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Is DRM on 26 MHz an Option for Local Digital Broadcasting? Results from a Field Trial in Nuremberg, Germany

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Abstract

In this paper, we report about the setup and operation of two DRM transmitters in Nuremberg and Dillberg (30 km south east of Nuremberg) operating in the 26 MHz broadcasting band and about the resulting coverage for stationary and mobile reception.

Keywords

Digital Broadcasting, DRM, 26 MHz band, local broadcasting, coverage, propagation, fading, noise, sporadic E-Layer.

INTRODUCTION

In many countries digital sound broadcasting systems are being introduced. In Germany, in particular, the setup of DAB networks has started in the mid – 1990s. DAB is very well suited to provide large area coverage using single frequency networks. Typically, six or more radio programmes are bundled together in a Multiplex. This works very well for country – wide or national broadcasting stations.

In some German states, however, there are also local radio stations. In the metropolitan areas, several local stations can share a local DAB multiplex which is often broadcast in local L-Band DAB networks (1452-1492 MHz). In rural areas there are usually only single local radio stations and it does not seem to be practical to use DAB for the future digital transmission of these stations, because either the multiplex cannot be filled with a sufficient number of programmes or L-Band is economically not suitable for the coverage of the relatively large areas thinly populated.

Fig. 1 shows the distribution of low power FM stations in Bavaria. It can clearly be seen that in many regions there are single stations using several FM frequencies to cover the desired region.

In the meanwhile, the DRM digital broadcasting system is fully developed and the use of this system for local broadcasting could be an attractive solution for single local stations. In principle, two frequency bands are available for this purpose, the medium frequency band and the 26 MHz broadcasting band in the short wave region. Concerning the medium wave band, there are a number of facts that make this band less suited for local stations in Germany.

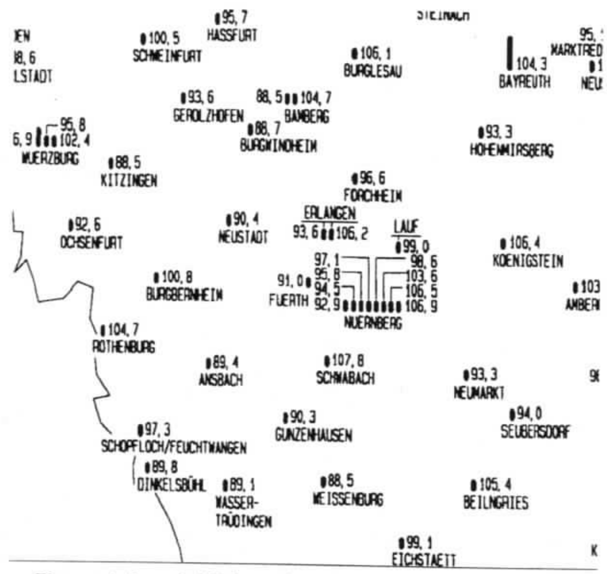

Figure 1. Local FM broadcasting stations in a part of northern Bavaria, Germany (1.1.2003). From [1].

The number of channels which can be used for this purpose is very limited, the transmission antennas are relative large. The indoor noise floor is relatively high, and sky wave propagation during night time leads to high interference levels on the channels that are used for local broadcasting by many stations simultaneously. This leads to a much smaller coverage during night time. Concerning mobile reception, significant attenuation occurs e.g. near bridges and power lines.

The 26 MHz band is only occasionally used for international broadcasting during the maximum of the 11-year sunspot cycle. Therefore, this band could also be used for local broadcasting. The local coverage would only use ground wave propagation which is expected to result in similar coverage than in the VHF bands. A number of experiments have shown promising results [2]. However, these transmissions were usually only set up for a short period of time. Mostly there were only mobile reception tests, but no long term fixed reception measurements. Due to the propagation conditions in the 26 MHz band, reasonable results concerning the reliability of coverage can only be obtained in a long term test covering all seasons of the

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year. This is the major aim of the project the first results of which we present in this paper. Other important issues are:

- to show that DRM local broadcasting stations can be set up with minimal hardware effort,
- to investigate mobile reception in the 26 MHz band,
- to investigate stationary reception, in particular in-door-reception and the impairments resulting from local noise sources,
- to study the interference from sky wave propagation phenomena at different seasons of the year.

SETUP OF THE FIELD TRIAL

We obtained two licenses for experimental transmissions in the 26 MHz band from two transmitter sites. The main features of the two transmitters are listed in table 1.

