Precise Time and Frequency References In

DVB and DTV

(Digital Video Broadcasting and Digital Television)
Introduction

With the introduction of Digital Television, the need arose to re-think how to handle and transmit the large increase in data required with higher efficiency to more effectively use available bandwidth. Out of the many different architectures investigated, two main schemes emerged. COFDM (Coded Orthogonal Frequency Division Multiplexing), and 8VSB (8-level, Vestigial Side Band). The COFDM system has been widely adopted in Europe while the 8VSB system is used in North America.

Whilst it is not the purpose of this paper to describe in detail the intricacies of these different modulation schemes, a brief summary of some of the intrinsic characteristics will be described to show the importance of employing sufficiently accurate and stable frequency and timing references, and the role that the GPS system plays in order for these systems to function.

Comparison of COFDM and 8VSB Techniques

8VSB

The 8VSB methodology effectively converts a binary stream into an octal representation by amplitude modulation of the carrier to one of eight levels. The eight (octal) levels represent a "symbol" and each symbol effectively transmits 3 binary bits ($2^3 = 8$). The term Vestigial Side Band is derived from the fact that the modulation technique results in a symmetrical double sided sideband signal and one of the sidebands then is removed (as it is redundant) however in practical terms it is not possible to filter it out 100% and therefore a "vestige" of the sideband remains.

The symbol rate in the 8VSB 6MHz broadcast channel is 10.76 MBaud which equates to 32 MBits/second (3 x symbol rate).

COFDM

The COFDM technique is considerably different. The digital stream is split into multiple digital streams and each digital stream (orthogonally)modulates a different carrier frequency spaced either 1kHz or 4kHz apart dependent on the mode (8k mode or 2k mode respectively) giving either 6,817 or 1,705 separate carriers. The throughput of the system on the 8MHz broadcast channel is 24 MBits/second.

Comparison

In both systems the actual useable bit rate is somewhat reduced, in the 8VSB method because some of the bits are used for forward error checking, and in the COFDM method because of "guard" intervals injected to avoid interference between signals coming from different antennas.

In general the benefit of COFDM is that it is far more tolerant of multipath signals typical when signals are being transmitted in highly variable terrain (hills, valleys, buildings etc.). The big plus for 8VSB however is the much reduced power required to give the same signal coverage over a specified area.
Precise Timing and Frequency References.

While the two systems described above use very different architectures to obtain the same objective they both have one critical aspect in common, they both need precise time and frequency references in order for the systems to function effectively.

There are limited commercial technologies that can provide the necessary accuracy and stability but from those available the one that stands out as being able to meet the stringent performance requirements at reasonable cost is the GPS (Global Positioning Satellite) system.

Although the widest use of GPS is for precise position determination (planes, boats, vehicles, ground based troops, hikers) this is in practice achieved by transmission from the satellites of precise timing signals. A receiver determines its distance from the satellites by time of arrival of the transmitted signals, and when a receiver has determined this from at least 3 satellites determines its position by triangulation.

A GPS time and frequency receiver then uses these same signals to generate a very accurate timing pulse (usually once per second, referred to as 1PPS) and a very accurate frequency. By employing an integrated high performance quartz or rubidium oscillator the GPS receiver is able to filter the inherent noise in the GPS signals and provide an extremely accurate and low phase noise/highly stable output frequency that can be used as the precision frequency reference.

Another major advantage of GPS based systems over other technologies is that the precision 1PPS output is synchronized by the satellites to the international time reference, UTC (Universal Time Coordinated), so the 1PPS output from receivers in physically widely separate locations is in synch.

There are many things to consider within the design of a GPS time and frequency receiver in order to squeeze the best possible performance from the supplied GPS signal, however suffice it to say that frequency offset accuracies of better than parts in 1E-12 are attainable with stabilities to match. To put this in perspective, on a 10MHz reference signal, this level of accuracy represents a value of better than 0.00001 Hz (on 10,000,000Hz!).

Required performance for the COFDM and 8VSB architectures is in the region of a real time frequency accuracy of better than 1E-9, therefore a good quality GPS disciplined standard gives a substantial safety margin. This is very critical when considering operational issues (such as temporary loss of GPS signals) whereby a good frequency reference will continue to provide the necessary signal quality for a substantial amount of time, from 1 day for an integrated quartz oscillator to over 1 week for an integrated rubidium oscillator.

