Digital broadcasting below 30 MHz: DRM — a summary of the field tests

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Field testing of the Digital Radio Mondiale transmission system has been in progress since 1999. This article reports on the results of these comprehensive trials which have included NVIS propagation near the equator, long-range propagation over distances up to 23,000 km, and tests with SFNs.

Digital Radio Mondiale (DRM) has been designed as the successor to amplitude modulation (AM) transmissions that have been around since the early days of Radio. The AM bands (150 kHz to 30 MHz) were the first bands adopted by the early radio stations due to the large coverage areas that were possible by using these frequencies. During the second half of the 20th century, newer modulation techniques in higher bands, such as frequency modulation (FM) in the VHF bands, started to erode the audience share of the AM market. However, the AM market remains healthy, especially in the underdeveloped regions of the world.

The DRM system has been designed to co-exist with, and eventually replace, the current AM transmissions worldwide. In order to achieve this aim, DRM needs to preserve the benefits of the current AM standard:

- a universal standard;
- a non-proprietary system;
- a plentiful supply of inexpensive receivers.

It also needs to adopt the best features of modern communications systems:

- to fully use the load capacity of the RF channel;
- RDS- and DAB-type text features;
- High-fidelity sound;
- flexibility in adapting to different propagation conditions.

The DRM system was first proposed in 1998 and it has rapidly moved to an IEC, ETSI, and ITU standard. Part of this standardization process has required field tests of the system. The first field tests took place in 1999, and an intensive phase of field-testing was initiated in November 2000, with the start of the IST-Radiate project. This project was supported by the European Commission and involved ten organizations from across Europe and North America. This article summarizes the interesting conclusions of the Radiate field tests.

For further technical information on the DRM broadcasting system, see [1].

NVIS tests in Ecuador

In December 2000, the BBC and Radio Netherlands carried out a series of field tests using Near-Vertical-Incidence Sky-wave (NVIS) propagation, in conjunction with HCJB in Pifo, Ecuador. These tests explored the performance of the DRM digital radio system in the extreme propagation conditions faced by many tropical broadcasters. Transmitting their signals at vertical or near-vertical angles, it is often possible to cover an entire country with a single transmitter, by reflecting the signal off the ionosphere. The frequencies typically used for NVIS transmissions are in the tropical bands, i.e. between 2 and 5 MHz.

Although the system worked during daylight hours, problems were revealed. Firstly, the channel simulators that had been used in the initial laboratory testing of the system were modelled on the assumption that the earliest path received would be the strongest. In reality it was observed that, 40 km from the transmitter, a weak ground-wave signal was received prior to the first sky-wave signal. This observation enabled the channel simulators to be adapted and the receiver algorithms to be altered for later tests. Another problem was observed during the evening when the absorption of the D layer in the ionosphere decreased, allowing more reflections of the signal and hence a violation of the maximum delay spread (5 ms for robustness mode B) with which the guard interval could cope. At the same time, the maximum values of Doppler spread for mode B were also exceeded. In order to overcome these problems, the robustness of the prototype DRM system modes – with respect to the Doppler and delay spread – needed to be increased. As a result, two extra OFDM modes (named modes C and D) were introduced into the DRM system specification during 2001.

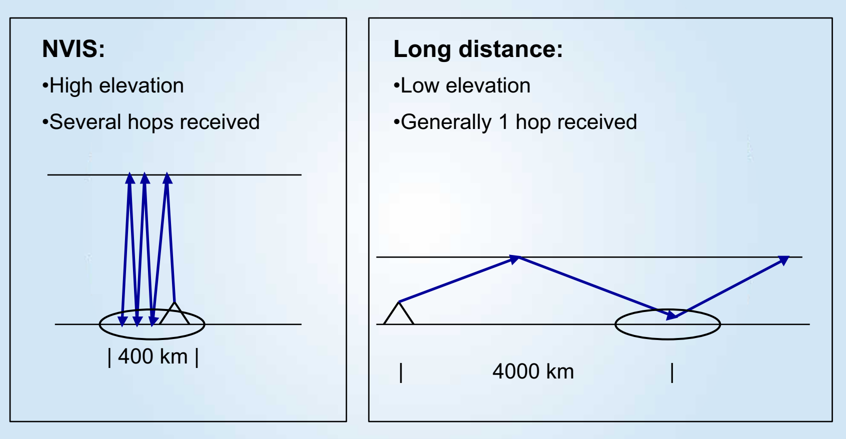

Figure 1
A receiver close to the transmitter often has to cope with a larger multipath spread than a receiver positioned further away

NVIS tests in Thailand

The next phase of the NVIS tests was primarily made to check that the changes made as a result of the first NVIS tests in Ecuador had been implemented successfully, and had provided the predicted improvement in robustness against high values of Doppler and delay spread

An existing Thales 250 kW transmitter (c1993), located at the BBC relay station in Nakhon Sawan in Central Thailand, was used. The only alterations required at the transmitter input were the fitting of a modified soundcard, connected to a DRM encoder. These modifications took less than half a day to complete, although older transmitters would require more extensive modifications to work with DRM. Tests were made between the hours of 05:00 and 20:00, which enabled testing during the interesting periods before sunrise and following sunset – when propagation conditions were expected to be the most challenging.

The NVIS antenna used was a TCI Model 611, designed to operate between 6 and 11 MHz. Thus, frequencies in the 6 MHz band were used as these were closest to the tropical-band frequencies.

The DRM transmissions were received at two sites; the first within the boundary of the ground wave at Nakhon Sawan, approximately 20 km from the station, and the second at a distance of 200 km further south – well beyond ground-wave reception. The test sequence contained the two new DRM robustness modes, C and D, in addition to the original modes A and B, so enabling testing of all four DRM modes.

Before sunrise there was no reception due to low signal strength but, within minutes of the sun rising, the channel “woke up” and reception of all modes, except mode A, worked very well. This stable condition lasted for about two hours. Following this period, the channel became unstable with slow cyclic flat fading in which all modes failed occasionally – even the most robust mode D. Under these conditions, which were due to high levels of ionospheric absorption, analogue AM reception would also have been unacceptable. In practice, the broadcaster would have to move to a higher frequency to overcome this problem. About two hours before sunset, the channel became more stable and modes B and D worked the best. This continued right the way through sunset and for an hour afterwards, but not as reliably as during the early morning reception period.

