IEEE-ISTO Std 4900-2021: Digital IF Interoperability Standard

Version 1.2.1

Feb 7th, 2025

Revision History

Release Level	Release Date	Description
1.0	August 18, 2021	Final v1.0
1.1	August, 2022	First working group cleaned up version v1.1 - Board approved 8.9.2022. Beside other the handling of IPv6 and use of UDP checksum has been clarified
1.2.0	August, 2023	Restructured document for clarity. Added table of deviations from VITA49.2 Added Information Class 0x0002 and Packet Classes 0x0002, 0x0003, 0x0005, and 0x0006. Added Appendices
1.2.1	February, 2025	Clarified issues arising from Plugfest Europe 2024 Added Information Class 0x0004. Combined class tables and descriptions for efficiency. Reworked Appendices.

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1. INTRODUCTION

The data plane interface provides the ability to transmit and receive digitized RF (radio frequency) or IF (intermediate frequency) data respectively as well as corresponding metadata over standard IP networks. This interface is substantially compliant with the VITA 49.2 standards [2], with some deviations as noted in Section 1.5.

Working knowledge of related documents given below is assumed.

1.1 RELATED DOCUMENTS

Industry Standard Documents:

[1] VITA Radio Transport (VRT) Standard, VITA 49.0 – 2015.

[2] VITA Radio Transport (VRT) Standard, VITA 49.2 – 2017.

[3] IEEE 802.1Q-2018. (2018). "IEEE Standard for Local and Metropolitan Area Networks--Bridges and Bridged Networks."

[4] IEEE 802.1ad-2005. (2005). "IEEE Standard for Local and Metropolitan Area Networks - Virtual Bridged Local Area Networks - Amendment 4: Provider Bridges."

[5] J. Postel, "Internet Protocol," RFC 791, IETF, Sep. 1981.

[6] S. Deering and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," RFC 8200, IETF, Jul. 2017.

1.2 DEFINITIONS FOR REQUIREMENTS WORDING

MUST This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.

MUST NOT This phrase, or the phrase "SHALL NOT", mean that the definition is an absolute prohibition of the specification.

SHOULD This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.

SHOULD NOT This phrase, or the phrase "NOT RECOMMENDED" mean that there may exist valid reasons in particular circumstances when the behavior is acceptable or even useful, but the full implications should be understood, and the case carefully weighed before implementing any behavior described with this label.

MAY This word, or the adjective "OPTIONAL", mean that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.)

1.3 DIFI Standard Definitions and Conventions

The definitions in Figure 1 apply to this document and are illustrated in Figure 2.

Figure 1. DIFI Standard Definitions

DIFI Device	Any hardware, firmware, or software that creates a Source or Sink using the Digital Intermediate Frequency Interoperability (DIFI) protocol.
Endpoint	A Source or a Sink.
Flow	Transmission or movement of data in the form of packets or a packet stream from Source to Sink.
Full Scale Amplitude	In the context of this document, for an I (Q) sample component with N-bits, the full scale amplitude is 2**(N-1)-1
Full Scale Complex Sinusoid	A digital full scale complex sinusoid is one for which the peak magnitude, $\sqrt{I^2 + Q^2}$, is equal to the available full scale amplitude, R, of I or Q taken separately, i.e., the peak magnitude of any full scale complex sinusoid falls on a circle of radius R in the complex IQ plane.
IF Converter	A device that transmutes signals between digital IF and analog IF
Intermediate Frequency (IF) Signal	IF Signal refers to any signal after it has undergone frequency translation. The frequency of this signal may or may not be a typical IF frequency. A zero-IF signal is equal to a complex baseband signal
Information Class	A group of one or more Packet Classes plus packet stream associations that define the structure and information exchange between DIFI devices
Information Stream	A flow of Packet Streams that contain signal data, signal metadata, and/or control information.
[IP] Socket	IP address and port number
Link Efficient Packing	Link Efficient Packing means that Signal Data Payload is packed in such a way as to maximise efficiency of the ethernet link.
Packet Class	A set of rules and structures that define the format and content of a packet.
Packet Type	The type of a packet to be sent. Types include Data, Context, and Command.
Packet Stream	A flow of packets that carries data from Source to a Sink
Process Efficient Packing	Process Efficient Packing means that Signal Data Payload is packed in such a way as to minimise the process load on the processing hardware, with permission to do this at the expense of link bandwidth.
Receive (Rx) Direction	Away from the RF communications aperture or its intended location

Reference Point	The point from which data is measured or referenced serves as a common baseline for defining time, frequency, phase, and other related parameters within the Information Classes.
RF Converter	A device that transmutes signals between digital IF and analog RF
Signal Data Packet Sink	Packet Stream signal destination socket, i.e., a VITA 49.2 packet "consumer"
Signal Data Packet Source	Packet Stream signal origination socket, i.e., a VITA 49.2 packet "emitter"
Stream Identifier (SID)	The Stream ID is a field within the DIFI header which (i) indicates that a particular Data, Context, or Command Packet is part of a sequence of packets of the same type bearing the same Stream ID, (ii) indicates which Context or Command Packet streams are associated with which Data Packet streams, and (iii) defines a specific location referred to as the SID location, which is used in conjunction with the time stamping.
Transmit (Tx) Direction	Towards the RF communications aperture or its intended location

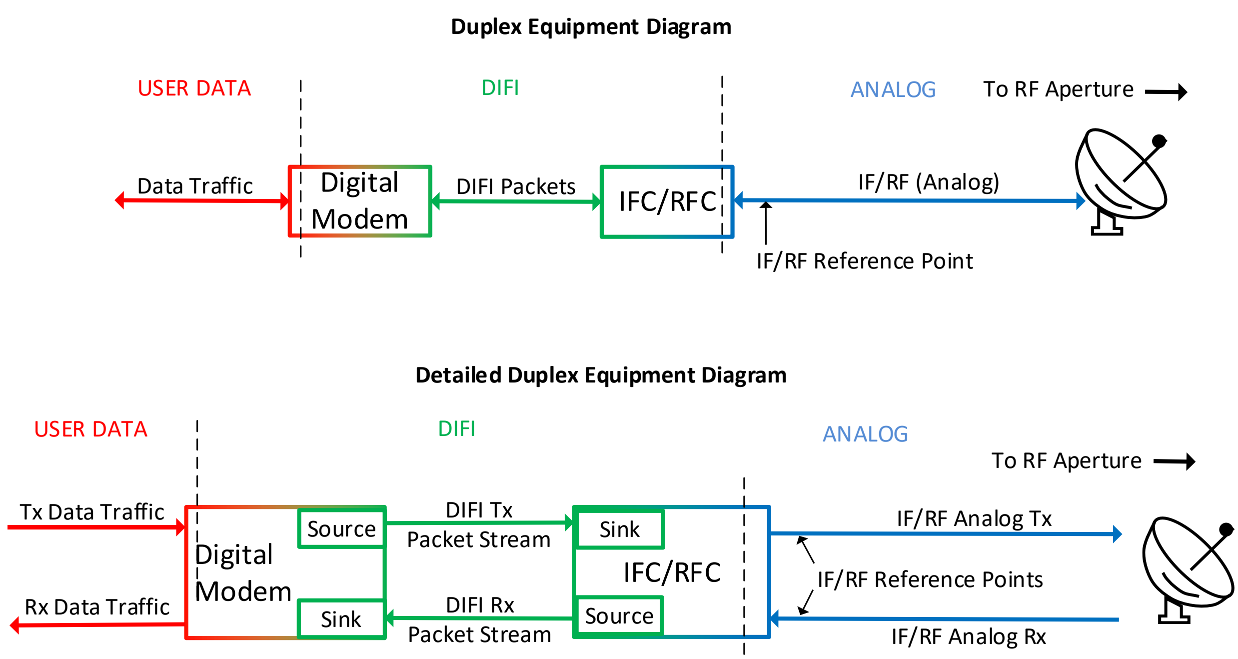


Figure 2. DIFI Standard Conventions

1.4 ABBREVIATIONS & ACRONYMS (INFORMATIVE)

ADC	Analog to Digital Converter
ARP	Address Resolution Protocol
CIF	Control Indicator Field
DAC	Digital to Analog Converter
dBFS	"Decibels Full Scale", a measure of power of a sampled signal relative to a full-scale sinusoid. The power of a full-scale sinusoid is 0 dBFS.
DIFI	Digital Intermediate Frequency Interoperability
FPGA	Field-Programmable Gate Array
GPS	Global Positioning System
I	In-phase component of a sinusoid with angle modulation
ICD	Interface Control Document
ID	Identifier
IEEE ISTO	IEEE Industry Standards and Technology Organization
IF	Intermediate Frequency
IFC	IF Converter
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IRIG	Inter-range Instrumentation Group
LAN	Local Area Network
MAC	Media Access Control
Msps	Mega-samples per second
N/A	Not Applicable
NIC	Network Interface Controller
NTP	Network Time Protocol
NTR	Non-Time Release
OUI	Organizationally Unique Identifier
POSIX	Portable Operating System Interface
PTP	Precision Time Protocol
Q	Quadrature component of a sinusoid with angle modulation
RF	Radio Frequency
TC	Time Continuous
TOD	Time of Day
TSF	Timestamp Fractional
TSI	Timestamp Integer
TSM	Timestamp Mode
UDP	User Datagram Protocol
UTC	Coordinated Universal Time
VLAN	Virtual LAN
VRL	VITA Radio Link Protocol
VRT	VITA Radio Transport

1.5 DEVIATIONS FROM VITA 49.2

While the DIFI Standard is based on VITA 49.2, there are deviations, some of which are indicated as follows:

Reference Level Field	The DIFI Standard breaks this up into two sub-fields. • Mandatory bits 15-0 follows VITA 49.2 for receive direction, and defines Reference Level for transmit direction. • Optional bits 31-16 convey RMS data sample amplitude in dBFS (decibels WRT full scale) where "full scale" is defined in section 1.3
Reference Level Field	The reserved bits in VITA 49.2 have been converted to the optional “Scaling” sub-field in DIFI
Buffer Size field	In VITA 49.2, the first 32-bit word in this 64-bit (two-word) field is the buffer size in bytes; in DIFI, the Buffer Size field is three 32-bit words, with the first two indicated the buffer size in bytes as a 64-bit word

2. DATA PLANE IMPLEMENTATION

The data plane is where the digital RF or IF data and its corresponding metadata are formed into packets for transmission.

The VITA 49.2 specification [2] provides many options for packing Digital IF data. This flexibility requires that an additional layer of documentation be provided to explain a manufacturer's implementation of the standard.

The IEEE-ISTO Std 4900-2021: Digital IF Interoperability Standard has two independent data plane flows as shown in Figure 3:

1) RF/IF-input to IP-network output (receive) and

2) IP-network input to RF/IF-output (transmit).

The following sections detail the Information Classes and Packet Classes used by this Standard, per VITA 49.2 requirements. Section 3 describes the Information Classes supporting various use cases. Illustrations of example applications of the Information Classes to use cases are provided in Appendices. Section 4 describes the Packet Classes used by the Information Classes, including Data, Context, and Command packet formats. Note that VITA 49.2 trailers and VRL framing are not currently used for any data flows.

This Standard provides strict definitions of which fields are included in Data, Context, and Command packets and their meanings, so as to maximize interoperability.

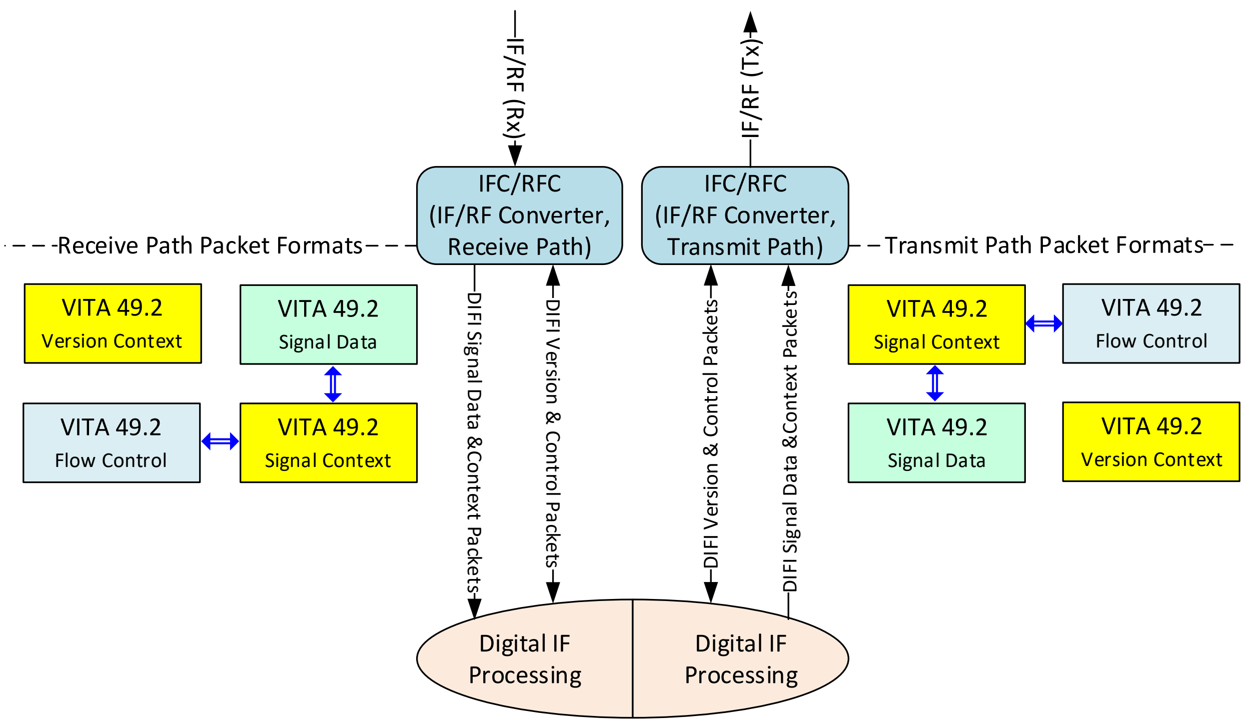


Figure 3. Data Plane Packet Formats

In Figure 3, the transmit direction is shown on the right half of the diagram, receive direction on the left. Streams that are associated with one another are connected by blue double-headed arrows. Although not indicated in the diagram, streams may also flow between Digital IF Processing blocks, examples of which include Digital IF modems and Digital IF Combiners and Dividers. Examples of detailed flows appear in the Appendix.

2.1 Protocol Overview

The DIFI protocol is used to support DIFI applications, which use DIFI to support IP transport of their application content in the form of DIFI packets. To support DIFI applications, the DIFI protocol layer contains three different types of packets:

1) Context Packets
2) Signal Data Packets
3) Command Packets

Figure 4 provides an overview of the DIFI protocol stack. The DIFI protocol layer is based on IP/UDP using Ethernet as the physical transport layer.

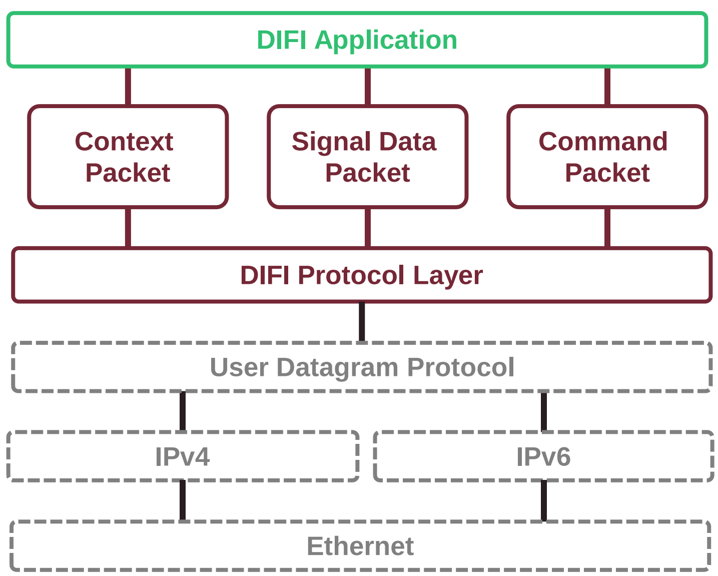


Figure 4. DIFI Protocol Stack

Figure 5 provides an overview of the packets at each protocol layer.

Requirements for Ethernet as well as IP and UDP to integrate DIFI are given in the following sub-sections. This is followed by the definition of the DIFI protocol layer.

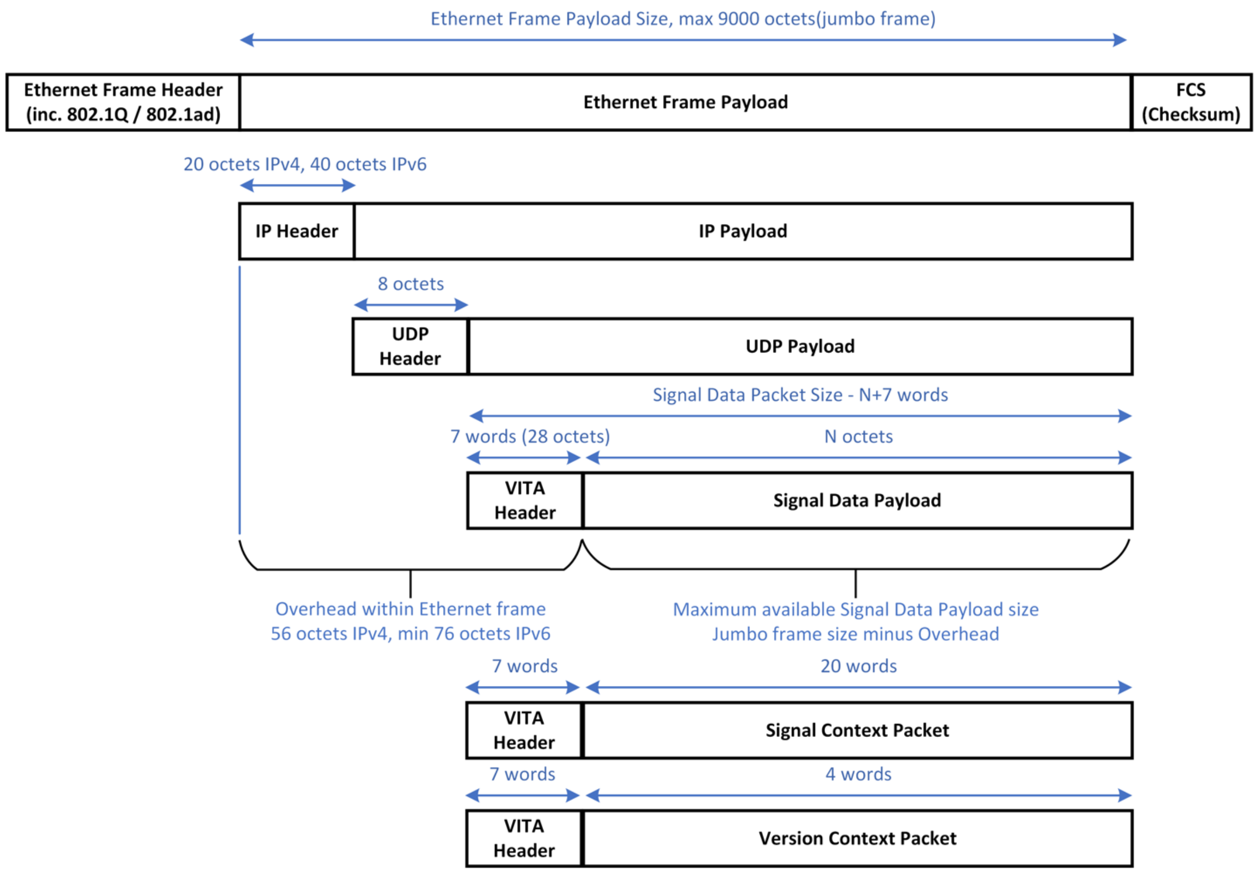


Figure 5. DIFI Protocol Stack – Packets

The total Ethernet packet size for Signal Data Packets varies based on the number and size of the data samples in the payload.

There is a fixed overhead within the Ethernet Frame which comprises:

IP Header (20 octets for IPv4, 40 octets (minimum) for IPv6)

UDP header (8 octets)

VITA header (28 octets)

The Ethernet frame payload is adjustable from 128 octets to 9000 octets.

The Signal Data Payload size is discussed in greater detail near the end of section 4.2.1.

2.1.1 Ethernet

DIFI packets shall be contained in standard 802.3 Ethernet frames and support the following extensions:

- Jumbo frames with maximum transmission unit of 9000 bytes
- 802.1Q (VLAN) and 802.1ad (QinQ)

A DIFI end point shall have at least one Ethernet MAC address.

2.1.2 IP

DIFI packets shall be contained in either standard IPv4 frames (RFC 791) or IPv6 frames (RFC 8200). For a given DIFI stream, the source IP address shall be the same for both the context and the data packets.

2.1.2.1 Ipv4 Fragmentation

IPv4 fragmentation shall not be produced at the source, and it is acceptable for the Sink to discard fragmented packets.

2.1.2.2 Ipv6 Extension Headers

DIFI shall support the presence of IPv6 extension headers. However, implementations may ignore the content of the extension headers, which may be present. Implementations shall process the payload of IPv6 packets, regardless.

2.1.3 UDP

Each DIFI packet shall be contained in a standard UDP datagram.

It should be noted that UDP checksums are mandatory to comply with IPv6 but optional for IPv4. The DIFI standard does not levy any further requirements. If used, checksums shall be valid for the appropriate packet transport type.

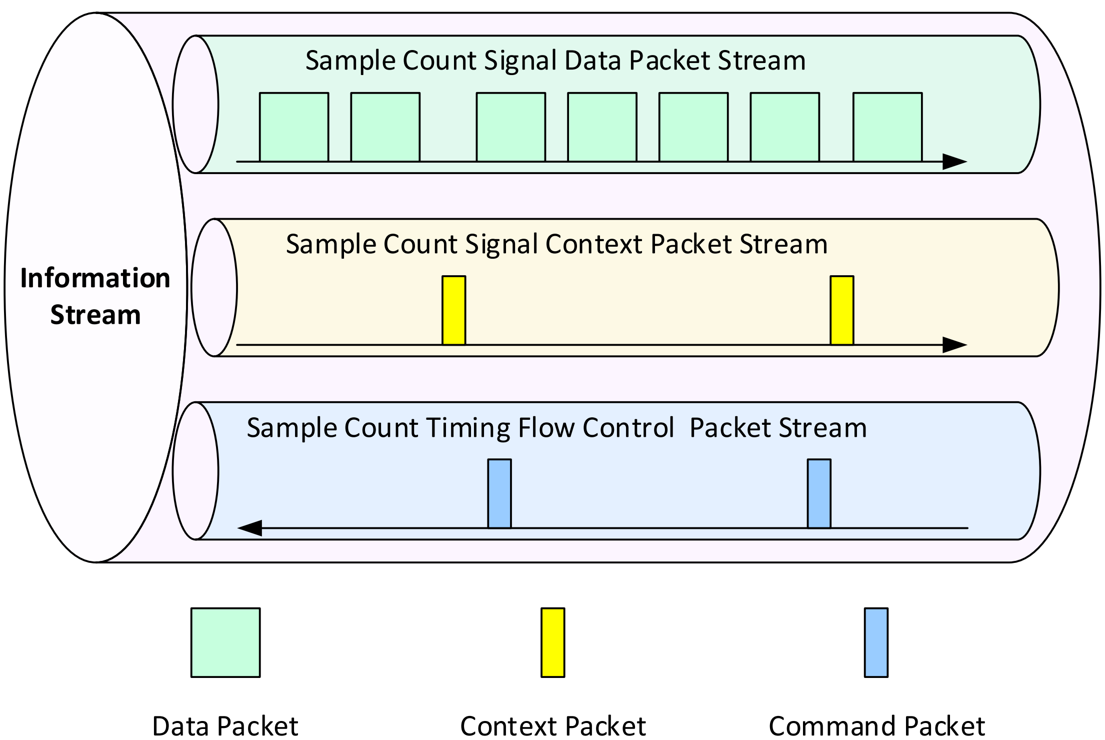
The data payload of the UDP datagram contains either a DIFI context packet, a DIFI control packet, or a DIFI data packet.

