# The AM Signalling System (AMSS)

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## 1. ABSTRACT

This paper describes a simple signalling system designed for use with AM broadcasts on frequencies below 30MHz. The motivation for such a system is not to do with a belated attempt to play catch up with FM, for which the RDS system has been in use for nearly 20 years, but in the realisation that tuning a digital radio is a very different matter to the "analogue experience" of finding radio stations. This listener-centred approach to radio design is in essence the reason that AMSS was developed: to facilitate the search, identification and tuning of AM broadcasts on the next generation of digital radio receivers.

The AM Signalling System (AMSS), published as an ETSI standard [1], uses low bit-rate phase modulation of the AM carrier to add a small amount of digital information to existing analogue AM broadcasts, and provides broadly similar (but constrained) functionality to that offered by the Radio Data System (RDS) in 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 digital, AM or FM version of the same service, if available.

This paper describes the business rationale for AMSS, its main features, a brief outline of how the system works, and the BBC's initial deployment of the system.

## 2. THE BUSINESS CASE FOR AMSS

### Background

In the era of mass-produced valve radios (1930's to 1950's) the ubiquitous tuning dial provided an excellent MMI: simple, informative and highly intuitive. Your station identification was usually silk-screened on the back of the glass! It's somewhat ironic therefore that we lost the plot in subsequent decades: stations are rarely marked on the dials of transistor radios from the 80's onwards, and "user-friendly" radio-tuning then entered a dark-age.

Normally, the only way for today's listener to identify an AM broadcast is to wait for a station's ident or jingle to be played. On medium-wave, regular listeners will probably have the station frequency stored on a pre-set, but for new or mobile listeners, finding and identifying an AM station is more of an issue. Worse still, for short-wave broadcasts you either need an excellent memory or access to an up-to-date frequency schedule[1].


**Fig 1. 1940's Radio dial**

In short, unless you stay at home and always listen to the same station, contemporary AM radio does little to make life easier for the consumer. FM, by contrast, at least enjoys the benefits of RDS/RBDS, which after a slow start in the 80's has become pretty much ubiquitous on vehicle radios in Europe, and also features on most home-radios with digital displays.

### The Birth of AMSS

The requirement to develop a simple signalling system which could operate on virtually any existing AM transmission was actually raised within the Digital Radio Mondiale consortium in 2003. The initial driver was to assist in the roll-out of digital services: by suitably tagging AM frequencies which are carrying a simulcast of a digital service[2], it is possible to explicitly hand a listener who's using a hybrid analogue/digital receiver from analogue to digital (and vice versa). This is done simply using the Alternative Frequency (AFS) feature which is common to RDS/RBDS, AMSS and both DRM and DAB.

The second (but equally important) reason for developing AMSS was to allow AM stations to appear on the "Station Menu" of future digital

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[1] A typical scenario for delivering a service on HF might involve the use of two or three simultaneous frequencies, which often change around dawn and dusk.

[2] in this case, DRM, but the application is much broader; see later

radios. This Menu listing has effectively replaced the tuning dial as the de-facto mechanism for tuning digital-capable radios: the listener selects a service by name from a list of all those available rather than having to remember irrelevant details such as frequency, waveband etc. Without AMSS, AM stations would inevitably be left off the menu, requiring the consumer to return to either frequency scans or manual frequency entry.

Thus implementing AMSS offers advantages to both broadcasters and listeners. For a broadcaster with both digital and AM services, an AMSS-capable receiver can

- inform a listener tuned to an AM service that a digital version is available and
- automatically retune to it, if desired.

Exactly the same principle may be applied to hand a listener from, say, AM to FM, aided by AMSS and RDS respectively, or from one AM frequency to another as a car travels between the respective coverage areas.

### Commercial aspects

The requirements set down for the system at the time of its development included

- compatible with most existing AM transmitters, regardless of age/modulation architecture
- low-cost to implement (both transmission and reception): open standard.
- robust under adverse reception conditions: operates in all broadcast bands below 30MHz
- compatible with existing envelope-detector receivers and with transmitters equipped with known forms of Dynamic Carrier Control (DCC).