These observations confirmed the prediction that: (i) after sunrise, the E and F layers build up very rapidly; (ii) the D layer then builds up, creating a large amount of attenuation for the multiple paths; (iii) as the sun sets, the D layer "dissolves" rapidly and (iv), after sunset, the E and F1 layers "dissolve" more slowly.

Throughout the tests, mode A was mostly unusable – as expected, as this mode is primarily intended for ground-wave propagation – due to excessive delay spread. Modes B and D tended to show better results than mode C. Delay spread and Doppler spread were less detrimental to the reception than deep flat fading.

However, it does show that broadcasters cannot use a single mode and/or frequency throughout the day, unless they are content with using the most robust mode with the lowest audio quality at all times.

Here the benefit to DRM of a real-time feedback system (such as the Thales-led IST-QoSAM project) becomes apparent. This system could dynamically manage both the DRM mode selected and the associated parameter set in response to the changing channel conditions. It would thus maintain the highest supportable bitrate and audio quality. Other features, such as alternative frequency switching (AFS), could enable the receiver to switch to the best frequency carrying a particular programme, where such a choice existed.

Further laboratory analysis

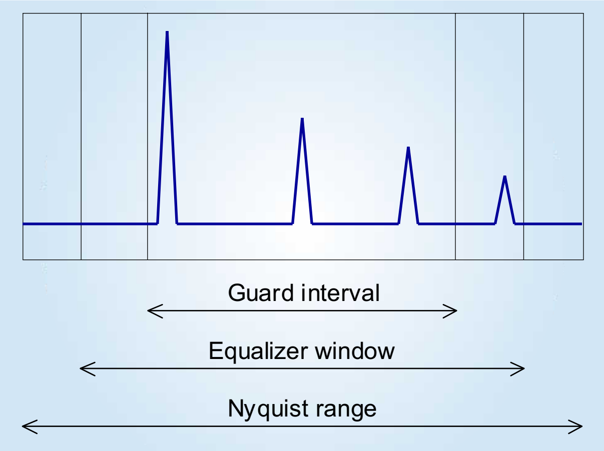

Figure 2
Typical impulse response measured by a receiver

As all the Thailand NVIS test transmissions were recorded as I/Q files on the hard disk of the receiver, it was possible to subsequently carry out further laboratory analysis in the UK. Some of the recorded signals showed interesting properties that are worth pointing out, as future receiver design could be modified to cope with these challenging conditions.

Fig. 2 illustrates an example impulse response in relation to three important time periods. The **guard interval** is the range of delays during which paths will not cause inter-symbol or inter-carrier interference (ISI/ICI). Paths in the **Nyquist range** can be correctly measured using the pilots; outside this range they are aliased. In between the two is the **equalizer window**: paths inside this range, but outside the guard interval, will cause some proportional damage to the OFDM signal; outside this range they upset the channel estimation and act as pure interferers.

A typical impulse response recorded using the QPSK channel-sounding sequence is shown in *Fig. 3*. This shows four main paths caused by reflection of the signal between the ground and the ionosphere.

In *Fig. 4* the wide guard interval of mode D allows all paths to fall within the guard interval. Therefore we expect the receiver to decode this signal.

In *Fig. 5*, for mode A with a much narrower guard interval, paths 1 and 2 are correctly placed, path 3 is aliased or "wrapped round"; path 4 is aliased and reappears inside the guard interval. These aliased paths will confuse the synchronisation. They are certainly outside the equalizer window so cause mis-equalization.

In mode C *(Fig. 6)*, path 4 has been aliased to lie before path 1, so causing sub-optimal timing and mis-equalization.

