DRM: AN EMERGING DIGITAL STANDARD FOR THE AM BANDS

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ABSTRACT

AM broadcasting uses frequency bands below 30 MHz which offer useful forms of coverage, on scales from local to international. However, propagation disturbances and intrinsic quality limitations of the present AM standard mean that AM broadcasts deliver a service which does not compare well in quality and user-friendliness with other media. Digital techniques offer a way to provide a higher-quality service without these disadvantages so that the unique coverage properties of these bands can continue to be exploited for broadcasting. A single world-wide standard is necessary if the ubiquity and cheapness of AM is to be replicated. The Digital Radio Mondiale consortium of broadcasters, transmitter and receiver manufacturers, and others is engaged in designing a digital standard that, with a range of modes, will meet the requirements of all types of broadcasters while providing new features for the listener, especially in simplifying the process of accessing the desired programme.

INTRODUCTION

There are many frequency bands 'below 30 MHz' which are used for sound broadcasting. Indeed, they can be considered to be the historical descendants of the spectral birthplace of broadcasting.

One thing they have in common is the use of *amplitude modulation* (AM) and so they are often known by the convenient, if perhaps misleading, name of 'the AM bands'. It's what is written on the dials or push-buttons of many radio receivers (in contrast to FM — frequency modulation — which requires spectrum at very-high frequency, VHF).

'AM' is taken to mean 'double-sideband, full-carrier AM', as this is what is used by virtually all broadcasts in these bands, and has been since the birth of broadcasting roughly eighty years ago. It is a method which is relatively simple to receive and to transmit. It has some limitations though.

LIMITATIONS OF AM

AM is an analogue technique. Limitations of bandwidth, and addition of noise or interference to the amplitude-modulated radio-frequency (RF) signal all have a corresponding direct effect on the audio signal that is conveyed.

The very first broadcasters were presumably only limited in bandwidth by what was achievable with the hardware of the day, and should have been free from mutual interference. They would have faced the inevitable steady decrease in audio signal-to-noise ratio as the distance from the transmitter increased. This remains an issue today, despite higher-power transmitters being feasible. Thermal noise is not the only problem, as AM is also susceptible to man-made noise/interference and to atmospheric noise.

As more broadcasters started operations, there arose the potential for mutual interference. Agreement was needed — who could use which frequency, with what power — and to limit the bandwidth. Frequency planning was born. Through the International Telecommunications Union (ITU) and national administrations, plans were drawn up. Channel spacing and bandwidth were regularised, albeit not in quite the same way throughout the world. Such plans do not eliminate interference between stations, they merely limit it to 'acceptable levels', otherwise the usage of the spectrum would be very limited indeed.

Signals at the 'AM-band' frequencies may propagate *directly* from transmitter to receiver along the surface of the Earth as a *ground wave*, or *indirectly*, via the ionosphere, which refracts the signal back to Earth as a *sky wave*. The refraction is often considered as being equivalent to a reflection.

The sky wave can be both a benefit and a problem. It provides a means whereby broadcasters can access target areas at a distance (which is therefore gratefully exploited in *international broadcasting*). It also means programmes intended for a local audience can be a source of unwanted co-channel interference far away. A further problem is where signals are received simultaneously by both ground and sky wave paths — as the path delays are different, some frequencies will combine constructively, and others destructively, giving rise to *selective fading*, see sketch of Fig. 1.

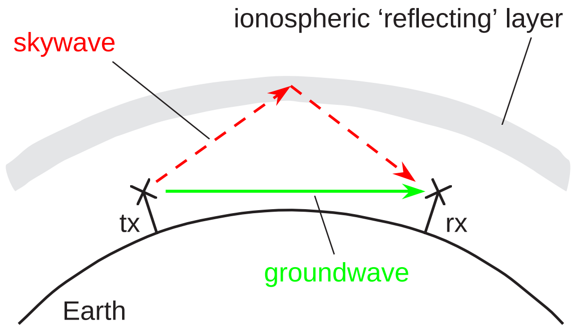

Figure 1. Interference of sky and ground waves.

This interaction between ground and sky waves is a significant factor in local/national broadcasting. But those broadcasting to distant targets face a similar problem when signals can take various numbers of 'hops' between the Earth and the ionosphere — this similarly provides a mechanism for selective fading, as sketched in Fig. 2.

