ARINC 818 Adds Capabilities

for High-Speed Sensors and Systems

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ABSTRACT

ARINC 818, titled Avionics Digital Video Bus (ADVB), is the standard for cockpit video that has gained wide acceptance in both the commercial and military cockpits including the Boeing 787, the A350XWB, the A400M, the KC-46A and many others. Initially conceived of for cockpit displays, ARINC 818 is now propagating into high-speed sensors, such as infrared and optical cameras due to its high-bandwidth and high reliability.

The ARINC 818 specification that was initially release in the 2006 and has recently undergone a major update that will enhance its applicability as a high speed sensor interface. The ARINC 818-2 specification was published in December 2013.

The revisions to the specification include: video switching, stereo and 3-D provisions, color sequential implementations, regions of interest, data-only transmissions, multi-channel implementations, bi-directional communication, higher link rates to 32Gbps, synchronization signals, options for high-speed coax interfaces and optical interface details. The additions to the specification are especially appealing for high-bandwidth, multi sensor systems that have issues with throughput bottlenecks and SWaP concerns. ARINC 818 is implemented on either copper or fiber optic high speed physical layers, and allows for time multiplexing multiple sensors onto a single link.

This paper discusses each of the new capabilities in the ARINC 818-2 specification and the benefits for ISR and countermeasures implementations, several examples are provided.

Keywords: ARINC 818, sensors, ISR, countermeasures, high-speed video.

1. INTRODUCTION

The ARINC 818 Avionics Digital Video Bus (ADVB) is the standard for cockpit video that has gained wide acceptance in both the commercial and military cockpits. The Boeing 787, A350XWB, A400M, KC-46A, and many others use it. Initially conceived of for cockpit displays, ARINC 818 is now propagating into high-speed sensors, such as infrared and optical cameras, due to its high bandwidth, low latency and high reliability.

The ARINC 818 specification, initially released in the 2006, has recently undergone a major update that enhances its applicability as a high-speed sensor interface. The ARINC 818-2 specification was published in December, 2013.

The revisions include video switching, stereo and 3-D provisions, color sequential implementations, regions of interest, data-only transmissions, multi-channel implementations, bi-directional communication, higher link rates to 32 Gb/s, synchronization signals, options for high-speed coax interfaces, and optical interface details. The additions to the specification are especially appealing for high-bandwidth, multi sensor systems that have issues with throughput bottlenecks and SWAP concerns. Additionally, systems with high speed sensors that do target tracking can also benefit from ARINC 818-2s ability to switch from full images to very high speed regions of interest. ARINC 818 is implemented on either copper of fiber optic high-speed physical layers, and allows for time multiplexing multiple sensors onto a single link.

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This paper discusses basics of ARINC 818-1, and provides an overview of the new capabilities in the ARINC 818-2 specification and the benefits for ISR and countermeasures implementations by highlighting several examples.

2. ARINC 818 BACKGROUND AND SCOPE

The world of motion intelligence is changing rapidly, trying to keep up with constant new threats and struggling to incorporate new technologies. One goal is to enable full motion video (FMV) 3.0, which will lead to smarter, faster, and more accurate processing, exploitation, and dissemination (PED) systems. The growing number of sensors that operate at higher and higher resolutions and update rates have the intelligence communities drowning in data and system designers scrambling to overcome technical challenges that allow systems to find, classify, and track more and more targets simultaneously.

This paper focuses on how changes to the ARINC 818 specification will allow the implementations of more complex systems, focusing especially on the sensor & mission processor/video processor interface. We will look at three example scenarios in which new features added into ARINC 818-2 will facilitate these complex interfaces. Example 1 is a sensor pod (turret) that includes various EO/IR sensors that will be fused. Example 2 is a high-speed target tracking application for ISR or countermeasures. Example 3 is an ultra-high resolution sensor for wide area surveillance (WAS).

2.1 Overview of the ARINC 818-1 protocol
Since the reader may not be familiar with ARINC 818, a brief overview of the protocol is provided. ARINC 818 was based on Fibre Channel Audio Video (FC-AV), but was simplified and tailored specifically for high bandwidth, low latency mission critical video systems.

