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Abstract

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Broadcasters can gain the most benefit from the improved audio quality and flexibility provided by DRM over traditional AM broadcasts by taking care over the design of the transmission infrastructure used to distribute their signals to transmitting stations.

Many of these issues have been addressed by the Multiplex Distribution Interface (MDI) protocol, developed by a sub-group within DRM.

This paper explains the advantages of using MDI over traditional methods of programme distribution and uses the transmission infrastructure developed for the BBC's DRM transmissions as an example.

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DIGITAL RADIO MONDIALE (DRM): TRANSMISSION INFRASTRUCTURE AND SYNCHRONISED NETWORKS

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ABSTRACT

Digital Radio Mondiale (DRM), the digital broadcasting system operating in the bands below 30 MHz, was officially launched in June 2003 and a large number of broadcasts are now on the air.

Broadcasters can gain the most benefit from the improved audio quality and flexibility provided by DRM over traditional AM broadcasts by taking care over the design of the transmission infrastructure used to distribute their signals to transmitting stations.

Many of these issues have been addressed by the Multiplex Distribution Interface (MDI) protocol, developed by a sub-group within DRM.

This paper explains the advantages of using MDI over traditional methods of programme distribution and uses the transmission infrastructure developed for the BBC's DRM transmissions as an example.

INTRODUCTION

2003 saw the introduction of regular Digital Radio Mondiale (DRM) (1) broadcasts worldwide, including medium-wave and short-wave services by the BBC World Service.

Digital Radio Mondiale is a digital broadcasting system operating in the frequency bands below 30 MHz, typically referred to as the short-wave (SW), medium-wave (MW) and long-wave (LW) bands. DRM offers near FM-quality sound and supports features which make receiver operation far more user-friendly than for AM broadcasts. DRM is designed to fit into existing AM channel allocations; one DRM transmission can replace one AM transmission. It supports synchronised Single Frequency Network (SFN) and Multiple Frequency Network (MFN) operation.

Traditional AM broadcasting has been carried out for over 80 years to transmit radio programmes both internationally and domestically. In the early years, the transmission infrastructure consisted of little more than a transmitter connected directly to the output of a studio mixing desk on the same site. Over time, as large international broadcasters developed global networks of high power HF transmitters, it was no longer practical to have the studio and transmitting station co-located.

Today, we are familiar with the idea that a broadcaster's studios are likely to be in a large population centre whilst the transmitter may be many hundreds or thousands of kilometres away. For traditional AM broadcasts it is sufficient for a single audio feed to be associated with each transmission.

Digital Radio Mondiale, however, supports multiple audio and data streams within a single transmission as well as other associated data such as lists of alternative frequencies, text messages and service labels. To gain maximum benefit from the DRM system, these features should be under the control of the broadcaster so that, for example, text messages can be updated in real-time and displayed on a receiver to match the programme being broadcast.

The issue of how best to distribute the data that makes up a complete DRM transmission has been addressed in the Distribution Interface (DI) sub-group of DRM, chaired by BBC R&D. This group has developed a protocol, the Multiplex Distribution Interface (MDI), to carry the entire contents of a DRM transmission from the studio centre to one or more transmitters. It is published as an ETSI standard (2).

This paper will explain the key features of this protocol, and show the extra benefits that MDI offers to DRM broadcasters over the distribution schemes typically used for AM.

It will be shown how MDI can be used to build a transmission network using the network currently in operation for the BBC World Service as an example. This makes use of equipment from a number of manufacturers, including prototype hardware and software developed by BBC R&D.

The inclusion of timing information in the MDI enables both SFNs and MFNs to be set up and it will be shown how this has been achieved in practice.

TRANSMISSION INFRASTRUCTURE

AM Transmissions

The traditional image of an international radio broadcaster consists of a person talking into a microphone in a studio at the base of a transmitting mast. Whilst this is still the reality for many broadcasters, studio centres today can be vastly complicated operations, encompassing many different studios and audio sources both from within and outside the building.

This complexity is largely hidden from the transmission infrastructure, the resulting output being one or more audio signals containing the appropriate languages and programme schedules for different parts of the world.

