Reference Level, Scaling, and Gain Fields in DIFI ISTO 4900-2012 v1.2

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Reference, Scaling, and Gain Fields in the DIFI Context Packet

- The DIFI Context Packets (Packet Classes 0x0001 and 0x0003) contain two 32-bit words, 18 and 19:
  - Word 18 contains two 16-bit sub-fields
    - Reference (bits 0-15)
    - Scaling (bits 16-31)
  - Word 19 contains two 16-bit sub-fields
    - Gain 2 (bits 0-15)
    - Gain 1 (bits 16-31)
- VITA 49.2 has definitions for
  - Reference Level (defined only for Rx*)
  - Gain 1/ Gain 2 (defined only for processes with both analog input and output or digital input and output)
- DIFI v1.2 has extended the definition of Reference Level, redefined Gain, and introduced Scaling

*"The Reference Level field has no meaning for processes with analog outputs." (VITA 49.2 §9.5.9)

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	0	0	1	0	0	TSM	TSI		1	0	Seq Num				Packet Size = 27 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 (number of incorporating class)																Packet Class = 0x0001																4
Integer Seconds Timestamp (per TSI field)																																5
Fractional Seconds Timestamp (Real Time [picoseconds])																																6
																																7
Context Indicator Field (0xFBB98000 -> context change or 0x7BB98000 -> no change)																																8
Reference Point = 0x00000064																																9
Bandwidth																																10
																																11
IF Reference Frequency																																12
																																13
RF Reference Frequency																																14
																																15
IF Band Offset																																16
																																17
Scaling																Reference Level																18
Gain 1																Gain 2																19
Sample Rate																																20
																																21
Timestamp Adjustment																																22
																																23
Timestamp Calibration Time																																24
State and Event Indicators																																25
Data Packet Payload Format																																26
																																27

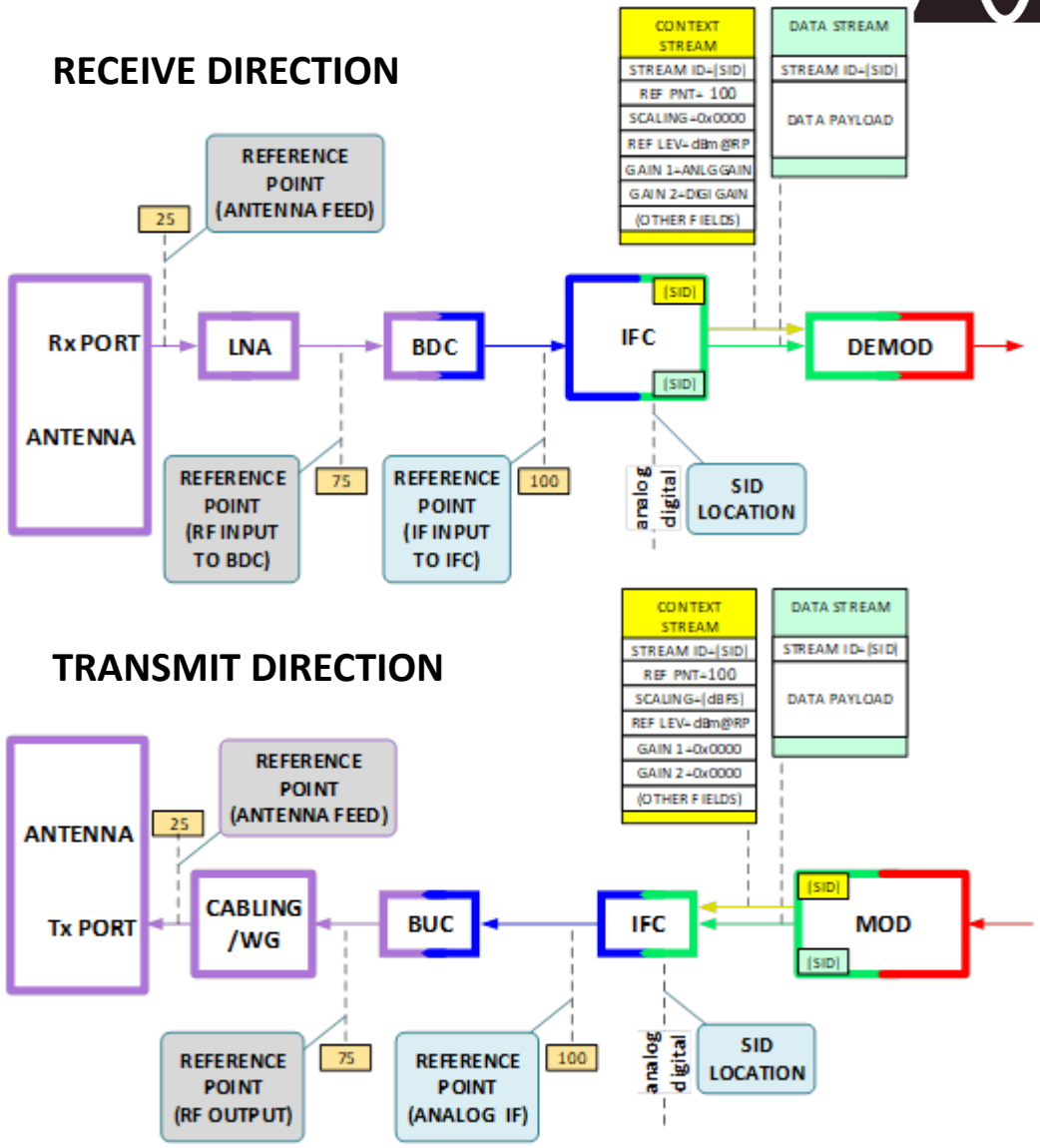
Table 13. Packet Class 0x0001 Format, Standard Flow Signal Context

