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DIGITAL RADIO MONDIALE – HOW FAR HAVE WE COME?

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ABSTRACT

Digital Radio Mondiale™ (DRM™) is a consortium of more than 80 organisations from across the broadcasting industry and the globe. The consortium has developed a universal, non-proprietary, digital transmission system for the AM broadcasting bands below 30MHz. The DRM system has been designed to replace analogue transmissions in the LF, MF and HF bands over a period of years; this will enable AM broadcasting to retain and enhance its competitive position in an increasingly diverse broadcast market.

Inaugural DRM services began at the WRC2003 World Radio conference in Geneva during June 2003. Since then both the number of broadcasters and the hours of broadcasting have steadily increased. By February 2004, 24 broadcasters were collectively providing regular DRM services on MF and HF to Europe, Africa, the Americas and Russia with 7 languages being used. To achieve the successful introduction of DRM services worldwide a number of key factors must be addressed; in particular access to spectrum for broadcasters and network operators to introduce digital AM services plus the timely availability of consumer receivers. HF broadcasting is planned in a dynamic way on a continuing basis; few problems are foreseen in the introduction of DRM. However the MF and LF bands are planned '*a priori*' with frequencies, locations and power levels set for much longer periods.

This paper addresses issues relating to access to the MF band for DRM services and to the ongoing work to ensure that DRM capable receivers reach the market in the near term.

INTRODUCTION

There were two reasons for the creation of DRM. Firstly broadcasters needed a digital sound broadcasting system that could compete in quality with FM whilst using the existing AM spectrum. Secondly as a response to ITU question (ITU-R 217-1/10). The system developed by the DRM consortium had to be complex due to the widely varying propagation conditions, frequency bands and needs of broadcasters across world markets. DRM has a range of modes and options meeting the requirements of the ITU for a system that is fully compatible with the international regulatory environment, while being a universal non-proprietary system. There are four main transmission modes designed to deal with the varying severity of propagation paths from daytime LF and MF propagation through to long distance HF skywave and near vertical incidence transmission. In addition the system fits within the 9kHz channels that exist in the MF bands in ITU Regions 1 and 3 and 10kHz in the HF broadcasting bands and MF in Region 2. In recognition of the status of the DRM system the full specification has been published by ETSI (ES 201 980 v1.2.1 {2002-05}) and by IEC (PAS 62272-1). Additional specifications for the carriage of data services and the interfacing between DRM encoders, multiplexers and exciters have been prepared by DRM working groups and published by ETSI. Work is also at an advanced stage to standardise the control and data interface for DRM monitoring receivers and the data protocols allowing consumer receivers to connect with external devices, such as palm PCs. An organisation has been chosen by the IPR holders to administer a patent pool for DRM equipment manufacturers.

It is not the intention here to go into details of the DRM system itself, as the system specification is publicly available from ETSI [1]. A good outline of the system and its operation is contained within an article in the EBU Technical Review [2] with a further article describing the AAC audio coding system and the SBR enhancement [3]. DRM has also recently published a *Broadcasters' User Manual*, which is designed to aid broadcasters in the introduction of their own DRM services. This manual is aimed at the management of broadcasting organisations as well as in programme making and technical planning.

SPECTRUM PLANNING

In developing any new MF broadcasting system, account has to be taken of the three agreements that govern the allocation and use of spectrum in this band. In the case of Regions 1 and 3 (broadly Europe, Africa and Asia) the Geneva 1975 (GE75) agreement governs the assignment of spectrum and the planning rules to be used; in the case of Region 2 (the Americas) the Rio 1981 & 1988 (RJ81 & RJ88) agreements provide the framework. Any new system to be introduced within these framework agreements must provide compatibility with the existing frequency assignment in the band. There must also be a way of ensuring that existing analogue services in the band are protected from the introduction of the new services. In the case of the GE75, RJ81 and RJ88 Agreements, the MF band is divided into a number of channels with fixed centre frequencies and defined bandwidth. For historical reasons this has led to Regions 1 and 3 opting for a plan based on 9kHz carrier spacing, with Region 2 opting for 10kHz. Based on the relevant spacing, and with an assumption that the transmitted analogue signals have defined spectrum occupancy, a series of protection ratios have been used that ensure, in planning frequency and power assignments, certain minimum protection is provided to all planned transmissions in the band. Assignments made within these plans enjoy protection from any new transmissions that an Administration might wish to plan in the future. Additional assignments may be made, provided that they do not increase the interference to existing assignments by more than 0.5dB.