These audio signals will typically be carried over satellite or landline to the transmitting station. Since the cost of a link is determined by the bandwidth required, the audio will be bit rate reduced so that a lower speed, and hence cheaper, link can be used. Whilst the audio quality provided by the link is important, the highest audio quality is not essential considering the impairments introduced by AM broadcasting such as poor audio bandwidth, low signal-to-noise ratio and the audible effects of multiple paths causing selective fading. A typical link might use MPEG-1, Layer II audio compression at a bit rate of 64 kbit/s.

Often the transmitting stations are not under the ownership of the broadcaster. The audio feeds provide the interface between the broadcaster and the transmitter operator, whilst a contract will specify to which areas, at what times and with which transmitter powers these audio feeds should be broadcast.

DRM Transmissions

Digital Radio Mondiale is designed to use existing AM transmitters[1] and antennas if required and so it is not immediately obvious that the transmission infrastructure needs of DRM would be any different to those for traditional AM broadcasts.

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[1] It is likely that an existing transmitter would need some modification to operate using DRM. The cost of these modifications, however, is small compared to the cost of a totally new transmitter. The majority of current DRM broadcasts are using modified existing transmitters.

The flexibility of the DRM system, however, means that, for the broadcaster and listener to gain maximum benefit from the system, a different approach is preferred.

DRM supports different channel bandwidths as well as different modulation parameters to allow ruggedness of reception to be traded against channel data capacity. In the SW bands, in a 10 kHz channel, DRM typically provides 20 kbit/s of total channel capacity. This could be reduced to around 6 kbit/s for a particularly poor channel, or could be as high as 28 kbit/s for a 9 kHz bandwidth, MW channel during the day-time when sky-wave propagation does not occur.

With the relatively low bit rates that are available, state-of-the-art audio coding schemes must be used to reduce the bit rate of the incoming audio to this level. Users of the system have a choice of three different coding schemes depending on the bit rate available and the type of programme material (see Table 1). Optionally, Spectral Band Replication (SBR) can be used, a tool that provides fuller audio bandwidth at low bit rates.

Audio coding scheme	Available bit-rates (kbit/s)	Application
MPEG-4 AAC (Advanced Audio Coding) (+SBR)	all	Mixed music & speech
MPEG-4 CELP (+SBR)	4-20	Speech only
MPEG-4 HVXC (+SBR)	2 or 4	Speech only

Table 1 - Audio coding schemes available in DRM

Not only can the overall bit rate of the DRM channel affect which of the audio coding schemes is suitable, but a broadcaster might decide to offer multiple audio or data services within one DRM transmission. Up to four different services can be offered. For the SW channel mentioned above, one option might be a main AAC+SBR coded service using 18 kbit/s with a speech-only rolling news service using HVXC at 2 kbit/s. Another alternative might be a four language service with four HVXC speech-only streams at 4 kbit/s each.

It is clear that the choice of audio coding system depends both on the bit rate available (determined by the modulation parameters chosen), and the type of services that the broadcaster wishes to offer. It may also be that the broadcaster wishes to have different configurations at different times of day to cope with varying propagation conditions or for targeting services at different groups of listeners. Figure 1 shows a possible MW service where the mode of the DRM transmission is changed at sunset, to one suited to the sky-wave propagation resulting from the loss of the day-time D-Layer absorption, with a resulting reduction in overall bit rate.