Table 1. Characteristics of the transmitters used in the trial

	FH - Nuremberg	Dillberg
Location	49°27'10" N 11°05'40" E	49°19'28" N 11°22'55" E
Height a.s.l.	300 m	600 m
Frequency	26012 kHz	26000 kHz
Antenna	Half wave Dipole	Vertical half wave antenna
Height of Antenna above ground	30 m	5 m
E.I.R.P	10 W	100 W
Operation since	March 2003	February 2004

Both transmitters are usually operated in DRM Mode A, with 10 kHz bandwidth and 16 QAM modulation for the Main Service Channel, delivering a Mono signal coded with 18 kbit/s using AAC-SBR. For tests other configurations can be used.

Generation of the DRM signal

Since the use of commercially available DRM coders was beyond our abilities, a software was developed which is able to generate a DRM signal. Written in JAVA, it allows real time operation on a sufficiently fast Pentium PC using the Linux operation system. The audio signal is either fed to the PC through the sound card interface or is generated by a media player from e.g. a sound file stored on the PC or a web stream. The audio is compressed using the DRM Audio Libraries from Coding Technologies. After that, the compressed data are processed according to the DRM standard [3]. A simple graphical user interface allows to preset the relevant parameters (e.g. bandwidth, mode, data rates, error protection). In addition, text messages and the elementary service information such as station label, PTY, and Language can be generated. The respective MSC, SDC and FAC data are generated. Finally, using an FFT library, the DRM signal is generated as samples of the time domain signal at an intermediate frequency of 12 kHz. The sampling rate is 44.1 kHz and the resolution of the individual samples is 16 bit. Hence, the signal bandwidth is limited to 10 kHz (DRM Mode 3). If a different IF is being used, also 18 and 20 kHz wide signals (DRM Modes 4 and 5) can be generated. The DRM signal can either be stored on the PC disk or can be fed to the sound card output for generation of an analogue signal.

In the setup we normally operate, both transmitters are fed from the audio stream that our Campus Radio studio produces and which is also delivered as an internet stream [4]. The Nuremberg transmitter PC is connected to the web stream via LAN, the Dillberg transmitter is connected to that stream through a DSL high speed internet access on a telephone line.

Transmitters

Both transmitters first use a mixing stage that converts the signal on the 12 kHz IF provided by the PC sound card to a second IF of 455 kHz. The signal is filtered and amplified. In the case of the Nuremberg transmitter, this signal is fed to a modified Collins S 32 Transmitter, which can provide an output of up to 20 W. For the Dillberg transmitter, the signal is converted to 26 MHz, amplified to 0 dBm and again filtered. This signal is fed to a solid state 1 kW peak amplifier which provides the 100 W output signal. With both transmitters, Signal – to – Noise Ratios better than 20 dB are achieved and the side band emissions are below the DRM spectrum mask (Fig. 2).

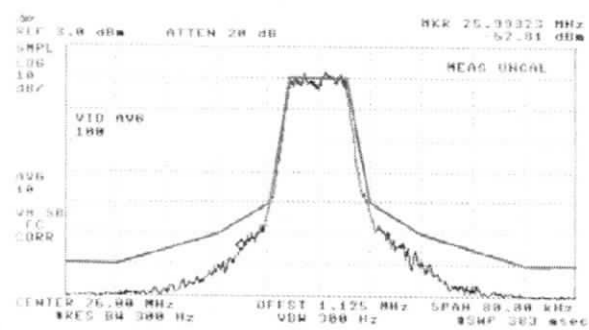

Figure 2. Output spectrum of the Nuremberg Transmitter and DRM spectrum mask.

Receivers

For coverage measurements and other purposes, a Yaesu FRG 100 receiver which is modified to provide an IF signal at 12 kHz was used. The S meter reading can be put out via a serial interface and the values were converted to input power level after the S meter had been calibrated in the laboratory. Software was written to record these data in parallel with the DRM reception.

For trials employing more test listeners, a simple single channel receiver front end was developed and supplied as an assembly kit. Fig. 3 shows the block diagram. In order to avoid the use of expensive parts, a dual conversion concept with a first IF of 1 MHz was chosen. This provides only limited image rejection. Since the image frequency is at 27988 kHz for a reception frequency of 26012 kHz (28000 kHz for 26012 kHz) this was not found to be a particular problem. However, due to the circuit of the second mixer LO the frequency stability is only sufficient after some minutes of operation. We found that the simple receiver front end provides good reception in fixed operation. The DRM signals were decoded on PCs using the DRM software radio or the "Dream" software, which are both able to create log files recording the calculated Signal – to –Noise – Ratio and the number of correctly decoded audio frames per minute.

