The AM Signalling System: AMSS

— does your radio know what it's listening to?

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The AM Signalling System (AMSS) adds a small amount of digital information to existing analogue AM broadcasts on short-, medium- and long-wave, giving similar functionality to that provided by the Radio Data System (RDS) on the FM bands. The system has been designed within the Digital Radio Mondiale (DRM) consortium, primarily to ease the transition from analogue to digital broadcasting.

A suitably-equipped receiver will allow selection of the AM service by name as well as the choice of re-tuning to other frequencies carrying analogue or digital versions of the same or a related service.

Several AMSS transmissions are already on air and some, if not all, of the first consumer DRM receivers will incorporate AMSS decoding.

If you're listening to an AM broadcast on the short-, medium- or long-wave bands, the answer to the question in the title has traditionally been a resounding "no".

Currently, the only way for a listener to identify an AM broadcast is to wait for a station's ident or jingle to be played. Without an up-to-date copy of the *World TV and Radio Handbook* or *Passport to World Band Radio* to hand, or an Internet connection available, it can be difficult to identify an AM station from the plethora available.

With increasing numbers of broadcasters switching on Digital Radio Mondiale (DRM) [1] broadcasts, the DRM consortium started to think about how the transition for broadcasters and listeners from AM to DRM could be eased.

The AM Signalling System (AMSS), now a published ETSI standard [2], has been designed within the DRM Coding and Multiplexing (DRM-CM) group. It uses low bitrate phase modulation of the AM carrier to add a small amount of digital information to existing analogue AM broadcasts on short-, medium- and long-wave, giving similar functionality to that provided by the Radio Data System (RDS) on the FM bands.

The additional digital information allows a receiver to positively identify the AM station, making it possible for the listener to select the station by name as well as offering the choice of switching over to a DRM version of the same service if available.

At least some of the first consumer DRM receivers, due to be available in early 2006, implement AMSS.

In this article, we describe what AMSS can offer and why it is needed. We detail the system itself and the implementation of an AMSS modulator designed by BBC Research & Development which is currently used for AMSS transmissions by BBC World Service. Finally we talk about AMSS transmissions and reception before drawing to some conclusions.

With AMSS, your radio *will* know which AM service you're listening to (even when you wouldn't have known without AMSS) and be able to guide you to a digital alternative when available.

What can AMSS offer?

The AM Signalling System carries a number of pieces of information including:

- Service ID;
- Language;
- Type of carrier control in use;
- Service label;
- Alternative frequency information and schedules for other DRM, DAB, AM and FM transmissions carrying the same or related programme material.

In addition it is possible to send the time and date, more detailed language and country information and to signal announcements.

The service ID is required so that each AM transmission can be uniquely identified, whilst signalling the language allows the listener to filter stations by language.

Many AM broadcasters adjust the level of the carrier and/or the amount of compression applied to the audio dynamically to conserve electricity. By making assumptions about the time constant of the receiver's Automatic Gain Control (AGC) it is possible to do this without unacceptable distortion of the received audio. AM demodulation in a DRM receiver is likely to be done digitally and if the receiver knew the type of carrier control in use, it might be possible to exactly reverse the algorithm and hence improve the audio quality.

Listeners will already be familiar, from using DAB and FM-RDS, with the service label, which allows the AM station to be identified by name.

Alternative-frequency information is particularly important for short-wave broadcasts where propagation conditions dictate that, for coverage of a given target area, different frequencies must be used at different times of day. This means that even for a receiver in a static location, the listener is often required to re-tune to continue listening to the same service. DRM has alternative-frequency and schedule signalling included so that it is possible for receivers to re-tune automatically as required. With AMSS, this alternative frequency information can also be carried on AM broadcasts and,