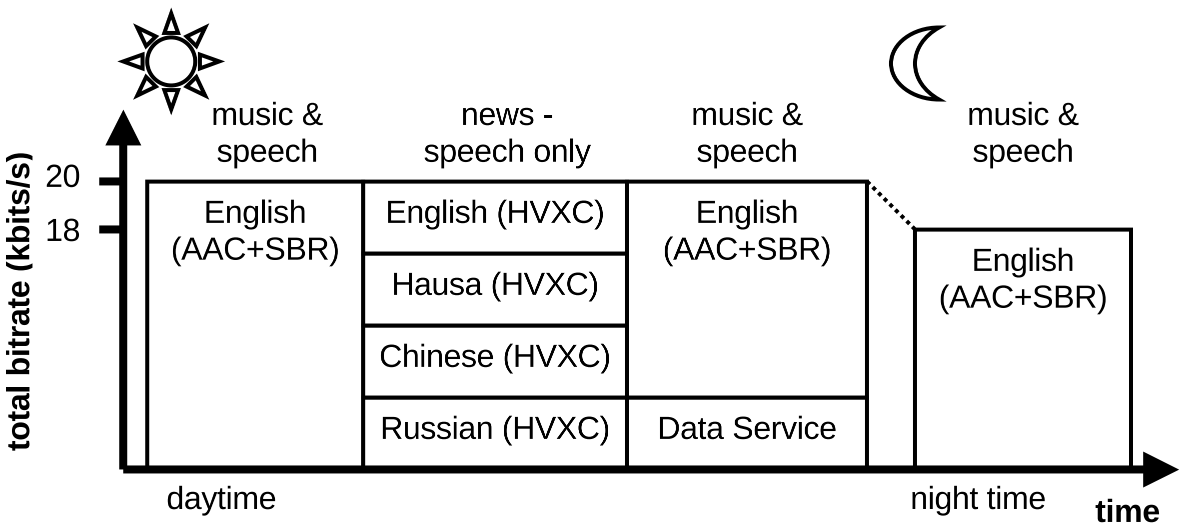

Figure 1 – Possible configurations of a MW DRM transmission

It is important that the broadcaster is in control of the various DRM parameters so that the coding scheme used can be matched to the programme material being broadcast. Anyone who has listened to 'on-hold' music on a mobile phone will be aware of the problems of transmitting music over the GSM audio coding system which was optimised for speech-based applications.

To perform at its best, any audio coding scheme requires a clean source of previously un-compressed audio. Any cascading of coding schemes leads to an increase in the number of audible artefacts. Given this, it makes sense to apply the final bit rate reduction system as close to the source as possible, i.e. at the studio centre. This avoids the problems of cascading and, since the final DRM output signal is of a low bit rate, keeps bit rate requirements and hence costs to a minimum on links to the transmitters.

A further consideration for broadcasters is that the potentially higher audio bandwidth (typically 11 kHz for DRM compared with approximately 5 kHz for AM[2]) and improved signal-to-noise ratio of the audio mean that impairments of the source audio such as background plant noise, mains hum or high-frequency noise will be audible to the listener. These impairments will also impact on the quality of the output produced by any audio coding scheme and the ones used by DRM are no exception to this. Therefore, a studio setup that may have been perfectly acceptable for AM may not be ideal for use with DRM.

The extra services that DRM can offer can be used most effectively if they are inserted directly by the broadcaster. A typical example might be the text message. If this is controlled by the broadcaster, it can contain information related to each programme such as contact details, sports results, news headlines or information regarding the subject matter of the programme.

For synchronised MFN or SFN operation, identical DRM signals must be transmitted from each transmitter site. The only way to ensure this, and to provide time synchronisation, is to send identical data, marked with timestamps, to each transmitter.

These various issues mean that the traditional single audio feed per transmission is no longer the most suitable method of transmission distribution for DRM. Clearly it does not make sense for each broadcaster to solve such problems individually and so it is to address these issues that the MDI protocol has been developed.

THE MULTIPLEX DISTRIBUTION INTERFACE (MDI)

Within a DRM transmission, a distinction is made between payload data and the various other forms of data that are needed by the receiver for it to find and decode the desired programme. This is in order to provide the correct balance between efficiency and flexibility whilst protecting each part to an appropriate degree. Three distinct *channels* are used to convey information to the receiver.

The payload, containing the audio and/or data services, is conveyed by the Main Service Channel (MSC). Two other channels, the Fast Access Channel (FAC) and Service Description Channel (SDC), are also provided. The FAC provides basic information that is needed by the receiver to acquire the signal quickly and always occupies the same part of the channel so that the receiver can always find it. The SDC contains data that is sent repeatedly and details the nature and make-up of the services carried within the MSC as well as the service label and lists of alternative frequencies.