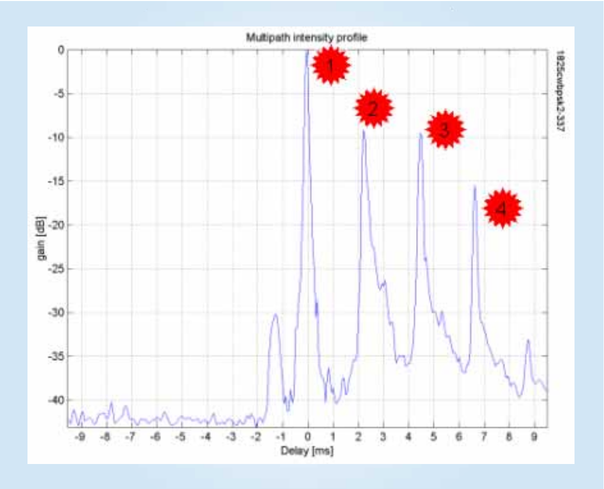

Figure 3
Typical impulse response recorded during tests

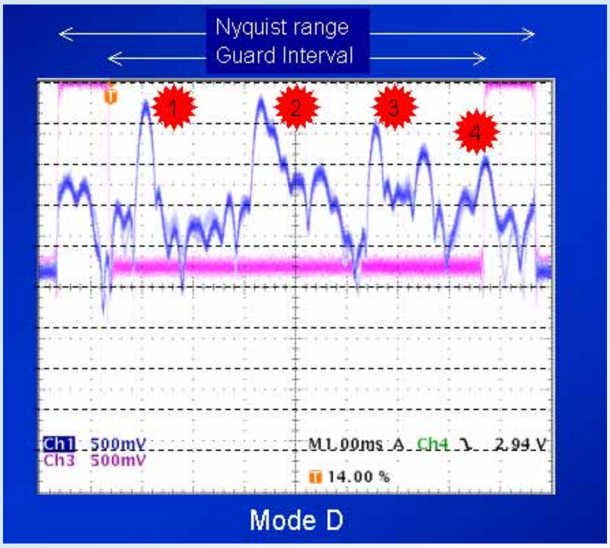

Figure 4
Receiver response to signal in *Fig. 3*: Mode D

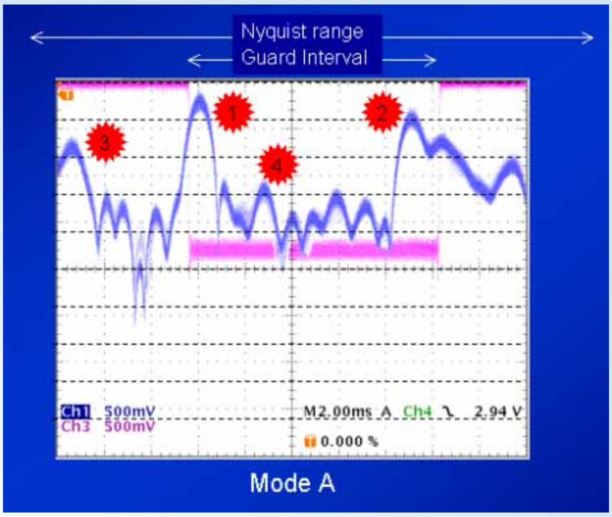

Figure 5
Receiver response to signal in *Fig. 3*: Mode A

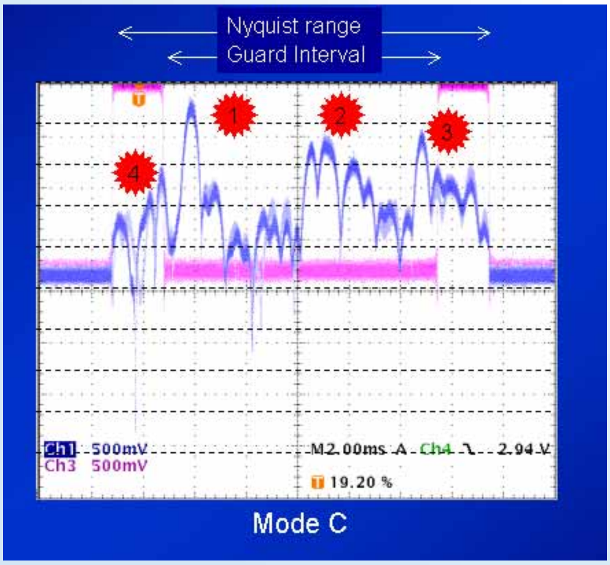

Figure 6
Mode C, with late (path 4) aliased

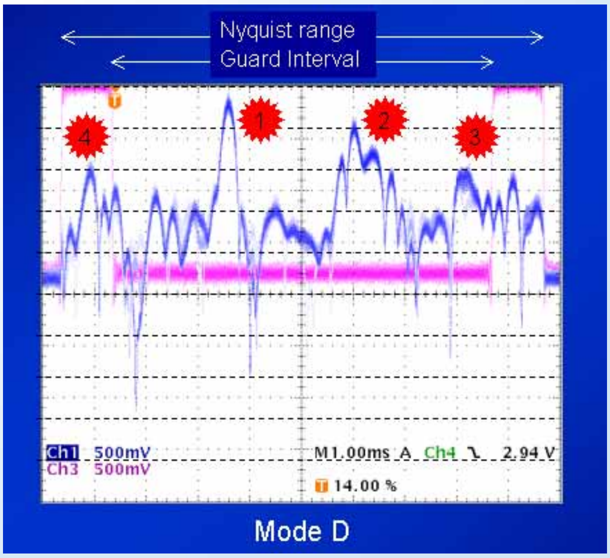

Figure 7
Mode D, with late (path 4) aliased

Although mode C has the same guard interval duration as mode B, the Nyquist range is less, so it is more prone to aliasing. Similarly, the equalizer window cannot be as wide as in mode B, meaning that the performance for echoes outside the guard interval is worse. This explains the sometimes disappointing performance of mode C in this particular situation.

Fig. 7 again shows mode D, but unlike in *Fig. 4*, path 1 has been placed too late by the receiver and this results in unnecessary aliasing. Unfortunately the situation is stable because the aliasing has confused the synchronisation.

In another similar situation, the receiver was forced (manually) to correctly position the paths earlier in the guard interval, and an improvement in the SNR of 3 dB was observed.

This shows that, in principle, improved receiver algorithms could give improved performance. However, the problem is difficult. The Nyquist range in mode D is only slightly larger than the guard interval, making the initial placement very critical.

Long-distance tests: Europe/Canada to Madagascar.

These tests were carried out in May 2001 to test the DRM system over long distances up to 13,180 km. Transmissions were received in Madagascar from Radio Canada International in Sackville/Canada, Deutsche Welle in Sines/Portugal as well as T-Systems Media&Broadcast in Jülich/Germany. *Table 1* gives details of the transmitting stations (quoted powers are average powers and give approximate values).

Table 1
Transmitting stations used for long distance tests

Transmitting site	AM power	DRM Tx	Azimuth	Slew	Distance
Sines (SIN)	250 kW	~100 kW	140	0	8583 km
Jülich (JUL)	100 kW	~40 kW	145	30	8739 km
Sackville (SAC)	250 kW	~100 kW	92	–13	13180 km

Table 2 summarizes the entire results of the mode B tests – by indicating how many slots consistently gave satisfying results for robustness, using either 16-QAM or 64-QAM. It shows that all the Jülich (JUL) "receptions", except the 12 MHz slots, consistently showed good digital audio quality using both 16-QAM and 64-QAM, despite the occasional appearance of a 2nd path at about 6 ms delay on the 19:00 and 21:00 UTC receptions. The reason was that the 2nd path was not strong enough to cause severe ICI/ISI degradation but was strong enough to potentially upset the receiver's time synchronization. The Sackville transmissions (SAC) could all be successfully received when the more robust 16-QAM constellation was used, whereas the 64-QAM constellation failed due to low signal strength. The Sines receptions (SIN) occasionally suffered from low signal strength for both 16-QAM and 64-QAM, preventing audio reception that was consistently good over a number of days.

