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Technical Specification

Digital Radio Mondiale (DRM);
Single Channel Simulcast (SCS)

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Foreword

This Technical Specification (TS) has been produced by Joint Technical Committee (JTC) Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELECtrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI).

NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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Introduction

The frequency bands used for broadcasting below 30 MHz are:

- Low Frequency (LF) band - from 148,5 kHz to 283,5 kHz, in ITU Region 1 [1] only;
- Medium Frequency (MF) band - from 526,5 kHz to 1 606,5 kHz, in ITU Regions 1 [1] and 3 [1] and from 525 kHz to 1 705 kHz in ITU Region 2 [1];
- High Frequency (HF) band - a set of individual broadcasting bands in the frequency range 2,3 MHz to 27 MHz, generally available on a worldwide basis.

These bands offer unique propagation capabilities that permit the achievement of:

- large coverage areas, whose size and location may be dependent upon the time of day, season of the year or period in the (approximately) 11 year sunspot cycle;
- portable and mobile reception with relatively little impairment caused by the environment surrounding the receiver.

There is thus a desire to continue broadcasting in these bands, perhaps especially in the case of international broadcasting where the HF bands offer the only reception possibilities which do not also involve the use of local repeater stations.

However, broadcasting services in these bands:

- use analogue techniques;
- are subject to limited quality;
- are subject to considerable interference as a result of the long-distance propagation mechanisms which prevail in this part of the frequency spectrum and the large number of users.

As a direct result of the above considerations, there is a desire to affect a transfer to digital transmission and reception techniques in order to provide the increase in quality which is needed to retain listeners who, increasingly, have a wide variety of other programme reception media possibilities, usually already offering higher quality and reliability.

In order to meet the need for a digital transmission system suitable for use in all of the bands below 30 MHz, the Digital Radio Mondiale (DRM) consortium was formed in early 1998. The DRM consortium is a non-profit making body which seeks to develop and promote the use of the DRM system worldwide. Its members include broadcasters, network providers, receiver and transmitter manufacturers and research institutes. More information is available from their website (http://www.drm.org/).

1 Scope

The present document gives a specification for the preparation of a transmission signal allowing the simultaneous transmission of analogue and digital versions of the same audio programme in one frequency channel (Single Channel Simulcast, SCS). The transmitted signal is compliant to existing frequency channel grids and bandwidths of ITU-R in the broadcasting frequency bands below 30 MHz (see ITU-R Radio Regulations [1]).

The signal consists of a sinusoidal carrier and two additional signal parts in the upper and lower sideband. The digital part in the upper sideband corresponds to a Digital Radio Mondiale (DRM) signal as specified in [2], therefore a standard DRM consumer receiver will be able to extract and decode the included digital data. An analogue audio AM receiver applying envelope demodulation on the overall received signal will provide an audio signal to the listener comparable to standard AM transmission.

NOTE: Other methods of signal generation for SCS are feasible. The present document may be revised in the future to describe one or more additional methods.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

[1] ITU-R Radio Regulations.

[2] ETSI ES 201 980: "Digital Radio Mondiale (DRM); System Specification".

[3] ITU-R Recommendation BS.1615: ""Planning parameters" for digital sound broadcasting at frequencies below 30 MHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Fast Access Channel (FAC): channel of the multiplex data stream which contains the information that is necessary to find services and begin to decode the multiplex

OFDM symbol: transmitted signal for that portion of time when the modulating amplitude and phase state is held constant on each of the equally-spaced carriers in the signal

Single Frequency Network (SFN): network of transmitters sharing the same radio frequency to achieve a large area coverage

3.2 Symbols

For the purposes of the present document, the following symbols apply:

k_n	fixed or variable coefficient for error weighting in the n-th iteration stage ($0 \leq n \leq N$) for generation of the DRM/AM SCS signal
N	maximum number of iteration steps during generation of DRM/AM SCS signal