Context Packets in VITA 49.2 and DIFI, and Data Representation

- The purpose of the Context Packets in both VITA 49.2 and in the DIFI Standard is to provide metadata describing the data in the Data Packets
    - includes parameters such as Sample Rate, bit depth of the samples, and RF Reference Frequency
    - enables the interpretation of the Data Packets
- VITA 49.2 supports the use of many different data formats; the DIFI Standard, however, mandates the use of complex Cartesian I and Q signed-integer samples, represented by a signed integers of a user-selected bit-depth between 4 and 16 bits
- For n-bit signed-integer samples, the largest number that can be represented is $2^{(n-1)}-1$ … for example, for an eight-bit representation, one can digitally represent a positive value up to 127, and a negative number as low as -128, and “full-scale” in this case is defined in VITA 49 as 128

Context Packets: Reference Points with IF Converters

- The Context Packet also calls out the Reference Point. The Reference Point Identifier Field is used within VITA 49.2 and the DIFI Standard to identify a location to which certain parameters pertain, including:
  - Reference Level
  - Scaling
  - Gain (Gain 1 and Gain 2)
  - Timestamp Adjustment
- When an IF Converter (IFC) is used, DIFI recommends the use of Reference ID 100 to call out the IF input (Receive) or IF output (Transmit)



