SMPTE Meeting

Discussion of business cards for the class for handing out at NAB.

Discussed Steve Lampen presentation choices; we will make a decision by the end of the day.

Be at SMPTE booth Tuesday at 10 AM at NAB for a group picture of current students and alumni.

DTV

Digital television is rocket science, developed by some pretty clever people.

COFDM

Not the standard in United States. Standard in Europe. Used sometimes in United States, like maybe between remote truck and studio. Handles multipath problem.

Multipath

Especially a problem with tall buildings. Signal bounces off the buildings differently; the receiving antenna receives all these. They arrive at different times. Think of ghosting on analog TV; that's multipath that appears as a ghost.

Slide

COFDM is a modulation scheme that divides a single digital signal across 1000 or more signal carriers simultaneously. The signals are sent at right angles to each other (hence, orthogonal) so they do not interfere with each other. This is sort of like QAM.

COFDM is used predominantly in Europe and is supported by the Digital Video Broadcasting (DVB) set of standards. We will see this at NAB. We will see the reference to DVB a lot at NAB.

In the United States, the Advanced Television Standards Committee (ATSC) has chosen 8-VSB (8-level vestigial sideband) as its equivalent modulation standard. This system does have multipath problems in big cities.

Why not switch to COFDM? Story goes that COFDM and 8-VSB both commissioned by ATSC to do side-by-side comparison. Tests on distance, multipath, signal quality, amount of signal, and others. Resulted in 8-VSB being chosen. ATSC was first to do this. The COFDM people said their equipment wasn't working right, but ATSC said that they couldn't wait. Turns out COFDM did have problems with equipment, and ATSC might have chosen it had it been set up properly.

In Europe, stations transmit the same signal 100 percent of the time across many borders using single frequency networks. A single frequency network is a network of several stations that broadcast the same signal simultaneously using multiple transmitters. This allows television viewers to watch the same broadcast anywhere in Europe without interference. COFDM is ideal for single frequency networks. COFDM has the ability to completely overcome multipath effects.

Because of movement, we can't receive television well in a car. COFDM systems would not have this problem.

What is Multipath?

When a signal is transmitted, it is met with obstructions such as canyons, buildings, airplanes, and even people, which scatter the signal causing it to take two or more paths to reach its final destination, the television. Multipath effects can occur simple by an individual walking into the room.

The late arrival of the scattered portions of th signal cause ghost images. For this very reason, some consumers in metropolitan areas or areas with rugged terrain opt for cable or satellite television instead of fighting their antennas for better reception.

COFDM is resistant to multipath effects, because it uses multiple carriers to transmit the same signal. Instead of signal scattering when met with an obstacle, it flows around the obstacle like a river flows around a rock making it perfect for free DTV programming and for mobile television viewing.

Problems with multipath effects were often cited in early evaluations of 8-VSB, although it is expected that devices such as internal antennas will overcome them. Steve's grandmother lives on a farm in rural Indiana, 80 miles from nearest big city. Small city has one station. Could not get the small city station as well as the one from the big city. But, ten years ago she had reception quality like cable, with same old antenna. Over time, made signals and processing better, benefiting the end user.

Analog TV has ghost-canceling signal that is sent along with the regular signal.

Quaternary Phase Shift Keying (QPSK)

Defined later.

Gray Code Mapping

Table

Data Bits	*Phase Change (degrees)*
00	0
01	90
11	180
10	270

The above mapping is called a Gray code mapping, because adjacent symbols (or in this case phase changes) only differ by the value of one bit, which lowers the probabilty of there being two bit errors for one symbol.

8-VSB

The transmitter must obviously be capable of handling the peaks, which could have been lower if the energy had been spread more evenly. 8VSB does this by pseudo-randomizing the data. This process has the additional benefit that potential DTV to NTSC interference is reduced.

Next, error correction is applied according to the Reed-Solomon scheme. This helps with noise and a certain amount of multipath.

To minimize the effects of interference, data is interleaved over a time span of around 4.5 ms so that if some data is destroyed by a refrigerator clicking into action, other data from that section of the image can be retrieved from a point earlier or later than the impulsive burst.

Another form of error correction is the Trellis encoder. This analyses trends in the signal, looking back to the signal's recent past and anticipating its future. If the signal bucks the trend, very likely it is because of an error, which can then be concealed.

