



**S-band Packetiser – Correlator Beam Former**

**Interface Control Document**

Document number M1000-0001-094  
Revision B  
Classification Commercial in Confidence  
Author D Horn  
Date 30 January 2017

**Document Approval**

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**Document History**

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision** | **Date of Issue** | **ECP/ECN Number** | **Comments** |
| A |  | N/A | 1st release for review (based on L-band Digitiser to CBF ICD ref [5]). |
| B | 27-02-2017 |  | Updated to indicate single s-band with TBD B/W, centre frequency set by DMC |
| C | 20-03-2017 |  | Updated with OAR comments |
|  |  |  |  |

**Document Software**

|  |  |  |  |
| --- | --- | --- | --- |
| **Function** | **Package** | **Version** | **Filename** |
| Word Processor | Microsoft Word | Word 2010 |  |
| Diagram Editor | Microsoft Visio | Visio 2010 |  |

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LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| AFN | Array Fibre Network |
| CBF | Correlator Beam Former |
| DMC | Digitiser Master Controller |
| ICD | Interface Control Document |
| IP | Internet Protocol |
| KAPB | Karoo Array Processor Building |
| LSB | Least Significant Bit |
| MeerKAT | 64 Dish Array |
| MSB | Most Significant Bit |
| N/A | Not Applicable |
| RFN | Receptor Fibre Network |
| SPEAD | Streaming Protocol for Exchanging Astronomical Data |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| UDP | User Datagram Protocol |
|  |  |
|  |  |
|  |  |
|  |  |

**Glossary**

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Digitiser | This term is used to describe either one of the four MeerKAT Digitisers. For S-band this includes the Receiver (sampling) and Packetiser combination. |
| Digitisers | This term is used to describe all four of the MeerKAT Digitisers. |
| S-band Packetiser | Refers to the S-band Packetiser only and is used where this Packetiser is explicitly discussed (primarily the case for this ICD). PUID numbers associated with this Digitiser will contain the letters ***SD.*** |

# Scope

This Interface Control Document (ICD) describes the details for the Streaming Protocol for Exchanging Astronomical Data (SPEAD) [4] data products interface between the S-band Packetiser subsystem and the Correlator Beam Former (CBF) subsystem. This ICD is based on the L-band Digitiser – CBF ICD (ref [5]), which provides a constraint on the S-band packetiser data rate which can be accommodated.

# Applicable and Reference Documents

The following documents of the exact issue shown form a part of this ICD to the extent specified herein. In the event of conflict between the text of this specification and the documents cited herein, the text of this ICD shall take precedence. Nothing in this ICD supersedes applicable laws and regulations.

## Applicable Documents

These documents are contractually enforceable to the extent specified herein.

1. S. Malan, **M1130-2000-001**, Rev 4, *L-band Digitiser Requirement Specification*, 11 March 2015
2. S. Malan, JSW Rust, **M1000-0001-006**, Rev 1, *Digitisers - CBF Interface Requirements Document*.

## Referenced Documents

These documents are not contractually enforceable and are merely listed for convenience.

1. C. Gumede, **M0000-0000V1-32 TM**, Rev 1C, *MeerKAT Internal Interfaces Identification*, 10 January 2013.
2. J. Manley, M Welz, A Parsons, S Ratcliffe, **SSA4700-0000-001,** Rev 1, SPEAD: Streaming Protocol for Exchanging Astronomical Data.
3. H Kriel, M1000-0001-053, Rev 3, L-Band Digitiser – Correlator Beam Former Interface Control Document 27 July 2015
4. M Welz, M1000-00001-0xx, Rev 1 DMC - S-band Packetiser ICD

# Interface Definition

## Interface Identification

This document specifies the details of the functional interface *S-band Packetiser to* *Correlator Beam Former Interface, I.TE.SD.15 (SD-CBF Interface)* existing between the *S-band Packetiser component* (**M.1120-0054**) and the *CBF component* (**M.1200-0000**).

The interface type is classified as a network interface and employs SPEAD over Ethernet for communication.