Table 2
Summary of all DRM "receptions" during part 1 of the long-distance tests

Tx site	Start time	Band MHz	Number of slots with Q > 90% for mode B		Main problem
			16-QAM	64-QAM	
Circuits on which mode B worked on all days on both 16-QAM and 64-QAM					
JUL	15:00	21	3/3	4/4	None
JUL	19:00	13	3/3	3/3	Delay spread
JUL	21:00	13	5/5	5/5	Delay spread
Circuits on which mode B worked on all days on 16-QAM					
SAC	20:00	17	3/3	2/3	Low SNR
Circuits on which mode B worked occasionally on 16-QAM or 64-QAM					
SIN	16:30	21	2/3	2/3	Low SNR
SIN	22:30	15	2/4	1/4	Low SNR
SIN	23:30	15	2/5	1/5	Low SNR
Circuits on which mode B never worked					
JUL	19:00	12	0/2	0/2	AM Interference
JUL = Jülich, SAC = Sackville, SIN = Sines					

Doppler spread was not a problem over the paths of around 8,000 km and was low enough to allow for good reception using mode B. However, delay spread was sometimes a problem for some night-time transmissions on 13 MHz from Jülich. Occasionally, a higher delay spread upset the receiver's time synchronization, especially for mode A.

From Sackville, a DRM transmission was demonstrated, for the first time, over a distance of more than 13,000 km. Here, the results show that neither Doppler nor delay spread were a major problem – the circuit merely suffered from occasional low signal strength.

In general, the results varied considerably from day-to-day, even on a minute-by-minute basis. However, if slots belonging to the same circuit showed a problem, the nature of the problem was consistent. For most circuits, reliable audio reception could at least be achieved using the 16-QAM constellation and, in the case of interference, a frequency change would have probably solved the problem.

Ultra-long-distance tests: Europe/Canada/Caribbean to Australia/New Zealand

In April and May 2002, a new series of (ultra) long-distance tests was carried out, this time aimed at receiving DRM signals over even longer distances of 23,000 km. For this purpose, reception locations in Australia and one in New Zealand were chosen. The transmitter sites were the same as the ones used in the earlier Europe/Canada to Madagascar tests, but with the addition of a 4th transmitter site in the Netherland Antilles in the Caribbean.

Table 3
Reception locations for part II of the long distance tests

Name	Symbol	Location	Host organization
Melbourne, Australia	MEL	37.7S 144.9E	WinRadio
Wellington, New Zealand	WEL	41.3S 174.8E	Radio New Zealand International
Sydney, Australia	SYD	33.9S 151.2E	Philip Collins & Associates

The Sydney reception site offered the possibility of testing the effectiveness of different receive antennas: a 1-metre whip, an 8-metre long-wire as well as a 20-metre long-wire. The whip performed best, with the highest SNR and comparatively shallow fading, compared with the long-wire antennas. It was observed at the reception locations that switched-mode power supplies (e.g. for the PC laptops) raised the electrical noise floor considerably. Magnetic chokes were fitted to the laptop power supplies and to the coaxial cable connecting the antenna to the receivers. This reduced the interference to reasonable levels.

It was possible to receive DRM signals over distances of more than 23,000 km. The signals originating in Jülich and Sackville were strong enough to allow for data bitrates of 17 kbit/s and above. However, the majority of the Bonaire (Netherland Antilles) transmissions could only be received at lower bitrates (those associated with a 16-QAM constellation) and most of the Sines transmissions were too weak to be received even when using the most robust modulator settings. Co-channel interference and adjacent-channel interference made reception consistently impossible on some circuits from Bonaire.

High values of delay spread could be identified as a major problem for at least two circuits from Bonaire. An impulse response of 8 - 9 ms made it impossible even for the receivers' implementation of the "long-delay" robustness mode D to decode the signal. The most likely explanation of the phenomenon is linked to antipodal focussing. The focusing effect leads to the main and side lobes of the transmission signal reuniting at the transmitter's antipodal point.

During the trip, recordings of the I/Q baseband signals were made. These recordings proved to be useful in recreating observed receiver anomalies in the laboratory. Anomalies identified on both the BBC and Fraunhofer receivers were subsequently examined and corrected, resulting in performance improvements. This experience showed that future generations of DRM receivers are likely to require special attention with respect to the development of certain algorithms. The areas of mode detection, synchronization and channel estimation proved to be especially critical.

Live DRM reception was demonstrated at all three reception locations with very positive response from local observers. The possibility of providing stereo transmissions – in 18 kHz MF channels – generated significant interest from these observers.

SFN tests

These tests were carried out to test the concept of a medium-wave Single-Frequency Network (SFN). The main advantage of an SFN is the efficient use of spectrum, as a single frequency can be used to cover a large geographical area. For these tests in Berlin, three transmitter sites were used *(Fig. 8)*. These sites used Telefunken TRAM 10 kW (carrier power) transmitters on 1485 kHz, which were set up to broadcast synchronized DRM signals with an average power level of 500 W. The time synchronization between the transmitters was realized on the basis of a specific network protocol introduced by DRM, the so-called *Multiplex Distribution Interface* (MDI). Reception measurements were made in the Berlin area by a T-Systems mobile test vehicle *(Fig. 9)*. A GPS device allowed positional data to be logged alongside information from the receiver such as signal strength, receiver status, signal-to-noise ratio (SNR) and corrupted audio frames.

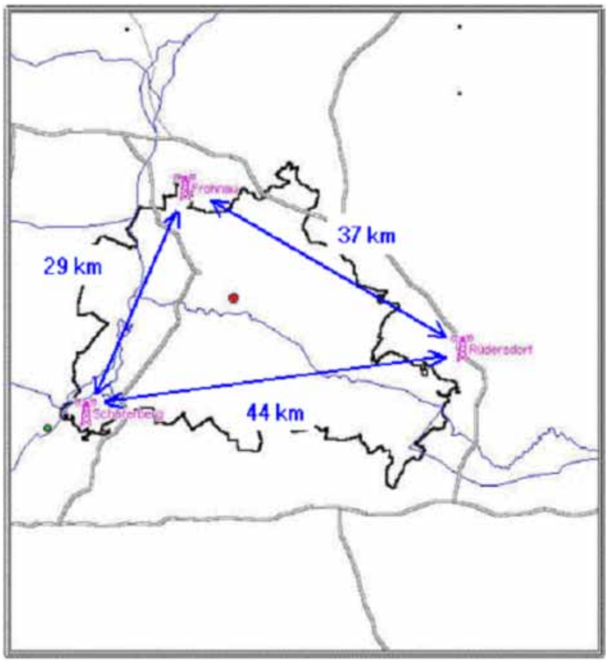

Figure 8
Three MW transmitters around Berlin at Frohnau, Schäferberg and Rüdersdorf

The routes followed by the vehicle enabled a number of different terrains to be covered, ranging from dense urban to open countryside.