Abbreviations

AFS	Alternative Frequency Switching	**ETSI**	European Telecommunication Standards Institute
AGC	Automatic Gain Control	**FM**	Frequency Modulation
AM	Amplitude Modulation	**GPS**	Global Positioning System
AMDS	AM Data System	**HF**	High-Frequency ("short-wave")
AMSS	AM Signalling System	**LCD**	Liquid Crystal Display
ASI	Asynchronous Serial Interface	**LF**	Low-Frequency ("long-wave")
CRC	Cyclic Redundancy Check	**MDI**	(DRM) Multiplex Distribution Interface
DAB	Digital Audio Broadcasting (Eureka-147)	**MF**	Medium-Frequency ("medium-wave")
DAC	Digital-to-Analogue Converter	**MPE**	(DVB) Multi-Protocol Encapsulation
DRM	Digital Radio Mondiale	**RDS**	Radio Data System
DRM-CM	DRM – Coding and Multiplexing group	**RF**	Radio-Frequency
DRM-DI	DRM – Distribution Interfaces group	**SDC**	(DRM) Service Description Channel
DSP	Digital Signal Processor	**SNR**	Signal-to-Noise Ratio
DVB	Digital Video Broadcasting	**UDP/IP**	User Datagram Protocol / Internet Protocol
DVB-S	DVB – Satellite		

although seamless re-tuning is unlikely to be possible, the receiver will at least be able to offer the user a choice to switch to alternative frequencies when available. These alternative frequencies are also flagged as to whether they carry identical or related programming.

Why is AMSS needed?

Combined DRM/DAB/FM/AM receivers are due to be available in early 2006. The digital systems DRM and DAB – as well as analogue FM, through the use of RDS – all carry additional information including a service ID, a service label and details of alternative frequencies. Without AMSS, AM transmissions are the only ones that are not capable of identifying themselves other than by their frequency.

The majority of DAB receivers are tuned by selecting a service by name from a list of all those available rather than the user having to remember on which frequency (and where in the multiplex) each service is transmitted.

The first consumer DRM receivers are likely to offer similar functionality and without AMSS providing an ID and service label, it would not be possible for AM services to appear by name in this available service list.

Implementing AMSS therefore offers advantages to both broadcasters and listeners. For a broadcaster with both DRM and AM services, an AMSS-capable receiver can inform a listener tuned to an AM service that a DRM version is available and automatically retune to it. In the initial phases of a broadcaster's DRM transmissions, there may be fewer transmitters carrying DRM than AM, possibly resulting in a smaller DRM coverage area. In a mobile environment, it would be possible for the receiver to switch to the AM carrying the same programme material, switching back to DRM once back in the coverage area. Alternatively, a broadcaster may begin DRM transmissions by time-sharing with AM on the same transmitter. In this case, the AMSS will be able to handle the AM to DRM transition in the receiver automatically.

Meanwhile, for an AM-only broadcaster, AMSS brings the benefit that their station is displayed by name in the station list, making it easier for the listener to find. AMSS capability could also be used as a selling point for a new DRM receiver since as well as offering reception of new DRM services the AMSS makes it easier to find existing AM transmissions.

In a DRM receiver, the cost of adding AMSS decoding is likely to be low since it can take advantage of the processing power already present for the DRM decoding. This is crucial to the success of AMSS since previous attempts to add data to AM transmissions have not seen widespread adoption, partly owing to the additional cost of incorporating it into receivers.

How it works

The AM Signalling System makes use of low bi-rate phase modulation of the AM carrier to convey the additional digital information. The use of phase modulation is of course nothing new. Since 1985, BBC Radio 4 on long-wave in the UK. has carried time and 'teleswitching' information used by the electricity supply industry for the remote control of electrical appliances such as night-storage heaters. In Germany, the AM Data System (AMDS) on some medium-wave and long-wave stations has been used to carry differential GPS information for a number of years.

Parts of both of these systems are described by ITU-R BS.706-2 [3]. This has also been taken as the basis for AMSS with the signalling adapted for the scenario of switchover from AM to DRM broadcasting. The opportunity has also been taken to optimize the modulation parameters for ruggedness on short-wave channels.

In a non-selective or Gaussian channel, such as that typically seen on long-wave or daytime medium-wave, there will be no crosstalk between the amplitude and phase modulation, and the envelope detector used in the vast majority of AM receivers will not respond to it.