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AM	Amplitude Modulation
DRM	Digital Radio Mondiale
DSB	Double Sideband
FAC	Fast Access Channel
HF	High Frequency
IF	Intermediate Frequency
ITU	International Telecommunication Union
LF	Low Frequency
LSB	Lower Sideband
MCS	Multi Channel Simulcast
MF	Medium Frequency
OFDM	Orthogonal Frequency Division Multiplexing
SCS	Single Channel Simulcast
SFN	Single Frequency Network
SSB	Single Sideband
USB	Upper Sideband
VSB	Vestigial Sideband

4 DRM simulcast transmission

The DRM system as specified in ES 201 980 [2] provides a significant improvement in audio reception quality and service reliability compared with existing AM radio in the broadcasting frequency bands below 30 MHz. An important requirement of ITU-R on the characteristic of a new digital broadcasting system was the possibility of simulcast transmission of analogue and digital audio within the limits set by the current frequency regulations ITU-R Radio Regulations [1].

Simulcast transmission is of particular interest to broadcasters who wish to introduce DRM services as soon as possible, but which have to continue to satisfy existing analogue listeners. After a transition period of several years (dependent on the market penetration of DRM receivers) it will be possible to fully switch to digital transmission. The final date to stop analogue transmission will be dependent on the type of broadcasters" audiences and certain economical factors (e.g. number of available frequencies and investment for transmitter digitisation) and therefore will differ from country to country as well as from broadcaster to broadcaster.

In Annex K of the DRM specification ES 201 980 [2] examples for simulcast modes are given by juxtaposition of analogue AM signals (DSB, VSB or SSB) and digital DRM signals. For all modes at least one and a half channels of 9 kHz or 10 kHz bandwidth are necessary to transmit the simulcast signal in a proper way (so-called Multi-channel Simulcast, MCS). The DRM signal can be located in the next upper or lower adjacent channel of its analogue counterpart and can occupy a half (kernel carrier group only) or whole channel depending on the bandwidth option chosen.

To provide on the one hand a high quality DRM service, but on the other hand to avoid significant impact of the DRM signal on the analogue sound quality the power levels between the DRM and the AM part of MCS signals have to be optimally adjusted. A drawback is the strong dependency on the receiver quality. For low-cost receivers the DRM level has to be in the range of 16 dB below the AM carrier power (30 % modulation depth assumed). For good-quality receivers the difference is only about 6 dB, which fits very well with the protection ratio given in ITU-R Recommendation BS.1615 [3].

Especially in LF and MF, the availability of frequency channels for realization of MCS is strongly limited (often only a single frequency per audio programme), and therefore a solution is required to allow broadcasters during the transition phase from analogue to digital to transmit both signals in one common channel: the so-called Single Channel Simulcast (SCS) transmission. A detailed description of SCS is given in the following clauses.

5 DRM/AM single channel simulcast

5.1 Transmission signal characteristic

A simple superposition of a double-sideband amplitude modulated signal (DSB-AM) by a digital DRM signal would result in strong degradation of both signals due to interference. Therefore the following requirements for the SCS signal have to be fulfilled:

- the reception of the digital DRM signal must not be appreciably distorted by the analogue signal in the same channel;
- the characteristic of the digital signal in the SCS channel has to be compliant with the DRM specification ES 201 980 [2];
- standard envelope demodulation of the transmitted SCS signal (as usually carried out by existing AM receivers) should be sufficient to deliver the analogue audio programme;
- the quality of the analogue audio signal should not be noticeably influenced by the DRM signal.

All requirements are fulfilled by a characteristic of the SCS signal as described in the following. The signal consists of three parts (see figure 1):

- the DRM kernel carrier group containing the full information of the Fast Access Channel (FAC) in the upper sideband (USB) with 4,5 or 5 kHz bandwidth;
- a so-called complementary signal with the same bandwidth in the lower sideband (LSB); and
- an additional sinusoidal carrier at the reference frequency in the middle of the channel.