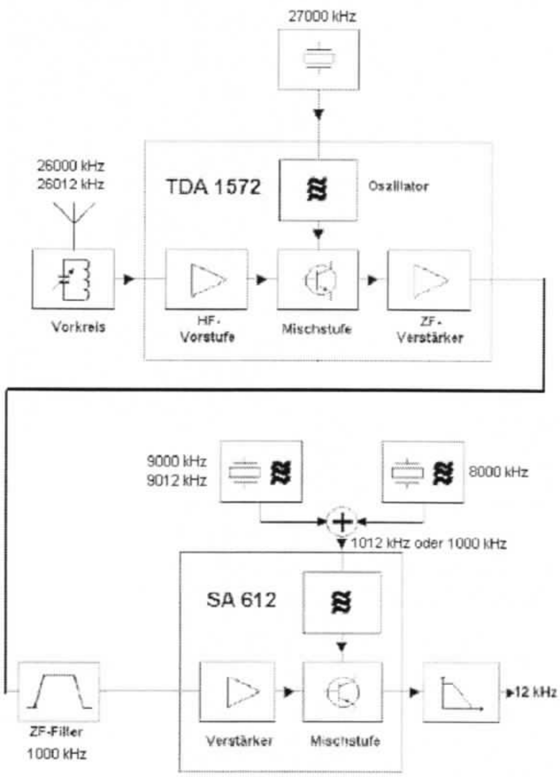

Figure 3. Block diagram of single channel receiver front end using two integrated circuits.

COVERAGE AREA AND MOBILE RECEPTION

Setup

To obtain a fast impression of the area being covered, a mobile was equipped with the Yaesu FRG 100 receiver and a laptop computer for decoding the DRM signal and recording the input power of the receiver.

All connections to the computer were carefully shielded to avoid interfering radiation and only batteries were used as power supply both for the receiver and the computer. Some remaining additional noise due to the car ignition system could not be avoided.

It was found that a usual rod antenna for car radios is not suitable for reception in the 26 MHz band. Therefore, a 1 m long shortened dipole antenna using inductive loads was designed and used for the mobile trials (Fig. 4). The mismatch to the coaxial cable was not corrected because this was not expected to significantly improve reception.

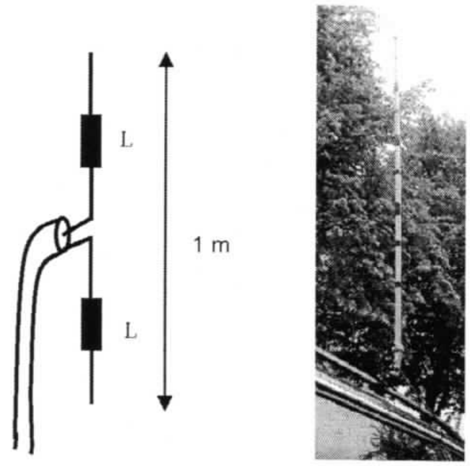

Figure 4. Antenna for mobile reception at 26 MHz.

Coverage Area

Using this setup, we studied reception both in Nuremberg and in the area around Dillberg. Figs. 5-6 show the results in maps. Continuous mobile reception was observed within a 3 km radius of the 10 W transmitter in the urban area of downtown Nuremberg and up to a distance of 12 km in the mostly rural and hilly area around Dillberg, including the city of Neumarkt which is 8 km from the transmitter site and does not have line-of-sight reception conditions everywhere.

Measurements of Deutsche Welle using a short vertical active rod aerial (Rohde & Schwarz HE010) and a Rohde & Schwarz EB 200 receiver basically confirm our own measurements but resulted in a slightly reduced coverage. Their measurements conclude that the threshold for 100 % audio is 23 dB(µV/m) in Nuremberg and 26 dB(µV/m) around Dillberg.