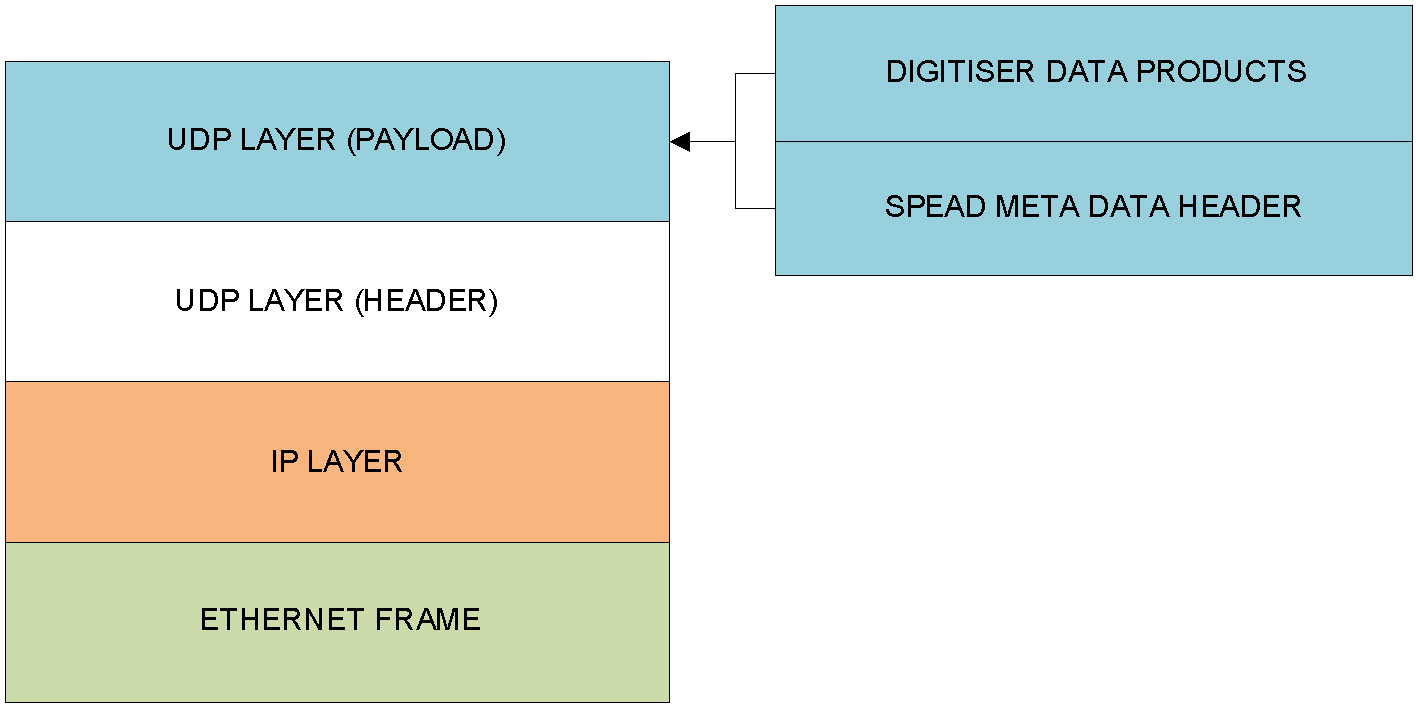
## Interface Boundary of Responsibility

Figure 1 shows the boundary of responsibility for this interface.

|  |
| --- |
|  |
| **Figure 1: Boundary of responsibility on interface** |

## Interface description

This interface transports S-band Packetiser data products (Figure 2) via the SPEAD protocol over Ethernet to the CBF for further processing. The S-band Packetiser interfaces via a 1 x 40G-BASE-CR4 copper link to the Digitiser Receptor Switch. The Digitiser Receptor Switch forwards the data over a 1 x 40G-BASE-LR4 fibre link over the Array Fibre Network (AFN) to the CBF within the KPB.



**Figure 2: Digitiser Data Product Ethernet Frame**

The interface requirements specified in [1] (*Packetise and Transmit L-band Digitiser data [F.D.1.5])* are listed below. They are for reference only and not directly applicable to the S-band interface. However the S-band performance of the interface should be comparable to L-band. The requirements are further clarified with respect to S-band in the paragraphs below are addressed with respect to this S-band interface in the following sections.