Context Packets: Reference Point with RF Converters

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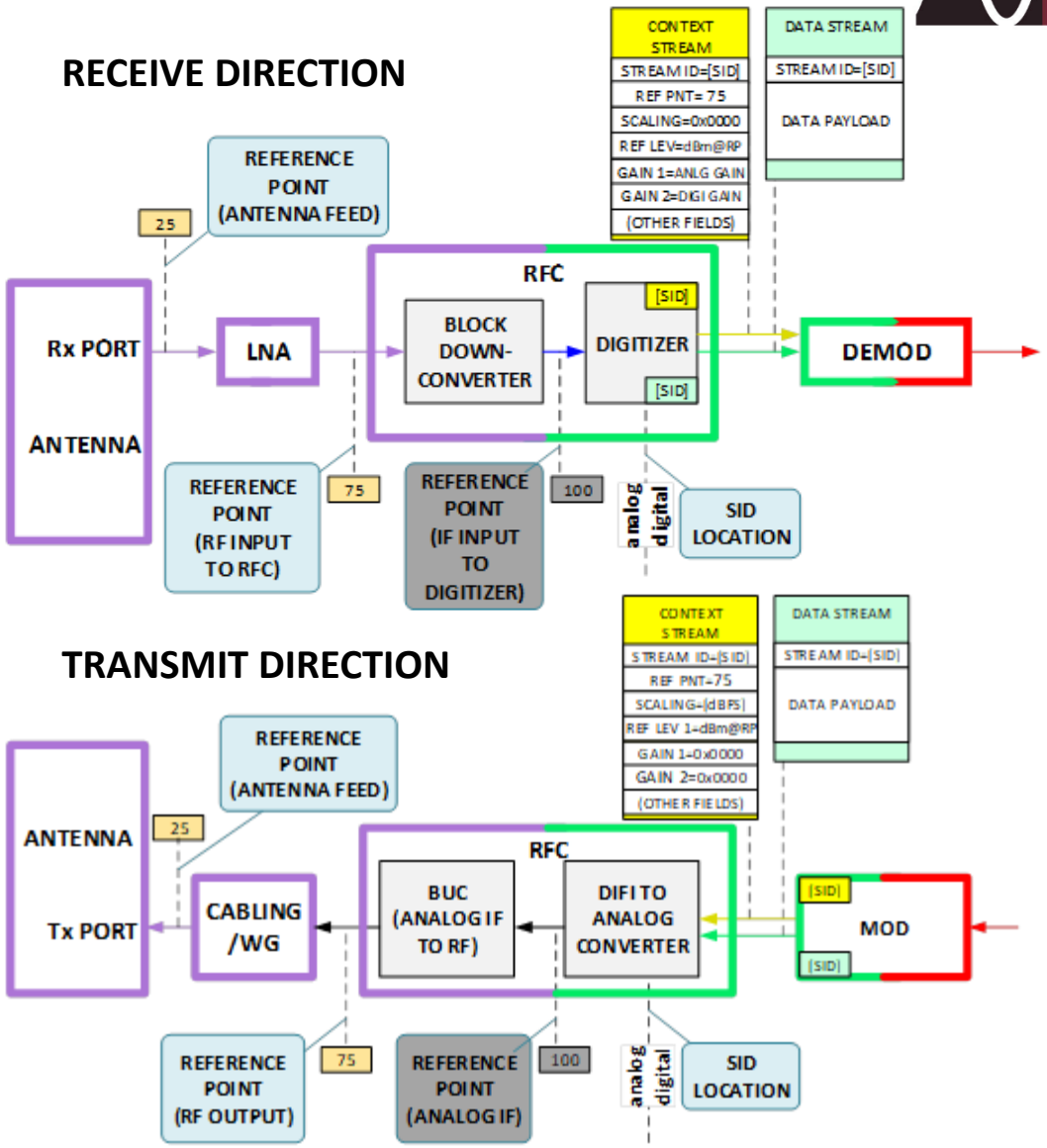
  - Reference Level
  - Scaling
  - Gain (Gain 1 and Gain 2)
  - Timestamp Adjustment
- When an RF converter (RFC) is used, DIFI recommends the use of Reference ID 75 to call out the IF input (Receive) or IF output (Transmit)

