DIGITAL RADIO MONDIALE (DRM)

A BROADCASTER'S GUIDE

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DIGITAL radio mondiale

A Broadcaster's Guide to
the DRM Digital Broadcasting System

PREFACE

This guide is aimed at the management of broadcasting organisations in areas of policy making as well as in programme making and technical planning. It explains in some detail the advantages gained by radio broadcasters introducing the Digital Radio Mondiale (DRM) technology and some of the technical and commercial considerations they need to take into account in formulating a strategy for its introduction.

The Digital Radio Mondiale (DRM) Consortium is **an international not-for-profit organisation** composed of broadcasters, network providers, transmitter and receiver manufacturers, universities, broadcasting unions and research institutes. Its aim is to support and spread a digital broadcasting system suitable for use in all the frequency bands up to VHF Band III. As of 2009/10 there are 93 members and 90 Supporters from 39 countries active within the Consortium.

DRM was formed in Guangzhou, China in 1998, initially with the objective of "digitising" the AM broadcast bands up to 30MHz (long, medium and short-wave). The DRM System Specification for broadcasting below 30MHz ("DRM30") was first published by ETSI in 2001, followed by an ITU Recommendation mandating the use of the system for digital radio broadcasting internationally.[26]

Subsequently, a number of ancillary supporting standards were issued, including a Distribution and Communication Protocol for long-distance multiplex-delivery to transmitter sites. In 2005 a decision was taken to extend the DRM system to operate in the VHF broadcast bands, known as "DRM+". This required additional development work in order to define the new VHF mode, which, following refinement through laboratory testing and field-trials, culminated in the publication of the current (extended) DRM specification ES 201 980.

A full list of DRM standards and specifications is available on-line at www.drm.org. A summary list is also included in Annex 1.

Readers looking for greater technical detail should refer to published information that covers various specialised aspects of the DRM system and which provides detailed explanations of its operation. The most important ones are noted in Section 11 or are listed on the DRM website: www.drm.org.

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2.1 WHAT IS DRM?

The DRM Broadcasting system has been developed specifically as a high quality digital replacement for analogue radio broadcasting in the AM and FM/VHF bands, and as such it can be operated with the same channelling and spectrum allocations as currently employed. An overview of the frequency-bands where DRM operates is shown in Figure 1 below. It has been designed by broadcasters, for broadcasters, but with the active assistance and participation of both transmitter and receiver manufacturers and other interested parties (such as regulatory bodies).

The DRM standard describes a number of different **operating modes,** which may be broadly split into two groups as follows:

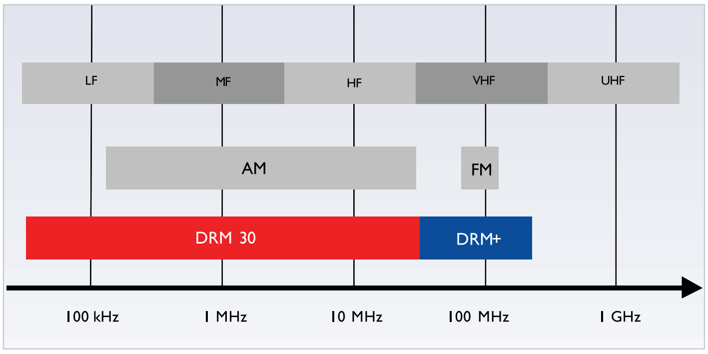

Figure 1 Frequency Band Overview

- "DRM30" modes, which are specifically designed to utilise the AM broadcast bands below 30MHz and
- "DRM+" modes, which utilise the spectrum from 30MHz to VHF Band III, centred on the FM broadcast band (Band II).

DRM has received the necessary recommendations from the ITU, hence providing the international regulatory support for transmissions to take place. The main DRM standard [1] has been published by ETSI. In addition ETSI publishes and is the repository of the entire range of current DRM technical standards.

Apart from the ability to fit in with existing spectrum requirements, the DRM system also benefits from being an **open system**[1]. All manufacturers and interested parties have free access to complete technical standards, and are able to design and manufacture equipment on an equitable basis. This has proved to be an important mechanism for ensuring the timely introduction of new systems to the market and for accelerating the rate at which equipment prices reduce. In addition, this approach creates confidence for the long-term stability and accessibility of such an open standard compared, for example, to proprietary technologies controlled by individual companies. This is a significant consideration for broadcasters and regulatory bodies, and even more so for entrepreneurs and manufacturers who wish to invest in and develop DRM infrastructure.

2.2 WHY GO DIGITAL?

The introduction of DRM services allows a broadcaster to provide listeners with significant improvements in service reliability, audio quality and, most importantly, **usability.** By usability we mean those features which enhance the listener experience, as outlined below.

The DRM standard provides many features and facilities which are impossible to replicate in analogue broadcasting. It is essential that prospective broadcasters understand the potential and flexibility of the system in order to allow them to optimise and configure their DRM networks in accordance with their particular market conditions.

From a **technical perspective,** a key and revolutionary feature of DRM is the ability to select from a range of transmission modes. This allows the broadcasters to balance or exchange bit-rate capacity, signal robustness, transmission power and coverage. What's more, it is possible to do this dynamically, in response to any local changes in the environment, without disturbing the audience. A classic problem which can be mitigated by this feature is dealing with night-time sky-wave interference in the AM bands.

From a **commercial perspective,** there is no demand from audiences to "consume" digital services for their own sake. It is essential therefore that the audience is presented both with receivers at prices it is prepared to pay and, more importantly, an attractive package of benefits:

- The availability of a wider range of services.
- Easier tuning and selection of programming – e.g. automatic switching between different transmitters or electronic programme guides.
- Improved formats such as stereo in the "AM bands" and surround-sound in cars.
- Improved and more consistent sound quality.
- Programme-associated data, textual content description or even independent services such as traffic information.

[1] An **open system** or standard is one in which a complete system description is openly published with sufficient technical detail to allow a manufacturer to implement the whole or part of the broadcast chain.

The importance of quality content, while outside the scope of this guide, cannot be stressed too highly. Subsequent sections of this guide provide more detailed information on these enhancements.

2.3 KEY SYSTEM FEATURES

The system is specifically designed to allow the new **digital transmissions to co-exist with the current analogue broadcasts,** and a significant amount of work has been undertaken to quantify the operating parameters which assure mutual analogue/digital compatibility. Furthermore, suitable analogue transmitters can be modified to switch easily between digital and analogue broadcasts. This can **significantly reduce the initial investment** cost for a broadcaster. An additional budgetary benefit is the **reduction of transmission energy costs** (see Figure 1a) DRM exploits the unique propagation properties of the **AM bands.** The introduction of DRM30 services allows a broadcaster to provide listeners with **significantly improved audio quality** and signal robustness. As a result, international broadcasters can provide services on SW and MW with an audio quality comparable to local FM services, whilst **enhancing the listener experience** with easier tuning and added data services. National and local LF and MF broadcasters will derive similar benefits.

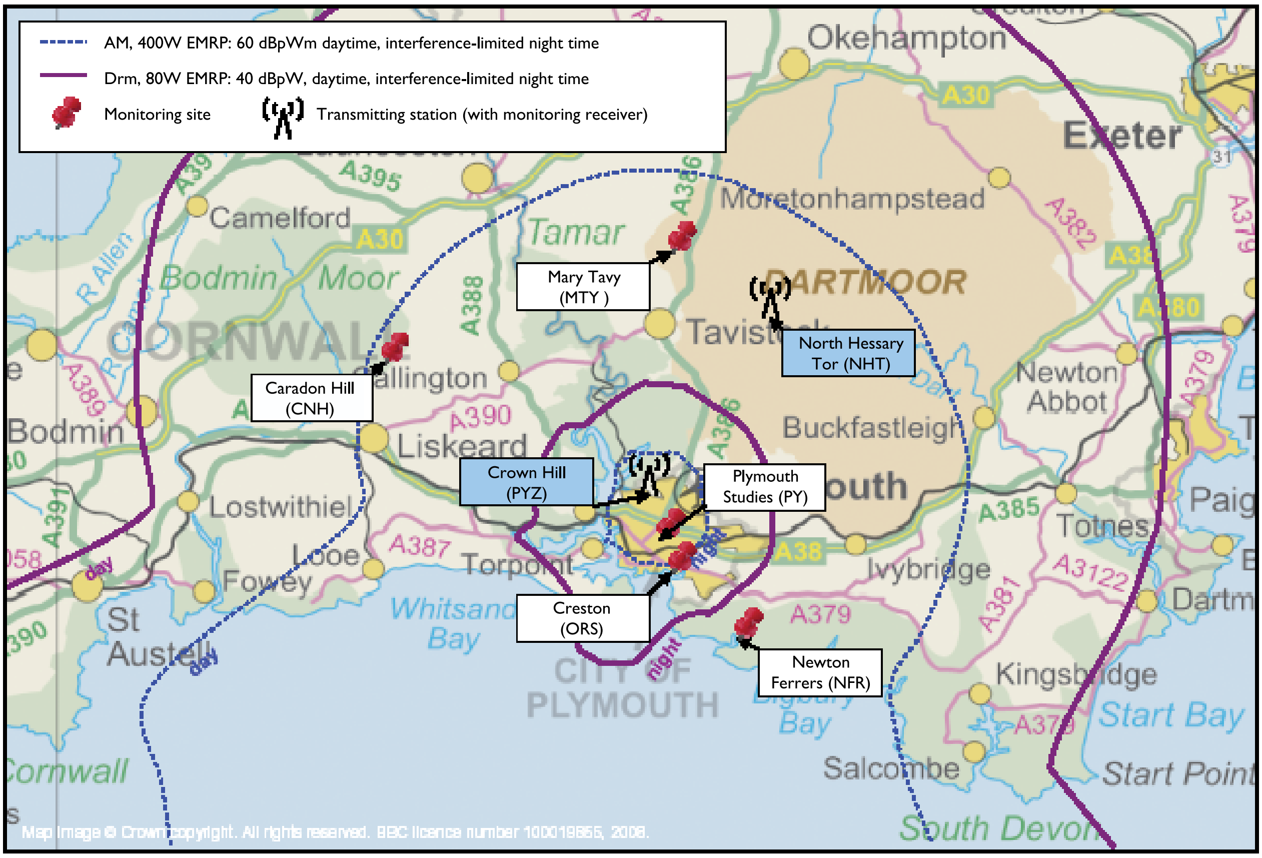

Figure 1a Illustration of the potential increase in coverage together with reduced transmission power for a local DRM service operating at MF.

In the **VHF bands**, DRM can be configured to use fewer spectrums than current stereo FM broadcasts, whilst additionally deriving the potential benefits of **increased robustness, reduced transmission power** and/or **increased coverage.**

DRM is unique in providing an extensive and extremely powerful array of operating modes, which allow a broadcaster to tailor the system to best meet the needs of his or her particular market. For instance, DRM allows the independent selection of modulation parameters (code-rates, constellation, guard-intervals etc.) to enable an optimum **trade-off between** capacity and **signal robustness.** DRM also supports both multi and single-frequency network operation, (MFN/SFN), **hand-over to other frequencies and even other networks** (AFS – Automatic Frequency Checking & Switching). This latter feature allows a broadcaster operating on several different platforms to hand a listener from DRM to AM, FM or DAB and back again. The appropriate signalling is intrinsically supported by DRM and DAB, and by data carriers on AM and FM (AMSS and RDS respectively).

[1] Annex 4 contains an overview of DRM 30 field-trials carried out over recent years

Of particular note amongst the various data services is the **DRM Electronic Programme Guide** (EPG), which allows listeners with appropriate receivers to access the broadcast schedule and set recording times accordingly, and **Journaline** – accompanying audio programmes with interactive textual information like news or graphics.

DRM is being operated at power levels ranging from a few watts through to several hundred kilowatts. It is possible to utilise the one technical standard to provide coverage ranging from international, national, regional and city all the way down to single-km radius suitable for local community radio[1].

Finally, the MPEG-4 HE-AAC v2 audio codec is included within the standard, encompassing a wide range of bit-rates, allowing for **stereo broadcast even in the AM bands**, and optionally providing stereo-compatible 5.1 surround sound. DRM30, in addition, supports two MPEG-4 speech-only codecs for very low bit-rates.

INTRODUCTION

3

3 INTRODUCTION

3.1 THE OBJECTIVES OF THIS GUIDE

This document is written primarily as a guide to any broadcaster who wants to contemplate transition from analogue to digital broadcast in the AM and VHF broadcasting bands. It will also be of interest to manufacturers, service-planners, administrations and regulatory bodies involved with broadcasting systems and/or policy. The document is intended to:

- Explain how and why a broadcaster might go digital, from both technical and commercial perspectives.
- Describe the basic operation of the DRM system and its many features.
- Provide a definitive source of references to key technical standards, including regulatory, co-ordination and planning information for DRM broadcasting.
- Supplement various existing documents, as appropriate.
- Provide additional information based on the practical experiences and know-how of DRM members, broadcasters and supporters.

3.2 WHAT'S INCLUDED IN THIS GUIDE?

This guide provides more detailed information on both the techniques described above and other useful features, such as bespoke commercial applications designed to run on the DRM platform.The techniques are generally applicable equally to international, national and local services.

This document addresses the following aspects of the DRM system in particular and Digital Radio in general:

- **Launching Digital Radio:** Includes a summary of the critical success factors and lessons learnt by broadcasters who have migrated and launched digital radio services.

- **DRM Technology:** Description of the broadcast chain and main features of the DRM System, followed by a look at the options for tailoring a DRM system to broadcasters' requirements. The DRM System section also introduces multi and single - frequency networks, alternative- frequency signalling and DRM simulcast options.

- **DRM Content:** This section covers all aspects of DRM content, from essential meta-data relating to receiver tuning through audio coding and quality issues, to finally, an overview of value - added services.

- **Broadcast Network Infrastructure:** It contains a description the broadcast network from studio output through to the radiated signal. This section includes a wealth of practical knowledge related to DRM transmitters, adapting AM transmitters for DRM, transmitter specifications and antenna systems. Also covered is programme distribution, network synchronisation and information relating to transmitter measurements and monitoring equipment.

- **DRM receivers:** It provides an overview of DRM receiver technology and relevant specifications.

- **Regulatory aspects and service planning:** Information on how DRM services may be introduced into the bands with respect to the HFCC planning process in the SW bands, and the existing Regional Plans covering the LW and MW or higher frequency bands. Specialised applications such as NVIS (Near Vertical Incidence Sky-wave) and SFN (Single Frequency Networks) are also explained here. Information is also included here, on how transmissions may be monitored in order to verify coverage.

- **IPR:** A description of DRM branding and logos, together with a description of the DRM technology licensing process.
- **Appendices:** Further technical descriptions of the DRM system and related technology, together with references to published articles.

LAUNCHING DIGITAL RADIO SERVICES

4


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4 LAUNCHING DIGITAL RADIO SERVICES

4.1 INTRODUCTION

Building a digital radio network is relatively easy. Migrating listeners and/or building an audience from scratch is a significant challenge. Over the last decade this has been amply demonstrated in a diversity of markets and driven by both public and commercial radio consortia. It is instructive to examine the underlying reasons for this situation, and indeed for those markets where digital radio has achieved some success, much analysis has already been undertaken to understand both the mistakes made and the critical success factors involved. These are summarised in section 4.2 below.

4.2 CRITICAL SUCCESS FACTORS FOR DIGITAL RADIO

Several factors have all been identified as key determinants to success in building an audience on digital radio. The principal challenge lies in getting digital receivers into the market in volume. Inevitably, for a new technology, we're starting from an installed-receiver base of zero. Consumers need to be initially made aware that exciting new services are on-air, and then be told how they can receive them. These are marketing issues.

The approach taken by an individual broadcaster will clearly be dependant on a number of factors, not least the budget available, access to broadcast spectrum, the nature, competitiveness maturity of the local radio market and the demographics of the target audience.

4.2.1 Working Together Promotes Success

All the stake-holders need to be co-ordinated and committed to the launch of digital radio services to reduce overall risk. Factors which are crucial to ensuring success include:

- Regulatory incentives and support from the local administration.
- Ideally, all broadcasters operating in the same region (both commercial and public service) participating in the launch, or at least a grouping with sufficient resources to launch a critical mass of new services.
- Similarly, the full engagement of transmission providers and crucially, retailers and receiver manufacturers.

Getting the whole process started involves a series of logical conditions to be met. These feed back "positively" in a loop which fundamentally requires the broadcaster to take the initiative:

Consumers won't buy new radio products unless there is a compelling reason to buy (exciting new content, "must have" added-value services or features etc.).

↓

Retailers won't stock new products unless they can see consumer demand.

↓

Manufacturers will not produce radios without retailers' orders.

↓

All too frequently, a broadcaster will not launch new digital services due to an absence of digital radios or very low market penetration.

In some countries this process is aided and the loop "booted" through the formation of one or more National Platforms, where plans are developed and co-ordinated and funding agreed.

4.2.2 Consumers Need A Reason To Buy

The most powerful driver found to date is access to new content. There are other drivers, for instance, launching services with an absence of advertising into a market where such advertising is perceived as intrusive by a large section of the audience. Additionally,

- Benefits need to match price of entry.
- Improved quality has only marginal attraction:- There may be some examples where this does assist take-up, but it is very much a secondary factor.

4.2.3 Technology Solutions Need To Be Readily Available

- It goes without saying that the receiver industry must play its part in ensuring that products are available at the right moment and at the right price-point. Creating a strong initial demand through appropriate marketing assists in raising volumes and reducing costs.

4.2.4 Marketing Needs To Be Right

- It is essential that the marketing of the new services is sustained and high-profile. Existing broadcasters can use their own media to cross-promote: TV, radio and on-line. Competitions can be held with prizes of digital radios. Using creative scheduling, it is possible to entice people to use digital services by, for example, pre-releasing prime content on digital ahead of analogue or vice-versa, using the digital service to repeat programmes which were missed the first time round.

It is important that all stakeholders play their part for the greater good. Each party may perceive high risks (though not at the same time): a collaborative model reduces these risks as far as possible and should lead more quickly to success.

4.3 DIGITAL MIGRATION

The DRM system was specifically designed to align with and make sure of current analogue spectrum allocations to co-exist with current analogue broadcasts[2]. This allows broadcasters to make the required investment on a timescale which meets their budgetary needs. It will ensure that expensively acquired and perfectly satisfactory transmission equipment and infrastructure is not suddenly made obsolete. Suitable analogue transmitters can be modified to switch between digital and analogue broadcasts, further reducing the initial investment required for a broadcaster wishing to migrate to DRM. This in turn allows broadcasters to focus their capital resources on new content and services. Additionally, the reduction of the transmitting energy costs allows additional revenue savings which can be ploughed back into programming.

Apart from the ability to fit in with existing spectrum requirements, the DRM system also benefits from being an "open" system, allowing any manufacturer to design and manufacture equipment on an equitable basis. This has proved, in the recent past, to be an important mechanism for ensuring the timely introduction to the market of new systems and for accelerating the rate at which equipment prices reduce. This is a significant consideration for broadcasters but even more so for the millions of listeners who will need to invest in new, DRM-capable receivers.

4.4 MIGRATION POLICY AND CHOICE OF TECHNOLOGY

It is clearly important for any administration regulating broadcasting to choose the systems used for digital broadcasting, both radio and TV, in order to avoid consumer confusion and a proliferation of standards. It also avoids the premature writing-off of investments made by broadcasters in the "wrong" technology.

Factors which might become of greater importance in the 21st century include:

- **Energy constraints:** Choice of system to minimise power consumption in both transmitters and consumer receivers. Efficient network planning and robust transmission parameters play a key part, optimising coverage and avoiding excessive transmitter power levels.
- **Economic and social benefits** which might flow from, for instance, the provision of universal real-time traffic information, or local design and manufacture of digital receivers.
- **Control of long-term costs** through a full knowledge of royalty charges and the ability to design and manufacture locally, free of operating licenses, trade secrets and similar barriers to a fully-competitive open market.
- **Market Regulation** which works toward the common-good, and avoids the disenfranchisement of some listeners and/or broadcasters. For instance, this might include the requirement to co-site transmitters to avoid local "holes" being punched in the service area of other radio stations and a mandate that radio receivers should incorporate all relevant standards used for radio within the territory.

4.5 MIGRATION STRATEGIES

Many creative solutions have been proposed which address the issue of how to initially launch a new digital service when there are no receivers in the market.

4.5.1 "Market Seeding"

The most radical example of this technique requires an up-front investment in receivers: the broadcaster places an order for a large quantity of digital receivers, which are then either given to consumers or sold with a significant discount. One broadcaster proposed purchasing 500,000 receivers, and free-issuing to taxi-cabs, retails outlets and domestic consumers. This strategy yields a low initial receiver cost, combined with the ability to guarantee potential advertisers a sizeable audience from day one.

4.5.2 "Trojan Horse"

The Trojan Horse approach to digital migration has the potential to seed the market with digital radios ahead of a formal digital radio service. This serves as a catalyst to the launch process and boots the positive feedback loop described earlier. The technique is simply to introduce and market new "analogue" receivers which include some new or distinctive features which are either intrinsic to the radio itself (e.g. recording-to-memory, radical styling), and/or can be readily supported by existing broadcasts (some RDS or AMSS data service, etc.).

These new radios also support DRM, but initially this is not the key feature used for marketing; the DRM function is "hidden", and hence the term "Trojan Horse". In this scenario, it is clearly vital to have a medium-term strategy agreed and co-ordinated with the receiver manufacturers. Once sales have reached some target, digital services can be launched to an audience which is ready-equipped with receivers.

[2] DRM30 modes have received the necessary mandate for use in the AM bands worldwide by way of ITU recommendations, and these provide the international regulatory basis upon which transmissions may take place.

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THE DRM SYSTEM

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5 THE DRM SYSTEM

This section includes a brief description of some of the more important features and supported services of the DRM system, followed by an overview of the main components found in the broadcast chain.

5.1 PRINCIPLE FEATURES

From a broadcaster's perspective, DRM offers a wealth of features and a powerful array of options. For instance, DRM provides support for:

- Broadcasting in all the AM and FM bands extending from 150kHz through to VHF Band III.
- Migration from and co-existence with analogue broadcasting: Complies with existing spectrum masks and analogue frequency grids.
- Up to four services per frequency, each of which can be any mixture of audio and data.
- Single-frequency and multi-frequency networks, plus associated signalling and automated receiver tuning.
- A choice of three audio coders supporting bit-rates from 2kB/s upwards.
- Text-messaging, slide-shows, multi-media object transmission, traffic and news headlines and a wide range of similar value-added services.

DRM additionally offers assistance to broadcasters and manufacturers by virtue of publishing an extensive range of open standards[3] which support the main system standard [1]

Above all else, however, DRM is designed to improve the listener experience through a combination of improved usability, improved audio quality and data-enhancements to the audio content.

5.2 THE BROADCAST CHAIN

Fig 5.2 shows a very simple "single-service, dual transmitter" broadcast chain and depicts the general flow of different classes of information (audio, data, etc.) from their origination in a studio or control centre on the left of the figure to a DRM receiver on the right.

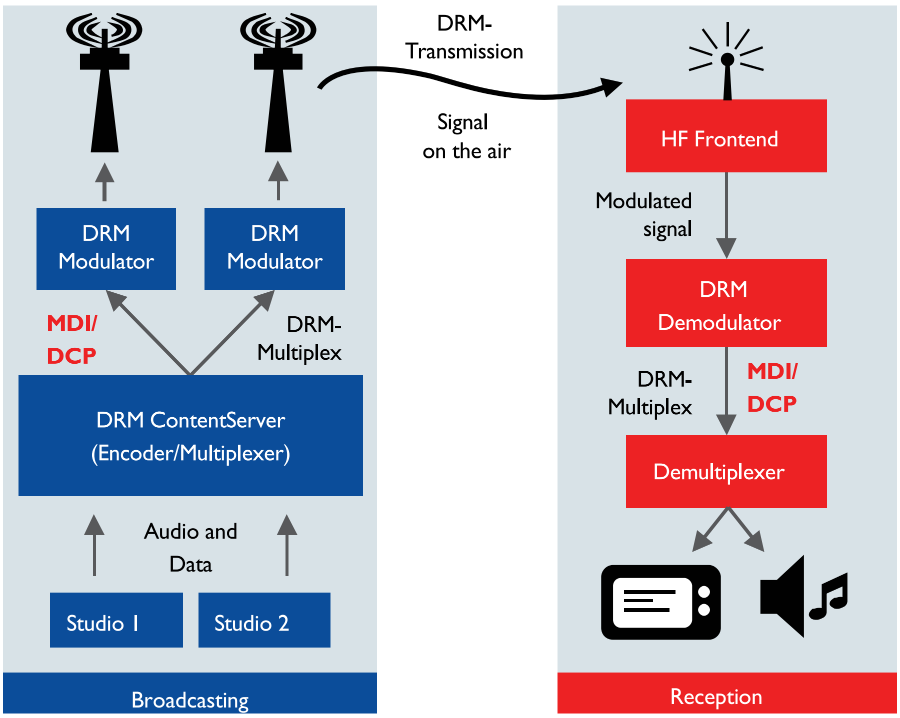

Figure 5.2 Simple DRM Broadcast chain

In the following sections we will examine the operation of the two main functional blocks shown above: The Content Server and the Modulator. In most (but not all) installations, these functional blocks correspond to commercially-available products. They communicate via a Multiplex Distribution Interface (MDI) over a Distribution and Communications Protocol (DCP), both of which have been standardised [3], [2].

[3] See Annex 1

5.2.1 DRM content encoding and Multiplexing

These functions may be integrated into a product which is known as a Content Server (Figure 5.2a).

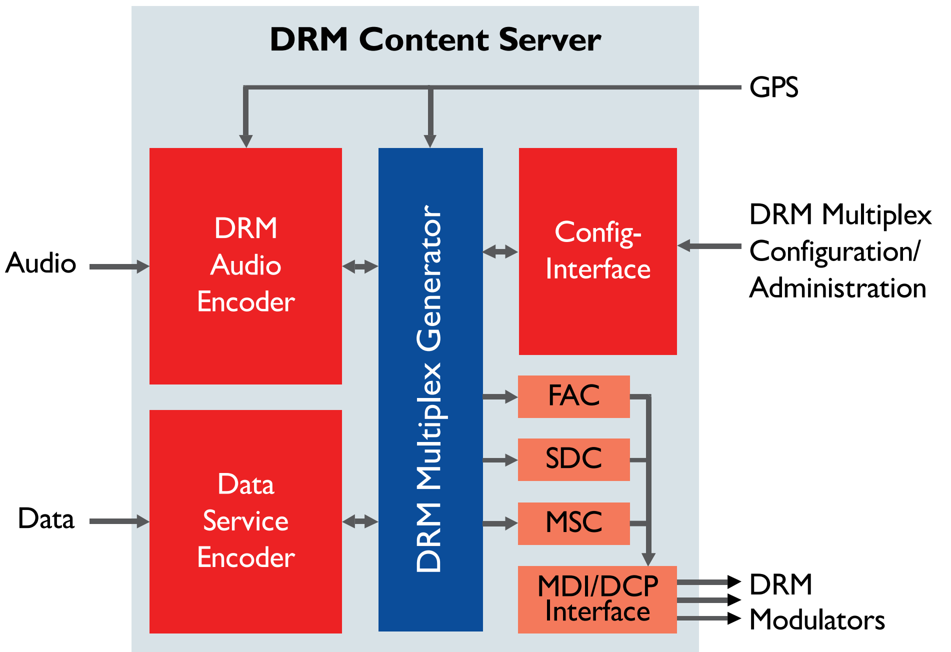

Figure 5.2a DRM Content encoding and Multiplexing

Setting aside local control and command interfaces, there are two basic classes of input information:

i. The encoded audio and broadcast data services which form the Main Service Channel (MSC).

ii. Information which travels via the Fast Access Channel (FAC) and Service Description Channel (SDC). These channels communicate service identification and parameter selection for a transmission and ensure that the appropriate decoding parameters are selected within a receiver.

- The FAC contains a set of core parameters required to quickly check for available services within a multiplex and to allow de-modulation of the DRM signal.

- The SDC carries advanced information like audio and data coding parameters, service labels, current time and date, AFS tables (Alternative Frequency Signalling), etc.

The audio encoder and the data encoders ensure the adaptation of the input streams into an appropriate digital format. The output of these encoders may optionally comprise a higher and a lower protected part, each of which will be given one of two different protection levels within the subsequent channel encoder.

The multiplexer combines the protection levels of all data and audio services, in a defined format, within the frame structure of the bit stream.

If the audio coding and multiplexing is performed remotely from the transmission site (as is the norm), the signal is distributed using the Multiplex Distribution Interface (MDI) protocol, described below.