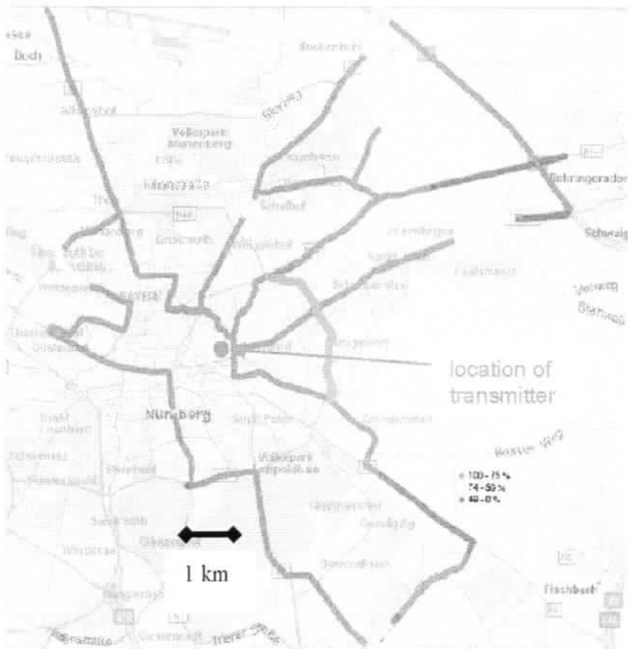

Figure 5. Mobile reception situation in Nuremberg on 26012 kHz. Green: > 75% of audio frames decoded, yellow: 50-74% of audio frames decoded, red: < 50% of audio frames decoded.

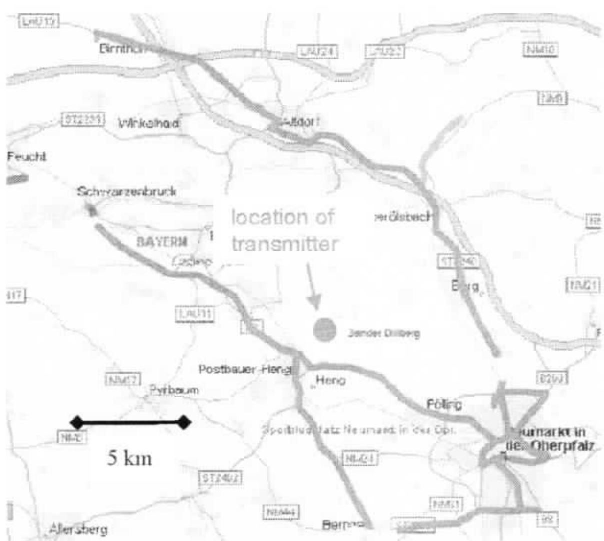

Figure 6. Mobile reception situation around Dillberg on 26000 kHz. Green: > 75% of audio frames decoded, yellow: 50-74% of audio frames decoded, red: < 50% of audio frames decoded.

Multipath Fading

Time variance of the channel is a particular problem with mobile reception. In the case of DRM at 26 MHz, it was unclear if the mobile channel can be expected to have similar properties than at VHF, i.e. the wave originating from the transmitter is reflected by e.g. buildings and topographic structures.

Some rough estimates can be obtained without particular reference to mobile radio channel theory. The superposition of several incident waves results in an interference pattern characterized by spots with constructive or destructive interference. When the mobile receiver moves through this pattern, the spatial distribution of field strength transforms into a temporal one. The separation of spots with destructive interference will generally be in the order of $\lambda/2$ (λ being the wavelength), which is the separation of nodes in a standing wave. This value is 5.75 m for 26 MHz. When a vehicle moves at speed v, successive fades will occur at time intervals of $\Delta t = c\ /\ (\lambda/2)$, where c is the velocity of light. Hence the frequency of fades is $\lambda/2c = f_D/2$, where $f_D = f\ (v/c)$ is the maximum Doppler frequency shift. If we apply this for a vehicle speed of 10 km/h = 2.8 m/s, this results in 0.25 Hz, which means that a fade is expected approximately every 4 s. This is sufficiently slow to be measured using the Yaesu receiver with a time constant of about 1 s. We therefore took several measurements in different places within the coverage area of the Nuremberg transmitter to study the fading characteristics of the 26 MHz mobile channel.

Fig. 7 shows the results obtained in Komotauer Straße, at a distance of about 2 km from the transmitter. Similar results were obtained in several other places at distances between 500 m and 3 km from the transmitter.