**Table 1: Interface requirements**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Requirement** | | | **Traceability** | | | |
| **Par. No.** | **PUID** | **Name** | **Par. No.** | **PUID** | **Name** | **Doc. No.** | |
| 3.1.2.4 | F.D.1.5 | Packetise and Transmit L-band Digitiser data |  |  |  |  | |
| 3.1.2.4 | R.D.SP.31 | *Digitiser timestamping* | 3.5 | R.T.P.31 | Timestamp accuracy relative to Telescope TFR subsystem | M0000-0000V1-13 TM | |
| 3.1.2.4 | R.D.SP.32 | *Digitiser timestamp reset accuracy* | 3.5 | R.T.P.31 | Timestamp accuracy relative to Telescope TFR subsystem | M0000-0000V1-13 TM | |
| 3.1.2.4 | R.D.RFI.8 | *Digitiser ADC saturation flagging* | 3.10 | R.T.P.116 | RFI impact reduction - system | M0000-0000V1-11 TM | |
|  |  |  | 6.5 | R.T.FD.20 | Automatically flag | M0000-0000V1-15 TM | |
|  |  |  | 5 | R.T.RFI.9 | RFI flagging | M0000-0000V1-17 TM | |
| 3.1.2.4 | R.D.SP.37 | Digitiser transmit packetised data | 2 | R.T.DC.3 | Digitization at antenna | M0000-0000V1-08 TM | |

### S-band Packetiser timestamping [based on R.D.SP.31 & R.D.SP.32]

The SPEAD meta data header shall include a 48 bit field for the S-band Packetiser local time stamp that aligns with the first (oldest) ADC sample in the data payload. Upon the reception of a DMC time stamp synchronization command, the local Packetiser calculates the count value to apply on the next PPS based on the epoch supplied by the DMC in the synchronisation request (refer to the DMC – S-band packetiser ICD [6]) for further details.

### S-band Packetiser ADC saturation flagging [based on R.D.RFI.8]

The SPEAD meta data header shall include a 16 bit field for the number of ADC samples that are saturated in that data payload. A 1 bit flag shall also be included to flag if any ADC samples saturated in the data payload.

### S-band Packetiser transmit packetised data [based on R.T.DC.3]

The data product shall contain 4096 contiguously packed, 10 bit signed ADC samples from the same polarization, with the oldest sample first. Table 2 shows the layout. Table 3 shows the link budget using 4x 10GbE links (S-band Packetiser) and 1x 40GbE link (Receptor switch). Each polarization will utilize 2 x 10G-BASE-SR links to ensure the projected data rate is sustained.

**Table 2: Packetised data frame**

|  |  |
| --- | --- |
| **ADC Data Frame** | **Number of bytes** |
| Preamble | 7 |
| Start of Frame | 1 |
| MAC | 12 |
| Proto | 2 |
| IP Header | 20 |
| UDP Header | 8 |
| SPEAD Header | 64 |
| Padding | 6 |
| CRC32 | 4 |
| Dead Time | 962 |
| Data Payload Max | 5120 (4096 ADC samples \* 10bits) |
| **Efficiency** | **95.37.60%** |

**Table 3: S-band Packetiser Data Link Rates**

*To be updated by MPIfR – vales below are for L-band. As S-band packet rate is limited to the L-band rate, S-band will provide a band of bandwidth TBD MHz centred at a frequency set via the DMC – S-band interface.*

|  |  |  |
| --- | --- | --- |
| **Digitiser Data Link Rates** | | **S-band** |
| BW (MHz) | | 770 |
| Guard Band (%) | | 11.17% |
| Sample rate | | 1712 |
| NOB | | 10 |
| Polarisations | | 2 |
| Required payload throughput (Mbps) | | 34240 |
| Link efficiency | | 97.60% |
| Effective data rate (Mbps) | | 35081.97 |
| ADC Snap Block Dump Rate (Mbps) | | 0.50 |
| Total (Mbps) | | 35082.47 |
| 10GbE | Utilisation | 87.71% |
| Number of links required | 4 |
| 40GbE | Utilisation | 87.71% |
| Number of links required | 1 |

### Derived SPEAD parameters

#### Noise Diode Status

The SPEAD meta data header shall include a 1 bit field to indicate the status of the Noise Diode switch at the time stamp of the first ADC sample in the data payload.

|  |  |
| --- | --- |
| **Value** | **Description** |
| 0 | Noise Diode Off |
| 1 | Noise Diode On |

#### Packetiser Serial Number

The SPEAD meta data header shall include a 24 bit field to indicate the serial number of the packetiser.