For domestic reasons it is possible for an Administration to allow transmissions that do not fully conform to these Regional plans. Of course, should such a transmission suffer from interference from a planned assignment emanating from another country then there is no recourse, as it is not a protected transmission. However should an existing planned assignment in one country suffer interference from an unplanned transmission from another country it has recourse to the ITU and may ask for the interfering transmission to cease or be reduced in power to comply with the required protection ratio.

The ITU Radio Regulations Board (RRB) has some degree of freedom to modify the Rules of Procedure under which the planning of frequency assignments is made. In particular where a new transmission system becomes the subject of an ITU recommendation the RRB can modify the planning procedures to allow the introduction of such a system into the frequency band(s) for which the system was designed and recommended. The DRM system is the only system recommended by the ITU (recommendation BS1514-1) for use in all the AM broadcast bands worldwide (i.e. the LF, MF and HF bands). Additionally ITU Task Group 6/7 determined the required protection levels for analogue AM signals interfered with by DRM signals, as well as the required analogue-to-DRM and DRM-to-DRM protection ratios. These are contained within the ITU draft new

Recommendation BS (Doc.6/324{rev.1}) as a response to ITU Question 223/10. Based on the information in this draft new Recommendation, the ITU RRB added two new Rules of Procedure that apply to the planning of assignments in the MF bands in Regions 1 and 3 under the GE75 Plan. These changes, allowing the introduction of DRM services, were endorsed by the WRC2003 conference, although the protection ratios (particularly DRM into analogue AM) have a provisional status and will require verification by the time of a WRC2010 conference.

For MF transmissions in Region 2, which operates under the RJ81 & RJ88 Plans, a Regional Conference will be necessary to allow any digital system to be introduced. This arises because the RJ81 Plan requires the transmitted signal to be receivable using a simple envelope detector and this clearly cannot be true when a wholly digital signal is transmitted. Although the RJ88 Plan, which extends the MF band, does not have a similar requirement, the RRB chose to make no change to that Plan either.

The change in the GE75 procedure means a DRM transmission meeting analogue planning requirements may be substituted for an existing assignment or entered as a new assignment. This is provided that it operates at an average power at least 7dB below the permissible analogue carrier power and that its spectrum occupancy conforms to the required spectrum mask. A DRM service introduced under these Rules of Procedure will be protected in a similar way to an existing or permissible planned analogue service. To date DRM is the only digital system that has gained ITU approval for assignments within the terms of Regional planning procedures for MF in Regions 1 and 3 and LF within Region 1.

One reason that it proved possible for the ITU to approve DRM for introduction stems from the spectrum occupancy of the DRM signal when operating within the 9 or 10kHz modes. In these two modes the transmitter output spectrum is designed to fit within the ITU spectrum mask (this has been used for the purpose of calculating the required protection ratios). The mask requires the DRM OFDM signal to exhibit a flat top across the channel. There must also be a very fast roll-off within the inner edges of the channel and a continuing roll-off outside the channel. This spectrum shape (see Fig. 1) places considerable demands on the performance of a transmitter, particularly one that was originally designed for analogue AM broadcasting. The DRM field test programme and the presence of many services on the air is testament to the fact that many transmitters in use today can meet this requirement. Several DRM members, including VT Merlin, are carrying out work to further improve the performance of existing transmitters converted to carry DRM signals. Meanwhile, transmitter manufacturers are developing the next generation of digital-ready transmitters.