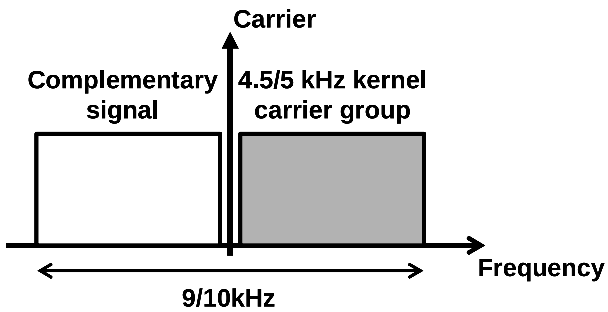

Figure 1: Characteristic of a DRM/AM single channel simulcast signal

To keep the first two requirements, the DRM signal has to be restricted in bandwidth, i.e. only half of the channel can be allocated (spectrum occupancy types 0 and 1, see ES 201 980 [2]). The complementary signal is determined in the modulator such that the received signal after envelope demodulation of the overall SCS signal will correspond under ideal conditions to the analogue audio baseband signal (third requirement), i.e. it has to minimize the influence of the DRM signal on the envelope and to add the analogue audio baseband part. To provide satisfactory quality of the analogue audio signal (last requirement) the power of the USB including the DRM part has to be reduced in comparison to the LSB power.

An example for the resulting signal spectrum characteristic is given in figure 2. It shows the power density spectrum of a DRM/AM SCS signal measured at the input stage of a DRM receiver. The modulation depth for the analogue AM signal was set to about 30 % and the USB power has been reduced by 18 dB compared to the carrier (i.e. -18 dBc).

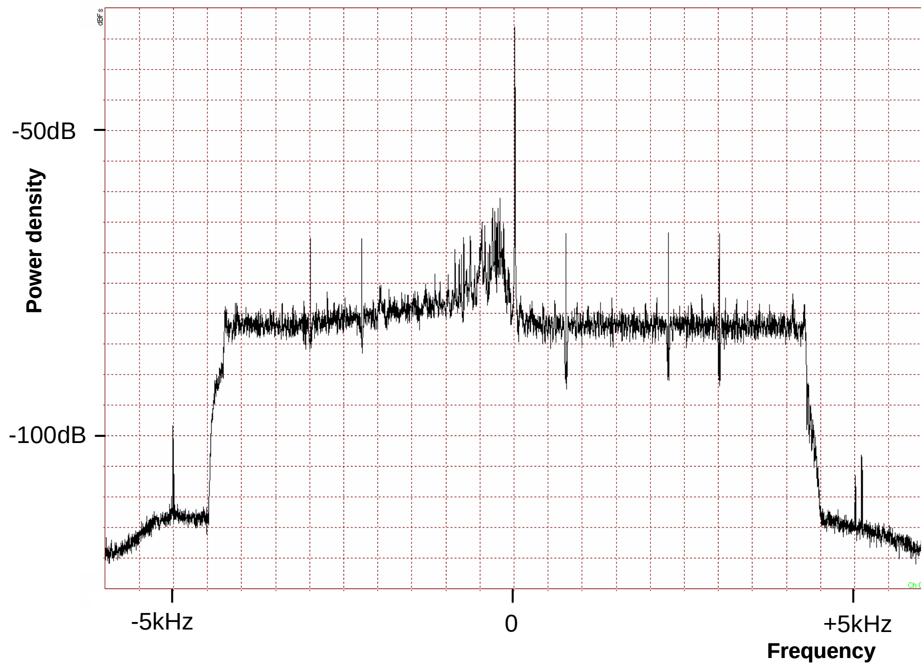

Figure 2: Example of a measured power density spectrum for a DRM/AM SCS signal (modulation depth about 30 %, USB power of -18dBc, channel bandwidth of 9 kHz)

Within the LSB the typical mirroring effect by the DRM signal in the USB can be clearly seen in addition to the AM part near the carrier (e.g. two of the three continuous pilots, see ES 201 980 [2]). If the USB power is further reduced, the resulting SCS signal would converge to a single sideband (SSB) characteristic.