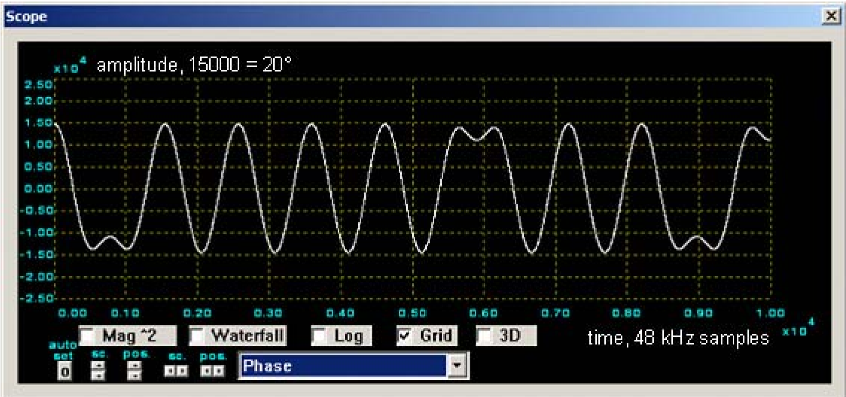
On short-wave and medium-wave at night where sky-wave propagation occurs, selective fading is likely to be present. Selective fading is caused by multiple delayed versions of the transmitted signal being seen at the receiver. Depending on the relative delays, these signals can destructively interfere leading to deep notches in the received spectrum. This can cause the phase modulation to crosstalk into the amplitude modulation and vice-versa meaning that the phase modulation becomes audible. The bitrate of AMSS has therefore been kept very low to minimize this effect.

The low bitrate of AMSS means that its entire transmitted spectrum is close to the AM carrier. In a purely Gaussian channel, this gives the AMSS an advantage over the AM. Whilst the carrier-to-noise ratio across a typical 9 or 10 kHz AM channel might be very low, in the 100 Hz or so taken up by the AMSS, the carrier-to-noise ratio may be considerably higher. The result of this is that even if the AM audio is almost completely swamped by noise, it is still possible for the receiver to decode the AMSS and identify the station.

In a selective channel, however, this can be problematic since the narrow-band nature of the system means that there is a possibility that a notch will completely wipe out the carrier, and with it, the neighbouring AMSS information. This is overcome by continually looping the transmitted information so that lost data can be recovered the next time it is transmitted.

Another feature of sky-wave propagation is for the received signal to be shifted in frequency by Doppler shifts due to movements of the ionosphere. The effect of Doppler is to cause a low rate of change of phase which could wipe out the transmitted phase modulation. To mitigate this, bi-phase modulation is used which has a null in its frequency response at DC and ensures that there is a large phase shift associated with each and every bit.

The structure of the baseband coding of AMSS is based on the German AMDS structure of groups containing two blocks of 47 bits, each protected by a Cyclic Redundancy Check (CRC) word. Synchronization and block identification are performed through the use of offset words which are applied to the CRC before transmission and break its cyclic nature.



The baseband AMSS waveform

Since AMSS will typically be implemented in DRM receivers, the signalling information carried by AMSS uses the same format as that used in DRM. In DRM, such information is carried inside Service Description Channel (SDC) [1] entities and it is these that are carried within the 47-bit blocks used in AMSS. Other items such as the service ID, language and type of carrier control, which are not part of the DRM SDC, are signalled separately.

Whilst modulation parameters attempt to minimize the problems of short-wave propagation, such a simple modulation scheme will never be able to overcome all the propagation effects — you only have to look to the DRM system to see the relative complexity required to overcome the short-wave challenge fully.

Whilst listening on long-wave and day-time medium-wave channels, reception is likely to be largely error-free: on short-wave channels, it is inevitable that some AMSS blocks will be received in error. As a result of this, and the low bitrate of the system, it is sensible to keep the amount of information transmitted to a minimum to ensure that it does not take too long for the receiver to acquire the complete set of data.

The AMSS specification

The basic parameters of the AM Signalling System are shown in *Table 1*.

Table 1
The basic parameters of the AM Signalling System

Modulation	Bi-Phase modulation of the carrier: Phase advance followed by retard = binary "1" Phase retard followed by advance = binary "0"
Maximum phase deviation	+/- 20 degrees
Gross bitrate	46.875 bit/s [a]
Block structure	94-bit group made up of two blocks of 47 bits (useful payload of 36 bits per block)
Error protection	11 bit Cyclic Redundancy Check (CRC) in each block

a. The data rate of 46.875 bit/s corresponds to a bit period of 256 samples at a 12 kHz sampling rate.