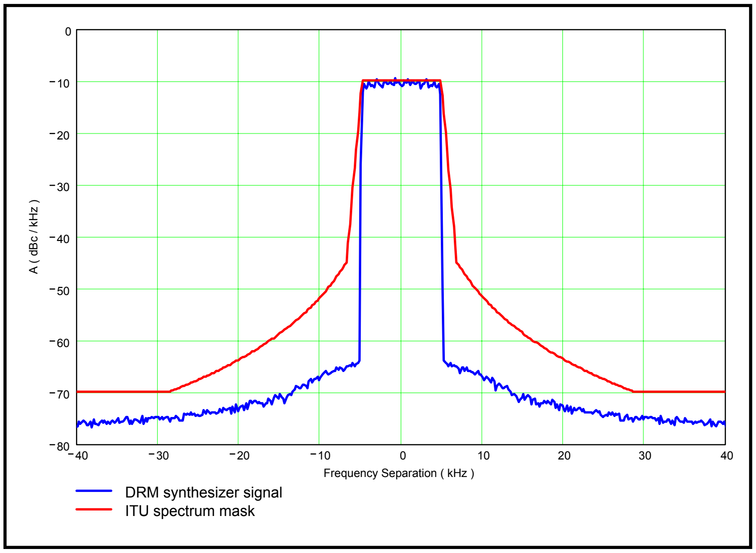


Fig. 1:
Red line is ITU spectrum mask required for transmission of 9kHz signal (Regions 1 and 3). Blue line shows the DRM signal, using 64QAM in 9kHz mode.

COVERAGE PLANNING AND QUALITY

Many broadcasters are interested to know how the adoption of DRM transmissions will affect their coverage areas, particularly in comparison to existing analogue services. The characteristic of a digital system is that once the limiting signal to noise ratio (SNR) is reached, failure is quite rapid and DRM is no exception. However whilst failure at the edge of coverage may be swift, within the service area the quality of the service remains consistently high. Testing of DRM has shown that even at the maximum permissible power of 7dB below analogue, the coverage area is at least as large as that of the analogue service that has been replaced. Moreover, DRM allows the broadcaster to trade robustness for audio quality, so there is some degree of freedom to decide whether to maximise coverage or quality for a given power level. With current analogue services there is no easy means of mitigating interference caused by incoming sky-wave interferers at nighttime but with DRM robustness **can** be increased to mitigate these interference effects. The broadcaster may wish to make use of the significant coverage gained at night due to sky-wave, so again the DRM signal robustness can be increased, at a cost of audio quality, to counter the adverse fading effects of sky-wave propagation.

There are a number of variables in the DRM system to be considered. Transmission mode (number of carriers and pilots), modulation (64 or 16QAM), code rate (e.g. 0.5, 0.6 etc) and interleaver length (0.4 or 2sec) can all be altered. For a typical MF daytime service, the determinant of coverage is mainly SNR and hence the distance from the transmitter, so the bit rate can typically be set between 20 to 28kb/s. A service using MPEG4 AAC with SBR parametric stereo can then be provided. During the night the available bit rate is more likely to be within the range of 16 to 24kb/s, depending on the broadcaster's trade-off between coverage and quality. So if audio quality is considered more important, parametric stereo may be retained. However where coverage retention (or coverage increase in the case of sky-wave service) is wanted the lower available bit rate will force the choice of mono audio.

MIGRATION TO DRM

The most difficult period for the introduction of any new service is likely to be during the transition. This is particularly true of DRM, where existing spectrum has to be used for both the present analogue services and the new digital services. In the case of Eureka 147 DAB this problem does not arise, as any new service is allocated new spectrum. Considerable work is going on within DRM to further the possibility of using a so-called simulcast mode. In simulcast the analogue and digital signals occupy the same channel during the transitional period. However the use of a 4.5 or 5kHz wide DRM signal in conjunction with a vestigial sideband analogue signal, although quite possible, limits the quality of both signals. Nevertheless testing continues, to fine-tune the performance of this option within the confines of the existing DRM system specification.