5.2.2 DRM Distribution

To enable both the audio and data services (together with the associated transmission parameter data) to be combined into one transmission feed, DRM has specified a standardised and efficient method for combining all this data into a single multiplex, known as:

- The **MDI** (Multiplex Distribution Interface - [3]), which in turn employs a standardised protocol.

- The **DCP** (Distribution and Communications Protocol - [2]).

Although the broadcaster is strongly advised to locate the audio encoder and or DRM Content Server at the studio centre, (for the reasons set out under 6.2.2 "Optimising Sound Quality"), there remains the option of distributing the audio to a DRM multiplexer at the transmitter site, in which case the existing programme distribution system would likely be used. There will be additional information required for the operation of the multiplexer, which would not typically be required for, say, an analogue AM service. This information relates to the choice of audio coding (AAC, CELP, HVXC, and SBR), audio data rate, AFS list, transmission Mode (A, B, C, D), modulation (e.g. 16 or 64QAM) and transmission bandwidth, etc. This must be supplied to the multiplexer and encoder to ensure that the correct parameters are used for a particular transmission. This will be particularly relevant to SW transmissions, but less so for "fixed" services on VHF frequencies.

5.2.3 DRM Coding And Modulation

Figure 5.2.3 below shows a simplified block diagram of a DRM modulator. The functions of the various components are described below.

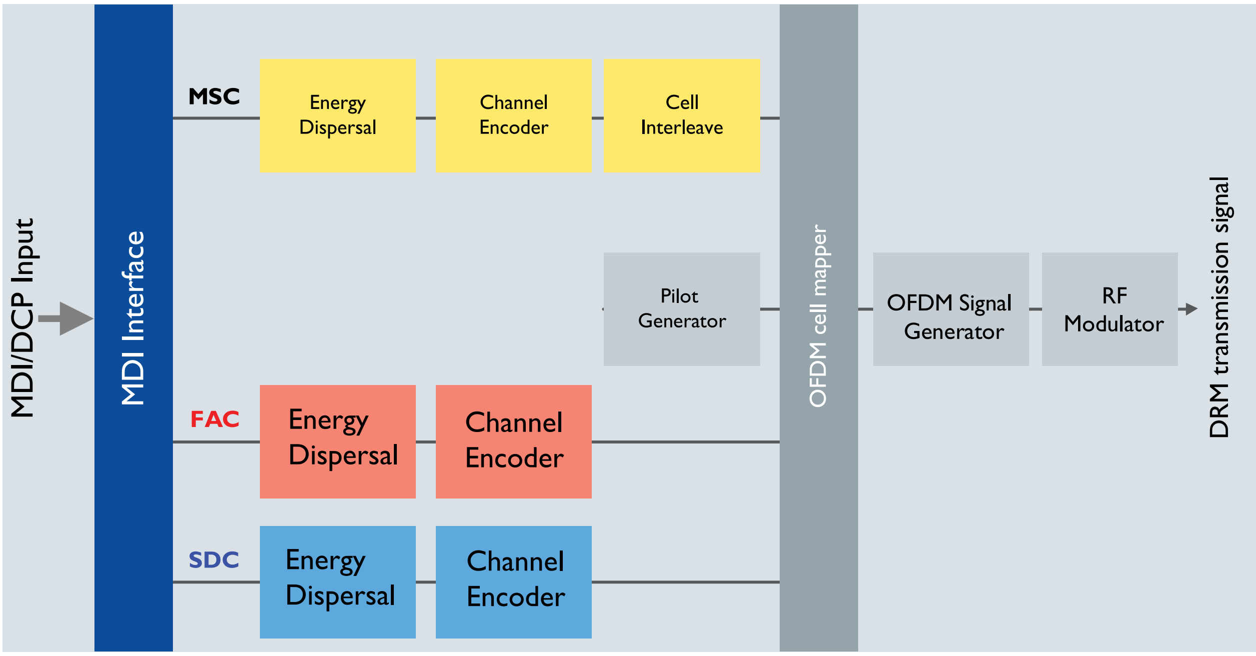

Figure 5.2.3 Conceptual Block diagram of DRM Modulator

- The energy dispersal provides a 'randomising' of the bits that reduces the possibility of unwanted regularity in the transmitted signal.
- The channel encoder adds redundant bits to the data in a defined way, in order to provide a means for error protection and correction, and defines the mapping of the digitally encoded information into QAM cells. These are the basic carriers of the information supplied to the transmitter for modulation.
- Cell interleaving rearranges the time sequence of the signal bits in a systematic way as a means of "scrambling" the signal, so that the final reconstruction of the signal at a receiver will be less affected by fast fading than would be the case if speech or music data were transmitted in its original continuous order.
- The pilot generator injects non-data carriers of prescribed amplitude and phase which permits a receiver to derive channel-equalisation information, thereby allowing coherent demodulation of the signal.
- The OFDM cell-mapper collects the different classes of cells and places them on a time-frequency grid, in effect distributing the information across the sub-carriers.

The output from the Modulation process can take one of several forms:

i. A complex waveform representing the broadcast signal, already modulated onto an IF or RF frequency.

ii. Analogue or digital representations of In-phase and Quadrature base-band signals ("I-Q"): the I-Q signals can then be used to modulate an IF or RF carrier.

iii. Analogue or digital representations of Phase and Amplitude signals, (which can be derived from a transform of the I-Q signals): This signal format is known as "A-RFP".

The A-RFP signal is of particular importance for DRM amplification using the traditional transmitter topography employed by high-efficiency AM transmitters. This is described in greater detail in Section 9.

5.2.4 Broadcast Signal Framing

Figure 5.2.4 shows the framing and temporal relationship between the three basic classes of transmitted data. The scheme employed is governed principally by the requirements of receivers for tuning, re-tuning and content operations.

The data carried in the Fast Access Channel is not time-interleaved, and is confined to a specific group of carriers in the frequency-domain. This enables the receiver to rapidly achieve synchronisation and determine the modulation parameters used for the MSC.

The SDC is broadcast across all carriers for a period of two symbols at the start of each super-frame. This data is normally static and hence repetitious: This allows a fully-synchronised receiver to use this period for alternative frequency switching (see section 5.3.5).

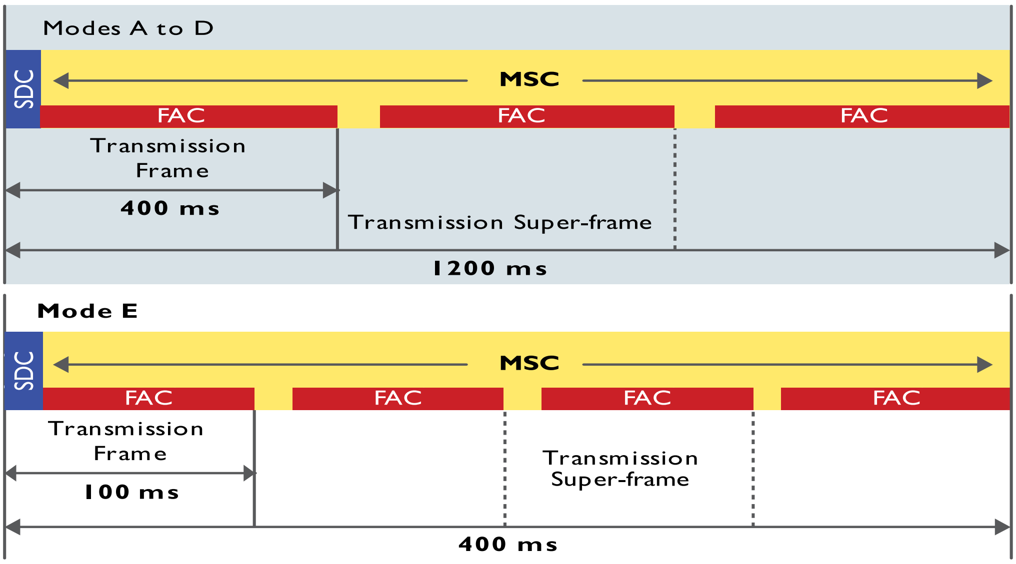

Figure 5.2.4 DRM Frame structure: DRM30 and DRM+ modes

5.2.4.1

The FAC's structure is built around a 400 or 100ms frame (Figure 5.2.4). The FAC is used to provide information on the channel parameters required for the de-modulation of the multiplex as well as basic service selection information for fast scanning.

The channel parameters (for example the spectrum occupancy and interleaving depth) allow a receiver to quickly decode the multiplex: It also contains information about the services in the multiplex which allow the receiver to decide to either decode this multiplex or, if the desired service is not present, to change frequency and search again.

Each transmission frame contains an FAC block. An FAC block contains parameters that describe the channel and parameters to describe either one or two services along with a CRC.

For robustness modes A, B, C and D, the FAC block contains parameters that describe both the channel together with one set of service parameters, along with a CRC.

For robustness mode E, the FAC block is similarly configured but includes two set of service parameters. When more services are carried in the multiplex than can be described within one FAC block, a number of FAC blocks are required to describe all the services. Full details and a description of the FAC structure and contents can be found in Section 6.3 of the DRM specification [1].

5.2.4.2

The SDC contains information on how to decode the MSC, how to find alternative sources of the same data, and gives attributes to the services within the multiplex.

The SDC's frame-periodicity corresponds to the super-frame length (1200 or 400 ms), as defined by the DRM mode. The data capacity of the SDC varies with the spectrum occupancy of the multiplex and other parameters. The SDC capacity can also be increased by making use of the AFS index.

Alternative frequency checking may be achieved, without loss of service, by keeping the data carried in the SDC quasi-static. Therefore, the data in the SDC frames should be carefully managed.

The SDC conveys key data and information, including:

- Multiplex description
- Alternative frequency signalling
- Announcement support and switching
- Time and date information
- Audio information
- FAC channel parameters
- Language and country data
- Signalling of reconfigurations

A comprehensive description of the SDC's structure and many components can be found in Section 6.4 of the DRM specification [1].

5.3 CONFIGURING THE DRM SYSTEM

The following sections describe how the various component parts of the DRM system work together in order to provide a system which can be optimised to meet the broadcaster's specific requirements for quality and number of audio services, data services and service robustness.

5.3.1 Modulation And Coding Parameters

This Section provides an indication of how some of the DRM signal parameter options might be used for typical applications. The following paragraph provides more detail on how these parameter options might best fit the broadcaster's particular coverage requirements.

i. Robustness Modes

In order to optimise the performance of the system, the transmission OFDM parameters (carrier-spacing, guard interval, pilot density etc.) need to be matched to the characteristics of the RF channel. The DRM system is designed to operate in both ionised and non-ionised media, and over an extremely wide frequency-range spanning some 3 decades. Propagation in the AM bands can range from ground-wave, where electrical noise is the predominant interference mechanism, to sky-wave with varying degrees of channel complexity and where both differential delay and Doppler effects are additional adverse factors. In some circumstances signals may reach some locations in the coverage area by means of both types of propagation. In all of these cases the received signal is likely to suffer from the addition of distortions or noise, which is caused by the imperfect transmission path.

Hence the system defines five pre-set "Modes", labelled A to E respectively, which are outlined in Table 5.3 below.

Mode	MSC QAM options	Bandwidth options (kHz)	Typical uses	
A	16, 64	4.5,5,9,10,18,20	LF & MF ground-wave, 26MHz band line-of-sight	DRM30 modes
B	16, 64	4.5,5,9,10,18,20	HF & MF transmission on sky-wave	
C	16, 64	10, 20	Difficult sky-wave channels on HF	
D	16, 64	10, 20	NVIS sky-wave (highest Doppler & delay spread)	
E	4,16	100	VHF transmissions 30MHz-Band III	DRM+

Table 5.3 DRM Transmission modes

- Mode A is designed to deliver the highest bit rate possible within the context of ground-wave or line-of-site coverage.
- Mode B will generally be the first choice for sky-wave services.
- Where propagation conditions are more severe, such as for long paths with multiple hops, or near vertical incidence, where several very strong reflections may occur, Mode C or Mode D may need to be employed.
- Finally, Mode E is used for the VHF frequency bands from 30 MHz up to Band III (DRM+).

ii. Modulation Parameters

In addition to the basic transmission modes, there is also a choice of modulation (QAM constellation) and coding (Viterbi) rates for the main service channel. Normally, provided the broadcaster has selected the transmission mode correctly, the service area achieved should be defined predominantly by the received signal-to-noise ratio. This allows the use of simple analogue planning tools (see Section 10).

In all DRM30 modes the option exists to choose either 64QAM or 16QAM for the Main Service Channel, and this choice will be largely influenced by the signal-to-noise+interference ratio (SNR) which can be achieved in the target area. The more robust 16QAM option is normally chosen where the SNR is expected to be too low to support 64QAM. For DRM+(Mode E), it is possible to employ either 16QAM or 4QAM for the Main Service Channel.

5.3.2 Service Multiplexing And Pay-Load Capacity

Within the constraints of the modulation parameters required to deliver the required quality of service, the broadcaster has some flexibility in the way the available capacity of the MSC is used. The broadcaster may wish to allocate some of the capacity to provide a data service alongside the audio or to split the capacity to provide more than one audio service. Examples might be, a high-quality service, containing music and speech, together with a low bit-rate speech service, carrying news headlines or a similar voice-only information service such as traffic updates. Table 5.2 "DRM system Bit Rate Table" sets out the range of bit rates which are available for different levels of signal robustness and channel bandwidth. The smallest bit-rate increment is 20bps in DRM30 modes, and 80bps (DRM+).

Table 5.3.2		Nominal Signal Bandwidth (kHz)							
Mode	MSC Modulation (nQAM)	Robustness level	4.5	5	9	10	18	20	100
			Approx. available bit rate kb/s (equal error protection, standard mapping)						
A	64	Min.	14.7	16.7	30.9	34.8	64.3	72.0	
		Max.	9.4	10.6	19.7	22.1	40.9	45.8	
	16	Min.	7.8	8.8	16.4	18.4	34.1	38.2	
		Max.	6.3	7.1	13.1	14.8	27.3	30.5	
B	64	Min.	11.3	13.0	24.1	27.4	49.9	56.1	
		Max.	7.2	8.3	15.3	17.5	31.8	35.8	
	16	Min.	6.0	6.9	12.8	14.6	26.5	29.8	
		Max.	4.8	5.5	10.2	11.6	21.2	23.8	
C	64	Min.				21.6		45.5	
		Max.				13.8		28.9	
	16	Min.				11.5		24.1	
		Max.				9.2		19.3	
D	64	Min.				14.4		30.6	
		Max.				9.1		19.5	
	16	Min.				7.6		16.2	
		Max.				6.1		13.0	
E	16	Min.							186.3
		Max.							99.4
	4	Min.							74.5
		Max.							37.2

Table 5.3.2 DRM system Bit Rate Table

In DRM, a "Service" may be either audio or data:

- Audio services consist of one audio component, plus either zero or one associated data component.
- Data services consist of one data component.

A stream may contain one audio component plus one data component in synchronous stream mode, or up to 4 data components in packet mode (see Fig 5.3.2).

The system is flexible in other ways as well, in that the broadcaster has the facility to vary the occupied bandwidth of the signal to exploit the spectrum available in different frequency bands and in different regions of the world. Alternatively, where planning conditions allow, double bandwidth signals (18 or 20 kHz bandwidth) can be transmitted in the AM bands to provide an increased level of audio quality.

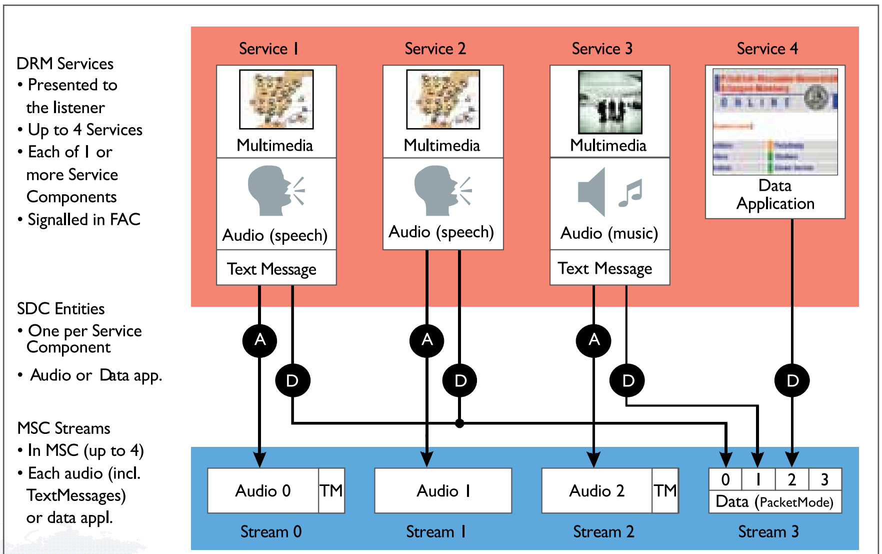

Figure 5.3.2: Relationship between DRM Services and MSC "Streams"

5.3.3 Single and Multi Frequency Networks

The DRM system is capable of supporting Single Frequency Network (SFN) operation. This is the case where a number of transmitters transmit, on the same frequency, identical DRM signals. Generally these transmitters are arranged to have overlapping coverage areas, within which a radio will receive signals from more than one transmitter. Provided these signals arrive at the receiver within a time difference of less than the guard interval, they will provide positive signal reinforcement. Thus the service coverage will be improved at that location, compared to that obtained if there was only a single transmitter providing service at that location. By careful design, and using a number of transmitters in a SFN, a region or country may be completely covered using a single frequency, rather than a number of different frequencies, thus dramatically improving spectrum efficiency. Figure 5.3.3a illustrates how an existing UK nation network, currently using 5 analogue MF frequencies, could be migrated to a DRM SFN, releasing four channels for other services.

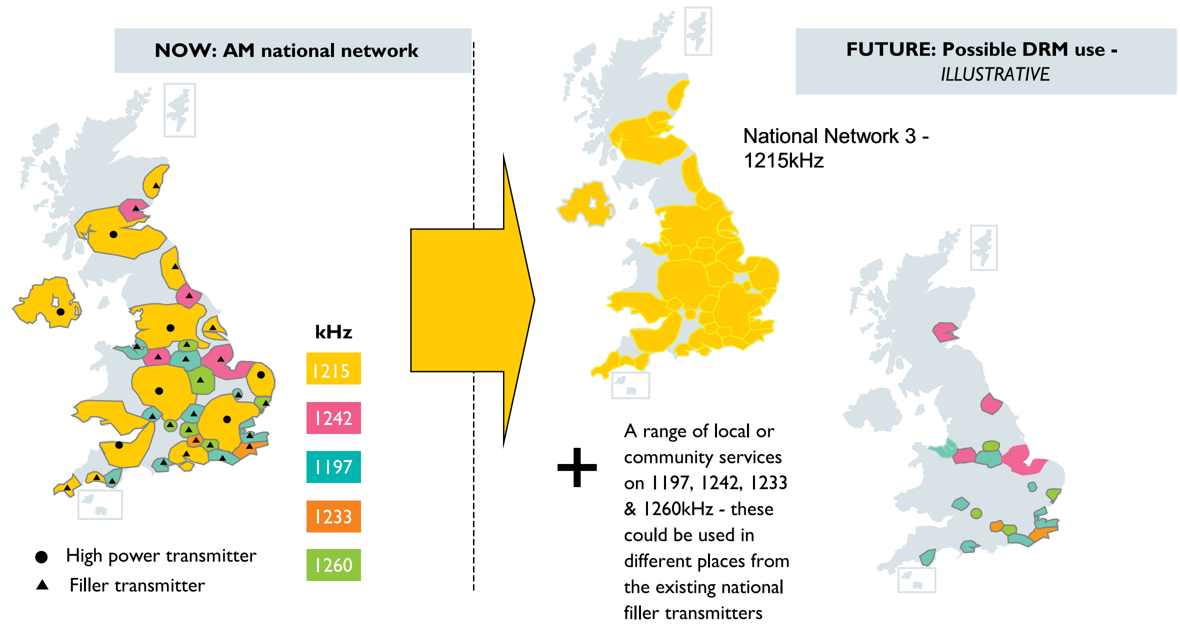

Figure 5.3.3 Illustrative example of potential spectrum saving: analogue MFN to a DRM SFN

Where use of an SFN may be impractical for some reason, a Multi-Frequency Network (MFN) may be employed. In this case the transmitted DRM signals are identical but the frequency used for each transmitter is different. The DRM signal provides a short period during which no MSC data is transmitted. This is not audible to the listener as the data is re-timed in the receiver to ensure continuous data arrives at the audio decoder. However, this period provides a short time interval, during which the receiver may tune to an alternative frequency carrying the same programme, in order to determine its signal quality. If the quality on the alternative frequency is better, the receiver can stay on that frequency, if not it can return to the original frequency. However, this operation will only work seamlessly if the signals on the alternative frequencies are accurately synchronised at the receiver. MFN operation relies on the use of AFS signalling, as described below in Section 5.3.5. Where a receiver is equipped with dual signal-decoding chains, it is possible to compare two or more signals on a continuous basis or even combine the signals to provide a significant improvement in reception reliability through frequency and propagation-path diversity.

5.3.4 Simulcast

5.3.4.1 DRM30 Modes

Simulcast is an option of particular interest to broadcasters who have to continue to satisfy existing analogue listeners for several years to come, but who wish to introduce DRM services as soon as possible. In many cases these broadcasters are restricted in the ways in which the digital service can be introduced. For example, they may have a single MW assignment and no prospect of receiving an additional frequency assignment to start a digital only version of their service. They may also be keen to avoid making a short-term investment in an additional transmitter and/or antenna and site to start a digital service on a new frequency. These broadcasters would like to be able to transmit simultaneously both the existing analogue service and a new DRM service, with the same content, whilst using the existing transmitter and antenna. This option is probably most applicable to broadcasters with LW or MW assignments, where there is generally less freedom to use new frequencies, although there may be similar SW applications where NVIS is used for domestic radio coverage.

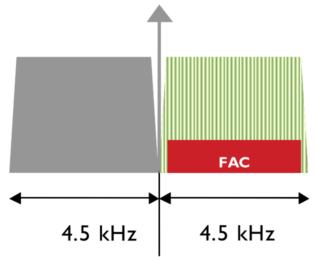

Figure 5.3.4.1
Single-channel Simulcast

Strictly the term simulcast can be taken to describe the simultaneous transmission of more than one signal carrying the same programme content. In this context it often describes the simultaneous transmission of analogue and digital versions of the same programme from the same transmitter and therefore from a common location. In some cases it could be more economical to add a new lower powered transmitter for the DRM service, feeding the same antenna, rather than making extensive modifications to an older less suitable transmitter currently carrying the analogue service.

DRM supports a number of different simulcast options. ETSI standard TS 102 509 [Annex 1, 3] describes a single-channel simulcast mode for 9/10kHz channels (Figure 5.3.4.1), whereby the upper sideband is replaced with a 4.5/5 KHz DRM signal, and the lower sideband is processed and shaped to produce a resultant composite envelope which can be demodulated by a conventional AM receiver.

However, the more attractive simulcast modes require the use of either 18 KHz channels or additional spectrum outside an assigned 9 or 10 KHz channel (Multi-Channel or Multi-frequency Simulcast, MCS). The DRM signal can be located in the next adjacent upper or lower channel (see Figure 5.3.4.2) and can occupy a half or whole channel depending on the bandwidth option chosen. Significant testing, both in the laboratory and in the field, has been carried out to determine the optimum level of DRM signal needed to provide a good quality DRM service, whilst avoiding significant impact on the analogue service.

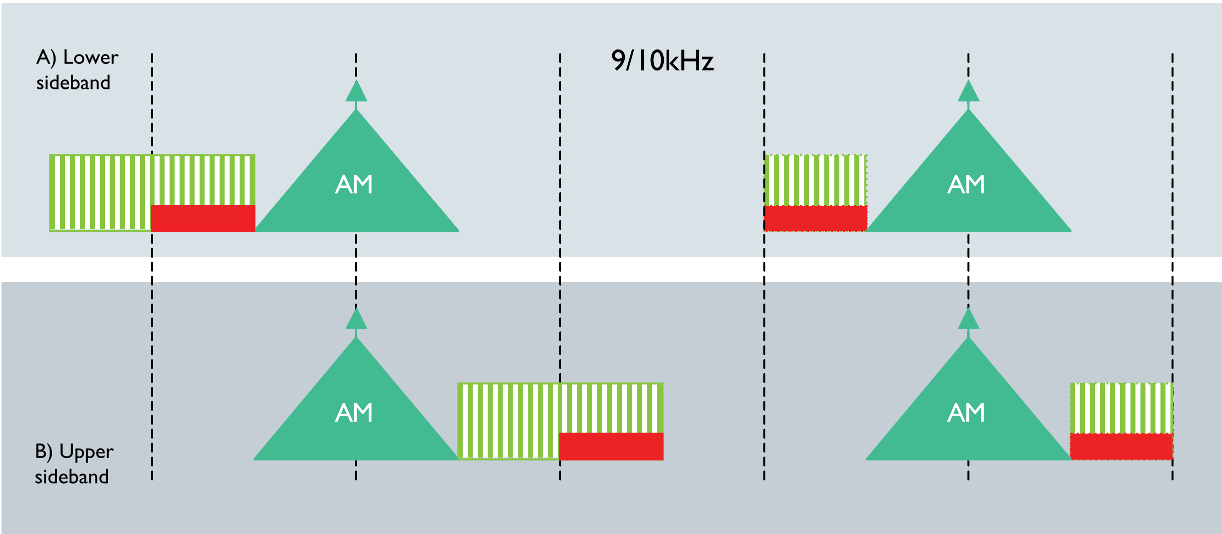

Figure 5.3.4.2 Adjacent-channel Simulcast Overview

The conclusion is that a satisfactory compromise can be obtained when the DRM power level is around 14-16 dB below the adjacent analogue carrier level.

5.3.4.2 DRM+ Mode E

FM / DRM+ Simulcast working is described in more detail in Section 9.3.

5.3.5 Alternative Frequency Signalling (Checking and Switching)

Alternative Frequency Switching forms an integral part of the mechanism allowing the use of MFN's. The AF list is transmitted in the SDC part of the DRM multiplex and provides the receiver with a list of frequencies carrying the same programme or associated programmes. The AF list can also provide information on non-DRM services, such as analogue AM, FM and DAB multiplexes which carry the same or associated programme. Depending on the coverage of the receiver, it may therefore be able to switch backwards and forwards between these other types of transmissions and the DRM service(s).

There are two distinct modes of Alternative Frequency Switching, as follows:

- **Seamless** AFS, whereby the receiver re-tunes with virtually no break in the audio. This is illustrated in Figure 6. Note that this mode requires network synchronisation similar to a Single-Frequency Network, and seamless switching is only supported between DRM transmissions.

- **"Generic"** AFS, which allows the receiver to be directed to another transmission carrying the same service, and which is not constrained to be either a DRM broadcast nor time-synchronised.

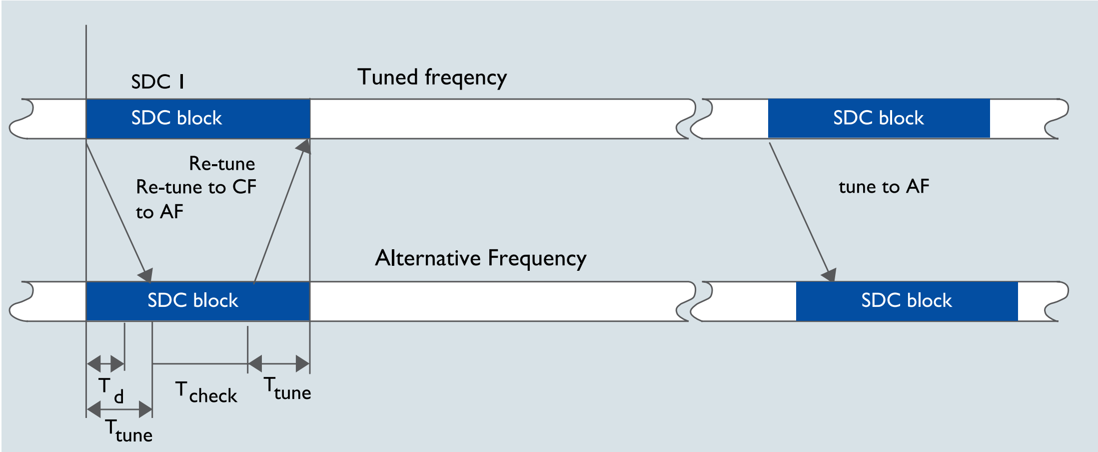

Figure 5.3.5 Seamless Alternative Frequency Switching

An example of "generic" AFS might be a metropolitan FM service, carrying RDS, which points to a DRM frequency. Outside the metropolitan area the coverage might be extended by using one or more DRM transmitters so that a car receiver could switch from the FM service to the DRM service. The reverse process would apply on returning to the metropolitan area. Another similar application might be an international SW service transmitted from outside a country, but where a local relay was provided in the capital city of that country, using a Band II FM frequency.