The MDI bit stream is a complete, yet highly compact description of the DRM transmission to be broadcast. It conveys all of the above elements including the audio, already pre-

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[2] In the case of a 10 kHz channel and when using double-sideband AM with carrier.

compressed in the appropriate form. Each packet describes a 400ms block of transmission information and has ‘tags’ that describe the FAC, SDC and MSC contents in their entirety. DRM operates on a system of 400 ms frames and so each MDI packet contains a complete description of 400 ms of a DRM transmission.

At the studio centre a device for generating MDI is installed, taking as its input the various audio and data services making up a single DRM broadcast. At the transmission site, a DRM modulator is used that reads the MDI directly to generate the RF signal.

To ensure that the rate of consumption of the MDI is the same as the rate of generation, the system is locked together using a timing reference such as the Global Positioning System (GPS). In addition each packet carries a timestamp. This timestamp describes the exact time at which the data contained in the packet should leave a DRM modulator as an RF signal[3]. This is of particular importance for MFNs and SFNs. In the case of a MFN, it is important that the signals leaving the different transmitters are co-timed to allow them to be combined appropriately by a diversity receiver or for a receiver supporting alternative frequencies to switch seamlessly between them. For an SFN, the signals must be timed to arrive at the receiver within the specified guard-interval throughout the required coverage area. The relative timing between transmitters can be adjusted to alter the size and shape of this area.

Since there is likely to be some delay through the MDI distribution network, such as satellite path delay, the timestamps of the MDI packets that are generated are set some time in the future to allow them time to arrive at the modulator before their timestamp indicates that they should be transmitted.

The protocol stack for MDI is shown in Figure 2. The Distribution and Communication Protocol (DCP) (3) includes an Application Framing (AF) layer and a Protection, Fragmentation and Transport (PFT) layer. The AF layer provides framing, a sequence count and a CRC check to each MDI packet.

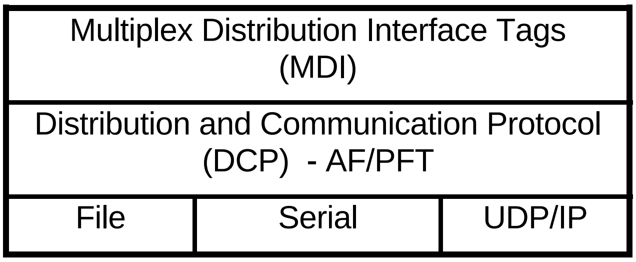

Figure 2 – The MDI Protocol Stack

The optional PFT layer provides Reed-Solomon coding for detecting, correcting, and re-building lost packets. This is potentially important since the MDI link is often uni-directional and so it is not possible for the DRM modulator receiving the packets to request a re-transmission. The PFT layer also provides fragmentation to allow use over links with lower Maximum Transmission Unit (MTU) sizes for each packet and finally a form of transport addressing for use over physical media such as serial links that do not themselves provide addressing.

The MDI can be carried using User Datagram Protocol (UDP) packets over Internet Protocol (IP) or using a serial (RS-232) link. The MDI can also be stored to file for later playback if required. For the broadcaster this could provide a useful way of logging a DRM transmission since it contains the complete broadcast in its most compact form.

The use of UDP/IP for wide-scale distribution of the MDI allows the use of standard devices capable of carrying IP traffic to be used for distribution, such as ATM networks or DVB satellite transponders.

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[3] The time at which 50 % of the energy of the first time sample from the Inverse Fast Fourier Transform (IFFT) of the first symbol of the DRM frame shall have been radiated on air.

Whilst there is nothing to stop a smaller broadcaster from transmitting DRM using their existing infrastructure for AM transmissions, they too should be able to gain cost savings from using the MDI protocol since the signal is sent to the transmitters at a low bit rate. In addition they will be able to take full advantage of the flexibility provided by the DRM system.