The baseband AMSS waveform is generated by impulses shaped by a root raised cosine filter to control their spectral content. The bitrate of 46.875 bit/s means that roughly one AMSS block is sent per second.

Two types of AMSS block are sent alternately. The first block of the group always signals the *service ID*, *language* and type of *carrier control*. This ensures that when a receiver re-tunes to a frequency carrying AMSS, the service ID can be recovered relatively quickly and the broadcast be positively identified.

The second block of the group carries segments of the DRM SDC entities. The number of segments required to make up a complete SDC entity or group of entities is signalled in the first block of the group, ensuring that the receiver knows how many block-2 segments to expect.

While some DRM SDC entities carry data that is applicable to AMSS, others carry DRM-specific information, for example information regarding the type of audio bitrate reduction coding used. As a result, only certain DRM SDC entities are specified for AMSS.

The BBC AMSS modulator

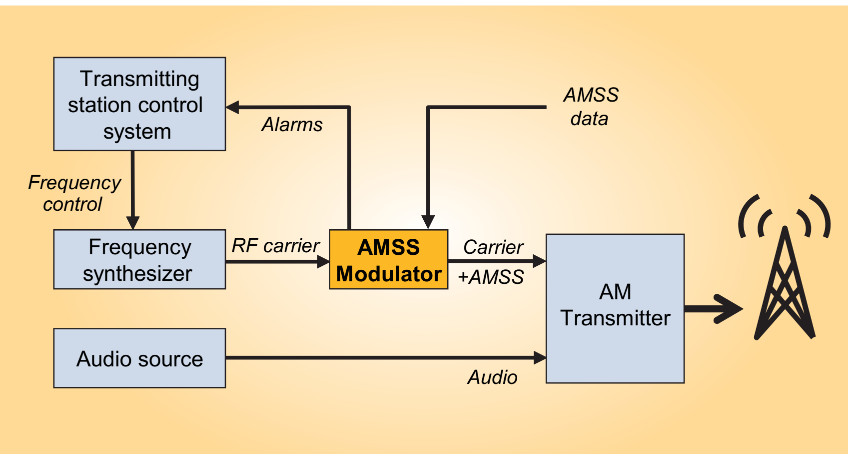


Figure 1
The position of an AMSS modulator in the AM transmission chain

In order for BBC World Service to begin AMSS transmissions, BBC Research & Development was commissioned to design an AMSS modulator unit. *Fig. 1* shows how this modulator fits into the transmission chain between the frequency synthesizer and the carrier input to the transmitter. Since short-wave transmitters are generally frequency agile, it was essential that the modulator could operate on any carrier frequency. Rather than attempting to interface to the

Figure 2
The BBC AMSS modulator

station control system to determine the required frequency at any given time, we decided to produce a broadband design. The unit takes an input carrier at any required frequency and applies the necessary phase modulation to it in accordance with the AMSS specification. As a result, installation is simply a case of interrupting the carrier input connection to the transmitter and looping it through the AMSS modulator. It is therefore suitable for installation at almost any AM transmitting station, requiring no user intervention to operate on different frequencies.

The AMSS modulator is housed in a 1U bay-mounted chassis and can be seen in *Fig. 2*. Two options are available: one for LF and MF transmitters (150 kHz to 1.7 MHz), and one for HF transmitters (3 MHz to 30 MHz). A baseband output is also available for driving an external phase modulator.

A simple user interface, comprising a two-line alpha-numeric display and four push-buttons, is mounted on the front panel. Its normal function is to provide the operator with status information, but it also allows some local control of the equipment — for instance, whether or not the RF output level is to be stabilised by automatic gain control. Static AMSS settings can also be entered on the front panel such as a station label and service ID. Alternatively, the unit accepts a live feed of data through its Ethernet interface.

All connectors are fitted to the rear panel. These are as follows: mains input, AMSS data input, baseband output, RF input and RF output. A further connector provides “warning” and “fault” indications for connection to a station control system by means of normally closed relay contacts.

The unit is divided into two halves, separated by an internal screen. On the left-hand side are the switched-mode power supply, the digital (PC) board and the interface for the LCD. The “clean” environment on the right-hand side contains the analogue RF board, where the phase modulation takes place.

Electrically, the equipment is self-contained. Testing and faultfinding is straightforward because there is no need to provide custom test-jigs.