The transmission mode chosen for the tests was mode A, using 64-QAM with code rate 0.6. With these parameters, the data rate is sufficient for a stereo audio service and the edge of coverage was expected to be at 39.8 dBµV/m. Measurement campaigns were made between June and September 2002, trying out different transmitter combinations with one, two or three transmitters on air.

The service quality obtained along the measured routes showed a high level of reliability. The predicted required minimum field strength fitted very well with the measured results. However, it is recommended that an additional margin should be added in the network planning, depending on the land usage (terrain). For example, signal fading was found to be much higher in urban areas compared with rural areas, and in urban areas the influence of man-made noise was also clearly noticeable. New propagation prediction models are required, as the current field-strength planning tools do not work well in predicting the field strength in urban areas. No influence on reception was observed due to the Doppler effect, even at high velocities of 120 km/h on highways around the Berlin area.

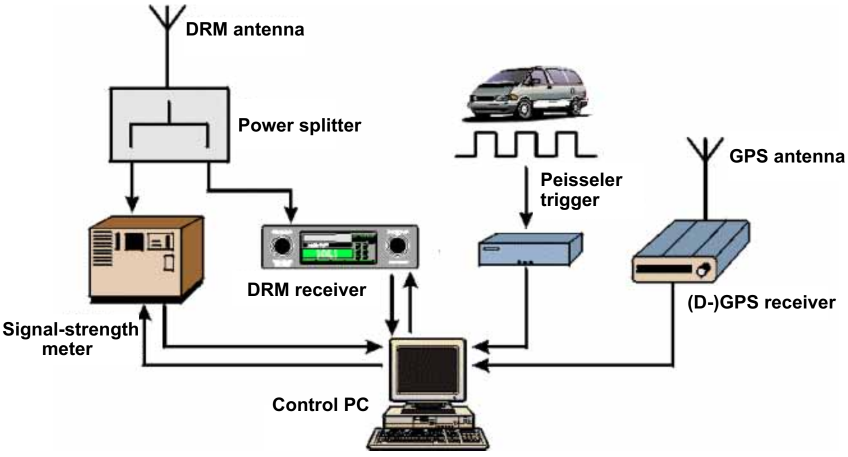

Figure 9
Block diagram of DRM reception-measuring equipment installed in T-Systems van