THE BBC DRM TRANSMISSION NETWORK

The BBC World Service uses MDI for its European DRM transmissions. All programme audio originates from Bush House in Central London. Two MDI streams are generated: one providing services on SW whilst the other is used for MW transmissions. Figure 3 shows the transmission infrastructure developed by the BBC for one of its services.

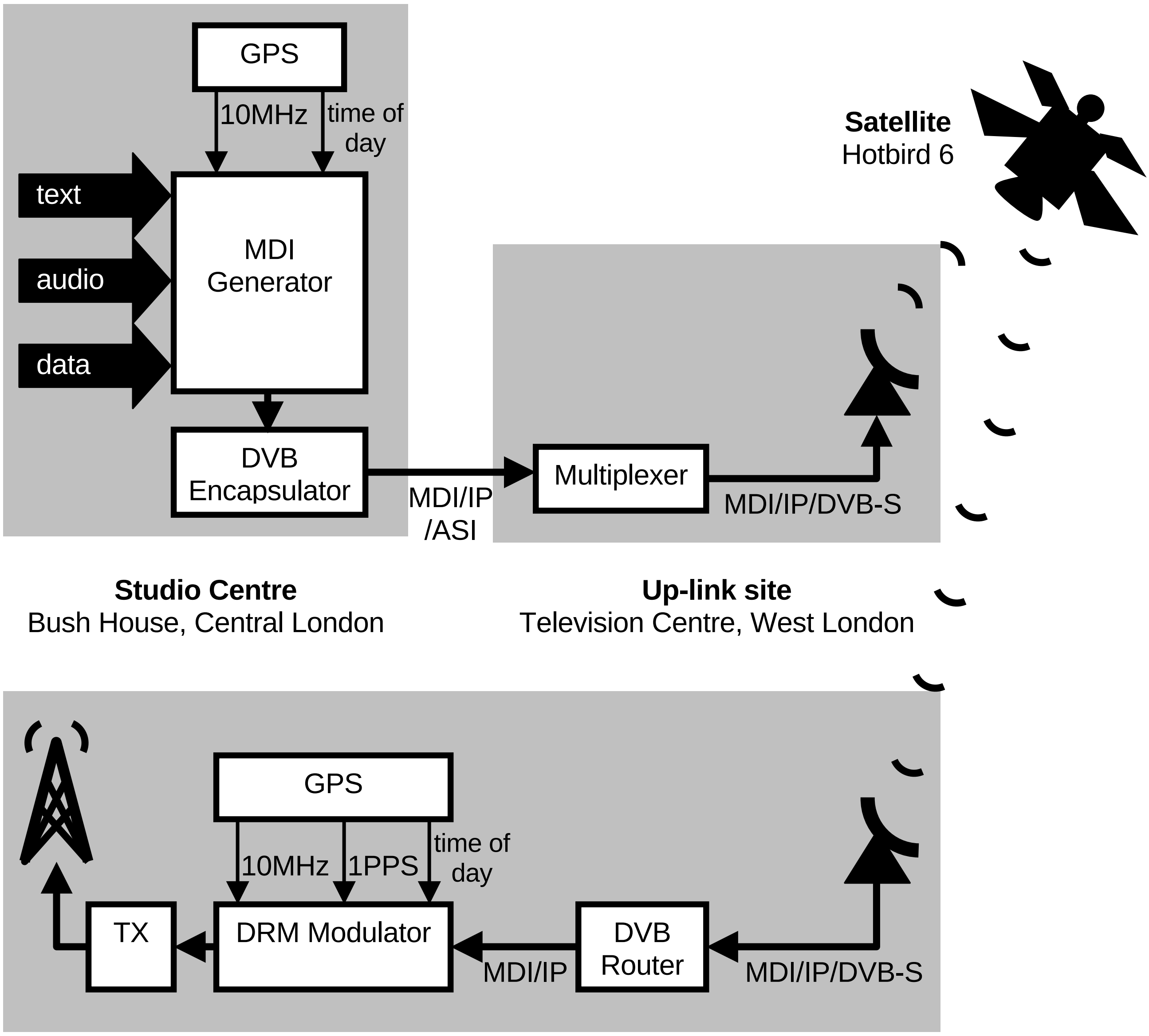

Figure 3 – The DRM distribution network in use by the BBC World Service

GPS-locked audio sources are used as the input to the two sets of MDI Generation equipment. The output of these is a sequence of MDI tags within UDP/IP packets which are sent out on a private, MDI-only Ethernet network; a second network is used internally for general traffic and remote configuration.