In the case of the DRM AFS function, it is possible not only to transmit information about current frequencies carrying the same programme but also other frequencies, which will carry the same service at other times of day or in other regions of the world. This can be particularly useful for SW services, where different frequencies are required to provide service to a region at different times of day, due to diurnal propagation variations, or to different regions, because of differing propagation paths. In these cases the receiver can be equipped with data storage to ensure that the listener can select a programme service by name and allow the receiver to select the optimum frequency for that region and time of day.

Annex G of the DRM system specification [1] contains some detailed information and guidance on AFS handling in receivers.

5.3.6 Programme Acquisition

Where DRM services are to be broadcast at bit-rates below 30kb/s, it is important to ensure that the processes of content acquisition, editing, storage and play-out retain the maximum audio fidelity prior to audio DRM coding, and avoid as far as possible multiple encode-decode concatenation. For further information see Section 6.2.

5.4 THE AM SIGNALLING SYSTEM ("AMSS")

DRM has developed a system for digital signalling over AM transmissions. This system has been designed so that AMSS-equipped analogue transmissions can be identified, selected and tuned on hybrid analogue/DRM (or even analogue only) radios, just as if they were digital services. This greatly simplifies radio tuning and service selection for the listener and provides an extremely powerful and cost-effective facility during the migration of an audience from analogue to digital. In addition, the system supports alternative frequency signalling, such that a station equipped with AMSS can hand the listener's receiver automatically to a digital, AM or FM simulcast transmission, as appropriate. The system was engineered to be extremely robust whilst preserving excellent compatibility with existing AM receivers. The gross bit-rate is c.47b/s, and the system has been successfully launched and tested on both MF and HF transmissions.

Figure 5.4: Live screen-shot of DRM receiver in AM mode displaying AM service name

AMSS has now been published as an ETSI standard [15] and has been implemented in at least one first-generation DRM radio module. A full description of the system, its features and implementation has been published by the EBU [16].

DIGITAL radio mondiale

DRM CONTENT

6


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6 DRM CONTENT

This section describes the various elements of the broadcast signal which may broadly be described as "content". This includes the following main elements:

1. Mandatory meta-data which is an essential component of the DRM system. Examples include much of the data carried in the Fast Access and Service Description channels (FAC/SDC).
2. Non-mandatory information which a broadcaster may chose to include and which is automatically supported by receivers (e.g. text messages).
3. The audio content (radio services): both encoding and audio quality considerations.
4. Any value-added and/or data services which broadcasters may chose to implement.

It should be noted that whilst 1, 2. and 3. above will automatically be supported by any receiver which meets the relevant DRM specifications [18, 27], broadcasters should work closely with the receiver industry to ensure that support for any additional features (4. above) is properly integrated into consumer radios. See Section 7 DRM Receivers for more information.

6.1 BROADCAST META-DATA

In this Section, data which is mandatory is indicated by appending [M] to the sub-heading.

6.1.1 Service ID [M]

The DRM Service ID is a worldwide unique identifier assigned to every DRM programme. It enables the AFS mechanism (Alternative Frequency Signalling) and allows a receiver to find and identify the selected programme even if its frequency has changed. It is not used by the listener for service or programme selection, nor is it shown on consumer receiver displays.

It is the broadcaster's responsibility to assign a unique ID to each of its DRM services. The DRM Service ID values are typically assigned by national authorities. More information on the format of the Service ID can be found on the DRM web-site.

6.1.2 Service Labelling [M]

The listener is informed about the tuned service by the name of the programme (DRM service label). The DRM service label is the primary programme identification and selection mechanism for the listener, while information about the current broadcast frequency or even the broadcast standard may not be disclosed at all by modern Digital Radio receivers.

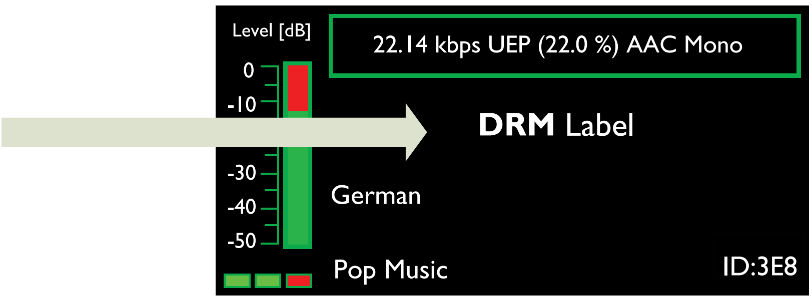

Figure 6.1.2 DRM service label

The DRM service label can be any free text, up to 16 characters long. All worldwide scripts are supported for broadcast (up to 64 bytes of UTF-8 encoded text), but the characters displayed by receivers will depend on those implemented by the manufacturer. If a station is known to its listeners currently by its AM or FM main frequency, this information could be sent as part of the DRM service label.

6.1.3 Programme Type

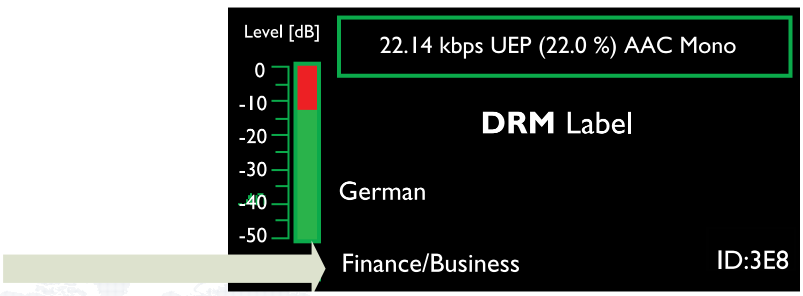

Figure 6.1.3 Programme Type ("Finance/Business")

The selection of a service can be made by the genre of the programme, for example, news, rock music or drama. The figure above shows Pop Music and below Finance/Business information, which could be information from the currency markets or stock exchange. DRM supports the optional signalling of 29 common programme types for audio services.

6.1.4 Service Language

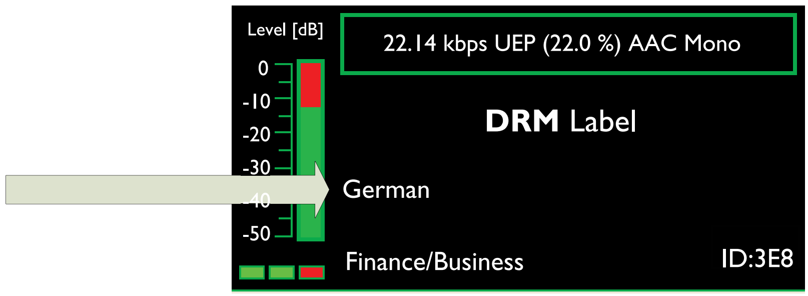

Figure 6.1.4 Example Service Language

The listener may be able to select the language of the programmes he wants to receive on the radio. In regions with many languages, this might be helpful to avoid tuning into services that cannot be understood. DRM supports the optional signalling of all languages worldwide by using their respective ISO language codes.

6.1.5 Country of Origin

The broadcast can optionally signal the country of origin for a particular DRM service. This information refers to the site of the studio, not a transmitter site. Thereby a receiver can enable the listener to scan for programmes originating from a particular country, for example to easily identify the national news programme whilst on vacation. All countries worldwide can be signalled by using their respective ISO country codes.

6.2 AUDIO CONTENT

6.2.1 Audio Coding

In order to allow a trade-off between audio quality and number of services, the DRM system provides 3 MPEG4 audio codecs (shown in Figure 6.2.1a) which vary in their field of application and bit rate requirements. AAC provides the highest quality, whilst CELP and HVXC require progressively lower bit rates but are designed for speech-only services. The performance of all three codec can be enhanced by the optional use of SBR coding.

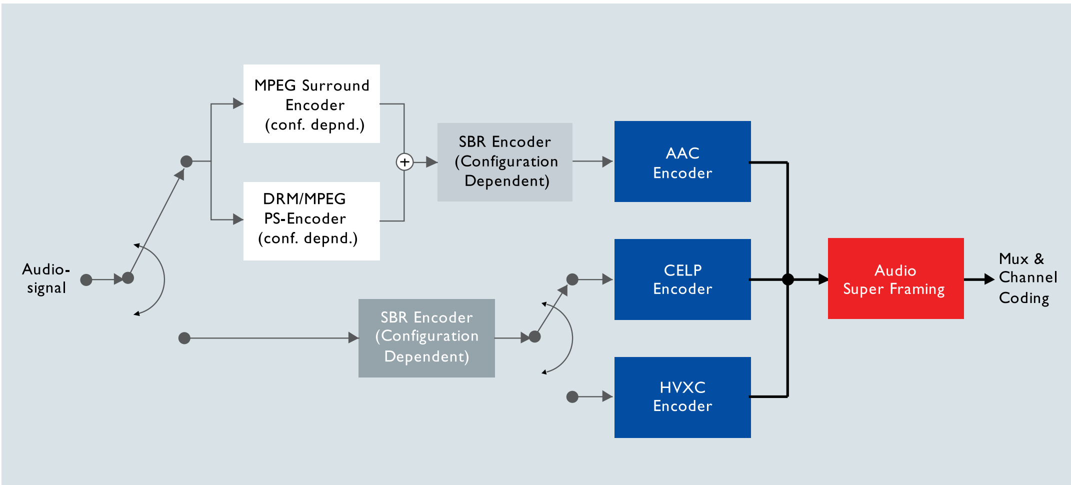

Figure 6.2.1a DRM Audio Coding

The enhancements of CELP and HVXC with SBR are specific to DRM audio coding. All three encoders can operate over a range of bit rates, and consequently support a range of programme content (see Figure12 below and the DRM standard [1]).

In the 18/20 KHz DRM30 modes and DRM+ mode, the available data rate allows the possible usage of MPEG 4 stereo-compatible 5.1 surround sound broadcasts.

- AAC (Advanced Audio Coder) provides the highest quality at higher bit-rates. This codec can be used to code in mono, Parametric Stereo or full stereo modes and is closely related to the audio coding used for the iTune's service.
- The CELP[4] (Code Excited Linear Prediction) Coder and HVXC (Harmonic Vector Excitation Coding) are designed for mono speech-only applications. The bit rate can be down to 2 kbit/s with HVXC or 4 kbit/s for CELP. The performance of all three codecs can be enhanced by the optional use of the SBR (Spectral Band Replication) tool, which requires an additional bit rate of around 2 kbit/s.

[4] The CELP and HVXV codecs are used only in DRM30 modes

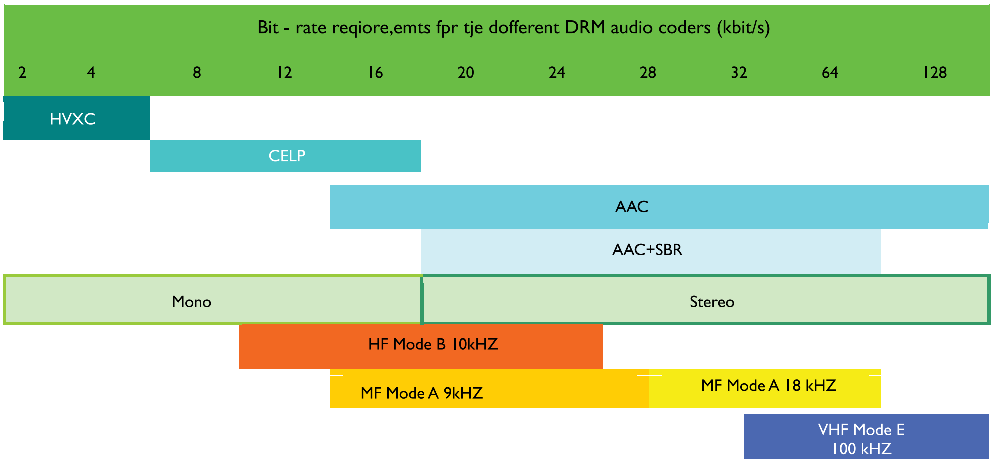

Figure 6.2.1b DRM Audio encoding options for the common transmission modes

Figure 6.2.1b provides an indication of the operating ranges of the various coders set against the bit-rate capacity of some of the most common DRM modes.

6.2.2 Optimising Sound Quality

Digital audio coding has been in use within broadcast organisations for a number of years. Most broadcasters have experiences of multiple tandem coding and the problems that this incurs in reducing the overall quality of the audio, after it has been through this process. Most digital audio compression systems work by endeavouring to remove information inaudible to the human hearing mechanism. This "lost" information is masked from audibility by higher-level sounds which are normally adjacent or close in frequency. However, this is an inherently lossy process. Each time the audio is encoded and decoded there is a danger that audio artefacts, introduced by a previous codec in a chain, are seen as "wanted" components for a later codec in the chain. This can lead to the artefacts being coded in preference to or as well as the "real" audio information. This progressively leads to worsening the quality as the audio proceeds through the broadcast chain.

The ideal solution to this "concatenation" problem is to avoid cascaded coding altogether. Where this is not feasible, it is good practice to maintain the highest-possible bit-rates in the content acquisition and editing processes, and to then code for distribution / transmission once only, at the correct bit-rate for broadcasting.

In many instances, broadcasters use audio coding for programme acquisition (via ISDN, Internet, etc.), followed by audio coding in their digital editing systems and finally they recode it again to save data bandwidth for distribution to one or more transmitters. It is quite possible that each of these coding processes will use different data rates and, often, different audio coding algorithms. Presently this signal would generally then be transmitted to listeners in analogue form via AM or FM transmitters. However, when a DRM transmission is introduced at the end of this chain there will be an additional audio coding process. As a direct response to the concatenation issues described above, the MDI specification is designed to encourage broadcasters to encode DRM transmissions at the earliest point in this chain, where the quality will be highest; for example at the studio centre, rather than at the transmitter site. This ensures that there are no further coding processes before the audio arrives at the receiver. The MDI specification provides additional advantages in terms of efficiently packaging together the audio with all the data that is needed for a DRM transmission.

The advantage of this is that the DRM audio can be encoded using the highest quality source available, avoiding any intermediate coding such as, for example, a studio to transmitter link using MPEG2 Layer II compression. For the case of a 9 or 10 KHz bandwidth DRM transmission (i.e. MSC data rate ~30kb/s or less) all of the MSC, SDC and FAC, together with the transmission control parameters, can be contained within less than 64kb/s of data capacity. The transmission control data allows the DRM exciter parameters at the transmitter to be remotely controlled, so that the Transmission Mode, modulation, etc. can be set at the studio centre, without intervention at the transmitter site.

6.3 VALUE-ADDED SERVICES

6.3.1 Overview

The DRM system provides for a number of data applications. These can range from a simple low bit-rate text service, alongside the audio, to the use of the entire MSC capacity for multimedia-type data services. In general, the simple text applications can be used to transmit programme-associated data services, such as news, sports or weather information services, alongside the main audio service.

The more complex multimedia types of service can include both text and pictures, although for DRM30 modes the relatively low bit-rate will constrain the quantity of data and the refresh-rate. In practice, for these modes, it is most likely that such a service would employ around 2 to 4kb/s of the MSC capacity, as the majority of the MSC capacity is likely to continue to be used for audio services for some time to come.

Providing data and multimedia services in addition to plain audio presentation gives Digital Radio the chance to evolve and to establish a stronger link between listeners and broadcasters.

User-targeted multimedia services will typically be presented on a receiver display. While most of the services require a simple text-only screen, some depend on a graphical display. Therefore manufacturers should be encouraged to provide the largest screen possible in order to support these advanced offerings.

Some of the data services focus especially on car radios and provide road traffic updates for integrated navigation systems. Providing this kind of service is most useful for local, regional or national broadcasters. TMC (described below) and TPEG are important travel services.

In addition to the multimedia services presented in this chapter, other features can also show the advantage of Digital Radio to the listener. For example, the option to enable a receiver to pause and rewind a program is of high interest for consumers. With the single touch of a button the reception of the favourite station can be paused. Later on, the user can continue listening from the point at which he or she left the programme. Depending on the internal memory capacity and the data rate of the service, several hours of content can be recorded. When using an additional flash card memory the recorded programme can also be replayed on other radios supporting this feature.

6.3.2 DRM Text Messages

DRM includes the facility for broadcasters to send a sequence of short text messages[5] each message composed of up to 128 characters in length. DRM Text Messages are always part of an audio programme; their content is therefore typically related to this audio service (current song title and artist, show name, station news, etc.). The update timing on the receiver's display is controlled by the broadcaster; therefore a minimum delay of 10 to 20 seconds between successive messages should be respected, to reduce the distraction of listeners, particularly in in-car scenarios. Where the receiver is unable to display the entire message on-screen, it is common to scroll the text smoothly from right to left (see Fig 6.3.2).

Figure 6.3.2 Scrolling text (bottom of screen) describing the programme currently on-air

DRM Text Messages support all worldwide scripts through UTF-8 encoding, using 1 to 4 bytes to encode one character (out of 128 bytes available per message). Therefore a single message may have more than a hundred character's in a Latin-based language, but only about 40 characters in The Chinese script.

6.3.3 Journaline text information service

Journaline is a text-focussed information service [see Annex 1:12]. It can be signalled as belonging to an audio programme (PAD – Programme Associated Data), or as a stand-alone service.

Figure 6.3.3a Journaline – textual information pages accompanying the radio programme

[5]see Clause 6.5 of ETSI TS 201 980[1]

The user is provided with a selection of information topics and sub-topics, from which he can interactively select those pieces he is currently interested in.

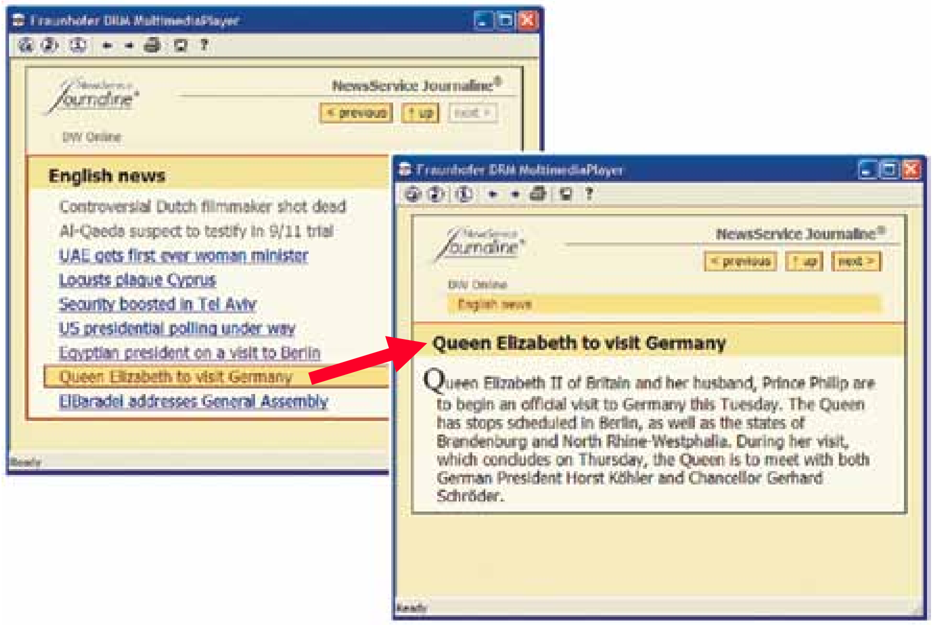

Figure 6.3.3b Navigating through the topics of a Journaline service

The service structure and information elements presented to the user are defined by the broadcaster. Information is provided in the form of plain-text pages, list/table pages, or ticker messages. Plain-text pages consist of a title followed by the detailed body text; they typically carry news items, programme background information, station contact information, etc. List/table pages are typically used for sports scores, financial tables and stock market updates, or airport arrival/departure times. Ticker messages (like news headlines, financial tickers, radio captioning subtitles, etc.) carry a single message at time, which should fully be presented on screen and these will automatically be updated. In total, a Journaline service can be composed of more than 65000 individual pages, each carrying up to 4 kBytes of textual content. All textual information is UTF-8 encoded, thereby allowing any worldwide script to be used. Information in multiple languages can be provided in parallel as part of a single Journaline service, for example, to cover mixed-lingual audiences whose language(s) are not currently carried by the main audio programme.

'Hot Button' functionality allows the broadcaster to optionally trigger back-channel interactivity from the user, if supported by a particular receiver; those links can point to online web URLs or phone numbers, send SMS messages or e-mails, jump to other Journaline pages, etc. Broadcasters also have the option to enhance Journaline pages with geo-references. This allows a receiver to present the user with a selection of locally relevant information, or to forward the location for e.g. a restaurant being advertised to the navigation system.

Figure 6.3.3c Re-using existing data sources to compose a self-updating Journaline service

On the broadcaster side, existing data source like RSS feeds, XML interfaces, or UECP real-time messages can be re-used, to compose a useful service for the listener without the need to manually update its content after its initial setup. Over the air, Journaline can work with very limited bit-rates; it has successfully been broadcast with a transmission capacity as little as 200 bps. Therefore a Journaline service can be added even to shortwave broadcasts without affecting the audio quality. On the receiver side, Journaline requires very limited decoding, cache memory, and user interface capability, and can therefore be implemented on all receiver types with at least a textual screen.

Figure 6.3.3d Journaline service rendered by UniWave® Di-Wave 100 receiver

6.3.4 Electronic Program Guide (EPG)

An Electronic Programme Guide (EPG)[6] is a digital guide to scheduled radio programmes. The content is typically displayed on-screen with functions allowing a viewer to navigate, select, and discover content by time, title, channel, genre, etc. by use of their remote control, a keyboard, or other input devices on the receiver. Both the EPG structure and transport protocol have been standardised [see **10, 11** of **Annex 1**].

The EPG could also allow the easy selection of broadcast content to be scheduled for future recording by the DRM radio or a digital recorder.

The DRM EPG can carry the full programme schedule for the next days, providing detailed information on shows and even sub-show elements (like individual news report items), station and programme logos, and much more. In addition, a simplified and reduced now-and-next information set can be provided, which can easily be decoded even on receivers with limited memory capacity, and presented on text-only screens.

In DRM, one EPG instance will typically carry the combined information for all programmes (DRM services) contained on the same frequency, and optionally for all other programmes provided by the same broadcast network. Therefore at least in the case that more than one audio programme is carried in a DRM broadcast, the EPG will be signalled as an independent DRM service instead of a PAD service (Programme Associated Data).

Figure 6.3.4 EPG examples, and typical bit-rate allocation

6.3.5 Slideshow

A slideshow is a sequence of images [ETSI standard, see Annex 1: 15]. The DRM terminal displays them in response to a trigger set by the broadcaster, which typically means immediately after their successful reception. The content of a slideshow should be composed such that the user is presented with useful information whenever he or she glances at the screen; it will typically be programme related (current album cover, show or program logo, presenter portrait, view into the studio, maps and celebrity portraits during the news, etc.), but may also carry programme independent elements (like graphical weather forecast or advertisements).

The broadcaster decides when a new slide replaces an older one on the receiver's display. So, it is also up to the broadcaster to ensure that slides change at an acceptable rate. As with DRM Text Messages, the broadcaster should allow at least a presentation time of 10 to 20 seconds for each slide, for example, to reduce the driver distraction in case of in-car radio consumption. Typically, the bitrate required

[6] or Interactive Programme Guide (IPG); or Electronic Service Guide (ESG)

to transmit images should not be below 4 kbps; therefore DRM30 double channel or DRM+ broadcasts offer the best opportunity to add the slideshow service to a radio programme.

The image files carried in a slideshow service are either in PNG or JPG format. While PNG is particularly suitable for logos and graphics, JPG is the primary choice for photos. A receiver supporting the slideshow application should be able to decode and present images with a minimum resolution of 320 x 240 pixels. Besides static images, the slideshow specification also supports simple animation sequences based on the PNG format (APNG – Animated PNG); those image files are encoded in a backward compatible way, so that every legacy PNG-decoder will present at least the first slide of the animation sequence.

Figure 6.3.5 Example Slide Show

6.3.6 Traffic Message Channel (TMC)

The Traffic Message Channel (TMC) was originally designed for the Radio Data System (FM-RDS). It is primarily used for broadcasting real-time traffic information. Data messages are received silently and decoded by a TMC-equipped car radio or navigation system. These messages can be delivered to the driver in a variety of ways; the most common of these is a TMC-enabled navigation system that can offer dynamic route guidance – alerting the driver to a problem on the planned route and calculating an alternative route to avoid the incident.

Benefits for users are:

- Updated traffic information, delivered in real time
- Instant knowledge of accidents, road-works and traffic jams
- Filtered information only for the immediate route
- Information in user's own language
- High-quality digital transmission
- Europe-wide compatibility of receivers
- Free or low-cost services right across Europe
- Instant information en route

Figure 6.3.6 TMC window example

TMC traffic information offers several advantages. First, it is received via a "silent" data channel, which means that users can listen to music or news broadcasts simultaneously with – and without interference from – TMC data transmissions. Second, messages arrive and are displayed immediately, so you don't need to wait for the scheduled traffic news bulletin or to listen to a specific programme. Also, TMC services are continuously updated and their information is constantly available to the driver, unlike occasional roadside information services such as variable message signs.

Thanks to TMC receiver technology, users can receive traffic information in their own language. The TMC unit, typically an in-car navigation system, decodes the received traffic information and presents it to the user. Whichever country the user is driving in, he or she can understand the local traffic situation immediately.

DRM has defined a dedicated TMC message encapsulation protocol, to allow for a bitrate-efficient transport of TMC messages within the DRM multiplex [ETSI standard, see Annex 1: 11].


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DRM RECEIVERS

7

7 DRM RECEIVERS

The DRM Consortium supports the vision of a vibrant international digital radio market. The DRM system was developed with the goal of promoting the development of low-cost, mass-market receivers, which is a precondition for the long-term market success. Over the next few years, DRM should become integrated into multi-standard receivers alongside other digital and analogue broadcast systems. The benefit for consumers is the ability to receive all radio services on one device. To support this process, many DRM receiver functions were chosen to be compatible to other digital systems, which decreases receiver costs. In addition, several data services are compatible with DAB+, RDS and AMSS to further reduce receiver development effort and improve usability.

7.1 DRM RECEIVER SPECIFICATIONS

DRM has issued two important documents which can be downloaded from the DRM web-site:

- Digital Radio Receiver Profiles, (also included in this document under Annex 3).
- Minimum Receiver Requirements for DRM.

Both provide guidance to broadcasters, manufacturers and consumers in the evolving market.

- Broadcasters receive the performance information required to plan their networks and gain confidence that their transmissions will be receivable.
- Manufacturers obtain guidelines about the necessary performance and features so that their technology investments will be supported by services.
- The consumer gains from knowing that the product they have chosen contains the necessary features to provide them with a consistent quality of experience and assured levels of inter-operability across their region and beyond.

The Digital Radio Profiles are composed of mandatory features which must be implemented, together with recommended features which offer enhancements with wide appeal. A standard radio receiver and a "rich media" radio receiver are defined. Manufacturers may offer additional features in order to differentiate their product from others.

The Minimum Receiver Requirements for DRM document describes receiver characteristics in more detail. It contains basic implementation and functional performance requirements. The most important features for the audio decoder, the channel decoder etc. are described as mandatory to allow reception of worldwide transmissions. In addition, minimum performance levels with the related measurement methods are described. Technical performance parameters including sensitivity, selectivity and linearity are included.

7.2 RECEIVER DEVELOPMENT

A typical radio receiver comprises several basic blocks:

i. Antenna
ii. RF Front End
iii. Demodulator / De-multiplexer
iv. Audio / Data Service Decoder
v. Amplifier / Loudspeaker
vi. Micro-processor controller / Display Driver

The antenna, amplifier and loudspeaker are common to analogue and digital reception and can clearly be used for both. Some companies have specialised in designing integrated modules which combine all the highlighted elements ii, iii, iv and vi above into one "component", which allows manufacturers to integrate digital radio into existing or new products very rapidly. "Modular" solutions capable of supporting both analogue and digital reception are also available. These can employ either Digital Signal Processors (DSPs) or on dedicated Integrated Circuits (ICs). The decision is a trade off between flexibility, power consumption and costs. Several DRM implementations running on DSPs are available on the market: see the DRM web-site for updates.