Placing a 9kHz bandwidth DRM signal adjacent to an existing 9kHz bandwidth analogue service might also seem an attractive possibility as it provides the immediate option of a stereo digital service. But it is important to note that the digital signal is unlikely to be protected from incoming interfering signals unless it is planned as a new assignment in its own right. The GE75 Agreement permits RF bandwidths of 9, 18 or 20kHz even though the channel spacing is 9kHz. In the majority of cases existing frequency assignments within Regions 1 and 3 are of 9 or 10kHz bandwidth. There are only a limited number of situations where an Administration has applied for and obtained an 18 or 20kHz ("wideband") assignment. This means that in most cases the simulcast digital signal would be unprotected and, if it caused interference to an existing external assignment, it could be forced to close down or reduce in power. For stations with wideband assignments, however, this option seems attractive and certainly worth pursuing.

The majority of broadcasters with 9 or 10kHz allocations that wish to start migration to DRM services will need to review their particular circumstances. In some cases a broadcaster may have several frequencies allocated to it for coverage of a country or a region and it may be possible to re-plan the analogue service so as to release one of these frequencies for DRM operation. This released frequency could then be used for a parallel DRM service, remembering that the option of building a truly seamless single frequency network exists with DRM where it did not with the analogue service.

In the case of a broadcaster with a single frequency allocation it may be possible to start a DRM service in the next adjacent upper or lower channel to the existing analogue service, subject to the modification procedure of the GE75 Plan. As DRM operates at a lower power level it may be most cost effective to employ a separate transmitter using either the existing antenna, if it has sufficient bandwidth, or a separate simple antenna. In other cases it may be better to look for an additional frequency in the band on which to start a DRM service. Broadcasters should investigate any existing unused assignments, registered by the host Administration, or consider applying for a new assignment for use during the transitional period. It should be noted that the permissible DRM power for a new assignment might achieve a coverage area less than that of the associated analogue service. However, use can be made of the DRM receiver’s automatic alternate frequency switching to swap to the analogue service at the outer edges of the digital service area. At a later stage, when a high proportion of listeners have DRM receivers, it may make sense to swap the frequency allocations between the two services to maximise the digital transmission’s coverage area.

It is interesting to note that DRM now supports a hierarchical transmission mode. This allows the data in two separate DRM frequency blocks or ensembles to be amalgamated. An example of the use of this facility might be to place a DRM base layer block of carriers in the next adjacent upper channel to an existing analogue transmission and an enhancement block in the next adjacent lower channel. The resultant signals would then occupy 27 (9+9+9kHz) or 30kHz (10+10+10kHz) of spectrum, depending on the Region in which the transmission is made. DRM receivers will be able to amalgamate the data from the two separate DRM transmissions and thus benefit from the much higher audio quality, which stems from the increased data rate. Because the DRM system also supports 4.5 and 5kHz bandwidth options these could also be used in the hierarchical mode to provide a good quality parametric stereo service but in 18 (4.5+9+4.5kHz) or 20kHz (5+10+5kHz) of bandwidth, which may be easier to introduce in some regions. In all cases the DRM signals would be transmitted at a lower power level than the analogue signal. It can be noted that such an assembly of signals bears a superficial resemblance to an IBOC transmission as it can occupy a similar bandwidth and be transmitted from a common transmitter and antenna (see Fig. 2).

