Applied Video Imaging

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A Clear Advantage: SDI and HD Video Standards

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Introduction

Modern electro-optical/infrared (EO/IR) sensors and geolocation systems provide image data that supports situational awareness for mission execution and safe aircraft operation. The transport and display of this uncompressed high definition imagery is critical to both safety and mission effectiveness.

As various video standards have evolved, they have been incorporated into airborne surveillance applications with mixed results. With the advent of the Serial Digital Interface (SDI), a set of standards have emerged that is ideally suited to airborne surveillance mission systems. SDI and the resultant High Definition imagery standards provide superior image quality over longer distances and video transmission that is more immune to amplitude and noise issues, as well as lowering installation weight and complexity.

SDI

SDI (Serial Digital Interface) is the digital transport of video signals over point-to-point serial links.

What is SDI exactly? SDI is the internationally based standard for the digital transport of uncompressed video signals over point-to-point serial links. With its genesis in television broadcasting, SDI based systems are now becoming more common in the military and law enforcement. The Society of Motion Picture and Television Engineers (SMPTE) is the standards body that has developed both the technical requirements and standards for SDI. These standards cover the physical interface, timing, encoding, payload and image format of video content.

SDI based system architectures for airborne video surveillance systems increase the effectiveness and safety of operators tasked with flying these missions. By setting the foundation for both current and future video technology, the SMPTE standards have resulted in creating a video infrastructure that has many advantages. The benefits and merits of the technology provide a superior solution that reduces costs, weight and complexity while maximizing the visual interface between imaging sensors and the operator.

SDI Physical Interface

SDI is designed for transmission of serially encoded digital video data over both coaxial and fiber-optic cable. Coaxial interfaces are based on 75Ω impedance using ECL (Emitter-Coupled-Logic) operating at 0 – 0.8 volts. Typically, BNC connectors are used as the terminating connectors on coax cables.

Figure 1 - RG179 BNC cable.

The type of image data being transmitted effectively sets the bit rate for the SDI interface. Nominal bit rates for SDI range from 143 Mb/s to 3 Gb/s. The data transmitted by SDI consists of active video framed by timing reference signals (TRS). Ancillary data can also be present in the data stream in any regions not occupied by active video or TRS sequences. This data may be audio or other information.

SDI data transmission on the cable is one-way. No separate sync or timing references lines or cables are required and sync signals are not coded as a signal level - they are part of the SDI data payload. Because of the technology employed, SDI provides a robust digital signal immune to amplitude and noise issues commonly found in analog and other digital video formats such as VGA, DVI, and HDMI.

The SDI serial data stream may contain both video data and ancillary data, such as audio and timing codes.

The popularity of SDI in many industries has produced a large ecosystem of companies that support SMPTE SDI standards. Typical transmission distances of SDI data over coaxial cable are dependent on the data rate and can range from 23 meters for 3Gb/s data rates to over 800 meters for 143Mb/s data rates. Over 200 meters for some cable types, drivers, and equalizers for 3 Gb/s data is not uncommon.

How the Physical Interface Relates to SMPTE Standards

The three main SMPTE standards within the scope of this article are shown in the table below.

SMPTE Standard	Bit Rate Mb/s	Nominal Bit Rate Mb/s	Name
ST 259:2008	143.1818182 177.344	143 177	SD SDI (Standard Definition)
ST 292-1:2012	1485 1483.516848	1500	HD SDI (High Definition)
ST 424:2012	2970 2970.032967	3000	3G SDI (Full High Definition)

Table 1 - SDI SMPTE Standards.

Standard Definition TV (SD) image formats fall under the SMPTE ST 259:2008 specification. SD based video image formats are usually referred to as either 525i or 625i line formats. The first two bit rates in Table 1 are composite video. The 143 Mb/s rate represents NTSC, while the 177 Mb/s rate represents PAL color encoding and was derived from the original analog television format. They are 4:3 aspect ratio interlaced images.

High Definition SDI (HD SDI) image formats are encompassed in the SMPTE ST 292-1:2012 specification. HD SDI formats are usually referred to as 720p, 1080i, or 1080p30Hz line formats (p – for progressive line scan, i – for interlaced line scan). All are 16:9 aspect ratio images.

