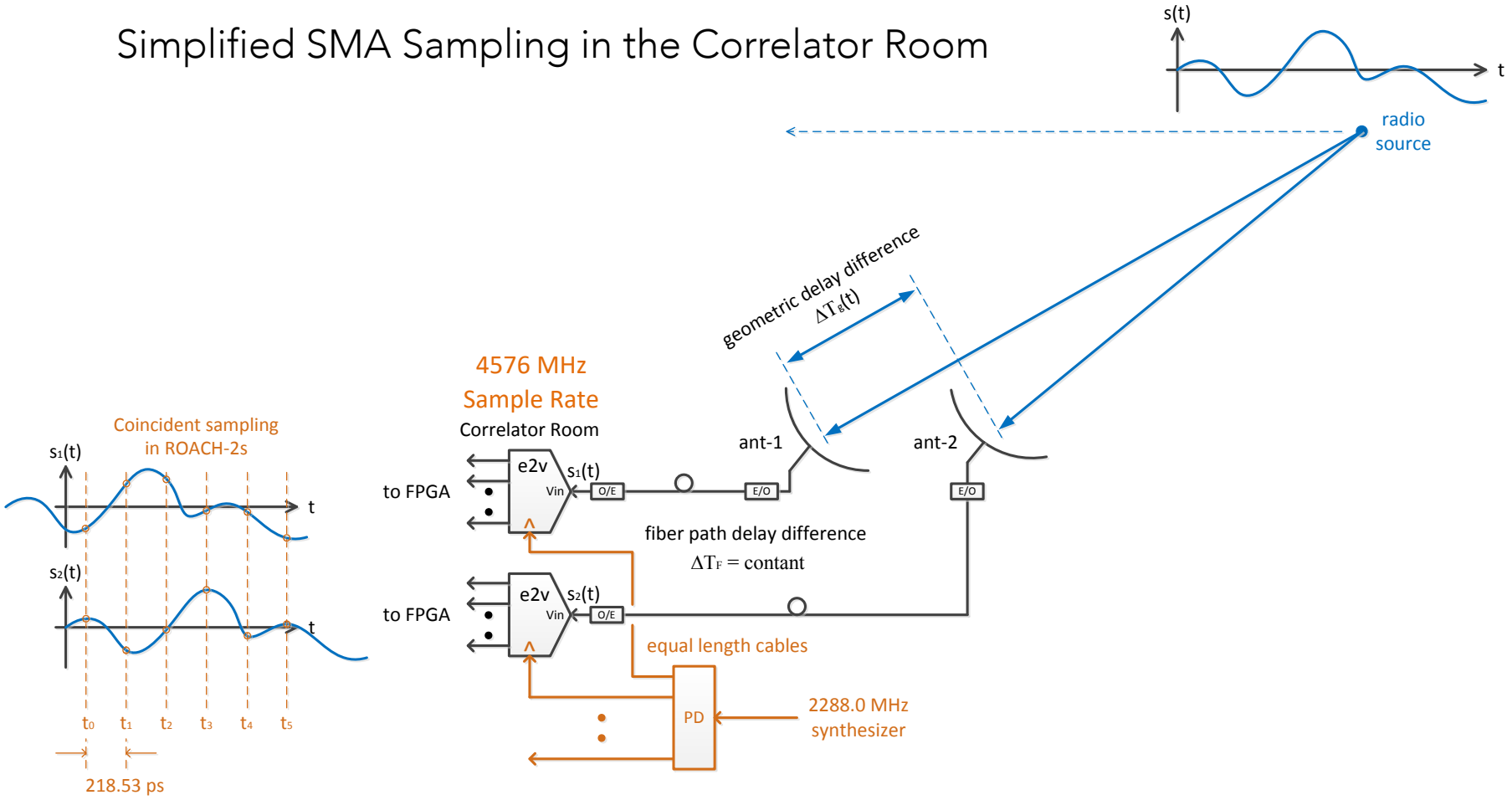
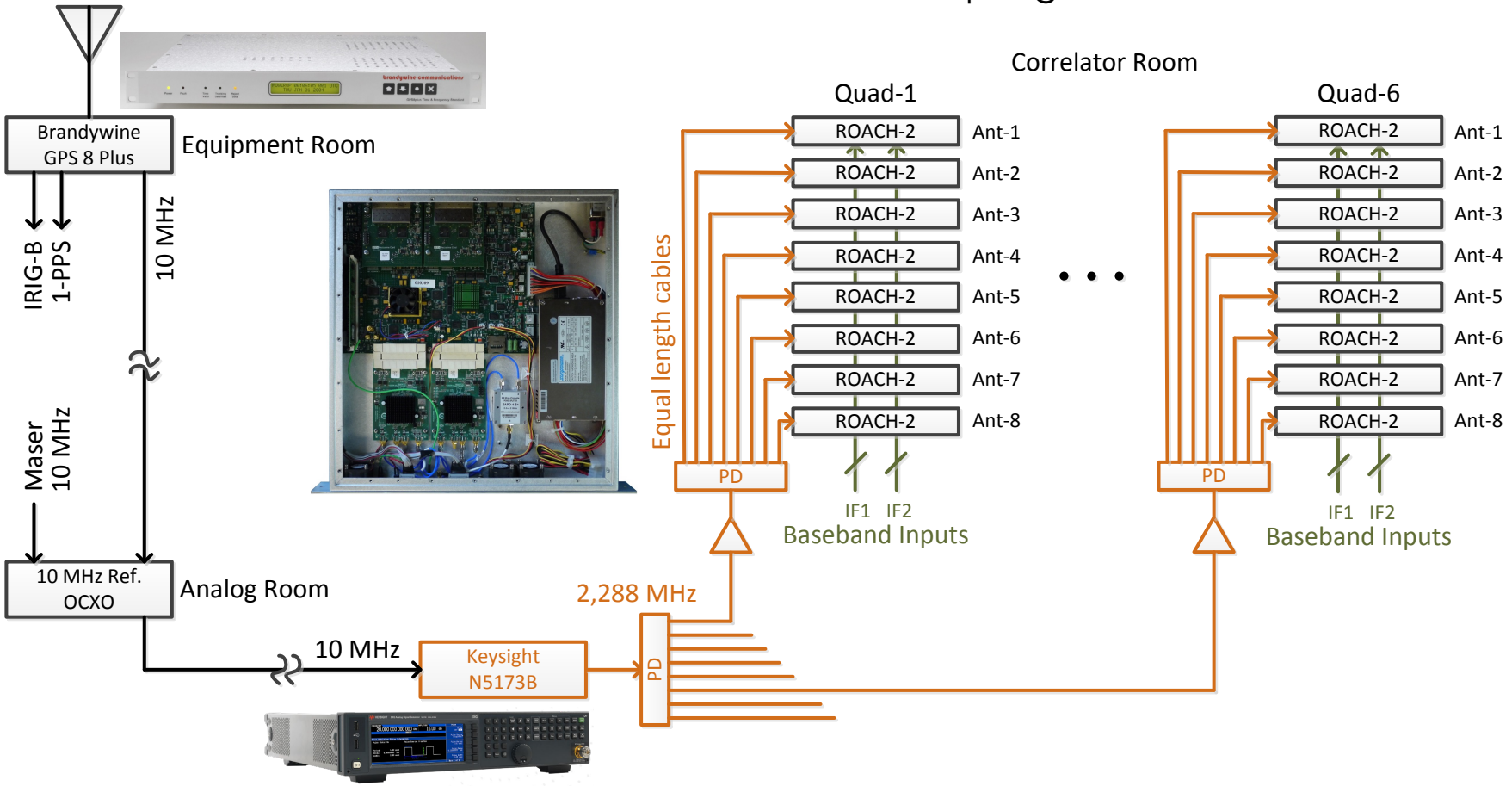
ADC Clock Requirements for Sampling within the Receiver Cabin