## 3. PRINCIPLE FEATURES OF AMSS

AMSS is a technology which really has avoided re-inventing any wheels: the modulation and base-band coding layers borrow heavily from the earlier AM data signalling standard (AMDS)[4], and much of the data/packet layers are derived from a sub-set of the signalling used in DRM (which in turn has its roots in RDS).

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

- Service ID
- Language
- Type of carrier control in use
- Service label
- Alternative frequency information and schedules for other Digital, AM and FM transmissions carrying the same or similar 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.

AMSS also signals the type of **AM carrier control** in use. Such systems, which fall under the generic descriptive title of Dynamic Carrier Control (**DCC**), include **DAM** ("Dynamic Amplitude Modulation") and **AMC** ("Amplitude Modulation Companding") [9,10]. These schemes are used by many AM broadcasters to dynamically adjust the level of the carrier and/or the amount of compression applied to the audio in order to conserve electricity. **AMC** was developed by the BBC, and the technique has been in widespread use on both its domestic and international networks since the late 80's. AMC saves not only significant amounts of revenue through reduced power bills, but also as an obvious consequence helps minimise $CO_2$ emissions.

By making assumptions about the time constants typically employed in the Automatic Gain Control (AGC) of AM receivers, it is possible to apply DCC whilst avoiding audible distortion of the received audio. The overall broadcast chain encompassing transmitter and receiver may thus be regarded as an open-loop companding system, but one in which the broadcaster has to make assumptions about the AGC behaviour of AM receivers.

However, AM demodulation in hybrid analogue /digital receivers is likely to be performed digitally, and with explicit knowledge of the time-constants used by the relevant DCC system, the receiver manufacturer can implement an AGC strategy which is optimally tuned for the DCC in use.

Listeners will already be familiar with the **service label** concept, which is used by both digital satellite and terrestrial radio systems and RDS/RBDS.

**Alternative frequency** information is particularly important for short-wave broadcasts, (for the reasons set out in section 2). Typically, for short-wave radio, the listener is required to re-tune to continue listening to the same service, even though the receiver is in a static location. For

Medium-wave broadcasters, the ability to hand listeners to simulcasts on digital, FM or other AM frequencies is a powerful feature of the system. Alternative frequencies can be flagged to indicate whether they carry identical or related programming.

## 4. THE AMSS SYSTEM AND TECHNICAL SPECIFICATION

The AM Signalling System makes use of low bit-rate bi-phase modulation of the AM carrier to convey the additional digital information: the basic parameters are set out in Table 1

The base-band data layer comprises a pair of alternating "Blocks", each 47 bits wide.

- **Block 1** contains static metadata which the receiver needs to rapidly acquire when the receiver first tunes to the transmission. Most important of these is the unique Service ID which, as a result of the interleaving with block 2, is sent approximately every two seconds.
- **Block 2**'s are used to transport information which is less time-critical and/or lengthier in terms of capacity demands: these data entities are listed in Table 2.

In general, the receiver will have to accumulate data from several consecutive Block 2's in order to acquire the complete set of transmitted data entities (selected by the broadcaster from Table 2). A **Transmission Group** is defined as a Block 1 + Block 2 pair of overall length 94 bits.

**Table 1: – The basic parameters of AMSS**

| | |
|---|---|
| Modulation | Bi-Phase modulation of the carrier:<br>+Ø then -Ø = binary '1'<br>-Ø then +Ø = binary '0' |
| Phase deviation | +/- 20 degrees p-p |
| Gross Bit-rate | 46.875 bits/s[3] |
| Block structure | 94 bit group comprising 2 blocks of 47 bits (useful payload of 36 bits per block) |
| Error protection | 11 bit Cyclic Redundancy Check (CRC) in each block |

**Table 2: – Data entities of AMSS† carried in Block 2**

| | |
|---|---|
| Type 1 | Service Label |
| Type 4 | Automatic Frequency Switching (AFS) schedules |
| Type 6 | Announcement support and switching |
| Type 7 | AFS regions |
| Type 8 | Time and Date |
| Type 11 | AFS other services |
| Type 12 | language and country |

†The data carried is based upon the data entities of the SDC (Service Description Channel) of the DRM system [1].