3 Gb/s High Definition SDI (3-G SDI or Full HD SDI) image formats are included in the SMPTE ST 424:2012 specification. 3G SDI formats are usually referred to as 1080p line formats. All are 16:9 aspect ratio progressive line scanned images.

Comparisons between SDI, NTSC/PAL Analog, VGA Analog, DVI/HDMI Standards

NTSC and PAL are color encoding and analog sampling definitions – not resolutions or image formats.

NTSC/PAL Analog video was the original TV based standards for TV. VGA analog standards were developed around the consumer computer industry. As the computer and TV consumer industries began to converge, the advent of digital video resulted in DVI and HDMI technologies.

The table below shows some of the attributes between the different video standards.

Standard	Encoding	Cable Description	Transceiver	Transmission Distance	Resolutions	Aspect Ratio
SDI (SMPTE)	Digitally encoded	Single 75Ω Coaxial One Pin	ECL Point-to-Point	23m – 800m	525i, 625i, 720p, 1080i, 1080p	4:3 and 16:9
NTSC/PAL Analog (EIA)	Analog signal level	Coaxial 75Ω One Pin	Analog Op Amp Point-to-Point	100m +	525i 625i	4:3
VGA (VESA)	Analog RGB	3-5 Coaxial for RGBHV Discrete for other signals 15 Pins	Analog Op Amp Point-to-Point (for video)	3m +	640-480 Through 1920x1200	Many
DVI/HDMI (DDWG) (EIA)	Digital and Analog	4 Coaxial, 4 twisted pairs and Discrete for other signals 29 Pins, 19 for HDMI	TMDS Point-to-Point (for video)	3m +	640-480 Through 1920x1200	Many

Table 2 - Video Standards attributes.

Most SDI based devices provide some sort of loop-through capability. The transmitters for these looped-through connections provide re-clocked output. A re-clocked SDI output can be transmitted another 23 to over 800 meters. For older analog based sensors, daisy-chaining the signal without amplification causes serious image degradation.

The image in Figure 2 is a single connection for an analog NTSC camera to the display. Figure 3 below, shows the effect of just one additional connection to the signal cable while Figure 4 below shows the effect after three connections. These images do not show the additional effects of noise and impedance issue due to miss-matched cable lengths that would be present in an actual installation. The use of video amplifiers would be required for each leg.

Sometimes Composite NTSC video is referred to as RS-170. This was the original "black-and-white" TV signal definition per EIA. NTSC defines the color encoding, whereas RS-170 defined the signal waveform and timing.

Impact of SDI on Mission Systems

Changes in the consumer video market are having a major impact on video systems used in rugged airborne applications. The convergence of the computer and TV video formats to HDMI and the extinction of older analog-based standards such as VGA and NTSC/PAL makes SDI based mission systems more relevant. Video transport using DVI and HDMI are not practical in airborne applications due to cable types, weight, transmission distances, and noise environments. Also, the multitude of older various interfaces and formats is problematic for installation, use, and support.

The major manufacturers of video sensors and geolocations devices have recognized this and are providing SDI based output. They are also improving sensor resolution within the SDI standards with both 720p and 1080p video output capability. Companies like Applied Video Imaging are supporting this transition by providing products that convert other video standards and resolutions to the SDI standard. SDI has mandated 16:9 aspect ratios for HD and 3-G SDI, along with progressive based scan line images which has had a positive impact on capability and effectiveness for mission system operators.

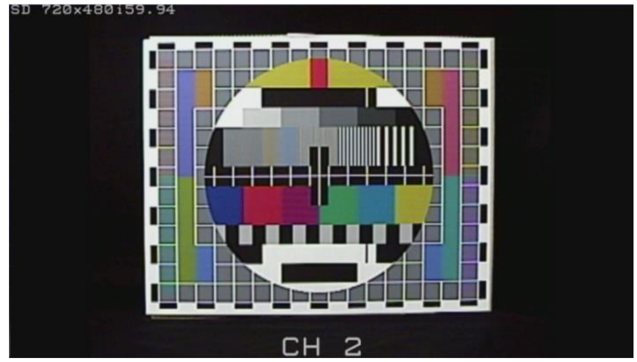

Figure 2 - Analog NTSC signal with one connection.