Digital (PC) board

The software for generating the baseband AMSS signal runs on a disk-less embedded PC board running Linux. The baseband analogue waveform is output through the built-in soundcard of the PC, the amplitude of the signal corresponding to the required instantaneous phase of the RF carrier. The digital board also drives the LCD display and handles user input as well as accepting monitoring inputs from the analogue board and generating “warning” and “fault” alarms when necessary.

Analogue RF board

The main purpose of the analogue board is to carry out the phase modulation, and to do so in a way that is independent of the carrier frequency: HF transmitters often change frequency, and it would be unacceptable for the AMSS modulator to require adjustment each time. A secondary function of the analogue board is to provide monitoring of such vital parameters as RF signal levels and peak phase deviation.

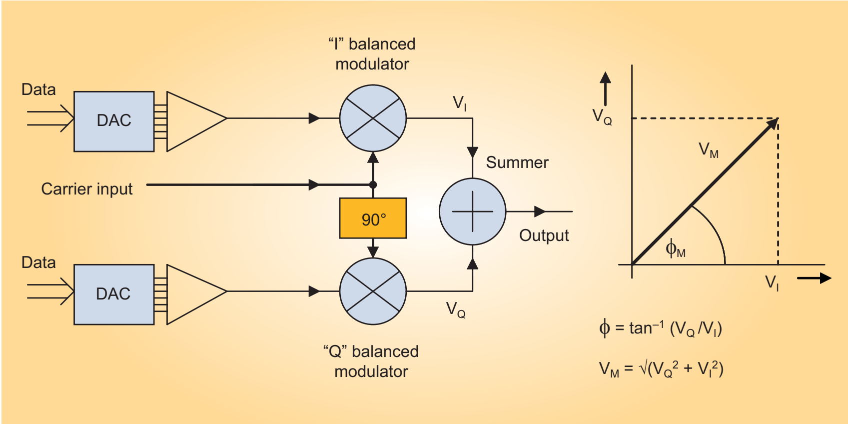


Figure 3
Amplitude and phase modulation by IQ balanced modulators

Conventionally, the phase modulation itself is accomplished by means of In-phase (I) and Quadrature (Q) balanced modulators driven by two DACs controlled by a micro-processor. *Fig. 3* illustrates this concept.

The great merit of this circuit is its versatility: by appropriate choice of the outputs from the balanced modulators, V_I and V_Q, any combination of phase angle and magnitude is possible. A minor disadvantage is the need for two DACs and the attendant data processing, while a more serious practical difficulty is in finding a device that will provide a constant 90° phase shift of the carrier over a frequency range of a decade or more to feed to the "Q" modulator.

Fortunately, a well-known component manufacturer advertises a hybrid signal-splitter with 90° outputs. It covers 3 to 30 MHz, and is available at an acceptable cost. This component was the obvious choice for the HF version of the modulator. For the LF and MF version, an active "Bedrosian" filter was used instead.

Although the use of two DACs is workable, we use a neater and more economical approach, dispensing with one DAC and replacing it with simple analogue signal processing as follows. If the "I" output V_I is held constant, the phase deviation ϕ at the output is given by the formula:

$$\phi = tan^{-1} (k\, V_Q)\text{ , where } k \text{ is a constant.}$$

Provided ϕ is small, it is approximately proportional to V_Q, as desired. However, the magnitude V_M will not be constant, and so the phase modulation gives rise to unwanted amplitude modulation. Analysis shows that using a quadratic term to drive the "I" modulator removes nearly all the unwanted amplitude modulation. Furthermore, a small cubic term driving the "Q" modulator linearises the phase modulation process and further reduces the spurious amplitude modulation. Analogue multipliers are used to produce these functions and the result is the circuit shown in *Fig. 4*.

