

SFN Synchronization over a Packet Backhaul Network

Where the use of GPS receivers for SFN synchronization is not desirable, it is possible to provide the TV transmitters with timing information through the backhaul network serving them, even if that network is packet-based.

The GPS system is an excellent source of timing information for synchronizing transmitters in a Single Frequency Network (SFN). However, there are circumstances where installing a GPS antenna and receiver at the transmitter site is not possible or desirable. If the transmitters in questions are connected by a wired content distribution (backhaul) network, that network can carry the necessary timing information. A TDM (either PDH or SDH) backhaul network is naturally suitable for that purpose. However, moving to a packet-based transport is desirable for many reasons, and it is therefore beneficial to be able to provide the transmitters with network timing over the same packet-based backhaul network.

SFN Synchronization

By employing of a suitably engineered OFDM waveform, it is possible to deploy multiple transmitters that use a single frequency channel to provide contiguous signal coverage over a large geographical area. For this Single Frequency Network (SFN) to operate properly, however, the transmitters' output signals need to be tightly synchronized: only then can the OFDM receiver handle signals from multiple transmitters without mutual interference and performance degradation.

Synchronizing the transmitters of an SFN involves two distinct measures:

Firstly, the OFDM symbols output by the transmitters need to be identical and, furthermore, synchronized to within a small fraction of the guard interval of the OFDM waveform. As long as this condition is met, the receiver can treat the signals from multiple transmitters as channel echoes and process them as it would a signal that was subjected to multi-path propagation. Keeping the timing difference between transmitters to a small fraction of the guard interval will leave the large part of the interval available for accommodating true channel echoes. With a GPS receiver, it is easy to achieve a timing accuracy of 100 nanoseconds, which is more than sufficient. Synchronization schemes over packet networks can achieve, when properly engineered, a timing accuracy of 1 microsecond – still adequately small compared to the typical guard interval, which is at least several tens of microseconds long for 8K OFDM.

Secondly, the carrier-wave frequencies of the transmitters need to be aligned to within a small tolerance. Unless this is achieved, multiple signals arriving at the receiver will appear as echoes from objects that are in relative motion and therefore experiencing a Doppler frequency shift, potentially degrading performance. A carrier-wave frequency difference of several Hertz is acceptable in this regard, but in practice what transmitter implementations invariably do is phase-lock the carrier wave to the network synchronization signal, thereby achieving a practically zero long-term frequency error.

However, phase-locking the carrier wave to an external frequency source raises yet another issue – that of carrier phase-noise. Phase noise is used to characterize short-term instability in the carrier wave, and is a strong function, among other things, of the quality of the



reference timing signal used to phase-lock the transmitter carrier-wave oscillator. Excessive phase noise will degrade receiver performance by making it harder to distinguish between the carrier phase states used to convey the information carried over the OFDM sub-carriers through QPSK or QAM modulation (Modulation Error Rate (MER) is the related transmitter figure of merit).

When GPS receivers are used for transmitter synchronization, it is relatively easy to engineer a high-quality receiver that will ensure adequate phase-noise of the transmitter carrier wave. This, however, is more challenging when network timing is provided through the backhaul network.

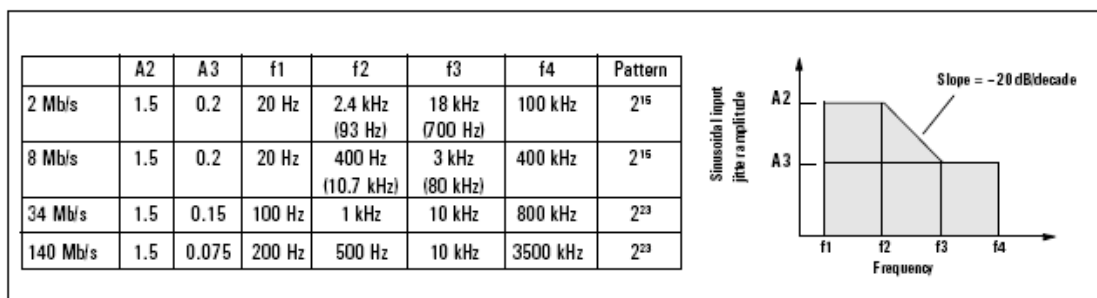
Synchronization Over a Packet Network

IEEE standard 1588, Precision Clock Synchronization Protocol, specifies an open protocol for transmitting timing information over packet networks. Typically, a “1588 Master” includes a high-accuracy clock source such as a GPS receiver on which it relies for the generation of 1588-compliant protocol messages. Those are transmitted over the packet network and received by 1588 Clients that use it to locally re-generate the desired timing signals.

1588-compliant equipment typically provides GPS-compatible timing signals, i.e. a 10 MHz clock and a 1 Pulse Per Second (PPS) timing pulse. In SFNs, the 1 PPS signal is used for OFDM frame and symbol synchronization, while the 10 MHz clock is used for phase-locking the transmitter’s carrier-wave oscillators.