A system similar to AMSS has been in use since 1985 on the BBC's Radio 4 long-wave service in the U.K., carrying time and 'tele-switching' information used by the electricity supply industry. This is used 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 technical basis for AMSS as set out in Table 1. The decision was taken at the design stage to rank ruggedness and compatibility above through-put (bit-rate). This trade means that practically, AMSS supports a sub-set of the data entities allowed by RDS or DRM: for convenience

[3] The data rate of 46.875 bits/s corresponds to a bit period of 256 samples at a 12 kHz sampling rate

AMSS has re-used data entities previously defined in DRM, as outlined in Table 2.

### Mapping data entities to the AMSS block-structure

Data for transmission is assembled as follows:

- Data entities from Table 2 are selected according to the broadcaster's requirements and assembled into sub-groups not exceeding 62 bytes in length
- padding bits and finally a 16-bit CRC are added to form groups with an overall integer multiple of 4-bytes length, but not exceeding 64 bytes.
- This Data Entity Group is then chopped into 4-byte **segments** and carried sequentially within the payload capacity of Block 2's: a four-bit segment address is inserted at the start of each Block 2 to facilitate correct re-assembly of the entire group in the receiver.

This process is illustrated in the following diagram (Figure 2 below).

Combinations of data entities can be packaged into data entity groups in different ways to suit the broadcaster. For example, if a data entity is required to be sent and decoded by the receiver quickly it should be sent in its own, smaller, data entity group. This allows the receiver to decode the entity without having to wait for many different blocks to be received before being able to decode the particular data entity. The downside of splitting entities into different data entity groups is that there is an overhead of the SDC CRC.

Block 1's contain generally static data, and are sent interleaved with Block 2's to ensure rapid identification of the service. They comprise the following elements:

| | | |
|---|---|---|
| i. | **language**, | 4 bits |
| ii. | **AM carrier control** in use | 3 bits |
| iii. | the **Service ID** | 24 bits |
| iv. | **No. of segments** carried | 4 bits |
| v. | **Version flag** | 1 bit |

The **version flag** changes whenever the contents of the data entity group changes. It allows the receiver to detect when new information is available.

The **AM carrier mode** and the table of **language** codes are listed in Annex 2.

The **number of segments** field is used to indicate to the receiver how many segments, minus one, is used to carry the data entity group.