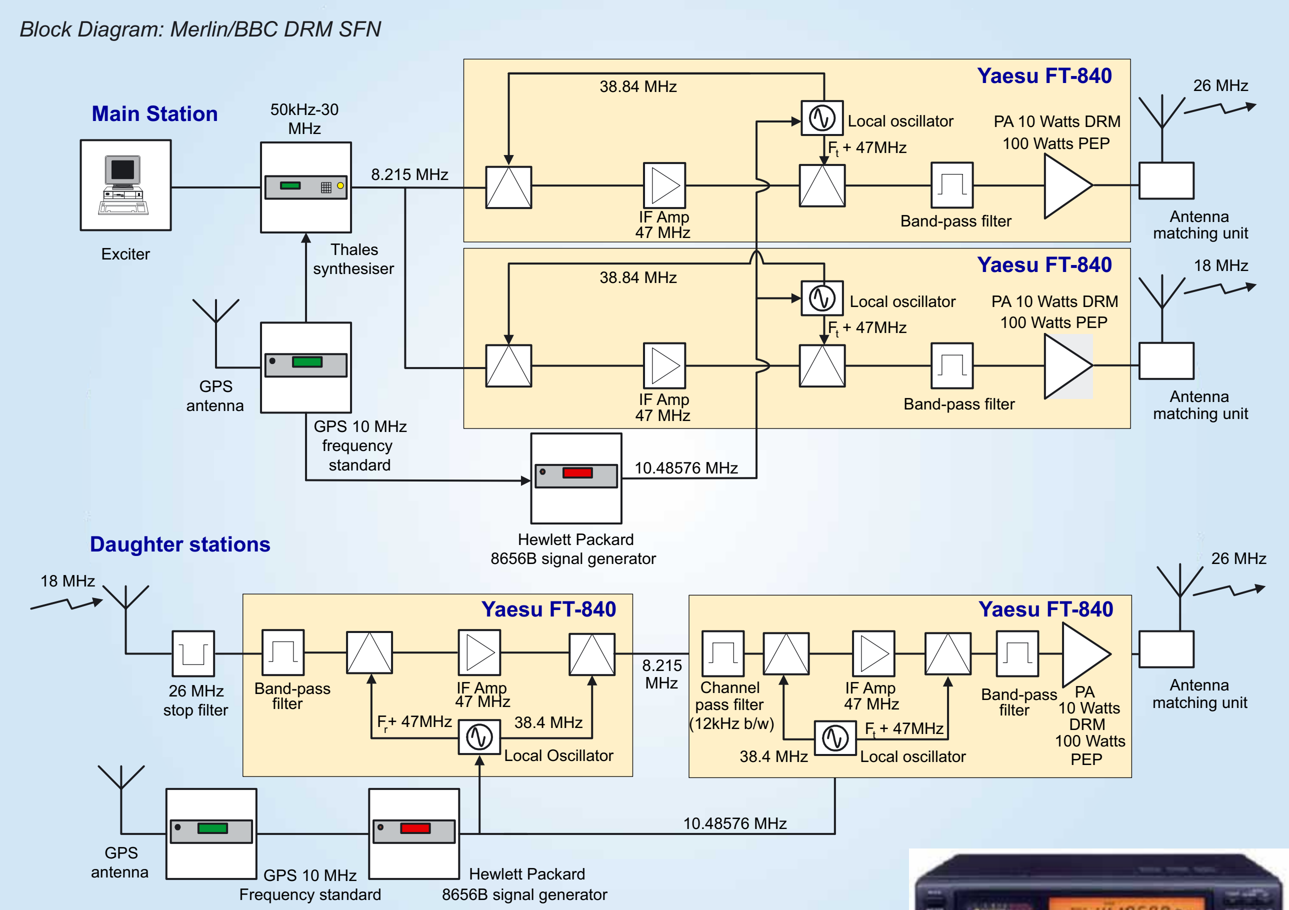

Figure 11
Block diagram of the transmitter/transposer arrangement

Figure 10: Yaesu FT 840 transceiver

A further series of SFN tests was run in parallel with the Berlin tests, but using a smaller SFN, based on lower-powered transmitters (each providing approximately 10 W average DRM power) operating in the 25/26 MHz band. These tests were carried out in Dorset, UK, by VT Merlin Communications and the BBC.

A commercial amateur radio transceiver, the Yaesu FT840 *(Fig. 10)*, was chosen as the building block for the transmitters/transposers *(Fig. 11)*. This receiver is a proven design, readily available, at low cost (€ 1000).

One site (the main site) was at VT Merlin Communications' high power HF transmitting station at Rampisham; the other two transposer sites were placed about 10 km away from this main site.

A test and measurement vehicle was used to collect data from around the transmitter sites. The vehicle route led mainly through rural terrain, but also passed through a number of villages *(Fig. 12)*. The fastest section of the route allowed speeds of 110 km per hour. Numerous power lines cross the route, mostly at 11 kV but also a few at 33 kV.

It was observed that mode A generally had a higher coverage area for a single transmitter and fixed output

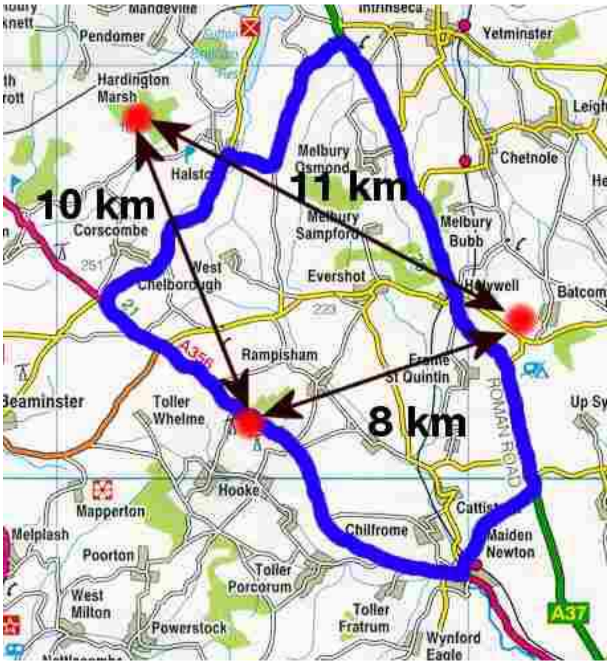

Figure 12
Map of transmitter sites (red dots) and vehicle route (blue line)