The DRM standard shares some commonality with the WorldDMB digital radio system, especially in the areas of audio coding and ancillary data, which simplifies the design of multi-standard receivers.

Nowadays, several stand-alone receivers are available in the market. The product range includes devices with colour screens supporting new radio features available with the DRM system, through to home entertainment systems with DRM included. The car radio manufacturers have also developed devices and modules for DRM. The market is constantly evolving and readers should refer to the DRM website for up-to-date information.

7.3 SOFTWARE RADIOS

DRM receivers, developed using an analogue receiver plus demodulation software running on a PC platform, were designed to satisfy the test and measurement requirements of DRM system developers. Modern consumer PCs have more than sufficient processing power to provide most of the functions of a DRM receiver. DRM originally developed a simplified version of a professional DRM receiver using this technique. This would allow enthusiasts to make the necessary modifications to their own analogue receiver and interconnect it with an existing home PC. This was followed by an open-source initiative, entitled Dream[1] [11]. Figure 7.3 shows a screen shot of a "Dream" receiver in operation.

Figure 7.3 DRM Software Receiver

7.4 MAN-MACHINE INTERFACE (MMI)

User-friendliness in operation is an important item for market success. DRM offers the tools to achieve this goal.

Service selection by station name instead of frequency from a list built-up automatically by the receiver has proved to be a popular way to "tune" a digital radio. Manufacturers are free to choose how to compile the station list according to market need, for example by evaluating AFS and EPG information, offering frequency scanning, or evaluating service lists provided by other broadcast systems, etc.

So ideally, the user of a Digital Radio set should not be asked for, nor presented with a station selection by broadcast standard and/or frequency (at least not as the primary option). As soon as the user has chosen a service by its service label from a system-spanning list of currently available services, it should be the receiver's task to identify the best suitable reception method for the indicated service, and to automatically follow the service in case of temporary frequency changes or when crossing coverage area boundaries.

[1] Dream is a software implementation of a Digital Radio Mondiale (DRM) receiver. With Dream, DRM broadcasts can be received with a modified analogue receiver (SW, MW, LW) and a PC with a sound card.


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REGULATORY & STANDARDS BODIES

8

8 REGULATORY & STANDARDS BODIES

Broadcasting and its use of spectrum is regulated on an international basis by the International Telecommunications Union (ITU). Any change in the use of this spectrum, such as is caused by the introduction of a new digital broadcasting system into the broadcasting bands, requires approval from Member Administrations.

The International Telecommunication Union's Radio communication Sector (ITU-R) has given this approval for the broadcast of DRM signals on a regular basis in all the broadcasting bands below 30 MHz, see ITU-R Rec. BS.1514. For the broadcasting bands between 30 MHz and 174 MHz, ITU-R Rec. BS.1114 is currently [Feb 2010] undergoing modification to include DRM as Digital System G. In addition, ITU-R Rec. BS.1615 provides the planning parameters for the deployment of DRM30 throughout the world by utilising the existing planning agreements for analogue AM services, for example the Geneva 1975 Assignment Plan for the LF and MF bands for Regions 1 and 3 (Europe, Africa, Asia) and the Rio de Janeiro 1988 plan for, Region 2 (Americas). For the HF bands above 5900 kHz, all DRM broadcasts are coordinated in accordance with Article 12, the 6 month scheduling procedure, in the same way as for analogue broadcasts. In the "tropical HF bands" - those below 5900 kHz intended for national coverage in low latitude countries - the coordination procedure is one of bi-lateral arrangements, rather than a global procedure. Countries in the "tropical zone" that wish to use DRM should be able to do so using "near vertical incidence" propagation just as they do now, with proper account taken of the average power factor.

Details of planning assumptions and references to protection ratios for DRM are set out in Section 10 Service Planning.

Finally, permission to use DRM has to take into account any policy put in place by a broadcaster's national administration.

8.1 DRM STANDARDS

The main DRM standard has been published by the global standards body based in Europe, the European Telecommunications Standards Institute (ETSI) as ES 201 980 [1] and is available for free download from the ETSI website http://pda.etsi.org/pda. All the supporting standards for distribution interfaces, data applications and so on are also published by ETSI and available the same way, searchable from the keyword "DRM". A comprehensive list of these standards is set out in **Annex 1.**

BROADCAST NETWORK INFRASTRUCTURE

9

9 BROADCAST NETWORK INFRASTRUCTURE

This chapter begins by detailing the way in which the DRM signal is distributed to the transmitter(s). It continues by outlining methods for adapting existing analogue AM transmitters and FM transmission facilities to provide DRM transmissions, and considers the performance requirements for the attached antennas and matching networks. Finally, there is an overview of monitoring and measurements of DRM signals to ensure that they achieve the desired quality of service.

Propagation and service planning aspects of the signal after it leaves the transmitter antenna and up to its arrival at the receiver antenna are dealt with in the next section.

9.1 PROGRAMME DISTRIBUTION

This section provides more detail on the way in which the various protocols and interfaces described previously link together. This enables the audio and control signals, required by the DRM receiver, to be packaged together in an efficient way, at the studio or control centre, and sent to the DRM transmitter(s).

9.1.1 Multiplex Distribution

The MDI stream comprises the following information:

- DRM Multiplex, consisting of MSC, FAC, SDC.
- All information necessary to run the DRM modulator with the correct settings. (robustness mode, time stamps for SFN etc.).
- Optional proprietary information.

The data is sent asynchronously in packets. Therefore, a large variety of basic transport mechanisms may be used, such as UDP/IP, serial lines, Satellite, WAN, LAN and ISDN. As the multiplex is based upon either a 100mS or 400mS DRM frame and the transmission of data is effected asynchronously, both the DRM multiplexer and modulator must possess their own source of time synchronization (GPS or Network Time Protocol, NTP),to ensure the long-term stability of this framing.

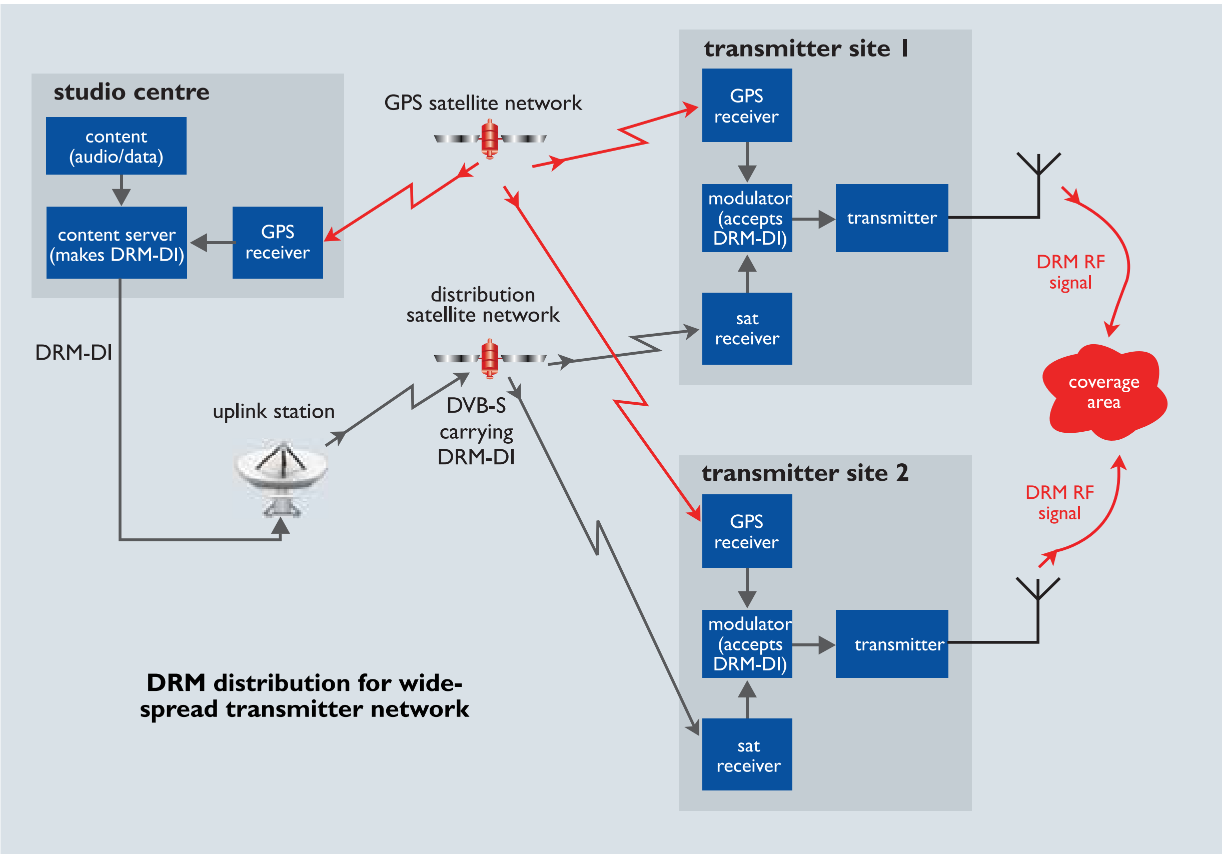


Figure 9.1.1a Example of DRM distribution suitable for international broadcasting

The MDI stream is a very efficient means of transferring encoded audio in terms of bandwidth usage, whilst retaining the original quality of the programme. By placement of the encoders and multiplexer at the studio the audio can be encoded directly using the efficient MPEG 4 coding system, eliminating degradation through trans-coding. With additional protection and control information the MDI bit rate is only about 20-25% higher than the encoded audio bit rate, with the result that a typical MDI stream is about 27kb/s for a standard HF channel and about 35kb/s for a typical MF service. A single 64kb/s distribution channel would therefore be adequate for most of the DRM30 system combinations, thereby saving on costly distribution bandwidth. However, where a number of separate DRM services are sent to one or more common sites, using a multiplexed system, it may be advisable to use distribution channels, which can be incremented in smaller steps than 64kb/s, in order to attain the highest capacity efficiency.

A further benefit of this method of distribution is that it is possible to send the same MDI stream to any number of modulators. The benefit is that only one DRM Content Server needs to be purchased; however the constraint is that each modulator has to transmit the same audio programme using the same Mode.

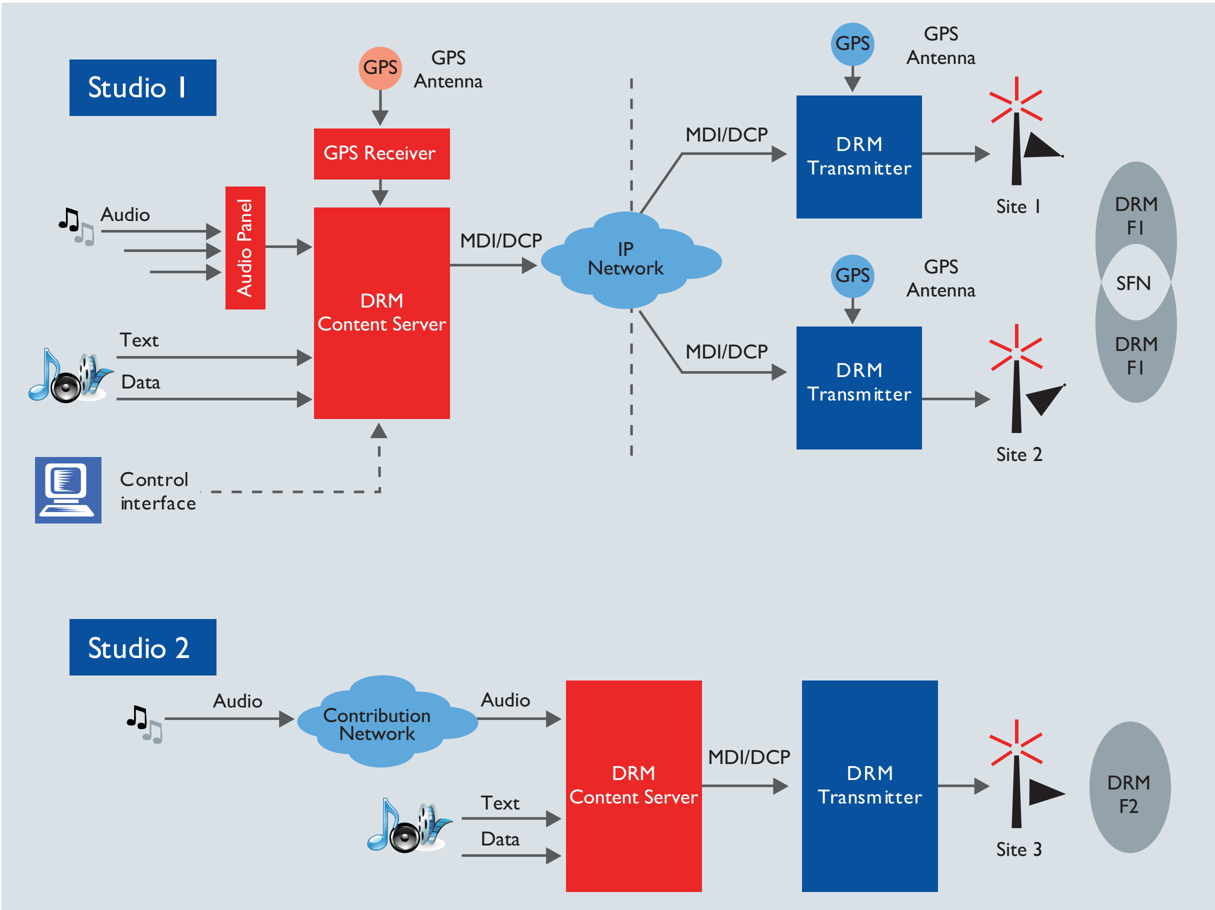


Figure 9.1.1b Typical DRM local/regional/national broadcast network topology

For broadcasters wishing to retain their present audio programme distribution network, placement of the Content Server at the transmitter site is acceptable. However, to retain the superior audio quality of the DRM system requires that the programme be distributed at the highest possible bit rate in order to minimize tandem-coding artefacts.

9.1.2 Network Synchronization

A major benefit of the DRM system is its support for Single and Multi-frequency Networks (SFN's/MFNs), which can provide reliable contiguous coverage, with seamless reception within the planned service area. The benefits of such networks to broadcasters are set out in Sections 5.3.3 and 10.2.

Creation of an SFN can be achieved using a single DRM Content Server at a broadcaster's studio; distribution of the MDI stream to the network of transmitters can utilize either satellite or land lines. Each transmitter requires a DRM modulator that can be assigned an individual identifier for adjusting time delay. The network is configured so that the DRM output from transmitter is received at precisely the same time at a specific location in the target zone. This is achieved through timestamps embedded in the MDI protocol, with each modulator capable of buffering at least 10 seconds of MDI data stream. The DRM Content Server and each DRM modulator require GPS timestamp information or an equivalent time reference. Without this synchronisation, the received signals would be insufficiently time-coincident. This could cause the delay spread to exceed the guard interval, causing inter-symbol interference, and audio dropouts would result. Additionally, inputs of 1 Pulse/second (1 PPS) and 10 MHz are required at the DRM modulator to provide long term RF stability.

9.2 TRANSMITTING IN DRM30 MODES

9.2.1 Overview

The fundamental requirement for all DRM modes is that the transmitter functions as a linear amplifier, and this section shows how linear amplification can be achieved with existing AM broadcast transmitter designs.

9.2.2 DRM Amplification

While it is possible to construct a linear amplifier to provide the power level required for broadcast transmission, the energy conversion efficiency is very poor, typically somewhere between 20 - 30%. Thus significant cooling will be required and operating costs will be high. However, it is worth noting that some HF transmitter designs implement SSB working by changing the operating conditions of the final stage so that it functions as a linear amplifier.

It thus so may be used for DRM transmissions. However, as the cooling system is generally sized for high-efficiency non-linear operation, available power output is reduced in "linear" mode. As an example, the peak power capability of one example of a 500kW PDM transmitter, when operating as a linear amplifier, is reduced to about 300kW. Thus the maximum average DRM signal power available is about 30kW. The relevant figure must always be checked with the transmitter manufacturer.

A number of current DRM services use transmitters working as linear amplifiers. Essentially the transmitter RF input is driven by the I/Q signal from the DRM Modulator or the full modulated DRM RF signal at the required centre frequency. Some linearity correction has been found to be necessary and existing correctors provided for SSB working have been used successfully.

Although some earlier low power transmitters were configured as linear amplifiers, high power AM transmitters invariably use a non-linear RF amplifier to achieve high conversion efficiency. In a valve (electronic tube) transmitter, the final RF amplifier valve will have a resonant circuit connected to the anode (plate). The grid bias voltage is chosen such that the valve conducts over a limited range of the RF cycle and effectively delivers energy to the anode circuit as a series of pulses (Class B or Class C operation). This sets up oscillatory currents in the anode resonant circuit and RF power is coupled from this circuit to the antenna. With the use of modern high power valve technology and efficient cooling systems, very high output power can be achieved for relatively low drive power with high conversion efficiency. Solid-state modular MF/LF transmitters use a switching technique to achieve high conversion efficiency, typically between 70 to 80%. The output stage of each power amplifier module uses MOSFET transistors as switches arranged in an "H Bridge" arrangement. RF power is taken from a transformer connected between the mid-points of each arm. In operation, diagonally opposite transistors are sequentially switched at carrier frequency rate to produce alternate current reversals in the output transformer primary. In this way significant RF power levels can be generated at high conversion efficiency.

9.2.3 Using Non-Linear Amplifiers For DRM

Non-linear amplifiers cannot be used directly for DRM amplification, for the same reason that they are unsuitable for AM amplification: AM and DRM signals both comprise multiple RF carriers, which when passed though a non-linear process will generate intermodulation and cross-modulation products. However, a technique exists where a modulated non-linear amplifier can be driven with suitable RF and base-band signals derived from the original low level complex I/Q signal, such that the component signals combine in the modulated final amplifier to form a high level replica of the original signal. The overall effect is that the modulated amplifier functions as a linear amplifier even though the amplifier itself continues to work in a non-linear manner. This technique is described in Section 9.2.5 below. Although a modular solid-state MF/LF transmitter does not have a separate modulated amplifier as such, the functionality is identical.

9.2.4 The DRM Signal

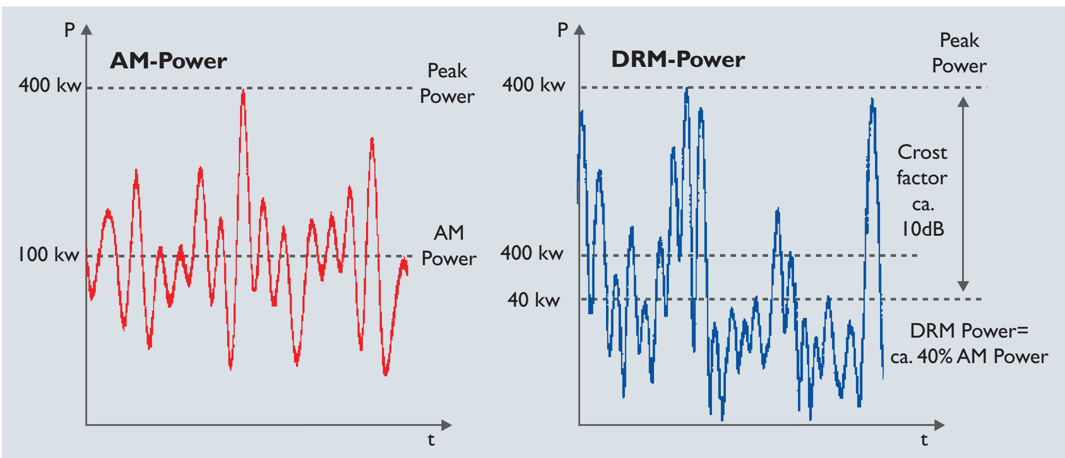


Figure 9.2.4 AM and DRM RF envelopes

As it has been described earlier, the DRM signal from the COFDM modulator may take the form of an I/Q signal, i.e. the complex signal is described by two signals representing the In-phase and Quadrature components respectively. In raising the level of this signal to the power required for broadcast transmission it is imperative that the correct phase and amplitude relationship of the "I" and "Q" components is maintained.[2] If the signal is distorted, the MER[3] may well fall to unacceptable levels (together with out-of-band intermodulation products), and ultimately the DRM signal will be rendered unusable.

The DRM signal, as broadcast, closely resembles band-limited noise. This is an advantage when considering the protection ratio of analogue systems interfered with by DRM, but not when it comes to amplification. The statistical variation of envelope voltage theoretically follows a Raleigh distribution, but in practice the peak-to-mean ratio lies between 10 and 11dB[4]. Fortunately, for DRM30 modes, current AM transmitter topologies can be adapted to amplify the DRM signal in an efficient manner.

9.2.5 AM Transmitter Conversion

With a traditional AM high-powered transmitter (see Figure 9.2.5), the DRM signal is first converted into amplitude (A) and phase (RFP) format for injection into the modulator audio input and carrier-frequency drive circuits respectively. The relative timing of the A and RFP signals is adjusted to ensure synchronism at the modulator, and they are effectively recombined through this hybrid modulation scheme.

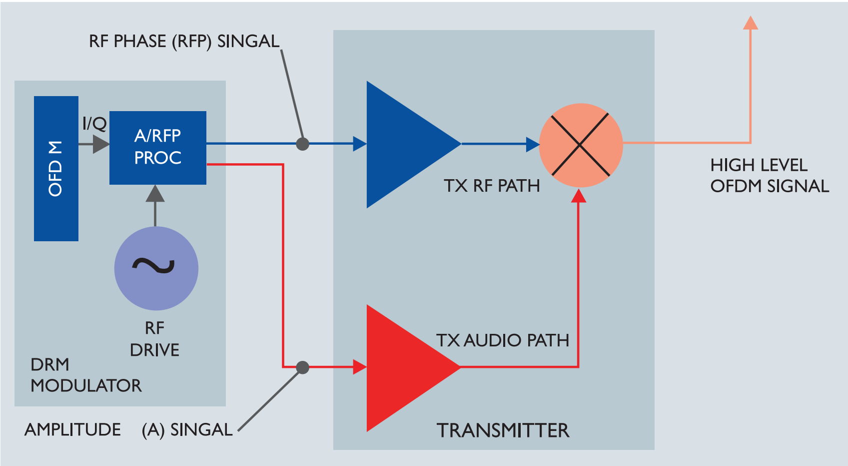


Figure 9.2.5 DRM Transmitter with A/RFP topology

For this technique to work correctly there are a number of requirements that must be satisfied by the transmitter.

1. There must be a Direct Connection (DC) between the modulator and the final amplifier. Unfortunately, this means that the A/RFP technique cannot be used with transmitters having Class B transformer coupled modulators. The DC Offset must be matched accurately to the transmitter to avoid unwanted emissions.
2. The relative timing of the RFP and A signals need to be adjusted to ensure optimum modulation performance.
3. The bandwidth of the audio path in the transmitter needs to be significantly greater than that required for normal AM working. Typically, the audio path bandwidth should be at least 3.5 times the bandwidth of the wanted DRM signal. The sampling frequency of solid-state Pulse Step or Pulse Duration Modulators (PDM/PSM) must be more than twice this frequency limit to meet Nyquist criteria. Any bandwidth limiting filters in the audio path must be removed and the modulator output filter will need to be modified to achieve the required bandwidth. In modifying the filter response it is important to ensure that a substantially flat group delay characteristic is maintained over the pass-band.

A considerable body of know-how has been accumulated by transmitter manufacturers, who now offer DRM and AM transmitters which can switch rapidly between AM and DRM modes if required. They can also advise on the conversion of existing AM transmitters (both LF, MF and HF), many of which have been field-converted over the last few years.

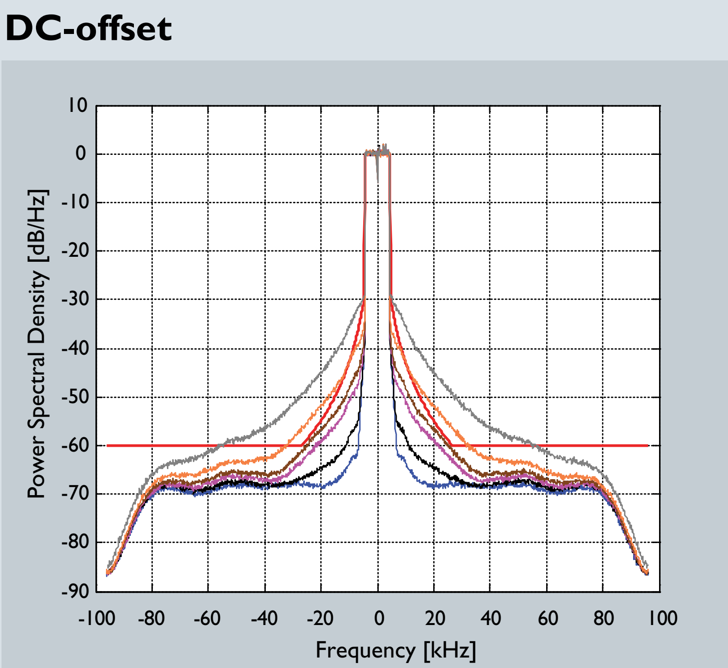
9.2.6 Performance of DRM30 Transmitters

DRM transmitters based on AM amplifiers and employing A/RFP modulation are capable of providing excellent performance, provided the technical criteria outlined previously are addressed. Typical efficiencies of modern DRM transmitters lie in the range 70 to 85% (mains in to RF out) over the corresponding power range 10 to 250kW.

The following plots illustrate the relative impact of differential signal timing, DC offset and the bandwidth of the Amplitude (envelope) channel on the transmitter output spectrum (N.B. the red curve is the DRM spectrum mask).

[2] Similarly, for a modulator with A/RFP outputs
[3] (see 9.5.1)
[4] This figure represents the normally-observed peak-to-mean ratio, and applies to a DRM signal which has not been deliberately clipped (9.5.1)

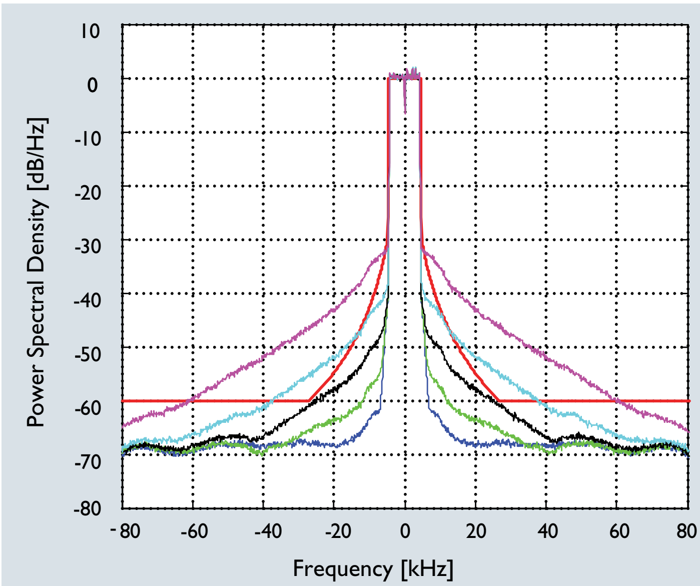
a) The DC offset error must be less than 1% (relative to the mean DRM envelope level).



error [%]	Colour
0	Blue
0.2	Black
0.7	Magenta
1.0	Brown
2.0	Orange
5.0	Grey

Figure 9.2.6a DC-Offset influence on DRM Output Spectrum

b) A/RFP signal delay. The time delay between envelope and phase signal must be matched to better than 1 μs. in order to fulfil the DRM spectrum mask.



error [μs]	Colour
0	Blue
0.25	Green
1	Black
2	Cyan
5	Magenta

Figure 9.2.6b Influence of DRM A /RFP signal delay

c) Bandwidth of A /RFP paths. Figure 9.2.6c illustrates the influence of a band limitation in the envelope signal path on the DRM spectrum. All other parameters which influence the DRM spectrum are matched perfectly in this figure.

The envelope (A) bandwidth should normally be at least 3.5 time the bandwidth of the DRM signal in order to fulfil the DRM spectrum mask. If the bandwidth is less than optimum, but the roll-off is not too steep, it may still be possible to meet the mask using pre-correction in the modulator.

