Digital Audio Broadcasting
Eureka-147

Minimum Requirements for Terrestrial DAB Transmitters

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1 Scope

This document recommends a minimum set of requirements for terrestrial DAB transmitters according to ETS 300 401 [1]. A transmitter comprises all the functions of a chain starting with the input of an ETI signal and ending with the power output of the DAB signal (including power filter if applicable).

It is expected that standard broadcasting transmitter requirements shall apply for features not mentioned here (i.e. features not directly related to DAB).

Retransmitters receiving RF DAB signals are not under the scope of this document.

The antenna system is not subject to this recommendation, as the local situation may often require individual solutions. However, it is assumed that the deviations of the radiated signal from the power-amplified signal can be derived by taking into account the properties of the antenna system.

In practice a back-up technique may be necessary to ensure a continuous service. However, within this document only a basic transmitter is considered.

2 Minimum Functionality

2.1 Digital Signal Processing – COFDM Encoder

2.1.1 Input Signal

The CODFM encoder shall be fed with a signal according to [2]. The processing of the network independent layer [ETI(NI)] is the minimum requirement in any defined physical interface (currently G.703 [3] and V11 are defined).

For MFN applications, the time stamp and the Multiplex Network Signalling Channel (MNSC), which may be present in the ETI(LI), need not be processed as a minimum requirement. The signal processing may be synchronized to the clock-rate of the ETI(NI) input or an external reference.

For SFN applications, the time stamp from either the ETI(LI) or ETI(NA) must be processed. The MNSC need not be processed as a minimum requirement. It must be possible to utilise an external time and frequency references, e.g. as derived from GPS. The recommended external frequency reference is a 10 MHz sine wave >-10dBm. The recommended external timing reference is a 1pps (1 pulse per second) signal, rising edge significant, between 2V and 5V peak-to-peak.

> Remark: The MNSC within the ETI(LI) provides a low data rate channel that can allow the ensemble multiplex operator to control certain transmitter functions. To date, provision has been made for control of Transmitter Offset Delay and Transmitter Identification Information (TII) using the MNSC.

2.1.2 Output Signal

The type of the output signal of the COFDM encoder – base band digital, base band analogue, IF or RF – is subject to the choice of the manufacturer. However, if the COFDM encoder delivers digital base band I and Q signals, the interface should follow the specification given in [4].

2.1.3 Functionality

The COFDM encoder shall be capable of generating signals compliant with [1] in the desired DAB operating mode. If multiple modes are supported, it shall be possible to select the DAB mode from the ETI(NI) input.

The COFDM encoder shall appropriately follow any allowed multiplex reconfiguration. In particular, those Sub channels of the Main Service Channel that are not subject to the reconfiguration shall not suffer any interruption.

The insertion of TII (Transmitter Identification Information) in the Null symbol shall be possible. Manual setting is minimum requirement.

2.1.4 Delay Management

Definition: The overall signal delay of the DAB transmitter is the time difference from the start of the ETI(LI) frame (i.e. the start of $B_{0,n}(b_0)$ of ETI(LI) frame n) with frame phase 0 to the start of the Null symbol of the corresponding transmission frame at the RF output (see 5.2 for measurement).

Manual setting of the adjustable delays is the minimum requirement.

Further information regarding delay types and management is given in Annex B.

2.1.4.1 Internal Processing Delay

The internal processing delay of a transmitter comprises the delay in the digital and analogue stages when all adjustable delays are set to minimum. The processing delay shall not exceed 200 ms in mode I, 120 ms in modes II/III, and 150 ms in mode IV.

> Remark: Larger processing delays are allowed in Modes I and IV because the FIC data of four or two ETI(NI) frames, respectively, must be combined to form a transmission frame.

2.1.4.2 Adjustable delay for use in MFN

Transmitters that are operated in MFNs (Multiple Frequency Networks) shall provide additional adjustable delay sufficient to extend the inherent processing delay to match the maximum permissible processing delay as given above, with a maximum step size of 1 µs.