The digital signal complete with data randomizing, error correction coding and interleaving is converted into eight discrete levels, hence the 8 of 8VSB and employed to amplitude modulate a carrier.

This results in a central carrier frequency with mirror-image sidebands containing identical copies of the data. One is suppressed in level and becomes a vestigial sideband – the VSB in 8VSB.

One of the problems of distributing a signal with a noise-like frequency spread is that signals with regular periodic characteristics have to be considerably suppressed in level, otherwise the object is defeated. The noise is like the noise we hear when a modem connects before it shuts off the speaker.

Vestigial because there is a significant, important DC component to digital signals, which is low frequency and must be preserved. So must protect the low frequencies in one sideband just like we do in NTSC.

One helper signal which the receiver uses to lock onto the signal is the ATSC pilot (it is a continuous reference independent of anything else is happening) which is achieved by applying a DC shift to the baseband signal creating a fixed signal at the zero frequency of the transmitted band, which is independent of anything else that is happening.

Recall that FM pilot at 19 kHz.

In addition, segment and frame syncs are used by the receiver to lock firmly onto the signal. So firmly in fact that lock can be achieved at a signal-to-noise ratio of 0 dB – the noise is as high in level as the signal.

If then the signal to noise ratio for some reason momentarily decreases to the point where an image cannot be retrieved, the receiver is still locked and can get back to work when conditions improve. The high stability of the signal is very important. The receiver always knows when to expect the next sync information, and should there be any other spurious competing information – as there will be in multipath reception conditions – an adapter equalizer can be adjusted to cancel the multipath signal out.

8VSB vs COFDM

8VSB features

Effective use of spectrum.

Data interleaving to combat burst noise (lightning, refrigerator turning on, light switch).

Trellis coding anticipates errors.

Adaptive equalizer attempts to cancel multipath.

COFDM Features

Frequency division multiplexing spreads signal over 2000 carriers.

Guard intervals prevent loss of data due to multipath.

Coding offers error correction based on confidence in the integrity of each carrier.

Why Keep 8VSB?

Cost too much to convert existing 8VSB receivers.

Take too long to convert to COFDM.

Problems will be solved in next generation receivers.

Multipath

If the multipath signal arrives later than one **symbol period**, then one symbol will interfere with another.

Symbol period. This is like the eye between 1 and 0, where we can't read the signal if the eye closes.

However if the delay could be shorter during the symbol period, then at least some, perhaps most, of the interference will come from the symbol itself, and it turns out that error correction in this case is a very much more manageable proposition.

Allow each symbol to occupy a longer time period.

COFDM

Multiple carriers? Use as many as necessary to achieve the desired data rate. This 'frequency division multiplexing' is the FDM of COFDM. O stands for orthogonal.

COFDM employed in Europe has 2000 carriers (exceptionally difficult terrain can require more). If the carriers are spaced appropriately in frequency it is possible to demodulate each carrier without having to filter out the others.

The O in COFDM is still orthogonal, which is the selection of the carrier frequencies so that they can be easily demodulated in this way. In addition, guard intervals are placed between symbols to ensure that any phase or amplitude discrepancies in the received signal do not compromise the benefits of orthogonality.

The C in COFDM stands for coded. Suppose there was a multipath signal at the same level as the original. According to the delay, some carriers will be completely destructively interfered out of existence leading to the complete loss of some symbols. These carriers are not subcarriers. They don't have a main carrier within their bandwidth. The carriers are all the same amplitude.

Depending on the guard interval, up to a quarter of all symbols could be lost! It would take quite some error correction code to deal with this. The answer, in essence, is to move away from the notion of error correction telling us whether a bit is right or wrong.

A system that, among a range of other techniques, allows more confidence to be placed in channels that having a high signal to noise ratio than channels that are mostly noise, depending on reception conditions, allows good reception even in the presence of strong multipath interference.

By contrast, the OFDM system is a multicarrier technology. The principle of OFDM is to break a single data stream into many parallel, lower rate data streams. OFDM then uses many "subcarriers" to transmit these lower rate streams of data simultaneously. They seem like subcarriers but they are not within some main carrier.

To ensure that the subcarriers do not interfere with one another, the frequency spacing between subcarriers is carefully chosen so that each subcarrier is orthogonal to one another.

What is orthogonality?

