TEST AND MEASUREMENT

Advanced Time and Frequency Domain Analysis of Serial Component Digital Transmission of Video Signals

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Introduction

Serial transmission of data representing video and audio signals has become standard practice across the broadcast industry. The advantages are many, with high data rate capability, self-clocking encoding schemes, and acceptance by standards-making bodies being just a few. Yet with these advantages comes a new set of parameters that needs to be monitored and controlled to insure ensure proper data transmission. Certainly the attributes of the data waveform itself have a major impact upon transmission accuracy -_ commonly referred to as monitoring of the signal's "eye pattern.". Yet, at any time, domain monitoring of the eye pattern can only give partial information about one of the most important serial transmission parameters- _ jitter. Other, more advanced testing means are required for full jitter analysis.

This paper discusses the parameters essential to proper serial data transmission of serial component video signals and a. Advanced monitoring methods. are also presented.

A Brief Explanation of Serial Video Transmission

The standardization of encoding and serial transmission specifications is one of the major advantages to the present state of the industry. The Society of Motion Picture and Television Engineers (SMPTE) has codified the methods used in the broadcast industry, and these are now universally accepted by equipment manufacturers, broadcasters and all the intermediate contributors.

Serial data transmission involves taking the stream of 10-bit words used in uncompressed component video schemes, turning the parallel stream into serial, generating a new serial clock (at a frequency equal to the serial data rate), encoding the serial stream to lower the average frequency and more evenly distribute frequencies within the allotted bandwidth and, finally, creating an electrical signal to launch onto a cable.

NRZI (Non-Return to Zero Inverted) is the basic encoding scheme used in video transmission. Using NRZI, any binary "1" produces a transition in the serial data stream. A binary "0" does not cause a transition. This technique is advantageous since it lowers the average transition frequency and makes the resulting data stream polarity independent.

Further encoding is performed to more evenly distribute transitions in the final serial stream. This encoding uses a SMPTE-defined scrambling polynomial, ensuring a long series of binary "0" values does not cause a corresponding lack of transitions in the serial stream. A side effect of the scrambling polynomial is that certain flat field signals can cause relatively long periods without transitions in the serial data stream. These signals, referred to as "pathological," can cause up to 20 bit periods without a transition.

Parameters Influencing Serial Transmission Integrity

As effective as these techniques are, there are still numerous challenges in transmitting data at these high rates. These challenges are exacerbated in the broadcast industry by the fact that almost all physical interconnects are still 75 W coaxial cable terminating in BNC connectors. Typically, fiber is used only for very long transmission paths.

The issue of bandwidth is especially crucial for high-definition (HD) serial data transmission, where the data rate is 1.485 Gb/s. Even with the NRZI and data scrambling techniques, this data rate still requires approximately 2.1 GHz of bandwidth to maintain the data waveform integrity. Other networking technologies use similar or higher data rates. However, these typically use either fiber as the physical medium or are intended for shorter distances than that used with video data transmission.

Bandwidth limitations and impedance discontinuities are factors directly related to using coaxial cable and connectors. Numerous manufacturers produce cable with bandwidths capable of supporting these data rates, but obviously no coaxial cable will have the bandwidth of fiber. Limiting bandwidth produced the same effects on the data transmission waveform as on any other non-sinusoidal wave shape — rise and fall times are slowed, causing the waveform to appear more sinusoidal, and other time-domain effects may appear, such as over- and under-shoots.

Longer cable lengths will also attenuate the electrical signal amplitude. Some of this loss is ohmic, caused just by the resistance of the wire within the cable itself. Additionally, some is related to bandwidth, since the higher frequencies of the data carrier are more attenuated than the lower.

Reduced signal amplitude can indirectly cause frequency domain effects as well. Every piece of equipment used with serial data transmission uses a cable equalizer component to automatically restore the received signal to nominal amplitude. Obviously, the lower the received amplitude, the more gain required to perform this equalization. Noise introduced in this analog process will appear as jitter in the equalized data waveform.

This is, however, only one way that jitter can be introduced into the serial transmission path. The generation of the serial data rate clock signal (from the parallel rate clock) is typically performed by a phase locked loop (PLL). The design of this PLL circuit is critical in the overall jitter performance. Some amount of residual jitter is always present, but this process can either attenuate or amplify the jitter present on the parallel clock, or do both simultaneously but at different jitter frequencies. This circuit can also introduce patter-dependent jitter; this occurs when the jitter changes throughout the video frame based on the video signal contents. One common example of this effect is a step change in jitter amplitude occurring during the video vertical interval. Other similar effects may be observed, such as jitter steps during high-luminance video content.