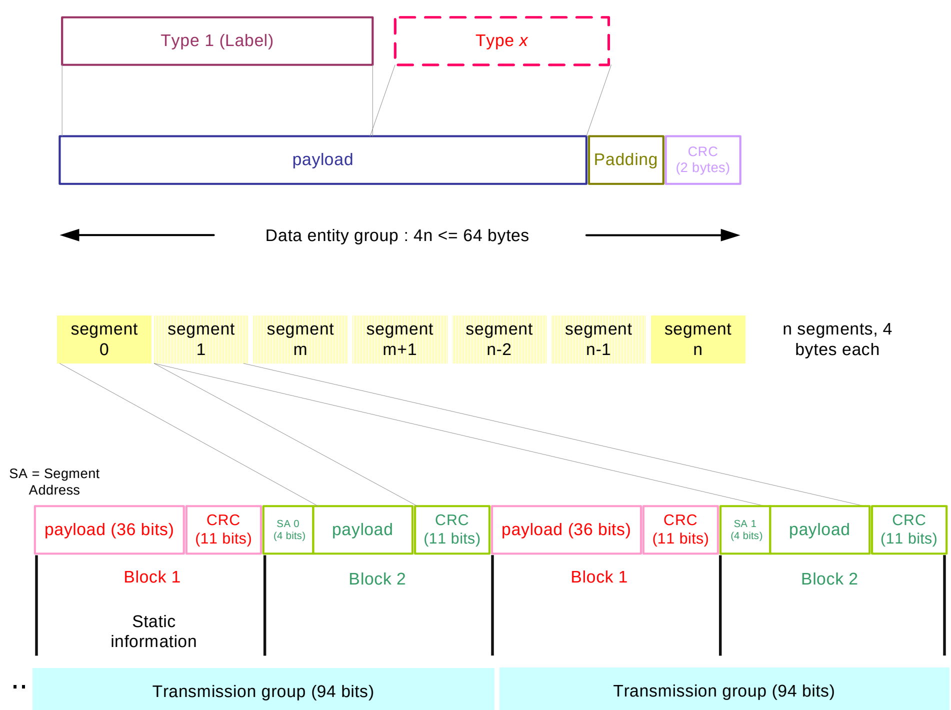



**Fig 2 mapping of Data Entity Groups into AMSS Transport stream**

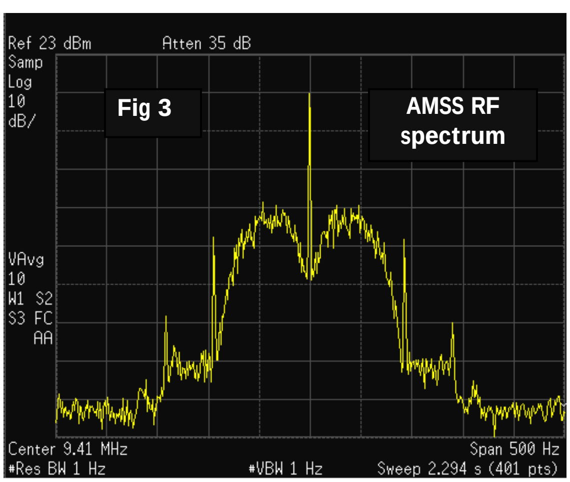
## 5. AMSS COMPATIBILITY AND RECEPTION

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

Selective fading is likely to be present on short-wave and night-time medium-wave services which rely on sky-wave propagation. Selective fading is caused by reception of multiple delayed versions of the transmitted signal. 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: under these circumstances the phase modulation can become audible. There are, however, a couple of mitigating factors which make this relatively benign:

- The relatively low bit-rate of AMSS (around 47 bps) results in low-frequency audio cross-talk: frequencies where many radios have a reduced response (and the ear is less sensitive).
- The channel impairments which give rise to this cross-talk have already caused relatively gross distortion of the received audio, which renders the presence of LF cross-talk somewhat academic.

The low bit-rate of AMSS means that its entire transmitted spectrum is close to the AM carrier. The spectrum of an AM carrier with AMSS applied is shown in Figure 3 below.




In a purely Gaussian channel this gives AMSS an advantage over the audio channel. Even when the carrier-to-noise ratio in a 9 or 10 kHz AM channel is poor, in the 100 Hz or so taken up by the AMSS, the carrier-to-noise ratio is around 20dB better. 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 sidebands. This is overcome by data carouselling in the receiver and continually looping the transmitted information so that any missed data can be recovered. The use of bi-phase modulation makes the system relatively immune to the effects of Doppler.

As stated previously, the structure of the base-band coding of AMSS is based on the two blocks of 47 bits each protected by a Cyclic Redundancy Check (CRC) word: synchronisation and block identification are performed through the use of offset words which are applied to the CRC before transmission and break its cyclic nature.

Whilst reception on long-wave and day-time medium-wave channels is likely to be largely error free, on short-wave channels it is inevitable that some AMSS blocks will be corrupted. Hence it is sensible to keep the amount of information transmitted to a minimum to ensure that receivers acquire the complete set of data rapidly.

## 6. IMPLEMENTING AMSS

As stated earlier, the design brief for AMSS was to ensure that transmitter conversion is simple and cost-effective. Normally the modulator can be inserted between the frequency synthesiser and the transmitter carrier input: this is usually a 50 ohm port driven at a level of +10 to +20dBm. This is illustrated in Figure 4.

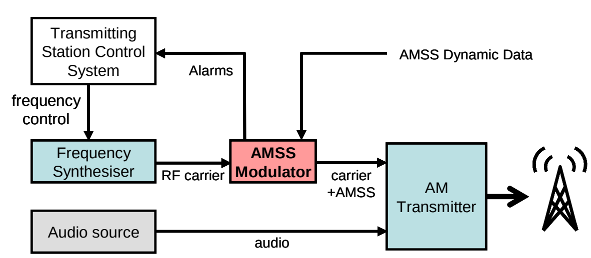



**Fig 4 AMSS Modulator interface with Tx**

The AMSS modulator is designed to operate with 0dB insertion gain, and to fail-safe in the event of failure (mains or unit) by incorporation of a simple by-pass relay.