2021-May-5
Derek Kubo

Simplified SMA Sampling in the Correlator Room

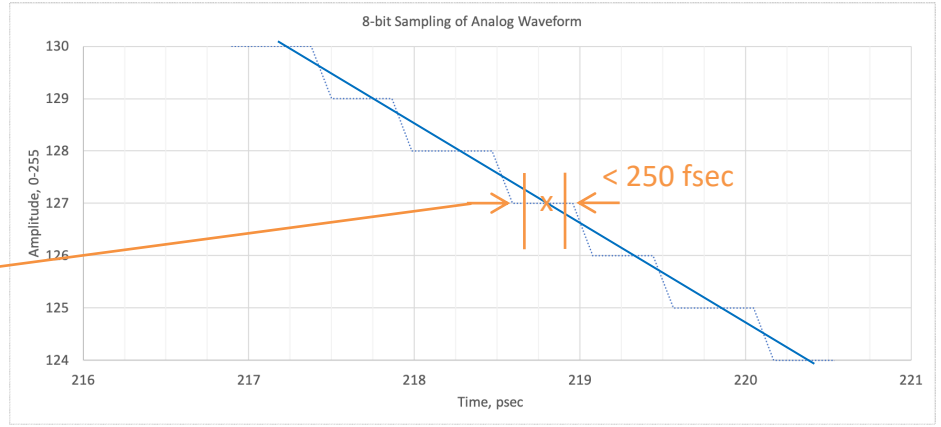


Derivation and Distribution of Sampling Clock



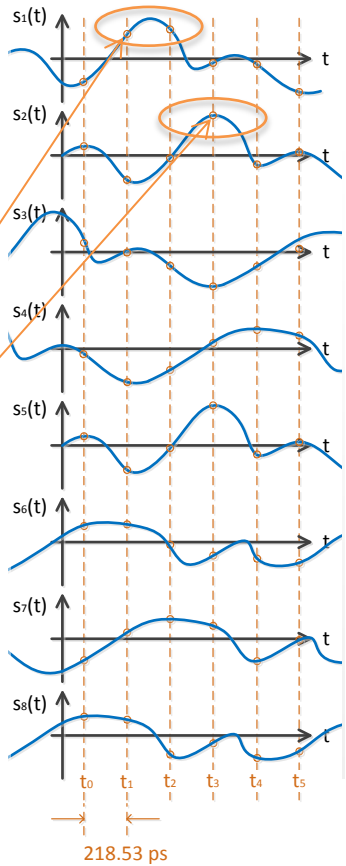
SMA Sampler Clock Performance

	Digitizing in the Correlator Room	
	Clock Performance	Comments
REFERENCE INPUT		
Frequency, MHz	10.0	Brandywine GPS spec
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec
Waveform type, sine or	Sine or Square	Input to Agilent N5173B
square	-	-
Input impedance	50 Ohms nominal	Input to Agilent N5173B
Input VSWR	Not Available	Input to Agilent N5173B
Coupling, AC or DC	AC	Input to Agilent N5173B
Amplitude, dBm	5 +/- 2	Input to Agilent N5173B
Duty cycle, %	50 +/- 1 (TBR)	Input to Agilent N5173B
Spurs, harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B
Spurs, non-harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B
Phase jitter, integrated from	< 81 (TBR)	< 2.9e-4 degrees rms
1 Hz to 1 MHz, fs rms	-	-
Phase stability, antenna to	Not Applicable	Only 1 reference
antenna, ps	-	-
CLOCK OUTPUT		
Frequency, MHz	2,288.0	Agilent N5173B
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec
Waveform type, sine or	Sine	Agilent N5173B
square	-	-
Output impedance	50 Ohms nominal	-
Output VSWR	1.5:1 (TBR)	Power divider spec
Coupling, AC or DC	AC	-
Amplitude, Vpp	1.0	4.0 dBm into ROACH-2
Duty cycle, %	50 +/- 1 (TBR)	-
Spurs, harmonic, dBc	-55	Agilent N5173B spec
Spurs, non-harmonic, dBc	-66	Agilent N5173B spec
Phase jitter, integrated from	170	0.14 degrees rms
1 Hz to 1 MHz, fs rms	-	-
Phase adjust increment	none	-
degrees	-	-
Phase stability, antenna to	< 5 ps	Calc'd from delta cable
antenna, ps	-	drift