While the overall jitter amplitude is a crucial factor in assessing a serial video transmission system, it is meaningless without knowledge of what jitter frequencies are present. Jitter at a particular amplitude (time value) will have a drastically different effect on a system if its frequency varies widely. The two jitter quantities _ amplitude and frequency _ cannot be separated when analyzing a system; knowledge of one parameter is meaningless without knowledge of the other.

Common Measurement Techniques

Any amplitude vs. time display _ such as produced on an oscilloscope _ will give information about the amplitude parameters of a serial data electrical signal. Simple jitter analysis _ the overall jitter amplitude _ can also be measured with a data waveform. When allowed to accumulate over many bit periods, the waveform commonly referred to as an "eye pattern" is produced. All possible combinations of transitions or lack of transitions are displayed over many bit periods, producing a square-wave type data waveform.

However, using an oscilloscope to view an eye pattern is difficult for a variety of reasons. The first is bandwidth _ for proper evaluation of HD signals, an oscilloscope with at least 10 GHz response should be used. This allows enough harmonic content to accurately reproduce the edge times of the data signal. Obviously, oscilloscopes with these bandwidths are quite expensive and cannot be used for any other digital video signal analysis. Waveform storage is another concern; many data points need to be accumulated in order to view a proper eye pattern, requiring substantial memory. Accurate triggering is also critical. An oscilloscope must be able to accurately trigger at the serial data rates, and do so while introducing a minimum of variable triggering delay, which will appear as jitter in the serial waveform.

The jitter high-pass (HP) filters required by SMPTE specs will not be available in an oscilloscope. These filters are intended to show the range of jitter frequencies present. For instance, selecting an HP filter of 1 kHz will show only (within the filter's passband response) those jitter frequencies above 1 kHz, eliminating low frequencies and wander. Since these filters require clock regeneration using a PLL, no similar capability exists with oscilloscopes.

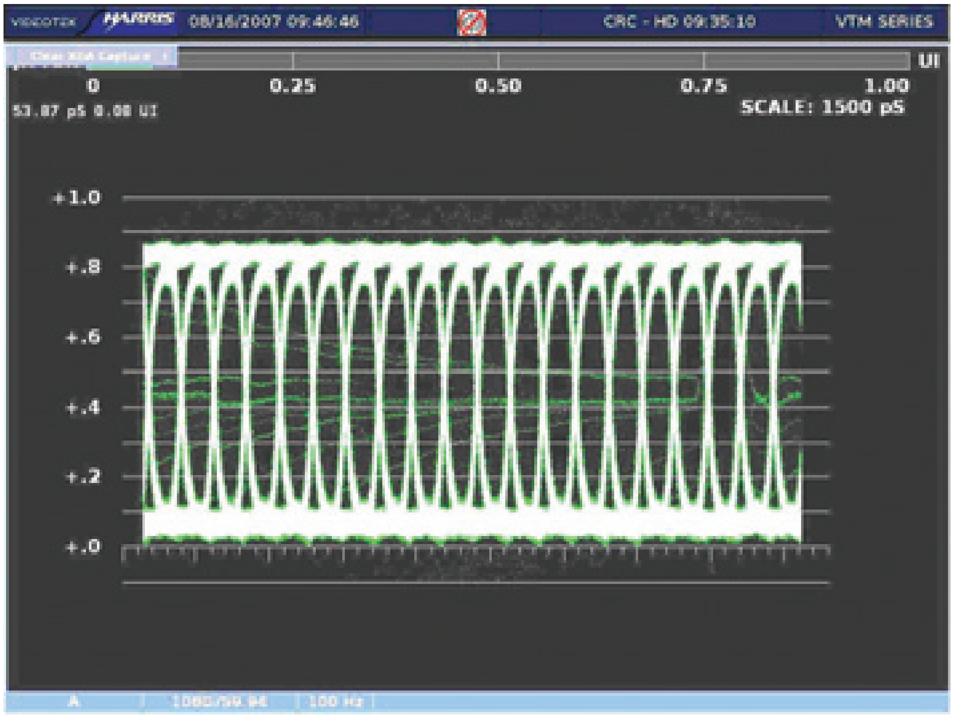
For these and other reasons, eye patterns are typically viewed on video-specific test equipment. Many waveform monitors designed for the serial data interface (SDI) also have the ability to display eye patterns. The display is still essentially that of an oscilloscope _ a voltage vs. time analog waveform. However, being a video specific device, the controls are already optimized for eye pattern display. There is no specific sweep control, for instance; instruments typically just have a setting for the number of "eyes" (bit times or unit intervals (UI)). The amplitude setting is also preset to the expected value. The eye pattern's jitter response can also be readily viewed; all current models allow the use of jitter high-pass filters to display only jitter frequencies above a set value.

