DRM — progress on the receiver front

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The Digital Radio Mondiale (DRM) system provides a universal, non-proprietary, digital transmission system – designed to replace, eventually, the current analogue transmissions in the LW, MW and SW bands.

This article provides information on the DRM receivers that were demonstrated at IBC-2002 during September. It also oulines the work being carried out within a number of projects which aim to enable the early introduction of DRM consumer receivers.

Digital Radio Mondiale^{TM} [1] is a consortium of some 75 broadcast-related organizations, which has worked to develop a digital transmission system for the current AM broadcast bands. The DRM^{TM} system provides a universal, non-proprietary, digital transmission system – designed to replace, eventually, the current analogue transmissions in the LW, MW and SW bands.

The DRM system, and the primary audio coding used, have been described in previous articles of EBU Technical Review [2][3]. The system specification has been published by both ETSI {TS 101 980 V1.1.1 (2001-09)} and the IEC (PAS 62272-1) and is the subject of an ITU recommendation, BS1514. There is also a new draft ITU recommendation, BS1514-1, which includes minimum signal strength and protection ratio information.

Several broadcasters expect to start regular DRM services in 2003, to coincide with the frequency-planning conference, WRC2003. In this context, the market availability of consumer receivers is vital if the introduction of these services is to be successful. In light of the problems encountered with the lack of consumer receivers at the outset of DAB services, DRM Members are striving to avoid a repetition of this problem.

This article provides information on the DRM receivers demonstrated at IBC-2002 and the work being carried out within a number of projects which aim to enable the early introduction of DRM consumer receivers.

Receivers shown at IBC-2002

Altogether, seven different DRM receivers were on display at the DRM stand during IBC-2002. All the receivers were demonstrated receiving, at different times of the day, live SW transmissions from Sines in Portugal (Deutsche Welle: 1,922 km.), Sackville in Canada (Radio Canada International: 4,892 km.), Bonaire in the Netherlands Antilles (Radio Netherlands: 7,796 km.), Juelich in Germany (T-Systems MediaBroadcast: 188 km.) and Rampisham in the UK (VT Merlin Communications carrying BBC WS programmes: 546 km.) and a continuous local 26 MHz SW service of audio with multimedia from Hilversum (RNW: 22 km). It is perhaps also worth noting that several examples of the professional and test receivers described below are in daily use, automatically logging DRM long-term field test transmissions which are now on air every day.

Professional and test receivers

Thales

The first receiver produced for monitoring DRM test transmissions was designed and built by Thales (formerly Thomcast) and was available in two versions – a desktop PC version and a ruggedised portable PC version (the TSW 1002D), shown in *Fig. 1*.

Figure 1
Thales TSW 1002D DRM receiver

The receiver is implemented on a number of PC plug-in cards and uses the PC keyboard and screen primarily as a man-machine interface. In addition to providing the primary reception functions, the receiver provides a number of analytical tools *(see Fig. 2)* which can be employed during reception of a DRM transmission or, by virtue of recording the I/Q signals to the internal hard disk, enables post reception analysis to be carried out.

