

DIGITAL BROADCASTING SYSTEMS INTENDED FOR AM BANDS

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1 Introduction

In the last decades, very few innovations have been brought to radiobroadcasting techniques in AM bands (150 kHz - 30 MHz). The simplicity of the receiver has always been a great asset to amplitude modulation, and because of their long range, these AM waves still stand as best suited to national and international broadcasting.

However, under typical conditions of propagation such as ionospheric instability, a classical analogue system may provide poor quality reception.

The technical developments in the other frequency bands of sound-programme broadcasting and also political changes have resulted in the situation that the AM bands have evidently lost their practical and strategic significance to a large degree.

The poor transmission quality inherent in AM transmission is mainly characteristic of the modulation procedure rather than of the frequency band. If amplitude modulation is replaced by a digital modulation procedure, we can achieve a very good transmission quality and at the same time retain the long range of the transmission. However, The digital transmission has to fit into the existing channel pattern.

Digital transmission is suitable not only for sound-programme broadcasting but also for the transmission of additional information and for data transmission in general (value-added services).

2 AM channel characteristics

AM bands include long waves (LF, 150 to 285 kHz), medium waves (MF, 525 to 1605 kHz), short waves (HF, 3.3 to 26 MHz).

The characteristics of AM channels vary considerably depending on the frequency bands:

LF: 150 - 285 kHz, channel width 9 kHz; ground-wave propagation, little interference by sky-waves.

MF: 525 - 1 605 kHz, channel width 9 kHz or 10 kHz; propagation during daylight hours: as LF, but shorter range. Propagation during night hours : ground- and sky-wave propagation and, as a consequence, strong interference.

HF: 3.3 - 26 MHz, channel width 10 kHz (DSB); 5 kHz (SSB), sky-wave propagation.

The ionosphere is a dispersive propagation medium which is characterized by the presence of multi-modes and multi-paths, each mode (or path) presenting a particular group delay, amplitude, polarization and Doppler frequency shift.

Table 1 gives the typical order of magnitudes of the main parameters of the ionospheric propagation.

TABLE 1
Order of magnitude of the main ionospheric propagation parameters

Parameter	Average channel behaviour	Extreme channel behaviour
Modes and paths number	Depending on the length of the radio link ≤ 8 for sky waves with a 0 to - 40 dB level Ground wave for short distances	
Total delay spread	≤ 5 ms	≤ 8 ms
Delay spread on each path	A few 10 μ s	
Mean Doppler shift for each path	A few 1/10 Hz $fd \leq 2.5$ Hz	A few Hz $fd \leq 10$ Hz
Doppler spread for each path	A few 1/10 Hz $\Delta fd \leq 2$ Hz	A few Hz A $\Delta fd \leq 5$ Hz

Because of these propagation characteristics, severe selective or deep flat fading often deteriorate ionospherically-propagated signals mid significantly affect the quality of the conventional AM reception).

As far as mobile reception is concerned, the contribution to the Doppler shift from the movement of a mobile reception is smaller than the contribution to Doppler shift due to the movement of the ionospheric layers.

3 Selection criteria for a digital modulation procedure

Theoretically, single-carrier procedures and (orthogonal) multi-carrier procedures are almost equivalent if transmission is performed via time-variable and frequency-selective channels and if coding and/or equalization is used to compensate for the error patterns typical of the modulation procedure.

So both types can be used for Single Frequency Network (SFN) operation.

The number of modulation states is the same in both cases. It depends on the ratio between the needed data rate ad the symbol rate. The symbol rate depends on the existing channel spacing.

Finally, mention must be made of the 9 kHz (or 10 kHz) bandwidth of AM channels which will only afford a few tens of kbit/s data rate.

The different channel spacing of LF and MF (9 or 10 kHz) and HF (10 or 5 kHz) lead to differences in the digital modulation procedures, if we require that the digital procedure be compatible with the existing channel spacing.

From these limitations the digital sound encoder should provide a data rate of approximately 20 kbit/s.

With a usable RF bandwidth of 7 kHz for both the LF and the MF bands, a spectral efficiency of the modulation procedure of approximately 3 bits per Hz of bandwidth is required.

For the HF bands, with a usable RF bandwidth of 4 kHz, a necessary spectral efficiency of 5 bits per Hz of bandwidth is required if the same sound quality as in the LF and MF bands is desired.

Depending upon the parameters selected for the roll-off, code rate, frame structure ratio and guard period, both procedures require 32 to 64 modulation states.

The decision in favour of a multi-carrier or single-carrier procedure is mainly influenced by the length of the channel pulse response, which is specified in terms of the symbol length. In consideration of the technical outlay needed in the receiver the procedure is normally selected according to the following rule:

- Single-carrier procedure: Length of the channel pulse response is less than or equal to the length of 16 symbols.
- Multi-carrier procedure: Length of the channel pulse response is more than or equal to the length of 64 symbols.