3. INFORMATION CLASSES[1]

Within the DIFI standard, an Information Stream conveys various types of user information from one point in a system to another. An Information Stream is a collection of Packet Streams, which can only have a single Stream ID, configured to enable some particular use case. The Information Stream provides a complete set of Data, Context, and Command for one or more related signals. An Information Stream may consist of only a single type of Packet Stream, but in general it involves more than one (e.g. Data and Context). For example, a Signal Data Packet Stream may be paired with a Context Packet Stream which provides the metadata needed to fully understand the contents of the Signal Data Packet Stream. A Data Packet Stream may be paired with at most one such Context Packet Stream. A Signal Data Packet Stream may also be paired with a Command Packet Stream, or with both Command and a Context Packet Streams. The structure of an Information Stream is defined by an Information Class.

A DIFI Information Class is a structure consisting of one or more Packet Classes. The Packet Streams comprising the Information Stream are associated by using the same Stream Identifier. Packet Classes that are defined for the DIFI standard are described in detail in Section 4.

Figure 6 is an illustration of the relationship between Information Streams, Information Classes, and Packet Classes. Figure 7 is an illustration of a data link supporting multiple simultaneous Information Streams.



[1] Section 3.6 of VITA 49.2 describes the purpose and requirements of an Information Class in detail.

Figure 6. Information Stream Components Example

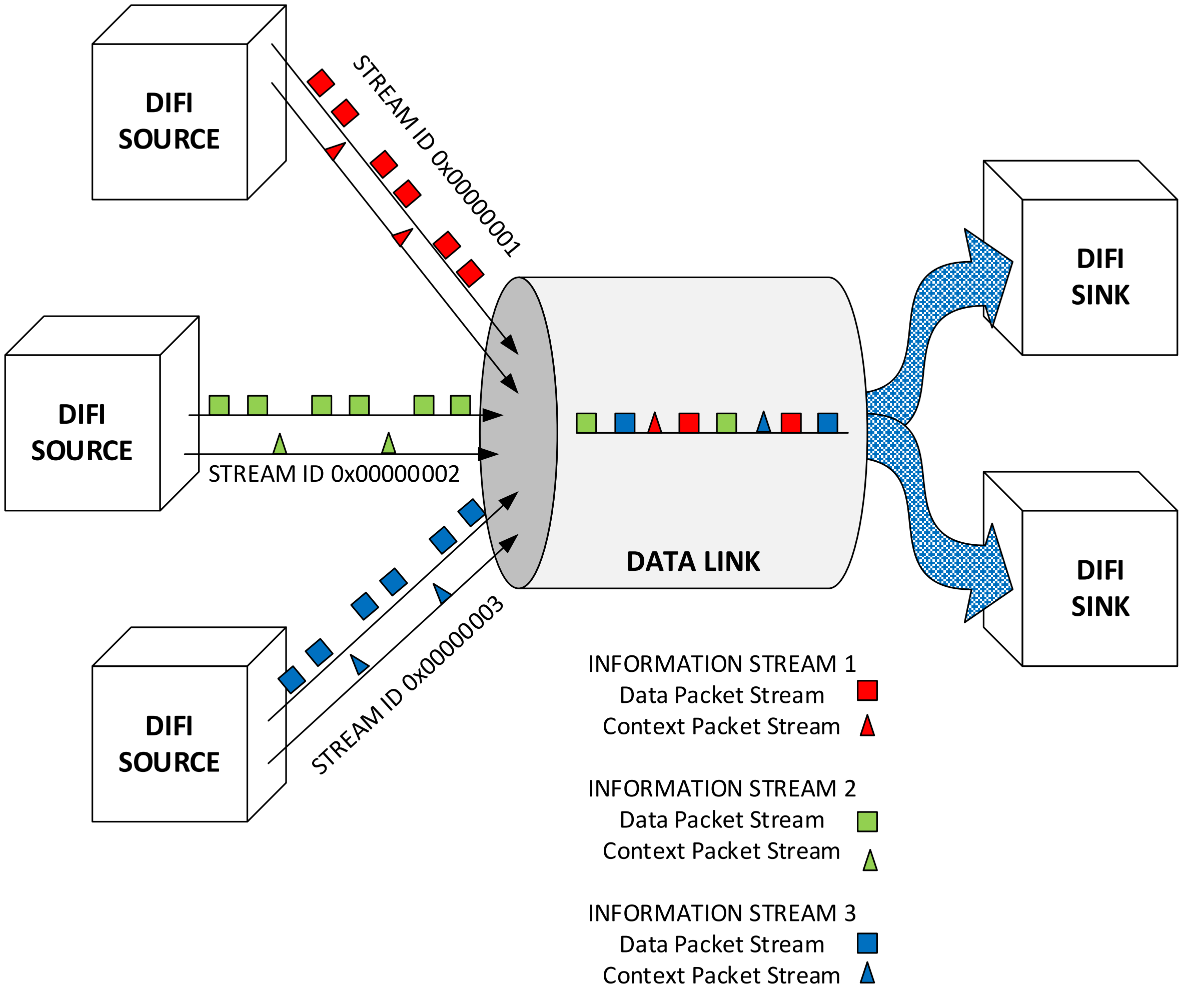


Figure 7. Data Link With Multiple Simultaneous Information Streams with Distinct Stream IDs.

The description of the structure of an Information Stream is called an Information Class. The Information Class defines which Packet Classes are included in the Information Class, and the purpose of each. More specifically, there are eight components to an Information Class. These components encompass every aspect of the Information Stream. In addition to specifying the included Packet Classes and their purposes within the Information Stream, the Information Class also specifies several other details of the Information Stream. The eight components are:

1. Class Name and Code
2. Information Stream Purpose
3. Names of included VRT Packet Streams
4. Purpose of each included Packet Stream
5. Packet Classes
6. Packet Stream Details
7. Reference Points
8. Packet Stream Associations

Individual Packet Classes may be invoked by multiple Information Classes, and therefore those are detailed out separately in Section 4 of this Standard.

All available information classes are described in Table 3-1. Class Code 1 is intentionally in the far-right column, because it is considerably different from the other classes. The individual classes are described in subsequent paragraphs.

Table 3-1 All Information Classes

Information Class Component	**Information Class Component Specifications**				
Class Name, Code	**"Basic Data Plane", Class Code 0 (0x0000)**	**"Basic Data Plane", Class Code 4 (0x0004)**	**"Data Plane plus Flow Control", Class Code 2 (0x0002)**	**"Data Plane plus Flow Control packets, Real Time TSF", Class Code 3 (0x0003)**	**"Version Flow", Class Code 1 (0x0001)**
Information Stream Purpose	To convey digitized I and Q samples, with all control and reference configuration information communicated in advance or using non-VRT streams.		To convey digitized I and Q samples in either the transmit direction or the receive direction, with all control and reference configuration information communicated in advance or using non-DIFI streams, except for the inclusion of 'Flow Control' Command Packets intended to convey timing information for configurations in which a Data Stream sink device is the reference for the Sample Rate timing.		To convey type and version information and convey precise time of day for software applications that require synchronization of the stream source to the stream sink.
Packet Stream Names	1. Signal Data 2. Signal Context		1. Signal Data 2. Signal Context 3. Timing Flow Control		1. Version Flow Signal Context Packet

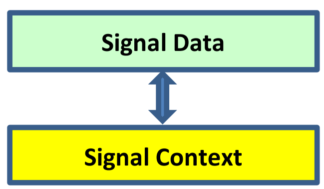
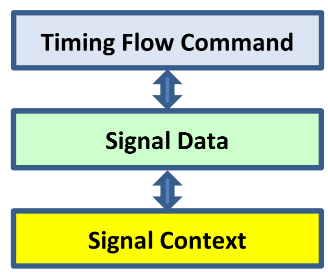
Information Class Component	Information Class Component Specifications				
Class Name, Code	**"Basic Data Plane", Class Code 0 (0x0000)**	**"Basic Data Plane", Class Code 4 (0x0004)**	**"Data Plane plus Flow Control", Class Code 2 (0x0002)**	**"Data Plane plus Flow Control packets, Real Time TSF", Class Code 3 (0x0003)**	**"Version Flow", Class Code 1 (0x0001)**
Packet Stream Purposes	1. Convey signal data as IQ samples 2. Convey data stream context information		1. Convey signal data as IQ samples 2. Convey data stream context information 3. Convey timing information to permit the data source device to synchronize to the data sink device sample rate		1. Convey type and version information 2. Convey time of day information

<table>
<tr><th>Information Class Component</th><th colspan="5">Information Class Component Specifications</th></tr>
<tr><td>Class Name, Code</td><td>"Basic Data Plane", Class Code 0 (0x0000)</td><td>"Basic Data Plane", Class Code 4 (0x0004)</td><td>"Data Plane plus Flow Control", Class Code 2 (0x0002)</td><td>"Data Plane plus Flow Control packets, Real Time TSF", Class Code 3 (0x0003)</td><td>"Version Flow", Class Code 1 (0x0001)</td></tr>
<tr><td>Packet Classes</td><td>1. Standard Flow Signal Data (Packet Class 0x0000)
2. Standard Flow Signal Context (Packet Class 0x0001)</td><td>1. Sample Count Signal Data (Packet Class 0x0002)
2. Sample Count Signal Context (Packet Class 0x0003)</td><td>1. Sample Count Signal Data (Packet Class 0x0002)
2. Sample Count Signal Context (Packet Class 0x0003)
3. Sample Count Timing Flow Control (Packet Class 0x0005)</td><td>1. Standard Flow Signal Data (Packet Class 0x0000)
2. Standard Flow Signal Context (Packet Class 0x0001)
3. Real Time TSF Timing Flow Control (Packet Class 0x0006)</td><td>1. Version Flow Signal Context (Packet Class 0x0004)</td></tr>
<tr><td>Packet Stream Details</td><td colspan="4">1. Data Packet size is not restricted, subject to:
• link-efficient packing
(Note: In class 0, bit padding not permitted; in all other classes bit padding is permitted on final word in payload)
• maximum Ethernet packet size of 9000 bytes
The packet rate is as needed to support the sample rate at the selected packet size.

2. Context packets are required and must be issued upon change of field content, or upon a user-determined periodicity, whichever comes first.

3. For Class 2, Flow Control Packets are issued at a uniform, user-determined rate of no more than one thousand per second.</td><td>1. Packet size is 11 words. This class does not use data packets.

2. Context packets may be issued at any rate from zero (off) to one hundred packets per second.</td></tr>
</table>

Information Class Component	**Information Class Component Specifications**				
Class Name, Code	**"Basic Data Plane", Class Code 0 (0x0000)**	**"Basic Data Plane", Class Code 4 (0x0004)**	**"Data Plane plus Flow Control", Class Code 2 (0x0002)**	**"Data Plane plus Flow Control packets, Real Time TSF", Class Code 3 (0x0003)**	**"Version Flow", Class Code 1 (0x0001)**
Context/Control Reference Points	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).				Reference Point field is not included, reference is to the SID.
Packet Stream Associations					No associations

3.1 Information Class 0x0000, Basic Data Plane

The Basic Data Plane Information Class is the original DIFI Standard's Information Class for conveying signal data and the corresponding metadata. It uses Real Time (picoseconds) for its Fractional Seconds Timestamp field and contains only data and metadata (Context) packets, with no Command Packet Stream defined for this Information Class.

3.2 Information Class 0x0001, Version Flow

The Version Flow Information Class contains only a Context Packet Class and can be used either for conveying information regarding which version of the DIFI Standard is being used or to convey timestamp information from a Packet Stream Sink to a Packet Stream Source. The use of this class for timing purposes is legacy usage, and users who have an application requiring a DIFI Device Sink to emit timestamped packets for synchronization purposes should use Information Classes 0x0002 or 0x0003.

3.3 Information Class 0x0002, Data Plane plus Flow Control

The Data Plane Plus Flow Control Information Class provides a fully featured approach to synchronize the sample rate and timestamp of a Packet Stream Source to that of a Packet Stream sink beyond what Information Class 0x0000 provides. It uses Command Packets, which can be emitted by a Packet Stream sink, but can share a Stream ID with a Packet Stream emitted by a different device in the system. The Command Packet Type includes two subcategories: Control Packets and Acknowledge Packets. This Information Class does not make use of Acknowledge Packets. This Information Class permits any device in the system to emit the Control Packets (referred to as the "Controller") and any device or devices to consume the Control Packets (referred to as the "Controllee").

3.4 Information Class 0x0003, Data Plane plus Flow Control, Real Time TSF

Information Class 0x0003 is identical to 0x0002 except for using real time (picoseconds) for the Fractional Seconds Timestamp (rather than Sample Count used in 0x0002).

3.5 Information Class 0x0004, Basic Data Plane Sample Count TSF

Information Class 0x0004 is identical to 0x0000 except for using Sample Count rather than real time (picoseconds) for the Fractional Seconds Timestamp (used in 0x0000).

4. PACKET CLASSES

DIFI defines three categories of Packet Types, each having a specific purpose, aimed at the overall goal of interoperability.

- Data Packets are defined and constructed to standardize signal data transport.
- Context Packets are defined and constructed to help ensure standardization of the transport of metadata describing the sampled signal data, e.g., sample rate and bit depth.
- Command Packets, which include Control and Acknowledge Packets, are used to provide and acknowledge device settings and support control of timing.

A Packet Class defines the structure and function for packets belonging to one of the above Packet Types. A Packet Class is used in one or more places in an architecture to create Packet Streams.

A Packet Stream is a sequence of packets of the same Packet Class that serves a particular purpose described by the Information Class that incorporates the Packet Stream. Information Classes are described in Section 3 of this Standard.

Table 4-1 shows the Packet Types and Packet Classes supported in this version of the DIFI Standard.

Table 4-1 Supported Packet Types and Packet Classes

V1.2 Packet Types	V1.2 Packet Classes
0x1 **Data** packet with a stream ID	Standard Flow Signal **Data,** 0x0000
	Sample Count Signal Flow **Data**, 0x0002
0x4 **Context** packet with a stream ID	Standard Flow Signal **Context,** 0x0001
	Sample Count Signal **Context**, 0x0003
	Version Flow Signal **Context,** 0x0004
0x6 **Command** Packet with a stream ID	Sample Count Timing Flow **Control**, 0x0005
	Real Time TSF Timing Flow **Control**, 0x0006

Table 4-2 shows which Information Classes incorporate which Packet Classes, and conversely, in which Information Classes each Packet Class has membership. It also notes the purpose of each Information Class and the version in which each first appeared.

Table 4-2 Correlation between Information Classes and Packet Classes

Packet Classes →		0x0000	0x0001	0x0002	0x0003	0x0004	0x0005	0x0006		
↓	Information Classes	Standard Flow Signal Data	Standard Flow Signal Context	Sample Count Signal Data	Sample Count Signal Context	Version Flow Signal Context	Sample Count Timing Flow Control	Real Time TSF Timing Flow Control	Purpose of Information Class ↓	Version in which first incorporated
0x0000	Basic Data Plane	X	X						To convey digitized I/Q data samples and associated context	v1.0
0x0001	Version Flow					X			To convey version and time of day for synchronization (legacy)	v1.0
0x0002	Data Plane plus Flow Control			X	X		X		To convey I/Q data, associated context, and control for synchronization	v1.2
0x0003	Data Plane plus Flow Control, Real Time TSF	X	X					X	To convey I/Q data, associated context, and control for synchronization	v1.2
0x0004	Basic Data Plane, Sample Count TSF			X	X				To convey digitized I/Q data samples and associated context	v1.2.1
	Version in which first incorpora	v1.0	v1.0	v1.2	v1.2	v1.0	v1.2	v1.2		

Packet Types	
(light green)	Data Packet
(yellow)	Context Packet
(blue)	Command Packet

4.1 DIFI Packet Prologue

All DIFI Packets contain a prologue and a payload. The structures of the payloads of the different packet types – Data, Context, and Command – are significantly different, but the prologues have nearly identical structure. The Data payload is signal samples, the Context payload is metadata, and the Command packet payloads are use-specific and are described in Section 4.4.

The basic structure showing the elements of the prologue followed by a payload is illustrated in Table 4-3.

Table 4-3 Basic Structure of a DIFI Packet

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>Word #</td><td></td></tr>
<tr><td colspan="4">Packet Type</td><td>1</td><td>0</td><td>0</td><td>0</td><td colspan="2">TSI</td><td colspan="2">TSF</td><td colspan="4">Packet Count</td><td colspan="16">Packet Size (Number of Words)</td><td>1</td><td>Packet Header</td></tr>
<tr><td colspan="32">Stream Identifier</td><td>2</td><td>Stream Identifier</td></tr>
<tr><td colspan="5">Pad Bit Count</td><td>0</td><td>0</td><td>0</td><td colspan="24">24-Bit DIFI Organizationally Unique Identifier (0x6A621E)</td><td>3</td><td rowspan="2">Class Identifier</td></tr>
<tr><td colspan="16">Information Class</td><td colspan="16">Packet Class</td><td>4</td></tr>
<tr><td colspan="32">Integer Second Timestamp</td><td>5</td><td>Integer Second Timestamp</td></tr>
<tr><td colspan="32" rowspan="2">Fractional Second Timestamp</td><td>6</td><td rowspan="2">Fractional Second Timestamp</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="32" rowspan="3">Payload</td><td>8</td><td></td></tr>
<tr><td>:</td><td></td></tr>
<tr><td>N</td><td></td></tr>
</table>

The prologue contains the following 32-bit or 64-bit word fields:

- Packet Header Field
- Stream Identifier Field
- Class Identifier Field
- Integer-Seconds Timestamp
- Fractional-Seconds Timestamp

The values in the prologue fields differ based on the type of packet and the specifics of the packet class.

- **Word 1: Packet Header**
  - **Bits 31 – 28: Packet Type**

    This four-bit sub-field indicates the type of packet. Table 4-4 shows the codes for the various types of VITA 49.2 packets. This standard supports Packet Types 0x1, 0x4, and 0x6.

Table 4-4 Packet Type Codes

Packet Type	Meaning
0000 (0x0)	Signal Data Packet without Stream Identifier
0001 (0x1)	**Signal Data Packet with Stream Identifier**
0010 (0x2)	Extension Data Packet without Stream Identifier
0011 (0x3)	Extension Data Packet with Stream Identifier
0100 (0x4)	**Context Packet**
0101 (0x5)	Extension Context packet
0110 (0x6)	**Command Packet**
0111 (0x7)	Extension Command Packet
1000 (0x8) – 1111 (0xF)	Reserved for future VRT Packet types

  - **Bit 27: Class Identifier Indicator**

    This bit must be set to 1 for DIFI packets, which indicates the optional Class Identifier field is included. See section 5.1.3 of the VITA 49.2 specification [2] for] for more information.

  - **Bits 26-24:**

    The functions of these bits in the header is packet type dependent. These functions will be detailed in the descriptions of the Data, Context, and Command Packet Classes.

- **Bits 23-22: Timestamp Integer**

  The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources. The TSI is shown in Table 4-5.

Table 4-5 The Meaning of the TSI Codes

TSI Code	Meaning
00	The TSI code 00 is not allowed*
01	Coordinated Universal Time (UTC) which has an epoch of Jan 1, 1970, and includes leap seconds
10	GPS which has an epoch of Jan 6, 1980, but does not include leap seconds
11	POSIX time which has an epoch of Jan 1, 1970, but does not include leap seconds

*This value would indicate that the Integer Seconds Timestamp is omitted and is not permitted in DIFI packets.

- **Bits 21-20: Timestamp Fractional**

  Table 4-6 shows the Timestamp Fractional Codes and their meanings.

Table 4-6 The Meaning and Usage of the TSF Codes

TSF Code	Meaning	Packet Classes
00	The TSF code 00 is not allowed *	Not used in DIFI
01	Sample Count Timestamp	0x0002, 0x0003, 0x0005
10	Real Time (Picoseconds) Timestamp	0x0000, 0x0001, 0x0004, 0x0006
11	Free Running Count Timestamp	Not used in DIFI

*This value would indicate that the Fractional Seconds Timestamp is omitted and is not permitted in DIFI packets.

- **Bits 19 – 16: SeqNum**

  This 4-bit sequence number is incremented modulo 16 for each successive packet in each Packet Stream (e.g., Context Packets are numbered with one sequence, and Data Packets are numbered with a separate independent sequence).

- **Bits 15-0: Packet Size**

  This field contains the total number of words in the DIFI packet: the sum of the number of words in the header and the payload. This number does not include the words required for UDP encapsulation.

- **Word 2: Stream ID**

  The Stream ID (SID) defaults to 0 if unused and can be set to any unsigned 32-bit value before or at run time. When a Data Packet Stream is associated with a Context Packet Stream or Command Packet Stream, they will share Stream IDs.

  The SID location must be documented, and in this Standard, the SID location shall be the digital interface of the IFC or RFC, that is the point of generation of samples out of the ADC in the receive path direction and the point of consumption of samples within the DAC in the transmit path direction. If, in addition to an IFC/RFC, the system includes devices with both digital input and digital output (e.g., a digital combiner or splitter), the SID(s) for streams feeding such devices in the transmit direction should be at the point at which the samples are consumed, at the downstream end of the digital link.

See Section 5.1 of this document and section 5.1.2 of the VITA 49.2 specification [2] for more information.

- **Words 3 & 4, Class Identifier**
  - **Bits 31-27: Pad Bit Count**

    See Data Packet Classes section.
  - **Word 3, Bits 26-24: Reserved Bits**

    The reserved bits are set to zero, in alignment with VITA 49.2 specification [2] Rule 5.1.3-5. These bits are reserved in all DIFI Packet prologues.
  - **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    DIFI as an organization has been issued a Company Identifier (CID) by the IEEE. The CID is a restricted form of an OUI, the use of which has long been encouraged by the IEEE Standards Association when the 24-bit value is not to be used as part of a MAC address. The CID will be considered an acceptable form of OUI within all DIFI packets. The two will not be differentiated in the remainder of the document. This ID Value (0x6A621E) must be inserted in the OUI field of the Class Identifier. The canonical form is 6A-62-1E. This sub-field is identical in all DIFI Packet prologues.
  - **Word 4, Bits 31 – 16: Information Class Code**

    In the VITA 49.2 scheme, an Information Stream is a collection of one or more (typically more than one) Packet Streams that share a Stream ID – for example, a Data Packet Stream and a Context Packet Stream. An Information Class calls out the specific set of Packet Classes that comprise the Information Stream. In general, an Information Class can call out any defined Packet Classes – for example, DIFI-defined Information Classes 0x0000 and 0x0003 each incorporate the DIFI-defined Packet Class 0x0001.

    Each such Information Class, which describes the structure of an Information Stream, has a numerical code assigned to it. The numerical code of the Information Class is entered in the Information Class Code field. The details of the various DIFI-defined Information Classes are covered in section 3. The membership of DIFI Packet Classes in DIFI Information Classes is summarized in Table 3-1.
  - **Word 4, Bits 15 – 0: Packet Class Code**

    Any Packet Class may be called up by any Information Class – e.g., Packet Class 0x0001 is already used by Information Classes 0x0000 and 0x0003. The value in this field in a given packet indicates which Information Class is being used by the Stream that contains the stream of packets this one belongs to.

    The hierarchy is Stream>> Information Class>> Packet Classes.

    All possible packet class codes as of this version of the DIFI standard are shown in Table 4-7.

Table 4-7 Packet Class Codes

Packet Class	Meaning
0x0000	Standard Flow Signal **Data**
0x0001	Standard Flow Signal **Context**
0x0002	Sample Count Signal Flow **Data**
0x0003	Sample Count Signal Flow **Context**
0x0004	Version Flow Signal **Context**
0x0005	Sample Count Timing Flow **Control**
0x0006	Real Time TSF Timing Flow **Control**

Definitions of these class codes are given in Tables throughout this document.

- **Word 5: Integer-seconds Timestamp**

  This field value shall indicate seconds since epoch for the selected time reference (UTC, GPS, or POSIX). Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

  For Packet Classes using a Sample Count TSF, the Integer Seconds Timestamp field will be incremented each time the Fractional Timestamp field reaches the value of the Sample Rate (nominally once per second).

  The format of this field is dependent on the TSI value in the Header field. Subject to the TSI value, this sub-field is identical in all DIFI Packet prologues.

- **Words 6 & 7: Fractional-seconds Timestamp**

  Words 6 & 7 form a 64-bit field, formatted as an unsigned integer.

  For packet classes using the Fractional Seconds Timestamp (TSF) of Real Time (picoseconds), the value in this field reflects the number of picoseconds since the most recent incrementation or reset of the Integer-seconds Timestamp field. The field is reset to zero when the Integer Seconds Timestamp field is incremented or reset.