#### Receptor ID

The SPEAD meta data header shall include a 14 bit field to indicate the receptor ID where the packetiser is installed.

#### Digitiser Type

The SPEAD meta data header shall include an 8 bit field to indicate the frequency band of operation for the digitiser.

|  |  |
| --- | --- |
| **Value** | **Description** |
| 0 | S-band Packetiser |
| 1 | UHF-Band Digitiser |
| 2 | X-Band Digitiser |
| 3 | S-Band Digitiser |
| 4 - 255 | Reserved |

#### Polarization ID

The SPEAD meta data header shall include a 2 bit field to indicate the polarization of the data payload.

|  |  |
| --- | --- |
| **Value** | **Description** |
| 0 | Vertical Polarization |
| 1 | Horizontal Polarization |
| 2-3 | Reserved |

### SPEAD Packets Layout

The detailed SPEAD Packet layout of the ADC data is shown in Table 4. The bit range notation used is [MSB:LSB], unless otherwise specified. All fields are unsigned, unless otherwise specified. The SPEAD word entries spans 64 bits, with the SPEAD Item ID spanning 16 bits located at bits [63:48] of the word entry and the field value spans 48 bits, located at bits [47:0] of the word entry.

**Table 4: Digitiser ADC SPEAD Packet Layout**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SPEAD PACKET**  **Word Offset (64 bit Entries)** | **SPEAD Item ID Address Mode**  **Bit[63]**  **0 = Indirect**  **1 =**  **Direct** | **SPEAD Item ID**  **Bits [62:48]** | **SPEAD Item ID Field Value Bits [47:0]** | **Description** |
|  | **SPEAD HEADER** | | | |
| 0 | N/A  0x5304 0206 0000 0008 | | | [63:56] SPEAD Magic Number = 0x53  [55:48] SPEAD Version = 0x04  [47:40] Item ID width [bytes] = 0x02  [39:32] HEAP Address Width [bytes] = 0x06  [31:16] Reserved (0x0000)  [15:0] Number of item pointers after this header = 0x0008 |
| 1 | 1 | 0x0001 | HEAP ID | Header: HEAP ID - For the Digitiser implementation, this ID is set to the local Digitiser time stamp at the time of header generation. |
| 2 | 1 | 0x0002 | 5120 | Header: HEAP Size [bytes] = 5120 (4096\*10bits\*1 packet) |
| 3 | 1 | 0x0003 | 0 | Header: HEAP Offset [bytes] = 0 (One HEAP per packet) |
| 4 | 1 | 0x0004 | 5120 | HEAP payload length [bytes] = 5120 (4096 ADC Samples\*10bits = 5120 bytes) |
| 5 | 1 | 0x1600 | Time stamp | Local Digitiser time stamp of the first (oldest) ADC sample in this payload.  Refer to the DMC – S-band Packetiser ICD [6] |
| 6 | 1 | 0x3101 | Digitiser ID | [47:24] Digitiser Serial Number  [23:16] Digitiser Type  (0 = S-band Packetiser [1712MHz],  1 = UHF-Band Digitiser [TBD MHz],  2 = X-Band Digitiser [TBD MHz],  3 = S-Band Digitiser [TBD MHz],  4 - 255 Reserved)  [15:2] Receptor ID  [1:0] Polarization ID  (0 = Vertical,  1 = Horizontal) |
| 7 | 1 | 0x3102 | Digitiser Status | [47:32] ADC Saturation Count (Number of ADC Samples that saturated in this payload)  [31:2] Reserved (set to 0)  [1] ADC Sample(s) Saturation Flag  (0 = There are no saturated ADC samples in this payload,  1 = There are saturated ADC samples in this payload, see ADC Saturation Count field)  [0] Noise Diode Status  (0 = Noise diode was Off for this entire payload,  1 = Noise diode was On in this payload) |
| 8 | 0 | 0x3300 | 0 | Digitiser Raw ADC Sample Data (payload) starting at offset 0 after this header. |
|  | **SPEAD PAYLOAD** | | | |
| 9 - 649 | Payload Word 1,  [63:54] - ADC Sample 1 [9:0] (oldest sample),  [53:44] - ADC Sample 2 [9:0],  [43:34] - ADC Sample 3 [9:0],  [33:24] - ADC Sample 4 [9:0],  [23:14] - ADC Sample 5 [9:0],  [13:4] - ADC Sample 6 [9:0],  [3:0] - ADC Sample 7 [9:6],  Payload Word 2,  [63:58] - ADC Sample 7 [5:0],  [57:48] - ADC Sample 8 [9:0],  [47:38] - ADC Sample 9 [9:0],  [37:28] - ADC Sample 10 [9:0],  [27:18] - ADC Sample 11 [9:0],  [17:8] - ADC Sample 12 [9:0],  [7:0] - ADC Sample 13 [10:2],  ....  Payload Word 640,  [63:60] - ADC Sample 4090 [3:0],  [59:50] - ADC Sample 4091 [9:0],  [49:40] - ADC Sample 4092 [9:0],  [39:30] - ADC Sample 4093 [9:0],  [29:20] - ADC Sample 4094 [9:0],  [19:10] - ADC Sample 4095 [9:0],  [9:0] - ADC Sample 4096 [9:0] | | | SPEAD Payload: 10 Bit (Signed) ADC Samples, packed contiguously, over 64 bit word boundaries.  ADC 10 Bit Sample [9:0]:  MSB [9] - Sign bit (0 = Positive magnitude, 1 = Negative magnitude)  [8:0] - Magnitude ([8] MSB, [0] LSB)  Range +511 (01 1111 1111b) to -512 (10 0000 0000b) |