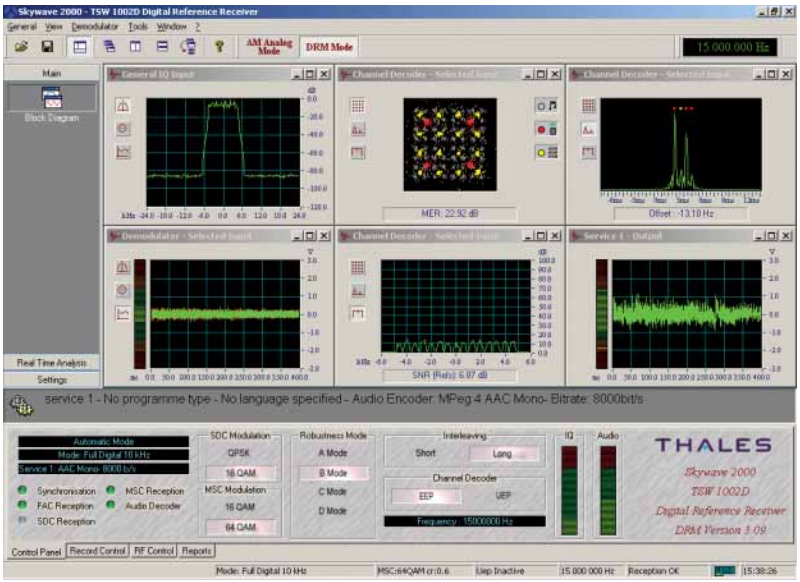


Figure 2
Screenshot of the Thales TSW 1002D receiver

As this receiver was the earliest available to DRM developers and testers, it has gone through a number of software revisions, in large part due to the need to adapt to the changing DRM specification, as development and testing took place. In concept it is somewhere between the largely software-based receivers, using a PC's processor to provide all the demodulation and decoding functions for the digital signals, and the more hardware-based solutions, where a specialised DSP chip with firmware provides the signal demodulation functions. This Thales DRM receiver provides analogue-to-digital conversion of the incoming signals at the front end so that, apart from some front end buffering and filtering, all the processing of the incoming signals is carried out entirely in the digital domain.

Abbreviations

A/D	Analogue-to-Digital	**ITU**	International Telecommunication Union
AFS	Alternative Frequency Switching	**LCD**	Liquid Crystal Display
D/A	Digital-to-Analogue	**LW**	Long-Wave
DAB	Digital Audio Broadcasting (Eureka-147)	**MW**	Medium-Wave
DRM	Digital Radio Mondiale	**OFDM**	Orthogonal Frequency Division Multiplex
DSP	Digital Signal Processor / Processing	**PCB**	Printed-Circuit Board
DX	Distance listening/viewing	**QAM**	Quadrature Amplitude Modulation
ETSI	European Telecommunication Standards Institute	**RF**	Radio-Frequency
FAQ	Frequently-Asked Questions	**S/N**	Signal-to-Noise ratio
IBC	International Broadcasting Convention	**SW**	Short-Wave
IEC	International Electrotechnical Commission	**WRC**	(ITU) World Radio Conference
IST	Information Society Technologies *(European research programme)*		

At IBC 2002, Thales showed the first version of a professional DRM receiver (the TSW 1003D, shown in *Fig. 3*) which used a PC's processor for signal processing, with a modified AOR 7030 analogue communications receiver providing the front-end tuning and signal selectivity. This first Thales PC software-based receiver provides the same signal analysis and recording tools as the TSW 1002D, but using lower cost off-the-shelf hardware.

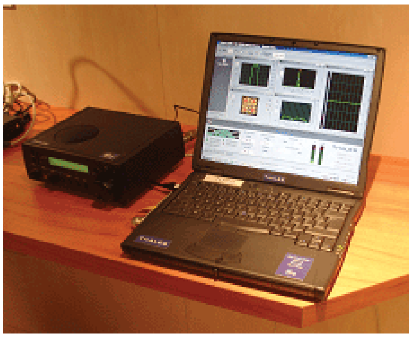


Figure 3
Thales professional software receiver (the TSW 1003D) with modified AOR receiver *(on the left)* **and a PC running the DRM receiver software**

The FhG software receiver

Over a year ago FhG showed a DRM professional test and analysis receiver covering the LW, MW and SW bands *(see Fig. 4)*, based on a laptop PC with an external AOR 7030 communications receiver. This has been continuously developed over the intervening period in order to remain compliant with the evolving DRM specification. The receiving system functions by using the AOR receiver to provide the front end tuning and selectivity so that unwanted adjacent channel and out of band signals are largely removed. The wanted signal is passed to the DRM demodulator, which is implemented in software on the PC. Additional IF filter options are installed to improve the performance of the standard AOR 7030 receiver. These filters provide 20 and 12.5 kHz pass-bands and more closely match the spectra of the OFDM DRM signals to be received.

Figure 4
FhG software receiver with modified AOR 7030 receiver *(on the left)* **and a PC running DRM receiver software**

In addition to the extended IF filter options, the AOR receiver is fitted with an additional IF down-converter *(the PCB shown in Fig. 5)* which down-converts the final IF signal, at 455 kHz, to a new final IF of 12 kHz. This unusually low IF frequency means that the DRM OFDM signal now occupies a frequency range from 7 kHz to 17 kHz (10 kHz signal) or 7.5 kHz to 16.5 kHz (9 kHz signal). The DRM signal is thus contained within the input bandwidth of the PC sound card analogue-to-digital (A/D) converter, when it is set to use the 48 kHz-sampling rate. Provided the sound card A/D converter has good linearity, it provides a low cost method of digitizing the DRM signal. After this, all the demodulation, de-multiplexing, data stream recovery and audio decoding may be carried out within the software running on the PC's processor *(see Fig. 6)*, provided that it is sufficiently powerful (>500 MHz PIII) and running Windows 98/NT/2000.