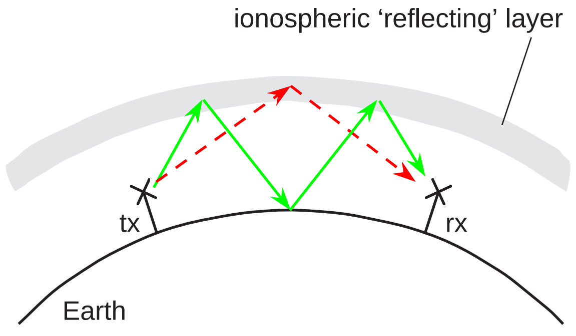

Figure 2. Multipath from 1 & 2-hop propagation.

One of the great merits of conventional AM is the simplicity of its implementation. A receiver can use a simple envelope detector to recover the audio signal. However, in the presence of selective fading, unpleasant distortion can result. For example, suppose there is severe attenuation around the carrier frequency. As far as the receiver is concerned, it is just as if the signal had been transmitted with a reduced carrier — in effect it is *over-modulated*. Other unpleasant effects happen when one sideband of the signal is attenuated differently from the other.

To some extent, these ill-effects of selective fading can be ameliorated by cleverness in the receiver. Using a synchronous detector removes the 'over-modulation' effect and reduces the impact of selective fading of one sideband. If the receiver has the ability to receive one or the other sideband only, then the effect of an interfering signal in one adjacent channel can be reduced.

A logical next step is to broadcast a signal which has only one sideband and a reduced carrier amplitude. This saves power for the broadcaster and increases the spectrum efficiency. This was recognised long ago and the ITU set out a timetable (Resolution 517) by which all HF AM broadcasting would switch to this reduced-carrier, single sideband (SSB) technique.

This changeover has shown little sign so far of taking off. There are relatively few receivers in the hands of listeners (other than hobbyist enthusiasts) which are equipped for synchronous reception of SSB. Nor are there many transmissions in the reduced-carrier SSB mode. To some extent, this is a standard chicken-and-egg stalemate.

The process of changing the entire stock of receivers is inevitably long-term. For this to get started there have to be clear incentives and benefits for the listener buying a new receiver. Perhaps these are just too few and too small in this case of analogue SSB. There would be an eventual benefit for all in the greater spectral efficiency — but this is not apparent at all to the potential early purchaser of a new SSB-equipped receiver. We shall meet a similar discussion later in this paper.

WHO/WHAT ARE 'AM BROADCASTERS'?

For the purposes of this paper, an 'AM broadcaster' is simply any broadcaster who currently broadcasts (in AM) in one or more of the 'AM bands' below 30 MHz. They may or may not have access to other means of broadcasting such as VHF/FM.

AM broadcasters come in many flavours, and this must be recognised in any proposals to change the usage of the 'AM bands'. Their differing needs must all be accommodated.

They may be authorised to make use of just one frequency or of many, in just one or many of the AM bands. They may be large or small, and funded (and thus also motivated) in many ways. Their intended coverage may be local, regional (meaning part of a country), national or international in extent.

CHALLENGES FACING EXISTING AM BROADCASTERS

Present 'AM broadcasters' do not have a monopoly of their listeners' attention. They face competition from:

- broadcasts using VHF/FM (in most areas of the 'developed' world, and in most urban areas elsewhere)
- 'radio' programmes accompanying TV broadcasts by satellite, etc. (e.g. using analogue or digital subcarriers), or on cable
- direct radio broadcasts from satellite, such as the nascent WorldSpace system
- the ever-growing use of Internet
- recorded media such as CDs, MiniDisc or cassette
- terrestrial radio broadcasts using digital modulation, such as Eureka 147 DAB, now available in many countries

All of these, in varying degrees, have some advantage in terms of audio quality over AM radio. Some offer benefits in user-friendliness and facilities. Many just have a more attractive, modern 'image'. All of this means that where this choice is available, an AM broadcast has to be very compelling in content to retain the listener who can otherwise find something else which, whatever its content, is simply more pleasant to listen to.

But the 'AM' bands have plus points in their favour.

ADVANTAGES OF THE 'AM BANDS'

The advantages of the 'AM bands' stem from propagation. Ground-wave propagation in the LF/MF bands (the familiar long and medium wave) is not limited to the line-of-sight behaviour of VHF. Thus a large area (even an entire country) can be covered at LF/MF using one transmitter or a network of a small number of transmitters. This is therefore economically attractive for domestic broadcasting, in comparison with the extensive network of transmitters needed to achieve the same coverage with VHF/FM. (Naturally, the advantage might not apply if only a few concentrated urban areas need be covered, so the strength of this advantage depends on the particular remit of the broadcaster).