The detailed SPEAD Packet layout of the basic spectrometer data is shown in Table 5. The bit range notation used is [MSB:LSB], unless otherwise specified. All fields are unsigned, unless otherwise specified. The SPEAD word entries spans 64 bits, with the SPEAD Item ID spanning 16 bits located at bits [63:48] of the word entry and the field value spans 48 bits, located at bits [47:0] of the word entry.

**Table 5: Basic Spectrometer Data SPEAD Packet Layout**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SPEAD PACKET**  **Word Offset (64 bit Entries)** | **SPEAD Item ID Address Mode**  **Bit[63]**  **0 = Indirect**  **1 =**  **Direct** | **SPEAD Item ID**  **Bits [62:48]** | **SPEAD Item ID Field Value Bits [47:0]** | **Description** |
|  | **SPEAD HEADER** | | | |
| 0 | N/A  0x5304 0206 0000 0008 | | | [63:56] SPEAD Magic Number = 0x53  [55:48] SPEAD Version = 0x04  [47:40] Item ID width [bytes] = 0x02  [39:32] HEAP Address Width [bytes] = 0x06  [31:16] Reserved (0x0000)  [15:0] Number of item pointers after this header = 0x0008 |
| 1 | 1 | 0x0001 | HEAP ID | Header: HEAP ID  [47:24] Digitiser Time Stamp [23:0]  [23:16] Digitiser Type  (0 = S-band Packetiser [1712MHz],  1 = UHF-Band Digitiser [TBD MHz],  2 = X-Band Digitiser [TBD MHz],  3 = S-Band Digitiser [TBD MHz],  4 - 255 Reserved)  [15:2] Receptor ID  [1:0] Data ID  (0 = Auto correlation VV\*,  1 = Auto correlation HH\*,  2 = Cross correlation Real(VH\*), Cross correlation Imaginary(VH\*) |
| 2 | 1 | 0x0002 | 512 | For VV\* and HH\*:  Header: HEAP payload length [bytes] = 512 (128 Channels\*32bits = 512 bytes) \* 1 Packet  For VH\*:  Header: HEAP payload length [bytes] = 1024 (128 Channels\*32bits = 512 bytes) \* 2 Packets |
| 3 | 1 | 0x0003 | 0 | For VV\* and HH\*:  Header: HEAP Offset [bytes] = 0 (One HEAP per packet)  For VH\*:  Header: HEAP Offset [bytes] = 0 (Packet1: Re{VH\*})  Header: HEAP Offset [bytes] = 512 (Packet2: Im{VH\*}) |
| 4 | 1 | 0x0004 | 512 | HEAP payload length [bytes] = 512 (128 Channels\*32bits = 512 bytes) |
| 5 | 1 | 0x1600 | Time stamp | [47:0] Local Digitiser time stamp at start of accumulation  Upon the reception of a DMC time stamp synchronization command, the local Digitiser time stamp is set to the value supplied by the DMC time stamp synchronization command. This value is an offset from the UTC time stamp. The local time stamp is then incremented by 8, every 1/(fs/8) ns, where fs is the applicable sample frequency in Hz. |
| 6 | 1 | 0x3101 | Digitiser ID | [47:24] Digitiser Serial Number  [23:16] Digitiser Type  (0 = S-band Packetiser [1712MHz],  1 = UHF-Band Digitiser [TBD MHz],  2 = X-Band Digitiser [TBD MHz],  3 = S-Band Digitiser [TBD MHz],  4 - 255 Reserved)  [15:2] Receptor ID  [1:0] Polarization ID  (0 = Vertical,  1 = Horizontal) |