If the length of the channel pulse response is less than the length of 64 symbols, the reduction in complexity expected from the multi-carrier procedure is no longer ensured. On the other hand, the efficiency of an equalizer required in the single-carrier procedure declines if the channel pulse responses exceed the length of 16 symbols.

3.1 Transmitter hardware

The decision in favour of a multi-carrier or single-carrier procedure is also influenced by the added complexity on the transmitter side.

If we wish to maintain the coverage zones of AM broadcasting, digital transmission would allow us to reduce the transmitter power by some dB compared with today's analogue transmission. In general, however, the required PF power level will still be large enough to rule out a linear transmitter output stage because of its poor efficiency.

Therefore, it must be possible to continue the operation of existing AM transmitters (class C). For this purpose the transmitter will be complemented by a phase modulator, which is inserted behind the master oscillator. The amplitude modulator should be capable of transmitting a DC component. This requirement is fulfilled by PDM modulators, pulse step modulators etc., i.e. by all modern modulator types.

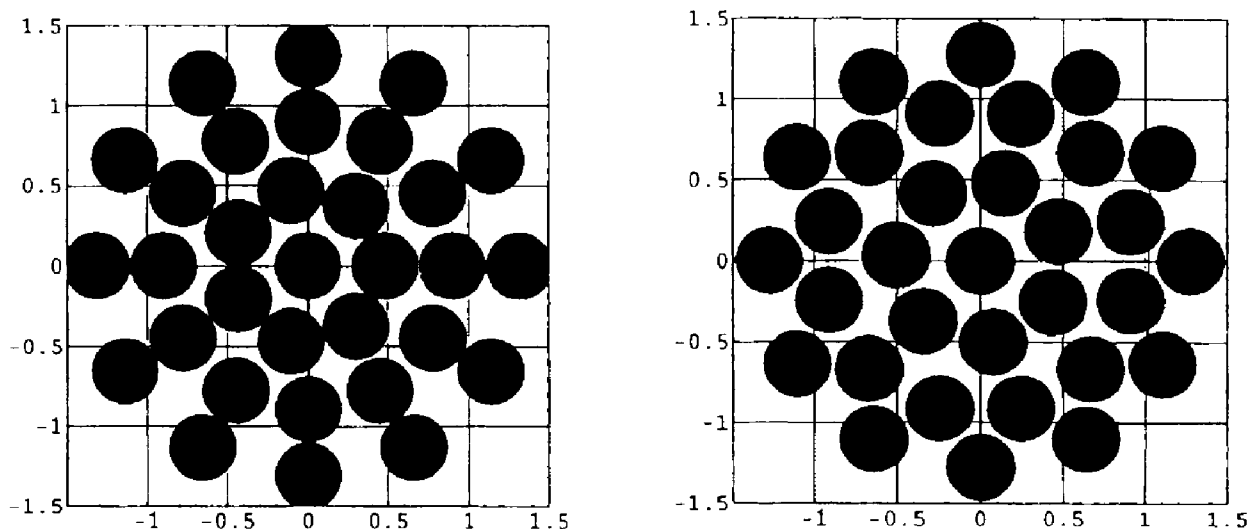
Usually, digital modulation is represented by Cartesian coordinates based on real and imaginary parts (I and Q signals). For this reason modulation procedures with a large number of states, e.g. the 64 QAM procedure, often have square phase stars (symbol constellations).

For a digital complex modulation of a retrofitted conventional AM transmitter, however, the modulation signal must be converted into an amplitude signal and a phase signal. This is the polar representation by means of A and ϕ signals.

The amplitude signal is applied to the amplitude modulator, while the phase signal is applied to the phase modulator. Therefore, it is expedient that modulation procedures including a large number of states show a certain rotational symmetry in the phase star. Such procedures should be called APSK (amplitude and phase shift keying) procedures. The state points are arranged on concentric rings. Figure I shows an example of APSK. Other forms of APSK are possible.

FIGURE 1

17/12/12 APSK = 32 APSK of a a) non-compact b) compact form



This modulation procedure, which is adjusted to the characteristics of the transmitter with high efficiency, has the following advantages:

- Non-linearities in the amplitude modulator affect only the diameters of the concentric rings.
- Amplitude-to-phase conversions in the transmitter output stage will result in a slight rotation of the concentric rings only. This may be compensated for by differential coding on the rings.

However, the procedure also has its drawbacks, which must be accepted if transmitter efficiency is emphasized :

- Despite the band limitation applied to I and Q signals, the A and ϕ signals are normally not band-limited. In practice, however, the A and (ϕ) signals can be band-limited to about 2.5 times the symbol frequency.