For large countries with dispersed populations the use of *near-vertical incidence* (NVIS) ionospheric propagation has advantages. The signal is sent more-or-less vertically upwards and 'reflected' back down to the surrounding area. This method normally uses frequencies at the lower end of the HF range, as the frequency has to be below the normal-incidence critical frequency of the ionosphere. It is especially favoured in tropical countries, which have access to so-called 'Tropical Band' allocations for this purpose.

Skywave propagation is also a key factor in the utility of 'AM bands' for *international* broadcasting. It provides a means to reach other countries directly, without hindrance. In contrast, both satellite broadcasting and local re-broadcasting using transmitters located in the target country require the assistance of others, who might act as 'gatekeepers' — so that service continuity cannot be guaranteed, especially in times of upheaval.

WHY GO DIGITAL?

Digital techniques have spread irrevocably through broadcasting in the past two decades. Initially they were only used by broadcasters themselves, for recording, production and distribution, but now several types of digital signals reach consumers, e.g. teletext, DAB and digital television. They have brought new facilities, better quality and greater spectrum efficiency, in varying proportion. Consumers are also familiar with CD and digital mobile phones, so that 'digital' applied to a consumer item is generally favourably perceived.

But there are much better reasons to use a digital system in the 'AM bands' than simply fashion (although that will no doubt help in introducing it!).

We have noted the quality limitations of AM (in comparison to other means of broadcasting and more general entertainment). Properly designed, a digital system should overcome the difficulties caused by the various types of multipath propagation that the 'AM bands' exhibit. The audio signal-to-noise ratio can be improved, and made independent of that of the received RF signal. The perceived audio bandwidth can be increased. All these will make it easier for broadcasters obliged to use 'AM bands' — for reasons of practicality (e.g. in international broadcasting), or by regulation — to compete for the audience's attention by content alone, with audio quality no longer being an issue.

Digital techniques can also make the whole process of listening more user-friendly, simplifying the process of choosing and finding the desired programme, and offering extra information such as text alongside the audio.

DIGITAL RADIO MONDIALE

All these potential benefits were recognised over recent years by the AM-broadcasting community. Initial informal discussions in autumn 1996 led to the formation of a world-wide consortium, Digital Radio Mondiale (DRM). DRM members, Table 1, include broadcasters, network operators, manufacturers of both receivers and transmitting equipment, academics and research centres.

DRM's mission is "… *to bring affordable digital quality sound and services to the world radio market*" and a key objective, to "… *formulate a digital system design, which could serve as a single, tested, non-proprietary, evolutionary world standard, which would be market-driven and consumer-oriented* …" was identified at the start.

Before discussing the standard DRM is developing, let us see why a standard is necessary.

WHY HAVE A STANDARD?

One of the great advantages of conventional AM broadcasting is that AM receivers are ubiquitous, and any particular receiver will work anywhere. There is very little about a conventional AM receiver that has to be precisely specified in order for it to work. If it can be tuned to the transmission frequency, you will hear the signal. It would be preferable for the receiver bandwidth to match the needs of the local channel spacing — but it won't completely stop you hearing the program if it doesn't. Listeners are thus free to hear any signal that reaches them, from the same country or afar.

With a digital system, the receiver must be designed for the precise format of the signal — every last detail of the modulation, multiplexing and audio source coding — or it will not work at all. Thus, unless a single standard can be agreed, listeners will be unable to choose between programmes from all broadcasters while using a single receiver. This might appear to some broadcasters to be advantageous to them — their listeners would be, as it were, held captive once a receiver for 'their' system was purchased. However, for every listener 'locked in' , there will be other listeners 'locked out', so this is a short-sighted approach. Furthermore, economy of scale greatly favours the single standard. One reason there are so many AM receivers in existence is that they can be made cheaply, and afforded by many, even in poorer nations. New digital receivers will inevitably be more expensive initially, so the economy of scale in producing for a world-wide market will be essential if worthwhile take-up is to be achieved in any but the richest nations.