ARINC 818 is a point-to-point, 8b/10b encoded serial protocol for transmission of video, audio, and data. The protocol is packetized, but is video-centric and very flexible, supporting an array of complex video functions including the multiplexing of multiple video streams on a single link or the transmission of a single stream over a dual link. Four different classes of video are defined, from simple asynchronous to stringent pixel synchronous systems.

2.2 ADVB Packet Structure

The ARINC 818 standard refers to the basic transport mechanism (packet) as an ADVB frame. It is important to refer to these packets as "ADVB frames" rather than simply "frames" to eliminate potential confusion with video frames.
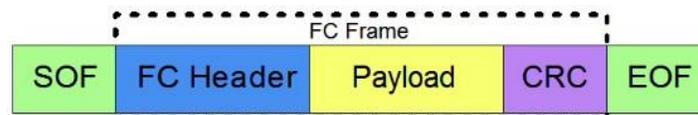

Figure 1: Structure of ADVB (Fibre Channel) frame.

The start of an ADVB frame is signaled by a SOFx ordered set and terminated with an EOFx ordered set as shown in Figure 1. Every ADVB frame has a header comprised of six 32-bit words. These header words pertain to such things as the ADVB frame origin and intended destination and the ADVB frames position within the sequence. The payload contains either video, or video parameters and ancillary data. The payload can vary in size, but cannot be greater than 2112 bytes. To insure data integrity, all ADVB frames have a 32-bit CRC calculated for data between the SOFx and the CRC word. The CRC is the same 32-bit polynomial calculation defined for Fibre Channel.

The ARINC 818 Specification, like FC-AV, defines a *container* as a set of ADVB frames used to transport video. In other words, a video image and data is encapsulated into a container that spans many ADVB frames. Within a container, ARINC 818 defines objects that contain certain types of data. That is, certain ADVB frames within the container are part of an object. The four types of objects found within a container are shown in Table 1 below.

Table 1. ARINC 818 defines four types of information, called objects that can be included in ADVB frames.

Object	Data
0	Ancillary Data
1	Audio (not used)
2	Video: progressive or odd field
3	Video: even field

In most cases, a single container maps exactly to a single video frame. However, it is permissible to have less than one video frame transported in one container. This may be the case where curser information for a display needs to be updated faster than the video frame rate, or a high speed region of interest is defined. In this case, a fractional part of the frame may be assigned to the container so that the occurrence of the Object 0 ADVB frames is more frequent. The cursor location data can then be loaded in these Object 0 ADVB frames that occur more frequently, perhaps several times per video frame. The ancillary data (object 0) is where user defined information can be included along with the video frame, for example, key-length-value (KLV) metadata could be inserted into the ancillary data field.

An example of how ARINC 818 transmits color XGA provides a good overview. XGA RGB requires ~141M bytes/sec of data transfer (1024 pixels x 3 bytes per pixel x 768 lines x 60 Hz). Adding the protocol overhead and blanking time, a standard link rate of 2.125 Gb/s is required. ARINC 818 packetizes video images into ADVB frames. An ADVB frame is defined in Figure 1, where the maximum size of the payload is 2112 bytes. Each ADVB frame begins with a 4-byte ordered set, called an SOF (Start of Frame), and ends with an EOF (End of Frame). Additionally, a 4-byte CRC is included for data integrity. The payload of the first ADVB frame in a sequence contains embedded header data that accompanies each video image.
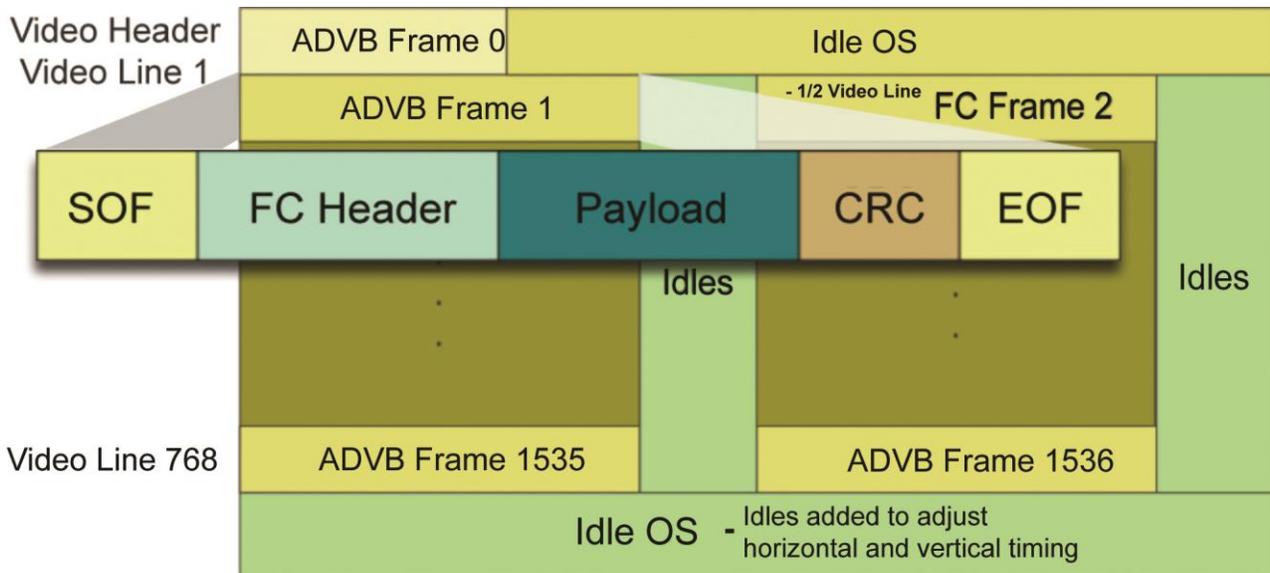