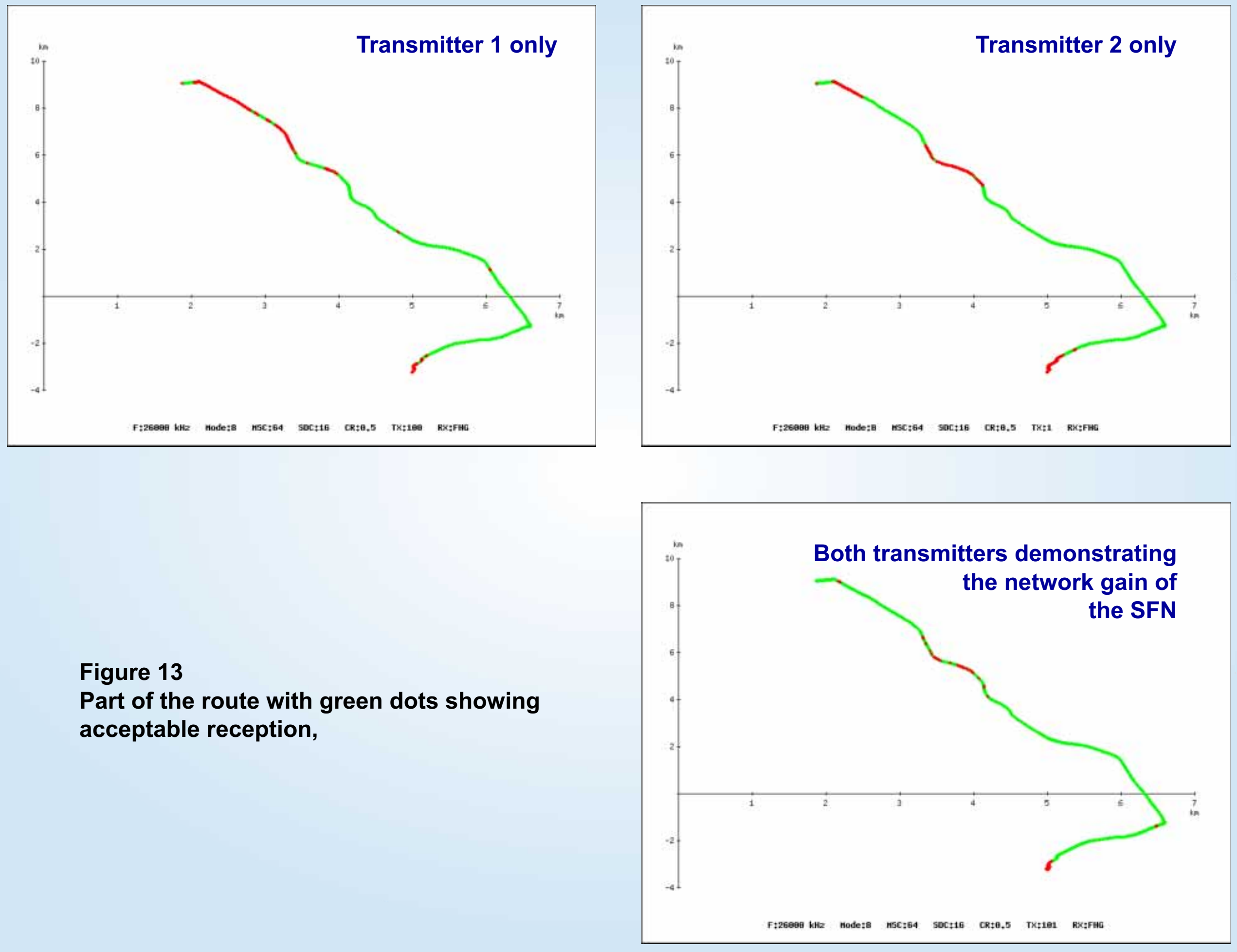

Figure 13
Part of the route with green dots showing acceptable reception,

power, when compared to mode B. The difference was typically 2 - 4% extra coverage for mode A. The explanation for this observed effect could be that mode A has a smaller proportion of boosted pilot cells and, consequently, the signal-to-noise ratio on the data cells is higher for a given overall SNR.

During the tests with two and three transmitters working, there was no observed effect on reception due to the vehicle speed. Although speed was limited over much of the route to 60 km/h, some sections of the route used a four-lane road where sustained speeds of over 110 km/h were attained. This lack of observed effect on reception, due to vehicle speed, agreed with the Berlin SFN tests.

The last phase of tests concentrated on the overlap area between two transmitters. These tests showed that a network gain could be achieved; an area that was poorly served by each of two transmitters operating alone was well served when both transmitters were switched on together *(see Fig. 13)*. However, in order to achieve this improvement, a relative delay had to be introduced between the signals radiated from the two transmitters. Without this delay, a network loss was incurred, so that an area that was covered by each transmitter on its own was not served when both were operated simultaneously. Experiments confirmed that this was due to flat fading, which became frequency-selective fading when a sufficient delay was introduced. Flat fading appears to be more difficult to deal with than selective fading, even though the data interleaving might be expected to mitigate it, at the vehicle speeds involved here. In this phase, mode B gave generally better performance than mode A. This is probably because it has more Doppler resistance, giving better performance in time-varying channels.

Long-term tests

Regular daily test transmissions have now been on-air since December 2001. Progressively, the hours have been built up from a few hours a day to 184 hours a day (using 16 transmission sites) as at July 2003.

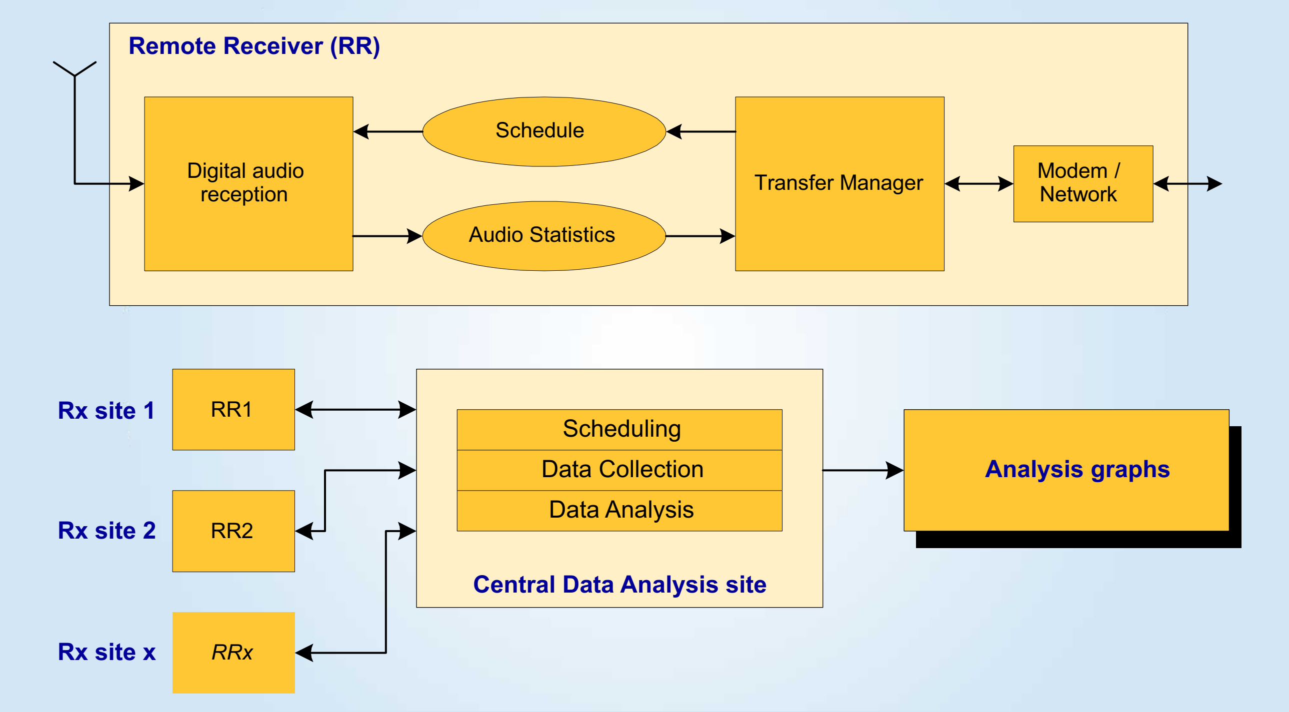

Figure 14
Overview of automatic collection of reception data

With a vast amount of reception data available from these many transmissions, it was sensible to automate the reception and logging process *(Fig. 14)*. DRM receivers across Europe are now used to gather the reception data automatically. The receivers upload their individual schedule files every five minutes.