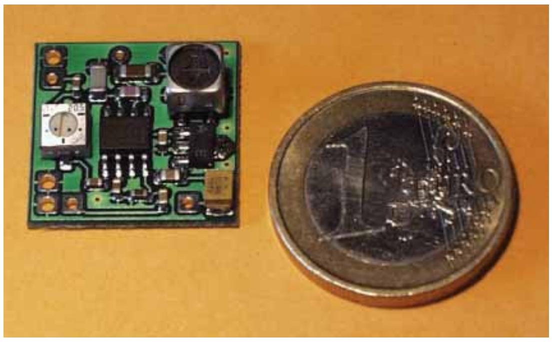


Figure 5
455-to-12 kHz down-converter using tuned inductor, compared to a €1 coin (http://www.sat-schneider.de)

The recovered, compressed, digital audio signal – after decoding – can be reproduced via the D/A section of the PC's sound card. In addition to the audio decoding function, the FhG receiver implements multimedia decoding, which allows a non-audio data stream within the DRM multiplex to provide other functions, such as the display of still pictures. During the IBC-2002 exhibition, this function was demonstrated using a 26 MHz DRM transmitter, located at Hilversum, to send both continuous audio and picture files in two separate data streams within the multiplex. The PC was able to decode the audio whilst simultaneously displaying, on its screen, a sequence of transmitted pictures.

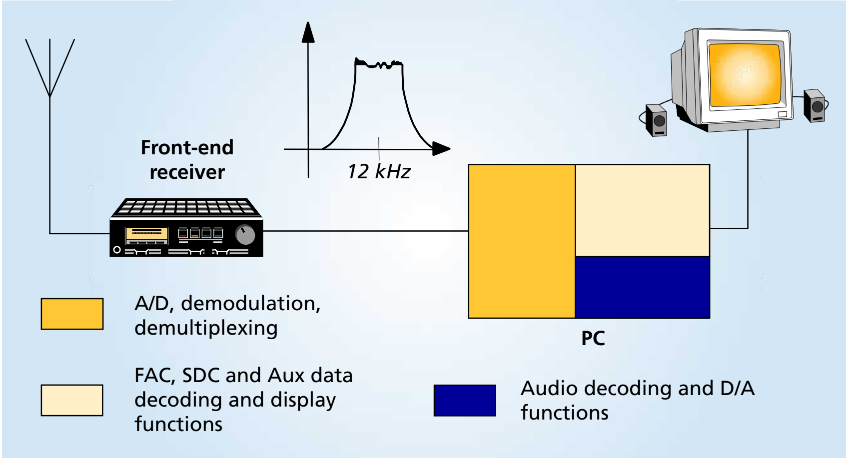
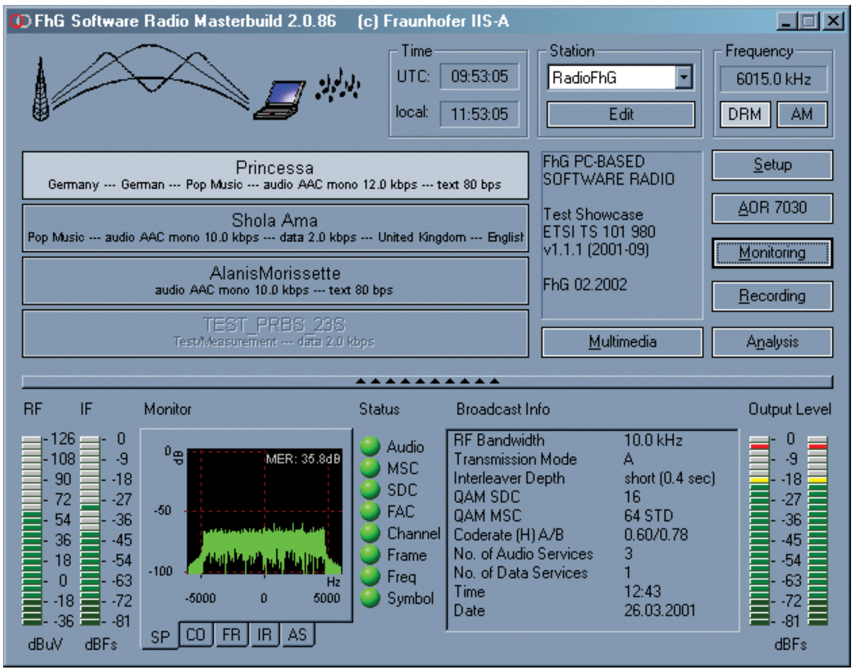
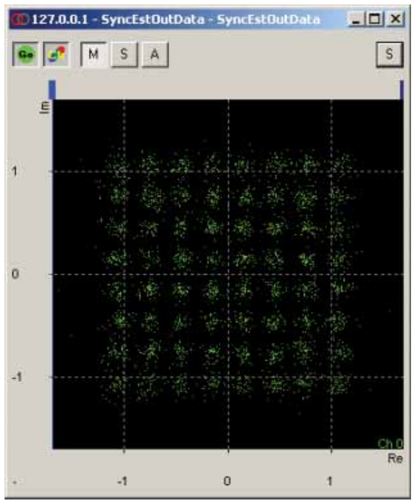