Modulation

The individual subcarriers are typically modulated using a form of either quadrature amplitude modulation (QAM) or quadrature phase shift keying (QPSK).

Coding techniques (the C in COFDM) can be used to improve performance.

The multicarrier design of COFDM makes it resistant to transmission channel impairments such as multipath propagation, narrowband interference, and frequency selective fading.

CODFM avoids interference from multipath echoes by increasing the length of the signal samples, so that it is greater than the temporal spread of the multipath, and by applying a guard interval between data symbols where the receiver does not look for information.

Guard intervals can be designed so that most multipath echoes arrive within the guard period and therefore do not interfere with the reception of data symbols.

This permits COFDM to successfully operate with echoes as large as the main signal (0 dB).

6 MHz divided by 2000 carriers is 3 kHz bandwidth per carrier. But this is reduced by the guard bands.

We don't cross sidebands because of the guard bands. So, we don't have the NTSC problem of cross-luminance and cross-chrominance. This NTSC history was taken into account when designing this.

Further, because information is spread among many carriers, if narrowband interference or fading occurs, only a small amount of information is lost.

The Sinclair demonstrations used a COFDM system based upon the European Terrestrial Digital Video Broadcasting (DVB-T) standard using equipment that was modified to operate in the traditional 6 MHz channel used in the United States. This is the company that did the demo in the United States for ATSC.

That system operated with 1705 subcarriers and 64 QAM, and provided a usable data rate of 18.66 Mbps.

Coded Orthogonal Frequency Division Multiplexing – a modulation scheme which is used by the DVB digital television system.

It allows for the use of either 1705 carriers (using known as 2k) or 6817 carriers (8k).

Concatenated error correction is used. The 2k mode is suitable for single transmitter operation and for relatively small single frequency networks with limited transmitter power.

The 8k mode can be used both for the single transmitter operation and for large area single-frequency networks.

The guard interval is selectable. The 8k system is compatible with the 2k system. There has been much discussion about the relative merits of COFDM versus the 8-VSB scheme used in ATSC standard.

The Japanese ISDB system uses a similar scheme, OFDM. Japan is mountainous and have lots of big cities.

6 MHz is sufficient ot carry one high definition (HDTV) channel, or around 4 channels comparable to NTSC standards. 8-VSB is the RF modulation format and MPEG-2 is the video compression/packetization format used in DTV.

That is, there are two distinct stages of processing needed to convert high-definition video into a form suitable for over-the-air broadcast.

MPEG-2 Encoding and 8-VSB Modulation

Accordingly, two major pieces of equipment form the heart of a DTV transmission system: an MPEG-2 encoder and an 8-VSB exciter.

MPEG-2 Encoder

The MPEG-2 encoder takes baseband digital video and performs bit rate compression using the techniques of discrete cosine transform, run length coding, and bi-directional motion prediction.

The MPEG-2 encoder then multiplexes this compressed video information together with pre-coded Dolby AC-3 audio and any ancillary data to be transmitted.

The result is a stream of highly compressed MPEG-2 datapackets with a data frequency of only **19.39 Mbit/sec**. Remember this number; you will see it over and over again. That's what is necessary in order to make 8-VSB work properly. 1.5 Gbits/second video data rate for HDTV, plus audio and ancillary data, crammed (compressed) into 19.39 Mbits/sec. This is the output data rate from the MPEG-2 encoder.

Europe uses MPEG2 level 3 for audio.

(Where are all the headers put in? Picture, GOP, slice, macroblock headers. Must be done before the multiplexer, and after the run-length encoding. Steve hasn't seen any information stating at what point the headers get added. The result/output of the entropy encoding is the payload. Then, the headers can be put on.)

This is by no means a trivial task since the high-resolution digital video (or multiple programs of standard resolution video) input to the MPEG-2 encoder could easily have a data rate of 1 Gbit/sec or more. This 19.39 Mbit/sec data stream exiting the MPEG-2 encoder is known as the **DTV Transport Layer**. It is transmitted from the encoder to the 8-VSB exciter in serial form via a 75-ohm coaxial cable.

8-VSB Exciter

Although MPEG-2 compression techniques can achieve stunning bit-rate reduction results, still more tricks must be employed to squeeze the 19.39 Mbit/sec DTV Transport Layer signal into a slender 6 MHz RF channel for over-the-air transmission. This is the job of the 8-VSB exciter.