Figure 2. Example of an XGA image packetized into 1537 ADVB frames showing blanking time (idle OS).

Each XGA video line requires 3072 bytes, which exceeds the maximum FC payload length, therefore, each video line is divided into two ADVB frames. Transporting an XGA image requires the payload of 1536 FC frames. Additionally, a

header frame is added, making a total of 1537 FC frames, as represented in Figure 2. Idle characters are required between ADVB frames because they are used for synchronization between transmitters and receivers and are the mechanism for adjusting vertical and horizontal blanking adjustments.

2.3 Flexibility and Interoperability

ARINC 818 covers an almost endless variety of video formats, color encoding schemes, timing classes, and embedded data sizes to provide maximum flexibility in system design. No one system can be built capable of handling all the different permutations possible, therefore, each program defines an interface control document (ICD) to narrow down scope of each project and simply the implementation. Free ICD templates are available at www.ARINC818.com.

3. BACKGROUND ON ARINC 818-2 AND NEW FEATURES

In the last eight years, ARINC 818 has propagated quickly through the military and commercial aerospace world as the video bus of choice for high-bandwidth, low-latency avionics applications. Modern glass cockpits have many channels of ARINC 818. An increasing number of ARINC 818 channels gave rise for switching ARINC 818 as well as interfacing ARINC 818 to sensors, cameras, radars, enhanced-vision systems, recorders, mission processors, and many types of displays. To accommodate the complex ARINC 818 systems that are now being designed, the ARINC 818 specification was updated to facilitate a wider range of sensors, larger displays, command and control information, compression, encryption, sensor synchronization and video switching. Many of the new features added make ARINC 818 applicable to new classes of sensors and systems in the ISR and countermeasures world. A brief overview of the new features is given, and then different examples are provided showing how ARINC 818 can be used in different scenarios.

Throughout the spring and summer of 2013, industry participants from Airbus, Boeing, Cotsworks, DDC, Honeywell, SRB Consulting, and Thales, along with Great River Technology as the Industry Editor, drafted Supplement 2 of the specification. At the 2013 AEEC Mid-Term session held in Zagreb, Croatia, at the end of October 2013, the supplement was unanimously approved by the AEEC Executive Committee. ARINC formally published it as ARINC Specification 818-2 on December 18, 2013.

3.1 Bandwidth

At the time ARINC 818-1 was ratified, the fiber-channel protocol supported link rates of 1.0625, 2.125, 4.25, and 8.5 Gb/s. Since then, link rates of 14.025 and 28.05 Gb/s have been released with even higher speeds planned. For example, a display at WQXGA resolution (2560 x 1600 pixels @ 24-bit color) at 30 Hz would need a bandwidth of 3,864 Mb/s. ARINC 818-2 added 5.0, 6.375 (FC 6x), 12.75 (FC 12x), 14.025 (FC 16x), 21.0375 (FC 24x), and 28.05 (FC 32x) Gb/s rates. The 6x, 12x, and 24x speeds were added to accommodate the use of high-speed, bi-directional coax with power as a physical medium.