  For packet classes using the Fractional Seconds Timestamp (TSF) of Sample Count, the value in this field reflects the number of sample counts since the most recent incrementation or reset of the Integer-seconds Timestamp field. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field.

Except for those sub-fields that are identified as identical in all DIFI Packet prologues, the values that are entered into the header fields above are Packet Type and Packet Class dependent, and are detailed in the following sections, as are the structure and content of the payloads.

4.2 DATA PACKET CLASSES

This DIFI Standard presently supports the following classes within the Data Packet Type:

- 0x0000, Standard Flow Signal Data
- 0x0002, Sample Count Signal Flow Data

These Data Packet Classes are nearly identical, except for the Fractional Seconds Timestamp (TSF), which is Real Time (picoseconds) for Class 0x0000 and Sample Count for 0x0002. Certain conventions apply to all Data Packet Classes unless explicitly stated otherwise:

- Header structure conforms to that described in section 4.1.
- The SID location shall be at the point of generation of digital samples in the receive direction and at the point of consumption of digital samples in the transmit direction (see Section 5.1 for more details).

Table 4-8 and Table 4-9 show information about each data packet class and its parameters.

Table 4-8 Data Packet Class General Information

Data Packet Information		
Class Number	**Data Packet Class 0x0000**	**Data Packet Class 0x0002**
Class Name	"Standard Flow Signal Data," Code 0x0000	"Sample Count Signal Data," Code 0x0002
Packet Stream Purpose	To convey digitized I and Q samples in either the transmit direction or the receive direction.	

Table 4-9 Data Packet Class Content

Parameter	Selected Options Packet Class 0x0000	Selected Options Packet Class 0x0002	Comments
Data Packet Header			
Packet Type	Signal Data Packet with Stream ID		Conveys digitized I and Q samples
Packet Size	Variable, user selected		Seven words in prologue plus "N" 32-bit words in the data payload
Stream Identifier	Yes		Selected by user at run time
Class ID	Present		The first word of this two-word field contains the Pad Bit count and the OUI, and the second word contains the Information Class and Packet Class to which the Packet Stream belongs.

Parameter	Selected Options Packet Class 0x0000	Selected Options Packet Class 0x0002	Comments
Integer-seconds Timestamp	May be UTC, POSIX, or GPS as specified in Packet Header	Routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate.	Time continuous streams may periodically re-synchronize to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded to reset to external reference.
Fractional seconds Timestamp	Real time, picoseconds	Sample Count	
Data Packet Payload			
Packing Method	Link Efficient		Data items are packed into 32-bit words. See Figure B-44 of VITA-49.2 for an illustration. Bit padding in the final word of the data payload is not permitted in Information Class 0x0000.
Data Item Size	Variable, user selected		Individual I and Q sample components may be 4 to 16 bits in length (I and Q pairs 8 to 32 bits in length)
Item Packing Field Size	Variable, equal to Data Item Size		
Real/Complex Type	Complex Cartesian		
Data Item Format	Signed Integer (V49.2 Signed Fixed-Point with code 00000, implying no fractional component)		
Sample-repeating/Channel-repeating	N/A		No repeating of any kind
Repeat Count	0		No repeating of any kind
Packet Trailer			
(Not Used)			

4.2.1 Data Packet Field Details

The packet format shown in Table 4-10 is used for both the Standard Flow Signal Data Packet Class (0x0000) and the Sample Count Signal Data Packet Class (0x0002).

Table 4-10 Data Packet Format

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Word #
0	0	0	1	1	0	0	0	TSI		TSF		Seq Num				Packet Size = N+7 words																1
Stream Identifier (assigned at run time)																																2
0	0	0	0	0	0	0	0	24-Bit DIFI CID (0x6A621E)																								3
Information Class Code																Packet Class Code																4
Integer Timestamp (per TSI field)																																5
Fractional Timestamp (per TSF field)																																6
																																7
Signal Data Payload (Complex Cartesian, 4 - 16-bit signed integers, N 32-bit words, bit padding per Information Class documentation)																																8
																																N+6
																																N+7

These two Data Packet Classes have identical format, except for the Fractional Seconds Timestamp field, the Packet Class sub-field, and in one of the Information Classes, the Pad Bit Count field.

- **Word 1: Packet Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x1 which indicates a Data packet with a stream ID.
  - **Bit 27: Class Identifier**

    A description of this field is given in the DIFI Packet Prologue section.
  - **Bit 26: Trailer Indicator**

    This bit must be set to 0, which indicates no packet trailer is used.
  - **Bit 25: VITA49.0 Indicator**

    This bit must be set to 0 which indicates the Data Packet should not be interpreted as the prior VITA 49.0 standard.
  - **Bit 24: VITA 49.2 Spectrum / Time**

- This must be set to 0x0 which indicates the packet contains time data (rather than spectrum data which is not currently supported by this standard). This maintains compliance with VITA 49.2 specification [2] Rule 6.3.1-2.
- **Bits 23-22: Timestamp Integer**

  A description of this field is given in the DIFI Packet Prologue section.
- **Bits 21-20: Timestamp Fractional**

  For Data Packet Class 0x0000, Bits 21-20 are set to 0x2 to indicate that this packet uses Real Time (picoseconds) fractional second timing.

  For Data Packet Class 0x0002, Bits 21-20 are set to 0x1 to indicate that this packet uses Sample Count fractional second timing.
- **Bits 19 – 16: SeqNum**

  A description of this field is given in the DIFI Packet Prologue section.
- **Bits 15-0: Packet Size**

  The Packet Size described in the first word of the Standard Signal Data Packet refers to the Size of VITA header (7 words) summed with the Signal Data Payload size.

  Sample padding is permitted for the combinations of Information Classes and Packet Classes indicated in Table 4-11.

  Sample padding is not supported in Packet Class 0x0000 when used in Information Class 0x0000. For this case only, the Signal Data Payload size is calculated as follows:

  Every packet must contain an integer number of I/Q pairs, each I/Q pair being "2 x sample depth" in bits. A whole number of such complex sample pairs must fit into a whole number multiple of 32-bit units. For example,

  - 5-bit samples = 10-bit complex samples; 16 samples fit into 5 units of 32 bits; so any multiple of 16 samples per packet is legal
  - 10 x 16 = 5 x 32 = 160 bits6-bit samples = 12-bit complex samples; 8 samples fit into 3 units of 32 bits, so any multiple of 8 samples per packet is legal
    - 12 x 8 = 3 x 32 = 96 bits
  - 7-bit samples = 14-bit complex samples; 16 samples fit into 7 units of 32 bits, so any multiple of 16 samples per packet is legal
    - 14 x 16 = 7 x 32 = 224 bits

Table 4-11 Sample Padding

bits per sample	sample count granularity	32-bit unit granularity
4	4	1
5	16	5
6	8	3
7	16	7
8	2	1
9	16	9
10	8	5
11	16	11
12	4	3
13	16	13
14	8	7
15	16	15
16	1	1

Where 2 x <bits per sample> x <sample count granularity> = 32 x <32-bit unit granularity> and every value is a whole number. Table 4-11 shows all variations of bits per sample.

- **Word 2: Stream ID**

  A description of this field is given in the DIFI Packet Prologue section.

- **Words 3 & 4: Class Identifier**
  - **Word 3, Bits 31-27: Pad Bit Count**

    The Pad Bit Count shall be an unsigned 5-bit integer indicating the number of non-data pad bits (from zero to 31) in the final word of the data payload. Permission to use bit padding in the final word of the Data Payload is dependent on the Information Class membership of the Packet Stream, as shown in Table 4-12.

Table 4-12 Bit Padding Permission Information

Information Class	Data Packet Class	Bit Padding Permitted
0x0000	0x0000	No
0x0002	0x0002	Yes
0x0003	0x0000	Yes

- **Word 3, Bits 26-24: Reserved Bits**

  A description of this field is given in the DIFI Packet Prologue section.

- **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

  A description of this field is given in the DIFI Packet Prologue section.

- **Word 4, Bits 31 – 16: Information Class Code**

  A description of this field is given in the DIFI Packet Prologue section.

- **Word 4, Bits 15 – 0: Packet Class Code**

  For Standard Flow Signal Data Packets, the Packet Class Code is 0x0000.

  For Sample Count Flow Signal Data Packets, the Packet Class Code is 0x0002.

- **Word 5: Integer-seconds Timestamp**

  A description of this field is given in the DIFI Packet Prologue section.

- **Words 6 & 7: Fractional-seconds Timestamp**

  Words 6 & 7 form a 64-bit field, formatted as an unsigned integer.

  For Data Packet Class 0x0000, the value in this field reflects the number of picoseconds since the most recent incrementation or reset of the Integer-seconds Timestamp field. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field.

  For data packet class 0x0002, the value in this field reflects the number of sample counts since the most recent incrementation or reset of the Integer-seconds Timestamp field. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field.

- **Words 8 through N+7: Data Payload**

  Data samples shall be formatted as Complex Cartesian. Each sample pair shall consist of an in-phase (I) sample followed by a quadrature (Q) sample, reading from left to right. Samples shall be signed integer format, with bit-depth specified by the Data Packet Payload Format Field in the associated Context Packet.

  DIFI Data Packets shall use “link-efficient” packing, in which sample pairs are packed with no padding bits between them, which, depending on the bit depth, may result in “wrapping” of some samples from one 32-bit data word to the next. Except for Data Packet Class 0x0000 when used in Information Class 0x0000, bit padding between zero and 31 bits is permitted at the end of the final 32-bit word of the Data Packet.

  Note that unless specifically otherwise indicated in Packet Class Documentation, the timestamp field values indicate the time that the first data sample in the data payload is present at the SID location. The relationship between the SID location, timestamps and the Timestamp Adjustment field are described in more detail in Sections 5.1 and 5.2.

4.3 CONTEXT PACKET CLASSES

The function of Context Packets in VITA 49.2 is to provide metadata that permits the interpretation of the data in the payload of the data packets. For example, DIFI samples are required to have a specific format – complex Cartesian – with a bit depth that can be selected between 4 bits and 16 bits. The Context Packets contain these and other metadata required for interpretation of the data in the payload.

Whilst V49.2 provides the facility for Command Packets, it is acknowledged that for backwards compatibility with extant equipment, standard flow signal context packets *may* be used as a pseudo control emitted by the signal data stream emitter.

The necessity of acting on standard flow signal context packets, in real time or otherwise, depends on the application and on the availability of out-of-band management beyond the scope of this standard.

Context Packets may also be used by a device with a DIFI compliant interface that is monitoring one or more DIFI VITA 49.2 streams flowing on a network.

This DIFI Standard presently supports the following classes within the Context Packet Type:

- 0x0001, Standard Flow Signal Context
- 0x0003, Sample Count Signal Flow Context
- 0x0004, Version Flow Signal Context

Certain conventions apply to all three Context Packets unless explicitly stated otherwise:

- All frequency and sample rate fields shall be expressed in Hz, and shall use the VITA 49.2 format, a 64-bit, two's-complement format shown in Figure 8. This field has an integer and a fractional part with the radix point to the right of bit 20 in the second 32-bit word. All DIFI packets describing frequency or sample rate shall be expressed as an integer number of Hz, with all bits to the right of radix point set to zero.
- Corresponding to the associated Data Packet Stream, the SID location for Context Packets shall be at the point of generation of digital samples in the receive direction and at the point of consumption of digital samples within the digital to analog converter in the transmit direction.

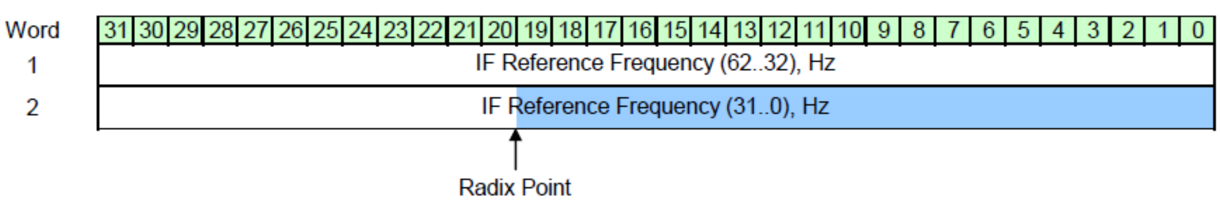


Figure 8. Format of Frequency and Rate fields within this Standard

Table 4-13 and Table 4-14 show information about each context packet class and its parameters.

Table 4-13 Context Packet Class General Information

Context Packet Information			
Class	**Context Packet Class 0x0001**	**Context Packet Class 0x0003**	**Context Packet Class 0x0004**
Class Name	"Standard Flow Signal Context"	"Sample Count Signal Context"	"Version Flow Signal Context Packet"
Class Code Number	Code 0x0001	Code 0x0003	Code 0x0004
Packet Stream Purpose	To convey Context related to the DIFI IQ Data Packet Stream with which it is paired by Stream ID		To convey type and version information and convey precise time of day for software applications

Table 4-14 Context Packet Class Content

Parameter	Selected Options Packet Class 0x0001	Selected Options Packet Class 0x0003	Selected Options Packet Class 0x0004	Comments
Packet Header				
Packet Type	Context Packet with Stream ID			Conveys Context for paired Data Stream (except for Packet Class 0x0004, which has a SID defined by the packet emitter, unrelated to the SID of the Stream containing signal data if emitted by a DIFI Sink)
Packet Size	27 words		11 words	
Stream Identifier	Yes			Matches SID for paired Data Stream
Class ID	Present			The first word of this two-word field contains the Pad Bit count and the OUI, and the second word contains the Information Class and Packet Class to which the Packet Stream belongs.
Integer-seconds Timestamp	Present			May be UTC, POSIX, or GPS as specified in Packet Header. For sample rate, routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate. May be periodically re-synchronized to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded to reset to external reference.
Fractional-seconds Timestamp	Real Time, picoseconds	Sample Count	Real Time, picoseconds	May be locked to an external reference
Context Fields				
Context Field Change Indicator (CIF 0)	Present			See packet detail descriptions
Context Indicator Field 1 (CIF 1)	Not Present		Present	See packet detail descriptions
VITA 49 Version	Not Present		Present	See packet detail descriptions
Year, Day, Revision, Type, ICD Version	Not Present		Present	See packet detail descriptions

Parameter	Selected Options Packet Class 0x0001	Selected Options Packet Class 0x0003	Selected Options Packet Class 0x0004	Comments
Reference Point Identifier	Present		Not present	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified. 3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B). 5. For systems in which the analog interface is an RF air interface (e.g., an electronically scanned beamforming antenna), the reference point default should be 15 (0x000F).
Bandwidth	Present		Not Present	Describes the equivalent analog bandwidth of the signal represented by the digital stream.
IF Reference Frequency	Present		Not present	In systems which employ an accessible analog IF signal, the IF Reference Frequency shall be populated with the sampling center frequency for IF conversion. The use of this field shall be determined by the “Reference Point” field.
RF Reference Frequency	Present		Not present	This field characterizes the frequency of the analog signal present at the Reference Point. This may be an IF signal in the case of a system incorporating an IF Converter or an RF signal in the case of a system incorporating an RF Converter.

Parameter	Selected Options Packet Class 0x0001	Selected Options Packet Class 0x0003	Selected Options Packet Class 0x0004	Comments
IF Band Offset	Present		Not present	The IF Band Offset field describes the frequency offset of the center of the equivalent analog band occupied by the signal, either from the IF Reference Frequency in the case of an IF interface conversion device or the RF Reference Frequency in the case of an RF interface device.
Scaling Level	Present		Not present	The value in the field represents the value in dBFS of a sine wave having the same average power as the signal represented by the samples in the data payload.
Reference Level	Present		Not present	Describes the analog level in dBm at the Reference Point corresponding to a full-scale sinusoid in the digital stream.
Gain	Present		Not present	One 32-bit word made up of two 16-bit fields, Gain 1 and Gain 2. These fields are reserved, populated with the value 0x0000 at the source and ignored at the sink. Usage per previous revisions of this standard is allowed, but it may be more useful to make use of the Reference Level in many situations, and interoperability is the responsibility of the vendor. Formatted per VITA 49.2 §9.5.3
Sample Rate	Present		Not present	The digital sample rate in Hz
Timestamp Adjustment	Present		Not present	This is the adjustment to the timestamp to account for implementation delays. It is a 64-bit field indicating the signal delay in femtoseconds between the Reference Point called out in this packet and the SID Location.
Timestamp Calibration	Present		Not present	Most recent time when timestamp was known to be correct (synchronized to external source)
State and Event Indicators	Present		Not present	Used to convey state of the calibrated time and frequency reference lock; refer to VITA 49.2 §9.10.8

Parameter	Selected Options Packet Class 0x0001	Selected Options Packet Class 0x0003	Selected Options Packet Class 0x0004	Comments
Data Packet Payload Format	Present		Not present	Data payload shall be formatted as link-efficient Complex Cartesian. Each sample pair shall consist of an in-phase (I) sample followed by a quadrature (Q) sample, reading from left to right. Samples shall be signed integer format, with bit-depth specified by bits 0-5 of the first word of this Data Packet Payload Format Field
Temperature	Not present			
Device ID	Not present			
Data Item Format	Signed integer		Not present	
Packet Trailer	Not present			
(Not Used)				

4.3.1 Signal Context Field Details for Classes 0x0001 and 0x0003

The packet format shown in Table 4-15 is used for both Context Packet Classes: the Standard Flow Signal Context Packet Class and the Sample Count Signal Context Packet Class.

Table 4-15 General Format for a Signal Context Packet

<table>
<tr><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th><th>Word #</th></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>TSM</td><td colspan="2">TSI</td><td colspan="2">TSF</td><td colspan="4">Seq Num</td><td colspan="16">Packet Size = 27 words</td><td>1</td></tr>
<tr><td colspan="32">Stream Identifier (assigned at run time)</td><td>2</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td colspan="24">24-Bit DIFI CID (0x6A621E)</td><td>3</td></tr>
<tr><td colspan="16">Information Class Code</td><td colspan="16">Packet Class Code</td><td>4</td></tr>
<tr><td colspan="32">Integer Seconds Timestamp (per TSI field)</td><td>5</td></tr>
<tr><td colspan="32" rowspan="2">Fractional Timestamp (per TSF field)</td><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="32">Context Indicator Field (0xFBB98000 -> context change or 0x7BB98000 -> no change)</td><td>8</td></tr>
<tr><td colspan="32">Reference Point</td><td>9</td></tr>
<tr><td colspan="32" rowspan="2">Bandwidth</td><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td colspan="32" rowspan="2">IF Reference Frequency</td><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td colspan="32" rowspan="2">RF Reference Frequency</td><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td colspan="32" rowspan="2">IF Band Offset</td><td>16</td></tr>
<tr><td>17</td></tr>
<tr><td colspan="16">Scaling</td><td colspan="16">Reference Level</td><td>18</td></tr>
<tr><td colspan="16">Gain 2</td><td colspan="16">Gain 1</td><td>19</td></tr>
<tr><td colspan="32" rowspan="2">Sample Rate</td><td>20</td></tr>
<tr><td>21</td></tr>
<tr><td colspan="32" rowspan="2">Timestamp Adjustment</td><td>22</td></tr>
<tr><td>23</td></tr>
<tr><td colspan="32">Timestamp Calibration Time</td><td>24</td></tr>
<tr><td colspan="32">State and Event Indicators</td><td>25</td></tr>
<tr><td colspan="32" rowspan="2">Data Packet Payload Format</td><td>26</td></tr>
<tr><td>27</td></tr>
</table>

- **Word 1: Packet Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x4 which indicates a Context packet with a stream ID.
  - **Bits 26 – 25: Reserved**

    These reserved bits must be set to 0x0.
  - **Bit 24: Timestamp Mode**

    For Packet Class 0x0001, this bit sets the Timestamp Mode (TSM) to either coarse or fine timing: 0 for fine or precise timing, 1 for coarse or general timing. The selection of fine versus coarse timing is determined by the Information Class in which this Context Packet Class, 0x0001, is used, as shown in Table 4-16.

Table 4-16 Timestamp Mode (TSM) field values for coarse and fine timing

Information Class	Timestamp Mode
0x0000	Coarse (TSM = 1)
0x0003	Fine (TSM = 0)

For Packet Class 0x0003, the TSM bit is set to 0 indicating the timestamp is conveying precise timing for packets with the associated Stream ID.

See VITA 49.2 Section 7.1.3 for more details of coarse and fine timing.

- **Bits 23 – 22: Timestamp Integer Seconds**

  A description of this field is given in the DIFI Packet Prologue section.

- **Bits 21 – 20: Timestamp Fractional Seconds**

  For Packet Class 0x0001, the TSF field indicates the type of fractional seconds, which is Real Time (picoseconds) (0x2), for this Packet Class.

  For Packet Class 0x0003, the TSF field indicates the type of fractional seconds is Sample Count (0x1).

- **Bits 19 – 16: SeqNum**

  A description of this field is given in the DIFI Packet Prologue section.

- **Bits 15 – 0: Packet Size (Header, Bits 15 – 0)**

  The number of 32-bit words in the packet including the header and any optional fields is fixed at 27 words for Packet Class 0x0001 and Packet Class 0x0003.

- **Word 2: Stream ID**

  A description of this field is given in the DIFI Packet Prologue section.

- **Words 3 & 4: Class Identifier**
  - **Word 3, Bits 31-27: Pad Bit Count**

    The Pad Count Bits are set to zero in the Context Packets, since they have no Data Payload.

  - **Word 3, Bits 26-24: Reserved Bits**

    A description of this field is given in the DIFI Packet Prologue section.

  - **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    A description of this field is given in the DIFI Packet Prologue section.

  - **Word 4, Bits 31 – 16: Information Class Code**

    A description of this field is given in the DIFI Packet Prologue section.

    Word 4, Bits 15 – 0: Packet Class Code

    The value placed in this sub-field is the numerical value corresponding to the Packet Class to which the packet, itself, belongs.

    For Standard Flow Signal Context Packets, the Packet Class Code is 0x0001.

For Sample Count Signal Context Packets, the Packet Class Code is 0x0003.

- **Word 5: Integer-seconds Timestamp**

  A description of this field is given in the DIFI Packet Prologue section.

- **Words 6 & 7: Fractional-seconds Timestamp**

  A description of this field is given in the DIFI Packet Prologue section.

  For context packet class 0x0001, this field contains the number of picoseconds past the integer seconds. The field is formatted as unsigned integer. The field is reset to zero when the Integer Seconds Timestamp field is incremented or reset.

  For context packet class 0x0003, this field contains the Sample count. The Integer Seconds Timestamp field will nominally be incremented each time the Fractional Timestamp field reaches the value of the Sample Rate (nominally once per second).

  Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Word 8: Context Indicator Field (CIF 0)**

  The purpose of the Context Indicator Field is to state which fields are reporting their values in this particular context packet. Every Context packet shall contain at least CIF 0. Bit 31 of the CIF 0 field indicates whether any values have changed since the last transmitted context package: if Bit 31 is set, there is new information; if Bit 31 is zero, there is no new information. All other set bits indicate that the corresponding Context field entry is included in the Context field section of the Context packet. Figure 9 shows the association of the CIF 0 field's bits to the context fields.

  When one of the CIF 0 bits 1,2,3 are set, this indicates that the corresponding CIF 1, CIF 2, or CIF 3 word is present in the Context packet.

  In a DIFI-compliant Context Packet, only certain bits are allowed to be set.

  Figure 9 shows the bits that must be set for Packet Classes 0x0001 and 0x0003.

  - 0xFBB98000 if there has been a change in any context value, or
  - 0x7BB9800 if there has been no change in context values

  The context fields themselves can be seen in the packet layout in Table 4-15.

  See Section 9 of the VITA 49.2 specification [2] for additional information.