Figure 6
Simplified functional schematic of the DRM software receiver

The FhG receiver additionally provides a number of analysis tools. The main operating screen *(see Fig. 7)* shows configuration details of the received multiplex as well as a view of the OFDM signal spectrum. The user can chose, from a number of other monitoring functions, such as a display of the signal constellation *(Fig. 8)* or the channel impulse response *(Fig. 9)*. The receiver also provides logging of reception data to the agreed DRM format.

In response to DRM's wish to significantly increase the number of receivers deployed to prove the system performance, FhG has produced a much-simplified version of this software – removing most of the signal analysis tools but still providing the multimedia option. This version, and the attendant project to distribute the software, is covered later in this article.





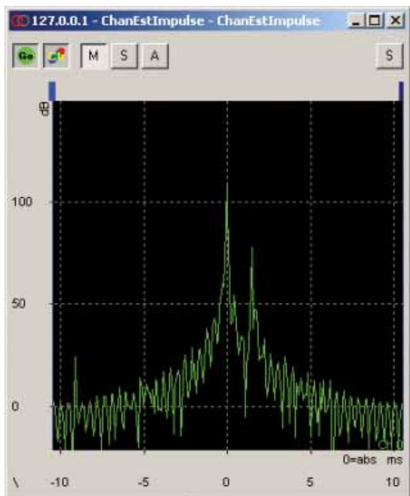


Figure 7 *(above)*
Screenshot of received DRM signal spectrum, FhG receiver

Figure 8 *(upper right)*
Screenshot of constellation diagram of received DRM 64-QAM signal, FhG receiver

Figure 9 *(lower right)*
Screenshot of channel impulse response from the FhG software receiver

BBC Research and Development

BBC R&D showed a DRM receiver at the IBC-2001 show and during the past year has been working on minor performance enhancements. The receiver is designed very much for professional use as it is built into a standard 19" rack-mount enclosure *(Fig. 10)*. An LCD screen on the front panel displays most of the significant parameters of the received signal and a rear panel connection allows the connection of an oscilloscope to display the channel impulse response. The receiver is composed of two PCBs: a main board containing the primary DSP for demodulation and de-multiplexing together with audio decoding, and a second RF-processing board.

Figure 10
BBC R&D DRM receiver *(top)* **with an oscilloscope** *(below)***, displaying the channel impulse response time, referenced against the symbol period and guard interval**

The receiver has only buffering and filtering at the front end, simply to exclude signals above 30 MHz. After this, the whole RF band up to 30 MHz is digitized and all frequency selection is carried out in the digital domain. The processing power of the RF chain allows for up to four signals, on different frequencies, to be simultaneously selected for subsequent demodulation. This is intended to provide the receiver with the ability to simultaneously demodulate DRM signals on more than one frequency. This allows the use of the Alternate Frequency Switching (AFS) function in the DRM system, which is designed to ensure that, where more than one frequency is carrying the same programme, the best quality signal is always used for reception. Provided that the signals carry the same main service channel data, AFS ensures that minimal disruption occurs when switching between different signal frequencies. This is one of the first DRM receivers capable of providing this function and as a result will be used to verify the correct operation of the AFS function. BBC R&D are also working on a frequency-diversity facility which, rather than simply switching between signals, will combine the data streams in such a way as to further reduce the bit error rate and provide an overall performance gain.

In common with a number of other professional receivers, this receiver provides logging of reception data in the agreed DRM format and a number of units are currently in use, providing automated logging of long-term field test reception data.