The industry is starting to use very high speed implementations for sensors and displays. Both the Xilinx Virtex 7 and the Altera Stratix V FPGAs have variants with 28Gb/s transceivers, making ultra-high speed ARINC 818 implementations possible.

3.2 Compression and encryption

ARINC 818 was originally envisioned as carrying only uncompressed video and audio. Applications such as high-resolution sensors, UAV/UAS with bandwidth limited downlinks, and data only applications are driving a need to compress and/or encrypt a link. There was a great deal of discussion about how much detail should be put into the specification. For example, should it define codecs, algorithms, and key exchange? In the end, it was decided to only put flags in the ARINC 818 containers to indicate whether the payload (be it audio, video, or data) was encrypted, compressed, or both.

Though ARINC 818 was originally designed for "man-in-middle" control and display applications, there are scenarios where encryption, compression, or both may be required. Compression, allows the video data to be shrunk so it can be transmitted or recorded using limited downlink budgets or storage limitation. Encryption protects the data during

transmission for sensitive or classified data.   These additional features might allow a sensor that was developed using ARINC 818 for a manned program to also be used on an unmanned platform with minimal changes to the ARINC 818 interfaces.

In sticking with the ARINC 818 philosophy of maximum flexibility, the interface control document (ICD) for each project specifies the implementation details.

3.3 Switching

To ensure 100 percent quality of service, ARINC 818 was designed as a point-to-point protocol. However, as cameras, sensors and the number of displays proliferate on aircraft increasing the number of channels of ARINC 818, adding switching became essential.

Because of Fibre Channel legacy, ARINC 818 containers have source and destination IDs. It is possible to route based on those addresses, though from a practical standpoint this would be hard to achieve for items such as data or audio, where the container size may change and latency becomes too large prior to the end of the payload. With video, the specification requires that active switching can only occur between video frames. In effect, to prevent broken video frames, the switch must wait until the vertical blanking period. To insure interoperability, the specification formalized only a few hard requirements. To meet the goal of flexibility, it offered only guidance in addressing other details through the project ICD.   Again, the ICD controls the implementation details.

3.4 Field Sequential Color

A video format code was added to support field sequential color. The field sequential color mode will typically send each color component in a separate container and more than just the traditional primary colors can be transmitted. Typically, each color is transmitted at a higher rate enabled by fast LED strobing.   For example, the RGB mode typically would send R, then G, then B and repeat as shown in Figure 3. Each container would be at 3X the base rate, i.e. 180 Hz for blended 60Hz video.
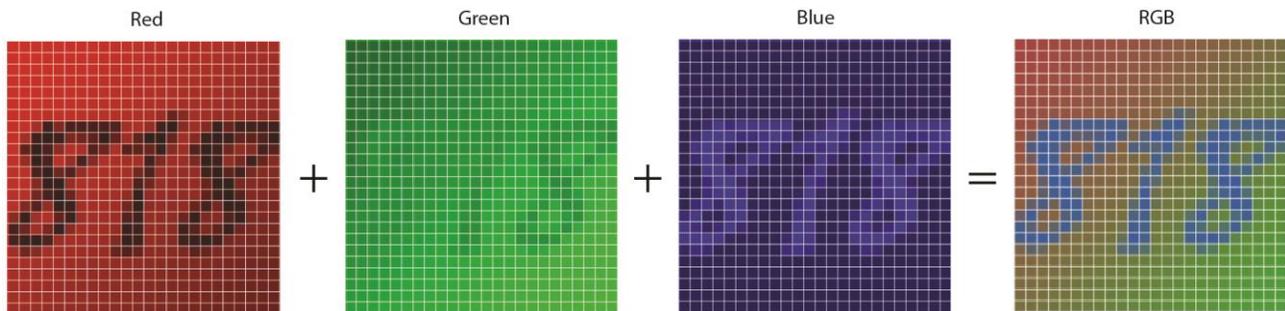

Figure 3. Field Sequential Color example showing how an RGB image is sent via three color sequential images

Today, new LCD technologies are using it for cheaper and smaller displays as one does not need sub-pixels.   These displays can be transparent as they don't require color filters. They also typically can have higher contrast and wider viewing angles.   These features make this technology very well suited for helmet-mounted and wearable displays.