Context Fields →	Context Field Change Indicator	Reference Point Identifier	Bandwidth	IF Reference Frequency	RF Reference Frequency	RF Reference Frequency Offset	IF Band Offset	Reference Level	Gain	Over-range Count	Sample Rate	Timestamp Adjustment	Timestamp Calibration Time	Temperature	Device Identifier	State/Event Indicators	Signal Data Packet Payload Format	Formatted GPS	Formatted INS	ECEF Ephemeris	Relative Ephemeris	Ephemeris Ref ID	GPS ASCII	Context Association Lists	Field Attributes Enable	Reserved for CIF Expansion	Reserved for CIF Expansion	Reserved for CIF Expansion	CIF 3 Enable	CIF 2 Enable	CIF 1 Enable	Reserved
Context Classes ↓	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x0001 and 0x0003	X	1	1	1	1	0	1	1	1	0	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 9. CIF 0 Bit Assignment for Packet Classes 0x0001 and 0x0003

Word 9: Reference Point Field

Reference Point is the location in a system the packet is conveying information about. For a Context packet, it is the place in an architecture where the context information applies. The value of the Reference Point field should be one of the following:

- 100 (0x00000064), indicating the input to the IF converter on receive or the output of the IF converter on transmit, used when the analog input to or output from the converter is at IF frequency
- 75 (0x0000004B), indicating the input to the RF converter on receive or the output of the RF converter on transmit, used when the analog input to or output from the converter is at RF frequency
- 25 (0x00000019), indicating the antenna feed, used primarily when transmit/receive timing is critical (e.g., in ranging applications) and Timestamp Adjustment must be calibrated to the antenna feed
- 15 (0x0000000F), indicating the air interface, used for active electronically scanned arrays that do not have defined locations corresponding to Reference Points 100, 75, or 25

- **Words 10 & 11: Bandwidth**

  For Packet Class 0x0001 and 0x0003, these two words represent the useable bandwidth of the digitized signal. The bandwidths for the standard are specified in 1 Hz increments. Refer to section 9.5.1 of the VITA 49.2 specification [2] for complete details.

- **Words 12 & 13: IF Reference Frequency**

  In systems which employ an accessible analog IF signal, the IF Reference Frequency shall be populated with the sampling center frequency for IF conversion. In systems having an RF output or input and no accessible IF output or input, the IF Reference Frequency shall be populated with the value 0x00000000 at the source and ignored at the sink. The use of this field shall be determined by the value in the “Reference Point” field.

  This field contains the IF center frequency of the digitized signal which defaults to 0 for zero-IF architectures. Refer to section 9.5.5 of the VITA 49.2 specification [2] for complete details.

- **Words 14 & 15: RF Reference Frequency**

  In systems which employ an analog IF, the RF Reference Frequency field shall be populated with the intended RF center frequency realized through analog conversion (for transmit or receive). In systems employing only direct RF conversion, the RF Reference Frequency field shall be populated with the sampling center frequency for direct RF conversion. The use of this field shall be determined by the value in the “Reference Point” field.

  For packet class 0x0003, this field contains the center frequency of the RF spectrum on the RF input port for the RF-to-IP direction or the center of the spectrum on the RF output port for the Transmit direction. The RF reference frequency in the Transmit direction is status information only. The output center frequency is programmed and is independent of the RF frequency at the stream source to allow frequency translation. Refer to section 9.5.10 of the VITA 49.2 specification [2] for complete details.

- **Words 16 & 17: IF Band Offset**

  The stream offset from the IF center frequency of the digitized signal which defaults to 0 Hz. The IF center frequency is always 0 Hz for zero IF architectures. The stream offset is a signed number with a 1 Hz resolution and can be set anywhere within the system bandwidth as long as no portion of the stream bandwidth extends beyond the system bandwidth edges. The system bandwidth is defined by the bandwidth parameter above.

  The IF Band Offset value is the Stream Offset for the receive direction. It is used as the default Stream Offset in the transmit direction but can be overridden. Refer to section 9.5.4 of the VITA 49.2 specification [2] for complete details.

- **Word 18: Reference Level**

  The purpose of the Reference Level field is to relate the physical signal amplitude at the reference point with the data samples in the Signal Data packet. Refer to section 9.5.9 of the VITA 49.2 specification [2] for complete details. Refer to VITA 49.2 specification [2] section B.6 for an example.

  - **Bits 31 – 16: Scaling Level**

    This field is used to describe scaling applied to the digital signal representation to prevent overflow of the signal sample words (4-16 bits) in the Signal Data packet payload. Filling the Scaling Level field is optional. Note, it is used in the transmit direction only, and the value placed in the field shall default to a value of 0x0000 when the field is not used.

    When used, the field characterizes the digital scaling of the samples in the IP payload. The value in the field represents the value in dBFS (dB full-scale) of a sine wave having the same average power as the signal represented by the samples in the data payload.

  - **Bits 15 – 0: Reference Level**

    This field is used to relate the physical analog signal amplitude at the reference point with the data samples in the associated Signal Data packet. Filling the Reference Level field is mandatory.

    In the receive direction, the field describes a power level in dBm incident at the Reference Point. The power value conveyed by the Reference Level field is the AC power of a single sine wave at the Reference Point that results in a full-scale digitized sine wave in the payload of the paired Data Packet Stream.

    In the transmit direction, the field specifies the power level in dBm that is intended at the Reference Point in response to a full-scale digital representation of a sine wave in the Data Payload. In the case of an electronically scanned array (ESA) using the air interface as the Reference Point (Reference Point 15, 0x000F), the Reference Level describes the intended EIRP in dBm on boresight (i.e., in the direction in which the main lobe of the antenna pattern is pointed).

    Observation 4.2.1-1: Noting that ESA gain is generally a function of pointing angles, the ESA device must dynamically account for effects of pointing angles and frequency in calculating the relationship between DAC output and EIRP in determining the required electronic gain to properly realize the Reference Level.

- **Word 19: Gain/Attenuation**

  One 32-bit word made up of two 16-bit fields, Gain 1 and Gain 2. These fields are reserved, populated with the value 0x0000 at the source and ignored at the sink. Usage per previous revisions of this standard is allowed, but it may be more useful to make use of the Reference Level in many situations, and interoperability is the responsibility of the vendor. Refer to section 9.5.3 of the VITA 49.2 specification [2] for complete details. Refer to VITA 49.2 section B.7 for an example.

- **Words 20 & 21: Sample Rate**

  The sampling rate of the samples in the Signal Data packets which can be set. Refer to section 9.5.12 of the VITA 49.2 specification [2] for complete details.

  For interoperability purposes DIFI refers the reader to the external Sample Rate Vendor Interoperability area of the DIFI website.

- **Words 22 & 23: Timestamp Adjustment**

  With the presence of Prologue Timestamp and the inclusion of the Reference Point field and this Timestamp Adjustment field in this Context Packet, the value in the Timestamp adjustment field should be a 64-bit two's-complement value in femtoseconds, representing the signal delay between the Reference Point called out in this Context Packet and the SID location. On the transmit path, this value will generally be positive, and on the receive path, it will generally be negative. Section 5.2 describes the relationship between the signal timing, SID and Reference Point locations, and the Timestamp Adjustment.

- **Word 24: Timestamp Calibration Time**

  This field indicates the last time the timestamp was known to be correct. This is populated on the Transmit side for applications that require knowledge of when the timing signal was last locked.

  Refer to Section 9.7.3.3 of the VITA 49.2 specification [2] for complete details.

- **Word 25: State and Event Indicators**

  Used to convey the state of the calibrated time (bit 19) and frequency reference lock (bit 17) for the samples in the Signal Data packets.

  The calibrated time reference can be IRIG-B, IRIG-DC, 1PPS, NTP, GPS.

  The frequency reference can be 10 MHz, IRIG-B, IRIG-DC or 1PPS, GPS.

  The lock statuses of the time and frequency references are updated about once per second in the RF-to-IP direction.

  The status information is used by the Transmit side to determine if it can operate in Programmed Delay mode and if it can measure end-to-end latency (Measured Delay) or Network Delay. The Measured and Network Delays will be set to 0 if the calibrated time (bit 19) is not locked on the RF-to-IP side.

  Refer to section 9.10.8 of the VITA 49.2 specification [2] for complete details.

- **Words 26 & 27: Data Packet Payload Format**

This field is required to interpret the samples in the Signal Data packets. This standard support only supports complex Cartesian samples (I and Q), link-efficient packing, signed integer (V49.2 signed fixed point with code 00000) and no event or channel tags. It supports sample sizes from 4 through 16 bits without sample component repeats. Refer to section 9.13.3 of the VITA 49.2 specification [2] for complete details.

All sub-field values in the Data Packet Payload field are specified by this standard except for those that define the bit depth of the samples (Word 26, bits 11-6 and bits 5-0), which the user shall determine based on application requirements. The meanings and specified values of the sub-fields are illustrated in Figure 10**.**

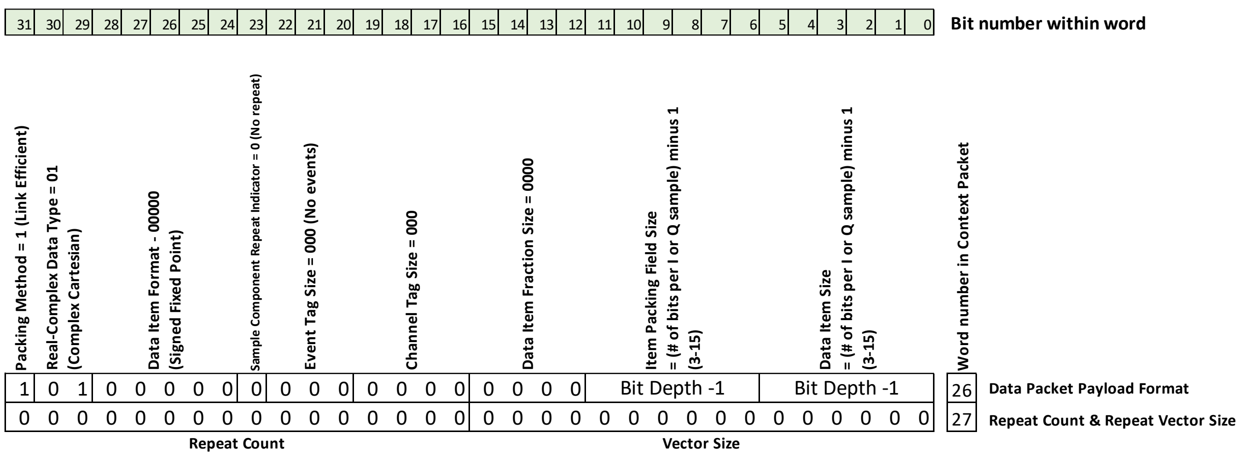


Figure 10. Data Packet Payload Format sub-field definitions and values

The packet rate for this Standard Flow Signal Context Packet may be set from 0 (off) through 20 packets/second for any configuration of stream sample rate, sample size, and data packet size for the standard context flows.

Additionally, Standard Flow Signal Context Packet transmission is required upon change to any signal context packet field, e.g., change to the “Reference Amplitude” field.

4.3.2 **Packet Class 0x0004, Version Flow Signal Context Packet**

This context packet is used to convey type and version information and conveys precise time of day for software applications.

The version packet format is created on the receive side and used by the transmit side to auto-select a compatible packet format, if possible. The version packet may optionally be used on the transmit flow when appropriate for the application.

The Packet Format is shown in Table 4-17 and is new in VITA 49.2 specification [2], which has added four new Context Indicator Fields to provide for additional metadata for the Signal Data Packets. The Version information is contained in the CIF 1 indicator field (see Section 9.1 in the VITA 49.2 specification [2]).

Table 4-17 Packet Class 0x0004 Format, Version Flow Signal Context Packets

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	1	0	0	1	TSI		1	0	SeqNum				Packet Size = 11 words															
Stream ID = variable																															
0	0	0	0	0	0	0	0	OUI = 0x6A621E																							
Information Class Code = 0x0001																Packet Class Code = 0x0004															
Integer-seconds Timestamp (UTC/GPS/POSIX seconds)																															
Fractional-seconds Timestamp (picoseconds)																															
Context Indicator Field 0 (0x80000002 -> context change or 0x00000002 -> no change)																															
Context Indicator Field 1 = 0x0000000C																															
V49 Spec Version = 0x00000004																															
Year							Day									Revision						Type				ICD Version					

4.3.3 **Packet Class 0x0004, Version Flow Context Packet Field Details**

- **Word 1: Packet Header**
  - **Bits 31 – 28: Packet Type**

    For the Version Flow Signal Context Class 0x0004, this must be set to 0x4.
  - **Bit 27: Class Identifier Indicator**

    A description of this field is given in the DIFI Packet Prologue section.

    Bits 26 – 25: Reserved

    These reserved bits must be set to 0x0.
  - **Bit 24: Timestamp Mode**

    For Packet Class 0x0004, this bit is set to 1 indicating coarse timing.

- **Bits 23 – 22: Timestamp Integer Seconds**

  See description in Section 4.3.1
- **Bits 21 – 20: Timestamp Fractional Seconds**

  For Packet Class 0x0004, the TSF field is set to 0x2 indicating Real Time (picoseconds)
- **Bits 19 – 16: SeqNum**

  A description of this field is given in the DIFI Packet Prologue section.

  Bits 15 – 0: Packet Size (Header, Bits 15 – 0)

  For Packet Class 0x0004, the size is fixed at 11 words.

- **Word 2: Stream ID**

  A description of this field is given in the DIFI Packet Prologue section.
- **Words 3 & 4: Class Identifier**
  - **Word 3, Bits 31-27: Pad Bit Count**

    The Pad Count Bits are set to zero in the Context Packets, since they have no Data Payload.
  - **Word 3, Bits 26-24: Reserved Bits**

    A description of this field is given in the DIFI Packet Prologue section.
  - **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    A description of this field is given in the DIFI Packet Prologue section.
  - **Word 4, Bits 31 – 16: Information Class Code**

    A description of this field is given in the DIFI Packet Prologue section.
  - **Word 4, Bits 15 – 0: Packet Class Code**

    A description of this field is given in the DIFI Packet Prologue section.

    For Version Flow Signal Context Packets, the Packet Class Code must be 0x0004. The Receive side uses the version information to automatically configure itself to a compatible mode, if possible. (A future version of this standard will include a Control and Acknowledge Packet procedure.)
- **Word 5: Integer-seconds Timestamp**

  A description of this field is given in the DIFI Packet Prologue section.
- **Words 6 & 7: Fractional-seconds Timestamp**

  A description of this field is given in the DIFI Packet Prologue section.

  For context packet class 0x0004, this field contains the number of picoseconds past the integer seconds.
- **Word 8: Context Indicator Field (CIF 0)**

  Refer to the description of this field in Section 4.3.1.

  For Packet Class 0x0004, Figure 11 shows the required values for CIF word 0
  - 0x80000002 if there has been a change in any context value, or
  - 0x00000002 if there has been no change in context values

The context fields themselves can be seen in the packet layout in Table 4-17.

Context Fields →	Context Field Change Indicator	Reference Point Identifier	Bandwidth	IF Reference Frequency	RF Reference Frequency	RF Reference Frequency Offset	IF Band Offset	Reference Level	Gain	Over-range Count	Sample Rate	Timestamp Adjustment	Timestamp Calibration Time	Temperature	Device Identifier	State/Event Indicators	Signal Data Packet Payload Form	Formatted GPS	Formatted INS	ECEF Ephemeris	Relative Ephemeris	Ephemeris Ref ID	GPS ASCII	Context Association Lists	Field Attributes Enable	Reserved for CIF Expansion	Reserved for CIF Expansion	Reserved for CIF Expansion	CIF 3 Enable	CIF 2 Enable	CIF 1 Enable	Reserved
Context Class ↓	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x0004	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Figure 11. CIF 0 Bit Assignment for Packet Class 0x0004

The CIF word 1 must be set to 0x0000000C to indicate that the V49 Spec Version Word and the Year/Day/Revision/Type/ICD Version Word are to be included.

The V49 version must be 0x4 (VITA 49.2 specification [2]). The Receive side uses the version information to automatically configure itself to a compatible mode, if possible.

- **Year (Bits 31 – 25)**

  The year the software/firmware was compiled starting from the year 2000. See section 9.10.4 of the VITA 49.2 specification [2] for additional details.

- **Day (Bits 24 – 16)**

  The day within the year the software/firmware was compiled starting with a 1 for January 1st. See section 9.10.4 of the VITA 49.2 specification [2] for additional details.

- **Revision (Bits 15 – 10)**

  The Revision number can be used to account for which version created on the same year and day is being used. This will normally be set to 1. See Section 9.10.4 of the VITA 49.2 specification [2] for additional details.

- **Type (Bits 9 – 6)**

  The user defined subfield within the version word is used to convey the type of device. The types which may be assigned are 0..15. This field shall be set to 0x0. The types are currently undefined.

- **ICD Version (Bits 5 – 0)**

  This subfield denotes the version of the data plane standard, as shown in Table 4-18

Table 4-18 The Meaning of the Version Codes

Version Code	Meaning
0	Version 1 corresponds to DIFI v1.x
1 – 31	Reserved

4.4 COMMAND PACKET CLASSES

VITA 49.2 specifies the Command Packet type. There are two sub-types within this packet type, Control Packets and Acknowledge Packets. At the present revision, this DIFI Standard uses only Control Packets. Where descriptions apply to all Command Packet types, the "Command Packet" nomenclature is used. When features described apply only to Control Packets or the comment refers to a specific Control Packet, the "Control Packet" nomenclature is used.

The DIFI Standard presently supports the following classes within the Command Packet Type:

- 0x0005, Sample Count Timing Flow Control
- 0x0006, Real Time TSF Timing Flow Control

4.4.1 Command Packet Classes

The Timing Flow Control Packet Classes, 0x0005 and 0x0006, are intended for the synchronization of the DIFI sources and sinks. The packet documentation is shown in Table 4-19 and Table 4-20.

Table 4-19 Command Packet Class General Information

Command Packet Class Information		
Class	**Command Packet Class 0x0005**	**Command Packet Class 0x0006**
Class Name	"Sample Count Timing Flow Control"	"Real Time TSF Timing Flow Control"
Class Code Number	Code 0x0005	Code 0x0006
Packet Stream Purpose	To provide timing and buffer level information to permit synchronization of upstream devices.	

Table 4-20 Timing Flow Control Packet Classes 0x0005 and 0x0006

Packet Header		
Parameter	**Selected Options, Packet Classes 0x0005 and 0x0006**	**Comments**
Packet Type	Control Packet with Stream ID	Conveys timing and buffer fill and status information for paired Data Stream
Packet Size	21 words	
Stream Identifier	Yes	Matches SID for paired Data Stream
Class ID	Present	OUI is 0x6A621E Packet Class Code is 0x0005 or 0x0006
Integer-Seconds Timestamp	Present	Routinely incremented at Fractional Seconds Timestamp count equal to Sample Rate. May be periodically re-synchronized to UTC, POSIX, or GPS as specified in Packet Header, when externally commanded reset to external reference.
Fractional-Seconds Timestamp	Present	0x0005, Sample Count 0x0006, Real Time (picoseconds)
Context Fields		
Parameter	**Selected Options**	**Comments**
CAM Field	Present	
Message ID	Present	Sequentially assigned to the series of Control Packets issued by a Controller device
Controllee ID	Present	Pre-assigned value identifying each Controllee device in a system
Controller ID	Present	Pre-assigned value identifying each Controller device in a system
Control Indicator Field CIF 0	Present	32-bit word indicating which fields are present in the Control Packet; in the case of this Flow Control Packet, indicates the presence of the Reference Point field, the Timestamp Adjustment field, and the CIF1 field
Control Indicator Field CIF 1	Present	32-bit field indicating which fields are present in the Control Packet; in the case of this Flow Control Packet, indicates the presence of the Buffer Size (3-word) Field
Reference Point Field		
Reference Point	Present	1. Transmit Direction: The reference point is set as the analog output of the conversion device. This applies by default unless otherwise specified. 2. Receive Direction: The reference point is set as the analog input of the conversion device. This is the default reference point unless otherwise specified.

		3. For systems using a device with an IF analog interface, the reference point default should be 100 (0x0064). 4. For systems using a device with an RF analog interface, the reference point default should be 75 (0x004B).
Sample Rate Field		
Sample Rate	Present	64-bit field indicating the digital sample rate in Hz. Unsigned integer with the radix point to the right of bit 20in the second 32-bit word of the 64-bit field. Only integer Hz sample rates are permitted, that is, all bits to the right of the radix point must be zero.
Timestamp Adjustment Field		
Timestamp Adjustment	Present	64-bit field indicating the signal delay in femtoseconds between the Reference Point called out in this packet and the SID Location called out in the associated Context Packet. This field is formatted as a signed integer
Buffer Size Fields		
Buffer Size	Present	64-bit field indicating the size of the Buffer in bytes. This field is formatted as an unsigned integer
Buffer Level/Buffer Status	Present	The 16 MSBs of this field are reserved. The next 8 MSBs comprise the Buffer Level sub-field. The four MSBs of the Buffer Status field are used to extend the Buffer Level sub-field to 12-bit resolution. The Buffer Level subfield represents an average of the buffer fill level where the details of the averaging are left to the implementation. The four LSBs of the Buffer Status sub-field provide discrete status indicators. In the description, immediately following, of the four status indicator bits, the term «current interval» shall refer to the interval between the issuance of the previous Flow Control Packet and the issuance of the present Flow Control Packet. • The Buffer Overflow (set to «1» whenever a buffer overflow occurs during the current interval). • The Nearly Full indicator (set to «1» if the Buffer Level exceeds the nearly full threshold during the current interval). • The Nearly Empty indicator (set to «1» if the Buffer Level falls below the nearly empty threshold during the current interval). • The Buffer Underflow (set to «1» if the Buffer underflows during the current interval).

4.4.2 **Command Packet Field Details**

The packet format shown in Table 4-21 is used for both Command Packet Classes: the Sample Count Timing Flow Control Packet Class and the Real Time TSF Timing Flow Control Packet Class.

Table 4-21 Timing Flow Control Packet Format

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Word #	
0	1	1	0	1	0	0	0	TSI		TSF		Packet Count				Packet Size (21 Words)																1	Packet Header
Stream Identifier																																2	Stream Identifier
0	0	0	0	0	0	0	0	24-Bit DIFI CID (0x6A621E)																								3	Class Identifier
Information Class																Packet Class																4	
Integer Second Timestamp (per TSI)																																5	Integer Second Timestamp
Fractional Second Timestamp (per TSF)																																6	Fractional Second Timestamp
																																7	
1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8	Control/Ack Mode (CAM) field
Message ID																																9	Message ID
Controllee ID																																10	Controllee Identifier (default to 0x
Controller ID																																11	Controller Identifier (default to 0x
0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12	Control Indicator Field: CIF 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13	Control Indicator Field: CIF 1
Reference Point (Default = 0x00000064)																																14	Reference Point
Sample Rate																																15	Sample Rate
																																16	
Timestamp Adjustment (femtoseconds)																																17	Timestamp Adjustment
																																18	
Buffer Size																																19	
																																20	Buffer Size Field
Reserved																Buffer Fill												OF	NF	NE	UF	21	

* Recommendation: All zeros in these fields should indicate that Controller or Controllee IDs are unused

- **Word 1: Packet Header**
  - **Bits 31 – 28: Packet Type**

    This must be set to 0x6 which indicates a Command Packet with a stream ID.
  - **Bit 27: Class Identifier**

    A description of this field is given in the DIFI Packet Prologue section.
  - **Bits 26 – 24: Control vs Acknowledge indicators**

    These bits must be set to 0x0 for a Command Packet (that is not a cancellation packet).
  - **Bits 23 – 22: Timestamp Integer**

    A description of this field is given in the DIFI Packet Prologue section.
  - **Bits 21 – 20: Timestamp Fractional**

    The TSF field indicates the type of fractional seconds.

    For the Sample Count Timing Flow Control Packet Class 0x0005, this is set to the code for Sample count (0x1).

    For the Real Time TSF Timing Flow Control Packet Class 0x0006, this is set to the code for Real Time (Picoseconds) (0x2).
  - **Bits 19 – 16: SeqNum**

This 4-bit sequence number is incremented modulo 16 for each successive Flow Control Packet.

- **Bits 15 – 0: Packet Size**

  The number of 32-bit words in the packet including the header and any optional fields. Fixed at 21 words for the Timing Flow Control packet.

- **Word 2: Stream ID**

  A description of this field is given in the DIFI Packet Prologue section.

  The Stream ID for the Timing Flow Control Packets shall match the SID of the Data Packet Stream with which it is paired.

  Words 3,4: Class Identifier

  - **Word 3, Bits 31 – 27: Padding Bits**

    There is no data payload, and therefore Pad Bit Count is set to zero.

  - **Word 3, Bits 26 – 24: Reserved Bits**

    A description of this field is given in the DIFI Packet Prologue section.

  - **Word 3, Bits 23 – 0: Organizationally Unique Identifier (OUI)**

    A description of this field is given in the DIFI Packet Prologue section.

  - **Word 4, Bits 31 – 16: Information Class Code**

    A description of this field is given in the DIFI Packet Prologue section.