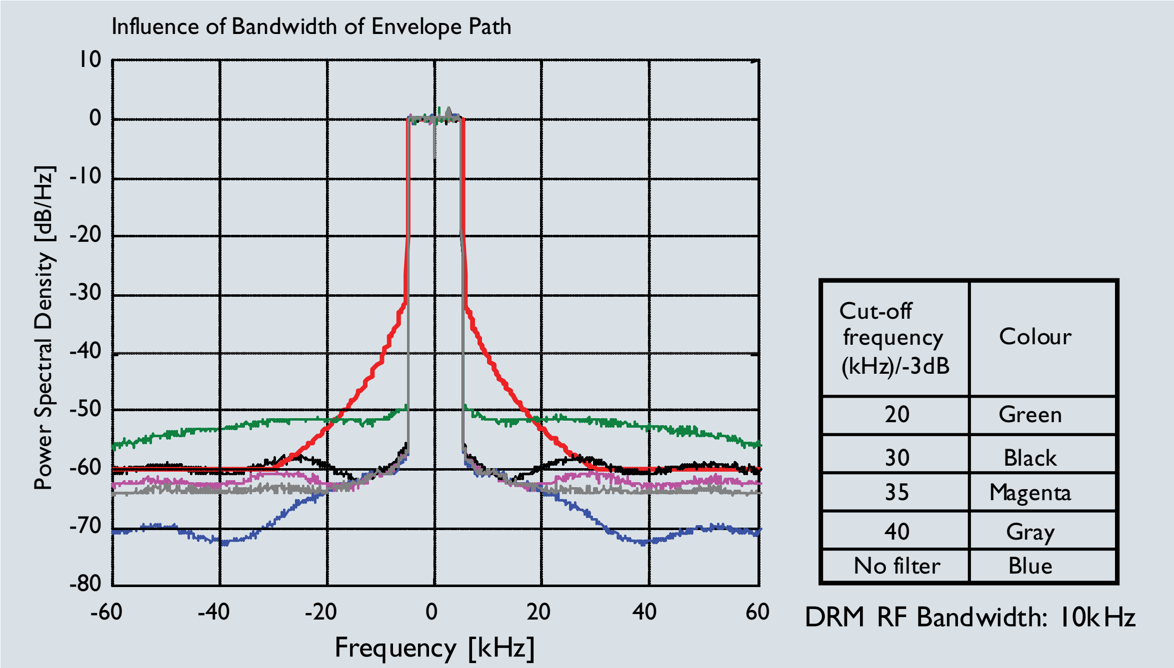


Figure 9.2.6c Impact of envelope bandwidth on DRM output spectrum

9.2.7 Out of Band Power (OOB)

All transmitters, whether AM or DRM, will generate some power outside of the bandwidth needed for transmission of the required signal. In order to avoid undue interference to adjacent channels, the ITU has laid down recommendations (ITU-R SM. 328) in the form of a spectrum mask within which the out of band power spectrum of AM transmitters must be confined. A similar shaped spectrum mask will be applied to DRM transmissions.

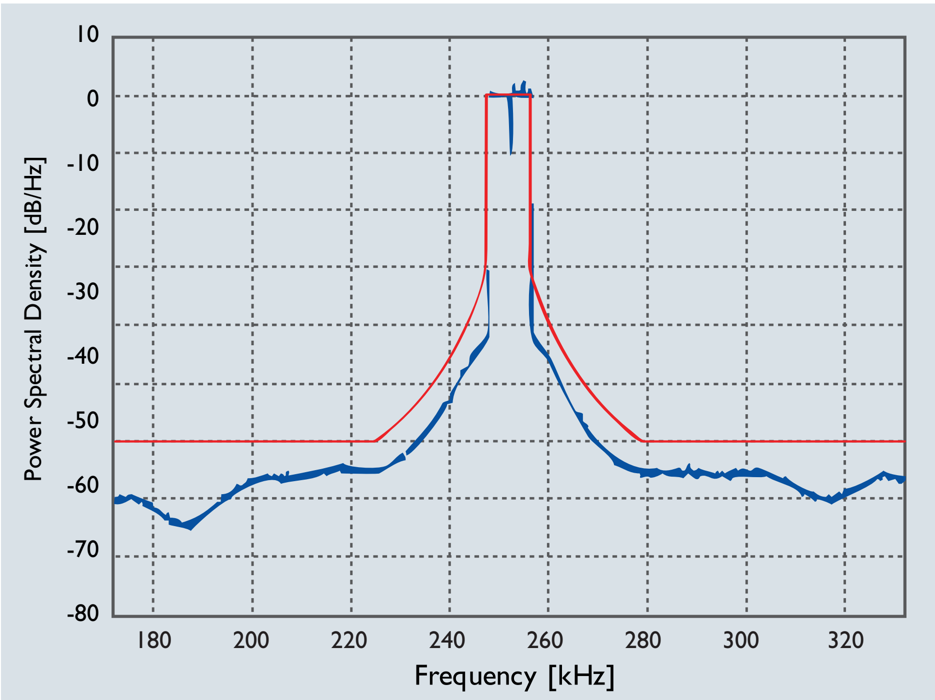


Figure 9.2.7 DRM LF TX Spectrum

The plot in Figure 9.2.7 shows both the spectrum mask and the spectrum obtained from an example of the A/ RFP topology used in a LF transmitter with a 9 kHz DRM signal.

9.2.8 Use of Older Transmitters For DRM Trials

In some older transmitters[5], it is often found that one or more of the parameters set out above cannot be met. This normally results in higher OOB which exceed the spectrum mask. As an interim measure, for instance to allow demonstrations or trials to take place, it may be possible to re-introduce the normally-suppressed centre-frequency carrier, some DRM Modulators provide this facility. Re-introducing this CW signal has the effect of changing the composite signal amplitude-distribution in such a way that the signal bandwidth of the "A" channel is reduced. This results in improved linearity and ensures that out-of-band radiation is minimised (Figure 9.2.8 DRM spectrum with additional carrier). The level of the re-introduced carrier is adjusted experimentally for best results while observing the RF output spectrum with the transmitter connected to the antenna system. This technique, while effective, is not ideal due to the energy wasted in the carrier signal and the impact of the carrier on the performance of DRM receivers. For these reasons it is not recommended to use this technique for a permanent DRM service.

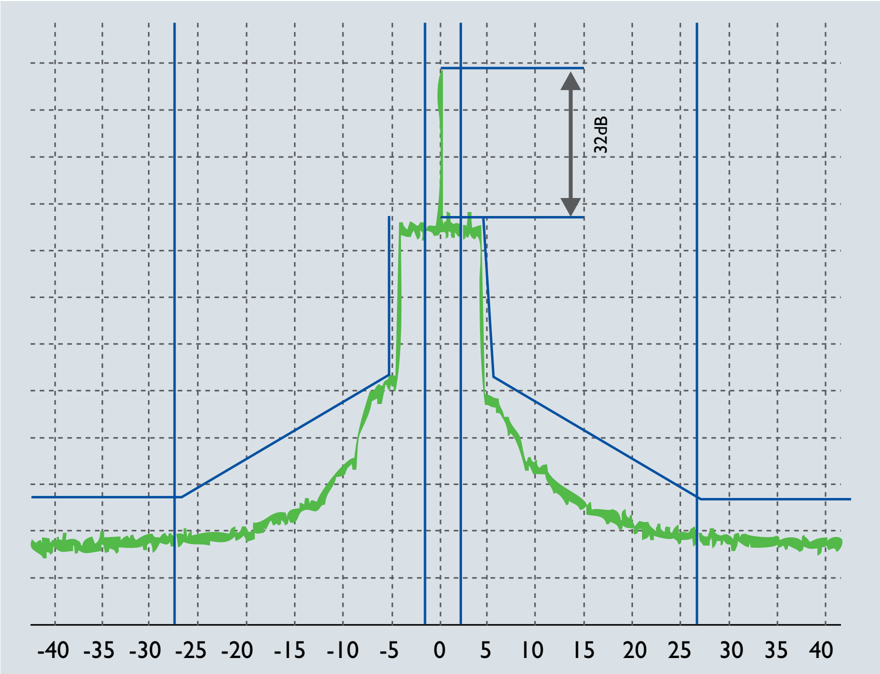


Figure 9.2.8 DRM spectrum with additional carrier

9.3 TRANSMITTING IN DRM+ CONFIGURATION

For the DRM+ setup it is also possible as in DRM30 to use a variety of configurations for existing or new installations to bring the DRM+ service on air.

Table 9.3 DRM+ Mode E parameters			Bit-rate (kbit/s) @	
		Code-rate	4-QAM	16-QAM
Occupied bandwidth	95kHz	0.25	37.3	
Number of carriers	213	0.333	49.7	99.4
Carrier spacing	444.44Hz	0.4	59.6	
Symbol length Tu	2.25mS	0.411		122.4
Guard interval Tg	0.25mS	0.5	74.5	149.1
Overall symbol length Tu+Tg	2.5mS	0.625		186.4

9.3.1 Network system architectures for DRM+

In all digital transmission systems with a non-constant amplitude, the amplifiers need to be as linear as possible to get the best performance out of the system. One possible arrangement is to use a linear class A or in preference a push-pull Class A-B amplifier. Future developments may lead to VHF amplifiers employing topologies similar to the A/RFP arrangement which is now ubiquitous in AM transmitters.

[5] Older transmitters using phase and amplitude (A/RFP) topology

9.3.1.1 Full DRM+ Setup

For a DRM+ only transmitter, the typical architecture is very simple and in block diagram form could look like Figure 9.3.2b. The audio programme and the additional digital information are combined in the content server and feed to the modulator over the MDI data stream. The DRM+ modulator provides a final-frequency modulated RF output signal which is directly connected to the power amplifier device.

The output spectrum, shown together with the DRM+ spectrum mask superimposed, will look similar to Figure 9.3.2.1:

For more information on the provisional DRM+ spectrum mask, see 9.4a

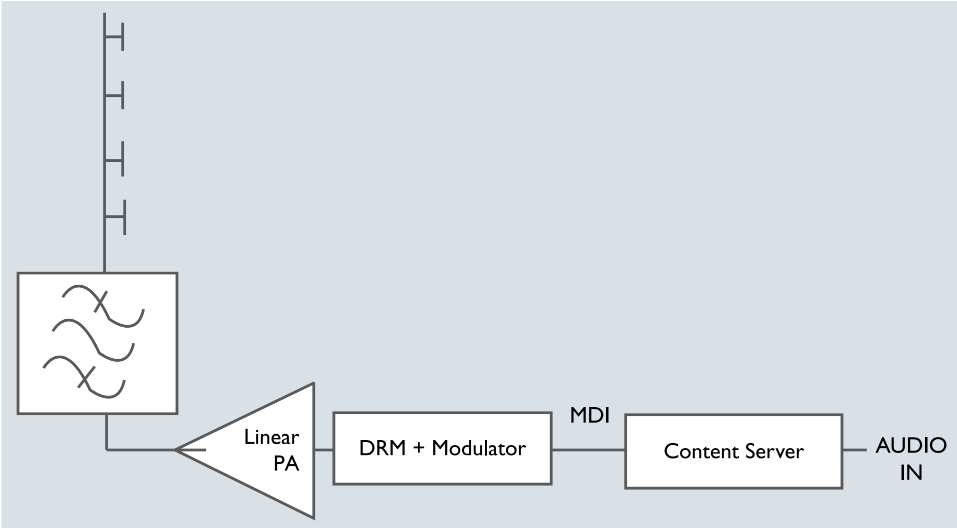


Figure 9.3.1 DRM+ only with linear PA

9.3.2 DRM+ "Simulcast" Mode

It is also possible to have a mixed setup of the DRM+ signal with an existing FM broadcast installation. In the case of combined mode, where a DRM+ has to be added to an existing analogue transmitter, Figure 9.3.2a & 9. 3.2b shows the spectrum arrangement and the two principle variables (frequency offset and relative amplitude).

The most common architecture to have such a signal configuration on air will be combining the respective power amplifier outputs (FM and DRM+) with a "high-level" combining system. This may take several forms, as outlined below.

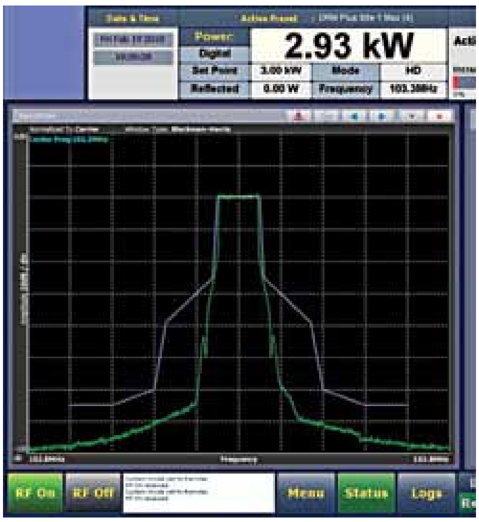


Figure 9.3.2a DRM+ transmitter: measured output spectrum for 3kW transmitter

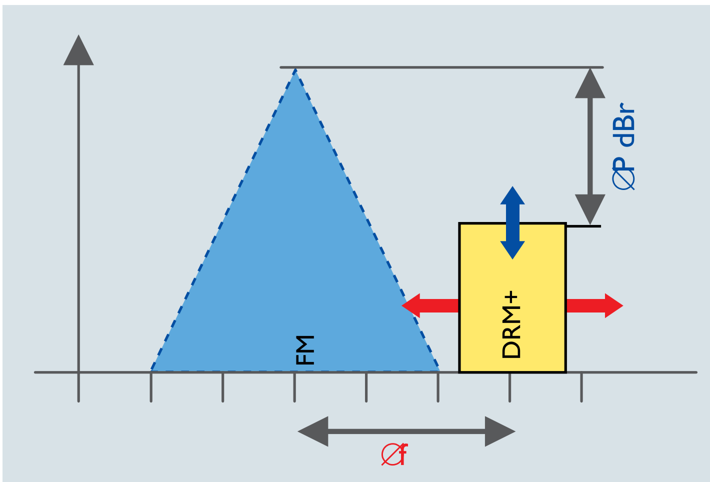


Figure 9.3.2b FM & DRM+ combined mode spectrum

9.3.2.1 Directional Coupler Combining

The DRM+ and FM signals are combined using a hybrid coupler after the two power amplifiers (Figure 35). The coupling factor is chosen to strike the optimum compromise between power loss in the FM channel, and the size (power rating) of the DRM+ amplifier. The coupling chosen is normally in the range of 6 to 10dB (see Table 9.3.2.1).

Mode	FM RF out (kW)	DRM+Tx rating (–10dB relative to FM) (kW)	FM Power reduction	Overall efficiency (Mains to RF, indicative)
1. FM Only (reference)	10	-	0%	64
2. a) 6dB Coupler-combiner	7.5	3.0	25%	44
2. b) 10dB coupler-combiner	9.0	9.0	10%	36
3. "In-air" combiner (antenna)	10	1.0	0%	56

Table 9.3.2.1 DRM+ combiner options.

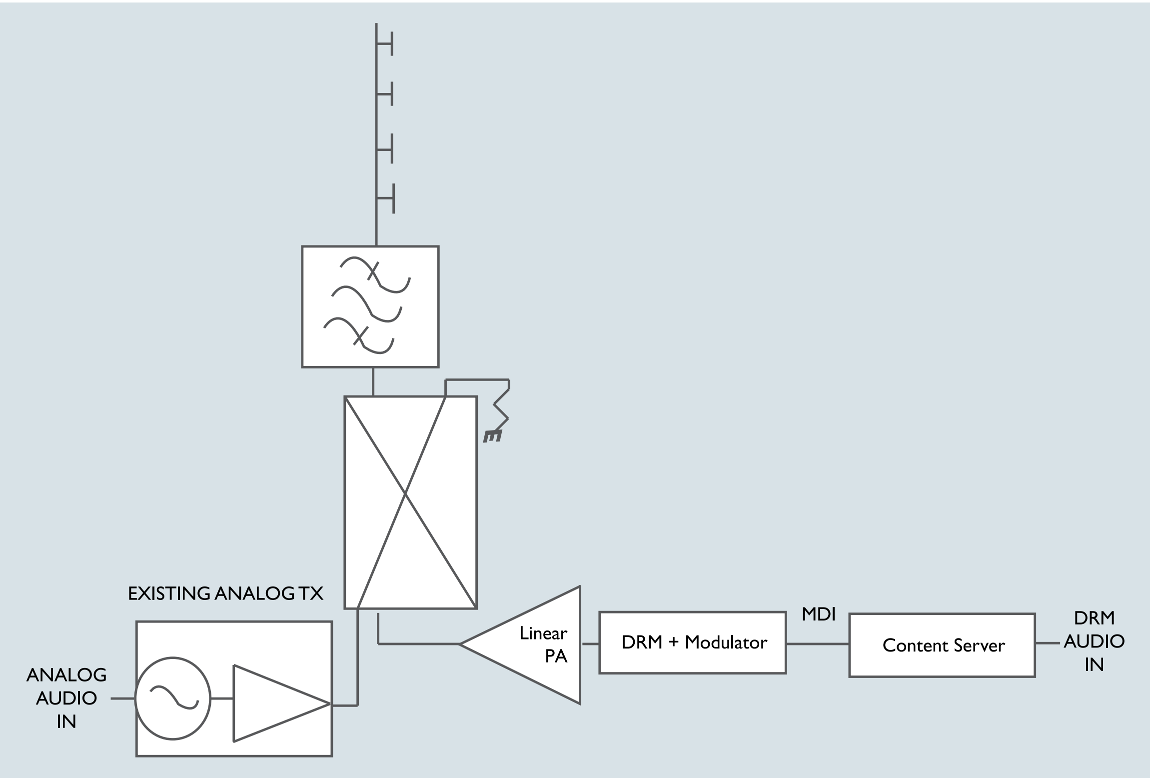


Figure 9.3.2.1 DRM+ combined mode with RF power combining

Transmission power is lost in the dummy load connected to the necessary hybrid coupler, but the advantage is that the analogue and digital chains are fully independent in operation.

9.3.2.2 "In Air" Combined Mode With Separate Antennas

It is also possible to use two antennas for the different signals, one for the DRM+ signal and one for the FM signal. The two antennas should ideally be on the same mast and have similar radiation patterns in order to preserve the amplitude relationship between analogue and digital signals. From an energy consumption point of view, this is the most efficient way to operate a combined mode arrangement (see Table 9.3).

But it doesn't guarantee that the power level between analogue and digital transmission stays absolutely constant as it is possible in multipath conditions.

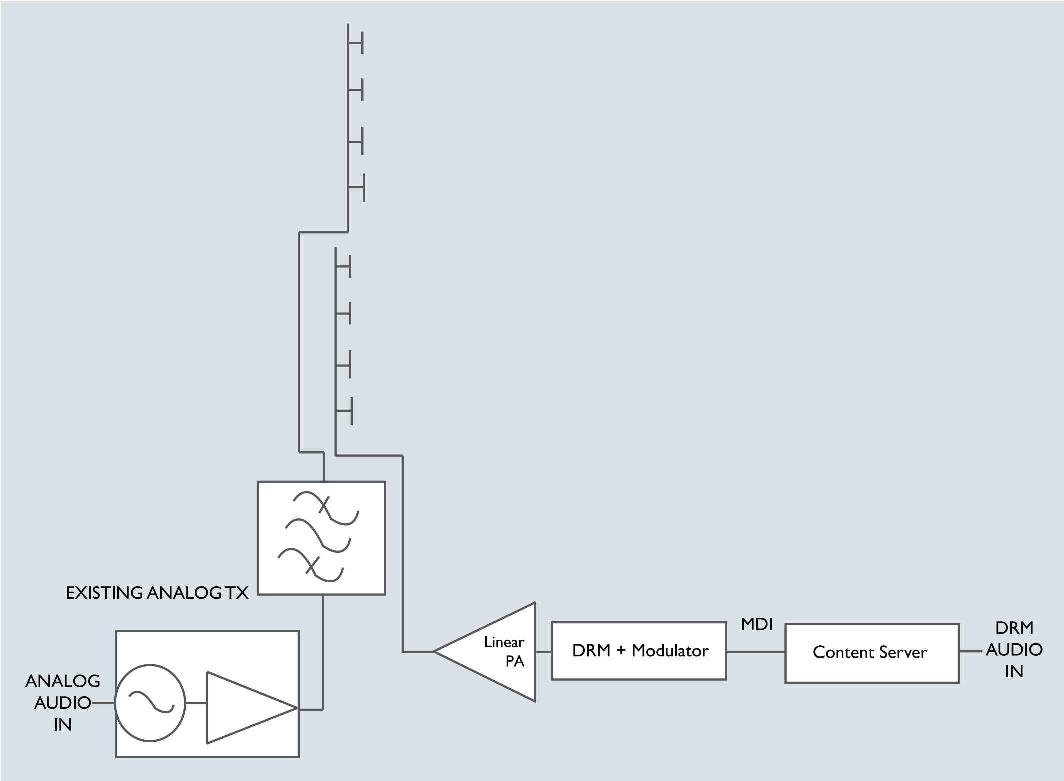


Figure 9.3.2.2a DRM+ combined mode (antenna coupling)

A very elegant option is to use a mixed, slant or circular polarisation antenna with independent input feeds of the H and V polarisation elements (split feed antenna, see Figure 9.3.2.2a).

Note that in multipath conditions, neither option above will guarantee that the power level between analogue and digital transmission will stay absolutely constant.

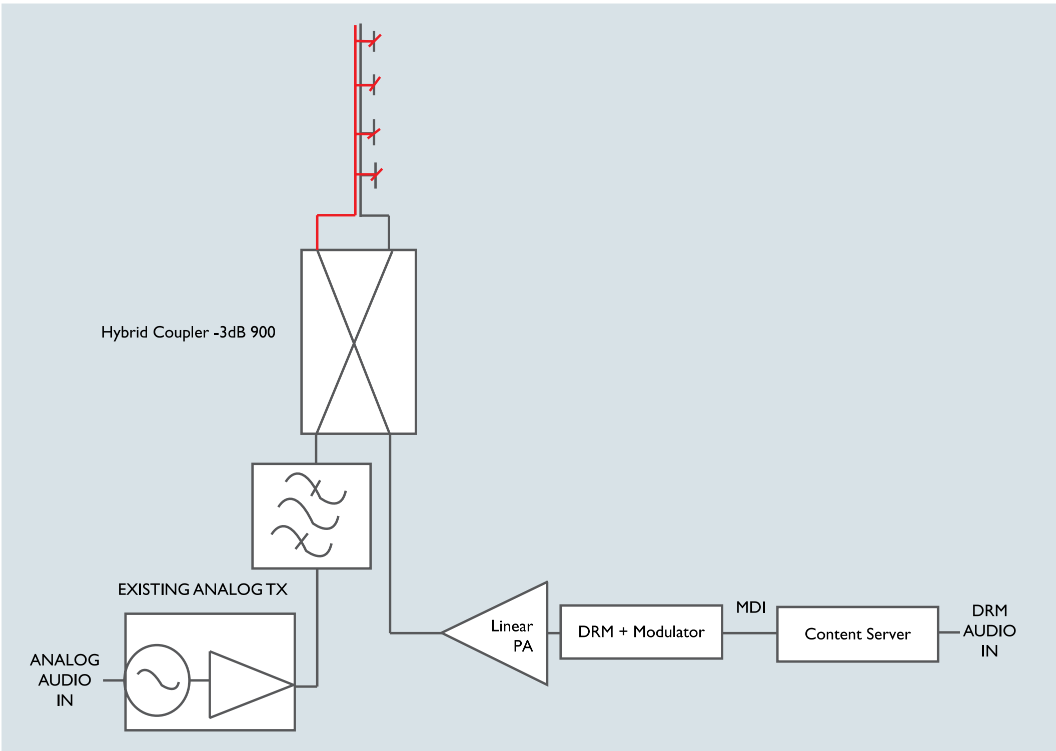


Figure 9.3.2.2b DRM+ Combined Mode, split feed Antenna coupling

9.3.3 Drm+ Combined Mode Setup (Signal Level Combining)

It is also possible to combine the FM and DRM+ signals prior to the main power amplifier. For this mode, the PA is required to be modified or designed specifically to accommodate the two signals without generating excessive intermodulation products.

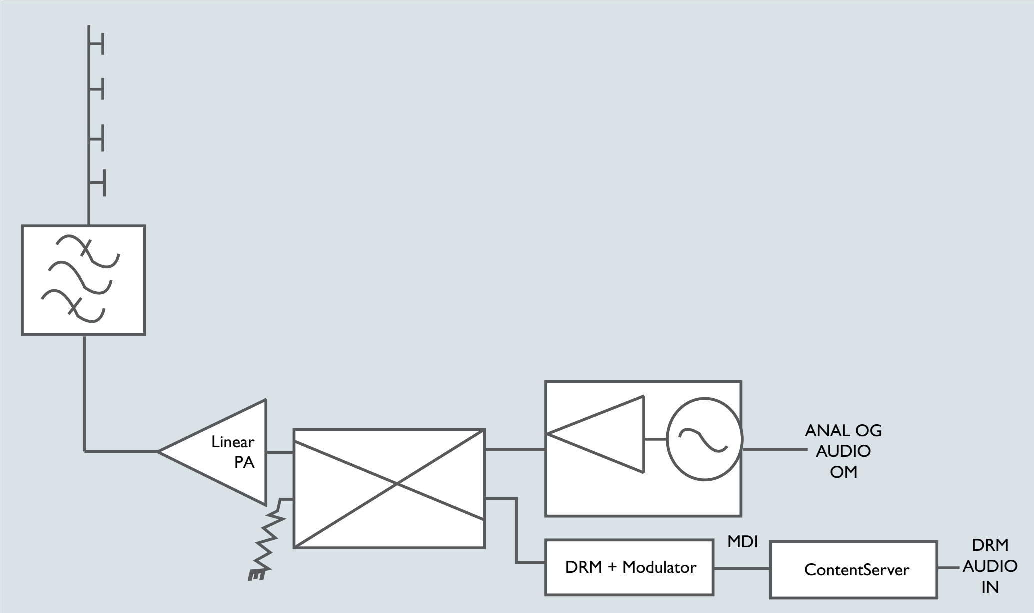


Figure 9.3.3 DRM+ and FM combining at low signal level

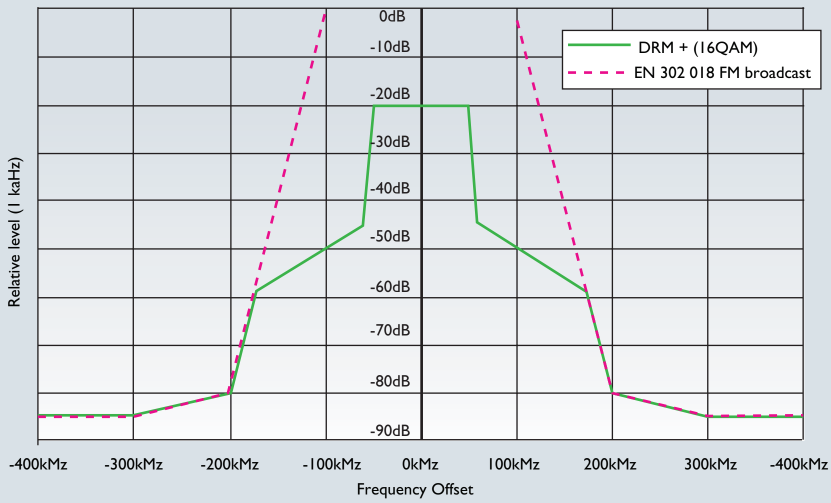
In this configuration the DRM+ signal and the FM signal are combined in front of the power amplifier. The coupling is done at low signal level and the energy losses on the dummy load resistor connected to the hybrid coupler is insignificant.

9.4 SPECTRUM MASKS AND PROTECTION LEVELS FOR DRM+

To broadcast with DRM+ in the existing bands alongside other transmissions, the protection levels and a transmitter spectrum mask have been defined. The goal for a broadcaster is to tune all the parameters perfectly to stay within the masks, avoiding interference with other transmissions and maximise the coverage of their own transmission.