The BBC World Service is using AMSS to support its European English language DRM service which targets the Benelux countries and most of Germany and France. AMSS is currently being transmitted on all the BBC's AM services in this region: 648 kHz (500kW) medium-wave from Orford Ness in the UK and 9410 kHz (250kW) short-wave from Zygi in Cyprus. Both of these sites are equipped with AMSS Modulators which were designed and built by BBC R&D: further details can be found in the EBU Technical Review [7].

The BBC's 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 already in place for DRM signal distribution.

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

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

Other broadcasters adopting AMSS include *RTL* who have recently started transmitting AMSS on their long-wave AM transmission from Beidweiler in Luxembourg.

## 7. AMSS RECEIVERS

In 2005, in order to help raise awareness of AMSS within the wider radio community, the BBC added an AMSS decoder to **DReaM** [8], a PC-based open-source (GPL) DRM receiver which also includes standard AM demodulation.

Figure 5 shows reception of one of the BBC's AMSS transmissions using DReaM. The service label 'BBC WS' 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 box to the right of the display gives details of alternative frequencies (AFS) of both DRM and AM transmissions carrying the same programme material. Currently, the *DReaM* software only displays this information; a consumer receiver would normally use the information to automatically change to a frequency offering better reception quality.

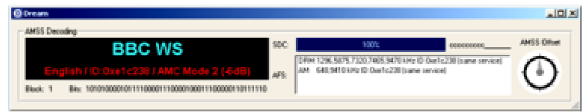



**Fig 5 DReaM receiver displaying BBC service label**

The first consumer DRM/DAB receivers available in Europe will support AMSS when they become available in 2006. RadioScape, who supply digital radio modules to the receiver industry, have recently implemented AMSS in their RS500 DAB/DRM module, which is used in the Roberts MP-40 radio[4]. A pre-production model is shown here (Figure 6) receiving and displaying the BBC service ID live "off air" from 648kHz medium-wave.

The first consumer receivers supporting DRM/DAB/FM/AM are due to be available during 2006. With AMSS rolled out on AM transmissions, all terrestrial radio services in Europe can be identified and listed alphabetically for browsing.

In any digital receiver, the cost of adding AMSS decoding is likely to be negligible since it can take advantage of the processing power already present for the digital decoding. This is crucial to

**Fig 6 Live reception of AMSS on medium-wave**

the initial uptake and success of AMSS since previous attempts to add data to AM transmissions have not seen widespread adoption partly due to the additional cost of incorporating it into (then) analogue receivers.

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4 This radio supports DAB, DRM, AM and FM broadcasts, together with AMSS and RDS

## 8. LOOKING FORWARD

The AM Signalling System provides a number of advantages to broadcasters, listeners and receiver manufacturers alike. By uniquely identifying AM broadcasts and providing alternative frequency information for the same service when carried on digital transmissions, it 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.

In this way, broadcasters can move towards the transition to digital broadcasting with minimal investment, but maintain their presence on the "dials" of digital radios. When sufficient numbers of digital receivers are available within a broadcaster's market, they can make the more expensive move of converting their analogue transmitter to digital using DRM.

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

## 9. 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. NRSC "United States RBDS Standard"

6. CENELEC EN 62106: "Specification of the radio data system (RDS) for VHF/FM sound broadcasting in the frequency range from 87,5 to 108,0 MHz".

7. RANULPH POOLE & ANDREW MURPHY January 2006 EBU "The AM Signalling Systems, AMSS – does your radio know what it is listening to?" EBU Technical Review No 5.

8. DReaM DRM Receiver: http://drm.sourceforge.net/

9. WILLIAMS, W F 1986. "AM companding: a technique for dynamic carrier control of AM broadcast transmitters."
International Broadcasting Convention, IBC 86.
IEE Conference Publication No 268 pp. 179-183.