The MDI packets are output to multicast IP addresses. This allows multiple recipients to receive data from a single source simultaneously.

A Digital Video Broadcasting (DVB) IP Encapsulator receives the MDI packets and uses Multi Protocol Encapsulation (MPE) for carrying IP packets within a DVB Satellite Multiplex. The data is sent as an Asynchronous Serial Interface (ASI) stream over a leased-line to BBC Television Centre in West London where the MDI data streams are combined into a multiplex with the BBC's other international TV and radio services and up-linked to the Hotbird 6 satellite.

The satellite has a footprint that covers most of Western Europe and the signal is received at two transmission sites provided by VT Merlin Communications: one at Orfordness on the East Coast of the UK for MW transmissions, the other at the SW transmitting station at Rampisham Down in the south of the UK.

Monitoring of the MDI stream is also important and so a third site at BBC R&D, Kingswood Warren provides off-air monitoring of the MDI streams. This consists of an 80 cm satellite dish connected to a DVB-S card in a Personal Computer (PC) running an in-house diagnostic tool. See Figure 4. The software allows the user to see the parameters of the DRM transmission, listen to the audio and to see whether packets have been dropped. An email report can be generated if a problem with the MDI stream is detected.

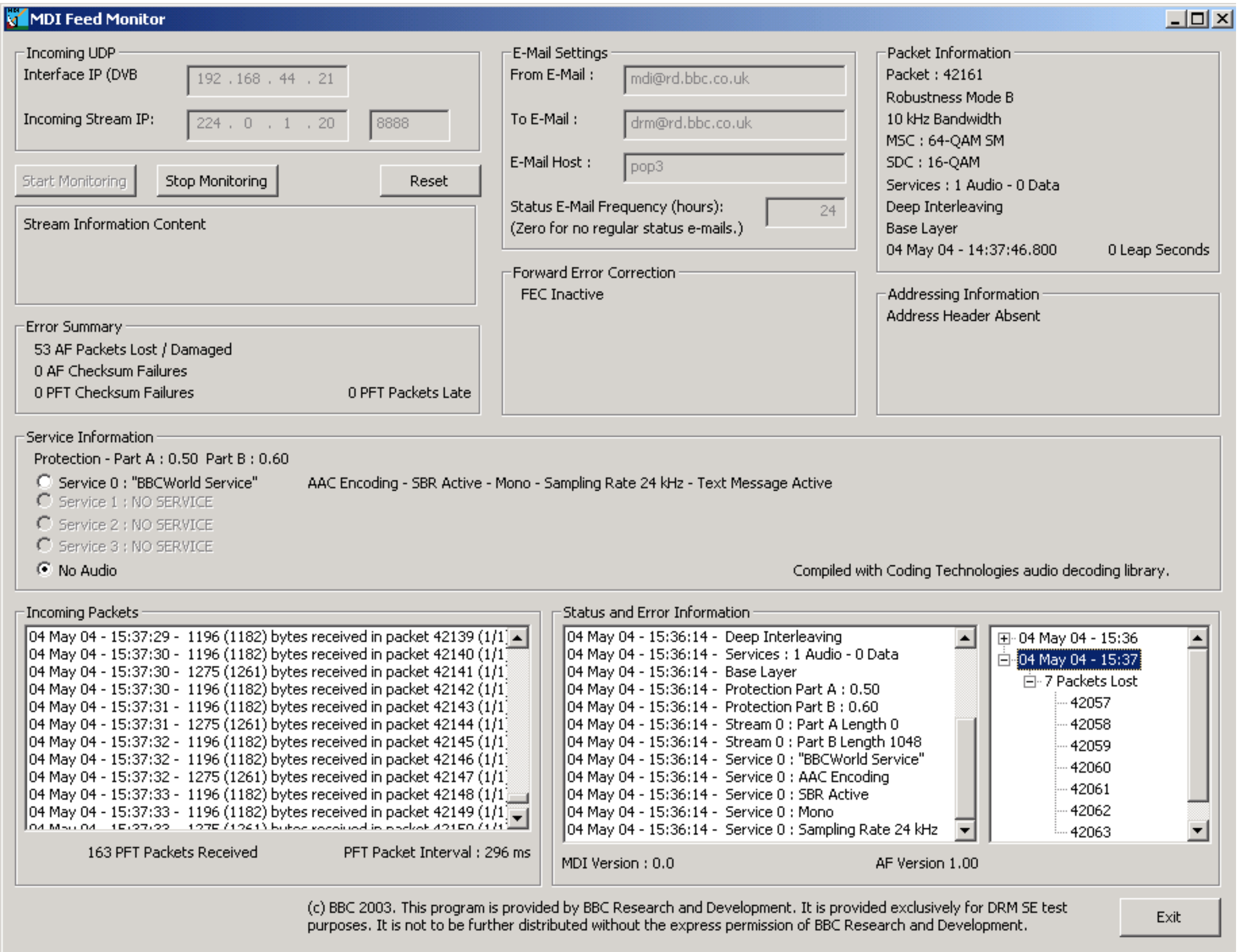

Figure 4 – A screen shot of the in-house MDI monitoring software

At the transmitting stations, a dedicated DVB-S Ethernet router is used to receive the MDI stream and forward it onto a dedicated MDI Ethernet network.

At the Rampisham SW site, the MDI stream is fed into two prototype BBC R&D DRM Modulators. These are also synchronised by a GPS clock unit and allow the operation of both MDI-driven SFNs[4] and MFNs from Rampisham. The prototype modulators support Multicast IP and support Internet Group Management Protocol (IGMP) to communicate with the DVB Router to request forwarding from satellite of the appropriately addressed IP packets.