    At present, the DIFI standard has two Information Classes that can incorporate the Timing Flow Control Packets, “Data Plane plus Flow Control”, Class Code 2 (0x0002), and “Data Plane plus Flow Control packets, Real Time TSF”, Class Code 3 (0x0003)

  - **Word 4, Bits 15 – 0: Packet Class Code**

    This field indicates which Timing Flow Control Packet Class is being used.

    Sample Count Timing Flow Control, 0x0005

    Real Time TSF Timing Flow Control, 0x0006

- **Word 5: Integer-seconds Timestamp**

  A description of this field is given in the DIFI Packet Prologue section.

  For the Timing Flow Control Packets, which have the intended purpose of permitting synchronization among the “clocks” of the DIFI devices connected in the identified stream, the timestamp indicates the time of issue using the “clock” of the issuing DIFI device.

  The Integer Seconds Timestamp field will nominally be incremented each time the Fractional Timestamp field reaches the value of the Sample Rate (nominally once per second). Upon issuance of an external reset signal, the Integer-seconds Timestamp shall be reset to the external source specified in the header.

- **Words 6,7: Fractional-seconds Timestamp**

  For the Timing Flow Control Packets, which have the intended purpose of permitting synchronization among the “clocks” of the DIFI devices connected the identified stream, the timestamp indicates the time of issue using the “clock” of the issuing DIFI device.

For the Sample Count Timing Flow Control Packet Class 0x0005, the value in this field reflects the number of sample count intervals since the incrementation or reset of the integer seconds. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

For the Real Time TSF Timing Flow Control Packet Class 0x0006, the value in this field reflects the number of picoseconds since the incrementation or reset of the integer seconds. This value is reset to zero at each incrementation or reset of the Integer Seconds Timestamp field. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification [2] for complete details.

- **Word 8: Control/Acknowledge Mode (CAM) Field**

  VITA 49.2 imbues the Command Packets with a great range of functionality. These are detailed in section 8.1 of the VITA 49.2 standard. The specific functionality is set by the CAM field, a 32-bit word. For Control Packets, the function of the CAM field bits is shown in Table 4-22.

Table 4-22 Sub-field Descriptions of the CAM field

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Control											Control and Acknowledge									Ack Only				Reserved							
Controllee Identifier	Controllee Identifier Format	Controller Identifier	Controller Identifier Format	Partial Packet Implementation	Warnings	Errors	Action Bit Field 1	Action Bit Field 0	NACK Only	Reserved	Request Validation Ack Packet	Request Ack Execution Packet	Req Ack Query State Packet	Request Warning Ack Packets	Request Error Ack Packets	Reserved	Control T2	Control T1	Control T0	Acknowledge Bits											

- **Bits 31 and 29: Controllee and Controller ID Identifier**

  The Controllee and Controller Identifier fields (Bits 31 and 29) shall be set to one (0x1), indicating the inclusion of the Controllee and Controller ID fields. The associated Identifier format fields (Bits 30 and 28) shall be set to zero, indicating the use of 32-bit ID fields.

- **Bits 30 and 28: Identifier Field Formats**

  The Identifier format fields (Bits 30 and 28) shall be set to zero, indicating the use of 32-bit ID fields.

- **Bits 27 -25:**

  The functionality associated with these VITA 49.2 fields is not used by the Timing Flow Control Packets. These bits are set to zero.

- **Bits 24 -23:**

  These bits are referred to as the Action Mode bits and describe whether the Control Packet is being used in “dry run” mode versus “execute” mode. For the Timing Flow Control Packets, these bits shall be set to “10” (0x2), indicating the packet action is to be executed

- **Bits 22 -15:**

  The functionality associated with these VITA 49.2 fields is not used by the Timing Flow Control Packets. These bits shall be set to zero.

- **Bits 14 -12: Timestamp Control Mode**

  These bits control the timing of the execution of the Command Packet. Because the purpose of the Timing Flow Control Packets is solely to convey timing and (if applicable) buffer status information, timestamp adjustment, and Reference Point, there are no commands to execute and thus no execution time frame. Therefore, the Timestamp Control Mode bits shall be set to zero (0x0).

- **Bits 11 -8: Acknowledge Bits**

  These bits are Acknowledge bits and shall be set to zero in a Control Packet.

- **Bits 7-0: Reserved**

  These bits are reserved and shall be set to zero.

- **Word 9: Message ID**

  Each Timing Flow Control Packet corresponding to any specific Stream ID shall be issued with a unique sequential 32-bit Message ID

- **Word 10: Controllee ID**
- In systems having multiple controllee devices, each shall be assigned a distinct 32-bit Controller ID if there is a requirement that each be controlled separately. This value should default to 0x00000000 (see Recommendation below).
- Recommendation
- In systems not requiring distinct Controllee IDs (e.g., systems having a single controllee device, or systems in which all controllee devices are to respond identically), a Controllee ID of 0x00000000 should be used.
- **Word 11: Controller ID**
- In systems having multiple controller devices, each shall be assigned a distinct 32-bit Controller ID. This value should default to 0x00000000 (see Recommendation below).
- Recommendation
- In systems not requiring distinct Controller IDs (e.g., systems having a single controller device), a Controller ID of 0x00000000 should be used.

  .

- **Word 12: Control Indicator Field CIF 0**

  CIF fields are used to call out which fields are included in the packet. Bit 30 is set to 1, indicating the inclusion of the Reference Point field, bit 21 is set to 1, indicating the inclusion of the Sample Rate field, bit 20 is set to 1, indicating the inclusion of the Timestamp Adjustment field, and bit 2 is set to 1, indicating the inclusion of the CIF 1 field.

- **Word 13: Control Indicator Field CIF 1**

  The Buffer Size field inclusion is called out by bit 1 in the CIF 1 field. This is the only bit set in the CIF 1 field.

- **Word 14: Reference Point Field**

  The Reference Point is the point in the signal path that the Flow Control Packet is conveying timing information about. See Section 5.2 for more detail.

- **Words 15-16: Sample Rate Field**

  The sampling rate of the samples in the Signal Data packets which can be set. This Sample Rate shall correspond to the Sample Rate in the associated Context Packet.

- **Words 17-18: Timestamp Adjustment Field**

  With the presence of Prologue Timestamp in the associated Context Packet and the inclusion of the Reference Point field and this Timestamp Adjustment field in this Control Packet, the value in the Timestamp adjustment field should be a 64-bit two's-complement value in femtoseconds, representing the signal delay between the Reference Point called out in this Control Packet and the SID location. On the transmit path, this value will generally be positive, and on the receive path, it will generally be negative. Sections 5.1 and 5.2 describe the relationship between the signal timing, SID and Reference Point locations, and the Timestamp Adjustment.

- **Words 19-21: Buffer Size Field**

  The Buffer Size field comprises three 32-bit words. The subfield in Word 19-20 is a 64-bit unsigned integer field that describes the size of the stream sink's buffer in bytes. The 16 MSBs of the second subfield (Word 21) are reserved and are set to zero. The next most significant eight bits are designated in VITA 49.2 as the Buffer Level sub-field, and the eight least significant bits are the Buffer Status sub-field. In this Packet Class, the four most significant bits of the Buffer Status sub-field are used as an extension to the Buffer Level sub-field, making up a 12-bit sub-field indicating the fill-level of the buffer. A value of 0xFFF shall indicate a full buffer, a value of 0x000 shall indicate an empty buffer, with intermediate values distributed proportionately to the fill level. The value to be placed in this sub-field shall be an average of the buffer fill level during the interval between the previous issuance of a Timing Flow Control Packet and the present one (the "current interval"). The method of averaging (e.g., rolling average, exponential average, etc.) should be determined by the manufacturer of the equipment.

  The remaining four bits are used for discrete status.

  Bit 3 of Word 21 is the Buffer Overflow indicator and is set whenever an overflow occurs at any point within the current interval.

  Bit 2 of Word 21 is the Nearly Full indicator and is set whenever the buffer level exceeds the nearly full threshold at any point within the current interval. For Information Class 0x0002, the Nearly Full and Nearly Empty thresholds are pre-assigned or set by non-VRT means.

  Bit 1 of Word 21 is the Nearly Empty indicator and is set whenever the buffer level falls below the nearly empty threshold at any point within the current interval.

  Bit 0 of Word 21 is the Underflow indicator and is set whenever a buffer underflow occurs at any point within the current interval.

5. STREAM AND REFERENCE POINT ID

5.1 STREAM IDENTIFIER (SID) AND SID LOCATION

The Stream Identifier (SID) has three distinct functions:

1. To indicate that a particular Data, Context, or Command Packet is part of a sequence of packets of the same type bearing the same Stream ID
2. To indicate which Context or Command Packet streams are associated with which Data Packet streams.
3. To define a specific location (generally the source or destination of the stream) referred to as the SID location, which is used in conjunction with the time stamping.

The actual number selected for the Stream ID is an arbitrary 32-bit number which can be selected at run time. In the DIFI Standard, the inclusion of the Stream ID is mandatory. The DIFI Standard also mandates the inclusion of the Integer Seconds Timestamp and the Fractional Seconds Timestamp fields in the Data Packets. Together, these two fields are referred to as the "Prologue Timestamp". Generally, the Prologue Timestamp corresponds to the time at which the first sample in a Data Packet is present at the SID location (the first sample will be present at the Reference Point at a time which is the sum of the Prologue Timestamp value and the Timestamp Adjustment – see 5.2 for more details). Alternatively, one may think of the SID location as the point in the system at which the Prologue Timestamp is referenced.

The DIFI Standard mandates the SID location based on system configuration. There are three general categories of devices, and the SID location depends on the category:

1. For digital streams sourced by an analog to DIFI stream converter, the SID location shall be the point of generation of digital samples within the analog to digital converter, illustrated in Figure 12 and Figure 13.
2. For digital streams having a sink device implementing a DIFI stream to analog signal conversion, the SID location shall be the point of consumption of the samples within the digital to analog converter, illustrated in Figure 14 and Figure 15.

For digital streams having intermediate DIFI stream inputs and outputs, the SID location shall be at the point of generation of the digital samples if the device is in the receive path (e.g., as a splitter would most typically be) and shall be at the point of operation on the samples – e.g., the point at which samples are combined in a combiner, subsequent to any buffering – if the device is in the transmit path (e.g., as a combiner would most typically be). This is illustrated in Figure 16 and Figure 17

For the IF signal replication application (also known as "bookend") in which there is an IF-DIFI device sourcing the digital signal stream and a DIFI-IF device sinking the same stream with the purpose of replicating the original IF signal at a remote location, the SID location shall be at the point of generation of the digital samples within the category (i) device. This is illustrated in Fig. Figure 18.

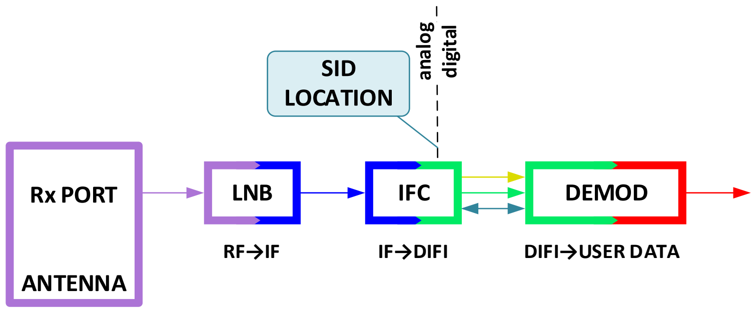


Figure 12. SID location – analog IF to DIFI

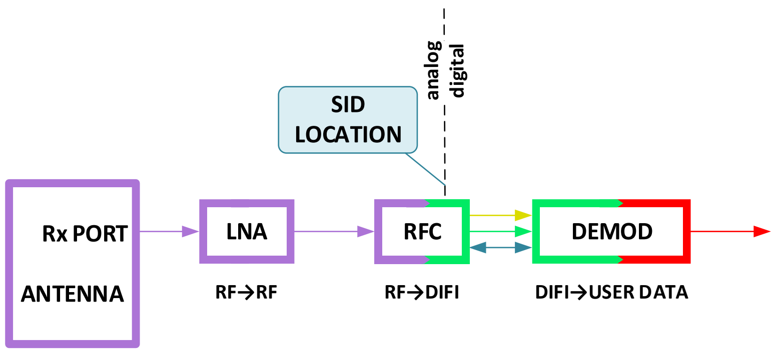


Figure 13. SID location – analog RF to DIFI

Figure 12 illustrates SID locations for typical receive path applications with a conversion device that converts from an analog IF signal to a DIFI digital signal stream, whilst Figure 13 illustrates a conversion device that converts from an analog RF signal to a DIFI digital signal stream.

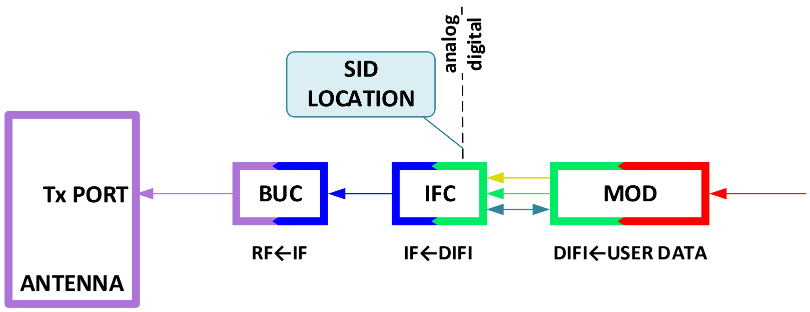


Figure 14. SID location –DIFI to analog IF

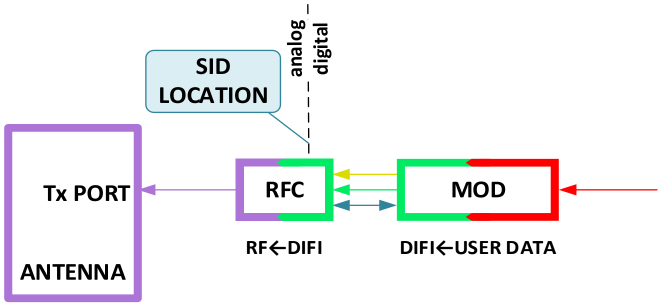


Figure 15. SID location –DIFI to analog RF

Figure 14 illustrates the SID location for a transmit path using a conversion device that converts a DIFI stream to an analog IF signal that is subsequently upconverted to the RF transmission frequency by an analog block upconverter. Figure 15 illustrates the SID location for a transmit path that uses a device that converts a DIFI stream directly to an analog RF output at the RF transmission frequency.

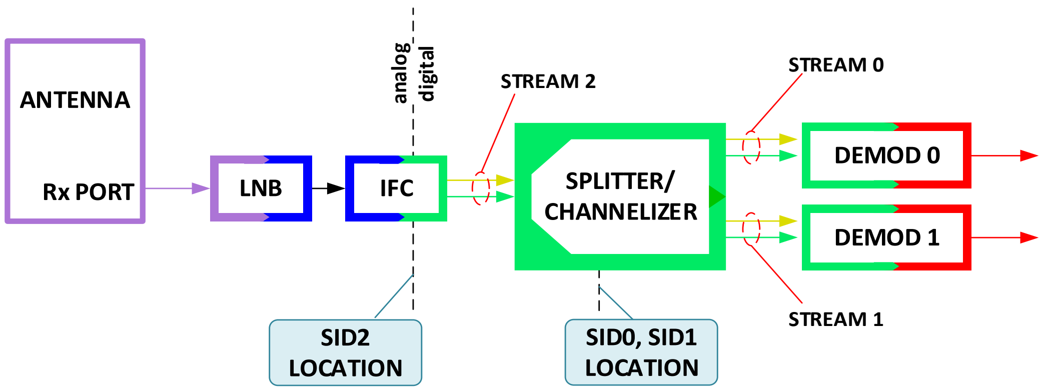


Figure 16. SID locations for category (iii) devices on the receive path.

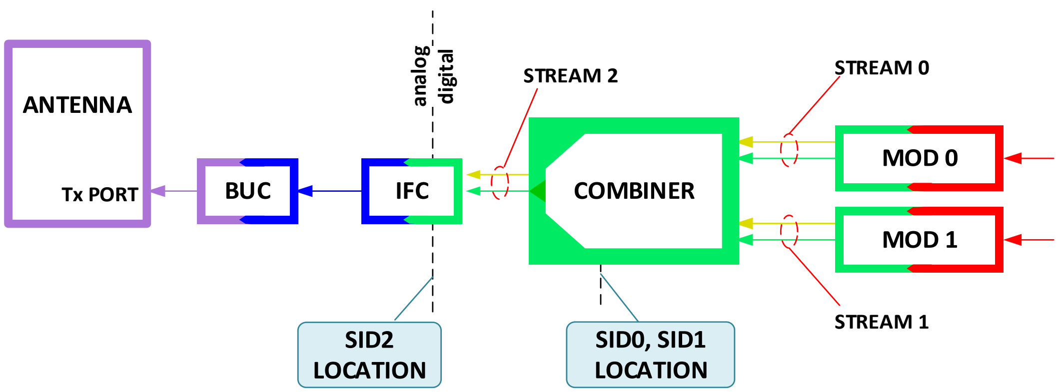


Figure 17. SID locations for category (iii) devices on the transmit path.

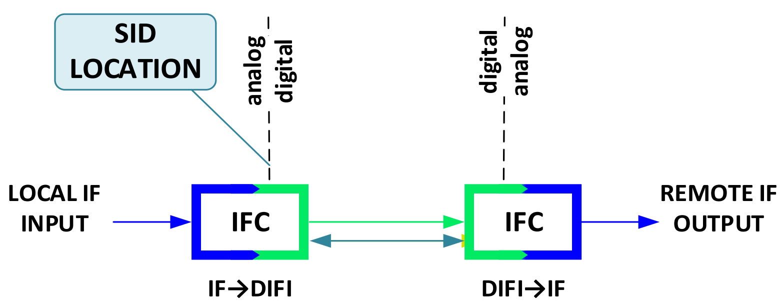


Figure 18. SID location for IF signal replication at a remote location

5.2 REFERENCE POINT IDENTIFIER AND TIMESTAMP ADJUSTMENT

The Reference Point Identifier Field is used within VITA 49.2 and the DIFI Standard to identify a location, other than the SID location, within the system, to which certain parameters – e.g., Timestamp Adjustment, Reference Level, and various reference frequencies – pertain. The Reference Point Identifier field, the Reference Level field, the various reference frequency fields, and the Timestamp Adjustment field, are mandatory within the DIFI Standard.
The Standard recommends that in both the transmit and receive directions, systems having a converter that operates between an analog IF signal and a DIFI digital stream should have the analog input or analog output of the conversion device referred to as Reference Point 100 (0x0064). The analog output of the RF device on the transmit path and the analog input to the front-end RF device on receive should be referred to as Reference Point 75 (0x004B).
For systems having a well-defined input or output port at the antenna feed, this Reference Point should be referred to as Reference Point 25 (0x0019) if it is to be used.
Finally, for electronically scanned arrays that accept a DIFI input but do not have a meaningful single point RF Reference Point nor antenna feed port, the air interface of the antenna, referred to as Reference Point 15 (0x000F) may be used.

The Reference Level field refers to the analog value in dBm that is present at the Reference Point. The IF Reference Frequency field indicates the frequency at Reference Point 100 (as defined above) if such a signal point is well-defined and accessible. The RF Reference Frequency indicates the frequency at Reference Point 75 (as defined above).

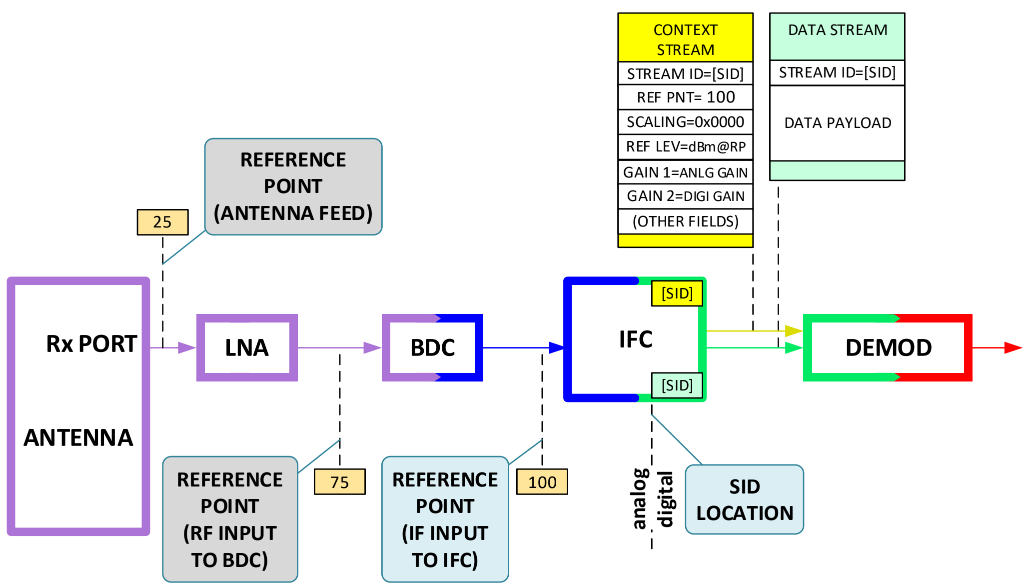


Figure 19. Receive Reference Points Using an IFC

Figure 19 illustrates the receive path using an IFC. Reference Points are labeled, Reference Point 100 (IF input to IFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (100), Reference Level (analog signal level in dBm at

Reference Point that results in a full-scale sine wave output in DIFI payload), pre-conversion analog gain and post conversion digital gain.

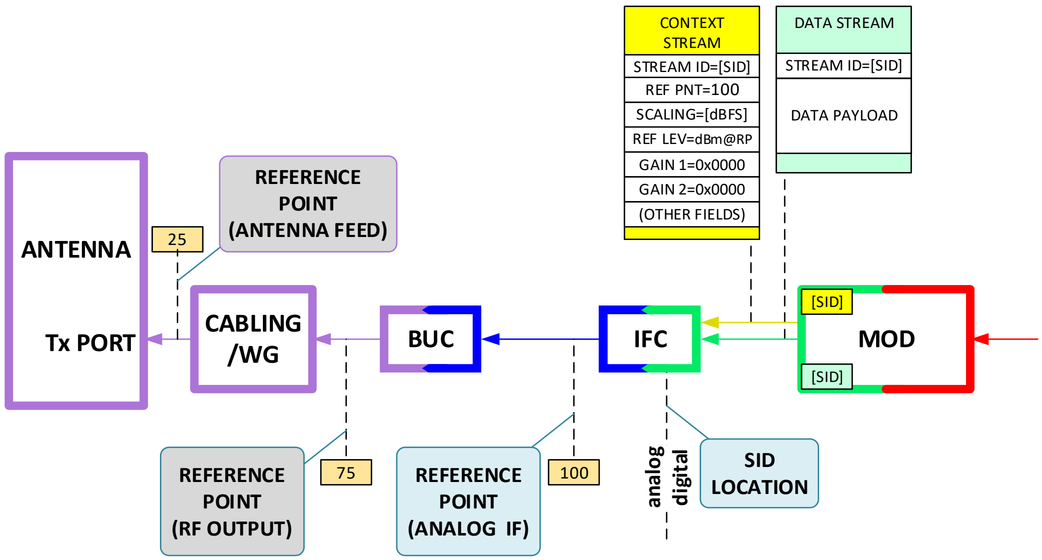


Figure 20. Transmit Reference Points Using an IFC

Figure 20 illustrates the transmit path using an IFC. Reference Points are labeled, Reference Point 100 (IF output from IFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (100), Reference Level 1 (analog signal level in dBm at Reference Point that results from a full-scale sine wave input at the DIFI input).