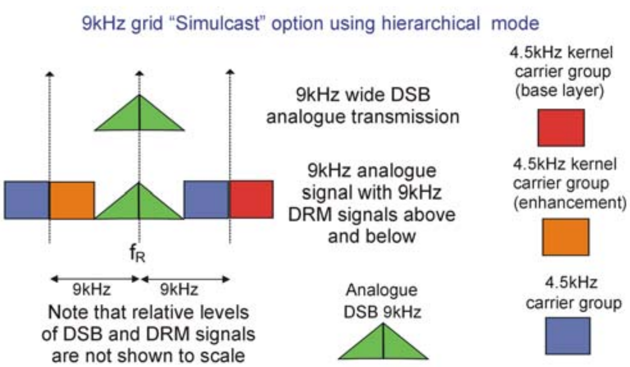


Fig. 2: Simulcast options using hierarchical modes

RECEIVER DEVELOPMENTS

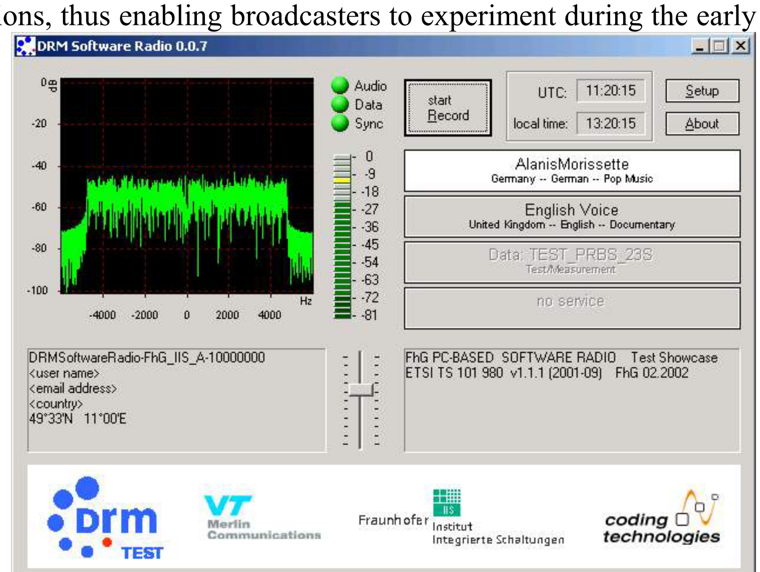
As discussed in the opening to this paper, availability of receivers is vital if the introduction of DRM broadcasters' services is to be successful. In light of the problems encountered with the lack of early consumer receivers for DAB services, DRM is striving to avoid a repetition of this problem. During IBC 2003 in Amsterdam, a number of DRM receivers were displayed at the DRM consortium booth and live reception of SW and MW services was demonstrated both there and in a car, driven around the local area. Some important developments towards consumer receivers are discussed in this section. Further details on receiver developments can be found in an article in the EBU Technical Review [4].

The DRM Software Radio Project [5]

The DRM consortium realised there would be considerable merit in providing a low cost PC-based DRM software receiver, which could be made available to the Amateur Radio and DX community. This was seen as having a number of benefits:

- Significantly increasing the number of reception sites for long term field testing;
- Reaching enthusiasts who had already indicated their interest in being involved in DRM tests;
- Providing a test bed for verifying the performance of receiver software, which could be eventually be used in consumer receiver chips;
- Promoting and raising awareness of the DRM system worldwide.

As a result a simplified version of the Fraunhofer Institute (FhG) PC-based software receiver has been available since 1 January 2003. This receiver provides the same level of performance as the professional version but does not have the extensive signal analysis tools of its parent. It also supports DRM multimedia transmissions, thus enabling broadcasters to experiment during the early service period. No limitation will be placed on the lifetime of this version of the receiver, although support will be limited to two years. During this period users are able to download new versions of the software when they become available. Participants are charged 60€ for the DRM PC software, almost entirely to cover the cost of the relevant licence fees. VT Merlin is running this project on behalf of the DRM consortium.



To construct the working receiver participants need a suitable PC plus a receiver to be used as the front-end RF tuner. Users must modify the front-end receiver, either by constructing a suitable IF down-converter, or purchasing a ready-made circuit board, which converts the DRM signal to a final IF of 12kHz. Having downloaded and installed the software on a suitable PC and connected the 12kHz IF signal to the input of the PC sound card, users can then demodulate and listen to DRM transmissions. The receiver allows users to record a file onto the PC's hard disk, containing information about the received signal. This file can then be uploaded to the DRM receiver project website. After amalgamation and processing, summary information on DRM transmissions is made available to DRM members and project participants on the project website. Fig. 3 illustrates the user screen of this receiver.