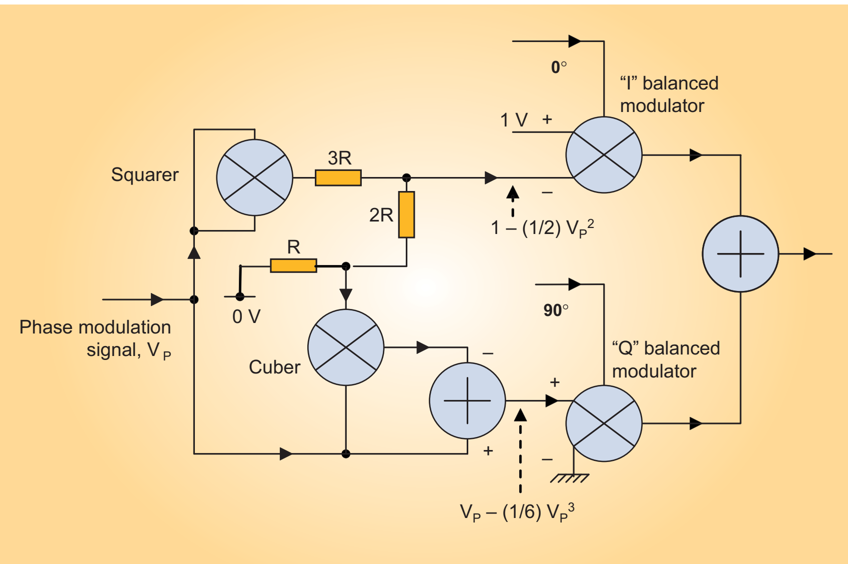


Figure 4
The BBC implementation of a phase modulator

The remaining circuitry is largely conventional. The balanced modulators themselves are also analogue multipliers, and were chosen because, being "linear", they do not introduce harmonics — an important consideration in a broadband design. Another possible advantage is that any amplitude modulation, or carrier level change, at the input is preserved. This feature could be needed at transmitting stations where dynamic carrier control is applied before the AMSS modulator unit in the transmission chain. Normally, however, the modulator's inbuilt automatic gain control (AGC) is enabled, which usefully stabilises the system performance and removes any small residual amplitude modulation. *Fig. 5* shows the AMSS modulator being tested at a short-wave transmitting station.

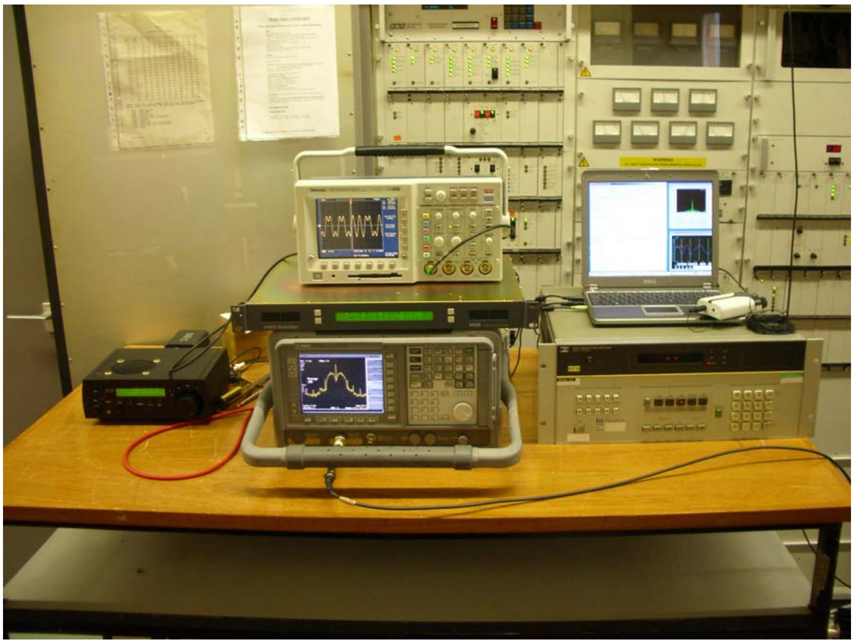


Figure 5
The BBC AMSS Modulator being tested at Rampisham short-wave transmitting station. (On the left the baseband waveform and the resulting spectrum of the AMSS can be seen. On the right-hand side, a laptop is used to decode the received signal.)

AMSS transmissions

BBC World Service is using AMSS to support its European English-language DRM service which targets Benelux countries, Germany and northern France. AMSS is currently being transmitted on two AM frequencies: on 648 kHz medium-wave from Orford Ness in the UK and 9410 kHz short-wave from Zygi in Cyprus. Both of these sites are equipped with BBC AMSS Modulators.