2.1.4.3 Adjustable delay for use in SFN

Transmitters that are operated in SFNs (Single Frequency Networks) shall provide additional adjustable delay sufficient to extend the inherent processing delay to at least 500 ms in all modes, with a maximum step of 1 µs.

> Remark: Adjustable delay may also be a requirement in particular situations when analogue and digital transmissions have to be synchronised. In such cases delays of up to one second should be expected. This delay is not subject to a minimum requirement.

2.1.5 Behaviour in case of erroneous ETI signal

If the input signal is absent, or if frame synchronization is not achieved, the transmitter shall deliver no RF signal.

After the warming-up time of the transmitter the output RF signal shall be valid within two seconds following the application of an error-free input signal.

2.1.5.1 CRC errors

If frame synchronisation is achieved but CRC violations are detected, the transmitter shall offer at least the following two alternative responses:

a) The output RF signal is not affected by sporadic single CRC violations. The output RF signal is switched off after p CRC violations in q frames, and switched on after m consecutive frames free from CRC violations. Typical values for p, q and m will be p=4, q=40, m=80 (four errors in ~1 second to shut down, ~2 seconds error-free to restore) however the exact values may be configurable and may exceed those given here.

b) The output RF signal is transmitted irrespective of CRC violations.

2.1.5.2 Error status field

If frame synchronisation is achieved but the ETI(NI) ERR field is set to indicate upstream errors, the transmitter shall offer at least the following two alternative responses:

a) The output RF signal is switched off when the ERR field indicates level 2 or 3

b) The output RF signal is switched off when the ERR field indicates level 3

2.2 Analogue Signal Processing

It shall be possible to convert the output from the COFDM generator into an RF DAB signal, which may be broadcast.

Any signal processing delays incurred during this conversion shall be included when complying with the requirements laid out in section 2.1.4.

The resultant signal shall comply with the requirements laid out in section 3.

3 Minimum Performance

3.1 Power Classes

The output power of the DAB transmitter is measured according to 5.3.

The scheme for output power classes could be based on the quasi-logarithmic system of 1, 2, 5, 10 steps.

If the RF output filter forms part of the transmitter the output power is measured after this filter.

The output power stability shall be better than ±1 dB for all climatic conditions

A reduction of the nominal output power by at least 3 dB should be possible without otherwise affecting the performance.

3.2 Unwanted Emission

3.2.1 Out-of-band emission

The spectrum of the output DAB signal shall comply with the masks given in [1]. In the case of non-critical L-Band situations (not covered by [1]) the relaxed spectrum mask given in [5] shall apply. The spectrum masks shall be applied up to ±3 MHz and ±5 MHz from centre frequency of the signal in VHF and L-Band respectively. See 5.4 for measurement.

Remark: Other masks may be requested and defined in the future.

Remark: Demands of national licensing authorities may be more stringent.

Remark: It is recommended that the level of a spurious central carrier in the DAB signal should not exceed -30 dB of the total power of the DAB signal.

3.2.2 Spurious emission

Spurious emission outside the range of the spectrum mask as defined in 3.2.1 shall be limited according to [6].

Remark: Demands of national licensing authorities may be more stringent.

3.3 RF Accuracy and Frequency Synchronisation

3.3.1 MFN Transmitters

The centre frequency of the RF signal shall not deviate more than 10 % of the relevant carrier spacing from its nominal value. This results in the following allowance for frequency deviation:

Transmission mode I < 100 Hz
Transmission mode IV < 200 Hz
Transmission mode II < 400 Hz
Transmission mode III < 800 Hz

The stability of the centre frequency shall be better than

Transmission mode I ± 10 Hz
Transmission mode IV ± 20 Hz
Transmission mode II ± 40 Hz
Transmission mode III ± 80 Hz

within a three-month period when measured under identical operating conditions at the start and at the end of the period.

3.3.2 SFN Transmitters

For SFN transmitters the same requirement for frequency deviation applies as for MFN transmitters. However, provision has to be made to minimise the differential frequency shift of any two transmitters in an SFN.