The DRM Software Radio project [4]

As mentioned above, many DRM Members felt that there would be considerable merit in providing a low-cost DRM software receiver, which could be made available to the Amateur Radio and DX community. This was seen as having a number of benefits. It would:

- significantly increase the number of available reception sites over that currently available for long-term field testing;
- involve a community of enthusiasts in the field testing, who had already indicated their strong interest in being involved;
- provide an important test bed for proving the performance of the software, a version of which could be eventually ported to consumer receiver chips;
- raise awareness and promote the DRM system on a worldwide basis.

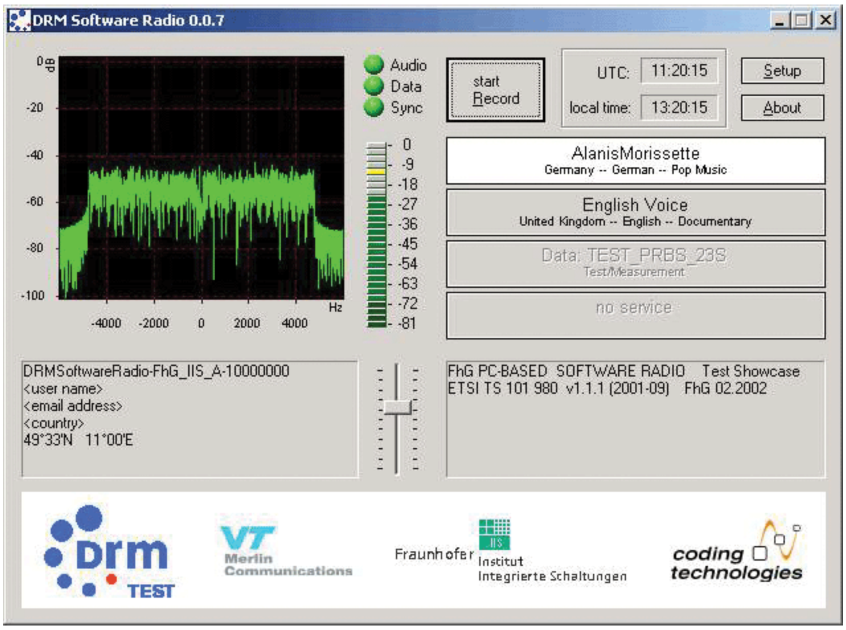


Figure 11
Screenshot of DRM software receiver designed by FhG for the Amateur Radio / DX community

As a result, FhG offered to design a simplified version of the software receiver, which they were already offering to DRM Members *(see the screenshot in Fig. 11)*. This receiver provides the same level of performance as the professional version but does not provide the extensive signal analysis tools or options of its parent.

It was also felt important that it should support the multimedia options, as this would enable broadcasters to experiment during the field-testing and early service period with such options. No limitation will be placed on the lifetime of this version of the receiver, except that support will have a limited lifetime of two years. During this support period, users will be able to download new versions of the software as and when they become available. Participants will be charged 60€ for the DRM receiver software, almost entirely to cover the cost of the relevant licence fees.

To construct the Software Receiver participants will need to possess a suitable PC and a receiver that can be used as the front end RF tuner. They will need to modify the receiver by either constructing a suitable IF down-converter (455 kHz to 12 kHz) or purchasing a ready made circuit board, so that the DRM signals will be converted to a final IF of 12 kHz. Having downloaded and installed the software on a suitable PC and connected the 12 kHz IF signal to the input of the PC sound card, they will then be able to demodulate and listen to DRM transmissions.

To enable participants to provide reception quality reports, the DRM Software Receiver allows them to record a file onto the PC's hard disk, which will contain information about the received signal. This file can then be uploaded to the DRM Software Receiver project web site. After amalgamation and processing, summary information on DRM transmissions will be available to both DRM Members and project participants.

To test out the software, a number of organizations – including DRM Members – are modifying various different front-end receivers. Information on the work required to satisfactorily modify these receivers, and on receivers found not to be suitable, will be carried on the project web site. The website will also provide a number of fora for participants, a frequently-asked questions (FAQ) section and a technical support area. The project will go live in December 2002.

At a late stage, Thales also offered to provide a version of the DRM Software Radio and it is planned to make this second version available as a choice on the project web site, as soon as it has been tested and proved. Although the software will have a different origin, it is intended that this second version will be functionally identical to the version developed by FhG. However it will enable a comparison to be made to see if there are any performance differences between the two applications. Participants will have the choice of which version they wish to download for the €60 fee, but will be at liberty to separately purchase both versions if they wish to make the comparison.

