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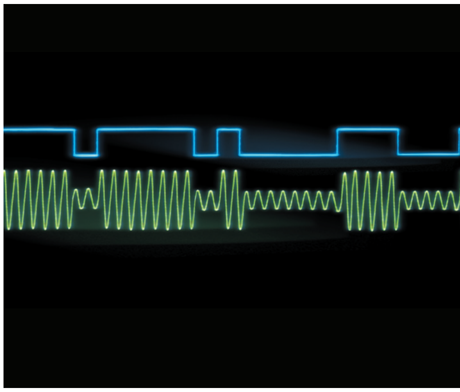
Single Frequency Networks Require Robust Time and Frequency Synchronization



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Doug Lowrie and Randy Cronk,
Symmetricom Timing, Test & Measurement Division

Both high precision and high reliability are critically important in the technology that provides timing references pervasively throughout a carrier's single frequency network infrastructure.

A single frequency network (SFN) enables highly efficient distribution of digital content over a wide area. It does this by having multiple transmitters send exactly the same digital information on exactly the same frequency and at exactly the same instant (from the point of view of a receiver). The technology is now specified within the Digital Video Broadcast-Terrestrial (DVB-T) and Digital Video Broadcast-Handheld (DVB-H) standards. SFNs are based on the idea that it may be easier, faster, and less expensive to service a geographic area from a grid of transmitters than it would be using a web of copper or fiber. SFNs also address the need to bring high-quality video and audio services to mobile users, with a network that can serve all users.

Pervasively distributed synchronization — that is both highly precise and highly reliable — is a key operational requirement of SFNs. That's because a user is likely to receive signals from more than one transmitter at a time. If those signals are out of synch, they will interfere with each other — an effect known as fading where the amplitudes of radio waves whose phases are out of alignment subtract from each other. Other timing problems can occur as well. For example, the data arriving from one transmitter may be late relative to the data arriving from another (even if the signals themselves are synched) — so what the user receives is scrambled. Also, the signal itself may be corrupt — for example, if assigned frequencies are not maintained, causing signals assigned to adjacent frequencies to overlap and interfere with each other.

Such problems can be avoided if all steps along the way — including frame encoding, modulation, and transmission — are synchronized to microsecond precision among devices that are spread throughout the head end and across all transmit stations. To get from sender to receiver intact each data packet relies on a highly choreographed chain of events — all of which depend on each other and on the same timing index. That's why both precision and reliability are important in any synchronization technology designed to support SFNs.

Precision in Both Frequency and Time

First of all, synchronization is fundamental to how SFNs send data over the airwaves — using a technique known as coded orthogonal frequency division modulation (COFDM). The method offers two advantages over a standard analog broadcast: 1) More information can be sent using the same bandwidth (up to eight video programs in an eight MHz signal versus one for analog); and 2) The signal is much less vulnerable to interference. In fact, COFDM is a key reason why adjacent transmitters broadcasting on the same frequency don't interfere with each other.

In COFDM, different parts of the same program are allocated to different tones, or sub-channels, within a slice of bandwidth. (This is different from frequency division multiplexing (FDM) in which different programs are broadcast on different sub-channels.) Each sub-channel is separated from others by a frequency gap that keeps the channels from mutually interfering. In addition, each data bit traversing a sub-channel is separated from the next data bit by a time gap, or delay. The delay between bits allows all echoes of a bit to arrive at a receiver before the next bit starts to arrive. Such echoes could be copies of the bit sent by multiple SFN transmitters or reflections from objects such as buildings or trees.

The time gap also helps prevent fading — echoes of the same bit canceling each other out. How so? The gap is not empty. Each bit is preceded by a "guard interval" — a copy of the second half of the bit's wave "signature." If a bit-echo collision is as much as 50% out of phase, the effect will be mutual reinforcement rather than cancellation. If the collision is more than 50% out of phase then fading may occur. Of course, inserting a delay between bits traversing the sub-channel means lower bit rates. But because bits flow across multiple parallel sub-channels the aggregate bit rate of an entire data frame can be high. The DVB forum specifies up to 8K sub-channels to carry a "megaframe" consisting of some number of contiguous MPEG packets corresponding to an integer number of COFDM bits.

The timing implications of COFDM are clear. Unless the boundaries defining both gaps are strictly enforced — one in frequency, the other in time — signal quality degrades. A very precise frequency source is required to space eight sub-channels uniformly across the correct 8MHz band — and to do so uniformly across multiple geographically dispersed SFN transmitters. A very precise clock is also needed to ensure all stations agree on precisely when its time to launch a bit and when its time to sample for it. For example, the guard interval for bits carried on 8K sub-channels is 28ms with transmitters spaced up to 8.4 kilometers apart. Megaframe duration is about .5 seconds.

Synchronization Everywhere

To achieve synchronization, multiple devices at the head end and at each transmit site reference a common timing source — a device that has a GPS receiver and a holdover clock to maintain required accuracy for some period if GPS reception is lost. The timing source provides two outputs: a 10MHz signal for frequency and a 1pps (pulse per second) for time.

Figure 1 shows key components of a SFN consisting of a head end (that assembles megaframes from MPEG packets) and multiple transmit stations (that send copies of each megaframe over the air simultaneously). An IP network distributes the packets from the head end to the transmit stations where they are modulated into a CODFM waveform and broadcast.

Table 1 shows each step and how timing matters:.