The receivers then follow this schedule, and output the reception data which is automatically condensed into a tabular format to minimize network bandwidth requirements and database size. This minute-by-minute summary of the transmission is then uploaded to a central database for further analysis. Up to July 2003, the database had collected over 50,000 entries. If a particular transmission is identified that requires in-depth analysis, then the receivers can be scheduled to output detailed statistics every 400 ms, or even to record the baseband I/Q signals.

Normally the results are presented in a tabular format *(Table 5)*. This table summarizes the reception statistics obtained from ten DRM receivers tuned to the 10 kW Bonaire transmitter on 19th July 2002, over the time interval 05:30 - 06:30 UTC . *Table 4* explains the symbols used in *Table 5*. Note that < ` > represents 100% of the audio frames received during a particular minute, whilst the numbers < 1 to 5 >, the < – > and the < _ > symbols indicate a loss of frames.

Table 4
Explanation of the symbols used in *Table 5*

% of audio frames received OK	Total dropout length	Symbol
0.0% - 10.0%	54 sec - 60 sec	_
10.0% - 90.0%	6 sec - 54 sec	-
90.0% - 91.6%	5 sec - 6 sec	5
91.6% - 93.3%	4 sec - 5 sec	4
93.3% - 95.0%	3 sec - 4 sec	3
95.0% - 96.6%	2 sec - 3 sec	2
96.6% - 98.3%	1 sec - 2 sec	1
98.3% - 99.9%	0 sec - 1 sec	*
100%	0 sec	`

Table 5
Summary of reception results from 10 receivers for a transmission from Bonaire

05:30-06:30 Fri 19th July Mode:B MSC:16 SDC:4 Prot:A0/B1 14480 bps 11655 kHz													
Rx name	**Quality (%)**		**AudioQ > 0%: MER**	**AudioQ = 100%: MER**				**Signal (dbmV)**			**Delay90 (ms)**		
	Slot	**Audio**	**10% (dB)**	**10%**	**Med**	**90%**	**(dB)**	**10%**	**Med**	**90%**	**10%**	**Med**	**90%**
BBC1	100.0	100.0	9	9	24	28		34	41	48	1.3	2.1	3.6
BBC3	100.0	100.0	23	24	27	27		35	41	47			
DW1	99.7	99.9	23	24	25	27		43	48	58			
DW2	100.0	100.0	-1	2	19	22		-	-	-			
FhG1	84.4	84.1	1	22	23	26		23	28	45			
RNW1	0.0	0.0		-	-	-		3	13	35			
RNW2	100.0	100.0	-3	-3	15	19		-	-	-			
RNW3	99.9	99.9	21	21	24	26		32	38	46			
TSY1	99.9	99.9	18	19	20	21		43	45	53			
ULM1	93.9	93.8	13	20	23	25		30	37	60			

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BBC1  ````````````````````````````````````````````````````````````
BBC3  ``````````````````1*````````````````````````````````````````
DW1   -```````````````1*``````````````````````````````````````````
DW2   ``````````````````**````````````````````````````````````````
FhG1  ```````````**-----_-`---____-`````````````````````*`````````
RNW1  ____________________________________________________________
RNW2  ``````````````````**````````````````````````````````````````
RNW3  ``````````````````1*````````````````````````````````````````
TSY1  `````````````***`**``****```````````````````````````````````
ULM1  ```````````````*-___**3-****````1`````````````````*``*``````
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In *Table 5* it can be seen that receiver "BBC1" showed perfect reception, whilst receiver "RNW1" seems to have been faulty (it was co-sited with "RNW2" and "RNW3"). Many receivers lost some audio frames between 05:43 UTC and 06:00. This could have been due to signal fading or interference. In practice, the receiver could easily conceal these occasionally erroneous audio frames.

Abbreviations

16-QAM	16-state Quadrature Amplitude Modulation
64-QAM	64-state Quadrature Amplitude Modulation
AM	Amplitude Modulation
DAB	Digital Audio Broadcasting (Eureka-147)
DRM	Digital Radio Mondiale
ETSI	European Telecommunication Standards Institute
FM	Frequency Modulation
GPS	Global Positioning System
I/Q	In-phase/Quadrature
ICI	Inter-Carrier Interference
IEC	International Electrotechnical Commission
IF	Intermediate-Frequency
ISI	Inter-Symbol Interference
ITU	International Telecommunication Union
MDI	Multiplex Distribution Interface
MF	Medium-Frequency
NVIS	Near-Vertical Incidence Sky-wave
OFDM	Orthogonal Frequency Division Multiplex
QoSAM	Quality of Services in digital AM
QPSK	Quadrature (Quaternary) Phase-Shift Keying
RDS	Radio Data System
SFN	Single-Frequency Network
SNR	Signal-to-Noise Ratio
UTC	Universal Time Co-ordinated
VHF	Very High Frequency

James Briggs studied Chemistry at Exeter University, graduating with honours in 1988. He then joined the BBC Transmission Department, qualifying in Transmission Engineering at the BBC training college at Wood Norton, Evesham, in May 1991. He then worked for BBC Transmission throughout the Southeast region of England and was involved in the installation of prototype DAB equipment in 1994.

When the BBC Transmission Department was privatised in 1997, Mr Briggs transferred to the newly formed Merlin Communications. In January 2000, he started working full-time on the DRM project, and was appointed Coordinator of the DRM Radiate field trials in July 2001. He is the vice chairman of the DRM Systems Evaluation group.

Conclusions

The DRM field tests have been a very worthwhile exercise. The tests uncovered problems and allowed improvements to be addressed before the final system specification was set.

Receiver design evolved throughout the trials, often as a result of shortcomings observed during the tests. The developments and performance improvements made to the test receivers can be directly applied to optimizing the performance of future consumer receivers.

The field trials also made a significant contribution to the standardization of DRM. In just five years, the system has rapidly moved from concept to IEC, ETSI and ITU standards.

Following the launch of inaugural DRM transmissions in June 2003, we now look forward to the next step: the appearance of the first consumer receivers.

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