A number of organisations, including DRM members, are modifying various front-end receivers to test their suitability for use with the receiver software. Information on the work required to modify these receivers and on receivers found not to be suitable, is given on the project website. The website also provides a forum for participants, a frequently asked questions (FAQ) section and a technical support area.

The CTS Radio

When discussing DRM inevitably the most commonly asked question is "…when will consumer radios will be available…?". Expectations were first raised by the showing at IBC 2002 of a production-ready world-band DRM consumer radio made by Coding Technologies (CTS) in collaboration with BBC Research & Development and AFG. The receiver was packaged in an existing consumer radio casing and could be tuned in both analogue and DRM modes via the front panel controls in the usual way. Most of the original electronics, inside the case, were replaced. At

Fig. 4: Production-ready Coding Technologies DRM receiver, DRM2010. Dimensions 21x7x13cm.

IBC 2003 CTS showed an updated version of this receiver (Fig. 4) packaged in a smaller case and with improved performance. A limited production run of these receivers is being marketed to the public by Mayah (http://www.mayah.com/). The receiver retails for 695€ before tax, and as the price indicates this is not intended for the mass market. Due to the use of a DSP chip, not intended for portable devices, the receiver requires connection to a mains power supply, as the power consumption is too great to use internal dry batteries,

The production of this receiver represents an important milestone for the DRM consortium; it demonstrates there is no inherent problem in providing all the required functions of a DRM receiver in an enclosure of the same type and size used for current analogue receivers.

INTEGRATED CIRCUITS (IC's) FOR CONSUMER DRM RECEIVERS

Noting that the power consumption of the above receiver is too high for operation with dry batteries, it is clear that alternative approaches are needed to allow mass production of consumer receivers. Suitable alternatives can be by using available consumer DSP chips designed for digital portable equipment or the design and manufacture of new DRM enabled chips. Either of these approaches will enable the production of DRM receivers with much reduced power consumption, whilst allowing manufacturing costs to be progressively and significantly reduced. In the first instance the required software has to be written and ported to the chips and this exercise is being undertaken by at least one DRM Member in co-operation with a chip manufacturer. In the second case two projects are currently in progress in Europe to design and manufacture or adapt suitable chips or chipsets. One of these, DIAM, is currently working under a Eureka designation and involves companies from several European countries. The other, Radiomondo, involves German participants alone.

DIAM Eureka Project [6]

This project involves organisations from five European countries (France, Germany, Greece, Italy and Sweden) and is lead by Atmel Rousset of France. Six of the ten participants are DRM members. The project has a budget of nearly 30 million euros and the aim of providing sample chips during 2004. The primary aim of DIAM is to design a DRM receiver on a chip (Fig. 5), which will in turn enable a number of semiconductor and receiver manufacturers to develop the required hardware for consumer receivers. This is intended to allow DRM receivers based on such a platform to be launched during late 2004 or early 2005.