5.2 Generation of the complementary signal

The determination of the complementary signal is based on an iterative process, which reduces the residual error for the reconstruction of the analogue audio signal by envelope demodulation within small time intervals, see ITU-R Rec. BS.1615 [3]. In figure 3 the block diagram of an iterative system for the generation of a DRM/AM SCS signal is shown.

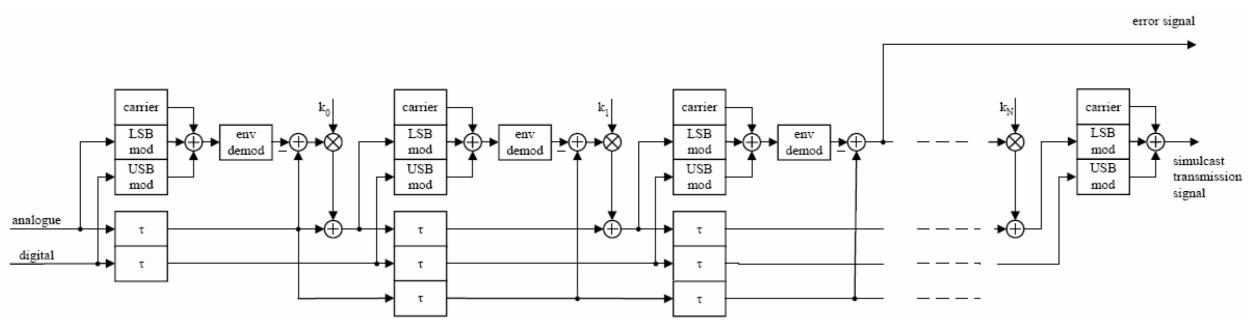

Figure 3: Conceptual block diagram for iterative generation of a DRM/AM SCS signal

The iterative process can be described as follows:

- In the first stage, the USB is modulated with the DRM signal (kernel carrier group) and the LSB with the analogue audio baseband signal. Both sideband signals are added and the sinusoidal carrier is included at the centre between both. The resulting signal is envelope demodulated. An error signal is generated by subtracting the demodulated signal from the analogue audio baseband signal which is delayed according to the processing time τ needed to generate and demodulate the simulcast signal. The error signal is weighted with a fixed or variable coefficient k0 and the new analogue (complementary) signal part is generated by adding the weighted error signal to the delayed analogue audio baseband signal. The USB is also delayed corresponding to the LSB.
- The whole procedure is repeated N times with other weighting coefficients kn, $0 \leq n \leq N$, and newly generated complementary signal parts in the LSB. The maximum number N of iterations can be determined according to the wanted accuracy of the correcting signal, i.e. by means of the squared magnitude of the error signal falling below a certain threshold.

To prevent instability of the iterative process in case of too high instantaneous amplitudes of the analogue signal part it is required to detect and attenuate amplitude peaks in the different stages of the signal generation process. The extended block diagram of figure 3 including the peak attenuation processing is shown in figure 4.

