VLBA ACQUISITION MEMO #347

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To: VLBA Data Acquisition Group

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Subject: Digital tone extractor normalization

The digital tone extractor firmware has been initially implemented with the following multiplication tables:

1. Input data: 2-bit (sine and magnitude) [0 x 73 bit 15 = 1]

   Sine/cosine representation: 4-level for data = 00 and 11
   2-level for data = 01 and 10

   Multiplication table: (4-level x 4-level reduced multiplication table)

DATA \	0	30	60	90	120	150	180	210	240	270	300	330
11	2	3	3	3	3	2	1	0	0	0	0	1
10	2	2	2	2	2	2	1	1	1	1	1	1
01	1	1	1	1	1	1	2	2	2	2	2	2
00	1	0	0	0	0	1	2	3	3	3	3	2

Sin ϕ x data (cos ϕ x data shifted by 90°)

Harmonic content: (normal signal levels) -13, -21, -26 dB for 3rd, 5th, 7th harmonic

Extractor normalization: $$RSIN = \left[\frac{COUNTMSB * 2 + COUNTLSB - 1.5N}{N * 1.02}\right]$$

where COUNTMSB = SINMSB COUNT
COUNTLSB = SINLSB COUNT
N = # clock cycles
= 32×10^6 per second
= 0 x 112A8800 for 9 seconds

2] Input data: 1 - bit (sign bit only)
[0 x 73 bit 15 = 0]

Sine/cosine representation: 4-level

Multiplication Table: (2-level x 4-level full table)

DATA\	0	30	60	90	120	150	180	210	240	270	300	360
1	2	3	3	3	3	2	1	0	0	0	0	1
0	1	0	0	0	0	1	2	3	3	3	3	2

Harmonic content: -14, -26, -31, dB for 3rd, 5th, 7th harmonic

Extractor normalization: $$RSIN = \left[\frac{COUNTMSB * 2 + COUNTLSB - 1.5N}{N * 1.2}\right]$$

3] Input data: 1 - bit (sign bit only)

Sine/cosine: 1 - bit

This mode is known as the "doubling" mode and is envolved by 0 x 76 bit 11 = 1.

Multiplication table: (2-level x 2-level)

DATA\	0	30	60	90	120	150	180	210	240	270	300	330
1	1	1	1	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	1	1	1	1

Harmonic content: -9, -14, -17 dB for 3rd, 5th, 7th harmonic

Extractor normalization: $$RSIN = \left[\frac{COUNT * 2 - N}{N * 0.76}\right]$$

In this "doubling" mode extractor processes 2 phase cal tones.

Not yet implemented in the firmware is the following:

4]

Input data: 2-bit

Sine/cosine: 6-level

Multiplication table: (4-level x 6-level reduced multiplication)

DATA \	0	30	60	90	120	150	180	210	240	270	300	360
11	9	13	15	15	13	9	6	2	0	0	2	6
10	8	9	10	10	9	8	7	6	5	5	6	7
01	7	6	5	5	6	7	8	9	10	10	9	8
00	6	2	0	0	2	6	9	13	15	15	13	9

Harmonic content: -29, -33, -38 dB 3^{rd}, 5^{th}, 7^{th} harmonic

Extractor normalization:

$$\left[\frac{COUNT\ 3*8 + COUNT\ 2*4 + COUNT\ 1*2 + COUNT\ 0 - 7.5N}{N*2.2}\right]$$

Conversion to amplitude and angles:

$$\text{Amp} = (RSIN^2 + RCOS^2)^{1/2}$$

$$\text{PHASE} = \tan^{-1}(RSIN,\ RCOS)$$

The normalization factors (1.02, 1.2, 0.76, and 2.2) were calculated using numerical integrations of the gaussian probability distribution, quantized, and weighted by the multiplication table.