BTV 240 - Tuesday 13 February 2007

Quiz

Ten-question quiz on the reading on serial digital video data in Whitaker's text book.

Lecture

Continue with where we left off on Thursday.

How Digital Signal Propagates through a Coaxial Cable

Instead of changing entire infrastructure of the studio, decided to stick with 75-ohm coax. Other cables would work OK, like CAT-6. Lamp cord would not work; carries low-frequency AC and DC OK.

The square wave is affected by the losses in the cable and is attenuated and distorted. Why does it become attenuated? DC resistance at higher frequencies due to skin effect. Why does the wave become distorted (why does the wave end up looking more like a sine wave than a square wave)? Different frequencies react differently; higher frequencies have a tendency to reflect if the line is not perfectly terminated. Standing wave created. We can live with this.

The higher the data rate, the shorter the cable length that the signal can pass through for a given amount of attenuation. For example, can go farther on composite digital D-2 (143 Mbits/sec) than component digital D-1/601/SDI (270 Mbits/sec). However, want to avoid cross-color, cross-luminance so we want to go component (601/SDI). Could run 48 kHz forever down a coax cable, but don't do so now because historically have run audio on twisted pair.

The signal starts out with a peak-to-peak voltage of 800 mV +/- 10%. This is part of the SDI specification. This is the raw SDI signal. If look at it on a oscilloscope, we should see a voltage level of 800 mV +/- 10%.

At the end of a 220 meter (600 ft) cable run using 270 Mbit/sec signal, the peak-to-peak level will be attenuated down to only about 30 mV. A 143 Mbit/sec signal after 300 meters is about 30 mV). What is the dB loss? Gain in decibels for a voltage ratio = 20 log (Vout / Vin) = 20 log (30/800), which is about -28 dB.

Not only will the amplitude be reduced, but also the square shaped pulses will have become more like a sine wave. So is a challenge to fully recover the signal at the receiving end and reproduced to be exactly like the original signal.

Diagram 1. Reclocking the signal. Reclocking serial receiver. On cameras there is a signal equalization board that equalizes the high and low frequencies to compensate for the additional losses in high frequencies. Do same in cameras; have long cable runs. NMT might run a cable for a football field length. Most cameras today have automatic equalizers. Go through a high-pass filter. The stage in the diagram is called a slicer.

Diagram 2. Shows equalization to compensate for the loss of high frequencies to end up with a flat signal (no frequency-related losses).

Cliff Effect

Sudden complete loss of signal as signal amplitude decreases (like when running longer and longer coax). Either a perfect picture or nothing.

Whenever the signal goes through a connector, there is very likely a loss because of the imperfection of making a connection (crimp, etc.) and the resulting resistance loss or change in impedance.

As come to cliff edge, errors appear in bit stream and increase dramatically as additional obstacles inserted in the path. Can use this assumption to provide an early warning system. This is known as **error detection and handling** (**EDH**). This is a bit like monitoring an analog tape system, except analog tape would lose signal more gradually.

EDH may correct the errors. Reclockers don't do corrections.

Two types of receivers: reclocking and non-reclocking. All the receivers Steve sees are reclocking; hasn't seen a non-reclocking. Maybe non-reclocking for a short run in the studio. Reclocking circuitry is cheap, so people don't bother to not reclock, just in case.

Reclocking receivers use a PLL to clock incoming pulses and restore original square waveshape. Non-reclocking receivers simply pass the rounded pulses. Either type may incorporate automatic equalization circuitry to restore level to 800 mV.

Can use edge shaping techniques instead of reclocking, but jitter isn't removed from signal and reliable recovery not possible after 50 meters of cable at 270 Mbits/sec. Not as good as a reclocker.

Any Schmitt trigger stuff used? Maybe. Schmitt trigger detects a slow-moving signal change and makes the change happen rapidly, but causes a slight delay, which isn't that slight at 270 Mbits/sec.

Remember that when a cable length is specified, the data rate must be included in the specification.

Looked at Ikegami CCUs. Have a knob on the front left that sets the cable length of the triax. This manually adjusts the equalization.

How do we move signals around a facility?

Parallel interface 25-pin DB-style connectors at each end of a 25-conductor cable. This is an old style. Distances of up to 50 meters are allowed.