Advanced Measurement Features

Some existing tools exhibit anomalies that can yield incomplete or even misleading measurements.

One such area is in the most basic display _ the eye pattern itself. Most existing test instruments perform adequately with basic test patterns, such as color bars. However, many of these same instruments do not display some of the serial data stream characteristics that are unique to the SDI check field (often colloquially referred to as a "pathological" signal).

The receiver equalizer test portion of the SDI check field is defined for HD signals in SMPTE RP198 and produces 19 consecutive bit times without level transitions, followed by one bit time of the opposite polarity (either starting level can occur). This pattern produces a high DC level in the serial stream. It also produces an asymmetrical eye waveform because of this DC offset. Many instruments lack the sample rate and display persistence to properly see this asymmetrical result. An example of the eye pattern produced by such a signal is shown to the right



Two items are apparent from this display. First, the single period leading to the high DC offset can clearly be seen. Second is the effect of this offset _ it produces middle logic levels while the input coupling capacitors are charging and discharging.

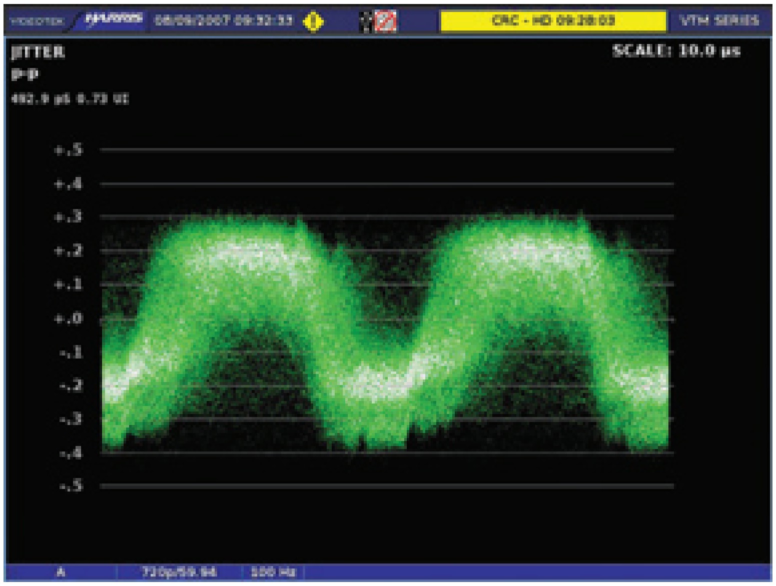
Another advanced feature of the basic eye pattern display is extended triggering capability. Many instruments need to decode certain embedded timing reference signals within the video data stream in order to synchronize the display. This is quite functional for SMPTE 259 or 292 signals. However, any other type of stream cannot be viewed as an eye pattern.

One such commonly used format is a transport stream using DVB-ASI. DVB-ASI (often referred to as just "ASI") is a method of transport that uses SMPTE 259 data rates (270 Mb/s) to carry MPEG-encoded video. Multiple video signals can be carried in an ASI transport stream. ASI streams use non-return to zero (NRZ) encoding, differing from the non-return to zero inverted encoding scheme of SMPTE 259 and 292. The difference in payload and encoding prevents many instruments from locking to an ASI input. However, jitter evaluation is still critical in an ASI system, and the same displays and techniques used for uncompressed streams apply to ASI transport streams as well.

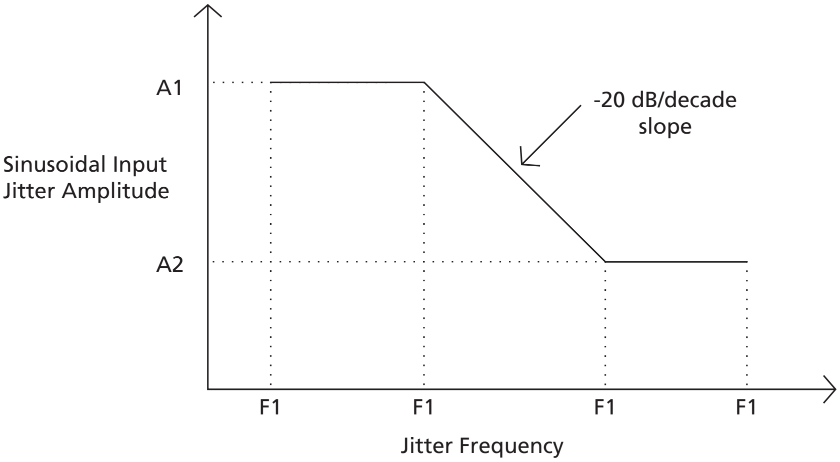
As useful as eye waveform analysis is, it has numerous weaknesses when analyzing jitter. An eye pattern display can tell us the total amount of jitter, but it gives no indication of jitter frequency or jitter variances over time. Other techniques are required for these analyses.