Remark: In case of SFN operation the following “differential” frequency accuracy (static and dynamic deviations) shall be maintained between any two transmitters:

Mode I < 10 Hz
Mode IV < 20 Hz

Mode II < 40 Hz
Mode III < 80 Hz

Differential frequency shift of transmitters in an SFN can be minimised by locking all oscillators to an external reference.

The recommended external frequency reference is a 10 MHz sine wave >-10dBm. The recommended external timing reference is a 1pps (1 pulse per second) signal, rising edge significant, between 2V and 5V peak-to-peak.

3.4 Deviation of the Output Signal from the Theoretical Form

The distortion of the output signal due to linear and non-linear signal processing inside the DAB transmitter is in general not subject to a minimum requirement. However, limitation is implicitly given by the BER performance degradation (see 3.6) and by the spectrum mask of the ETS.

Remark: It is expected that a variation of not more than ± 1 dB (in addition to the 3dB variation due to symbol prolongation by the guard interval) of the spectral power density inside the nominal signal bandwidth will not impact the BER performance significantly. See 5.1 for details of measurement technique.

Remark: Intermodulation up to -25 dB (non-linear products close to the edge of the nominal signal spectrum, often referred to as "shoulder attenuation") will not impact the BER performance significantly.

The group delay distortion across the ensemble bandwidth shall not exceed 2.5 µs in any transmission mode.

Remark: Group delay distortion up to the length of the guard interval may not impact BER performance when measured without multipath propagation; therefore a specific limitation is necessary.

Remark: The contribution of the analogue part of the transmitter to the group delay distortion may be derived from measurements. A complete measurement needs a new definition of procedure and equipment.

3.5 Limitation of Peak Power Levels

The peak envelope level of the output RF power signal shall not exceed the mean envelope level by more than 13 dB.

3.6 BER-Performance degradation

An operational transmitter shall not degrade the theoretical system BER (with channel coding and decoding) by more than 1 dB, under the conditions set out below (see 5.1 for measurement).

Code Rate R for equal convolutional coding	0.5
Transmission modes	all applicable
Theoretical performance	according to Table 1

BER	C/N
$1*10^{-2}$	5.0 dB
$3*10^{-3}$	5.4 dB
$1*10^{-3}$	5.8 dB

$3*10^{-4}$	6.2 dB
$1*10^{-4}$	6.6 dB
$3*10^{-5}$	6.9 dB
$1*10^{-5}$	7.2 dB
$3*10^{-6}$	7.5 dB
$1*10^{-6}$	7.8 dB

Table 1: Theoretical BER performance in Gaussian channel (equal error protection with R= 0.5)

4 Controlling and Monitoring

In this section only DAB related matters are included. Standard broadcasting transmitter techniques for control and monitoring shall apply for features not mentioned here.

4.1 Control

The minimum requirement includes the provision of sufficient means for the following operations:

- Delay setting
- TII comb and pattern setting
- Response to CRC violations
- Response to ERR field

All applicable settings shall be stored in non-volatile memory. Stored values shall be used at start-up to ensure continuous operation (e.g. after interruptions of main supply).

It shall be possible to verify the parameters above without interruption of the output. In addition, it shall be possible to set the value for all the parameters listed above, except the Delay setting, without interruption of the output.

Remark: Turning RF power on and off, adjusting RF-levels and -thresholds as well as adjusting frequency and other transmission characteristics are expected to be implemented according to standard broadcasting transmitter requirements.

Remark: The ETI(NI) MNSC (Multiplex Network Signalling Channel) provides means for remote setting of TII and transmitter offset delay.

4.2 Monitoring

The minimum requirement is the provision of the following indications:

- Loss of ETI frame synchronisation
- CRC violation
- RF disabled
- RF disabled by ETI signal error

Remark: Storage for the history of error events, indication of power and return loss, as well as the provision of measurement points with defined signal levels are expected to be implemented according to standard broadcasting transmitter requirements.