Different broadcasters — and different environments — will have different requirements, so does this mean that a single standard that suits all is impossible? The answer is that the standard must be a single specification of a system which has options — modes — which between them meet all the requirements. Something similar has been done for other systems such as digital television, where the DVB project produced a family of standards for satellite, cable and terrestrial broadcasting, each with a range of modes, Stott (1). While this can be complicated to explain and specify, it does not really add anything significant to the complexity of a receiver chip.

The DRM consortium has followed the example of DVB, in that the development is driven by a list of agreed requirements drawn up by its Commercial Committee. The list is substantial, so only some of the key aspects will be mentioned here.

HIGHLIGHTS OF THE REQUIREMENTS

- a single world-wide standard
- better reception quality and reliability
- ease of use for the listener
- new features
- flexibility for broadcasters to trade capacity, quality and reliability
- possibility to re-use existing transmitters

A single open standard is essential, so that "a DRM receiver bought anywhere in the world will work anywhere in the world" — the stated aim of DRM.

Self-evidently, the system must facilitate its own introduction, and to do this will need modes adapted to the regulatory situations of each country or region. It must also look forward, recognising that frequency allocations and channel spacing (and bandwidth) may change over the lifetime of the standard — remember, AM has been around for eighty years or so!

The system must carry digitally-coded audio and various kinds of data, each receiver automatically extracting the information it is equipped to use.

Some of the data will be used to provide facilities that will make the receiver easier to use. For example, AM broadcasters often use several frequencies to convey the same programme. A network of MF transmitters may use two or more frequencies, so a mobile receiver will have to switch while travelling from one coverage area to another. HF broadcasters have to change frequency according to daily and seasonal changes in the ionosphere. They may also use more than one frequency simultaneously, as forecasting which frequency band will work best remains an inexact science — and in any case, if the coverage area is large, the best frequency will depend on location. With a manually-tuned AM receiver, the poor listener has a difficult time of it to find (and stay with) the wanted programme. Furthermore, announcing spoken lists of frequencies and impending changes detracts substantially from the pace of programming.

Automating the selection of so-called ‘Alternative Frequencies’ and generally improving the ease of programme selection is therefore a key feature.

The audio quality must be significantly better than that achieved by conventional AM. It must cope with speech in all languages. Not only must the perceived quality be good under ideal conditions — a function of the bit rate and the source-coding method of data compression — but the overall impression must remain so during real conditions (with selective fading, etc.). What has to be optimised is the combination of fundamental ideal-conditions quality with the effects of transmission impairments. Indeed, a range of possibilities is needed so that the broadcaster can choose a robustness/intrinsic-quality compromise that suits each situation. For example, for daytime LF/MF broadcasting using ground wave, it will probably be possible to support a high bit rate with commensurate high basic quality which will be maintained, as the transmission conditions are relatively undisturbed. In contrast, long-distance HF will not be able to support so great a bit rate (within the same RF bandwidth) and greater transmission disturbances can be expected, so a different compromise will be needed, implying a different mode. In extreme circumstances, a broadcaster might perhaps choose to use a speech-only form of coding (at low bit rate) so that greater reliability could be ensured for urgent information in times of disaster. A less extreme example might be for a programme to split into two or more languages for say news before rejoining a single stream for music. This last example presents another situation where clever user-interface design is needed so that the process is transparent to the listener.

The challenge is to provide all these features that the listener will perceive as significant and worthwhile improvements (much more than was offered by synchronous-SSB receivers) at a price which is affordable even in the poorest regions. Not only that, it must be possible to go on using them, so the power consumption must be low. Ideally solar power or clockwork generators would avoid the cost of battery replacement.

The listener is not the only one whose budget is limited. Broadcasters have a substantial investment in transmitters, so the system must be such that a substantial proportion of existing AM transmitters can be adapted to carry it.

THE EMERGING STANDARD

At the time of writing, the standard is currently being developed within various sub-groups of the DRM Technical Committee so it is inappropriate to give much detail of a moving target in print here.

It appears that the modulation will be based on some variety of multicarrier modulation, having something in common with the various forms of Coded Orthogonal Frequency-Division Multiplex (COFDM) used in DAB and DVB-T. These are known to cope well with time-varying multipath without requiring excessive receiver complexity, Stott (2). However, the multipath transmission impairments in the ‘AM bands’ are different and, especially at HF, are perhaps even more extreme. So studies continue to ensure that the solution chosen is a good match to the problem.