With regard to phase noise, a figure of better than -55dBc is required at a 10Hz offset from a 701MHz carrier. This translates to a requirement at 10MHz of better than -92 dBc at a 10Hz offset. A good GPS frequency reference with integrated OCXO will provide phase noise of better than -125dBc at a 10Hz offset from the 10MHz carrier, so again provides substantial margin on the requirement.

The diagrams below show the different architectures of the COFDM and 8VSB implementations, together with the positions of the frequency and time references providing the necessary synchronization.
Synchronized DTV Transmitter System (from the ATSC Standard)

The common external precise time and frequency reference is used at several locations in the system. The following is an extract from the ATSC Standard for transmitter synchronization;

"External Time and Frequency Reference
A common time and frequency reference (i.e., GPS) is required at several locations in the system. The Transmission Adapter uses the time component of the external reference to produce the time-offset information to be sent to the Slave Synchronizers to adjust the emission times of their associated transmitters, and the Slave Synchronizers use it to adjust the emission times of their transmitted signals. The TA uses the frequency component to precisely maintain its output Transport Stream data rate to tight tolerances. The transmitters use the frequency component to precisely set their output frequencies to minimize the apparent creation of Doppler shift and the consequent burdening of receiver adaptive equalizers by frequency differences between transmitters, and they use it to reestablish the precise bit rate, and thereby stabilize the timing, of the Transport Stream after its transmission through STLs, which may have some amount of time variation in their delivery of the signal, as, for instance, in satellite relay, some over-the-air receivers, and some microwave systems."
Functional Block Schematic of Baseline DVB-T System (from ETSI EN 301 701)

Comments from the ETSI standard regarding the frequency and time reference are shown below;

"Phase Noise Requirements

Meeting the phase noise requirements for OFDM systems at microwave frequencies is more difficult to achieve than it is at UHF or VHF frequencies. The dependence of the system behaviour with respect to the phase noise is a function of the total phase noise power. This means that it is important to specify the phase noise between 1 KHz and 1 MHz from the carrier. For example, a synthesizer may have a very good phase noise at both 1 KHz and 10 KHz from the carrier; but if the phase noise density is high between 10 KHz and 1 MHz the total phase noise power could be too high for a good reception of the signal.

As a rough guide, the following phase noise values have been used in a number of research projects:
-65 dBc/Hz @ 1 kHz;
-68 dBc/Hz @ 10 kHz;
-86 dBc/Hz @ 100 kHz;
-105 dBc/Hz @ 1 MHz.

(note these values are at the transmission frequency of ~500MHz, and relate to a 10MHz reference by the equation:

\[
\text{phase noise}(10\text{MHz}) = \text{phase noise}(500\text{MHz}) - 20 \log n
\]

where \(n\) = multiplication factor [from 10MHz(ref) to 500MHz (tr)]

This yields a result of approximately -100dBc/Hz at 1kHz off a 10MHz carrier.
Frequency stability is clearly also a critical factor and again the following is an extract from the ETSI standard;

"Meeting the frequency stability requirements for OFDM systems at microwave frequencies is more difficult to achieve than it is at UHF or VHF frequencies. The frequency stability requirements of the system will usually depend on the receiver’s sensitivity to frequency drift. The frequency drift that can be accommodated may vary from receiver to receiver according to the manufacturer specifications.

Typical AFC lock range in consumer receivers is ±70 kHz, but most of this tolerance may be required to compensate for internal frequency inaccuracies within the receiver.

In more complicated systems where very high microwave frequencies are used, pilot recovery circuitry may be used to correct the frequency errors due to all previous oscillators. The extent to which these pilot signals can restore frequency stability may be limited and loop recovery systems may not work with high levels of drift."

Summary

In summary, whatever the methodology employed for transmission of Digital Video Signals, there is an underlying requirement to insure a precise frequency and time reference in order to synchronize the system.

Precise Time and Frequency, Inc. (ptf) has been designing and manufacturing such systems for many years, supplying frequency and time systems, including redundant configurations, to much of the Digital TV infrastructure in North America and overseas.

With a special focus on excellent stability, low phase noise implementations, ptf has developed a track record of reliability and functionality that is recognized throughout the world.

For more information or just to comment, please visit:

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