5 Measurement Technique

The properties of a DAB transmitter are tested while the transmitter is connected to a dummy load.

Remark: In some cases channel output filters may not be integrated into the transmitter unit (particularly on multi transmitter sites) and due regard should be made to this fact when measuring the Spectrum Mask and Output Power parameters.

5.1 BER measurement

For this measurement a reference receiver with a performance that is known and is close to theory is used. In principle only the degradation of the whole chain (transmitter and receiver) can be assessed, but this can provide a useful indication of transmitter degradation.

The receiver is connected to the output of the transmitter (without insertion of a channel simulator). Band limited noise is added to the DAB signal at the receiver input in order to achieve a given value of BER. Adjustable attenuators are used to set both the input power (C) and the noise power (N) to appropriate values at the input of the receiver. BER is the ratio of erroneous bits of the received data to the total bits of the received data during the measurement interval. The power of the added noise, N, is measured within the nominal DAB bandwidth of 1.536 MHz (for power measurement see 5.3).

5.2 Delay measurement

A possible means of determining the delay of a transmitter is to insert a specific test pattern into the ETI signal and observe the COFDM signal at IF or RF. Annex A provides details of one implementation of this method.

5.3 Power Measurement

The power of the signal of a DAB transmitter is defined as the long-term average of the time-varying short-term signal power. An appropriate instrument for DAB power measurements is a thermal power meter.

Remark: CW power meters are now available, and these should be treated with caution as a measurable error is introduced. Depending on the type of meter used, the error may be as much as 3dB.

Remark: The signal power is constant symbol by symbol. A certain short-term variation is especially given by the Null symbol.

5.4 Spectrum Measurement

The spectrum mask in the ETS is defined in relation to spectrum density measured in 4 kHz bandwidth.

The spectral density of a DAB signal shall be defined as the long-term average of the time-varying signal power per unity bandwidth (i.e. 1 Hz). Values for other bandwidths can be achieved by proportional increase of the values for unity bandwidth.

The spectral density of a DAB signal can in principle be determined by the following procedure: The DAB signal is applied to a band filter with rectangular pass band characteristics and a known bandwidth (typically 10 kHz) and with an adjustable centre frequency. The output of the filter is measured by a power meter that delivers real mean values and integrates as long as necessary (typically 2 transmission frames) to get constant readings. These readings can be interpreted as the average spectral density for the measurement bandwidth used. By moving the centre frequency step by step across the DAB signal and adjacent frequency regions the frequency dependent average of the spectral density can by found. The derivation of the average spectrum density for the unity bandwidth is straightforward. In practice using a spectrum analyzer will often perform such measurements. It has to be analysed to what extend the device follows the principles given above. In particular, equivalent noise bandwidth and RMS measurement need to be carefully checked.

Due to the prolongation of the COFDM symbol by the guard interval the spectral density inside the nominal bandwidth varies by about 3 dB with a periodicity of the carrier distance (see ETS). This variation can only be observed in its entirety if the bandwidth of the spectral density measurement filter is low compared to the carrier distance. (The carrier distance is mode-dependent.)

> Remark: Low measurement bandwidth allows detection of small CW components within the COFDM spectrum. Those components that fall outside the nominal DAB frequency block should be treated separately from the COFDM signal, as their impairment effect may be different.

To avoid regular structures in the modulated signal a non-regular, e.g. a PRBS (Pseudo Random Binary Sequence) like or a programme type digital transmitter-input signal is necessary.

Care has to be taken that the input stage of the selective measurement equipment is not overloaded by the main lobe of the signal while assessing the spectral density of the side lobes, i.e. the out-of-band range. Especially in cases with very strong attenuation of the side lobes non-linear distortion in the measurement equipment can produce side lobe signals that mask the original ones. Selective attenuation of the main lobe has proven to be in principal a way to avoid this masking effect. However, as the frequency response of the band-stop filter has to be included in the evaluation the whole measurement procedure may become somewhat complex.

