Single Frequency Network
Structural Aspects & Practical Field Considerations

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Single frequency network
Structural Aspects & Practical Field Considerations
Single Frequency Networks

- All transmitters in the SFN send the same signal at the same time on the same frequency
  - careful network planning required
  - synchronisation (timing !)
  - low frequency demand

Audio/Video Encoder -> Transport Stream Multiplexer -> Distribution Network -> Modulator Amplifier

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Audio/Video Encoder -> Modulator Amplifier
Transmitter Spacing in an SFN

Wide Transmitter Spacing
- low “on-air” redundancy
- lower number of sites with higher powers

Narrow Transmitter Spacing
- high “on-air” redundancy
- higher number of sites with lower powers

The maximum allowed distance between two transmitters in a SFN is defined by the Guard Interval:
- DVB-T (8k, GI 1/4): 224µs → d ≤ 67 km
- DVB-T (8k, GI 1/32): 28µs → d ≤ 9 km
- DVB-T (2k, GI 1/4): 56µs → d ≤ 17 km
- DVB-T (2k, GI 1/32): 7µs → d ≤ 2 km

Max. Distance = Guardinterval * c (speed of light)
DVB-T Network Structure
Using Dynamic Delay Compensation

- MPEG-2 Multiplexer
- SFN-Adapter
- TX Network Adapter
- Distribution Network
- RX Network Adapter
- SYNC system
- DVB-T Modulator Amplifier
- GPS
- 1 pps 10 MHz

MPEG-TS

DVB-T Network Structure
Maximum delay:
The maximum delay describes the difference in time between a specific Mega-frame leaving the SFN adapter and the corresponding COFDM Mega-frame available at the antenna output of each Transmitter in the SFN.

The maximum delay is a value adjustable in the SFN-Adapter. The set value has to be always higher than the longest actual network delay. The value is transported in each MIP.
Transmitter Synchronisation
Dynamic Delay Compensation

Telecom Network (Microwave, Fibre optics)

GPS
1 pps 10 MHz

SFN Adapter
Max. Delay 700ms

SYNC System
500ms

DVB-T Modulator Amplifier

SYNC System
400ms

DVB-T Modulator Amplifier

Signal transmitted at the same time

Signal transmitted at the same time

Calculated TX delay time 400ms
Synchronisation Timestamp (STS)
The synchronisation timestamp value is the difference in time between the rising edge of the 1pps Symbol and the beginning of a mega-frame M+1.

The STS is carried in the MIP of each Mega-frame.

The STS carried in the Mega-frame M describes the beginning of the Mega-frame M+1.

The STS carried in the Mega-frame M+1 describes the beginning of the Mega-frame M+2.

eetc.
The time a frame has to be stored in the transmitter before it is sent is calculated like this: Max. delay - actual delay = 900 ms - 350 ms = 550 ms

The difference in time between the latest pulse of the 1pps signal and the start of the Mega-Frame M+1 is copied into the MIP of Mega-Frame M

The actual delay of the M+1 frame at the input of the Transmitter is calculated like this:
Arrival time of frame (M+1) - STS value = 650 ms - 300 ms = 350 ms

Adjusted max. delay = 900 ms.
SFN DVB-T2

- All transmitters in the SFN send the same signal with SISO or MISO processing at the same time on the same frequency.
The main feature of SFN DVB-T/T2 network is a high spectrum efficiency. A large number of programs can be broadcast on the same frequency in a local, regional or nationwide transmitter’s network.

Various modulation schemes with FFT sizes and guard intervals allow construction of SFN networks designed for different applications: from low bit-rate but robust mobile reception to the high bit-rate fixed reception for domestic and professional use.

In general, the SFN mode has many advantages but one drawback is the frequency selective fading in DVB-T or DVB-T2 network in SISO configuration. Depending on phase relationship signals may cancel each other and this will appear as a “notch” or a slope across the band.
Some specific aspects of SFN

The notch depth will depend on the relative amplitude of the receiving signals and delay.

The worst case will happen if the RX signals have the same amplitude and delay.

Measured results are shown below.

Amplitude/Delay differences between two RX signals are “zero”

Notch in the spectrum
Some specific aspects of SFN

Continued: Amplitude/Delay differences between two RX signals = 0

Variations of MER values

Variations of MER by carriers
Some specific aspects of SFN

Continued:

Ripple in the spectrum

Delay difference between two RX signals is 0.5us

Delay difference is 1us

Amplitude difference between two RX signals is 0 dB

Delay difference is 3us

An increase of the SFN offset delay in one of two transmitters will decrease the notches and improve the signal quality of receiving signal.
In the field there are many different configurations of SFN DVB-T/T2 networks but here will be considered three:
- Transmitter spacing is within the safety distance for SFN with high on-air redundancy (Fig. 1)
- Transmitter spacing is within the safety distance for SFN with low on-air redundancy (Fig. 2)
- Transmitter spacing is out of the SFN limit (Fig. 3)

It is supposed that all transmitters have the same ERP (Effective Radiated Power) and the SFN offset delay.

![Diagram](image)

**Fig. 1**
In the middle of the SFN overlap area (dashed line) can occur the „notches“ in the spectrum
Practical consideration

In the middle of the SFN overlap area (dashed line) can occur the "notches" in the spectrum.

Type 2.

Fig. 2

In the middle of the SFN overlap area (dashed line) can occur the "notches" in the spectrum.

Type 3.

Fig. 3
To avoid the notches in the spectrum an SFN offset delay should be introduced in one of two transmitters. This could move the problem to another location if the delay is relative small (3us...5us...)
The delay should guarantee a reliable reception which will happen at the distance where the amplitude difference between two RX signals are relative large. If possible this distance should be set outside the overlap area.

Based on the propagation curves defined in the ITU Recommendation ITU-R P.370-7 (see Annex) it is possible to determine the distance and using the formula:

\[ \text{Delay [us]} = \left( \frac{\text{Distance [km]}}{\text{Speed of light [km]}} \right) \times 10^6 \]

to calculate appropriate SFN offset delay.
Setting up of transmission site delays in the SFN

Example:

An SFN offset delay 35us will avoid the “notches” in the middle of the SFN overlap area and move this “problem” to the distance 10 km far away where the amplitude difference between two RX signals is large enough to prevent an reoccur of the notches.

In general, the SFN offset delay will reduce the safety distance for SFN and could lead to the scenario 3 (see Fig. 3). This will not cause a problem if the power level between signals from TX1 and TX2 is greater than 35 dB in this Non-SFN area.

Delay: 35us

RX Spectrum
For Coverage estimation

the free-space path loss (FSPL) formula can be used given by:

\[ \text{FSPL}(\text{dB}) = 20 \log_{10}(d) + 20 \log_{10}(f) + 32.45 \]

where \( f \) (frequency) is in MHz and \( d \) (distance) in km,

and the propagation curves defined in the ITU Recommendation ITU-R P.370-7