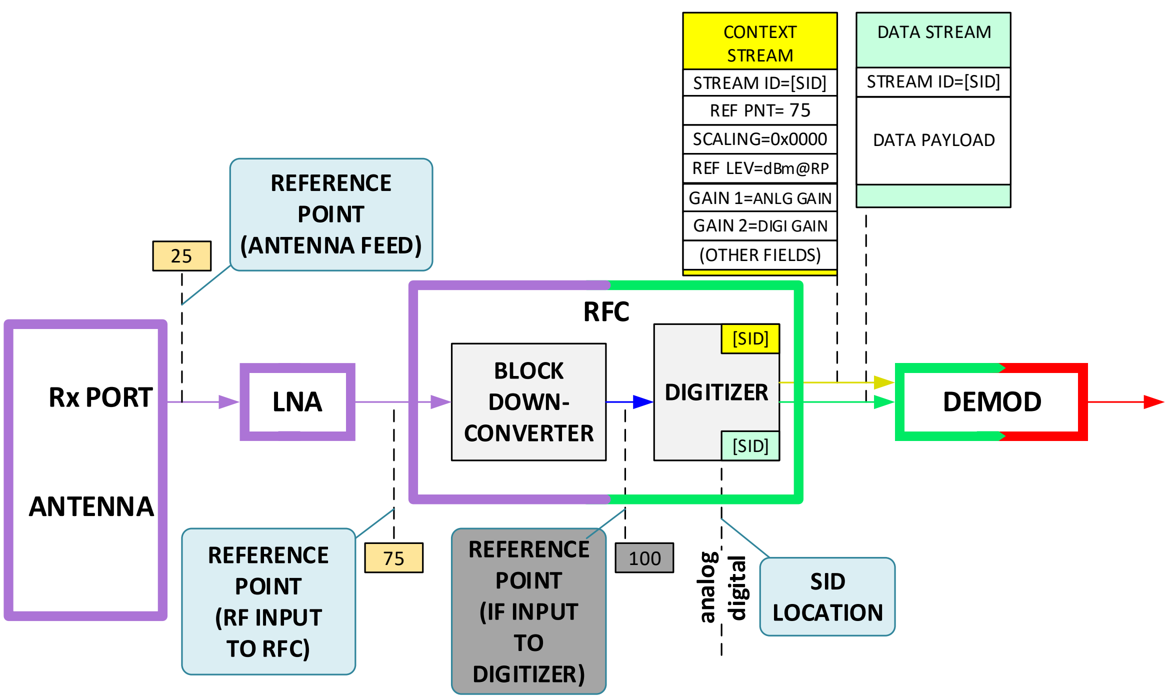


Figure 21. Receive Reference Points Using an RFC

Figure 21 illustrates receive path using an RFC. Reference Points are labeled, Reference Point 75 (RF input to RFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (75), Reference Level (analog signal level in dBm at Reference Point that results in a full-scale sine wave output in DIFI payload), pre-conversion analog gain and post conversion digital gain.

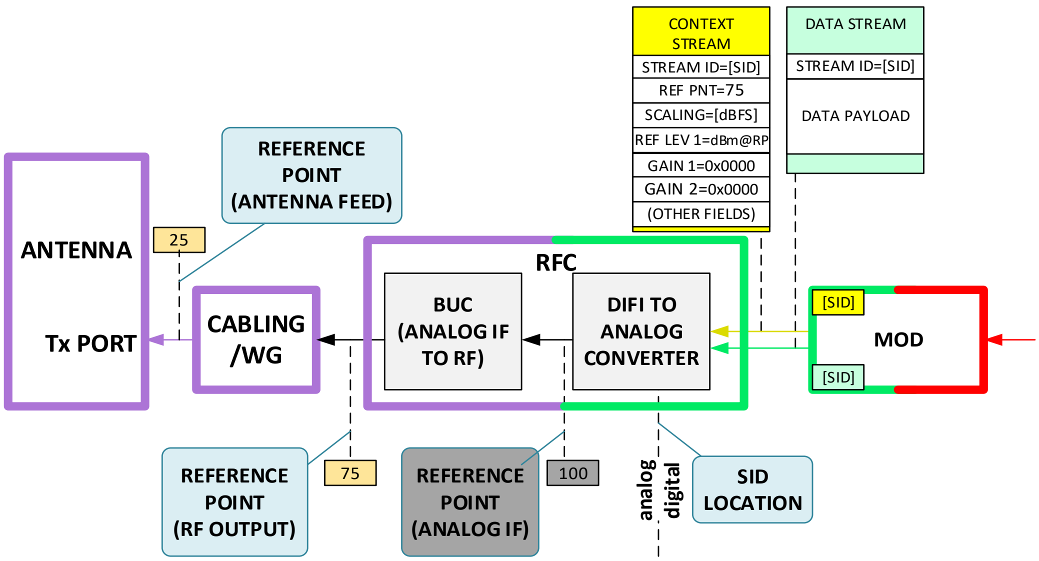


Figure 22. Transmit Reference Points Using an RFC

Figure 22 illustrates the transmit path using an RFC. Reference Points are labeled, Reference Point 75 (RF output from RFC) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (75), Reference Level represents the intended power in dBm at the Reference Point.

Figure 23 illustrates the transmit path using a DIFI-input electronically scanned array. Reference points are labeled. Reference Point 15 (air interface) is the preferred Reference Point for this configuration. Context Packet contains Reference Point ID (15). Reference Level represents the intended EIRP in dBm at the air interface.

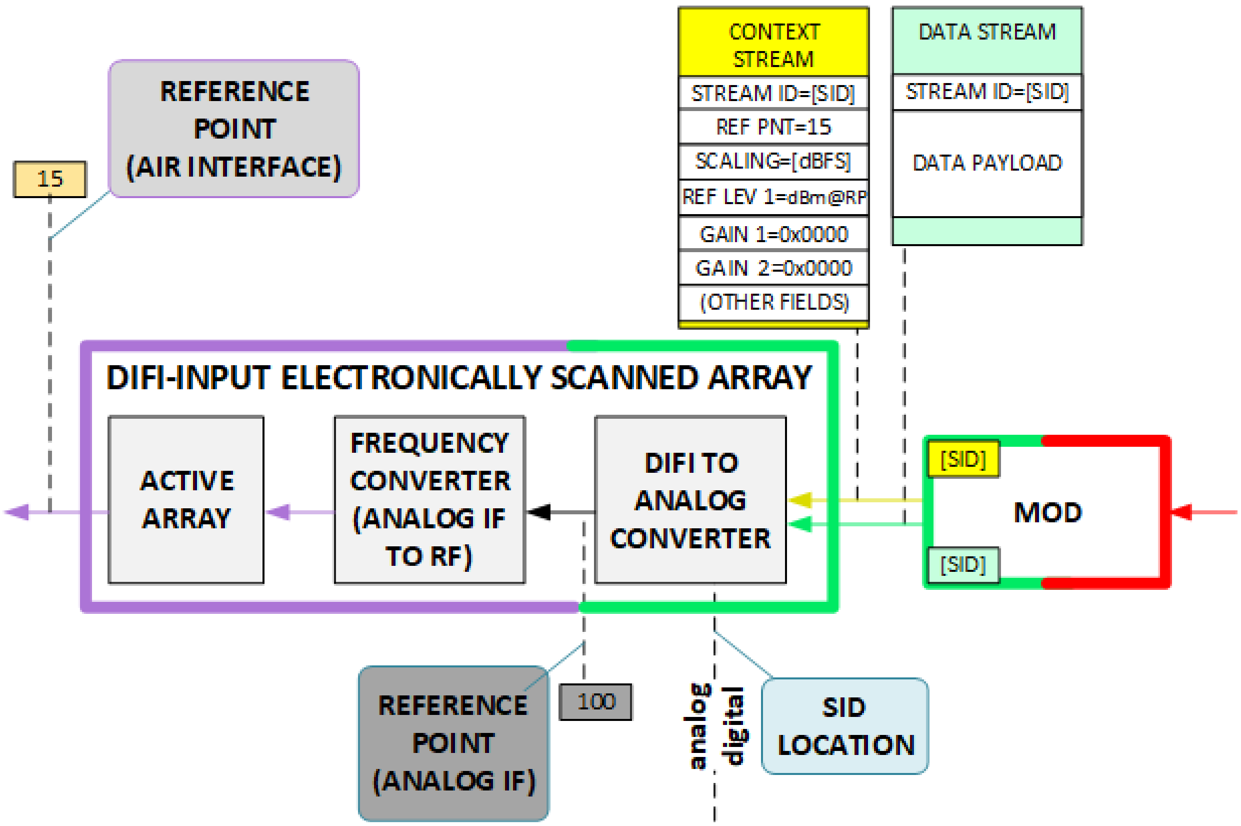


Figure 23. Transmit Reference Point Using a DIFI-interface ESA

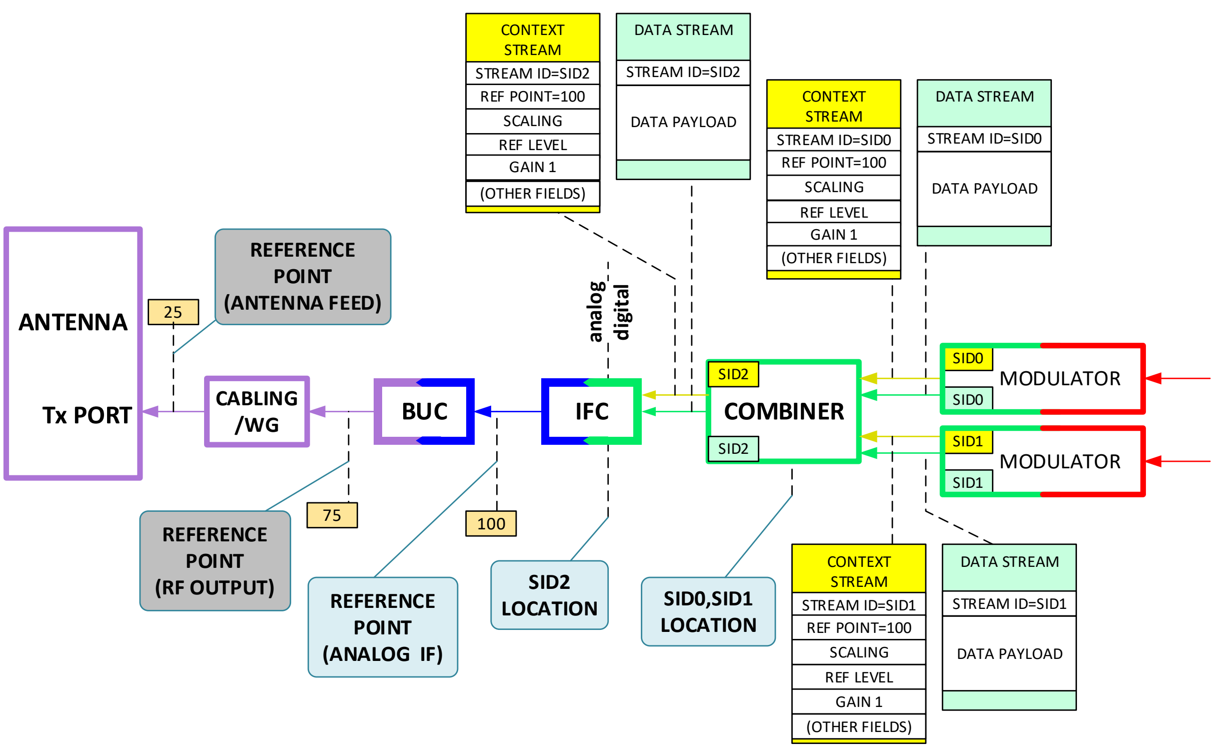


Figure 24. Configuration using a DIFI stream to DIFI Stream device in addition to an IFC.

Figure 24 illustrates a configuration using a DIFI stream to DIFI Stream device in addition to an IFC. Reference Point 100 is used by the Combiner output stream to indicate the analog level at the IFC output. Reference Level for the other two streams has no meaning, but Reference Point and SID location can be used for timing and synchronization purposes.

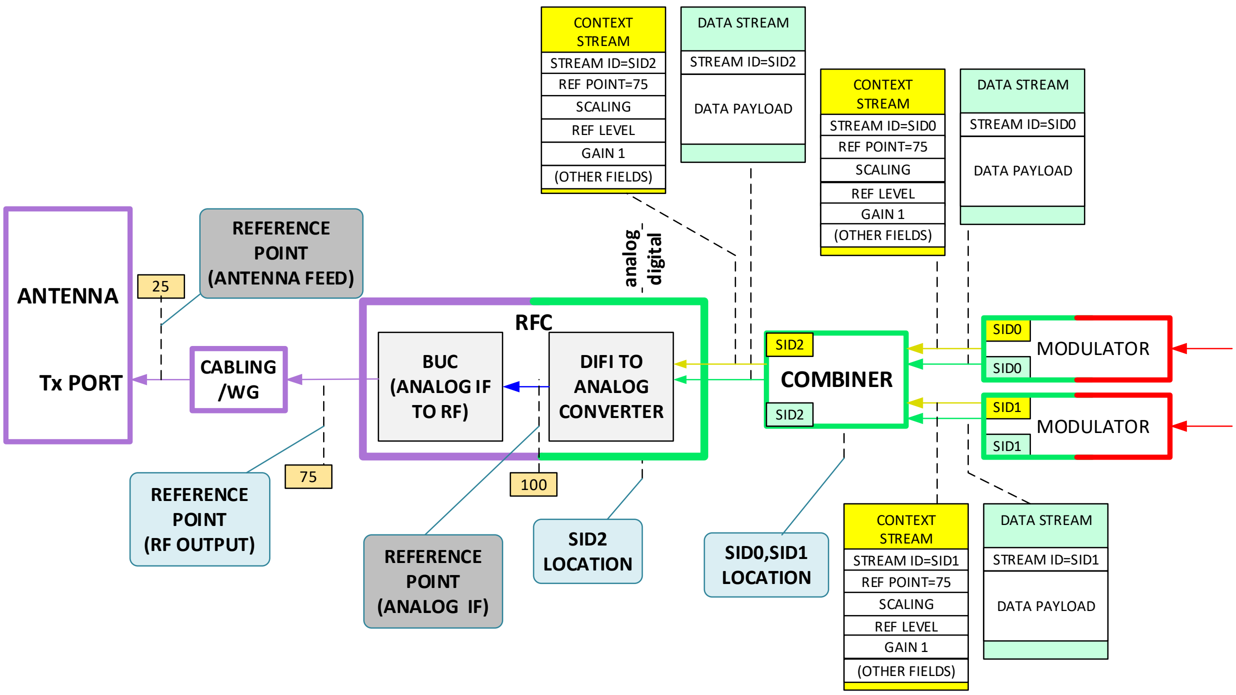


Figure 25. Configuration using a DIFI stream to DIFI Stream device in addition to an RFC.

Figure 25 illustrates a configuration using a DIFI stream to DIFI Stream device in addition to an RFC. Reference Point 75 is used by the Combiner output stream to indicate the analog level at the RFC output. Reference Level for the other two streams has no meaning, but Reference Point and SID location can be used for timing and synchronization purposes.

The Timestamp Adjustment field characterizes the physical signal delay between the Reference Point and the SID in a particular physical implementation. This field is in femtoseconds and is generally a negative value on the receive path and a positive value on the transmit path. Figure 26 illustrates Reference Point locations and associated field values for various configurations.

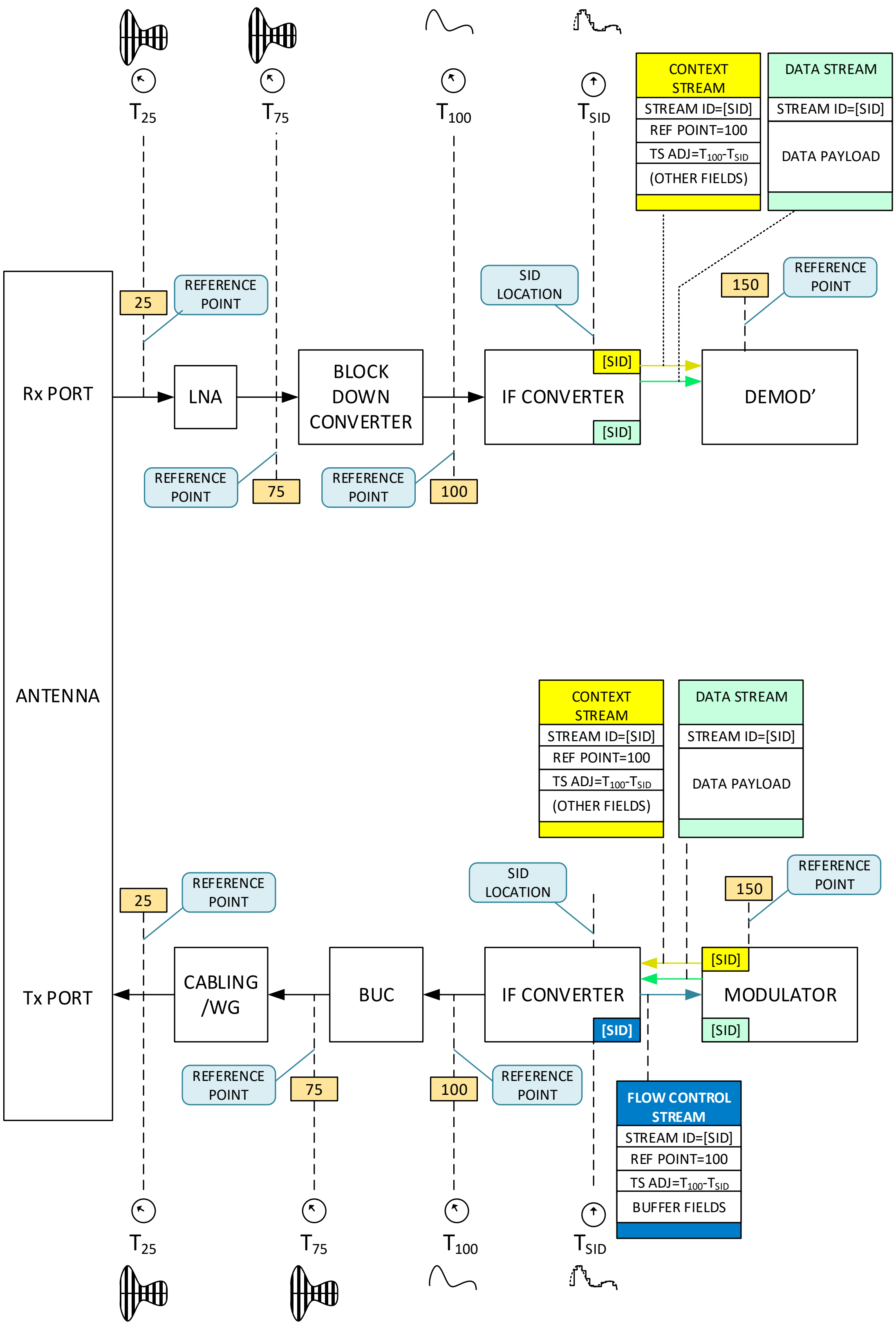


Figure 26. Time values at various reference points

In Figure 26, Reference Point 100 is used, so that the Timestamp Adjustment is given by T100-TSID.

6. APPENDIX – DIFI DEFINITIONS AND USE CASES

This appendix is intended to help align the DIFI community on a shared understanding of the terminology in use and how this shared vocabulary can help make the standard a widespread, useful, and perhaps even effective tool in making the flexible Digital IF-based interoperable vision into a reality. To that end, the following sections lay out definitions to serve as the basis for discussion; high level descriptions of how the previously described information and packet classes can be useful; and deep dives into implementation to illustrate the nuts and bolts of the kind of system design that the DIFI spec enables.

6.1 DEFINITIONS

DIFI Device: Any hardware, firmware, or software that creates a Source or Sink using the DIFI protocol.

The term is intended to be flexible and able to describe both hardware-centric and software-only systems.

Examples: Modems, combiners, channelizers/splitters, recorders, digitizers, etc.

DIFI Use Case: The operational use of a DIFI device for the generation, transmission, and/or consumption of a Packet Stream.

Examples: analog-to-DIFI conversion, recording and playback of DIFI streams, samples-to-user-data conversion, combiner/divider

Figure 27 shows example diagrams with a DIFI device (defined below) demonstrating each listed use case:

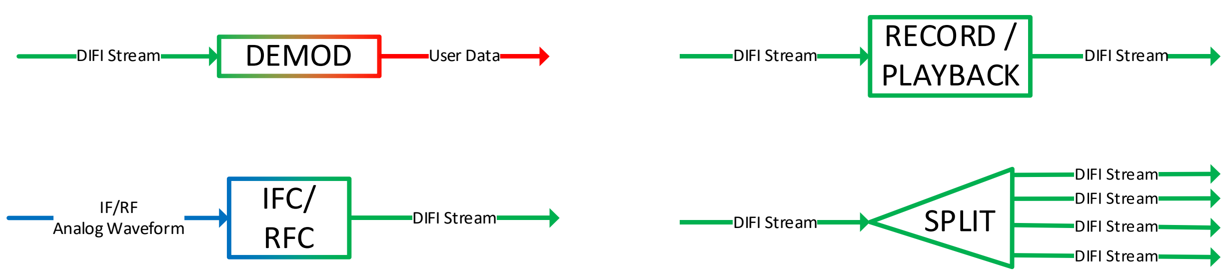


Figure 27. Example DIFI Devices

DIFI Implementation: A DIFI implementation is anything that implements one or more DIFI use cases. From the perspective of the standard, anything that uses DIFI packets to carry out a system design is an implementation.

Examples: inter-facility link (IFL), gateway, terminal, STAR network

Figure 28 shows an example of a DIFI application.

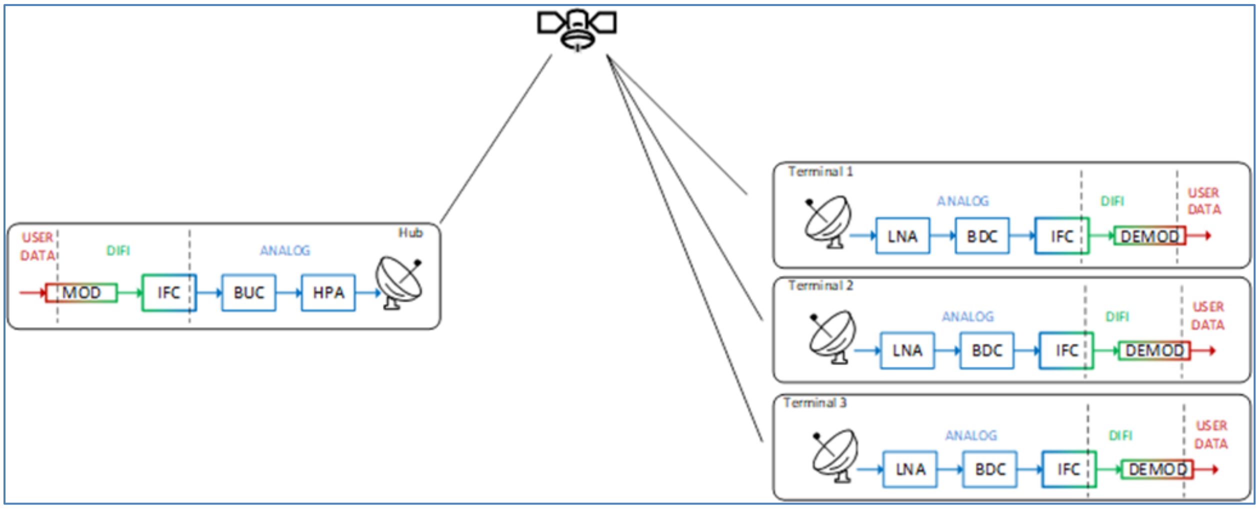


Figure 28. Example DIFI Application

DIFI Application: A DIFI application refers to the content of the DIFI sample stream.

This is probably the broadest category and encompasses the overall communication methods/systems that are currently in use (and may be developed in the future) that the DIFI standard needs to enable but by definition cannot predict. Applications drive the design of the information and packet classes because they use Digital IF in the real world. A readily available example of this is the driver for Information Class 0x0002, namely the specific application of supporting an SCPC waveform as implemented in a DIFI terminal with no shared reference plane.

6.2 USE CASES

DIFI use cases involve the generation, transmission, and/or consumption of a DIFI sample stream, i.e., the movement or transformation of the Digital IF samples. In the case of a modem communicating with an IFC, this is self-explanatory: the modulator processes user data into Digital IF samples, and the IFC then transforms the digital samples into an analog waveform.

The use case of transmission may include storage and can be observed in devices such as a recorder that may also be used for playback, to move DIFI-compliant Digital IF sampling data for processing, troubleshooting, or other uses.

6.3 IMPLEMENTATIONS

Implementations, as considered by the DIFI standard, are where the rubber meets the road in terms of using DIFI to carry out a system design. The implementation diagrams and descriptions that follow are attempts to illustrate how DIFI and the particular choices made within the specification enable both simple and complex system designs.

Since DIFI is a network standard, verification of emitted packet conformance to the specification is the primary criteria for compliance. There are some general categories for endpoints (Sources and Sinks) based on the packets that they emit in addition to when those packets are emitted and the relationship between timestamps contained in sequential packets. The following represent compatible pairs:

- **NTR Source**: Non-Time Release Source. Timestamps are unspecified. Emission time is unspecified but may be coherent to some external TOD source.
- **NTR Sink**: Non-Time Release Sink. Timestamps are used for information only or not at all. May require a source that meets some criteria for emission timing offset, slope or variance. Emits no packets. Is compatible with both NTR and TC Sources.