At Orfordness, GPS is used to regulate the rate of consumption of MDI packets but the timestamps are not examined since the Orfordness MW transmissions are not part of an SFN or MFN.

FIELD TRIALS

For the official launch of DRM at the World Radiocommunication Conference (WRC) in June 2003, the BBC distribution system was successfully used to generate a synchronised MFN covering Western Europe (4). Large-scale SFN trials are currently ongoing. The system is now in daily use for the BBC World Service's DRM transmissions.

CONCLUSIONS

Digital Radio Mondiale not only has the ability to offer better audio quality compared with AM transmissions, but gives broadcasters flexibility in the choice and type of services that they can offer to listeners within a single channel allocation. The traditional transmission infrastructure used for AM broadcasts is not best-placed to take full advantage of DRM.

The MDI protocol solves the problem of signal distribution to transmitter sites for DRM. It ensures that the broadcaster retains full control over the complete DRM transmission as well as providing the maximum possible audio quality. The use of IP-based protocols to carry the MDI packets ensures that off-the-shelf equipment can be used to distribute the signal to transmitters. The fact that the MDI is a low bit rate signal completely describing a DRM transmission ensures that distribution costs are kept to a minimum.

REFERENCES

1. Digital Radio Mondiale (DRM); System Specification, ETSI ES 201 980, April 2004.
2. Digital Radio Mondiale (DRM); Multiplex Distribution Interface (MDI), ETSI TS 102 820, December 2003.
3. Digital Radio Mondiale (DRM); Distribution and Communication Protocol (DCP), ETSI TS 102 821, December 2003.
4. Haffenden, O. P. et al., April 2004. Digital Radio Mondiale (DRM): Multi-Transmitter Networks and Diversity Reception, Proceedings of the International Broadcasting Convention, September 2004.

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[4] A SFN network operating from a single site, as well as acting as a proof of concept, allowed the use of two transmitters and two antenna arrays on different bearings simultaneously to provide a wider coverage area on a single frequency.