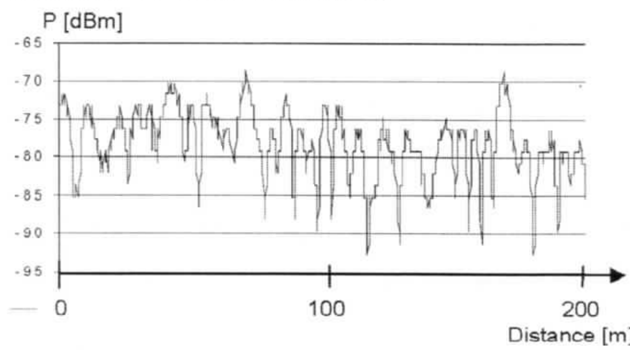

Figure 7. Recorded input power at the receiver when driving through Komotauer Str. at a vehicle speed of 10 km/h.

Figure 7 clearly shows that multipath propagation in urban areas is a fact in the ground wave range on 26 MHz. From the deep fades it may be concluded that the signals interfering have about the same power. The path differences will be small, especially since the coverage area of the transmitter is only a few kilometers. We therefore conclude that the fading is not frequency selective in the 10 kHz bandwidth of the DRM signal, but flat. This will lead to the unfavorable situation that audio dropouts will occur during mobile reception of DRM signals at low vehicle speeds or at stops e.g. at traffic lights. The same problem will occur for indoor reception without external antennas.

Concerning the influence of the DRM parameters, we recorded the reception performance when driving through the same streets several times with different parameter settings. No significant difference was observed between Mode A and Mode B transmitter operation. The interleaving depth of 2 sec. performs better than 0.4 sec. in mobile reception, and a relatively short AGC time constant of the receiver seems to be favourable.

LONG TIME FIXED RECEPTION AND PROPAGATION PHENOMENA

Several long time (> 3 days) monitoring campaigns and mobile tests were carried out on both transmissions. Stationary reception using wire antennas, dipoles, vertical antennas and active antennas was found to be possible at distances of up to 15 km from Nuremberg and 40 km from Dillberg.

Interference due to Ionospheric Propagation

During winter 2003/04 the solar activity allowed for long distance propagation. Since the frequencies being used in the trial have not been allocated to other transmissions, no interference was expected. However it turned out that interference occurred from narrow band FM radio services apparently originating from Eastern Europe. At the fringe of the coverage area this lead to significant impairment. Fig. 8 shows the percentage of correctly decoded audio frames at receiving site Altenfurt, 8 km southwest of the Nuremberg transmitter, where a dipole at 13m above ground was used for fixed reception together with the single channel receiver. The impairments were observed during day time. On several other days, the same observation was made.

The sunspot numbers on these days were 34, 26 and 17, respectively [5]. It should be noted that these figures are considerably lower than in the maximum of the solar activity.

If a situation is envisaged where many local broadcasting stations share the limited number of channels in the 26 MHz band (a total number of 43 channels are available at 10 kHz bandwidth, of which a certain number would have to be reserved for international broadcasting) significant mutual interference is unavoidable during the propagation conditions of the sunspot maximum. It is doubtful if any measures concerning the vertical antenna diagram can reduce this interference, because the highest operating frequencies and longest skip distances are obtained at low angles of radiation. Even if only radiation towards the ground in the target area from a high transmitter antenna location would be used, this would still create reflected signals which would be able to propagate via ionospheric scatter, because the reflectivity of the ground is quite high in this frequency range, which makes multihop propagation possible.

In summer, when the usable frequencies in the shortwave bands are lower in the northern hemisphere, there are still propagation effects that cause interference in the 26 MHz band.

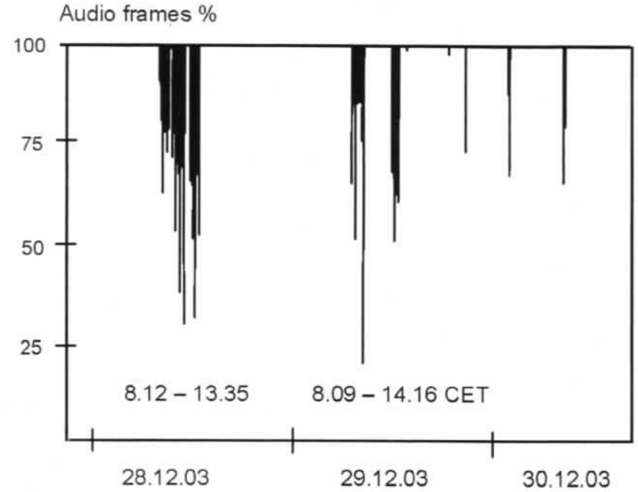

Figure 8. Percentage of correctly decoded audio frames per minute during 3 days in December 2003. Distance to transmitter: 8km.