3.5 Channel Bonding

One strategy to overcome link bandwidth limitations employs multiple links in parallel. The video frame is broken into smaller segments and transmitted on two or more physical links. This need may be driven by legacy cabling constraints or implementation costs where using an FPGA capable of two 4.25 Gb/s links may be cheaper than one capable of a single 8.5 Gb/s link.

For example, a WQXGA (2560 x 1600 pixels) image with 24-bit color depth at 60 Hz would require bandwidth of 737,280,000 B/s. With channel bonding, this image could be split and transmitted on two ARINC 818 4.25 Gb/s links.

ARINC 818 allows for two methods of channel bonding, at the pixel level (odd/even pixels) or at the video line level (Left/Right) as shown in Figure 4 below.
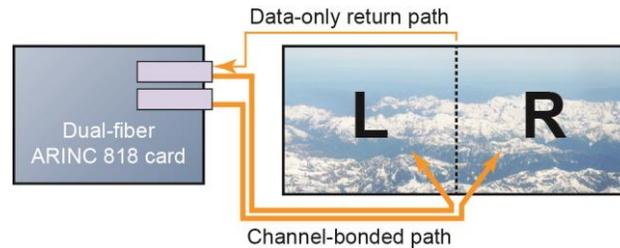

Figure 4. Example of Left/Right Channel Bonding.

3.6 Data-only Links

Added to the specification was the provision for data-only links. Data-only links are typically used as command-and-control channels. For example, a normal ARINC 818 link from a camera or sensor would carry the video stream. A data-only link would go to camera to perform functions such as focus or white balance. Another example is a return path for touchscreen or bezel-button input while video is being transmitted to a cockpit display as shown in Figure 4.

Data-only transfers can be of any size and may be comprised of multiple ADVB frames. Any special rules for packetization (e.g., the ADVB frames will be of a fixed size) must be specified in an ICD. Data-only ADVB link rates may be one of the standard link rates described above, or may be at a different rate established by the ICD. A bit in the header declares that ARINC 818 is a data only link.

3.7 Bi-directional links, high-speed coax and sensor synchronization

ARINC 818 was originally defined as a point-to-point interface to ensure 100% QOS, eliminating the handshaking required in Fibre Channel networks in favor of simplicity. However, as ARINC 818 propagated into cameras and sensors, it was necessary to establish bi-directional communication. In reality, a bi-directional camera interface is just a special case of a data-only link but it was felt that some guidance for these classes of implementations be incorporated. One important feature of providing for bi-directional links is that they allow for the video path and the command-and-control path to operate at different link rates. Allowing different rates is important on new physical layers that provide bidirectional communication over a single coax cable, in particular, 3, 6, or 12 Gb/s in on direction with a return path of 20 Mbps. Commercially available chipsets (for example, from Eqcologic/Microchip) have been demonstrated bi-directional performance over 25 meter cables and longer and has been proven through slip rings that are common in sensor pallets mounted in gimbals. ARINC 818 has been demonstrated on these high-speed coax interfaces[1].

A synchronization methodology was incorporated using bit in the header indicating that the start of frame initiate (SOFi) character is a synchronization signal. This allows the packet to be used for synchronization of multiple sensors to make operations such as sensor fusion blending easier. With ARINC 818-2, the ability to transport, merge, and control multiple devices while still maintaining the benefits of ARINC 818 is possible.

3.8 Stereo and other displays (banding and regions of interest)

ARINC 818 has always allowed stereo displays, but Supplement 2 added some control parameters to give more flexibility. It can handle not only stereo but also partial image, tiling, and regions-of-interest. Examples include vertical banding (Figure 5, Frame A), horizontal banding (Frame B), and tiling or regions of interest (Frame C).
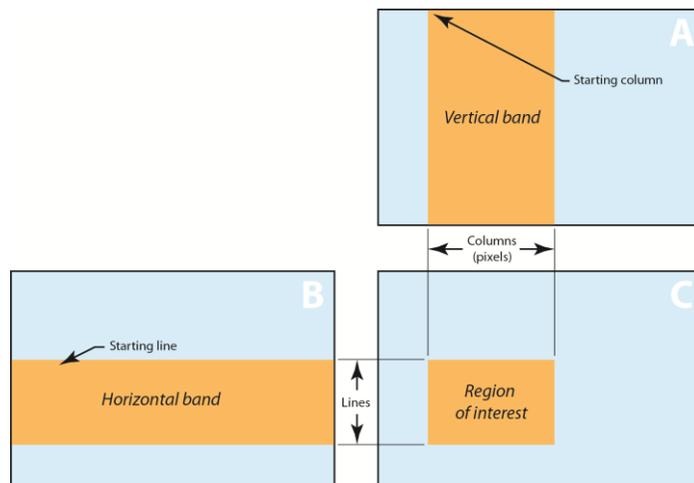
Figure 5. Tiling, banding and Regions of Interest