A transmitter mask for this signal is not standardized, but from the intention not to overshoot the existing mask for FM broadcast from ETSI EN 302 018-1, the following mask was used:

Transmitter masks for DRM + /160AM and FM broadcast



EISI mask for FM:

Offset	rel.level (1kHz)
-400kHz	-85.0 dB
-300kHz	-85.0 dB
-200kHz	-80.0 dB
-100kHz	0..0 dB
100kHz	0.0 dB
200kHz	-80.0 dB
300kHz	-85.0 dB
400kHz	-85.0 dB

DRM + mask

Offset	rel.level (1kHz)	Attenuation
-400.00kHz	-85.0 dB	-65.0 dB
-300.00kHz	-85.0 dB	-65.0 dB
-200.00kHz	-80.0 dB	-60.0 dB
-172.00kHz	-53.0 dB	-39.0 dB
-60.00kHz	-45.0 dB	-25.0 dB
-50.00kHz	-20.0 dB	0.0 dB
50.00kHz	-20.0 dB	0.0 dB
60.00kHz	-45.0 dB	-25.0 dB
172.00kHz	-59.0 dB	-39.0 dB
200.kHz	-80.0 dB	-60.0 dB
300.00kHz	-85.0 dB	-65.0 dB
400.00kHz	-85.0 dB	-65.0 dB

Figure 9.4a Spectrum mask for DRM+ and FM broadcast

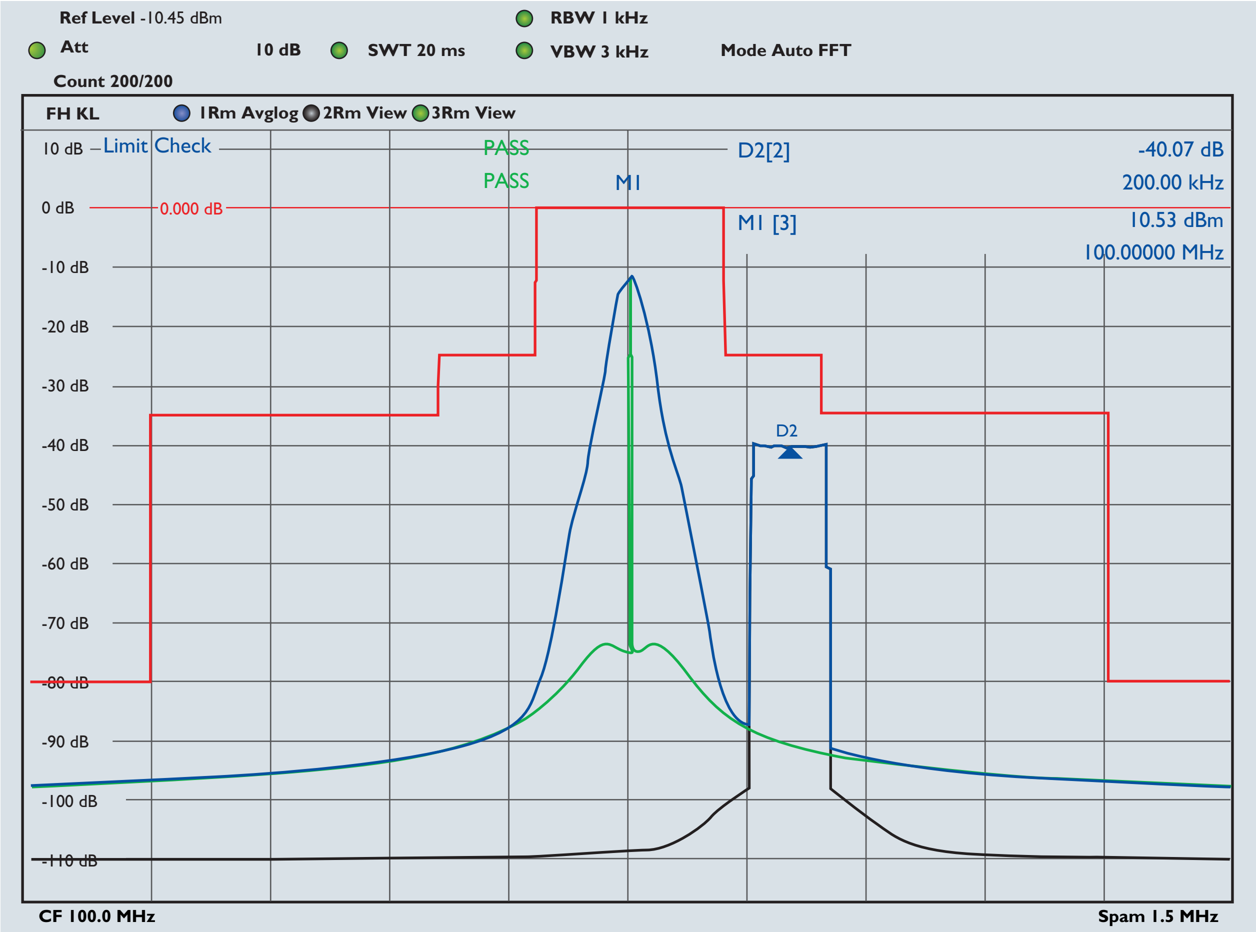


Figure 9.4b DRM+ combined mode spectrum plot

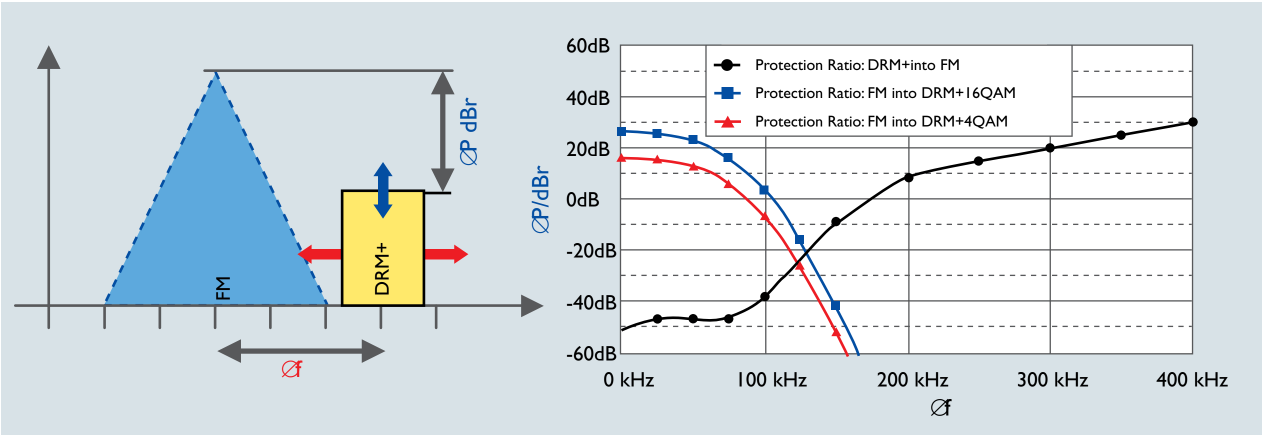


Figure 9.4c DRM+ combined mode power setup and protection levels

- The black curve shows the maximum DRM + power ratio that will not impair the analogue signal beyond the recommended protection criteria.
- The blue curve shows the minimum power ratio for 16 QAM DRM+ in the presence of an analogue FM interferer.
- The red curve shows the minimum power ratio for 4 QAM DRM+ in the presence of an analogue FM interferer.

9.5 TRANSMITTER MONITORING

DRM requires a different approach to monitoring, than that normally used for analogue broadcasting. Observation of the DRM RF envelope on an oscilloscope reveals little useful information and the RF spectrum of a DRM pseudo random binary test sequence (PRBS) is essentially identical to the spectrum of a DRM programme or data signal. A simple AM or FM demodulator can of course no longer be used to monitor the transmitter.

An immediate and simple monitoring solution is to employ a software receiver, which uses an analogue receiver as a front-end together with a PC decoder. At least one manufacturer offers the front-end receiver with the necessary 12 kHz IF output. The decoder can be easily implemented on a laptop PC, which is set up alongside the DRM transmitter with the audio output routed into the station monitoring system - or the system can be included as part of the maintenance engineer's toolkit when visiting unattended transmitter sites. This simple system will allow basic monitoring and programme checking to be carried out on the transmitter.

Some DRM exciters on the market use built in test receivers to supervise the output signal.

9.5.1 Characterising Transmitter Performance: The MER

As well as compliance with the OOB power spectrum mask, a useful way of characterising the performance of a DRM transmitter is to measure the Modulation Error Ratio (MER). Every DRM capable transmitter must match the DRM spectrum mask and the MER limit at the same time. As it has been explained in an earlier section, the DRM signal consists of a group of discrete equally spaced carriers.

Each carrier is modulated in terms of amplitude and phase and so can be represented as a vector. Errors in the modulation process, phase noise in the RF drive synthesiser and less than ideal response in the transmitter amplitude and phase paths can be considered to add an error vector which, when added to the distortions introduced by the RF channel and receiver may cause overall errors in the decoding process in the receiver. The MER indicates the ratio between the undistorted "wanted" vector and the error vector introduced by the system, averaged over many carriers, and is normally expressed in dB. Thus a high MER figure shows that the error vector is small compared with the wanted vector and in consequence there should be little difficulty in correctly decoding the data represented by the carrier phase and amplitude. For a compliant DRM transmitter, an MER of 30 dB or greater should be expected.

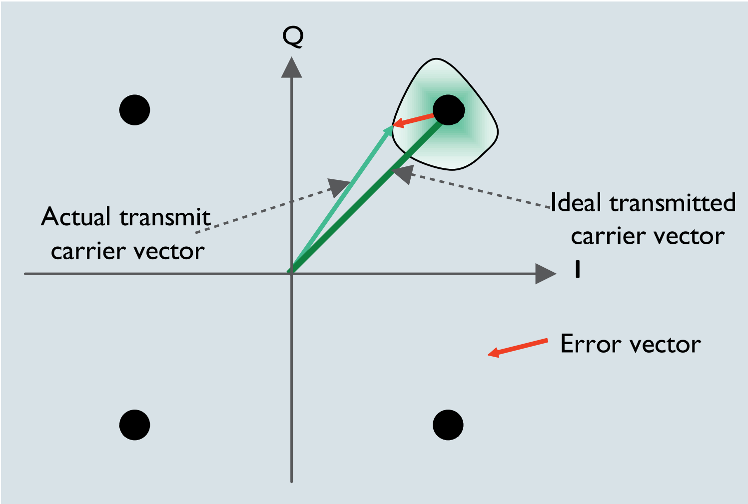


Figure 9.5.1a Derivation of Modulation Error Rate MER

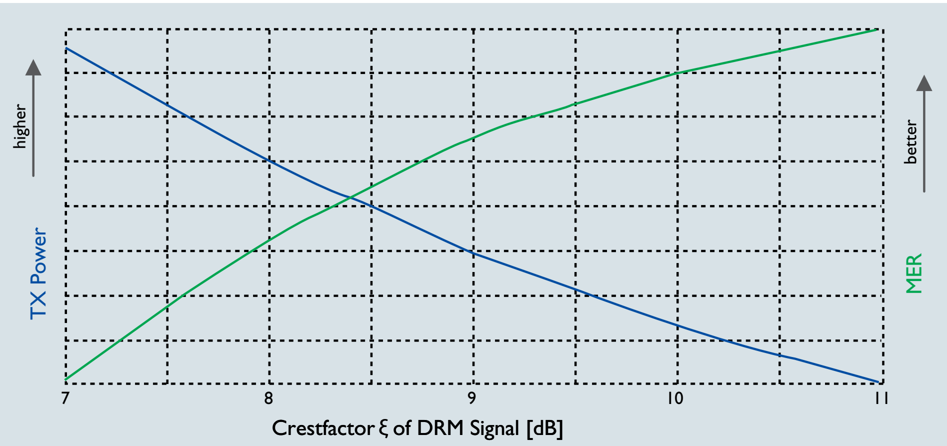


Figure 9.5.1b Power Crest factor relation

As mentioned earlier, DRM power available from an AM transmitter is normally lower than the rated AM power. This is because the peak-to-mean ratio of the DRM signal is around 4dB higher than that for 100% AM modulation. Thus from a broadcaster standpoint, it might be desirable to enhance the DRM power by effectively clipping the peak envelope and hence reducing the transmitted crest factor of the DRM signal. The price paid for this power enhancement is a decrease in MER. Figure 9.5.1b illustrates the relation between the maximum RMS DRM power obtainable (from a given amplifier), the MER and the crest factor of the DRM signal.

9.6 TEST EQUIPMENT

As a minimum, a Spectrum Analyser having sufficient dynamic range to confirm out of band spectrum mask compliance and a DRM Reference Receiver for determining MER, bit error rates and audio quality checks on the transmitted signal, will be needed to commission and maintain a DRM system. See the DRM web-site for links to manufacturers and suppliers.

9.7 ANTENNA SYSTEMS

As a very broad generalisation, the antenna systems used for analogue broadcasting in the HF and FM Bands can be used for a DRM service operating in the same band.

For LF and MF services, the primary concern is that of obtaining adequate bandwidth, as determined by the return-loss seen by the transmitter. This is particularly important where 18 or 20 KHz DRM signals are to be radiated or where analogue 9/10 KHz DSB and 9/10 KHz DRM signals are to be radiated on adjacent channels in simulcast modes. In the later case it may not be practical to use the existing antenna, if it cannot be economically modified to provide sufficient bandwidth.

An immediate effect of a restricted antenna system bandwidth is to attenuate the amplitude and alter the phase relationship of the outer carriers. This is not actually a problem for DRM, as the receiver is able to correct such distortions. There is also a possibility that a restricted bandwidth may react on the associated transmitter and increase the OOB power. Equally well, a restricted antenna response may serve to attenuate some OOB power. In extreme cases, excessive reflected power can cause transmitter to cut back output power, or even trip.

Where the antenna bandwidth is commensurate with the DRM signal bandwidth, it can be expected that the RF spectrum observed with the transmitter loaded with the antenna will be different to that observed with a resistive test load. In setting pre-correction, it may well be necessary to take account of antenna characteristics.

9.7.1 MF Antennas

MF Antennas are normally tuned to the service frequency, although in some installations two or more services may be radiated from a common antenna. Many types of MF antenna exist. The particular configuration used is determined by coverage area and whether ground wave only, or a combination of both ground- and sky-wave propagation, is to be used.

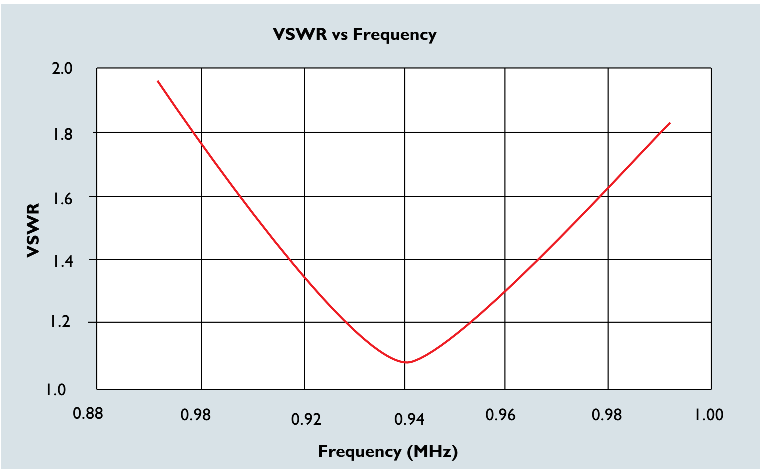


Figure 9.7.1 MF λ/4 Antenna: typical VSWR

MF Antennas are usually adjusted to present a resistive load at the service frequency. Either side of this frequency, the load impedance presented to the transmitter becomes complex with an increasing imaginary component. For DRM, the recommendation is that the antenna impedance characteristic is symmetrical, that is, the sign of the imaginary component changes either side of centre frequency and the rate of rise (or fall) of the antenna impedance either side is equal. Thus, if the imaginary component is -j below centre frequency it must be +j above centre frequency or vice versa. Antenna bandwidth can also be expressed in terms of the VSWR characteristic. Investigations undertaken by several companies indicate that for DRM, the VSWR at ± 10 kHz from centre should be not greater than 1.1:1 and not greater than 1.05:1 at ± 5 kHz from centre. Performance parameters better than this may be required for the satisfactory radiation of DRM 18/20 kHz wideband signals.

To illustrate this, the basic VSWR characteristic for typical single λ/4 resonant mast radiator is shown in Figure 9.7.1. This characteristic refers to a base fed 75 metre mast, having a diameter of 0.5 metre, and was obtained by NEC modelling. The resonant frequency is approximately 939 kHz.

Shunt fed and folded monopole resonant configurations have a similar response and the VSWR characteristic meets the requirement for DRM. In electrical terms the antenna "Q" factor, and hence bandwidth, is very dependent on the physical size and form of the radiator. Thus a "cigar " shaped mast would have a low Q, flat VSWR characteristic and wide bandwidth, whereas a "thin" antenna would have a high Q, steep VSWR characteristic and narrow bandwidth.

Generally, practical single mast radiators, operated at their resonant frequency, are unlikely to present bandwidth problems for DRM. In very extreme cases, however, modifications may be needed to the physical structure of the mast in order to achieve the required bandwidth.

In multi-mast antenna configurations, such as Yagi arrays and "Four Posters", the coupling between radiators and reflectors will have an influence on the bandwidth of the driven masts and generally tends to increase the Q and decrease the bandwidth. For these examples, some further work may be required to ensure satisfactory operation.

As has been shown, the bandwidth and hence VSWR characteristic of the basic practical MF resonant antenna is unlikely to present any serious problems for DRM. Consideration must however be given to the likely effects on bandwidth of matching networks, reject filters, combining networks and feeder systems that are interposed between the antenna and transmitter.

9.7.2 LF Antennas

The plot in Figure 9.7.2a shows the input impedance characteristic of a 220 metre base fed mast.

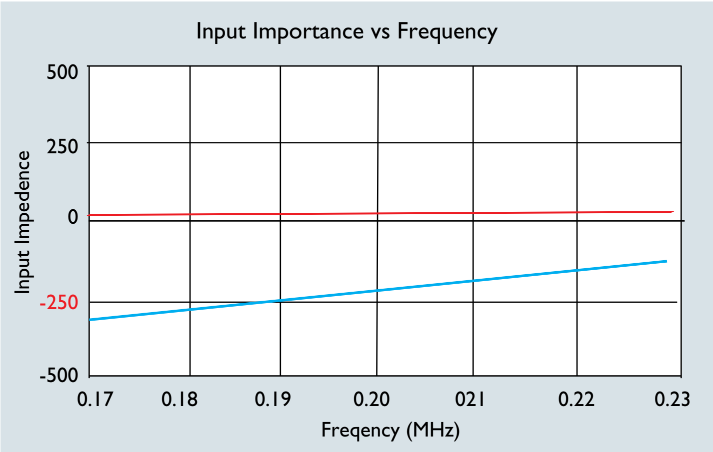


Figure 9.7.2a LF Antenna Input Impedance

The red curve represents the resistive component and the blue, the reactive component. As can be seen the antenna is predominantly capacitive with a very small resistive component, typically this is of the order of 5 – 10 Ohms.

The use of non-resonant antennas may reduce the bandwidth; however the implications are not considered here.

In plot Figure 9.7.2b we can see a characteristic Smith Chart of a folded monopole 198kHz LF antenna over +/- 10kHz both before and after an optimised broadband matching ATU network.

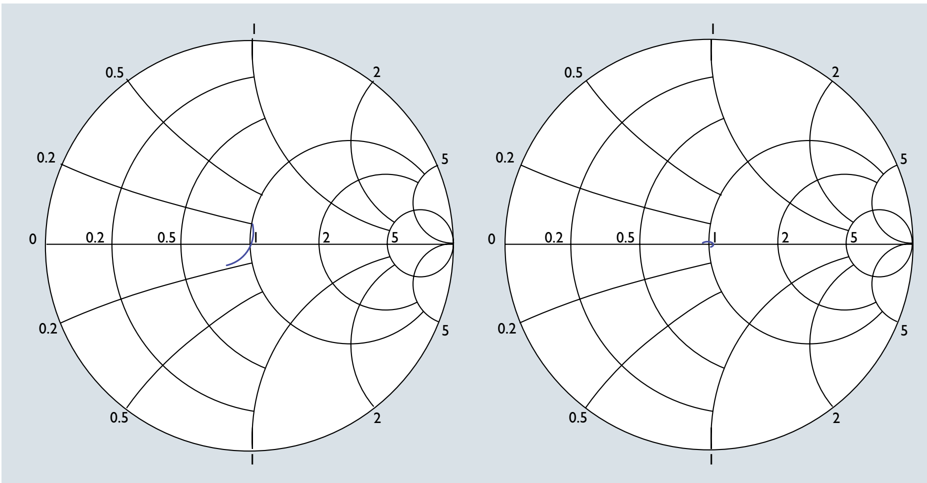


Figure 9.7.2b LF Antenna Smith Chart: left, antenna only; right, including ATU

9.7.3 Matching And Combining Networks

In order to ensure that the transmitter is presented with a symmetrical impedance characteristic, it is necessary that the matching network and feeder system interposed between the antenna and transmitter corresponds to an integer-multiple of quarter wavelengths at the channel centre-frequency. Where this criterion is not met, symmetry can be restored with the addition of phase shift or phase rotation networks. This will also often improve the bandwidth. Matching networks for non-resonant antennas, or those including rejection filters and combiners at multi-service sites may have a restricted bandwidth. Methods of overcoming restricted bandwidths are discussed in the next section.

9.7.4 Implementing A Drm Service On An Existing Antenna System

As mentioned earlier, the intrinsic bandwidth of HF and FM antennas is more than adequate for the DRM signal, and such antenna systems can normally be used without alteration.

The situation is however different at LF & MF. As a first step, the antenna impedance characteristic must be established. This is most easily obtained using a Network Analyser and if presented in the form of a Smith Chart, the amount of phase rotation needed to correct an asymmetrical characteristic can be determined directly from the plot. The required phase rotation can either be implemented with an additional phase shift network or the existing matching circuit modified.

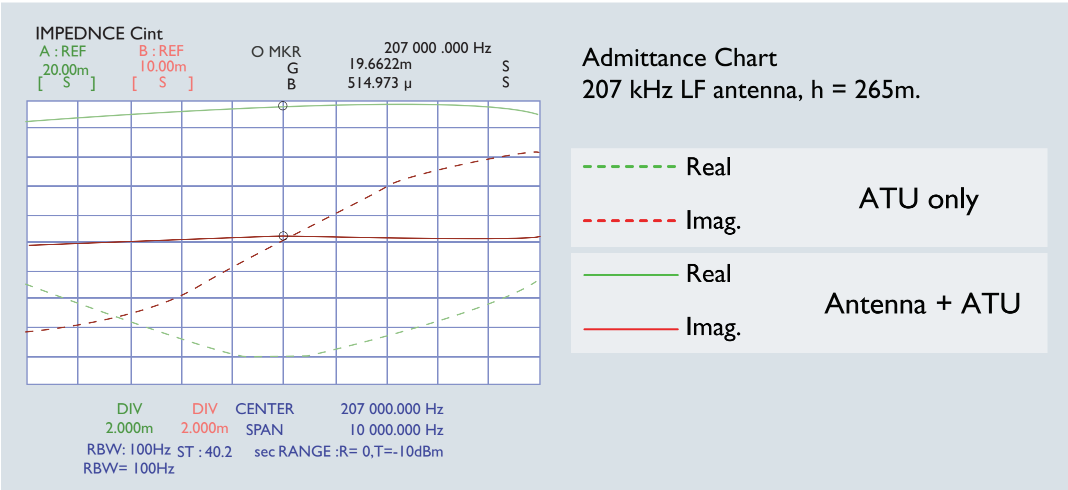


Figure 9.7.4 Matching of LF antenna

Where system bandwidth (in terms of the VSWR characteristic — which can also usually be obtained from the Network Analyser), is less than optimum, the first line of approach is to consider the transmitter and antenna system response as a whole. The overall response is then measured and used to determine the pre-correction required at the DRM Modulator and so compensate for the restricted antenna bandwidth. The better solution is to review the antenna system design in consultation with the suppliers as they may be able to offer alternate matching / combiner network configurations having a wider bandwidth.

SERVICE PLANNING

10

10 SERVICE PLANNING

10.1 SCOPE

This section provides some illustrative background information (and a number of important references) to documents which detail the work undertaken to derive the protection and planning criteria required for DRM transmissions. Service planning is a complex subject, and it is neither appropriate nor feasible to reproduce all the relevant information in this manual, especially as it is already openly published elsewhere [24, 25].

However, we have included an overview of some of the more important techniques and know-how gleaned from several years of operating and monitoring DRM and similar digital services.

Finally, a short summary of reception monitoring is provided.

10.2 NETWORK TOPOLOGIES

Normally, the service planner is set the task of designing a transmission system to achieve a prescribed quality-of-service over a given target area (local, regional, national etc). In most instances, the editorial or geographic boundary of the target service area will not coincide with the service area dictated by propagation physics. In other words, it normally requires careful planning and optimisation of transmitter powers, site locations and antenna configuration to achieve something close to the desired coverage. The whole process is further constrained by (in particular) budgets, site access, frequency allocations and co-ordination issues.

The DRM system provides the planner with a powerful tool-kit of techniques which can significantly ease these problems when designing a digital network.

i. **Choice of frequency-band**
   As DRM supports broadcasting in all the LF, MF and HF bands, together with VHF Bands I, II and III, finding suitable frequency allocations should be made much easier.

ii. **Out-of-band operation and cross-network signalling**
   Frequently, broadcasters who are currently confined to one band (e.g. MF or FM) often make the assumption that they should seek to migrate to digital transmissions operating in the same band. With the ability to signal (AFS) and cross-link between AM, FM and all DRM modes, it is possible to commence digital services in any band. The listener will tune a radio using a list of station names derived from band-scans, and will be unaware of (and unconcerned by) the actual frequencies used for transmission.

iii. **Multi-band (hybrid) digital networks**
   Whilst SFN's and MFN's can provide a flexible range of coverage options, it is also feasible to exploit the unique advantages of the various DRM modes when planning services. For instance, an MF frequency can be used for wide-area rural coverage, supplemented by 26MHz or Mode E transmissions in cities, where man-made noise-levels and steel-framed buildings cause reception difficulties.

iv. **Dynamic mode-changing**
   The ability to change the broadcast signal parameters in response to propagation conditions is an extremely powerful tool which is only available in digital modes.

One illustration of the use of such a technique is dealing with the thorny issue of night-time (sky-wave) interference to services in medium-wave. In addition to any possible change to transmitter power, by moving from 64 to 16QAM and applying stronger coding, an additional 6 to 10dB of protection can be obtained, helping to equalise day and night-time coverage.

10.2.1 Single Frequency Networks (SFNs)

Although analogue synchronous networks are sometimes used at MF and LF to provide extended coverage, there will always be problems with mutual interference in the overlap regions, sometimes known as "Mush Areas". This usually requires the use of additional frequencies to supplement coverage in these areas. FM transmissions are particularly susceptible to multipath, especially in stereo, and single-frequency networks are therefore only rarely used, and then under very prescribed conditions[6].

With careful design, these problems can be all but eliminated using a DRM SFN. Provided the received signals all arrive within the guard interval they will reinforce each other and reception should be improved compared to a single-transmitter case. There are two separate mechanisms at play which lead to improved reception

i. Increased strength-strength as a result of the "power-sum" of the individual transmission components (see Fig 46)

ii. At VHF frequencies, a phenomena known as "network gain" whereby the standard deviation of the median field-strength is reduced as a result of contributions from two or more transmissions received over uncorrelated paths.

The impact of network gain at VHF frequencies can be significant[7]: in essence, it is a quantitative figure reflecting the benefit of diversity in reducing the probability of a flat fade in a Raleigh channel.

[6] For instance, providing coverage along a highway using a "linear" network of transmitters each feeding a directional antenna
[7] Research results for DAB SFN's in Band III yielded a figure of around 4dB for Network Gain

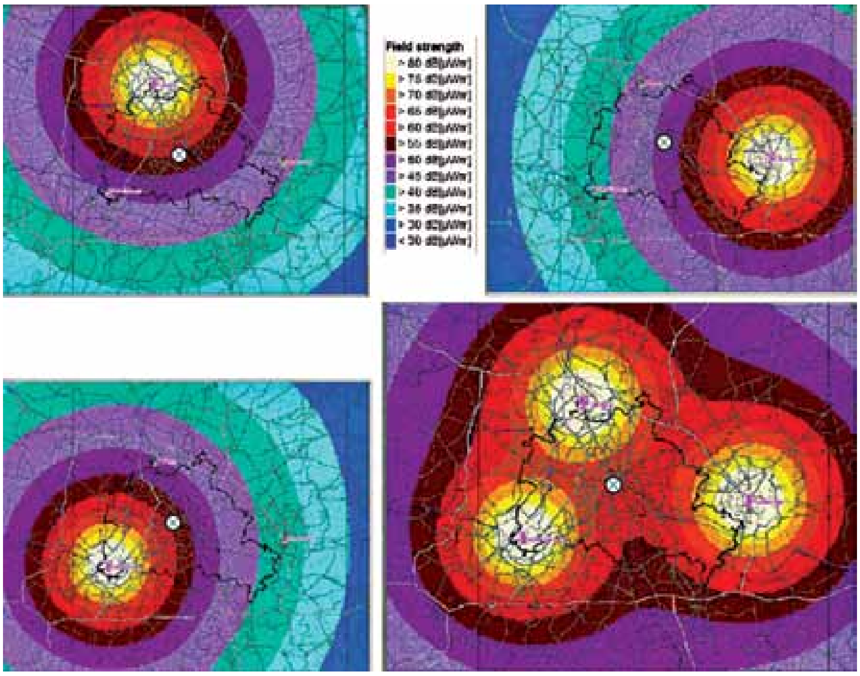


Figure 10.2.1Three-transmitter MF SFN covering Berlin

10.2.2 Multi-frequency Networks

MFN's offer an attractive solution to providing wide-area coverage in situations where any one frequency cannot be co-ordinated or licensed across the desired territory. As described earlier in Section 5.3.5, provided the same DRM mode is used for all transmissions then it is possible for a DRM receiver to switch between frequencies without breaks in the audio, (in a similar manner to the AFS feature of FM RDS). Network synchronisation requirements are virtually identical to those required for an SFN.