As mentioned above, good-quality 1588 equipment connected by a carefully engineered network can provide a 1 PPS signal with a timing jitter of less than 1 microsecond. While not as good as GPS timing, this is adequate for frame and symbol synchronization, as the typical OFDM guard interval is at least several tens of microseconds long. Carrier wave synchronization, however, is a more difficult matter:

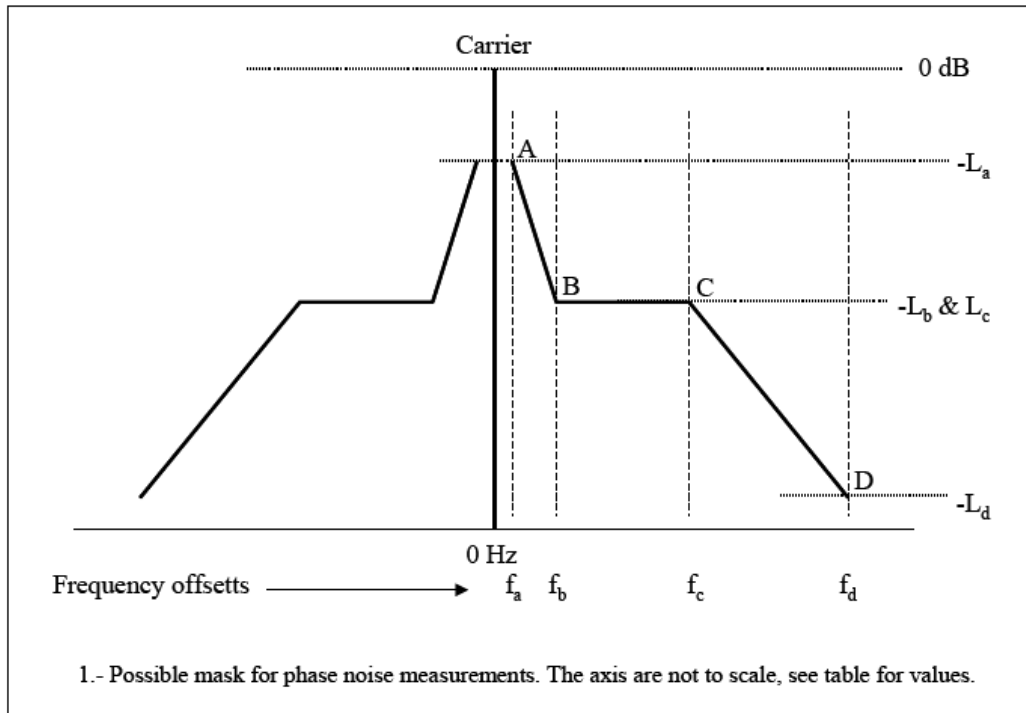
IEEE 1588 was designed to provide synchronization for wired telecom network applications, where timing accuracy is usually specified according to the ITU G.823 standard. The following diagram illustrates the jitter limits according to G.823:



ETSI TR 101 290 specifies the phase noise limits on the carrier wave of DVB-T/H-compliant transmitters:



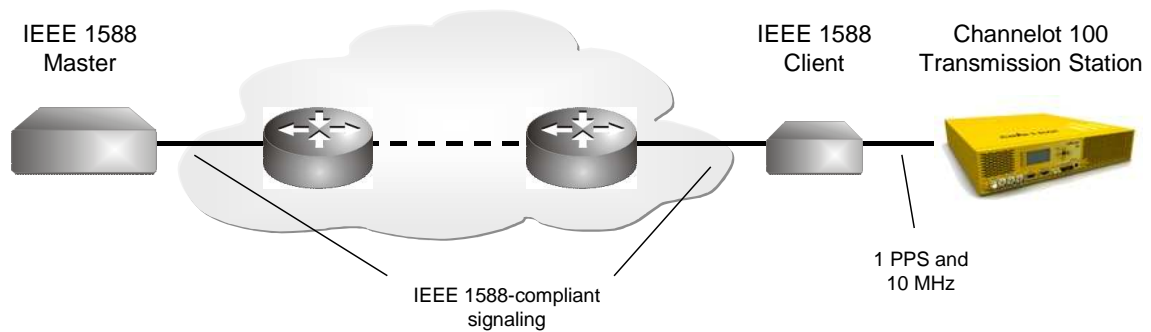
	f_a	f_b	f_c	f_d
Frequency	10 Hz	100 Hz	3 kHz	1 MHz
Limits L_a to L_d	-55 dBc/Hz	-85 dBc/Hz	-85 dBc/Hz	-130 dBc/Hz



Proper analysis readily shows that the DVB-T/H limits are many orders of magnitude more stringent than those of G.823. Using, therefore, a G.823-compliant clock source as is for DVB-T/H carrier synchronization will not provide adequate performance.

A Solution for SFN Synchronization Over Packet Networks

Channelot's Channelot 100 DVB-T/H Micro-Transmission Station includes, among its many features, a built-in GPS receiver for SFN synchronization where GPS antenna installation is possible. The Channelot 100 also includes the necessary post-processing functions for network synchronization by IEEE 1588 packet signaling. A typical implementation will look like this:



A central site IEEE 1588-compliant Master is the primary source of network timing information. The Master generates IEEE 1588 signaling which is sent over the packet network to the SFN transmitter sites. There, an IEEE 1588 client re-generates the two GPS-compatible signals that are fed into the Channelot 100 transmission station – a 1 PPS pulse and a 10 MHz clock. The Channelot 100 station performs the necessary post processing and filtering which make it possible for it to use the timing information for proper SFN operation, including both OFDM frame synchronization and carrier wave locking.

Conclusion

The Channelot 100 DVB-T/H Micro-Transmission Station, together with a suitable IEEE 1588 client device (optionally supplied by Channelot), provides a cost effective, low-footprint solution for transmitter site implementation in SFNs that employ synchronization over a packet backhaul network.