- **TC Source**: Time Continuous Source. Source produces packets with timestamps that are continuous and potentially related to some TOD source. Emission time may be coherent with an external time of day reference.
- **TC Sink**: Time Continuous Sink. Sink requires timestamps to be continuous. May require a source that meets some criteria for emission timing offset, slope or variance. Emits no packets.

- **TC Source Follower**: Time continuous source that is capable of following a sink master using the flow control packets issued by the master. Timestamps are continuous and sufficiently early to allow for time release at the Sink if it supports that. Emission time is coherent with the master.
- **TC Sink Master**: Sink capable of issuing flow control packets with timing information and buffer level information. A TC Sink Master must work when samples arrive at the correct rate and early enough to be time released.

- **TC Source Burst**: Time continuous source that issues flow control packets to maintain time continuity between bursts of source packets which are non-contiguous but time continuous.
- **TC Sink Burst**: Sink that can operate with intermittent sample packet bursts using flow control to maintain output timing. Emits no packets.

Table 6-1 and Table 6-2 show the timestamp and emission times that should be characterized for categories/endpoints which emit packets:

Table 6-1 Timestamp and Emission for Data/Context Packets

		Data/Context Packets								
		Header	Timestamp	Emission TOD Ref			Emission Flow Control Ref			Buffer
Endpoint Category	IC	Format	Continuity	Offset	Slope	Variance	Offset	Slope	Variance	Level
NTR Source	0,4	✓		✓	✓	✓				
TC Source	0,4	✓	✓	✓	✓	✓				
TC Source Follower	2,3	✓	✓				✓	✓	✓	✓
TC Source Burst	2,3	✓	✓	✓	✓	✓				

required test fixture:	
	PCAP only
	Flow Control Packet Playback
	Simulated/Real Sink Master Buffer Level

The device categories shown in Table 6-2 are those that emit Flow Control packets:✓

Table 6-2 Timestamp and Emission for Flow Control Packets

		Flow Control Packets						
		Header	Timestamp	Emission TOD Ref			Buffer	
Endpoint Category	IC	Format	Continuity	Offset	Slope	Variance	Level	flags
TC Sink Master	2,3	✓	✓	✓	✓	✓	✓	✓
TC Source Burst	2,3	✓	✓	✓	✓	✓		

required test fixture:	
	PCAP only
	Simulated/Real TC Source Follower

The ticks in the above table identify relevant checks and measurements that can be performed on the emitted packets to characterize the behavior of the given category of endpoint with respect to this specification.

1. Sample/Context Packets
    a. **Header Format**: Verify that the packet is correctly formatted, ignoring the data itself.
    b. **Timestamp Continuity**: verify that timestamps are continuous. Times are represented by integer seconds and either a fractional sample count or picoseconds.
        1. First, if using fractional ps, convert to fractional sample count using integer math: ((ps+1) x freq)/1,000,000,000,000. The +1 is necessary since the ps value may have been truncated from a fraction.
        2. The value used to verify continuity is the number of samples since T0 (integer seconds 0, fractional sample count 0). This is the absolute index of the first sample of a packet and is simply: (Integer Seconds x frequency) + fractional sample count.
        3. The absolute index of a given packet + the count of samples in that packet must equal the absolute index of following packet

c. **Comparison to Time of Day (TOD)**: Packet captures include the capture time which is a useable Time of Day reference, especially if the capture system is synchronized to Precision Time Protocol (PTP) or Network Time Protocol (NTP).
    1. Offset: time offset between packet timestamp and a reference. Expected value depends on the device under test. For capture sources (e.g. an ADC), the timestamps represent time the data was captured and are likely to be in the very recent past. For sources that are producing data for later conversion to RF or other real time use (e.g., a SW modulator), the timestamps may be in the near future such that the packets are being sent/arriving early to allow for time release.
    2. Slope: slope of the time offset. The slope should be 0 for a source claiming to be TOD referenced. A drifting offset (slope is non-zero) is DIFI compliant if the source/sink are not TOD referenced.
    3. Variability : When interoperating, variability in packet arrival time must be considered when determining buffer size at the sink.

d. **Comparison to Flow Control Reference**: A plot of the flow control reference against the same TOD reference should show the following: For a **TC Source Follower**, the slope of TOD comparison for sample and context packets should match the slope of the flow control packets. I.e., sample production rate should match the sample consumption rate shown by the flow control packets.

e. **Buffer level**. For a **TC Source Follower**, buffer level should be constant if the source emission rate is correct and/or the timestamps are sufficiently early to allow for time release at the Sink.

2. Flow Control Packets
    a. **Header Format**: same as in Sample/Context Packets above
    b. Timestamp Continuity:
    Test measurement should measure step size.
    For **sample count TSF**, the following must be true:
    (Integer_Seconds$_n$ x Sample Rate) + Sample_Count$_n$ +Step = (Integer Seconds$_{n+1}$ x Sample Rate) + Sample_Count$_{n+1}$, where Integer_Seconds$_n$ is the integer second timestamp of the nth Packet, Sample_Count$_n$ is the fractional seconds timestamp of the nth Packet, Integer_Seconds$_{n+1}$ is the integer second timestamp of the (n+1)st Packet, Sample_Count$_{n+1}$ is the fractional seconds timestamp of the (n+1)st Packet, and Step is the number of sample periods between the nth and (n+1)st Packets. It is recommended that Step size be held constant across the Packets in a stream. Values are by definition valid sample indexes since each individual sample is counted in Sample Count TSF (whereas not every picosecond value is on a sample edge with in Real Time TSF).
    For **Real Time (picoseconds) TSF**, it is again recommended that step size in picoseconds be held constant across Packets in a stream. Picosecond values in the flow control timestamps should be an exact valid picosecond value for time release at the sink. This allows a source to produce picosecond timestamps that lie on exact samples at the sink (instead of fractional samples) if required. The reported timestamp adjustment is with respect to these exact sample timestamps such that if the source uses the exact flow control picosecond value, the release time at the reference point will be the timestamp plus the timestamp adjustment
    c. Comparison to TOD: same as in Sample/Context Packets above
    d. Buffer Level/Flags: Use **TC Source Follower** to send packets to **TC Sink master** and verify that Buffer level and flags respond as expected to changes in the sample arrival rate

and/or timestamps. Buffer level and flags should reflect the effects of time release. E.g. Sample packets arriving 100ms early at the correct rate should result in a 100ms buffer level.

6.3.1 Information Class 0x0000

The Basic Data Plane Structure of Information Class 0x0000, the original class described by the DIFI specification, supports a simple data plane configuration and presumes that much of the configuration and command/control of the system in operation is done out of band. In a system with a single emitter and consumer, if a shared reference signal exists for synchronization, using the Information Class 0x0000 is a straightforward choice for data transmission.

Additionally, if two-way traffic is present, i.e., two devices in a system are both emitting and consuming data, then synchronization information can be extracted from the existing traffic, and the functionality provided by Information Class 0x0000 is sufficient.

An example of this second case, with two devices in a system acting as both emitters and consumers, follows here. Given a digitizer/IFC and a modem that can each share information between Tx and Rx, the modem receive side can synchronize to the ADC sample rate using the arrival rate and timestamps of received data packets. The modem's Tx and the IFC's Tx can each synchronize to the Rx side of their own device, and thus the system is synchronized.

Endpoint Categories: The ADC is a TC Source, the DAC is a TC Sink, the Demod is a TC Sink and the Mod is a TC Source.

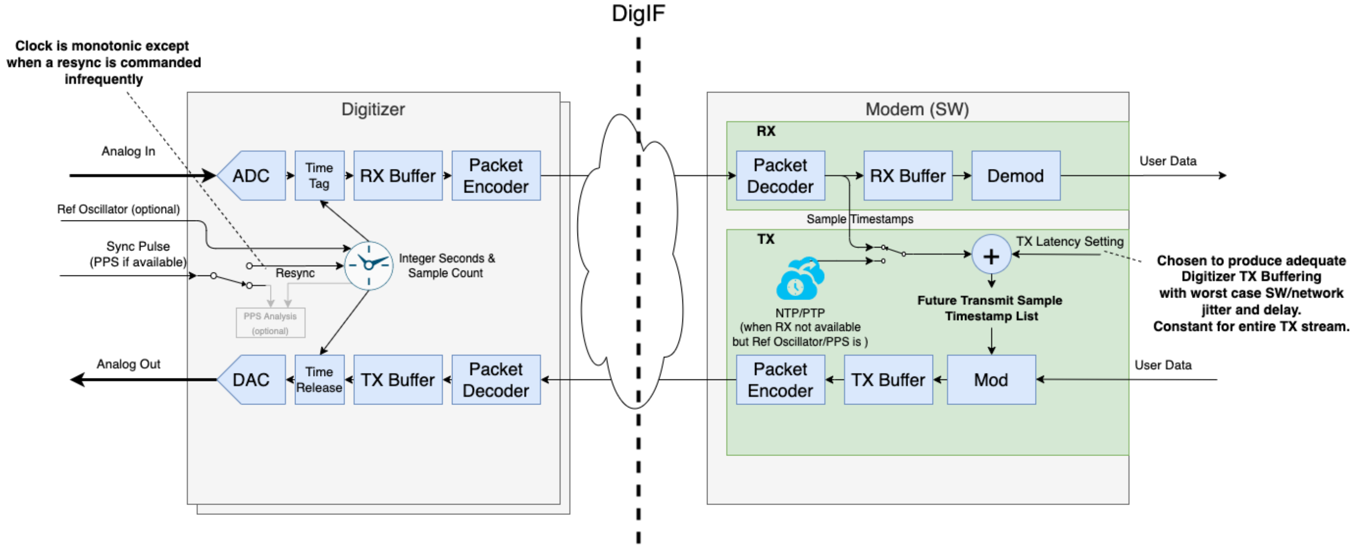


Figure 29. Implementation Class 0x0000 Example

6.3.2 Information Class 0x0002

The addition of Information Class 0x0002 to the DIFI Standard allows for a standard flow control mechanism to be used and frees up the system designer from requiring a two-way data flow for synchronization.

Three examples of the usage of this flow control mechanism follow, each of which involves data flow in the transmit direction with no shared reference plane between the source(s) of the data and its (their) destination(s).

The first example involves a single digital modulator sending data and context packets to a single IFC / BUC, where there is no shared reference plane, and indeed the two devices may be physically separated by a significant distance. In this case, the IFC is considered to be the source of timing truth, due to its hardware component, and the digital modem requires a mechanism to track the clock rate and/or the buffer depth of the IFC to ensure that data is available when it is required and that there are no discontinuities in the analog waveform.

Endpoint Categories: The BUC is a TC Sink Master, the Digital modem is a TC Source Follower. Figure 30 describes this implementation.

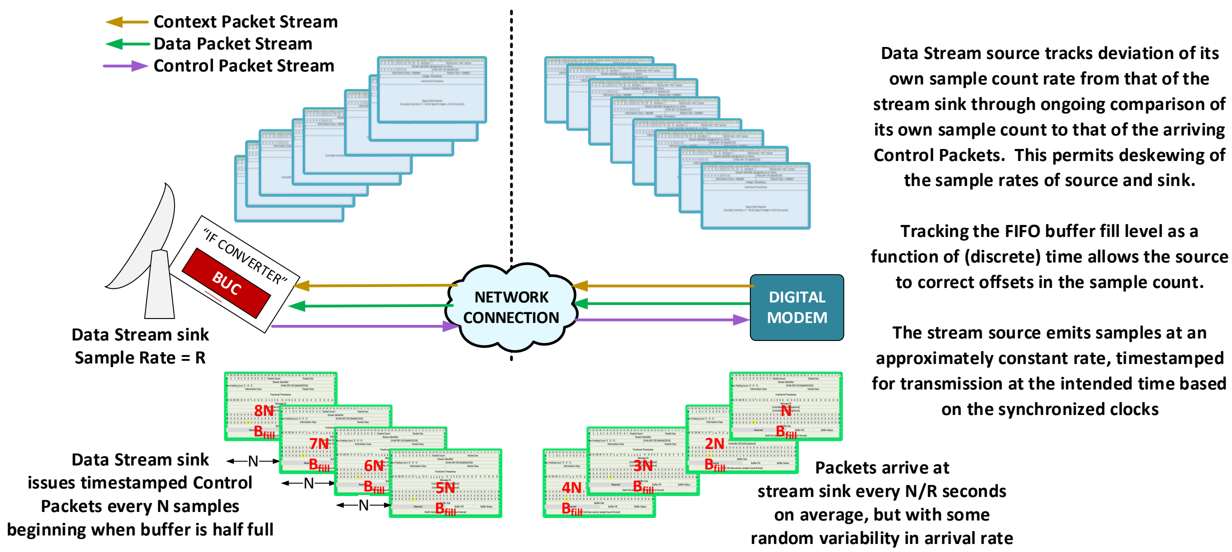


Figure 30. Implementation Class 0x0002 Example – Single Source, Single Sink

The second example covers the case in which there is a single sink that serves as sample rate master receiving streams from "X" multiple sources. It makes several assumptions, including that X=3, i.e., there are three streams from three separate data stream sources; one source is running at a sample rate of 20Msamp/sec and the other two at sample rates of 10Msamp/sec; the sink has a clock that is deemed "accurate", for example, locked to a GPS source; and there is no reference plane to provide external synchronization of the three stream sources, and the sources do not have accurate clocks. Figure 31 describes this implementation.

It is also assumed that at the start of transmission, each of the sources is synchronized only to a loose reference (e.g., NTP). The stream sources emit their data streams by UDP multicast with data packet timestamps (integer and sample count) set at a future time chosen to account for latency, jitter, and sink buffer size. The sink would need to depacketize each of the three streams into a separate buffer, interpolate samples to bring the two “slow” streams up to the higher sample rate, and combine them (weighted sum) into an aggregate buffer. Using the proposed method, the sink would emit three separate Control Packet streams, each conveying buffer information for one of the three buffers, and each bearing the Stream ID associated with the stream feeding that buffer.

Endpoint Categories: The BUC is operating as three TC Sink Masters. The Digital Modems are TC Source Followers.

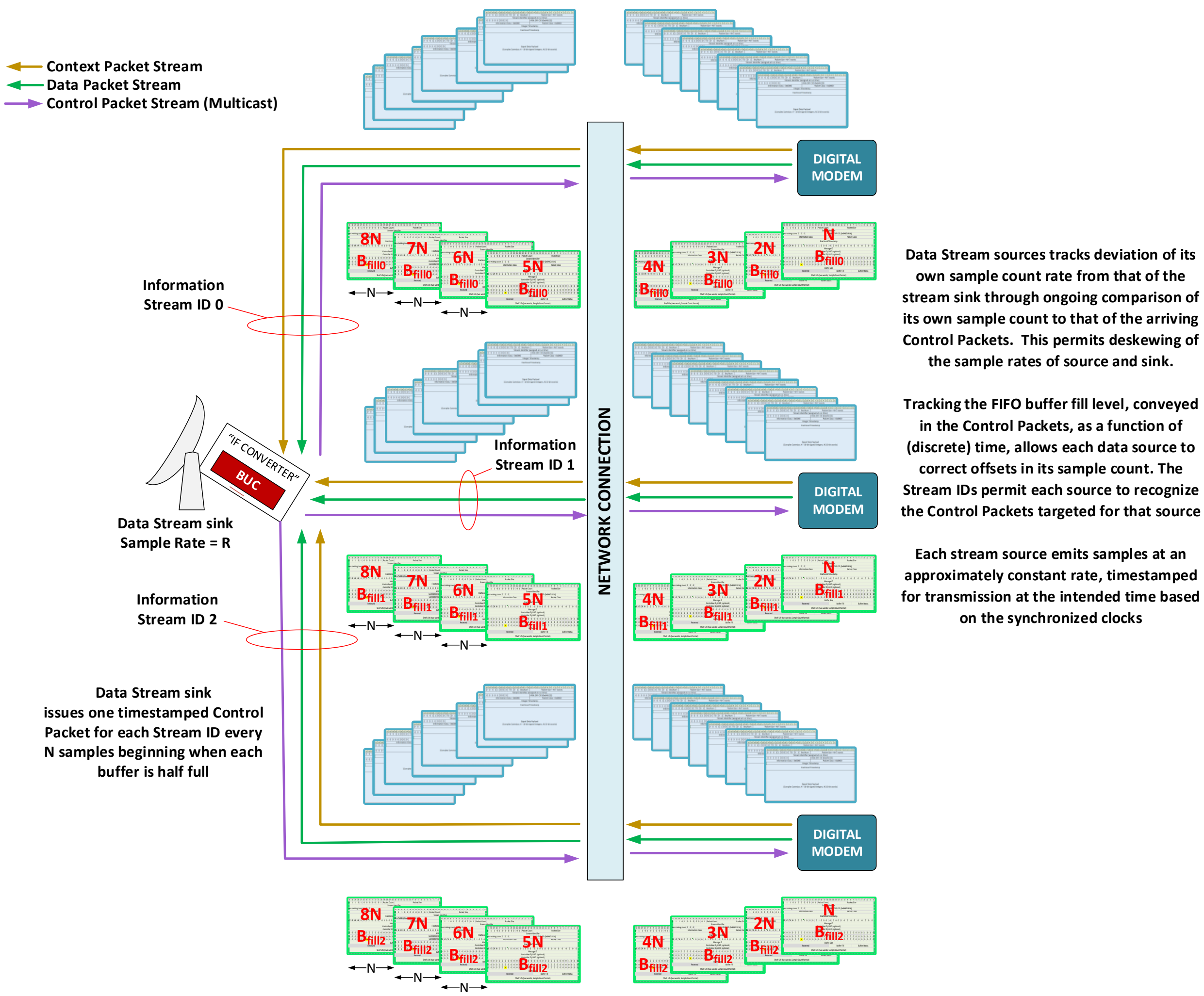


Figure 31. Implementation Class 0x0002 Example – Multi-Source, Single Sink

The third example implementation of the flow control capability provided by the Information Class 0x0002 addition is a multi-source, multi-sink phased array. In this implementation, there are (as the name would suggest) multiple sinks, operating as a phased array, which has access to an accurate time reference (e.g., GPS) as well as multiple data sources. Additionally, this system design includes an intermediate combining device that accepts multiple data stream inputs from multiple sources and generates multiple output streams having appropriate phase adjustments to enable multiple sinks to operate as a phased array; this device also has access to an accurate time reference that is shared with the phase array sink devices.

It is worth noting that an extremely accurate phasing/timing is required for this implementation, requiring the use of calibrated timestamp adjustments to specific reference points (e.g., antenna feeds).

Figure 32 describes this implementation. The combiner and IFCs are synchronized to a common high-accuracy reference, the modems are synchronized to the combiner using Flow Control Packets, and each IFC responds to packets bearing the associated SID. Timestamp adjustments in the Combiner's associated output Context Packets implement beam forming timing/ phasing.

Endpoint Categories: Each BUC is a TC Sink, Combiner output to BUCs are TC sources. Combiner inputs are TC Sink Masters and Digital modems are TC Source Followers.

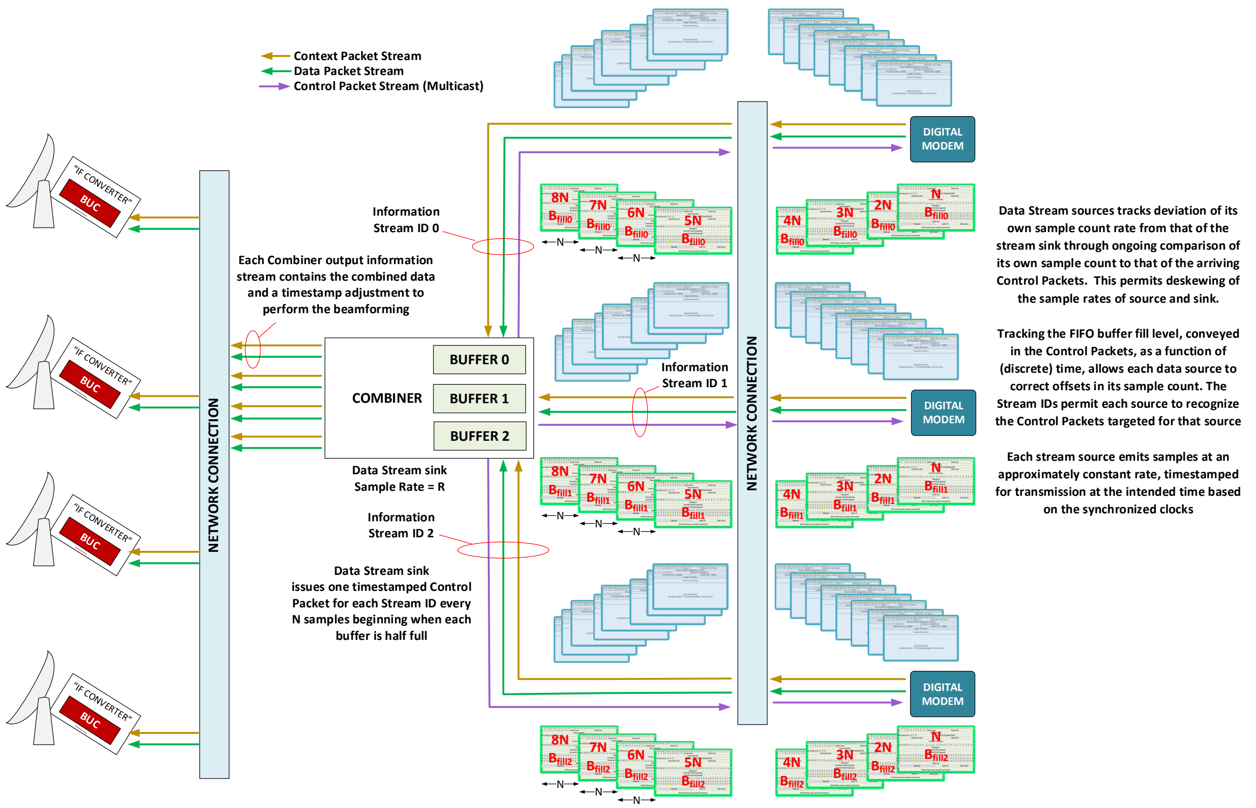


Figure 32. Implementation Class 0x0002 Example – Multi-Source, Multi-Sink

6.4 APPLICATIONS

A DIFI application refers to the content of the DIFI sample stream. As a result, applications require and consider each of the other definitions – they encompass the use cases, make use of devices, and require a system design or implementation to meet the needs of the particular application. Two ready examples of DIFI applications are SCPC waveforms, which require a constant data flow and are less susceptible to timing variation, and TDMA waveforms, which typically make use of a bursty data flow and are very sensitive to reference synchronization.

6.4.1 Supporting SCPC Waveforms with DIFI

Single channel per carrier (SCPC) waveforms use a single signal at a given frequency and bandwidth and are a common configuration on communications satellites. In this kind of system, the communications channel is constantly occupied by an uninterrupted signal and demodulators typically rely on the signal to be consistently present. These needs then drive requirements in the DIFI standard to be able to maintain consistent data traffic both in transmit and receive configurations as well as adjust sample rates and power according to the implementation design.

6.4.2 Supporting TDMA Waveforms with DIFI

Time-division multiple access (TDMA) waveforms use a single frequency channel divided up into multiple time slots to allow multiple users to share the same transmission medium by using only a part of its channel capacity. In this kind of system, the communications channel is not consistently occupied by a signal, and demodulators must be able to operate on burst data. These needs then drive requirements in the DIFI standard to be able to precisely timestamp packetized data samples as well as adjust sample rates and signal power according to the implementation design.

7. APPENDIX – BEST PRACTICES

This appendix is intended to document the use of the DIFI protocol in a number of scenarios, viewed as best practices.

7.1 SUPPORTING TDMA WAVEFORMS WITH DIFI

Time-division multiple access (TDMA) waveforms use a single frequency channel divided up into multiple time slots to allow multiple users to share the same transmission medium by using only a part of its channel capacity for each user. In this kind of system, the SATCOM communications channel is not continuously occupied by a single user data signal, and modulators and demodulators must be able to operate on burst data. These needs then drive requirements in the DIFI standard to be able to precisely timestamp packetized data samples as well as adjust sample rates and signal power according to the implementation design.