The distribution network for the AMSS transmissions is illustrated in *Fig. 6*. The AMSS generator software runs in the control room of Bush House in London, allowing the AMSS information being broadcast from any transmitting station to be controlled dynamically. It is distributed to the transmitting stations using the DVB-S infrastructure put in place for the BBC's DRM transmissions.

The generator outputs multicast UDP/IP packets which are encapsulated using Multi-Protocol Encapsulation (MPE) and sent to BBC Television Centre in West London where they are up-linked onto the satellite.

At each transmitting station, a DVB-S receiver outputs the UDP/IP packets over Ethernet to each AMSS Modulator for transmission over the air.

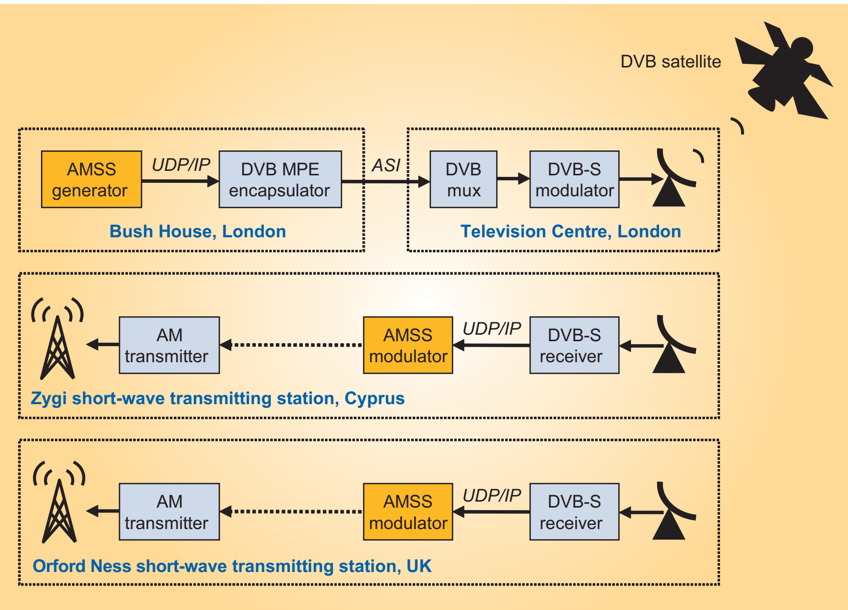


Figure 6
The AMSS distribution network used by BBC World Service

Currently, a simple proprietary protocol is used to distribute the data to the transmission sites. At the time of writing, work is under way within the DRM Distribution Interfaces group (DRM-DI) to standardize the protocol for AMSS Distribution. The AMSS Distribution Interface will draw heavily on the Multiplex Distribution Interface (MDI) [4] which has already been standardized through ETSI and is used for the distribution of DRM to transmitter sites.

Other broadcasters are also beginning to transmit AMSS including RTL who have recently started transmitting AMSS on their long-wave AM transmission from Beidweiler in Luxembourg.

AMSS reception

At least some of the first commercial DRM receivers will implement reception of AMSS when they become available in early 2006. In the meantime, and to help raise awareness of AMSS within the wider DRM community, we added an AMSS decoder to *DReaM* [5], an existing PC-based open-source software DRM receiver which already featured AM demodulation.