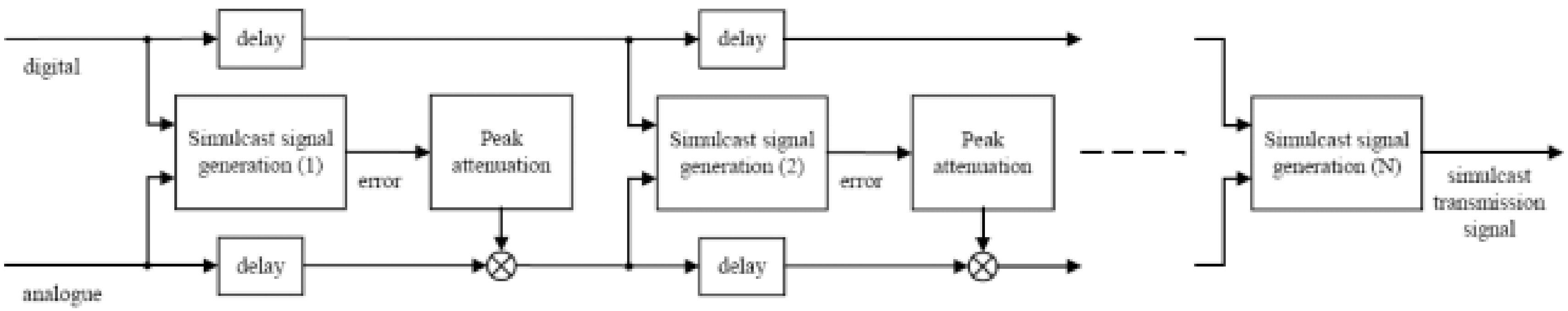

Figure 4: Extended block diagram from figure 3 with additional peak attenuation

To improve further on the performance of the signal generation process with respect to resulting analogue audio quality, pre-processing of the available audio material in view of amplitude limitation might be useful.

5.3 Notes on generation and reception of DRM/AM SCS signals

The parameterization of the weighting coefficients in the iterative stages for the generation of the SCS signal as well as the necessary number of iterations are dependent on the audio material to be transmitted and on the quality level the broadcaster wants to achieve. Therefore no explicit values are given in the present document.

In view of power reduction of the USB, i.e. of the DRM part in the SCS signal, a value of 18 dB compared to the carrier power (-18 dBc) as evaluated by laboratory listening tests and already shown in the example in figure 2 has been proven as a good compromise between achieving satisfactory quality for analogue audio and sufficient DRM power for area coverage. For the complementary sideband the power is adjusted according to the wanted modulation degree in the AM signal (typically about 30 %).

Theoretically the analogue signal part as well as the DRM signal should be free of any distortions. Unfortunately, in practical use the demodulated analogue audio signal contains distortions caused by:

- asymmetrical characteristics of receiver IF filters; and
- frequency-selective fading on the radio channel

which will result in a higher noise floor in the received audio baseband signal.

Due to the large range of different characteristics of existing AM receivers, especially in view of IF filters, the quality of the analogue SCS reception will vary from receiver type to receiver type similar to MCS.

Also the spectrum symmetry of the radio channel between transmitter and receiver has influence on the quality grade at the recombination of the two SCS sidebands. The effect is comparable to the asymmetry caused by the IF filter. Asymmetries in the spectrum are generated by multipath propagation of the transmitted signal resulting in frequency-selective fading. Due to the fact that multipath propagation via the ionosphere is a typical characteristic of radio channels in HF broadcasting, the use of SCS is recommended only for LF and MF bands with mainly ground wave propagation. In addition the utilization of Single Frequency Networks (SFN) should be avoided for SCS, because the signal parts of the different transmitters will perform as multipath components in a receiver and will cause frequency-selective fading.

The effect of multipath propagation on the reception quality of the DRM signal part in the SCS signal is comparable to "normal" DRM transmission. Planning parameters describing any degradation dependent on the channel characteristic can be found in ITU-R Rec. BS.1615 [3].

In practical use of SCS, two other factors have influence on the reception quality of the DRM part in the SCS signal:

- non-linearities in the transmitter power amplifier stage; and
- non-linearities in receiver front-end.

Both result in a frequency-dependent crosstalk from the LSB (complementary signal) to the USB, i.e. the OFDM carriers of the DRM signal near to the SCS carrier are more disturbed than those at the upper end. Therefore transmitters used for SCS transmission should be subject to appropriate linearization.

The front-end of a DRM receiver should be highly linear to provide a proper digital audio quality in the case of SCS transmission. In addition, a steep bandwidth filter might be useful to suppress the influence of the SCS carrier on the OFDM carriers in the case of frequency deviations.

Annex A (informative): Bibliography

- Sony International (Europe) GmbH: "DRM/AM Simulcast", European Patent Application, EP 1 276 257 B1.

History

Document history		
V1.1.1	May 2006	Publication