to 40…44…47 dBuV/m, received from AM broadcasting station (Germany) operating at the co-channel carrier frequency (549 kHz). The field strength of the wanted signal was 54…58 dBuV/m, and required protection ratios were met for protection level (1), but for protection levels (2) and (3) they could be violated with the growth of interference level and attenuation of wanted signal.

Thus, the performed measurements correspond to the actual interference environment "at the border of possible reception area" and allow comparing the interference immunity of "A" and "B" modes.

To perform this comparison, "A" and "B" immunity modes alternatively changed code rates, and RSCI files were recorded for each fragment with a subsequent calculation of percentage of correctly decoded audio frames. Recall that according to the international practice, "operability" of DRM broadcasting is determined by the "98% of decoded audio frames" criterion. The measurement results are shown in Table 3.

TABLE 3

Percentage of correctly decoded audio frames for different immunity modes

Immunity mode/ code rate	**"A"**	**"B"**
64QAM(0)	100%	100%
64QAM(1)	100%	100%
64QAM(2)	99.93%	97.68%
64QAM(3)	97.49%	63.27% 90.21%

Table 3 shows that with 10 kHz bandwidth, 64QAM(0) and 64QAM(1) both immunity modes ("A" and "B") demonstrated 100% decoding.

For 64QAM(2) and 64QAM(3) modes having almost equal field strength of the wanted signal, “A” mode provided higher percentage of decoded audio frames.

Hence, the experimental studies showed that “A” mode had higher interference immunity than “B” mode in the above conditions.

Taking into account that in the “A” mode a higher data rate is available, and that in order to achieve the same quality of sound content transmission, a lower code rate could be used requiring lower SNR for decoding, “A” mode of interference immunity is recommended for use in the MF band in the night-time at operating frequencies below 700 kHz.

This Recommendation will allow extending the service zone of the surface wave (which is reduced in the night-time due to the increase of the noise level) by the size of the fading zone.

7 Fixed reception in rural, urban and megalopolis areas

Fixed reception was performed in the following positions:

– Lvovsky township in the Moscow Region (rural area, 77 km from the transmitter, see Figure 2, position 69);

– Mytishchi town of the Moscow Region (urban area, 40 km from the transmitter, see Figure 2, position 68);

– Moscow City, Aviamotornaya street (megalopolis area, 40 km from the transmitter, see Figure 2, position 67).

During these tests the receiving equipment was installed indoors. Power supply was delivered by electric power network and batteries. Electric lights and computers were turned on in the rooms.

Measurements were performed using 4.5, 5.0, 9.0 and 10.0 kHz bandwidths, the “A” mode, 16QAM and 64QAM modulations with all available levels of interference immunity. Measurement results for the field strength and the SNR are shown in Tables 4, 5, 6.

TABLE 4

Measured data (rural area)

No.	Bandwidth (kHz)	Field strength (dBuV/m)	Signal-to-noise ratio (dB)
1	4.5	62	30.9
2	5	62	30.2
3	9	63.8	27.4
4	10	63.5	26.9

TABLE 5

Measured data (urban area)

No.	Bandwidth (kHz)	Field strength (dBuV/m)	Signal-to-noise ratio (dB)
1	4.5	80	34
2	5	80	32.5
3	9	80	30
4	10	80	29

TABLE 6

Measured data (megalopolis area)

No.	Bandwidth (kHz)	Field strength (dBuV/m)	Signal-to-noise ratio, (dB)
1	4.5	74	27.3
2	5	74	27.1
3	9	77	25.7
4	10	76.2	25.1

Measurements showed 100% decoding of the DRM signal using consumer and monitoring receivers for all used operating modes of the DRM modulator.

In the AM mode in the megalopolis fixed position at the distance of 40 km from the transmitter, SNR value was 23 dB, with specified SNR = 26 dB and 30% modulation. Thus, at the distance of only 40 km from the transmitter, in the Moscow City there is no reception of AM signal with the specified quality, but the DRM signal is received with the quality comparable to VHF broadcasting.

Additionally, it should be noted that in the environment with industrial and typical household interference which is always presented in living quarters (especially urban), reception using magnetic type antenna is more efficient than reception using rod antenna. This is due to the fact that in the electromagnetic field of this interference type, electric component prevails, and magnetic type antenna is not sensitive to the electric component.

Conclusion

The following conclusions are made based on the analysis of the measured test data in the DRM broadcasting pilot zone in the MF band:

a) In the day-time:

– In the AM mode, radius of service area was 75 to 90 km (specified SNR = 26 dB with 30% modulation).

– In the 64QAM(3) mode, 100% decoding of the audio signal was possible up to distances of 120 to 180 km from the transmitter (depending on the direction). Measurements at distance of 150 km from the transmitter in the South-East direction showed 100% decoding with field strength variations up to 8dB from place to place. Service area in the DRM 64QAM(3) mode (quality “better than VHF FM stereo”) is 4 times larger than in the AM mode, with DRM transmitter power twice as little.

– In the 64QAM(0) mode, 100% decoding of the audio signal in the South-East direction was observed at distance of up to 260 km from the transmitter. Measurements in the positions at the distance of 220 km from the transmitter in this direction showed reliable decoding with insignificant field strength variations from place to place. Service area in the DRM 64QAM(0) mode (quality "close to VHF FM") is 9 times larger than in the AM mode, with DRM transmitter power twice as little.

b) In the night-time:

– In the AM mode at the distance of 150 km from the transmitter, SNR value was 8 to 12 dB with audible fading.

– In the 64QAM(3) mode, 100% decoding of the audio signal was observed up to distances of 70 to 90 km from the transmitter (depending on the direction) with the prevalence of the surface wave. At distances less than 150 km, 100% decoding of the audio signal was possible in the 64QAM(0) mode. At distances greater than 200 km, reliable reception of the sky-wave (ionospheric wave) was observed in the 64QAM(0) mode.

In the fading zone at distances from 80 to 120 km for the given transmitter with the given antenna at the frequency of 549 kHz, the analysis showed that:

– 100% decoding was observed with 10 kHz bandwidth, 64QAM(0) and 64QAM(1) modulations for both ("A" and "B") interference immunity modes.

– In 64QAM(2) and 64QAM(3) modes having almost equal field strength of wanted signal, "A" mode provided higher percentage of decoded audio frames.

– In the reviewed conditions, "A" mode provides higher interference immunity than "B" mode.

– Taking into account that in the "A" mode a higher data rate is available, "A" mode could be recommended for use in the MF band in the night-time at operating frequencies below 700 kHz. This recommendation will allow extending the service area, which is decreasing in the night-time due to the growth of the noise level, by the size of fading zone.

Overall, the studies showed that the DRM broadcasting provides larger coverage with better quality of audio content with lower transmitter power than traditional AM radio broadcasting.

References

[1] ETSI ES 201 980 V3.1.1 (2009-08) Digital Radio Mondiale (DRM); System Specification.

[2] GOST R 51742-2001. Broadcasting transmitters, fixed AM modulated, ranges of low frequency, mean frequency and high frequency. Main parameters, technical requirements and methods of measurement.

[3] Recommendation ITU-R P.1147-4 – Prediction of sky-wave field strength at frequencies between about 150 and 1 700 kHz.

[4] Recommendation ITU-R P.1321-2 – Propagation factors affecting systems using digital modulation techniques at LF and MF.

[5] Recommendation ITU-R BS.1615 – Planning parameters" for digital sound broadcasting at frequencies below 30 MHz.