Parallel not as good as serial for distances. When we send down a pulse down a wire, pulses may not get there at the same time. Is a timing issue. Beyond the 50 meter point, the data and related clock information begin to skew in time because of their differing frequency content. Clock and data information arrive at different times, causing data errors. In addition, cable and connectors are bulky, difficult to use in a large facility, and expensive to implement.

The serial interface uses BNC connectors at each end of a 75 ohm coaxial cable, the same type as used for conventional analog video signals. Can go up to 300 meters before data can no longer be recovered.

There are manufacturers that make higher-quality coax for digital. There are specifications on the minimum radius of a cable bend.

Existing analog cables may be used, avoid cables with corroded connectors and poor grounds since serial signals have a wide bandwidth.

Some serial connectors downstairs are black. What caused them to turn black? Corrosion. Silver is oxidizing. Cause ground problem if on the outer conductor. Can cause problems with digital.

Passive looping inputs typically are not provided at the input to a serial digital device, as adequate return loss characteristics cannot be maintained.

Reflections in the cable caused by poor return loss can lead to bit errors in the digital stream.

Termination and Active Termination

Last thing on the coax line needs to be 75 ohms. Can be a passive terminator (a 75-ohm resistor). Active termination uses an amplifier with a 75-ohm output that continues on, and a 75-ohm input to terminate the incoming line. In SDI, we use strictly active termination.

Continuing On With SDI

A 16:9 format and two sampling frequency options considered (now in use) for the Y channel (13.5 MHz and 18 MHz). The resulting data rates are 270 Mbits/sec and 360 Mbits/sec, respectively.

Synchronizing Packets

A synchronization packet, commonly known as the **timing reference signal** or **TRS**, occurs immediately before the first active sample on each line. Is really the SAV (start of active video). TRS refers to EAV and SAV. Use EAV and SAV to be safer.

Synchronization packet consists of 4 10-bit words (for SAV, first 3 words always the same(0x3FF, 0, 0), the fourth consists of 3 flag bits, along with an error correcting code). As a result there are 8 different synchronization packets possible.

Flag bits found in fourth word (called **XYZ word**) known as H, F, and V. **H** bit indicates start of H blanking, and synchronization bits immediately preceding H blanking region must have H set to 1. Such packets are commonly referred to as EAV packets (end of active video). Likewise, SAV packet has H set to 0, which indicates SAV (start of active video).

Must know when SAV is in order to know how to interpret the data as active video.

After EAV, have ancillary data (about 55 megabits per line).

Likewise, **V** bit indicates start of vertical blanking region. EAV with V=1 indicates following line (lines said to start at EAV) is part of vertical interval; an EAV packet with V=0 indicates the following line is part of the active picture. Code is the same (0x3FF, 0, 0), and the three flags in the fourth word.

The **F** bit is used in interlaced and segmented-frame formats to indicate whether the line comes from the first or second field (or segment). In progressive scan formats, the F bit is always set to zero. 1 on an odd field, zero on an even field. Field 0 and field 1.

Video Timing Reference Codes

Data bit number	*Fourth Word (XYZ)*
9 (MSB)	1
8	F
7	V
6	H
5	P3
4	P2
3	P1
2	P0
1	0
0	0

These codes start before the start of active video, at the SAV marker.

The P's are all codes (protection bits) that are like parity; they can tell us where the mistake was and correct the mistake.

The values shown are those recommended for 10-bit interfaces. For compatibility with existing 8-bit interfaces, the values of bits D1 and D0 are not defined. 8-bit interfaces are obsolete dinosaurs. We may go to 12 bits as of last year.

These codes for SAV and EAV are defining our sync pulse.

Can't have 10 1's (3FF) or 10 0's (000) in active video.

FF and 00 values are reserved for use in timing reference signals.

The first three words are a fixed preamble. The fourth word contains information defining field 2 identification (F), the state of field blanking (V), and the state of line blanking (H).

Bits P0-P3 have states dependent on the states of the bits F, V, and H. At the receiver this arrangement permits one-bit errors to be corrected and two-bit errors to be detected.

This following table holds the allowable sets of values for this word.

F	*V*	*H*	*P3*	*P2*	*P1*	*P0*
0	0	0	0	0	0	0
0	0	1	1	1	0	1
0	1	0	1	0	1	1
0	1	1	0	1	1	0
1	0	0	0	1	1	1
1	0	1	1	0	1	0
1	1	0	1	1	0	0
1	1	1	0	0	0	1

Ninth and 18th harmonics of the 13.5 MHz sampling frequency (nominal value) specified in Recommendation ITU-R BT.601 (Part A) fall at the 121.5 and 243 MHz aeronautical emergency channels.