Consumer radios

The CTS Radio

Figure 12
Prototype DRM consumer receiver, manufactured by CTS in association with AFG and BBC R&D. The BBC DRM decoder PCB is shown leaning against the front of the receiver.

With several broadcasters stating their intention to launch DRM services during mid-2003, the inevitable question frequently asked is: *when will consumer radios be available?* Expectations were raised in this respect at IBC-2002 by the first showing of a production-ready world-band consumer radio made by Coding Technologies (CTS) together with the BBC and AFG. The receiver, shown in *Fig. 12*, is packaged into an existing consumer radio enclosure and it can be tuned via the front panel controls in the usual way. The audio can be listened to either via the internal speaker or the headphone socket.

Inside, most of the original receiver electronics have been replaced. There is a new RF front end, developed by the German company AFG, and a demodulator, de-multiplexer and audio decoder board produced by BBC R&D *(shown next to the receiver in Fig. 12)*. The BBC PCB is a simplified reduced-size version of the board used in the BBC professional receiver. At present, the power consumption of the receiver is too high to work off standard dry batteries, as the DSP used is not intended for portable devices. However it would be practicable to operate the receiver for a number of hours from an internal high capacity rechargeable cell. Although this makes the receiver unsuitable for direct large-scale mass production there are plans to produce around 100 of these receivers for demonstration purposes. The production of this receiver represents an important milestone for the DRM consortium, as it demonstrates that there is no inherent problem in providing all the required functions of a DRM receiver in an enclosure of the same type and size as is used for current analogue receivers.

Figure 13
AOR 7030 communications receiver, modified by BBC R&D with the addition of an IF down-converter (see Fig. 5) and the BBC decoder PCB to enable DRM reception.

The AOR 7030 with DRM reception capability

BBC R&D engineers developed the main processor board for the CTS receiver described above. As there were some circuit boards spare, they decided to modify an AOR 7030 communications receiver, to provide a second example of an integrated analogue/DRM receiver, albeit not a typical consumer receiver.

Thus, for IBC-2002, the BBC was able to show a working modified AOR receiver *(Fig. 13)* as an example of a practical compact communications receiver with DRM capability. In essence, the receiver was modified by the addition of one of the standard off-the-shelf 455/12 kHz IF down-converter boards which provided the necessary interface to an internal BBC DRM demodulator/decoder main board. The receiver retained all the existing analogue functions but also provided the facility of DRM signal reception. Received signals could be auditioned either by the small internal speaker or via external headphones.

Consumer ICs for DRM receivers

It was noted above that the power consumption of the CTS prototype consumer receiver was too high to provide useful operation using standard dry batteries. It is clear that, for the mass production of consumer receivers, dedicated chips must be designed and manufactured. Only these chips can enable the production of DRM receivers with much reduced power consumption together with the lowest possible manufacturing cost. Towards that end, two projects are currently in progress in Europe to design and manufacture or adapt suitable chips or chipsets. One of these projects, DIAM, is currently working under a Eureka designation and involves participants in several European countries. The other, Radiomondo, involves German participants alone.

The DIAM Eureka project [5]

This project involves participants from five European countries (France, Germany, Greece, Italy and Sweden) and is led by the French company, Atmel Rousset. Of the ten participating companies, six are directly DRM Members. The project has a budget of nearly 30 million euros and aims to complete its work by November 2003, although it is hoping that sample chips will be available during the first half of 2003. The primary aim of the project is to develop the design for a DRM receiver on a chip *(Fig. 14)*, which will enable a number of semiconductor and receiver manufacturers to develop the required hardware for consumer receivers. This could see DRM receivers based on such a platform being launched during 2004.