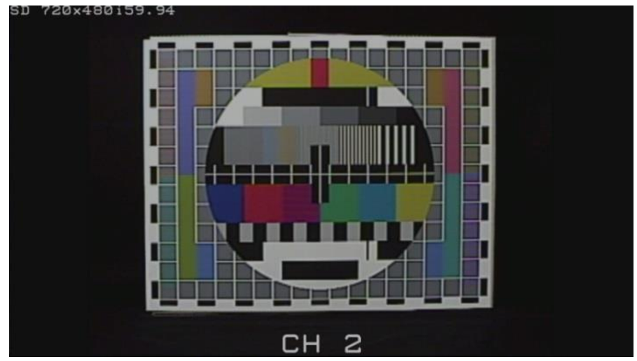

Figure 4 - Analog NTSC signal with two connections.

Figure 3 - Analog NTSC signal with three connections.

Benefits of SDI Architectures

As mentioned, there are numerous benefits for adopting SDI based architectures in today's airborne video mission systems. Lower installation costs, lower weight, higher performance, higher reliability, and more effective use of video sensor data for mission execution are the main benefits. The list below highlights these benefits.

- Accommodates full HD image presentation and beyond
- Low latency transport
- Uncompressed video with no image informational loss through compression such as MPEG4
- Superior image quality over longer distances

- Robust digital signal immune to amplitude and noise issues associated with analog and DVI signals
- Long cable lengths possible from 23 meters to over 800 meters, no amplifiers needed
- Only a single coaxial cable required
- Lower overall cable weight and cable installation complexity
- Transport of multiple image formats and resolutions over the same infrastructure
- Evolving standards accommodate existing cable plant
- An internationally accepted set of video standards
- Interoperability of standards-based SDI equipment
- Large commercial ecosystem of SDI based component suppliers
- Standards for fiber cable exist
- SDI provides transport of ancillary data for audio and other meta data
- Surveillance system components can be easily upgraded without changing the existing cabling plant
- Easily switched for routing purposes
- Easily looped through from device to device for daisy chained configurations

RG179 cable weighs 10 lbs/1000 ft. VGA cable weights 85 lbs/1000 ft

SD vs HD and 3-G

In a video system, image resolution is assumed to be the pixel count of the display device. For instance, an SD image at about 720 horizontal pixels by 480 vertical lines and 3-G image at 1920 horizontal pixels by 1080 lines. However, many more factors are involved such as bandwidth, Field of View, aspect ratio, viewing distance, visual acuity, and scanning technique. It is the perceived sharpness of the image presented to the viewer that is relevant.

Technical Factors - Frequency Response and Bandwidth

Any video system contains electric signals with varying frequencies from low to very high. The effects of capturing, processing, distributing, and the effects of spatial and temporal dispersion causes a system's frequency response to diminish at higher frequencies. When the system's frequency response falls below what can be visually detected, it has reached its limiting resolution. The ranges of frequencies that a system can capture, process, transmit, and display is known as its bandwidth.

The resolution of a display defines the upper bounds of the resolution of the image. However, the bandwidth of the image can be well under or well over the bandwidth that the display is capable of rendering.

To illustrate this, consider two CCD cameras – one that outputs a 1080p image and one that outputs a NTSC analog signal (720x480). Both cameras are capturing the exact same test pattern at 44" from the camera lenses. Both images are displayed on an AVI 17.3" 1080p SDI display. The NTSC signal has been converted to SDI so that both images could be displayed at the same time side-by-side. The image in Figure 5 represents the 1080p image. Figure 6 represents the NTSC image. The lower bandwidth of the NTSC signal is evident in both the ability to resolve the patterns and numbers and black to white transitions.