The clock signal is a 27 MHz square wave where the 0-1 transition represents the data transfer time. This signal has the following characteristics:

Width 18.5 +/- 3 ns

Jitter less than 3 ns

Clock to data timing chart. Diagram 3. Went over this too fast.

Line driver characteristics (source) not worth going over right now, but they are available for twisted pair. Line receiver characteristics also.

Idealized eye diagram corresponding to the minimum input signal level. Get some overlapping. As signal corners round out more andmore, will have the eye created by the overlapping distorted square wave. Diagram 6. Jitter creates a less sharp line. The diagram collapses the voltage readings over time; each voltage reading is either high or low,not both at the same time. This is what creates the eye, this collection of voltage readings over time.

How can we recover a signal like this? As we average the amplitude, it doesn't give good results. Look through the center of the eye, as long as the eye is open just a little bit. Can tell whether the point at the eye is high or low. As long as the eye is opened a little bit, we can recover the data perfectly.

The width of the window in the eye diagram, within which data must be correctly detected, comprises +/- 3 ns clock jitter, +/- 3 ns data timing, +/- 5 ns available for differences in delay between pairs of the cable.

If noise and jitter overwhelm the signal, the eye is closed and the signal is not recoverable. This is what can produce the cliff effect.

Look at chart back in the control room.

4:2:2

Component streaming.

Line i: Y CB Y CR Y CB Y CR Y ...

Line i + 1: Y CB Y CR Y CB Y CR Y ...

The actual start of video is a bit different so don't pay attentiion too much to this before.

In SD and ED apps, the parallel data format is 10 bits wide, in HD apps, it is 20 bits wide divided into two parallel 10-bit datastreams (known as Y and C).

The SD datastream is arrangedCB Y CR Y' CB Y CR Y'.

The HD datastreams are:

1. Y Y' Y Y' Y Y' Y Y'
2. Cb Cr Cb Cr Cb Cr Cb Cr

Cosited: the one without the prime.

CB, Y, and CR are sampled together, then Y prime is sampled separately. The Y prime is the Y sampled without sampling the C; it is not co-sited. The Y is sampled at the same time as CR and CB; the Y is co-sited.

For all serial digital interfaces, excluding the obsolete composite encodings, the native color encoding is 4:2:2 YCbCr format.

The luminance channel Y is encoded at full bandwidth (13.5 MHz in 270 Mbit/sec SD, ~ 75 MHz in HD), and the two chrominance channels (Cb and Cr) are subsampled horizontally, and encoded at half bandwidth (6.75 MHz or 37.5 MHz). 1.5 Gbits/sec total for HD. This is for a single stream/wire. The HD here is for HD-SDI. How far can run along a cable? Frequency is the biggest determinant, so would be substantially less than for standard definition SDI.

The Y, Cr, and Cb samples are **co-sited** (acquired at the same instance in time), and the Y' sample is acquired at the time halfway between two adjacent Y samples.

Video payload as well as ancillary data payload may use any 10-bit word in the range 4 to 1019 (004 to 3FB in hexadecimal) inclusive. The values 0-3 and 1020-1023 are reserved and may not appear anywhere in the payload. These reserved words have two purposes: synchronization packets, ancillary data headers.

The luminance channel defined such that a signal level of 0 mV is assigned the code word 64 (40 hex), 700 mV (full scale) is assigned the code word 940 (3AC hex). These voltages are going back to analog video.

For chroma channels, 0 mV assigned code word 512 (200 hex). There are positive and negative excursions on chroma since are taking Y out. Down to 64 at -350 mV, up to 960 (3C0 hex) at +350 mV.

Note that scaling of luma and chroma channels not identical. Minimum and maximum of ranges represent preferred signal limits, though video payload may venture outside these ranges. The reserved words of 0-3 and 1020-1023 are never used for video payload. Have some cushion at either end in case somebody didn't adjust things exactly. In addition, the corresponding analog signal may have excursions farther outside of this range.

Comment on Coax in Radio

Radio started out with 50 ohms; that's where you will see 50 ohm coax, tees, barrels.

What Device Would Reclock?