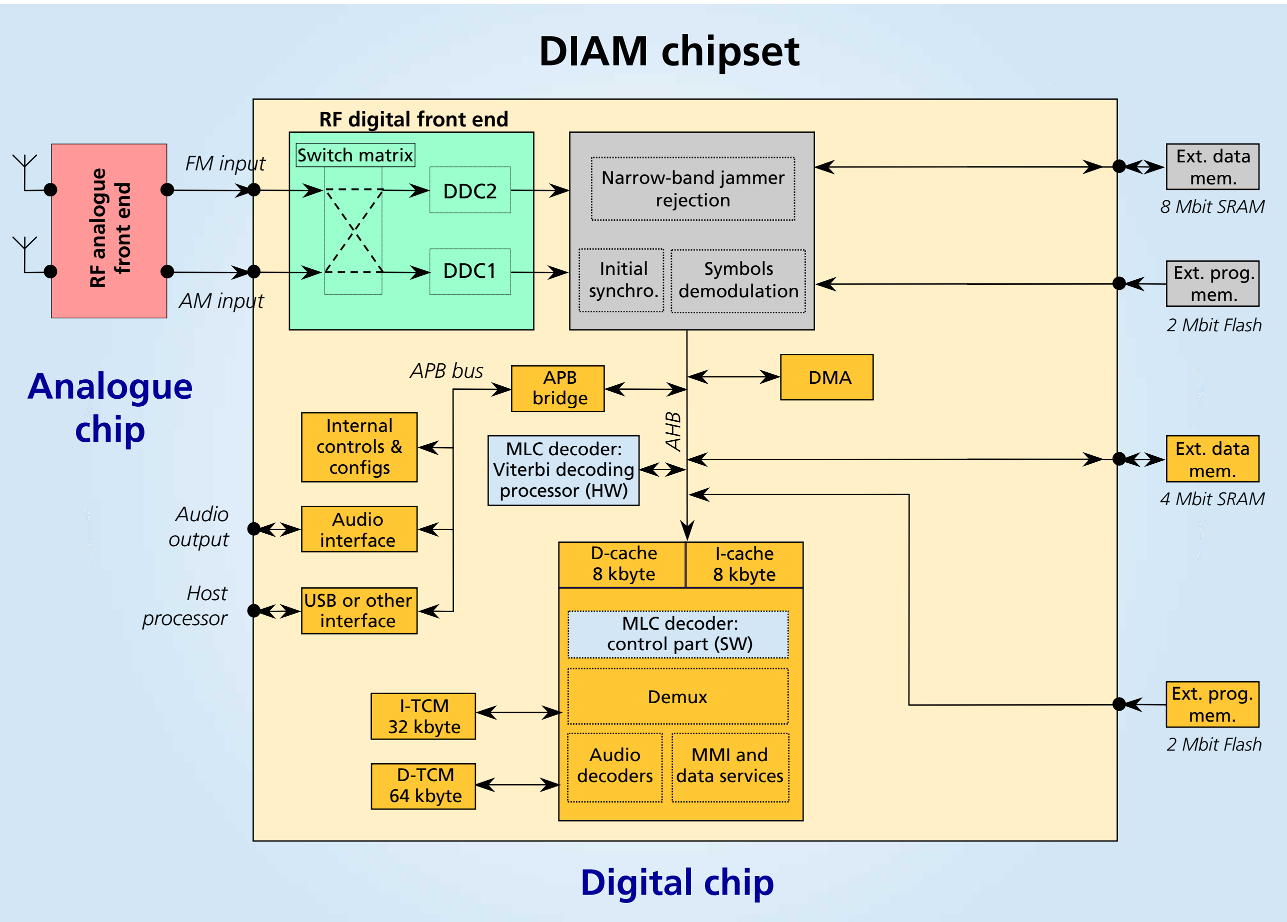


Figure 14
Schematic of the DRM chipset being designed under the DIAM Eureka project. It will be incorporated into DRM consumer radios.

The Radiomondo project [6]

This project has two aims:

- to investigate and develop data applications or services which can run on the DRM platform;
- to develop chipsets that will enable the production of DRM receivers, which can exploit these services.

The German Ministry of Education and Research is providing just under 4 million euros to fund this three-year project. The project involves six German-based organizations, all of them DRM Members, and is led by the Fraunhofer Institute for Integrated Circuits, IIS-A. The project has a similar timescale to the DIAM project.

Related work

Two other European-based projects are also running to assist in the verification and field-testing of the DRM system (the Radiate project) and the development of new tools for predicting and measuring the quality of service achieved with DRM transmissions (the Qosam project). Both projects are being assisted with funding under the European IST framework.

The RADIATE project [7]

The Radiate project has just recently been completed. It has involved a large amount of field-testing work to verify that the DRM system performs in the field in a manner similar to that predicted from laboratory simulations or measurements. The results of this work will be published in a few months time, but the preliminary conclusions are that the system has indeed performed largely as predicted. Measurements will have been made on test transmissions in all three AM bands (LW, MW and SW) over both short and long distances, including several multi-hop SW channels and including near-vertical-incidence SW paths.