The needs of alternative-frequency switching have some similarities to the Radio-Data System (RDS) used in VHF/FM broadcasts. The use of digital modulation offers some exciting possibilities for improvement. A simple RDS-equipped FM receiver, which has a single front end, has to mute the audio occasionally for a brief period during which it checks one of the known alternative frequencies to see if reception is better there. In this way it can re-tune to the best frequency as the situation changes (in this case because the receiver is moving). With a digital system, as in DRM, it should be possible to design a signal format so that the periodic interruption of the audio signal can be avoided altogether, making re-tuning a completely seamless process.

In designing this feature we have to take account of the relative timing of the signals received on the different frequencies. With international broadcasting the size of the coverage areas is such that the relative delay can vary appreciably within them.

As an example, Fig. 3 shows the relative delay between signals from two transmitters in Oman and Thailand which cover the Indian sub-continent. The calculations take account of spherical geometry, and different numbers of hops and effective ionospheric 'reflection' heights can be specified for the two paths. In this case the transmission from Oman is at MF and so a lower 'reflection' height has been taken than for the HF transmission from Thailand. Both are assumed to be 1-hop. The spread of relative timing over the desired reception area is about 20 ms. Other plots can be made for different combinations of hops and, by doing so, the overall requirement for this example can be shown to be about 22 ms. Plots for other parts of the world, including areas served by transmissions from more than two sites, suggest that roughly 30 ms is the total span of relative delays that needs to be accommodated.

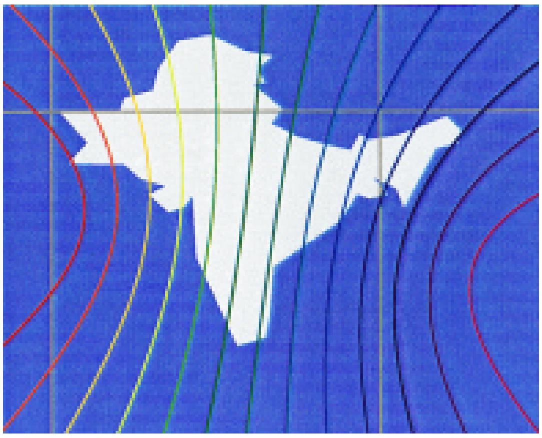

Figure 3. Contours, spaced at 2 ms intervals, of relative delay between single-hop skywave transmissions from Oman (MF) and Thailand (HF).

THE FUTURE

The DRM Consortium is working to complete a draft specification by end-99 covering all aspects of a complete digital broadcasting system, from RF aspects like modulation, through multiplex formats to encompass all the desired data facilities, to the details of the source-coding methods used to compress the data rate of the audio signal. The spoken presentation will include illustrations of progress. The DRM target is to bring the system to market in 2001 and full-scale operation a year later. Further information may be available on the DRM website, http://www.drm.org.

CONCLUSIONS

The bands currently used for AM broadcasting at LF, MF and HF constitute a valuable resource with unique propagation features, including the ability to provide large-area coverage suitable for both national and international broadcasting.

Some aspects of the propagation (such as multipath) unfortunately cause serious impairments to the quality of present-day AM listening, which in any case does not compare well with competing programme sources, even under ideal conditions. HF AM reception especially requires substantial commitment on the part of the listener to find and stay with the desired programme as conditions change.

Using a digital system instead of AM in these bands would make it possible to offer better audio quality and service reliability, despite the presence of multipath propagation, and could make the receiver much more listener-friendly.

A consortium — Digital Radio Mondiale — of broadcasters, manufacturers of transmitters and receivers, and others is developing a digital system for the AM bands. It is being designed according to a list of requirements drawn up by its Commercial Committee and in this way the needs of all users will be accommodated in a single multi-mode world standard. A single standard is key to achieving the economies of scale that will make receivers affordable by the poorer parts of the world.

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Academy Of Broadcasting Science	*China*	Motorola	*USA*
ABU (Asia Pacific Broadcasting Union)		NASB (National Association of Shortwaves Broadcasters)	*USA*
ASBU (Arab States Broadcasting Union)	*Tunisia*	Norkring	*Norway*
BBC	*UK*	Nozema	*Netherlands*
Robert Bosch	*Germany*	Radio Canada International	*Canada*
CCETT	*France*	Radio France Internationale	*France*
Coding Technologies	*Sweden*	Radio Nederland Wereldomroep	*Netherlands*
Comatlas	*France*	Radio New Zealand International (RNZI)	*New Zealand*
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TABLE 1 — DRM membership (at time of writing)