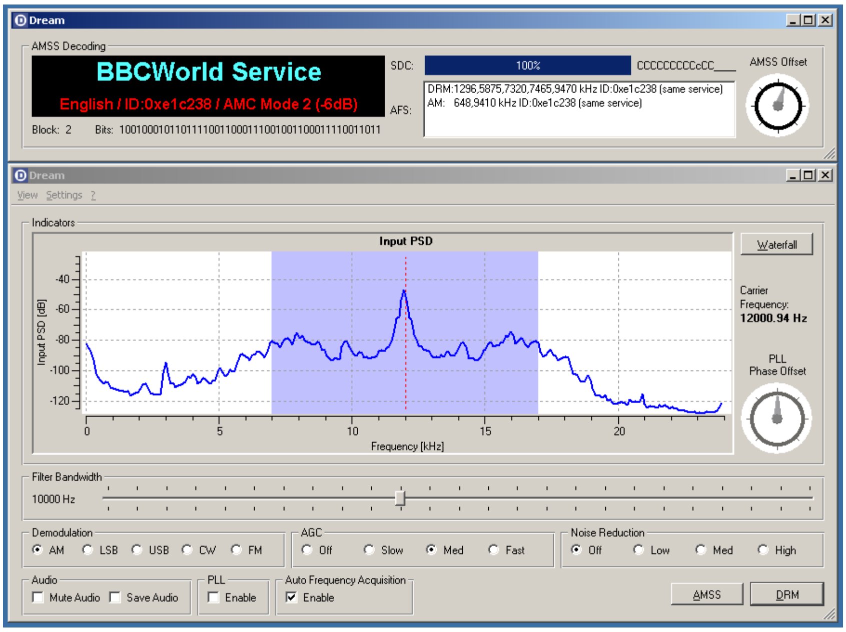


Figure 7
Reception of an AMSS transmission using the *DReaM* open-source software DRM receiver

Fig. 7 shows reception of one of the BBC's AMSS transmissions using the *DReaM* receiver. The service label "BBCWorld Service" and the language, service ID and type of carrier control being signalled can clearly be seen. The 47 bits of the currently received AMSS block are also shown. The AFS box to the right of the display gives details of alternative frequencies of both DRM and AM transmissions carrying the same programme material.

Currently, the *DReaM* software only displays this information; a consumer receiver would not need to display discrete frequencies but would instead use the information to automatically change to a frequency offering better reception quality.

Currently this alternative frequency information is only displayed whereas in a consumer receiver, the management of this information would be handled automatically behind the scenes.

We have also added AMSS decoding into the DSP code of a Mayah 2010 DRM receiver and have used it for numerous demonstrations.

Monitoring of the BBC World Service short-wave transmission from Cyprus has shown that reception of the AMSS is reliable, even when the audio quality is very poor.

Conclusions

The AM Signalling System provides a number of advantages to broadcasters, listeners and receiver manufacturers alike. By identifying AM broadcasts uniquely and providing alternative frequency information for available digital transmissions, AMSS eases the path from analogue to digital on the short-, medium- and long-wave bands. AMSS also ensures that AM-only broadcasts can appear by name in the station selection lists of new DRM receivers.

BBC R&D has developed an AMSS Modulator and its wideband design means that it is simple to install and operate. It is being used successfully to transmit AMSS from a number of BBC World Service transmitter sites.

Andrew Murphy joined BBC Research and Development in 2000, having graduated from Cambridge University with an M. Eng. degree in Engineering and Information Sciences. He has been a member of the Digital Radio Mondiale team for 3 years, working mainly on hardware and software for the BBC's DRM transmission infrastructure and, more recently, the development of the AMSS specification and the BBC AMSS modulator.

Prior to this, Mr Murphy worked on a number of projects including the development of a multi-camera capture system used in virtual studios for generating 3D models, and on software for improving the speed of Digital Terrestrial Television coverage predictions.

Ranulph Poole received a degree in physics from Oxford University in 1974. In that year he joined BBC Transmitter Operations, where he was involved with the maintenance of a wide range of broadcast equipment. He moved to BBC Designs and Equipment Department in 1989, to assist with the development of PAL television test equipment and the introduction of Nicam sound.

Since 1994, Mr Poole has been working in BBC Research and Development on the performance requirements for DVB-T transmission equipment. He has been an active member of the UK Digital Television Group and the ACTS VALIDATE project.

A number of broadcasters are looking into using AMSS and at least some of the first consumer DRM receivers will incorporate AMSS decoding.

So next time you tune through the dial and hear an unknown AM station from a far-flung corner of the world, perhaps your radio will be able to tell you exactly what you're listening to!

References

[1] ETSI ES 201 980: **Digital Radio Mondiale (DRM); System Specification**

[2] ETSI TS 102 386: **Digital Radio Mondiale (DRM); AM Signalling System (AMSS)**

[3] ETSI TS 102 820: **Digital Radio Mondiale (DRM); Multiplex Distribution Interface (MDI)**

[4] ITU-R BS.706-2: **Data system in monophonic AM sound broadcasting (AMDS)**

[5] DReaM Open-Source Software Implementation of a DRM Receiver: **http://drm.sourceforge.net**

Acknowledgements

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