The QoSAM project [8]

The Qosam project has only recently started and will run for approximately two years. The project aims to determine the best ways of measuring the quality of service of DRM transmissions and will investigate the number and density of monitor receiving sites that will be needed to provide a high confidence in the measurement of the performance level of any transmission. A standard monitoring-receiver measuring protocol has been agreed within DRM and this will enable monitoring receivers from a number of different suppliers to provide reception data in a common data format.

Additional work is being carried out to define the appropriate propagation prediction methods for use with DRM transmissions. In the past, analogue transmissions have concentrated mainly on predicting the signal strength (and thus the S/N ratio) of the received signal within the target area. For digital signals, such as the OFDM DRM signals, parameters such as Doppler and delay spread will also have an impact on reception coverage and the relative importance of these parameters and methods of predicting their likely values needs to be determined.

Further work will build on the concept of using a real-time monitoring receiver network to allow adjustment of the transmitter parameters in near real-time to achieve a defined level of availability. A number of transmission parameters could be adjusted such as the power, transmission mode, protection level and data rate – all of which would have a bearing on the level of service availability which is achieved over the target area. This technique is considered to be most applicable to the control of transmitters in the SW bands but could also be applicable to LW and MW services where reception conditions change between day- and night-time due to the change in the level of external interference. The hope is that such techniques will be able to provide improved levels of service reliability whilst saving on energy costs.

Compatibility testing

One other important process which is being carried out within one of the DRM working groups is that of testing the compatibility of DRM implementations from different organizations. Whilst not strictly a reception issue, since the testing is applied at the signal generation stage, it has an important bearing on ensuring that the DRM standard is unambiguous when interpreted by current and future equipment designers. All DRM signals on-air should be correctly received by future consumer receivers. Currently, six DRM Members have been involved in this testing process and, up to the present, there have been no cases where generated files have been provided but disagree. This suggests that, with 14 test cases having been examined to date, the standard can be considered robust, although there are further test cases to be examined and only four of the six organizations have tested all 14 cases so far.

Conclusions

The work on DRM receivers and chip development that has been detailed in this article gives good cause for optimism that consumer receivers can reach the markets during 2004 – within approximately a year of the start of regular DRM transmissions in mid-2003.

There is a strong feeling that the DRM system can eventually replace the majority of analogue transmissions in the AM bands. This confidence is based on:

- the significant number of specialised projects running;
- the ongoing work being carried out by the various DRM technical working groups;
- the strong support of DRM Members in the technical development and testing of the system.

Acknowledgements

The author is grateful to all the DRM Member organizations and personnel who have contributed to the successful development of the DRM system and without whose valuable assistance this article could not have been written.

Bibliography

[1] DRM website:
http://www.drm.org

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Mr Jackson worked for the UK's largest commercial radio broadcaster, Capital Radio, between 1973 and 1993 - for the last 10 years as its Chief Engineer - and in 1993 he joined BBC World Service (WS). In 1997, whilst still at WS, he was invited to become involved - together with other WS staff - in the formation of Merlin Communications. This led to Merlin's eventual successful bid to purchase and/or operate the assets used for BBC WS transmissions. In November 2001, Merlin Communications was sold to Vosper Thorneycroft (now VT Group) and is now named VT Merlin Communications.

Peter Jackson is currently Project Manager of the EBU B/DLMF project group, which is responsible to the BMC (EBU Broadcast Technology Management Committee) for the consideration of spectrum issues relating to the introduction of DRM digital services in the MF and LF broadcast bands.

[2] Jonathon Stott: **DRM – Key Technical Features**
EBU Technical Review No. 286, March 2001.
http://www.ebu.ch/trev_286-stott.pdf

[3] Martin Dietz and Stefan Meltzer: **CT-aacPlus – a state-of-the-art audio coding scheme**
EBU Technical Review No. 291, July 2002.
http://www.ebu.ch/trev_291-dietz.pdf

[4] DRM Software Receiver project website:
http://www.drmrx.org

[5] DIAM: **Digital AM Hardware and Software Platform-Based Set from C to Silicon**
Eureka Project No. E!2390
http://www.eureka.be

[6] Radiomondo: **Development of New data Services for Long, Medium and Short-wave Broadcasting**
http://www.radiomondo.de

[7] RADIATE: **Radio Digital AM Tests**
IST-1999-2013
http://www.ist-radiate.com

[8] QoSAM: **Quality of Service in the Digitized AM Bands**
IST-2001-33307
http://www.ist-qosam.com