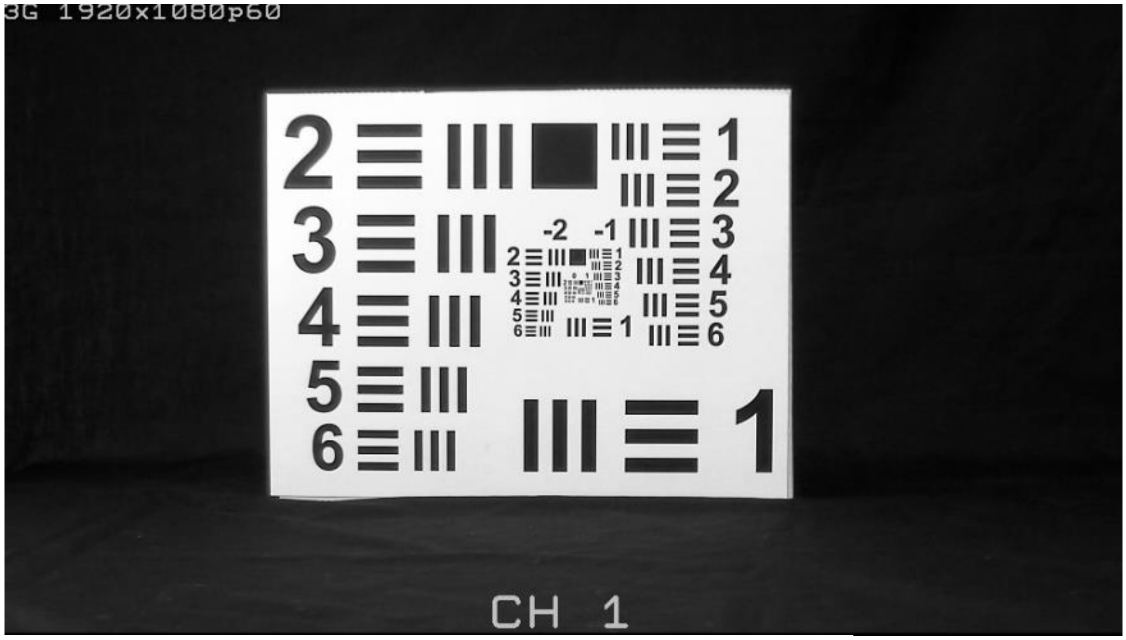

Figure 6 – 1080p image.

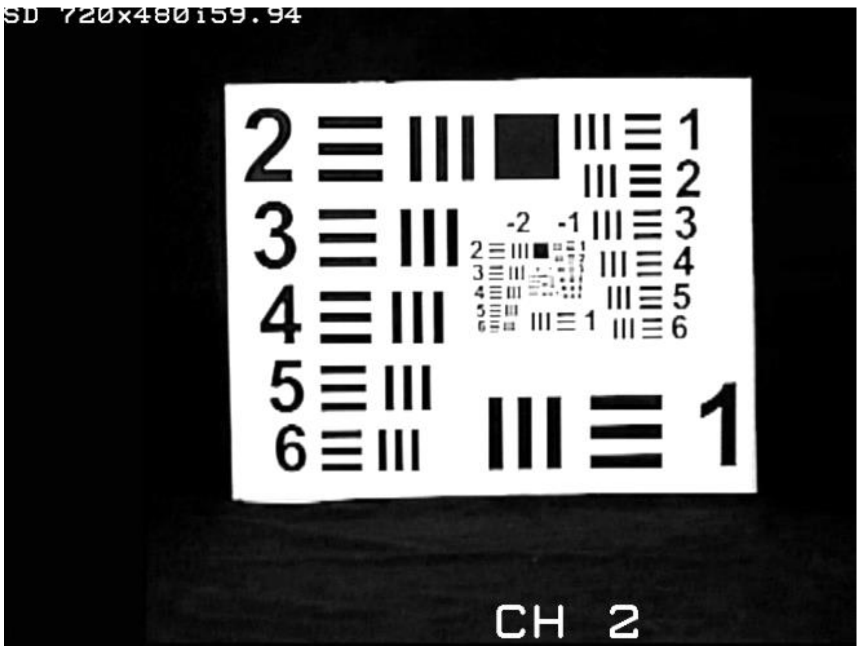

Figure 5 – 525i image.

Human Factors – Visual Acuity, Viewing Distance, and Angle

A person with 20/20 vision can discriminate elements of a pattern, such as numbers and lines, which subtend 1/60^{o}. This is the approximate limit of angular discrimination in normal vision. The optimal viewing distance from a display is the point in which individual pixel rows are no longer discernable and is also known as limit of visual acuity.