The output of the jitter demodulator gives an accurate view of jitter vs. time. This output is usually plotted as jitter amplitude (as the Y axis) and time (as the X axis) at typical video sweep rates _ one or two lines or fields. This yields a plot of jitter that shows any pattern dependencies, such as jitter steps during vertical interval or due to video content. Certain test patterns (particularly the SDI check field) can show appreciable jitter steps at the point in the field where the pattern changes.

Examining only the eye waveform cannot reveal this change of jitter with time. The figure to the right shows a jitter waveform at a two video line rate. Note the large change in jitter amplitude from the active portion of the line to horizontal blanking. Similar changes can often be seen at field rates with the changes in jitter amplitude occurring at vertical blanking.



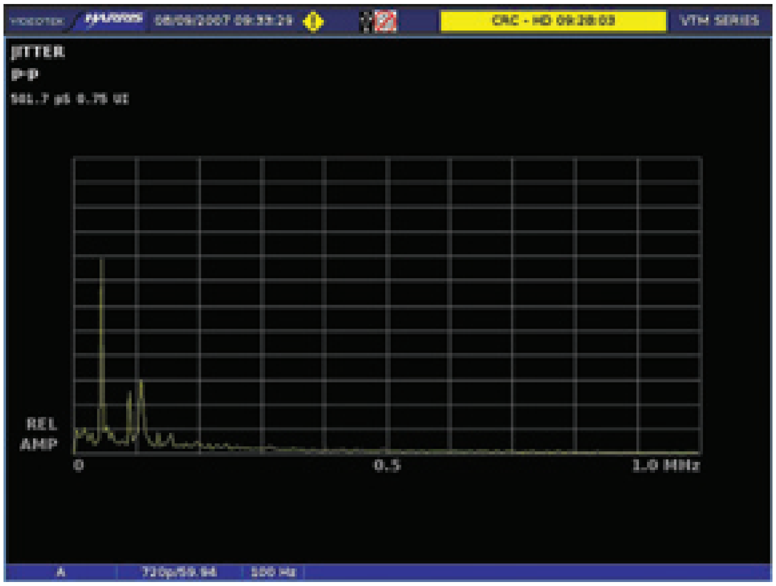
Further analysis of this waveform can yield information about the frequency content of the jitter. With additional processing of the jitter waveform, different jitter frequencies present in the jitter can be calculated and plotted as a histogram. Like a dedicated spectrum analyzer, both the total bandwidth and the resolution bandwidth can be adjusted, allowing anything from a coarse overview to a narrow and specific frequency range to be analyzed.



Analyzing jitter frequency is crucial, since it is a critical part of a system's jitter tolerance. The total amount of jitter that any system can process with acceptable performance is frequency dependent. Systems can usually tolerate more absolute jitter at very low frequencies. Jitter tolerance decreases at mid-band frequencies (roughly 100Hz to 1 kHz) before starting to decrease again at high frequencies outside the response range of the serial receiving circuitry. So, knowing the absolute jitter value is not enough to predict the response of the system; the frequency must be known as well.

The relationship between jitter amplitude and frequency in HD systems is well-defined in SMPTE RP 184 and S 292. These specifications define a lower frequency for jitter of any type. In HD systems this frequency is 10 Hz – frequencies below this are defined as wander. They also show the overall system jitter tolerance decreasing as jitter frequencies increase.

Measuring these amplitude and frequency relationships is critical in determining system performance. Simple jitter amplitude values are meaningless without knowing the frequencies comprising that jitter. Any other measuring or monitoring means _ such as alarms based on jitter values _ are similarly limited without knowing the frequency of the jitter being measured. The figure below shows one method of examining the relationship between jitter amplitude and frequency.



Conclusion

A set of SMPTE Recommended Practices and an Engineering Guide provides detail to the industry on the definition and measurement of jitter in bit serial systems. One of the key points in these documents is the relationship of jitter frequencies to system tolerance. Yet this aspect is often overlooked in system analysis.

Advanced jitter analysis requires not only accurate jitter values, but knowing what frequencies comprise the jitter present in any system. The ability to see jitter frequencies is key in determining system performance.

However, advanced analysis is not limited to frequency studies. Many current instruments have limitations even in simple time domain views, such as the eye pattern. Distortions and transient conditions are often not captured _ advanced triggering capabilities are required to do so. Other advantages of such triggering capability include the ability to analyze other signal formats, such as DVB-ASI transport streams.

For more information please visit www.broadcast.harris.com.

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