6 References

[1] ETS 300 401: ”Radio broadcast systems; Digital Audio Broadcasting (DAB) to mobile, portable, portable and fixed receivers”

[2] ETS 300 799: "Digital Audio Broadcasting (DAB); Distribution Interfaces; Ensemble Transport Interface (ETI)"

[3] ITU-T Recommendation G.703: “General Aspects of Digital Transmission Equipment; Terminal Equipment. Physical/electrical Characteristics of Hierarchical Digital Interfaces, Geneva, 1994”

[4] ETS 300 798: "Digital Audio Broadcasting (DAB); Distribution interfaces; Digital base band In-phase and Quadrature (DIQ) interface"

[5] TR 101 496: "Digital Audio Broadcasting (DAB); Guidelines and rules for implementation and operation"

[6] ITU: “Radio Regulations, Appendix 8, Geneva, 1994”

ANNEX A: Measurement of the overall delay of a COFDM-Encoder

In an SFN the transmitters have to transmit the symbols synchronous in time and frequency. To set up an SFN the overall delay time of each transmitter including delay compensation has to be known.

According to 2.1.3 the overall delay of a DAB transmitter is defined as the time difference from the start of the first bit of the ETI(LI) frame with phase 0 to the start of the Null symbol of the corresponding transmission frame at the RF output. It comprises the processing delay and the additional adjustable delay.

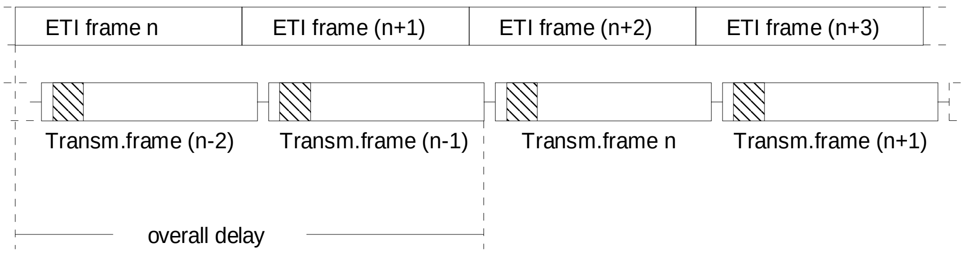

Fig. A1: Overall Transmitter delay, illustrated for the case of transmission mode II and III

The problem is to identify the output frame corresponding to a specific ETI frame.

Detection of a transmission frame in the analogue output signal

It is not possible to observe a specific sub channel because the sub channels are time interleaved. So the solution is to fill the FIC with a specific data pattern and to detect this specific FIC at the analogue output of the COFDM encoder or the whole transmitter.

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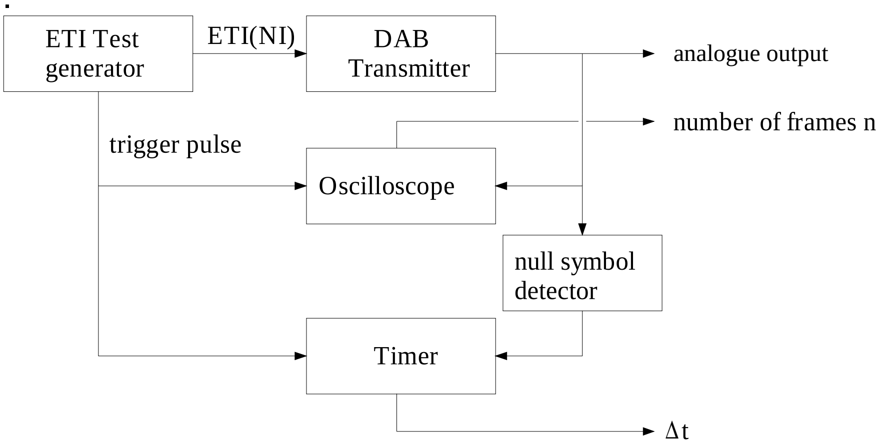


Fig. A2: Set-up for the measurement of the overall transmitter delay

The ETI test generator periodically inserts Fast Information Blocks (FIB) with a specific data pattern into ETI frames with frame phase 0. A suitable period might be 32 frames. It also generates a trigger pulse synchronous to the start of this ETI frame, which is used to trigger a storage oscilloscope.