10. PETKE G. 1982. "Economic modulation processes for AM broadcast transmitters". EBU Technical Review, No 193, June 1982, pp 114-122

## 10. ACKNOWLEDGEMENTS

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## ANNEX 1

## ABBREVIATIONS

| | |
|---|---|
| AGC | Automatic Gain Control |
| AFS | Automatic Frequency Switching |
| AMC | Automatic Modulation Control |
| AMDS | AM Data System |
| AMSS | AM Signalling System |
| DAB | Digital Audio Broadcasting |
| DAM | Dynamic Amplitude Modulation |
| DCC | Dynamic Carrier Control |
| DRM | Digital Radio Mondiale |
| DRM-CM | DRM Coding & Multiplexing Group |
| DRM-DI | DRM Distribution Interfaces Group |
| DSP | Digital Signal Processor |
| DVB-S | Digital Video Broadcasting over Satellite |
| ETSI | European Telecommunications Standards Institute |
| GPS | Global Positioning System |
| LCD | Liquid Crystal Display |
| MDI | The DRM Multiplex Distribution Interface |
| MMI | Man-Machine Interface |
| RDS | Radio Data System |
| RBDS | Radio Broadcast Data System |
| RF | Radio Frequency |
| SDC | DRM Service Description Channel |
| SNR | Signal to Noise Ratio |
| UDP/IP | User Datagram Protocol/Internet Protocol |

## ANNEX 2

### AMSS TECHNICAL DETAILS IN BRIEF

For full details see reference 2.

### 1. MODULATION

The data is conveyed by phase modulation of the AM carrier, using a peak deviation of +/- 20 degrees either side of the nominal rest position of the carrier.

For each data bit to be transmitted a pair of impulses are generated, separated by $t_d/2$, where $t_d$ is the data bit period of 1/46.875 seconds.

To send a binary "1" a positive going impulse followed by a negative going impulse is generated. For a binary "0" a negative going followed by a positive going impulse is generated. The impulses are then shaped by a root-raised cosine filter whose frequency response is given by

$$H_T(f) = \begin{cases} \cos\left(\frac{\pi f t_d}{4}\right) & : 0 < f \le 2/t_d \\ 0 & : f > 2/t_d \end{cases}$$

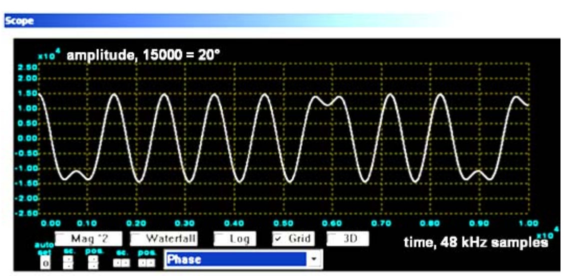


**Fig 7 AMSS base-band modulating signal**

This signal is then used to modulate a carrier of the appropriate frequency.

### 2. BLOCK 1 & 2: CRC AND SYNCHRONISATION

Each individual block is protected by an 11-bit CRC. The CRC is calculated using

$$c(x) = d(x) + \left(x^{11}.m(x)\right) \bmod g(x)$$

where g(x) is given by

$$g(x) = x^{11} + x^8 + x^6 + 1$$

and d(x) is an 11-bit offset word which is different for blocks 1 and 2. It is specified as follows:

**Offset word *d(x)***

| | $d_{10}$ | $d_9$ | $d_8$ | $d_7$ | $d_6$ | $d_5$ | $d_4$ | $d_3$ | $d_2$ | $d_1$ | $d_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Block 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Block 2 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 |

The different offset words allow the receiver to determine the location and identity of different blocks.

### 3. BLOCK 1 DATA TABLES

#### Language

| Decimal number | Language | Decimal number | Language |
|---|---|---|---|
| 0 | No language specified | 8 | Hindi |
| 1 | Arabic | 9 | Japanese |
| 2 | Bengali | 10 | Javanese |
| 3 | Chinese (Mandarin) | 11 | Korean |
| 4 | Dutch | 12 | Portuguese |
| 5 | English | 13 | Russian |
| 6 | French | 14 | Spanish |
| 7 | German | 15 | Other language |

#### Carrier Control

| AM carrier mode | | | Processing type |
|---|---|---|---|
| 0 | 0 | 0 | Normal AM, no carrier control |
| 0 | 1 | 0 | AMC mode 1 (3dB carrier reduction) |
| 0 | 1 | 1 | AMC mode 2 (6dB carrier reduction) |
| 1 | 0 | 0 | DAM mode 1 (3dB carrier reduction) |
| 1 | 0 | 1 | DAM mode 2 (6dB carrier reduction) |
| 0 | 0 | 1 | reserved |
| 1 | 1 | 0 | reserved |
| 1 | 1 | 1 | reserved |