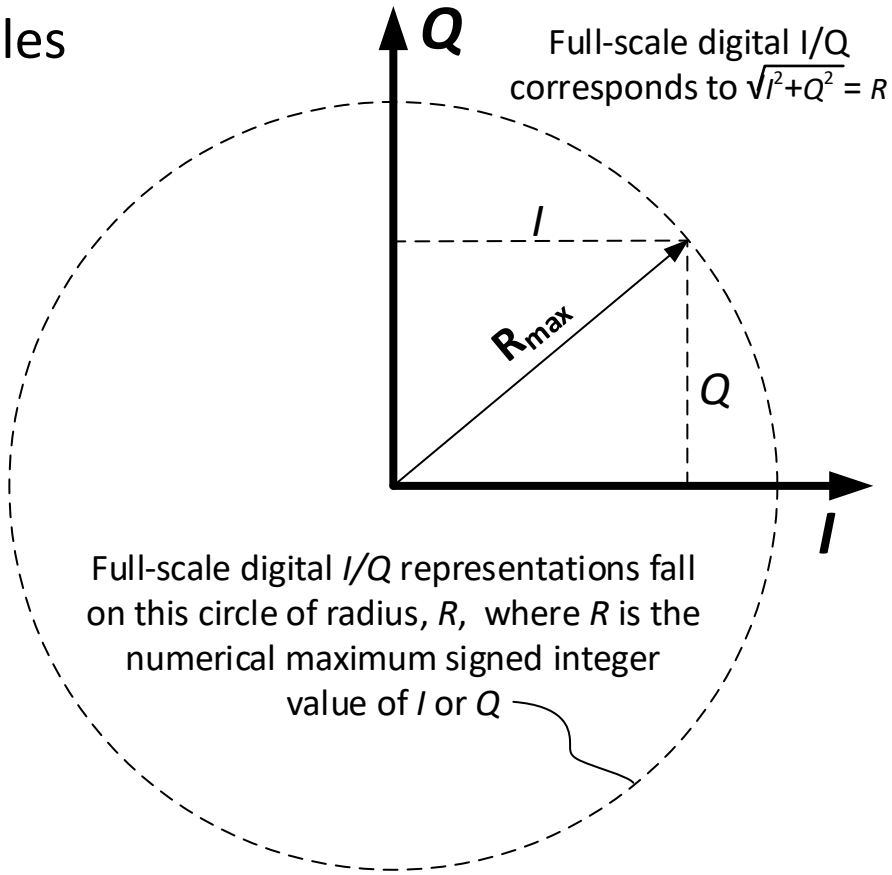


Definition of a “Full-Scale” Digital Sinusoid

- The Reference Level field will define the relationship between the analog power in dBm at the Reference Point called out in the Context Packets and a “full-scale digital sine wave” – therefore, we must define what a “full-scale digital sine wave” is for complex Cartesian samples

- If we define $R_{max} = 2^{(n-1)}$ for an n-bit signed-integer sample, the largest magnitude sine wave that can be represented by n-bit samples in *I* and n-bit samples in *Q* is described by a vector having its tail at the origin and its tip orbiting on a circle of radius R_{max} (shown by the dashed circle on the diagram at right)

- Therefore, a full-scale digital sinusoid has values of I and Q such that $\sqrt{I^2 + Q^2} = R_{max}$



Reference Level: VITA 49.2 Definition and DIFI v1.2.0 Extension

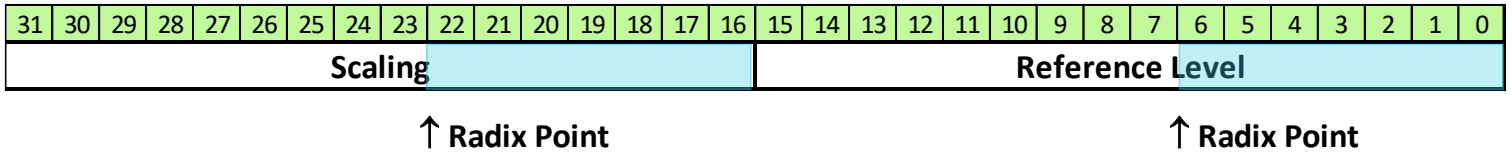
- VITA 49.2:

"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 digitized sine wave with peak amplitude of one[1], in the payload of the paired Data Packet Stream." (Applies to Rx direction only.)