In a COFDM encoder the first FIC symbol is calculated by differential encoding the frequency interleaved data with reference to the phase states of the phase reference symbol. For example if the frequency interleaved data of the following symbol would be all zero the envelope of the phase reference symbol would be repeated.

The specific FIBs result in specific FIC symbols. Their waveform can be detected with an oscilloscope suitable for the frequency range of the DAB Signal, e.g. an IF signal. So the user has to count the number of complete transmission frames until the specific FIC appears.

Finally the time difference between the start of the ETI frame and the first displayed transmission frame after the trigger pulse has to be measured. This can be done by detecting the null symbol and generate a synchronous pulse. Then the difference between this pulse and the trigger pulse can be measured with a timer.

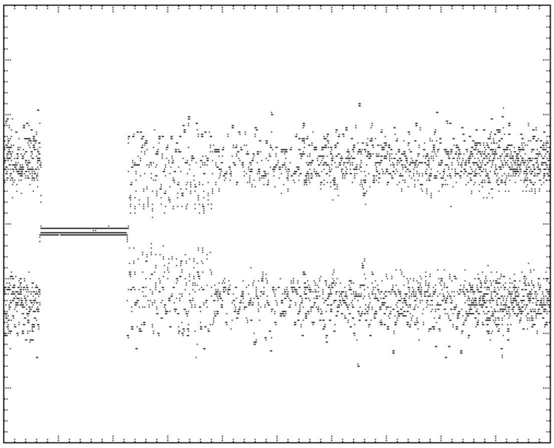
Calculating the overall delay

The overall delay is given by the following expression:

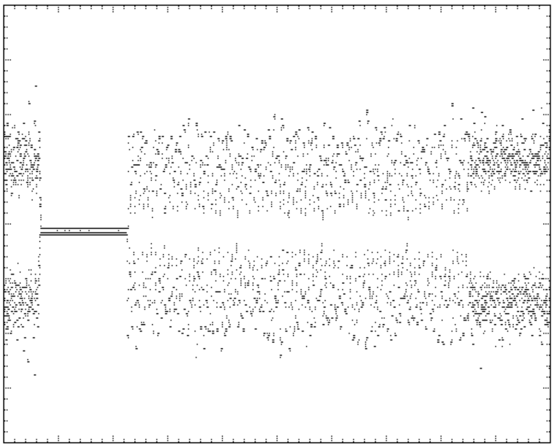
$\text{delay} = n \cdot Tf + \Delta t$

with	n	number of complete transmission frames
	Tf	duration of a transmission frame
	Δt	difference between trigger pulse and null symbol pulse

The following figures show the difference of a normal FIC waveform and a FIC waveform with a specific data pattern as can be observed at an oscilloscope screen.



FIC with normal data



FIC with specific data pattern

Fig. A3: Difference in FIC waveforms

ANNEX B: Delay type and delay management

There are a number of types of delay adjustment that may be defined for operational purposes. These are:

Transmitter Trimming Delay

Used to ensure that transmitters from different manufacturers have the same nominal delay. By implication, the adjustment range provided for this compensation, added to the delay to the basic transmitter, must meet the maximum delay specification as given in 2.1.4.1.

Transmitter Offset Delay

Used to adjust the relative timings of transmitters within an SFN, in order to optimise reception. The range needed for this adjustment is in the order of 0 to 2000 μs.

Network Padding Delay

Used to compensate the delays in the distribution systems, to ensure that the network is synchronized. Some introductory networks may require up to several hundred milliseconds of adjustment. Network adaptation would normally be expected to include compensation for delays in the distribution system, removing the need for Network Padding Delay in the basic transmitter.