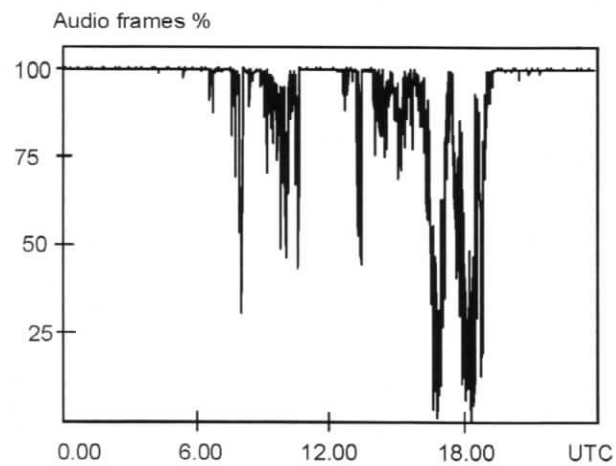

Figure 9. Percentage of correctly decoded audio frames per minute during May 25th, 2003. Distance to transmitter: 8km.

One of these is the occurrence of sporadic E-Layers in the ionosphere, in particular between April and July. This phenomenon lasts for several hours and occurs sporadically. Then propagation to distances up to 2000 km is observed. During May 2003 several sporadic E-Layers occurred, which lead to significant impairment of reception, probably again due to interference from the above mentioned FM radio services. Fig. 9 shows the percentage of correctly decoded audio frames at receiving site Altenfurt, 8 km on May 25th, 2003, when a highly ionized E-Layer cloud had formed over central Europe. In the course of the long term transmission, a number of reception reports were received from listeners who had received the signals of our transmitters. The Dillberg transmitter was reported to be received in Switzerland and Scotland [6]. In Nuremberg, we could receive the transmitter operated in Rennes, France on 25.775 MHz several times during May/June 2004. Listeners from Sweden confirmed reception of the Rennes transmitter in December 2003 [6]. We conclude that both during winter in times of high solar activity and during the sporadic E-Layer season there is a considerable probability for mutual interference once many stations use the 26 MHz band.

Other observations

In the course of reception campaigns where several receiving stations at different places recorded their reception quality in parallel, a number of further observations were made:

- The degree of impairment from distant interferers depends on the signal level at which the station receives the wanted signal. Receivers close to the transmitter generally show less impairment than stations far away.
- At times, even receiving stations close to the transmitter and close to each other show different performance. This is probably due to local noise sources (e.g. electrical appliances).
- The noise level recorded on an unused channel (e.g. 26050 kHz) shows significant variation over several hours or days (up to 20 dB)
- Despite these impairments, the overall percentage of correctly decoded audio frames for all stations during all times was between 97% and 99%.

CONCLUSIONS

The reported experience after more than one year of operation of low power transmitters in the 26 MHz broadcasting band may be summarized as follows.

- DRM is an attractive digital broadcasting system for local stations because single programmes are broadcast on an individual frequency and good audio quality sufficient for most types of content can be achieved even at 10 kHz bandwidth.
- Local DRM broadcasting stations in the 26 MHz broadcasting band can be set up with small effort concerning modulators, power amplifiers and antennas. High antenna towers are not required
- The 26 MHz broadcasting band offers propagation similar to the VHF bands at many times. Within the coverage area, 97 – 99 % availability was achieved for fixed reception.
- Mobile reception and indoor reception of DRM ground wave signals in the 26 MHz band will suffer from flat fading due to multipath propagation.
- During periods of high solar activity and sporadic E – Layers long distance propagation (over several thousands of km) resulting in mutual interference of station once the band is widely used for local broadcasting.
- Local sources of noise will lead to additional reception problems in some situations.

Due to the different propagation phenomena observed, the reliability of services provided in the 26 MHz band will be limited and longer periods of dropouts will occur at certain spots and at least at the fringe of the coverage area. To overcome these limitations, single frequency networks could be used to provide high levels of field strength inside the coverage areas but minimise the radiation towards the ionosphere. However, this would mean a significant increase of complexity which is not ideal for the purpose of local broadcasting.

Another interesting option might be to use the 26 MHz band together with a second frequency in the medium wave range. The 26 MHz frequency would be used at night time, when no long distance propagation occurs. For day time coverage, the medium wave band would be used because long distance propagation only occurs during night time there. Combining these two frequency bands could be the solution to local digital broadcasting of single stations when DRM receivers will actually be able to follow such frequency changes automatically.

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