For a more general case where the listener may be handed from DRM-to-DRM, but in different bands (and hence probably different modes) or to an analogue sustaining service, audio interruptions can be minimised by using dual-front-end receivers together with either:

- A receiver memory buffer or
- The use of delay-matched transmission networks.

The typical delays inherent in interleaving etc. in various broadcast modes are set out in Annex R of the DRM standard [1].

10.3 USE OF THE 26MHZ BAND

DRM is the only digital broadcasting system designed to operate in the shortwave bands (broadcast allocations within 3-30 MHz). The "26 MHz band" (25.67 to 26.10 MHz) is a 430 kHz wide broadcasting service allocation at the upper end of the HF range, providing forty two 10 kHz (or 21 x 20kHz) channels. International broadcasters tend to favour the lower frequency broadcast bands (below 21 MHz), partly because low cost HF receivers do not pick up the 26 MHz band and partly because there are few times in the 11 year solar Sunspot Cycle when the band supports long-range propagation. Therefore, part of the band may be available for local broadcasting.

The result of using low power "line of sight" transmission systems in the 26 MHz band is a coverage area very similar to a Band I transmission. An additional benefit of the band is that man-made noise levels are usually much lower than, for instance, the MW band[1]. For local coverage the system offers the following features:

- Coverage of an entire metropolitan area, or a small portion serving a specific community.
- Use of a 10 kHz channel provides equivalent "FM-mono" or "parametric stereo" audio quality. Use of a 20 kHz channel yields more capacity and hence greater flexibility in terms of transmission modes and audio configurations.
- Use of an SFN or MFN to cover a wider area with lower power transmitters than if a single transmitter were to be used.
- Employ Alternative Frequency Switching (AFS) if the same programme is broadcast on more than one frequency, with the receiver dynamically selecting the best signal.
- Significantly lower power levels than those needed for an MF transmission providing similar coverage.

The use of 26Mhz for local services has been studied by ITU-R Working Party 6A, and readers with a TIES subscription are referred to Document 6A/260-E [12], entitled "DRM: Planning digital local radio services using the 26 MHz band": further relevant DRM studies are likely to be published by this group.

[1] See Annex 4 for an overview of DRM field-trials in both the 26MHz and MF bands

10.4 PLANNING TOOLS

At the time of writing there are no planning tools available which have been specifically designed to calculate coverage and availability for DRM transmissions.

However, provided that the broadcaster uses a transmission mode appropriate to the channel being used, the more esoteric aspects of digital transmission and reception (delay spread, channel impulse response etc) are automatically catered for within the various DRM-mode parameters. This then leaves only the received field-strength (and predicted interference levels from other broadcasts) to be determined by the planning tool in precisely the same manner as when planning an analogue service. In other words, given the additional knowledge of the receiver performance and the relevant local noise-floor, the overall received c/n ratio can be calculated in the normal way.

Hence, current "analogue" planning tools capable of predicting mean and standard deviation of field-strength can be used to plan DRM services, provided the appropriate target s/n figure for the relevant DRM mode is used.

10.5 PLANNING DATA

The planning data for DRM networks has been derived from a mixture of theoretical and simulation modelling, complemented by laboratory and field-trial measurements. The starting point for this work is a set of theoretical minimum carrier-to-noise ratios for the DRM system: these figures assume perfect receivers and no man-made noise etc. It is then possible to derive real-world performance data using ITU planning assumptions and methodology, as described in outline below.

10.5.1 DRM Theoretical S/N Ratios

These values were derived by passing the various modes of DRM signals through one of six pre-defined channel models. These channel models in turn were based on real-world channel-sounding experiments which were used to characterise Doppler and delay spread, and multipath (number of paths, relative amplitudes etc.). These six channel models are imaginatively labelled 1 to 6: Table 10.5.1a gives an overview of their basic scope and intended use. They are defined in detail in [24].

Table 10.5.1a: Summary of DRM30 RF channel models		**Representative of:**		
Channel model No.		**Good**	**Typical**	**Bad**
1	Additive white Gaussian noise	LF MF HF	LF with var S/n	
2	Ground-wave + sky-wave		MF, HF	
3	4-path spread 2.2mS		HF	MF
4	2 equal paths spread 2mS			HF
5	2 equal paths spread 4mS			HF
6	Near vertical incidence in tropical zones			HF (NVIS)

Table 10.5.1a shows the required signal-to-noise ratios for four DRM30 modes when operating in Channel 1. A bit-error ratio of 1 in 10^4 corresponds to the point at which subjective audio quality starts to degrade to the point which is defined as "limit of service". Similar tables for all six channels are listed in both [25] and [26].

Table 10.5.1b: S/N (dB) to achieve BER of 1 x 10–4 for all DRM30 robustness modes Channel model No. 1						
Modulation scheme	Protection level No	Average code rate	Mode / Channel bandwidth			
			A/2	B/3	C/3	D/3
			(9 kHz)	(10 kHz)	(10 kHz)	(10 kHz)
16-QAM	0	0.5	8.6	9.3	9.6	10.2
	1	0.62	10.7	11.3	11.6	12.1
64-QAM	0	0.5	14.1	14.7	15.1	15.9
	1	0.6	15.3	15.9	16.3	17.2
	2	0.71	17.1	17.7	18.1	19.1
	3	0.78	18.7	19.3	19.7	21.4

For DRM+ (Mode E), Table 10.5.1b shows two sample modulation /code-rate combinations and the theoretical system C/N performance across a range of various propagation channels. More data will be published as field-trials continue to yield valuable results.

Table 10.5.1c: C/N (dB) to achieve BER of 1 x 10–4 for sample DRM+ (Mode E) modulation schemes					
Modulation scheme	**Average code rate**	**Channel model(s) [1]**			
		7	8	9	10-12
		AWGN	Urban @ 60km/h	Rural	SFN etc
4-QAM	0.33	1.3	7.3	5.6	5.4 to 5.5
16-QAM	0.5	7.9	15.4	13.1	12.3 to12.8

10.5.2 Drm Minimum Field-Strengths (MFS)

Extensive work has been carried out to determine the protection ratios and minimum field-strength for the various DRM modes.

For DRM30, the definitive data is published in ITU-R Recommendation BS 1615 [24]. Additionally, freely available as a PDF download, the EBU have published an excellent summary [25] of the DRM planning and co-ordination process, which includes much of the key data contained in the ITU document. Planners requiring detailed information on the various DRM planning parameters are urged to read this document.

10.5.2.1 MFS Derivation Process For DRM30 Modes

As DRM is intended to work alongside AM services for some considerable time, the planning process used is based on the same underlying principles and assumptions as those used for AM services. For AM planning purposes, the minimum field-strength is based on:

- An audio s/n ratio of 26dB referred to 30% modulation, and
- A notional figure for overall noise as seen by the receiver, and expressed as an equivalent field-strength. This equivalent noise-field is frequency-band dependant.

Table wy below sets out the ITU process used to derive the received noise field-strengths, from which the resultant minimum field strengths for DRM are calculated by adding the required DRM S/N data from the relevant source, e.g. Table 10.5.2.1a.

Table 10.5.2.1a: Procedure for estimation of the minimum usable field strength					
Parameter		**DSB (AM)**		**Digital**	
1) Required receiving quality		Audio frequency signal-to-noise ratio: 26 dB with 30% (–10.5 dB) mod. (Rec. ITU-R BS.703)		BER: 1.0E-04	
2) Required C/N for the above quality		(26 + 10.5 =) 36.5 dB		x dB (see e.g Table 10.5.2.1a)	
3) Receiver (IF) bandwidth		(8 kHz)		(10 kHz) (1 dB higher receiver intrinsic noise than DSB)	
4) Receiver sensitivity for the above C/N; dB(μV/m)	LF	60	Required in Rec. ITU-R BS.703	30.5+x	x dB above the receiver intrinsic noise
	MF	60		24.5+x	
	HF	40		4.5+x	
5) Receiver intrinsic noise related to field strength, for the above sensitivity; dB(μV/m)	LF	29.5	36.5 dB(C/N) below the sensitivity	30.5	1 dB higher than DSB
	MF	23.5		24.5	
	HF	3.5*		4.5	

Below [Table10.5.2.1b] is a typical example of one of the ITU tables reproduced in [25] which lists minimum useable field-strength for the different modulation options in Mode A (MF band). It should be noted that these results correspond to minimum noise-conditions, typically found only in quiet rural locations.

Table 10.5.2.1b: DRM mode A (MF ground-wave) Minimum usable field strength (dB(μV/m)) to achieve BER of 1 x 10–4				
Modulation scheme	**Protection level No**	**Average code rate**	**Channel bandwidth**	
			A/0 & A/1	A/2 & A/3
			(4.5/5 kHz)	(4.5/5 kHz)
16-QAM	0	0.5	33.5	33.1
	1	0.62	35.4	35.2
64-QAM	0	0.5	38.8	38.6
	1	0.6	40.3	39.8
	2	0.71	42	41.6
	3	0.78	43.7	43.2

Similar tables are listed in the EBU document [25] for the other DRM30 modes.

Data relating to levels of man-made noise is also published by the ITU, although some of the figures are believed to be out of date. More recent information has been gathered as a result of the various trials of DRM around the world: one conclusion which may be drawn from this work is that dense urban noise levels at LF and MF vary greatly between cities, and local surveys should be undertaken prior to any detailed planning in these AM bands.

10.5.2.2 Minimum Field-Strength (MFS) Derivation Process For DRM+ Modes

At the time of writing, the information relating to DRM Minimum Field-Strength requirements for various channels and reception scenarios (portable indoors, automotive, fixed installation etc) is in draft form: when finalised and approved (circa 2Q 2010) it will be submitted to the ITU and published on the DRM web-site [20].

10.6 RECEPTION MONITORING

An important part of assuring the quality of any radio transmission comes from monitoring the transmitted signals within the target coverage area. In the case of analogue services, this has generally been accomplished by using a high quality receiver for signal reception. The signal strength is then read from a calibrated meter, whilst making a subjective assessment of the audio quality. Such an assessment has historically been made by someone in the target area tuning a receiver to the required service and then listening to it in real time. More recently, this manual method has been supplemented by using unmanned remotely-controlled or scheduled receivers to receive the signals and record the various signal parameters, (such as MER[8]), and sometimes a sample of the audio. This information can include not only the signal strength and audio quality, which can be assessed from the audio bit error rate, but also continuous parameters describing the quality and nature of the transmission channel. Over time the accumulation of this information should lead to an improved understanding of the propagation channel. Data acquired by the monitoring receiver can be stored locally and downloaded from the reception site on a regular basis, to provide evidence of the performance of a particular transmission, or accessed in near real time. This enables the monitoring of reception to be completely automated. To this end, DRM has developed a specification and protocol for the control interface (RSCI). If manufacturers of professional receivers use this specification it will ensure that an operator can use monitoring receivers of more than one manufacturer to build a monitoring network, but use the same software to control and download data from all these receivers. Furthermore, this opens the possibility for several operators or broadcasters to share the same receivers, if they so wish.

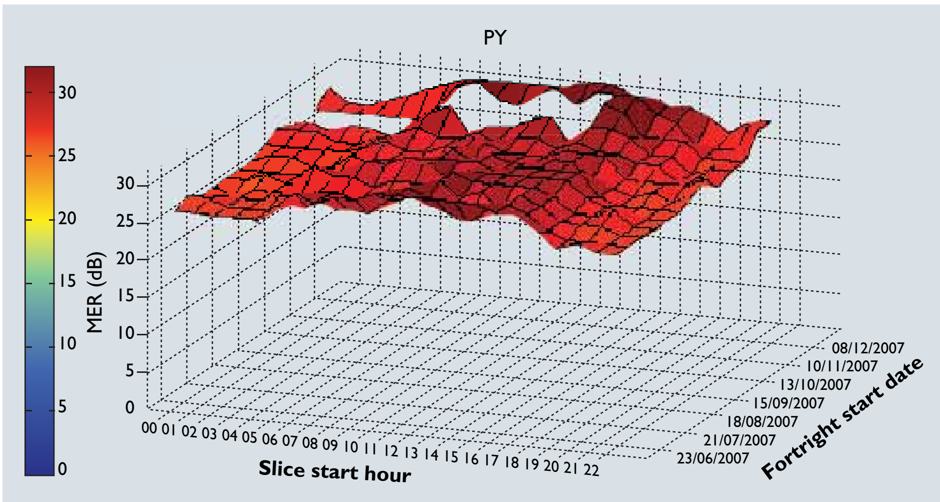


Figure 10.6 Example of MER statistics derived from Reception Monitoring [19]

Several DRM broadcasters have developed monitoring infrastructure: see for instance the BBC MF monitoring system [19] and the Deutsche Welle HF monitoring network.

[8]As described earlier in Section 9.5 the MER is based on the ratio of size of the error vector from the currently received point to the closest point on an ideal constellation. A number of different types of MER have been defined by the DRM Receiver Status and Control Interface (RSCI).

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DRM INTELLECTUAL PROPERTY

II

11 DRM INTELLECTUAL PROPERTY

11.1 SUMMARY

DRM is an open standard: all information relating to the technology is published in a series of standards administered by ETSI (see Annex 1).

- The DRM Consortium does not own any DRM patents and is completely divorced from the entire technology-licensing process.
- DRM Technology licensing is handled by VIA Technology, on behalf of a group of licensor companies.
- There is no running-royalty or other charge to broadcasters or listeners for use of the system.
- Royalties relating to DRM equipment (transmitters, receivers etc) are paid by manufacturers to VIA Technology and thence to the relevant patentees.
- The DRM Consortium does own the DRM trade-mark, which is administered by DRM as set out in 10.3 below:

11.2 IPR AND THE DRM CONSORTIUM

From a practical standpoint, there are two important classes of IPR which have a long-term impact on DRM:

- Essential patents relating to the DRM standard, i.e. patents which are necessarily infringed when implementing the system (hardware or software which is processing DRM signals: transmitters, receivers etc).
- The DRM trademark (Figure 11.2), which is registered in Switzerland and a number of other key territories, including the European Community, USA, Taiwan, Canada, South Korea, the Russian Federation, China and Singapore.¨

Figure 11.2 The DRM logo / trademark

11.3 LICENSES FOR DRM IPR

11.3.1 Manufacturers Of DRM Equipment

A DRM Patent Pool was formed in 2003 in order to facilitate a simple "One-stop" licensing regime for manufacturers. There is no link, either financial or managerial, between the DRM Consortium and this pool of licensors. The licensing of DRM IPR is undertaken by VIA Licensing, a Licensing Administrator acting on behalf of the licensor patent pool: see www.vialicensing.com

The VIA web-site gives details of royalty fees for all classes of DRM equipment. There is no royalty charge for actual use of the system (broadcasting or reception).

The DRM trademark (logo) is owned by the DRM Association on behalf of its members. It is protected through the process of trademark registration in target territories. Separately, it is also protected by copyright law and, in some territories, by laws prohibiting unfair competition.

There are a number of logo variants, comprising the basic logo plus a single word. examples are:

- Member - used by a DRM Member to denote membership, and to distinguish between this use and the use of the "basic" logo on official DRM business (or on behalf of the consortium).
- Supporter - used by DRM supporters to denote their participation in the DRM supporter's programme.

DRM Trademark use requires a formal licensing agreement to be signed and this is available, on request, from the DRM Project Office.

11.3.2 Marketing of DRM Products

The DRM Association, as owner of the DRM trademark, is responsible for setting the Terms and Conditions for use of the logo on DRM products.

It is highly probable that in many markets, DRM will be just one of several technologies bundled together, in an item of consumer equipment, to form an attractive "whole". Examples might include radios which support AM, FM, RDS, DAB+ and DRM, which will be marked as "Digital Radio", Any reference to DRM will be reserved either to denote functionality (as with "Intel Inside"), or compliance with the minimum performance requirement set by DRM. Thus the logo, whilst potentially performing an important short-hand or quality assurance role, will normally be displayed alongside other branding on the packaging and / or product itself.

11.3.3 Use of DRM Logo on Products

Manufacturers of DRM equipment may request a license to use the DRM logo on their products. The criteria for use are set out on the DRM web-site, but may be summarised as follows:

- For consumer receivers, the manufacturer is required to self-certify the performance and functionality of the design against the standards laid down in the DRM Minimum Receiver Requirements Specification [27].
- For professional equipment, the manufacturer is required to self-certify his product for compliance with the appropriate DRM standard(s).

REFERENCES

12


DiGiDiA
www.digidia.fr
the specialist of Digital Radio Transmission systems
ALTO
DRM/DRM+ AUDIO/CONTENT SERVER
SOPRANO
DRM/DRM+ MODULATOR/EXCITER
. Up to four services
. AAC+, CELP & HVXC encoding possibilities
. Text Messages insertion
. Data insertion as option (MOT SLS & BWS, IP Tunneling etc.)
. Management software through WEB
. SNMP agent (MIB v2)
. SFN Ready
. 1+1 redundancy
. All modes (A,B, C, D & E) and bandwidths
. IQ, Amplitude & Carrier, direct RF output types possibilities
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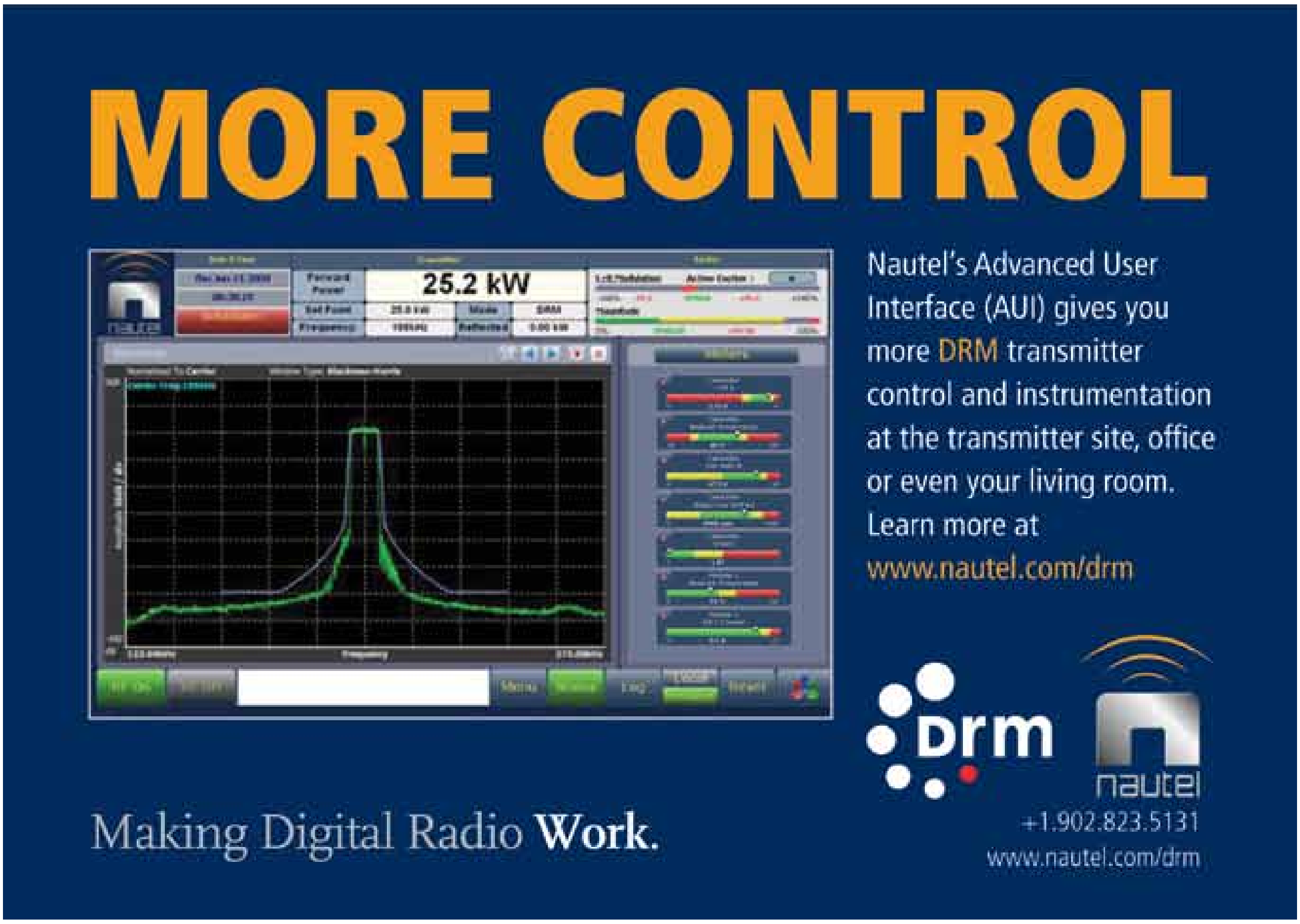
. SFN Ready
. Front Panel LCD for local settings
. Management software through WEB
. SNMP agent (MIB v2)
contact : sales@digidia.fr phone : +33 2 99 14 63 32 fax : +33 2 99 14 58 83


MORE CONTROL
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www.nautel.com/drm
Making Digital Radio Work.

12 REFERENCES

(Note: see Annex 1 for complete list of ETSI standards)

[1] ETSI TS 201 980 DRM System Specification.

[2] ETSI TS 102 821 - Distribution and Communications Protocol (DCP)

[3] ETSI TS 102 820 – Multiplex Distribution Interface (MDI)

[4] ETSI TS 101 968 – Data Applications Directory

[5] ITU-R 217/10 – MF and HF field tests report summary

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[17] User Manual_DRM-CS_R4_THOMSON.pdf August 2009

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[21] DRM software receiver project web site http://www.drmrx.org

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[24] Recommendation ITU-R BS 1615 (2003). "Planning parameters" for digital sound broadcasting at frequencies below 30 MHz

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DIGITAL radio mondiale

GLOSSARY OF ABBREVIATIONS

13

13 GLOSSARY OF ABBREVIATIONS

AFS	Alternative Frequency Switching
AM	Amplitude Modulation
AMSS	AM Signalling System
BER	Bit Error Rate
CELP	Code Excited Linear Prediction
COFDM	Coded Orthogonal Frequency Division Multiplex
DAB	Digital Audio Broadcasting
DC	Direct Current
DCP	Distribution and Communications Protocol
DRM	Digital Radio Mondiale
DRM30	Digital Radio Mondiale, system used in frequency range below 30 MHz
DRM+	Digital Radio Mondiale, system used in frequency range above 30 MHz
DSB	Double Side-Band
DVB	Digital Video Broadcasting
ETSI	European Telecommunications Standards Institute
FAC	Fast Access Channel
FM	Frequency Modulation
GPS	Global Positioning System
HF	High Frequency
HVXC	Harmonic Vector ecXitation Coding
IBOC	In Band On Channel
IEC	International Electrotechnical Committee
IP	Internet Protocol
IPR	Intellectual Property Rights
ISDN	Integrated Services Digital Network
ITU-R	International Telecommunications Union - Radio Communications Sector
LAN	Local Area Network
LF	Low Frequency
LW	Long Wave
MCI	Modulator Control Interface
MCS	Multiple Channel Simulcast
MDI	Multiplex Distribution Interface
MER	Modulation Error Ratio
MFS	Minimum Field-Strength
MLC	Multi Level Coding
MF	Medium Frequency
MFN	Multi Frequency Network
MPEG	Moving Picture Experts Group
MSC	Main Service Channel

MW	Medium Wave
NTP	Network Time Protocol
NVIS	Near Vertical Incidence Sky-wave
PFT	Protection, Fragmentation and Transport
QAM	Quadrature Amplitude Modulation
RDS	Radio Data System (see ISO EN 62106)
RF	Radio Frequency
RFP	Radio Frequency Phase
RRB	(ITU) Radio Regulatory Board
RSCI	Receiver Status and Control Interface
SBR	Spectral Band Replication
SCE	Service Component Encoder
SCS	Single Channel Simulcast
SDC	Service Description Channel
SDI	Service Distribution Interface
SFN	Single Frequency Network
SNR	Signal to Noise Ratio
SW	Short Wave
TAG	Tag
UDP	User Datagram Protocol
VSAT	Very Small Aperture Terminal
WAN	Wide Area Network
WRC	World Radio Conference

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www.drm.org

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With DRM's digital broadcasting system you can broadcast bands up to 174 MHz covering LW, SW, MW and FM Bands I and II.

DRM benefits:

- Encourages innovation
- Greater reach
- Cost-efficient broadcast
- Wider content/channels
- Zero disruption
- User friendly
- Saves energy

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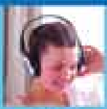

LISTENERS

Get excellent sound quality and undisrupted reception on the go. Get a wider choice of content, channels and programmes.

BROADCASTERS

Reach more listeners and roll out new, additional digital services and generate new revenue streams.

MANUFACTURERS

Generate a new market for digital radio sets & related hardware like receiver IC, Chip sets, transmitters and semi-conductors.

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ANNEX 14

1 ANNEX

List of main DRM Standards

All documents are available as free PDF downloads from ETSI (www.etsi.org).

DRM System Description:

1)	DRM System Specification:	ETSI ES 201 980
2)	Data Application Directory:	ETSI TS 101 968
3)	SCS – Single Channel Simulcast:	ETSI TS 102 509
4)	AMSS – AM Signalling System:	ETSI TS 102 386

Multiplex Distribution / Receiver Data Access:

5)	DCP – Distribution & Communication Protocol:	ETSI TS 102 821
6)	DCP/DRM – DRM specific restrictions for the use of DCP:	ETSI TS 102 358
7)	MDI – Multiplex Distribution Interface:	ETSI TS 102 820
8)	RSCI – Receiver Status & Control Interface:	ETSI TS 102 349
9)	ASDI – AMSS Distribution Interface:	ETSI TS 102 759

DRM Data Applications:

10)	EPG – Electronic Programme Guide: (structure)	ETSI TS 102 818
	(transport)	ETSI TS 102 371
11)	TMC – (Traffic Message Channel):	ETSI TS 102 668
12)	Journaline – Text based information service:	ETSI TS 102 979

In addition, the following applications standardised for DAB (Digital Audio Broadcasting) can be signalled and broadcast. Such applications and protocols used in DRM include:

13)	MOT – Multimedia Object Transfer Protocol:	ETSI EN 301 234
14)	IP Tunnelling:	ETSI ES 201 735
15)	Slideshow:	ETSI TS 101 499
16)	Broadcast Website:	ETSI TS 101 498

2 ANNEX

COFDM basics[9]

DRM is based on the use of COFDM (Coded Orthogonal Frequency-Division Multiplex). The 'C', the channel encoding employed to support error correction in the receiver, is described in 5.3.

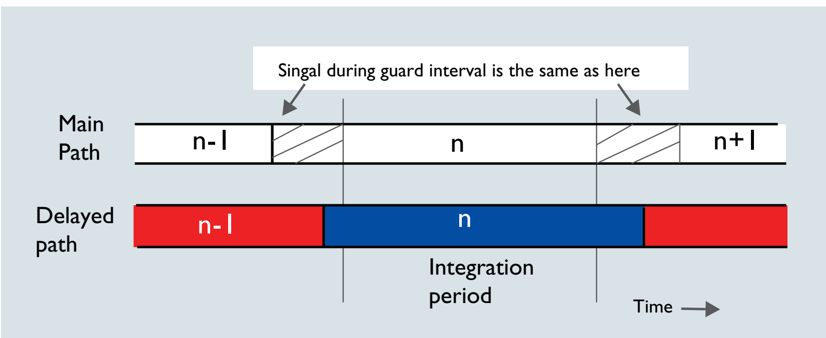


Figure A2 Total symbol period is longer than the receiver integration period by a time defined as the Guard Interval

The resulting coded information is then conveyed using OFDM (Orthogonal Frequency-Division Multiplex), by which the coded data is distributed over many sub-carriers for transmission. Each sub-carrier is modulated with a particular amplitude and phase combination — a QAM constellation point — for the duration of a transmitted symbol. As each sub-carrier only carries a small part of the total data, these transmitted symbols can be relatively long (= time duration), which together with the concept of guard intervals makes DRM tolerant of multipath propagation:— especially necessary to cope with ionospheric propagation or to permit single-frequency-network operation.