- DIFI v1.2.0:

"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." (Rx direction)

"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."



[1] "For complex, signed Data Samples, the Unit-Scale Sinusoid falls on the unit circle on the complex plane."

Gain Fields: VITA 49.2 Definition and DIFI Use

- **Rule 9.5.3-2**: “The Gain field shall only be used when the Reference Point and the Described Signal are either both analog signals or both digitized signals. A digital Described Signal with an analog Reference Point is more properly described using the Reference Level field.” [VITA 49.2]
- **9.5.3:** “The Gain Field contains two 16-bit subfields, Stage 1 Gain and Stage 2 Gain, which occupy the lower and upper 16 bits of the Gain Field, respectively…. Stage 1 Gain conveys the front-end or RF gain, and Stage 2 Gain conveys the back-end or IF gain.” [VITA 49.2]
- **Rule 9.5.3-1**: “…When the Reference Point and the Described Signal are both digitized signals, the gain shall be calculated with respect to the Unit-Scale Sinusoids at the two points.” [VITA 49.2]
- Since few DIFI applications involve analog input and analog output, **the DIFI Standard generally treats the two gain fields as disregarded fields, which should be filled with zeros**
- One exception is remote IF signal replication; in this case, the user may use the gain fields to permit the remote DIFI sink to replicate the analog, pre-digitization gain and the post-digitization digital gain used at the DIFI source; it is recommended that Gain 1 be used for the analog gain and Gain 2 be used for the digital gain

Scaling Field: Rationale

- Note that the Reference Level essentially represents a gain, the relationship between a full-scale digital sine wave and an analog output in dBm – if the IFC/RFC controls its gain, the Reference Level value is sufficient to set this gain
- Reference Level value alone is insufficient to know the intended average output power
- For example, a +2dBm increase in Reference Level could indicate either
  - an intended 2dB increase in output power with a constant waveform
  - no increase in output power with 2dB additional backoff in the digital representation (e.g., because of 2dB increase in signal PAR)
- For CONOPS that controls the output *power* of the IFC/RFC rather than gain, additional information is necessary beyond the Reference Level value
- By communicating the average value conveyed by the digital samples relative to full-scale (dBFS) along with the gain implied by the Reference Level value (analog output in dBm for a full-scale digital signal), the intended average output power level can be calculated and the output power controlled
- Additionally, for large-scale signal combining in gateway terminals, information regarding the backoff of the contributing signals can be useful as an aid in PSD allocation

Scaling Field in the DIFI Standard v1.2.0

- The Scaling field does not exist in VITA 49.2, and has been added in v1.2.0 of the DIFI Standard using the reserved bits 16-31 of the VITA 49 Reference Level word
- Per the DIFI Standard v1.2.0, “The value in the [Scaling] 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.”
- Since the average power will be less than the peak power, the Scaling field value will generally be negative
- This field communicates the headroom allocated between the average value of the signal represented in the digital stream and the maximum representable power (the power of a full-scale sine wave)
- The use of the field is optional; if it is not used, it should be filled with zeros

Summary

- In the DIFI Standard v1.2.0 the meaning of the Reference Level field
  - in the Rx direction is essentially the same as in VITA 49.2 … it is the value in dBm of an analog input sine wave that corresponds to a full-scale digital sine wave
  - in the Tx direction, DIFI extends the definition by analogy to be the intended value in dBm of an analog output sine wave that corresponds to a full-scale digital sine wave input
- In the DIFI Standard v1.2.0, the Gain fields are generally disregarded, populated with zeros at the source and disregarded at the sink – usage per previous revisions of this standard is allowed, but interoperability is the responsibility of the vendor
- In the DIFI Standard v1.2.0, a new optional field, Scaling, has been introduced using the upper 16 bits of the Reference Level word which, if unused, should be populated with zeros; this field communicates the average value in dBFS of the signal represented by the data samples