With the additional control, it is possible to do horizontal and vertical slices. Using a horizontal slice and vertical slice together, a region of interest can be defined. Also possible are left and right channel images, and inset areas.

4.   ARINC 818 IMPLEMENTATION EXAMPLES

4.1 Example 1: Sensor Pallet for ISR Sensor Fusion

In this example, a gimbled sensor pod containing LWIR, SWIR, and visible light sensors is interfaced using a single, ARINC 818 link over coax with a video path of 6.375 Gb/s and a return data path of 21 Mb/s as shown in Figure 6. This implementation requires a specific chipset from Eqcologic.
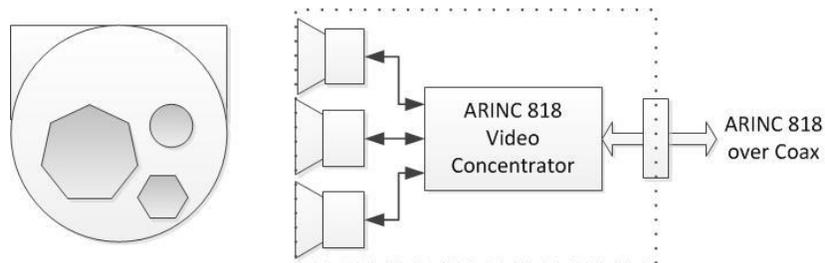
Representation of a sensor pod with three sensors an ARINC 818 interface through a single 6.375 Gbps bi-directional coax that passes through a slip ring.

Figure 6. Representation of a sensor pod containing three sensors that feed into an ARINC 818 concentrator and then through a signal coax cable through a slip ring.

Assuming the IR sensors are 1Kx1K, 14-bit mono at 60 Hz, and each IR sensor will require a bandwidth of ~110MB/s, a visible light camera is 1080p, 24 bit color at 60 Hz with a bandwidth of 373MB/s. The total sensor bandwidth would be 593 MB/s, when the ARINC 818 protocol overhead is added, the total throughput will be ~610MB/s. Using an ARINC 818 video concentrator, each sensor is packetized into ARINC 818, each with a unique Source ID field set in the packet header. The ADVB packets are then dropped onto the single ARINC 818 link that passes through the slip ring. Each of the three sensor signals can be reconstructed by a video processing card by screening on the source ID of the sensor. In addition, the return path of 21 Mb/s will contain command and control to interface with each of the sensors

The advantage of using a single ARINC 818 interface will be reductions in weight and power. Since ARINC 818 contains packet CRCs, corrupted data packets are easily identified. ARINC 818 breaks video into 2112 byte packets or less, therefore, if corrupted data existed, it would be in only a small fraction of a video image.

The three sensors are synchronized through the SOFi character of the return ARINC 818 data path so that fusion of the images are facilitated by being time synchronized.

4.2 Example 2: High Speed Sensor for Target Tracking & Countermeasures

In this example, a high-speed, high-resolution IR camera is used in an application looking to identify and track multiple targets of interest. In the event that one target becomes a higher interest, a region of interest will be established for closer tracking at a higher update. This could be part of a system that implements a Tip, Cue, Slew, Find, Fix, and Finish approach. In this case, we are focusing on how ARINC 818-2 enables the sensor to better find, classify and track.