For SD, there are approximately 480 vertical lines. The vertical line subtends 1/60^{o} at about 7 times the image height, which is the approximate optimal viewing distance from a SD image.

With approximately 720 pixels horizontally and given a 4:3 aspect ratio for standard definition image, the resulting view angle is 11^{o}.

For HD and 3-G, there are 1080 vertical lines. The vertical line subtends $1/60^{o}$ at about 3.2 times the image height which is the approximate optimal viewing distance from HD image. With 1920 pixels horizontally and given a 16:9 aspect ratio, a HD image results in a viewing angle of approximately 32^{o}.

So the main advantage of increased pixel count is an increased viewing angle. The human Field of View (FOV) is wide: 40^{o} FOV is considered comfortable. If the FOV is too wide, excess eye motion and lower scene cognition results. If the FOV is too narrow, the image seems too small resulting in eye strain and impaired scene cognition.

This mission system example using a 17.3" diagonal 1080p AVI display illustrates these factors:

- The display's image height is approximately 15". This gives an optimal viewing distance of 26", which is close to the fixed position of a pilot or tactical officer.
- A human with 20/20 vision has the visual acuity to discern 132 Dots Per Inch (DPI) at this distance.
- The display width results in 128 DPI, so the display closely matches both the visual acuity of the operator and his optimal viewing angle.
- A standard definition image on the same display would only contain 48 DPI worth of data.
- At a 26" viewing distance, the optimal distance of a 4:3 aspect ratio display would dictate a display of approximately 5x3.7 inches, otherwise, objectionable artifacts begin to show.
- The 11^{o} viewing angle at this distance would render the image too small.

To sum it up, the resolution that the operator can perceive is a factor of the distance from the display, the bandwidth of the information within the image, the operator's visual acuity, in addition to the actual pixel resolution of the display. The distance away from the display determines the FOV and impacts the perceived resolution.

Interlaced vs Progressive

Progressive scan line imagery is an important improvement that SDI has brought to mission systems. With interlaced systems such as NTSC and PAL (and even SDI 1080i), alternate lines are captured and transmitted from the sensor. First the odd lines are scanned, and then the even lines are scanned. Each group is known as a field. Video is captured at 50 or 60 individual fields per second. When objects within the image field move, the information in the second field is offset from the first field based on the objects' motion relative to the camera. This creates an effect called field tearing as illustrated in Figure 7.

Figure 7 - Field tearing in an interlaced image.

Many different processing methods help to minimize this effect but it cannot be totally eliminated without introducing other artifacts such as motion blurring or vertical resolution reduction.

Aspect Ratios

HD and 3-G SDI image standards, dictated a change from 4:3 image aspect ratios to 16:9 aspect ratios. Some of the benefits of 16:9 aspect ratios have been discussed such as larger fields of view.

Besides 28.57% larger image area, the use of 16:9 aspect ratio can provided the advantage of greater situational awareness.

Figure 8 - Aspect ratio comparison.

For example, an image captured by a SD 4:3 aspect ratio sensor in Figure 9 tells only part of the story. The same scene, Figure 10, captured by a HD 16:9 aspect ratio sensor significantly changes the context of the image.

Figure 9 - 4:3 Aspect ratio scene.

Figure 10 - 16:9 Aspect ratio scene.

Conclusions

SDI based system architectures for airborne video surveillance systems increase the effectiveness and safety of operators tasked with flying these missions. By setting the foundation for both current and future video technology, the SMPTE standards have resulted in creating a video infrastructure that has many advantages. The benefits and merits of the technology provide a superior solution that reduces costs, weight, and complexity while maximizing the visual interface between imaging sensors and the operator.

About Applied Video Imaging, LLC - Applied Video Imaging designs and manufactures advanced rugged video processing, distribution, recording, and display products for the airborne, ground, and marine surveillance markets. AVI's products, services, and solutions optimize surveillance sensor suites, enhancing the platform and operator's mission effectiveness. For more information, visit www.appliedvi.com or call 434-974-6310, toll free 855-974-6310