SFN Function	Timing Implication
Frame Encoding	Using the timing source as a reference, a SFN adapter inserts a time-stamp packet in the megaframe to instruct transmitters when to start broadcasting the megaframe's first packet over the air
Adjust Sync	After the data has traversed the distribution network, network delays are added to the timestamp to determine the exact time the first packet is to be transmitted
Build CODFM Waveform	Based on the 10MHz frequency input, data is modulated and spread across multiple sub-channel frequency bands
Transmit	All transmitters start to broadcast the megaframe's first packet at the same predetermined time

TABLE 1 Precisely synchronized timing across devices and sites is critical to SFN operation

A Robust DVB Sync Source

Robust synchronization (high reliability + high precision) calls for key attributes in the SFN's timing reference. Chief among them:

Highly accurate timekeeping

Direct GPS input should provide < 50NS accuracy to UTC (coordinated universal time — the international standard). This will maintain to the sub-millisecond level the spacing between bits traveling through the air — so bit echoes do not interfere with each other.

Low phase noise

The timing source utilized to generate a signal on a channel can contribute to noise on that channel — which can interfere with clear reception of information. Low phase noise in the timing source reduces the likelihood of that occurring.

Redundant time sources that are also highly accurate

Planners should take into account what happens if GPS reception is lost. That requires a holdover clock that tracks GPS and maintains accuracy if GPS is lost — at least for a day, or longer should operators decide to protect against outages of greater duration. Alternatively, the sync source may also take advantage of other available timing sources, such as T1 and E1 networks.

Redundant hot swappable design

Planners may also want the option to configure two sync sources — one as primary and one as backup — for automatic switchover if the primary fails. Designation of "primary" should depend on which has GPS reception. Even if the primary source goes down, the secondary should still track the primary's GPS receiver if that receiver still functions properly. Redundant GPS receivers

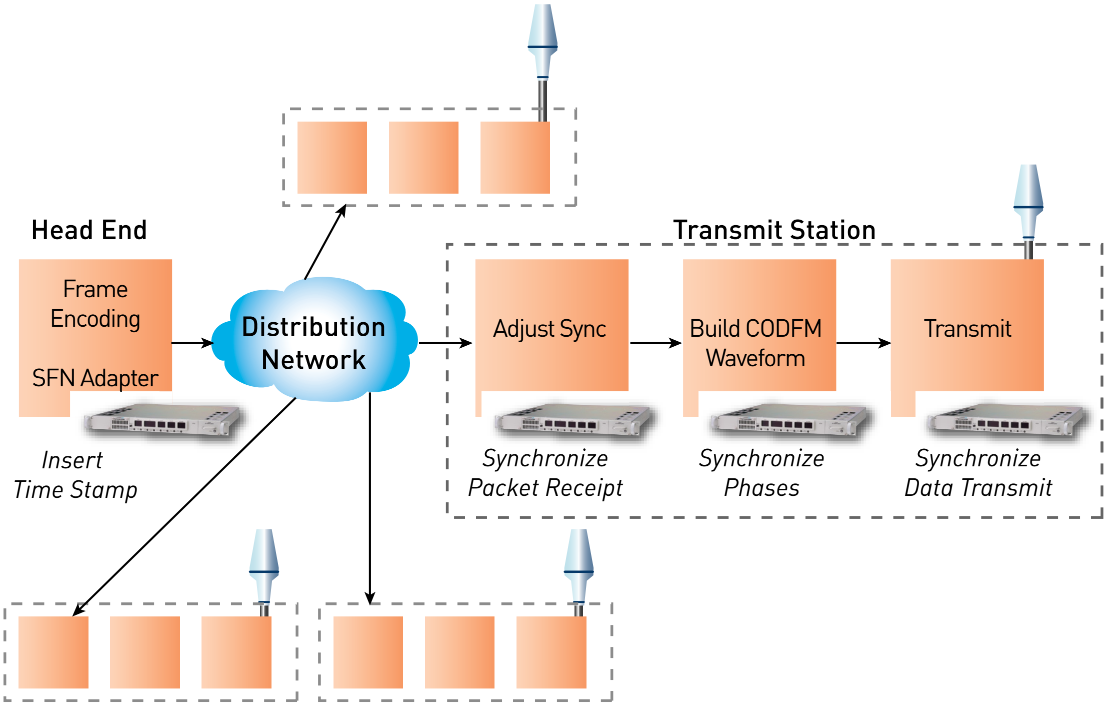

FIG 1 Timing elements are pervasively distributed across SFN sites and devices.

are also an option SFN planners may wish to consider. Making devices hot swappable means that technicians can replace modules in a chassis without powering down the system or disrupting the network. For example, network operators can specify dual hot swappable power supplies to further enhance reliability.

SNMP for configuration and monitoring

Technicians in the network operations center will want network-wide visibility to anywhere an out-of-spec condition may occur so they can take immediate action.

The Right Time

Fortunately, SFN operators can now specify as much timing precision and reliability as they need — in forms they can easily adopt within existing infrastructures. Technology providers have responded to operators' robust timing requirements — with high levels of accuracy, redundancy, phase noise reduction, hot swappable technology, and remote management built into off-the-shelf solutions. These solutions such as Symmetricom's DVB Sync Source (link to datasheet) are ready to deploy in 1U form factors that are plug-compatible with existing SFN adapters, COFDM modulators, up converters, and other equipment.

Clearly, the time is right for single frequency networks. They can, in a single network, satisfy the sometimes-conflicting calls for mobility, performance, and frequency conservation. In fact, the timing has never been better.

SYMMETRICOM, INC.
2300 Orchard Parkway
San Jose, California
95131-1017
tel: 408.433.0910
fax: 408.428.7896
info@symmetricom.com
www.symmetricom.com