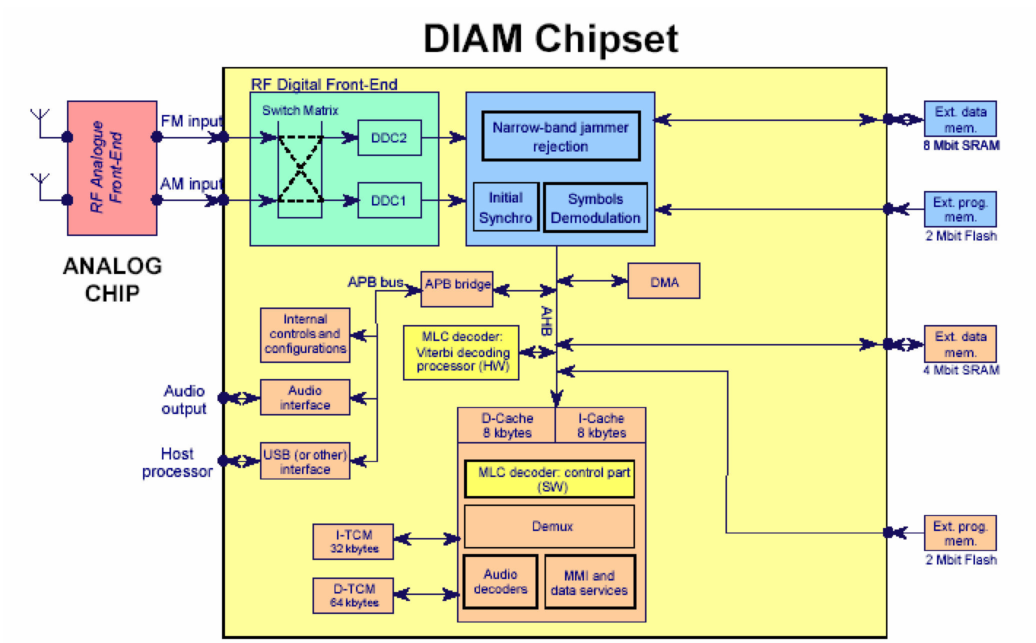


Fig.54: Schematic of DIAM chipset

Radiomondo Project [7]

The German Ministry of Education and Research is providing just less than 4 million euros to fund this three-year project. The project has two main aims:

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

The project involves 6 German based organisations, all of them DRM Members, and is led by the Fraunhofer Institute for Integrated Circuits IIS-A.

A CLOUD ON THE HORIZON

When planning broadcast services, just as with all other radio services, the assumption is made that Administrations will endeavour to comply with the ITU Radio Regulations by ensuring that interference to these services is minimised. Otherwise the planning assumptions made for required field strengths will be incorrect. Until recently this was a valid assumption and Administrations regulated transmissions to ensure that they were within the allocated powers and that unintentional interference to these transmissions was tracked down and eradicated as quickly as possible. However the introduction of Power Line Telecommunications or Communications (PLT/PLC) in some countries seems to be close to undermining this assumption. Due to political pressure in some regions to introduce competition into the broadband Internet market it seems that broadcast services could soon cease to be protected from unintentional interference. In Europe, for example, the European Commission has placed pressure on ETSI (the European Telecommunications Standards Institute) to introduce a standard for PLT that will allow its introduction. Because PLT systems use the existing power cable infrastructure to deliver high speed Internet services between the substations and the consumers' homes there is a high level of radiation from the unbalanced cabling. Furthermore this radiation penetrates not only the PLT customer's home but also those of neighbours connected to the power distribution system. In the case of European homes the proposed standard for PLT would allow a field strength of up to 58dBμV/m to be radiated within 3 metres of the power cabling in the frequency bands up to 30MHz. The exact nature of the radiated spectrum varies, depending on the system in use, but in many cases it will prevent in home reception of AM radio services in the MW or SW bands. This is a potentially disastrous state of affairs and threatens to prevent the continued use of the AM broadcasting bands. Broadcasters worldwide need to be aware of the threat posed by PLT/PLC systems to the continued use of the AM broadcasting bands.

CONCLUSIONS

In addition to the significant ongoing technical and regulatory work being carried out by the various DRM working groups, there are a number of specialised DRM projects running [8]. There is also strong support from DRM members in system technical development, testing and marketing. This all contributes to the feeling of confidence that the DRM system can replace a majority of analogue transmissions in the AM bands over the coming years.

Work on DRM receiver and chip development so far also gives cause for optimism that consumer receivers will reach the markets before the end of 2004, which is only just over a year since the inaugural DRM transmissions began in June 2003.

This paper has shown that many of the regulatory pieces are in place and there are MF migration routes for broadcasters seeking to take advantage of the clear benefits of DRM transmission. It has also introduced the progress being made towards availability of DRM consumer receivers. However a note of caution must be sounded, in the light of PLT developments, for broadcasters to be vigilant in the protection of the AM spectrum.

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