There are five use TDMA/MFTDMA use cases described in this appendix:

1. Reference Plane (e.g., distributed 10MHz reference signal) present
    a. DIFI packets are generated continuously, filled with “idle samples” when the user data signal associated with the Data Stream is “out of burst” in the TDMA system
    b. DIFI packet stream is discontinuous, with data packets generated only when the user data signal is “in burst”
2. No Reference Plane
    a. DIFI packets are generated continuously, filled with “idle samples” when the user data signal associated with the Data Stream is “out of burst” in the TDMA system, and the DIFI **source** is the sample rate “master”
    b. DIFI packets are generated continuously, filled with “idle samples” when the user data signal associated with the Data Stream is “out of burst” in the TDMA system, and the DIFI **sink** is the sample rate “master”
    c. DIFI packet stream is discontinuous, with data packets generated only when the user data signal is “in burst”, with either DIFI source or DIFI sink as sample rate “master”

In all cases, each new burst shall initiate a new Data Packet. Packet parameters, such as Sample Rate, bit depth, Reference Level, and RF Reference Frequency shall remain constant within any single burst. A Context Packet shall be issued for each burst, with a timestamp corresponding to the effectivity time for the new parameters (consistent with VITA 49.2 usage of the Context Packet timestamp), that is, the Context Packet timestamp corresponds to the time that the first sample in the first Data Packet in the burst will be present at the SID location.

Each Context Packet should be issued in advance of the Data Packet burst to which it corresponds. The required lead time for the Context Packet is an implementation detail that must, for the present version of this Standard, be resolved by the system designer. As a matter of good practice, the Context Packets should be issued as early as is practical once the next-burst information is available.

The alignment of the timestamp of the Context Packet describing the n^{th} burst with the timestamp of the first Data Packet of the n^{th} burst serves two functions. In the absence of dropped packets, it simplifies the association of the n^{th} Context Packet with the n^{th} user data signal burst – the n^{th} Context Packet and the first Data Packet of the n^{th} burst will share identical timestamps enabling ease of association for the parser. If, however, a Context Packet is dropped, the DIFI sink parser can identify that there is a Data Packet corresponding to a new burst for which there is no corresponding Context Packet available. The system designer can adjust the response to this situation, for example, in the case of an MFTDMA system, muting the transmission of the "context-less" burst since key transmission parameters such as the RF frequency are unknown.

The selection of the #1 versus #2 approaches depends on the availability of a reference plane. In the presence of a distributed reference signal, synchronization of sample rates is greatly simplified through the use of the reference signal. In the absence of a reference signal, use case 2.a. permits the DIFI sink sample rate to be synchronized to the DIFI source through the averaging of the arrival rate of samples without the need for Flow Control Packets, as described in this appendix, section 6.3 describing implementations. Approaches used in 1.b. and 2.c. would be preferable when it is desirable to minimize traffic on the Ethernet link over which the DIFI streams are carried. Illustrated examples of the use of Context, Data, and Control packets for the five cited cases are covered below.

7.1.1 TDMA Use Case 1.a. – Reference Plane, Continuous Packet Generation

In this use case, a reference signal is available to synchronize sample rates among all the DIFI devices. The DIFI source generates continuous Data Packets continuously, even when the user data signal is "out-of-burst". In this mode of operation, when the user data signal is "out of burst", the data payload shall be filled with idle samples having the same bit depth as the non-idle samples. The idle samples should be I=0 and Q=0. Note that for arbitrary bit depth and arbitrary burst length, it cannot be guaranteed that a burst will fill out an integer number of 32-bit words. Therefore, it is necessary that bit-padding be permitted (i.e., that some bits of the final word of the data payload of a packet are to be disregarded and not included by the DIFI sink parser as part of the data stream).

Figure 33 illustrates packet flow from the DIFI source for use case 1.a. The timing reference signal is depicted at the bottom above the time axis. Data Packets are issued continuously, and assuming constant sample rate and bit depth, are issued at a uniform rate. The sample time slots between user signal data bursts are filled with "idle samples" which should be I=0 and Q=0. These idle samples are shown in darker blue in the data payload in Figure 33. Given the variable size of user signal data bursts, depending on the bit depth being used, it may not be possible to fill an integer number of 32-bit words from the beginning of the n^{th} burst to the beginning of the $(n+1)^{st}$ burst (inclusive of idle samples). The "leftover" bits in the last 32-bit word of the n^{th} Data Packet are shown in brown in the Data Payload, and the number of such pad bits shall be indicated in bits 31-27 of the third word of the Prologue of the Data Packet containing the pad bits. Bit padding is permitted in all Information Classes except 0x0000 and may be used in any of the Data Packets for improved flexibility in choosing a consistent packet size despite varying burst parameters and sizes.

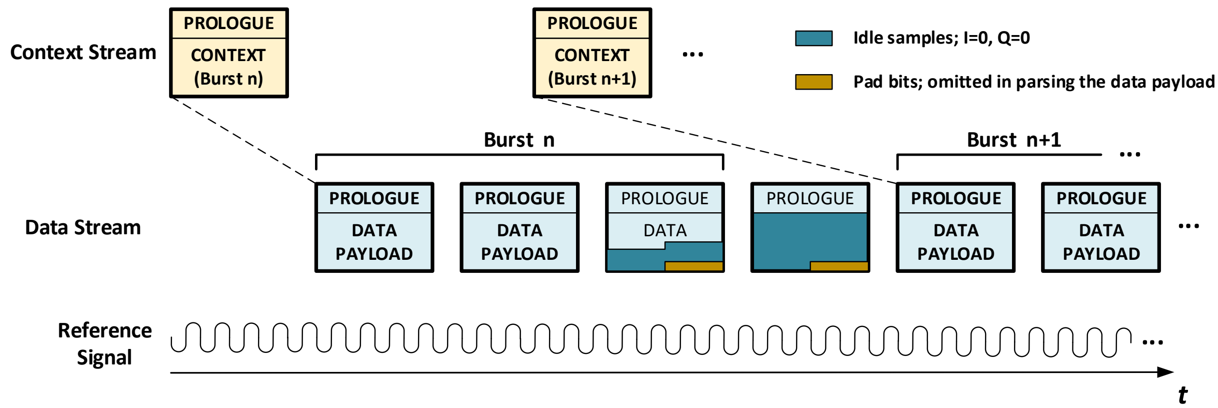


Figure 33. TDMA Use Case 1.a.

In proper operation, the first sample of each Data Packet should be presented by the buffer in the DIFI sink to the SID location at the time indicated by the timestamp in the Data Packet Prologue. As described in section 6.3, the DIFI source must timestamp Data Packets with a time that is at least the maximum Ethernet link latency later than the issuance time, to avoid having packets arrive at the SID location later than their timestamps. In the present version of this Standard, management of link latency, timestamp retardation, and buffer size at the DIFI sink device(s) must be resolved by the system designer.

7.1.2 TDMA Use Case 1.b. – Reference Plane, Discontinuous Packet Generation

In this use case, a distributed reference signal is again available to permit synchronization of the Sample Rates of all connected DIFI devices. In this case, DIFI Data Packets are issued only

when there is user signal data (i.e., when the SATCOM transmission is "in-burst"). The timestamp of the Context Packet for the (n+1)st burst informs the DIFI sink how many idle sample periods to insert between the end of the nth burst and the beginning of the (n+1)st burst (which begins at the timestamp shared by the Context Packet and the first Data Packet in the burst). Other than the DIFI sink determining the number of idle sample slots from the Context Packet timestamps and the Payload sizes of the bursts (rather than having these filled as idle samples by the DIFI source), use case 1.b. operates in the same way as 1.a. Packet streams are illustrated in Figure 34. Here, packets are shown with only bit padding, which means the last Data Packet in a user signal data burst might be of a substantially different size.

If it is desirable to keep all packet sizes the same for ease of parsing, idle samples may be used in conjunction with bit padding to keep Data Packet sizes consistent.

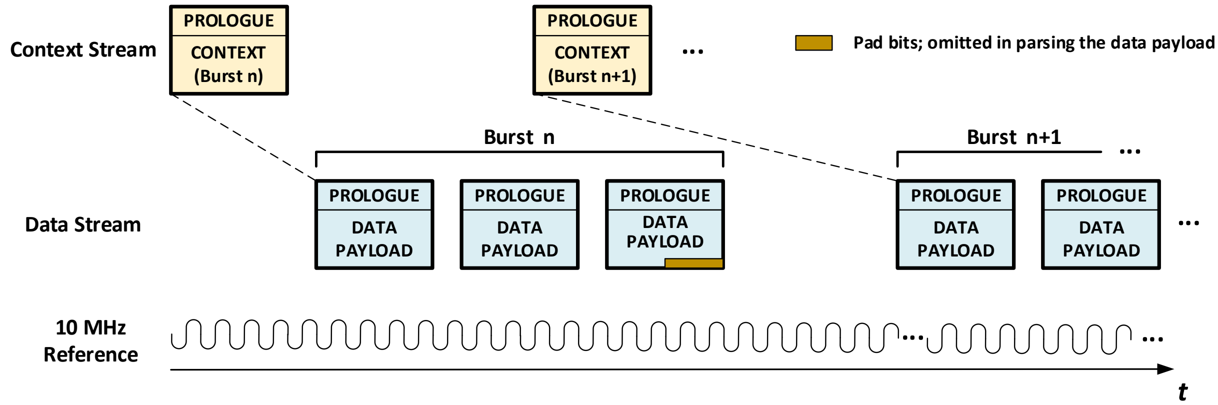


Figure 34. TDMA Use Case 1.b.

Figure 34 Illustrates a Context Packet stream and Data Packet stream for TDMA use case 1.b. in which a reference plane is present and DIFI Data Packets are issued only when the user data signal is "in-burst"

7.1.3 TDMA Use Case 2.a.– No Reference Plane, Continuous Packet Generation, Source Master

In this use case, there is no distributed reference signal, so the Sample Rates between DIFI source(s) and sink(s) must be synchronized by another means. In this use case, it is assumed that the DIFI source is the sample rate "master". The DIFI source issues Data Packets continuously, filling "out-of-burst" sample time slots with idle samples. Packet streams for this case are shown in Figure 35. As with all the uses cases described in this section, all new user signal data bursts initiate a new Data Packet, and this packet shares a timestamp with the Context Packet characterizing the parameters of the burst. Since the DIFI source is issuing samples continuously, and at constant rate (within each user signal data burst), the DIFI sink can synchronize its Sample Rate to the DIFI source by averaging arrival rate of samples, as described in section 6.3.

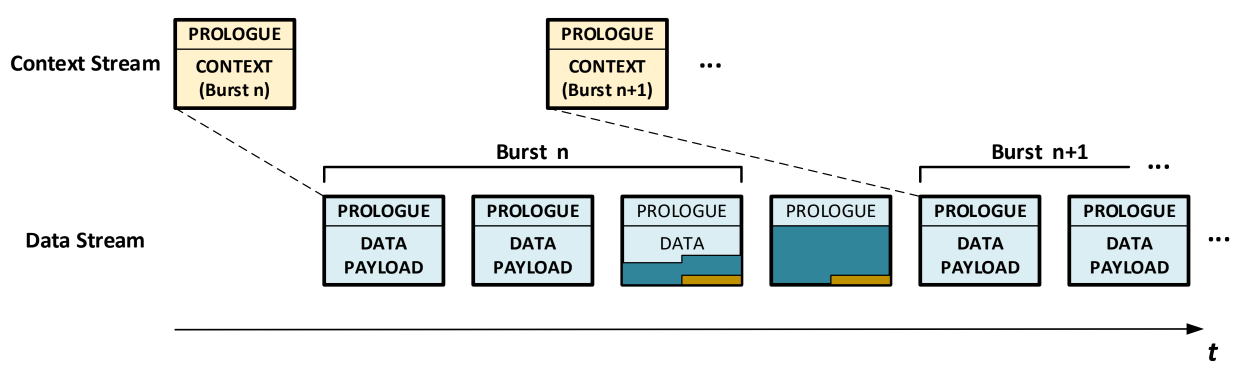


Figure 35. TDMA Use Case 2.a

Figure 35 Illustrates a Context Packet stream and Data Packet stream for TDMA use case 2.a. in which a reference plane is absent and DIFI Data Packets are issued continuously, and the Data Payload filled with idle samples when the user data signal is “out-of-burst”. DIFI source is assumed to be Sample Rate master.

7.1.4 TDMA Use Case 2.b.- No Reference Plane, Continuous Packet Generation, Sink Master

In this use case, there is no distributed reference signal, so the Sample Rates between DIFI source(s) and sink(s) must be synchronized by another means. In this use case, the DIFI source issues Data Packets continuously, filling “out-of-burst” sample time slots with idle samples. This differs from use case 2.a., in that in this case, the DIFI sink is the Sample Rate master. Synchronization of Sample Rates is accomplished using Flow Control Packets that flow from the DIFI sink to the source and are uniformly issued and timestamped by the DIFI sink. Using the method described in section 6.3, the DIFI source can use these Flow Control Packets to synchronize to the DIFI sink. Beyond this difference in synchronization method, this use case is otherwise identical to 2.a.

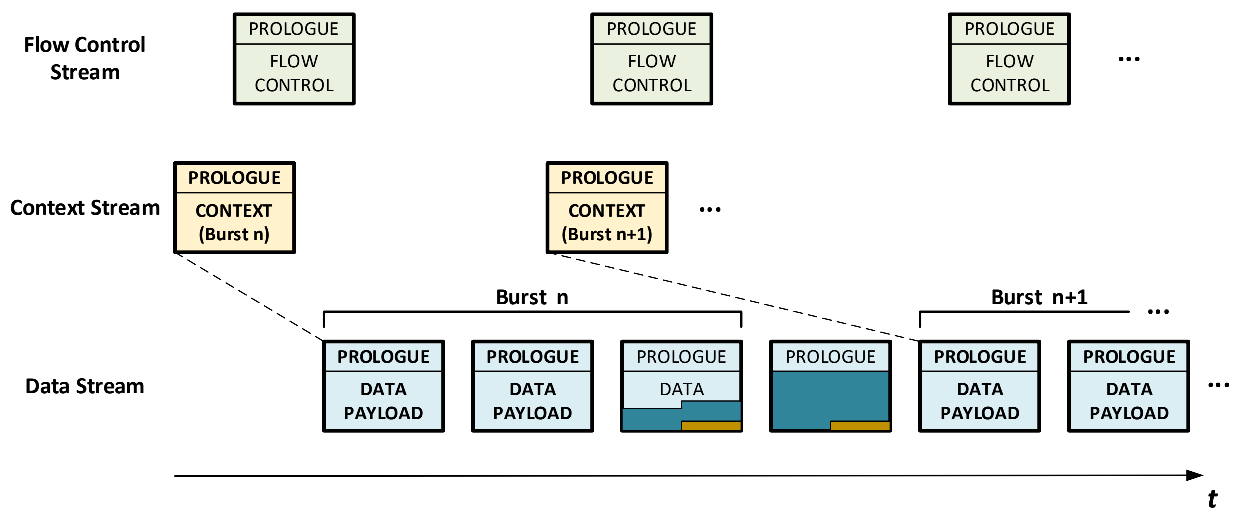


Figure 36. TDMA Use Case 2.b – Context and Data packet Stream.

Figure 36 Illustrates a Context Packet stream and Data Packet stream for TDMA use case 2.b. in which a reference plane is absent and DIFI Data Packets are issued continuously, and the Data Payload filled with idle samples when the user data signal is “out-of-burst”. DIFI sink is assumed to be Sample Rate master, and Flow Control Packets are issued by the sink.

7.1.5 TDMA Use Case 2.c. - No Reference Plane, Discontinuous Packet Generation

In this use case, there is no distributed reference signal, so the Sample Rates between DIFI source(s) and sink(s) must be synchronized by another means. Unlike use case 2.a., samples are not being issued continuously by the DIFI source, so even if the DIFI source is to be the Sample Rate master, the DIFI sink cannot synchronize by averaging arrival rates of samples. Figure 37shows the Packet streams for this use case. In this use case, Flow Control Packets are used for synchronization as described in section 6.3, but depending on whether the DIFI source or sink is to be Sample Rate master, the direction of the Flow Control Packets will be different. The Flow Control Packets are issued by the Sample Rate master (which could be either DIFI source or sink) and flow to the other device(s).

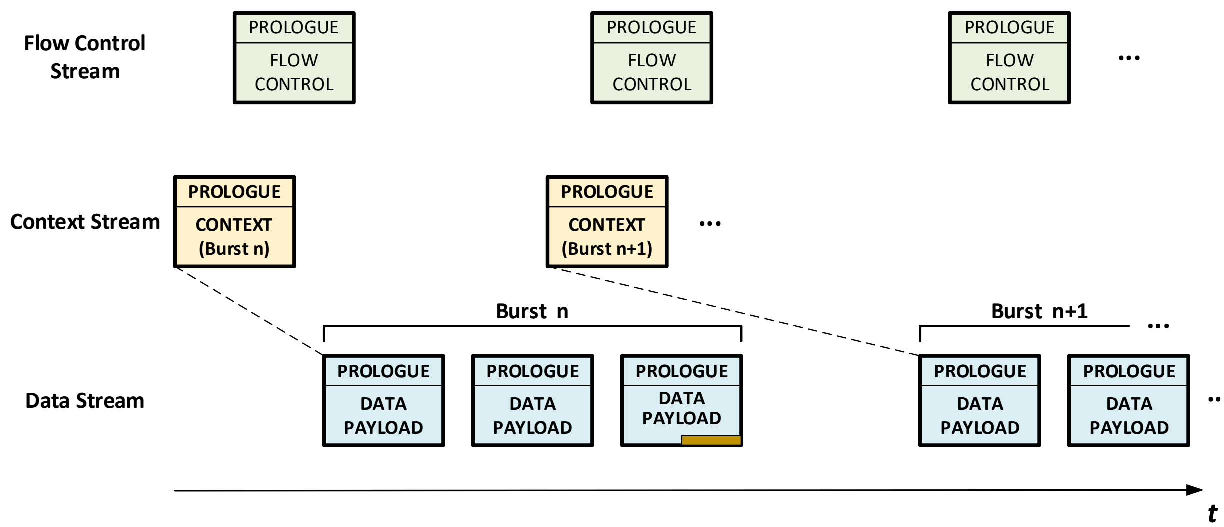


Figure 37. TDMA Use Case 2.c – Context and Data packet Stream.

Figure 37 Illustrates a Context Packet stream and Data Packet stream for use case 2.c. in which a reference plane is absent and DIFI Data Packets are issued discontinuously, only when the user data signal is “in-burst”. DIFI source or sink can be assigned Sample Rate master, and Flow Control Packets are issued by the master, and flow to the other device(s).

7.1.6 Synchronization in TDMA systems with Multiple Sources and a Single Burst Controller

When dealing with burst traffic within a DIFI stream, the DIFI sink might require precisely synchronized timing when receiving streams from multiple DIFI sources. This is crucial for a burst demodulator to determine the start of a packet, irrespective of its source. The accuracy of timing synchronization becomes increasingly important as the packets are more closely spaced. This is especially pertinent in scenarios such as:

- Large and intricate networks featuring multiple satellite networks.
- Antenna handovers within a Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) constellation.
- Antenna handovers within a system employing antenna redundancy.

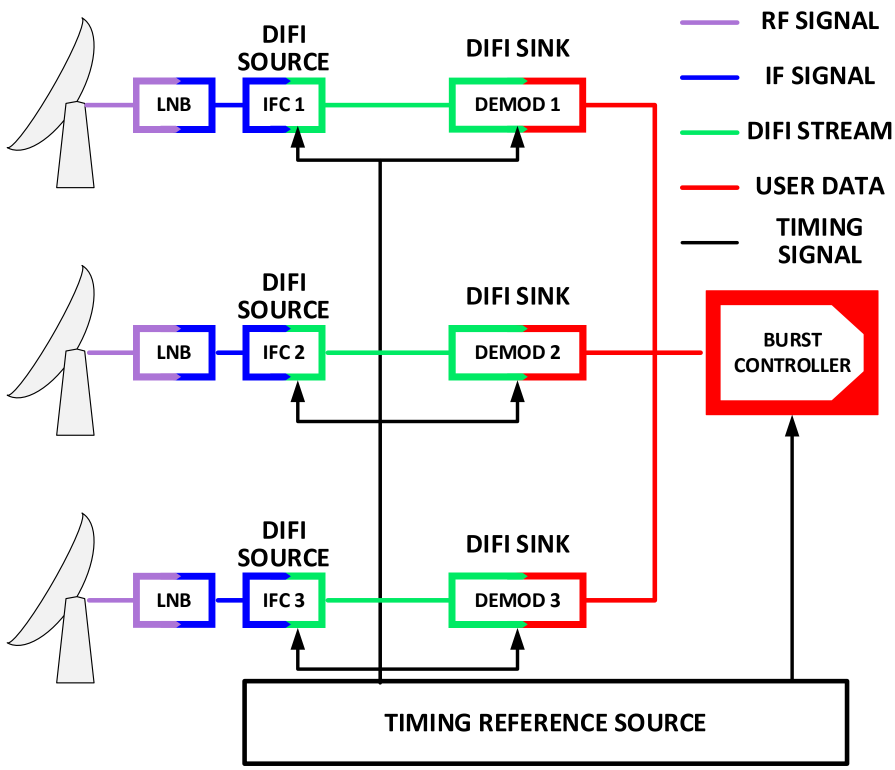


Figure 38. TDMA System Multi-source.

Figure 38 is a Block Diagram of TDMA system in which related DIFI streams emanating from multiple separate DIFI sources (IFCs/RFCs) must be coordinated by a burst controller.
Time synchronization between the various DIFI sources and their corresponding demodulators can be accomplished through a variety of means, depending on whether the demodulators and DIFI sources share a reference plane or not. It is likely that the burst controller and demodulators are co-located, share a reference plane, and can be synchronized using existing timing synchronization protocols such as PTP, SyncE, or GPS references. The demodulator/DIFI source pairs may or may not share a reference plane – for example, if the demodulators are virtualized at a location remote from the antenna sites, a shared reference plane may be unavailable.

In cases where the demodulators and DIFI sources do share a reference plane, shown in Fig. 33, the use of existing protocols, such as PTP, can be applied to all devices interacting with the DIFI streams, permitting the simultaneous synchronization of the "clocks" in all the DIFI sources and demodulators, as illustrated in Figure 39, where the DIFI Packetizer has access to the synchronized clock in the establishments of timestamps. This synchronization can then be employed concurrently with the DIFI streams as described in use cases 1. a. and 1.b.

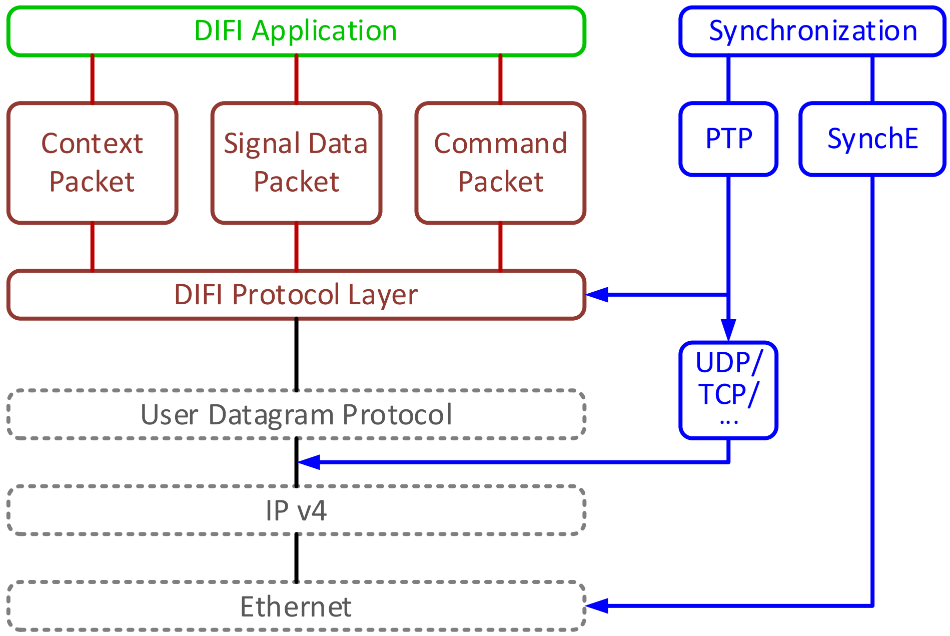


Figure 39. Protocol Stack including PTP for timing synchronization