[9] see [8] for a more comprehensive overview of COFDM

Orthogonality (absence of mutual crosstalk) between sub-carriers (the 'O') is ensured by choosing the sub-carrier spacing to be the reciprocal of the so-called 'useful symbol period'. This is the duration of the time window within which the receiver observes each received symbol. However, each symbol is transmitted for a slightly longer period, the "guard-interval" duration. This approach provides tolerance against multipath propagation, provided the delay difference between the various propagation paths do not exceed this Guard Interval.

Distributing the coded information across many sub-carriers helps when there is selective fading. Typically, only a few sub-carriers will be badly affected (and the receiver can determine which they are) so that error correction in the receiver can recover the transmitted information by exploiting the redundancy introduced by the coding.

The number of sub-carriers, and their spacing, depends on the DRM robustness mode, each mode being designed to suit particular operating conditions. For DRM30 there are 4 robustness modes (with 88 to 226 sub-carriers for a channel bandwidth of 10 kHz); for DRM+ there are some 213 carriers occupying a 96 kHz bandwidth.

3 ANNEX

DRM Digital Radio Receiver Profiles
Dated: 11th September 2009

Summary

The DRM Digital Radio Receiver Profiles are designed to help create a vibrant digital radio market across the world by defining minimum functionality for different classes of digital radio receivers that use the DRM system. This provides broadcasters with confidence that the services they plan will be receivable and manufacturers that their technology investments will be supported by services. The consumer gains from knowing that the product they have chosen contains the necessary features to provide them with a consistent quality of experience and assured levels of interoperability across their region and beyond.

Products designed to meet the DRM Receiver Profiles will decode all audio services, along with other features depending on the complexity of the receiver. The profiles were developed by DRM with the aid of member experts representing silicon manufacturers, consumer device manufacturers, radio broadcasters and other experts from across the industry. The composition of the profiles takes into account consumer experience, manufacturing issues, broadcaster requirements and other market aspects.

Scope

The DRM Digital Radio Receiver Profiles define the minimum functionality requirements of products within each profile.

The Receiver Profiles are composed of mandatory features which must be implemented and recommended features which offer enhancements with wide appeal.

Manufacturers may offer additional features in order to differentiate their product from others. Products conforming to the DRM Receiver Profiles will provide a step change in usability over analogue radios, with service selection by station name from a list built up automatically by the receiver.

Manufacturers are free to choose how to compile the station list according to market need, for example by evaluating AFS and EPG information, offering frequency scanning, evaluating service lists provided by other broadcast systems (if applicable), etc. DRM service tuning by frequency should be available to the user, but never be the primary option for selecting services.

The DRM Receiver Profiles describe minimum functionality; the implementation of each feature in conformance with the relevant ETSI standards is best determined by each manufacturer and is not proscribed. In-car products are subject to the normal safety related conditions. For example, limitations for scrolling, access to services while driving, image per second limitations, etc, according to regulators or OEM requests.

Products which do not meet the minimum requirements of the profiles may be manufactured on a market-specific basis.

Regulators may use the Receiver Profiles to develop strategies and policies for digital radio broadcasting within national boundaries or with reference to trans-national and harmonised markets.

The DRM Receiver Profiles reflect receiver design issues and broadcaster capabilities appropriate for the current period and for the foreseeable future. Future changes and additions to the ETSI standards defining the DRM system [1], technology advances and market developments will be reviewed and may lead to revision of these Receiver Profiles.

The DRM Digital Radio Receiver Profiles focus on features of the Digital Radio Mondiale system. However the profile definitions are designed to support the easy co-integration with other digital and analogue broadcast systems in multi-standard receivers; in particular we recommend that all receivers should include analogue AM-AMSS and FM-RDS reception.

The DRM Consortium will globally publicise the DRM Digital Radio Receiver Profiles and actively encourage its members to adopt them.

Receiver Profile 1 – Standard Radio Receiver

3.1 This is an audio receiver with at least a basic alphanumeric display.

Spectrum	DRM reception in the MF (530 kHz to 1720 kHz), HF (2.3 MHz to 27 MHz) and international FM (87.5 to 108 MHz) bands is mandatory in all territories.
	DRM reception in other broadcasting bands is mandatory on a regional basis according to the licensed service plan[10].
	DRM reception in all broadcasting bands below 174 MHz is recommended.
Channel Decoding	Decoding of all defined channel band-widths is mandatory.
Audio	Stereo Decoding (including Parametric Stereo) is mandatory if a stereo capable output is provided.
Emergency warning	Implementation of the emergency warning / alert feature is mandatory.
Text	Service label (station name) display is mandatory.
	Text message display is mandatory on products with a 2-line display or better (except for in-car products).
	Journaline[11] presentation is recommended.
	Support for regional character sets is recommended according to the region the product will be manufactured for or sold into.
EPG	Electronic Programme Guide[12] presentation is recommended.
Traffic & Travel	For in-car products, TPEG[13] and TMC[14] decoding is recommended.
Service following	DRM to DRM service following (automatic frequency switching) is mandatory.
	For products that include analogue service decoding (e.g. AM-AMSS[15], FM-RDS[16]), DRM to analogue service following is mandatory.
	For products that include other digital radio systems, DRM to digital service following is recommended.

Receiver Profile 2 – Rich Media Radio Receiver

3.2 This is an audio receiver with a colour screen display of at least 320 x 240 pixels.

All Receiver Profile 1 functionality, plus:

Audio	Surround Sound decoding9[17] is recommended.
Text	Journaline10[18] presentation is mandatory.
EPG	Electronic Programme Guide11[19] presentation is mandatory. Decoding of the advanced EPG profile is recommended.
SlideShow	SlideShow12[20] presentation is mandatory.

4 ANNEX

DRM Field-trials (MF and 26MHz)[21]

Part 1: MF Trials

4.1.1 DRM tests in Madrid 2004

An extensive measurement campaign was carried out in order to evaluate DRM's daytime performance. This campaign was based on a 4 kW (rms) DRM transmitter near Madrid at 1359 kHz.

The results showed similar field strength thresholds to those set out in Recommendation ITU-R BS.1615 for DRM mode A/64/16/0.6/S, and slightly higher values for modes B/64/16/0.5/L and A/16/4/0.5/S.

[10] In ITU region 1 this includes LF (153 to 279 kHz)
[11] As defined in ETSI TS 102 979; decoded from packet mode including FEC
[12] As defined in ETSI TS 102 818 and TS 102 371; decoded from packet mode including FEC
[13] As defined in ISO TS 18234
[14] As defined in ETSI TS 102 668
[15] As defined in ETSI TS 102 386
[16] As defined in ISO EN 62106
[17] Discrete multi-channel output and/or binaural rendering on stereo headphone output
[18] As defined in ETSI TS 102 979; decoded from packet mode including FEC
[19] As defined in ETSI TS 102 818 and TS 102 371; decoded from packet mode including FEC
[20] As defined in ETSI TS 101 499; decoded from packet mode including FEC
[21] See[28] for more results and references

All the suburban and rural locations within a radius of 100 km from the transmitter received 100% of the transmitted audio frames correctly for all the tested DRM modes, whereas in downtown Madrid the percentage of locations with correct reception ranged from 83% to 100%, depending on the selected DRM mode. The critical factor for perfect audio decoding in urban environments was the high level of man-made noise.

A comparison study between measured field-strength values in rural and suburban environments and the predicted values given by Recommendation ITU-R P.368-7 was also performed and showed good correlation. Nevertheless, the results indicate that the method fails when dealing with irregular terrain or urban environments.

Regarding mobile reception, several routes were measured along radials from the transmitter using three DRM modes. For distances up to 35 km from the transmitter, a perfect audio quality could be observed in rural and suburban environments. In the range of 35 to 70 km, very few audio dropouts were present. Audio dropouts were due to power lines, power plants and tunnels.

The possible effect of vehicle speed did not appear to have any significant impact on reception; thus, the wider carrier separation of mode B did not provide any benefit during these MW tests.

4.1.2 DRM Test in The MF Band in Mexico City

It was found that non-professional listeners would be unaware of any audio drop-outs for SNR's >17dB. The system presented highly-reliable reception, with values near to 100% in the different types of environment in Mexico City. However, due to other factors such as topography, the type of buildings or the type of human activity present, the relationship between the transmission power and the coverage area is not so easy to calculate. The measurements carried out in these tests demonstrated that with a power of 1.25 kW for DRM signals, correct reception was achieved in 32 out of 36 locations at distances from about 4 to 20 km from the transmitter.

Because the received signal-to-noise ratio depends heavily on the local position of the receiver, there are small areas even within the coverage contour where the power level dropped (e.g. when passing under a bridge) or where the noise level was high enough to force the receiver to mute. It can be emphasized that the overall noise encountered in the Medium Wave band has been very significant and quite a lot higher than the published references in ITU-Recommendations.

The results of the measurements provide a means of estimating the coverage radius as a function of average DRM power, taking into account increases of 3 and 6 dB above the 1.25 kW used in this test in order to achieve mobile reception coverage.

4.1.3 DRM/AM Simulcast Tests in Mexico

Simulcast transmissions with DRM and AM in adjacent channels were tested in Mexico with the following configuration:

- AM transmission: Frequency 1 060 kHz, power (AM carrier): 50 kW.
- DRM: Mode A/64/16/0.5/L, bandwidth: 10 kHz, frequency 1 070 kHz and a power of 1.25 kW (rms).

  The AM/DRM power ratio was 16 dB (see Figure A1).

  Static (more than 30 locations) and mobile (500 km) measurements were performed to assess:
- AM static/mobile measurements (subjective quality assessment by experts).
- DRM static/mobile measurements.
- Man-made noise levels.

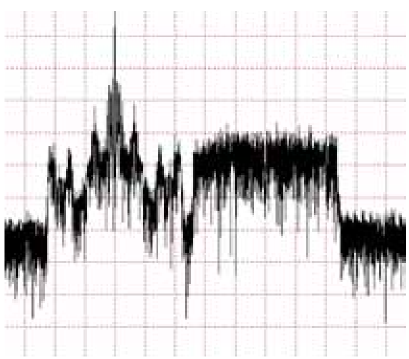


Figure A1 AM/DRM Simulcast spectrum plot and power ratio

DRM does not degrade the AM subjective quality with the tested configuration. Of 31 tested locations, 28 showed an AM subjective quality of 5 or 4 out of 5 and three showed an AM subjective quality of 3 or less (ITU 5-point scale).

The DRM reception quality results were excellent. Correct reception was obtained at 88.88% of locations and the measured SNR threshold was 17 dB. It was also noted that the DRM reception quality was independent of the environment.

Finally, man-made noise measurements conducted in Mexico City showed that the measured median values were around 40 dB higher than the ITU-R reference for the MF band. Other measurements made in Madrid have shown man-made noise levels that were 10 dB higher than the ITU-R reference. This leads to the conclusion that reception environmental factors must be taken into account for planning purposes.

4.1.4 DRM Trials in India: Simulcast, Full DRM 18 kHz

The tests took place during the DRM-AIR-ABU Showcase in Delhi from 7 to 12 May 2007.

Two transmitter sites in North Delhi (Nangli) were used for all the tests. Broadcast signals and its features are listed below:

a) Single channel simulcast in an 18 kHz MW channel is practically feasible with the following parameters:

- DRM mode: A/16/4/05/S which was found to be the most appropriate configuration.
- Analogue carrier peak power to DRM rms power ratio: 14 dB (Analogue carrier peak power: 96 kW and DRM rms power: 3.82 kW were used during the tests).
- Antenna: 115 m self radiating mast.

The coverage area for the DRM signal is marginally larger than the analogue coverage. It showed an approximately 100 km coverage radius. The reception of the DRM signal is consistently better in urban areas which were covered by the Simulcast signal up to 15 km, reaching more than 98% of locations. Another important conclusion is that the Simulcast configuration did not interfere significantly in the transmitted AM signal when using a set of representative receivers in the Indian Market.

b) Full 18 kHz DRM provides excellent quality stereo audio with the following parameters:

- DRM mode: A/64/16/06/S
- DRM power level: 50 kW.

The coverage area far-exceeded that of the analogue coverage (Current AM power on 819 kHz 200 kW) and urban environments were fully covered.

4.1.5 DRM NVIS Trials in Germany

The transmissions of the campaign were scheduled from 00:00 until 06:00 Middle European Time (MET) during one year and a half. The transmission power was 100 kW and the frequency was 1575 kHz. The radiating system featured a maximum elevation of 89.87 degrees and a beam width at 3 dB of 90 degrees. The transmitted DRM signal configuration was B/64/16/0.6/L.

The Long Term Monitoring Network was used. A new station located in Berlin (TS1) was added in order to study the system reception at distances near to the transmitter. This allowed higher detail for the analysis, along with the impulse responses estimated by the receiver.

The quality assessment performed to characterize the fixed and mobile reception showed the difficulty[22] of providing digital coverage throughout the year for the intended area, using NVIS MW night-time propagation. Field-strength level was not an issue.

4.1.6 DRM Test In The MF Band In Italy

A 9 kHz bandwidth DRM signal with transmission with configuration A/64/16/0.5 was radiated from a 148 m vertical dipole located in Siziano (20 km from Milan).

The whole north-west part of Italy was completely covered with a DRM signal whose level exceeded the minimum indicated in the relevant ITU-R Recommendation for the adopted transmission parameters (38.6 dBμV/m). Moreover, a minimum SNR of 14.1 dB was exceeded at each measurement point, even in deep valleys.

Reception was also monitored in the centre of Turin, 125 km from the transmitter. In 1 of 12 measurement points reception failed due to man-made noise: at this point a SNR of 13.4 dB was measured.

During daytime, no significant broadcast interference was recorded in the whole predicted and measured coverage areas.

4.1.7 Multi-Channel Simulcast, Urban And Indoor Reception In MW Band

The study, in which DRM configuration A/64/16/0.6/S was used, was focused on the following issues:

i. Evaluation of the DRM-AM Simulcast system; obtaining the system operating parameters for planning an AM-DRM commercial service. Specifically, two objectives were identified:

   a) To determine the coverage area, thresholds values and QoS of an AM-DRM MCS signal using a 16-dB back-off ratio between AM and DRM signals.

   b) To evaluate the influence of the DRM signal over the AM signal when using the Simulcast configuration by means of changing power back-off ratios (from 16 dB to 1.5) and evaluating the subjective audio of a representative set of AM commercial receivers.

A set of six different representative commercial AM receivers was used and overall, 33 static reception locations and more than 88 km of mobile measurements were analysed.

[22] Mainly due to delay spread and co-channel interference

The main cause of the DRM service unavailability was the lack of signal-strength. The coverage radius would have been considerably greater with an increase of power of 5 to 10 dB. The SNR threshold was fond to be 18 dB for static and 20 dB for mobile reception. The field-strength thresholds were difficult to establish because they depend on the radio electric noise whose values are very variable spatially, but a mean value of 43 dB(µV/m) was identified.

It is important to note that the DRM service part of Simulcast configuration was not interfered by the adjacent AM analogue signal.

The influence of the DRM signal on the AM subjective audio quality depends highly on the type of AM commercial receiver. The high-medium end AM receivers were not impaired or interfered by the DRM signal but some mid-range receivers begun to provide deficient audio quality with 11.8 dB back-off ratio. The low end range AM commercial receivers needed a minimum ratio of 16 dB.

ii. Evaluation of the influence of frequency in the MW band on DRM propagation in a city with dense urban areas.

The frequency-comparative study concludes that those locations where reception is affected by urban critical factors, such as high buildings and narrow streets, could improve their coverage by means of a change to a lower transmitting frequency. As a reference, in downtown Madrid, the mean difference between the measured field strength from 2 different signals (810 and 1260 kHz) broadcast from the same transmitter station with the same power is around 10 dB with a standard deviation of 5 dB.

iii. Evaluation of indoor DRM reception.

The measurements of this stage of the project were planned for six buildings of different types (apartment buildings and commercial ones) in the city centre of Madrid, and one in an industrial zone in the outskirts. 113 locations were measured.

These are the main conclusions drawn from this work:

- The best reception reliability has been found in non-dense urban environments. Values of SNR fluctuated between 12 and 29 dB.
- In dense urban environments, high buildings showed good reception, but only near windows.
- Field strength can vary up to 30 dB inside the same building with a median variation of 16 dB. The higher the floor, the better.

Finally, it is remarkable that a broadcast power of 10 kW is not enough to guarantee indoor reception in Madrid. However, with a 20 kW broadcast power, that is, 3 dB more, the coverage is increased considerably, obtaining acceptable levels in more than 80% of the analysed locations.

More tests have been carried out in Bilbao and Vitoria (Spain) in order to study MW DRM signal building penetration loss and indoor man-made noise.

Part 2: DRM 26 MHz Band Trials

4.2.1 DRM tests in Mexico

A test transmission and evaluation measurements were planned in 2005 in Mexico D.F. The main aim was to evaluate the field strength needed in a city for DRM transmission on the 26 MHz broadcasting band. The minimum field strength needed was calculated for different DRM transmission configurations and for different environments. The minimum SNR (signal-to-noise ratio) was analyzed separately. In addition, mobile reception reliability was also analysed.

The system tested had the features in Table A1.

Table A1 Transmission Centre Features

Transmission Centre	Radio Ibero (Santa Fe, México DF)
Broadcaster	Radio Educación
Frequency	25 620 kHz
Transmitted power	200 Wrms
Bandwidth	20 kHz
Radiating system	7-dBi 3 Element Yagi-Uda Antenna 40 m above ground level
Transmission site height	300 m above the average city height

Three system variants where tested, all having 18 kHz bandwidth:

1) DRM Mode A, 64-QAM, code-rate 0.6 offering a data rate of 48.64 kbit/s;

2) DRM mode B, 64-QAM, code-rate 0.6 offering a data rate of 38.18 kbit/s;

3) DRM mode B, 16-QAM, code-rate 0.5 offering a data rate of 21.20 kbit/s.

The trials showed that the third variant (Mode B, 16-QAM, CR 0.5) is the most suitable and is therefore recommended. This configuration required a minimum SNR of 18 dB and minimum field strength of 37 dB(μV/m) in order to get an availability of the service higher than 99%. This value is higher than the one given in Recommendation ITU-R BS.1615. This increase was probably required in order to overcome several sources of noise that affect the reception in urban environment (Voltage transformation plants, traffic).

The trials also showed that to provide 100% coverage for the whole Mexico City area an output power in the range of 2 – 6 kWrms would be necessary.

4.2.2 DRM Tests In Brasil

Similar tests to the ones carried out in Mexico were carried out in Brasilia, using another antenna type: a TCI Unbalanced Dipole. Again, the recommended system variant was: Mode B, 16-QAM, CR 0.5

The results showed good performance (Refer Figure A2) with a SNR threshold of 12-13 dB instead of 18 dB in Mexico. The estimated power required to cover the whole city of Brasilia was 800 Wrms. The field strength threshold was circa 37 dB(μV/m) for an availability of >99%.

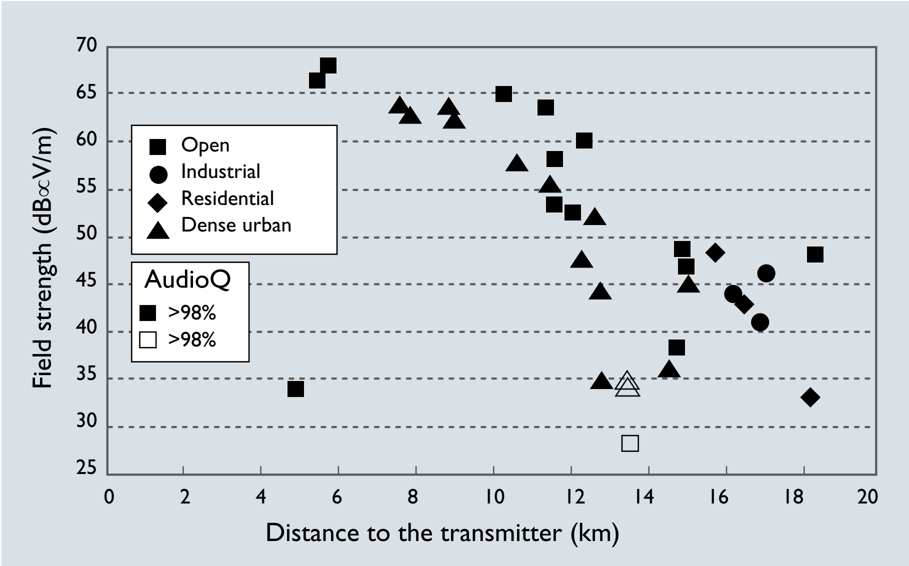


Figure A2

It was noted that the man-made noise values in this band were much lower than in the Medium Wave band. Moreover, the reference values of man-made noise given in the Recommendation ITU-R P.372 are valid in a "quiet" environment such as Brasilia.

4.2.3 DRM Tests in India

A series of tests and measurements were carried out in Delhi (India) from 9th to 12th May, 2007. The trials were a part of the DRM-AIR-ABU Showcase Project on Digital Radio Mondiale (DRM) Simulcast technologies that took place in Delhi from 7 to 12 May, 2007.

The 26 MHz DRM service provided very good quality local coverage with the configuration B/16/4/0.5/L and a bandwidth of 20 kHz. The power was 500 Wrms and the antenna a 3-element Yagi-Uda.

Cut-off point was detected at about 7 to 10 km from the transmitter and the reception quality was considered as GOOD by expert listeners.

4.2.4 DRM Tests in Germany

The potential interference from very distant locations (200 to 5000 km) due to Sky wave was considered in these tests. Some reports from Dr. Lauterbach provide a complete set of interference calculations.

A Maximum Usable Frequency of 25.67 MHz was considered and a minimum field strength of 12 dB(μV/m). With these values, a Sun Spot Number (SSN) higher than 50 would lead to very probable ionospheric propagation at any season from 6 to 20 hours UT. If a SSN higher than 125 is considered, very critical interference would be very probable from 8 to 16 hours UT in February, March, October and November. The use of antennas designed to reduce unwanted ionospheric emissions would lessen the potential interference significantly.

4.2.5 DRM Tests In The 26 MHz Band For Local Coverage In Italy

Vatican Radio, under a collaboration agreement with RAI, has performed test DRM emissions from their "Marconi building" in the Vatican City, broadcasting in the 26 MHz band to downtown Rome, in order to assess the subjective reception quality which could be obtained when low-power transmitters are used as gap-fillers.

Statistic				External Noise Figure Median Value	Time Variation Upper Decile Deviation	Upper Decile Deviation Variation
ITU VALUES	Rural			28.06	9.20	6.80
	City			37.66	11	8.40
	Residential			33.36	10.60	5.80
EMPIRICAL VALUES	Mexico	City / Residential	25.620 MHz	<37.0 (*)	-	9.40
	Brasilia		25.885 MHz	42.7	< 2	5
	Nuremberg		26.000 MHz	48.7	1.80	5.40
			26.020 MHz	52.7	2	3.40
			26,300 MHz	48.6	4.80	2
		Rural	26,000 MHz	< 35.7 (*)	1.13	1.90
			26.020 MHz	< 37.7 (*)	2	4.10
(*) Values influenced by the internal noise level of the measurement system						

The Vatican Radio test emissions featured a transmission mode A/64/16 with 20-kHz bandwidth at 26 060 kHz. The transmitting antenna was a 3-element Yagi antenna in vertical polarization, placed on a 20-meter mast. The receiver was a consumer type "Himalaya", with external antenna of a medium-quality commercial type.

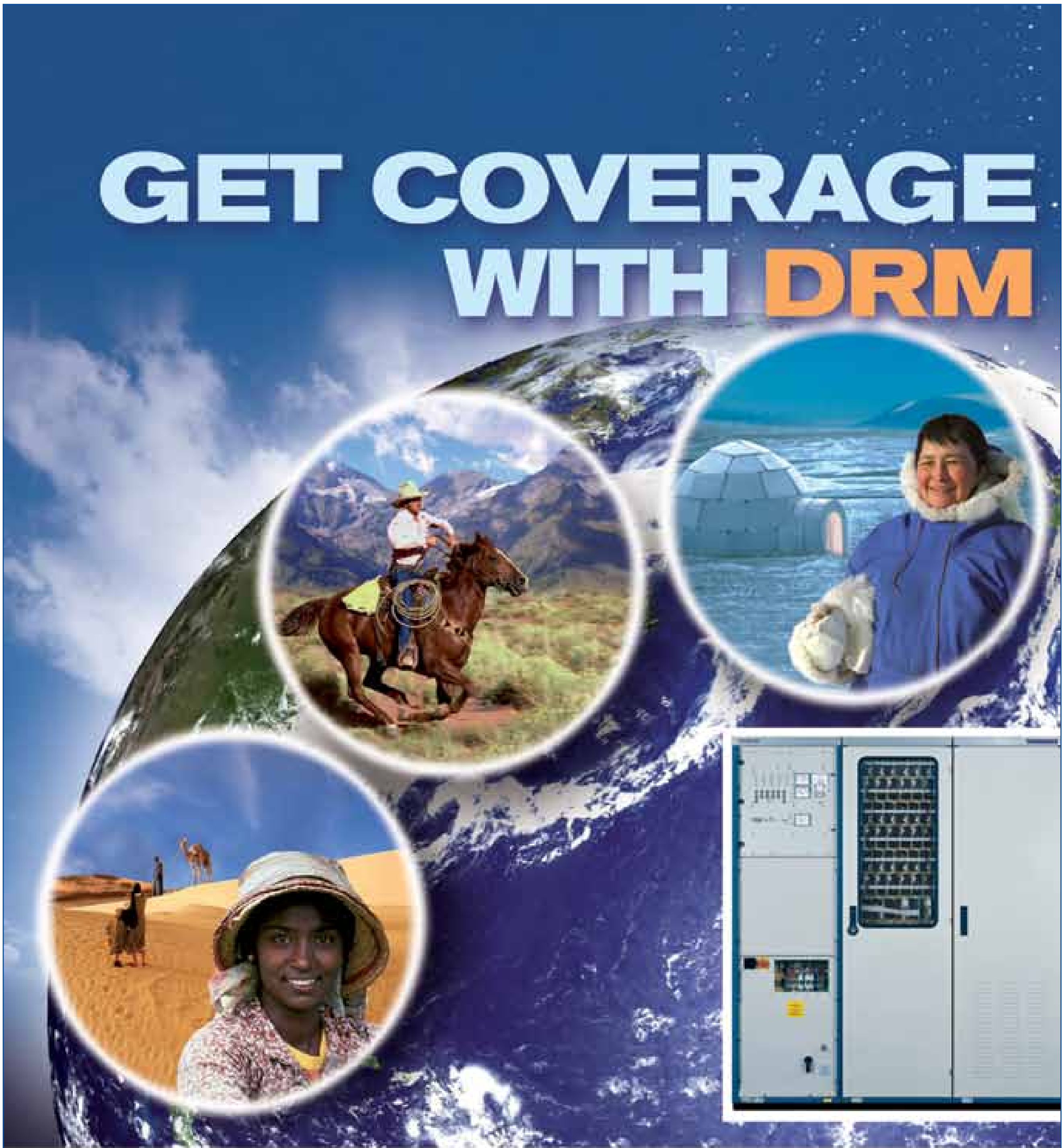
As a first result, it has been found that the coverage area for mobile reception, when emitting at 26 MHz with a power of 30 Wrms, appears to include most of the city of Rome, but it does not extend beyond the GRA, the Great Ring Road that girdles it.

Table A2: Summary of measured noise-floors in the 26MHz band

4.2.6 Analysis Of Coverage Prediction Methods

Studies have been carried out for evaluating different prediction algorithms on the basis of empirical measurements (mentioned Mexico, Brasil, India and Germany measurement campaigns). The algorithms under test were: ITU-R P.1546, Longley-Rice, Diffraction effects (Deygout and ITU-R P.526) and empirical algorithms for mobile reception such as Okumura-Hata. The results show that for close-to-transmitter coverage-calculation, ground wave propagation should be considered. As for the overall coverage area, no model outperforms the others in all situations. Nevertheless, the algorithm in ITU-R P.1546 provided the highest accuracy and it can be improved by considering clearance angle, elevation and diffraction issues.

For Annex 4 References: see [28]


GET COVERAGE
WITH DRM