| 7 | 1 | 0x3102 | Digitiser Status | [47:9] Reserved (set to 0)  [8] Imaginary (VH\*) Vector Accumulator Saturation Flag  (0 = There are no saturated vector accumulator samples in this accumulation,  1 = There are saturated vector accumulator samples in this accumulation)  [7] Real (VH\*) Vector Accumulator Saturation Flag  (0 = There are no saturated vector accumulator samples in this accumulation,  1 = There are saturated vector accumulator samples in this accumulation)  [6] HH\* Vector Accumulator Saturation Flag  (0 = There are no saturated vector accumulator samples in this accumulation,  1 = There are saturated vector accumulator samples in this accumulation)  [5] VV\* Vector Accumulator Saturation Flag  (0 = There are no saturated vector accumulator samples in this accumulation,  1 = There are saturated vector accumulator samples in this accumulation)  [4] FFT1 (H-Pol) Saturation Flag  (0 = There are no saturated FFT samples in this accumulation,  1 = There are saturated FFT samples in this accumulation)  [3] FFT0 (V-Pol) Saturation Flag  (0 = There are no saturated FFT samples in this accumulation,  1 = There are saturated FFT samples in this accumulation)  [2] ADC1 (H-Pol) Sample(s) Saturation Flag  (0 = There are no saturated ADC samples in this accumulation,  1 = There are saturated ADC samples in this accumulation,  [1] ADC0 (V-Pol) Sample(s) Saturation Flag  (0 = There are no saturated ADC samples in this accumulation,  1 = There are saturated ADC samples in this accumulation,  [0] Noise Diode Status  (0 = Noise diode was Off for this entire accumulation,  1 = Noise diode was On in this accumulation) |
| 8 | 0 | 0x3301/2/3/4 | 0 | Auto/Cross correlation accumulated data product Data (payload) starting at offset 0 after this header.  SPEAD Item ID:  0x3301 = Auto correlation VV\*,  0x3302 = Auto correlation HH\*,  0x3303 = Cross correlation Real (VH\*), Cross correlation Imaginary (VH\*) |
|  | **SPEAD PAYLOAD** | | | |
| 9 - 72 | Payload Word 1,  [63:32] - Channel 0,  [31:0] - Channel 1  Payload Word 2,  [63:32] - Channel 4,  [31:0] - Channel 5  Payload Word 3,  [63:32] - Channel 8,  [31:0] - Channel 9  ....  Payload Word 32,  [63:32] - Channel 124,  [31:0] - Channel 125  Payload Word 33,  [63:32] - Channel 2,  [31:0] - Channel 3  Payload Word 34,  [63:32] - Channel 6,  [31:0] - Channel 7  Payload Word 35,  [63:32] - Channel 10,  [31:0] - Channel 11  ...  Payload Word 64,  [63:32] - Channel 126,  [31:0] - Channel 127 | | | SPEAD Payload: Accumulated auto/cross correlation data, packed interleaved, over 64 bit word boundaries.  Type of data is determined by SPEAD Item ID:  0x3301 = Auto correlation VV\* 32 Bit (unsigned),  0x3302 = Auto correlation HH\* 32 Bit (unsigned),  0x3303 = Cross correlation Real (VH\*) 32 Bit (signed), Imaginary (VH\*) 32 Bit (signed) |