Assume a 2K by 2K IR sensor, 14-bit mono high-speed sensor that includes a bi-directional ARINC 818 interface (8.5 Gb/s from the sensor, 1.0625 Gb/s to the sensor). Initially, the sensor is running at full resolution mode of 2K x 2K at 100Hz, which requires a bandwidth of 7.34 Gb/s, which will easily fit on a single 8.5Gb/s ARINC 818 link or two channel-bonded 4.25Gbps links. To achieve the throughput, the 14-bit pixels are packed contiguously rather than using 16 bits for each 14 bit pixel. As shown in Figure 7, the full resolution image has three regions of interest, but one of the regions becomes an imminent threat requiring countermeasures. Using the banding/region of interest capabilities of ARINC 818, the data-only interface from the video processor to the sensor identifies a 512x512 ROI for closer tracking. The sensor then begins sending the ROI at 1000 Hz. This allows the countermeasures system the ability to lock on to the object of interest (a missile, for example) and track it with enough accuracy to successfully engage electronic counter measures or laser counter measures.

One of the challenges for any control system depends on how small you can keep the error signal from actual location of the target verses the predicted location in the control system. Given that a modern surface-to-air missile that can fly Mach 7, or approximately 2380 m/s, even at an update rate of 1000 Hz, its frame- to-frame change could vary by as much as be 2.38 meters, depending on the orientation of the missile being tracked. Modern control techniques allow for state (position/velocity) estimation. However, they are not infallible, and feeding a controller actual position and velocity data rather than estimated data will always increase accuracy. A system using an ARINC 818 interface will be limited more by the real-time update rate on the control system or the integration time of the IR sensor rather than the data throughput of the ARINC 818 link. For example, a full authority digital control (FADEC) on a turbine engine will typically use a 5 millisecond and 20 millisecond update rates (200Hz or 50Hz) due to the dynamics (frequency response) of the engine (surge protection and over-speed protection), whereas the dynamics of accurately tracking a missile in flight can be in the 1000Hz to 10,000Hz range. If the IR sensor and target tracking algorithms computer were capable, a ROI of 128x128 pixels at 10,000 Hz could be utilized over the same ARINC 818 link. The benefits of ARINC 818-2 with bi-directional control, regions of interest, and variable rate transmission of video images is that the physical interface to the sensor will not be a bottle neck and being able to send ROIs allows for more accurate target tracking and threat elimination.

Figure 7: Sequence of images first at 100 Hz full resolution, then at 1000 Hz for the ROI.

As a variation of this example, the ARINC 818 interface could be configured to send a mixture of both full resolution images (for example at 20Hz), while sending 1000Hz regions of interest or even 5 different ROIs at 200 Hz each. This would allow maintaining an overall situational awareness while tracking the most imminent threats.

4.3 Example 3: Ultra high resolution sensor for wide area surveillance

ARINC 818-2, extended the link rates from 8X fiber channel rates to 32X fiber channel rates (28 Gb/s). Using a newer class of FPGAs by Xilinx and Altera with 28Gbps transceivers, a channel bonded (splitting pixels over odd/even or video lines right/left) over two links is currently feasible. This type of implementation would allow ~50Gb/s using two channels (two fibers) or 100 Gb/s using 4 channels (4 fibers). For example, an 8K by 8K, 24-bit color camera at 20 Hz would require approximately 40 Gb/s of throughput, which would easily fit on a two-fiber 32X, channel bonded ARINC 818 implementation. Utilizing features of ARINC 818-2, such as: regions of interest, bi-directional communication, and multiple containers, a mix of full resolution images could be intermixed with much lower resolution images at a higher frame rate. Since in this example there is more than 10 Gb/s of spare bandwidth, additional lower resolution sensors could be time multiplexed onto the same link, similar to the sensor fusion example.

5. CONCLUSION

The ARINC 818 Avionics Digital Video Bus, initially designed for cockpit displays, has propagated into high-speed sensors due to its high bandwidth and high reliability. The recent ARINC 818-2 changes facilitates the use of the ARINC 818 protocol in ISR, countermeasures, and other systems requiring very high bandwidth, ultra high speed regions of interest or time-multiplying multiple sensors onto a single link. As ISR and countermeasures system designers run into certain technology barriers, such as physical link bottle necks, the need for high speed regions of interest and the need to support ultra-high resolution sensors, the ARINC 818-2 protocol can be used to simply system design and to help optimize SWaP.

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[1] Keller, T., Alexander, J, "ARINC 818 express for high-speed avionics video and power over coax" Proc. SPIE 8383, Head- and Helmet-Mounted Displays XVII; and Display Technologies and Applications for Defense, Security, and Avionics VI (2012)