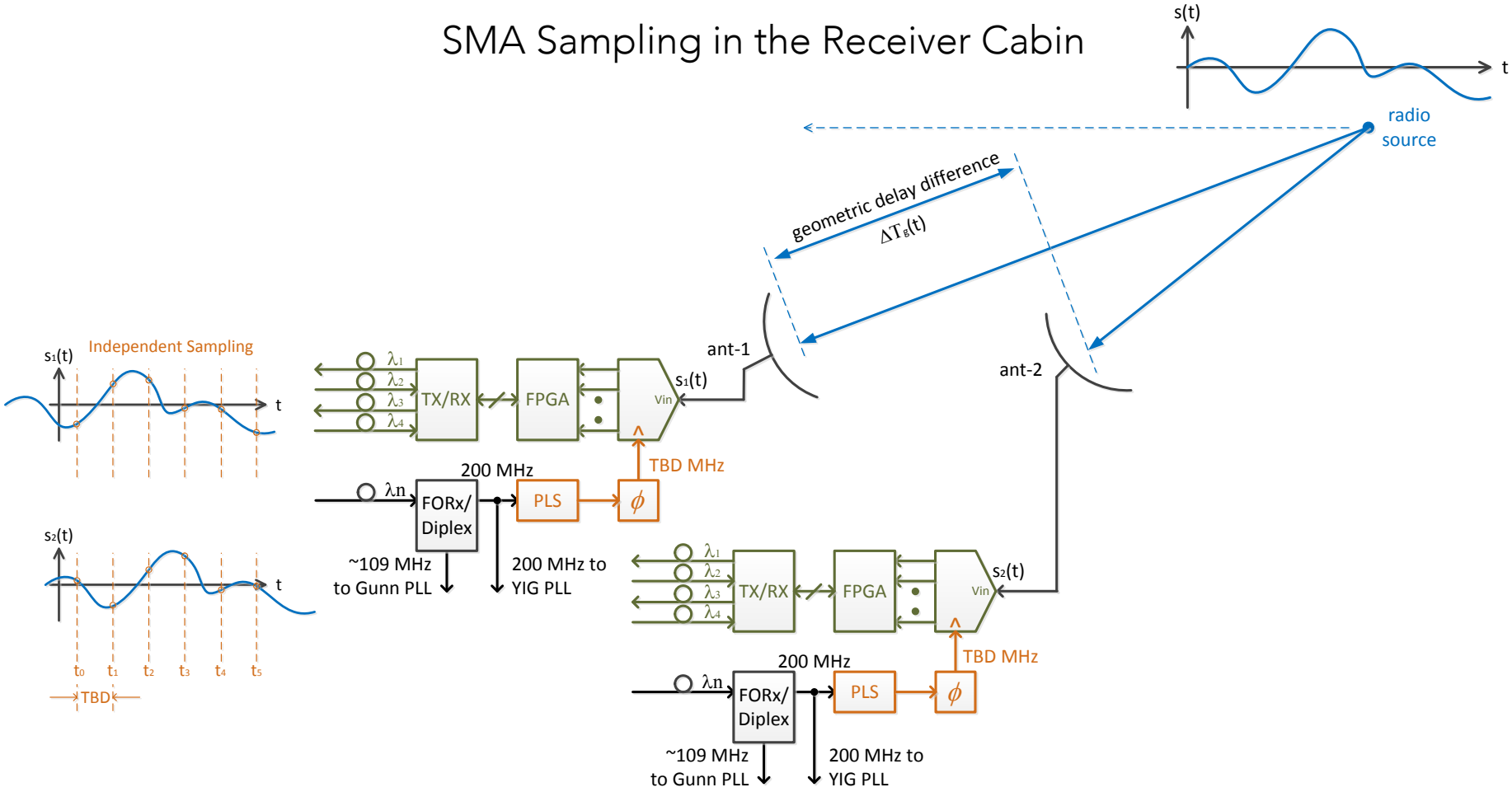


SMA Sampler Clock Performance

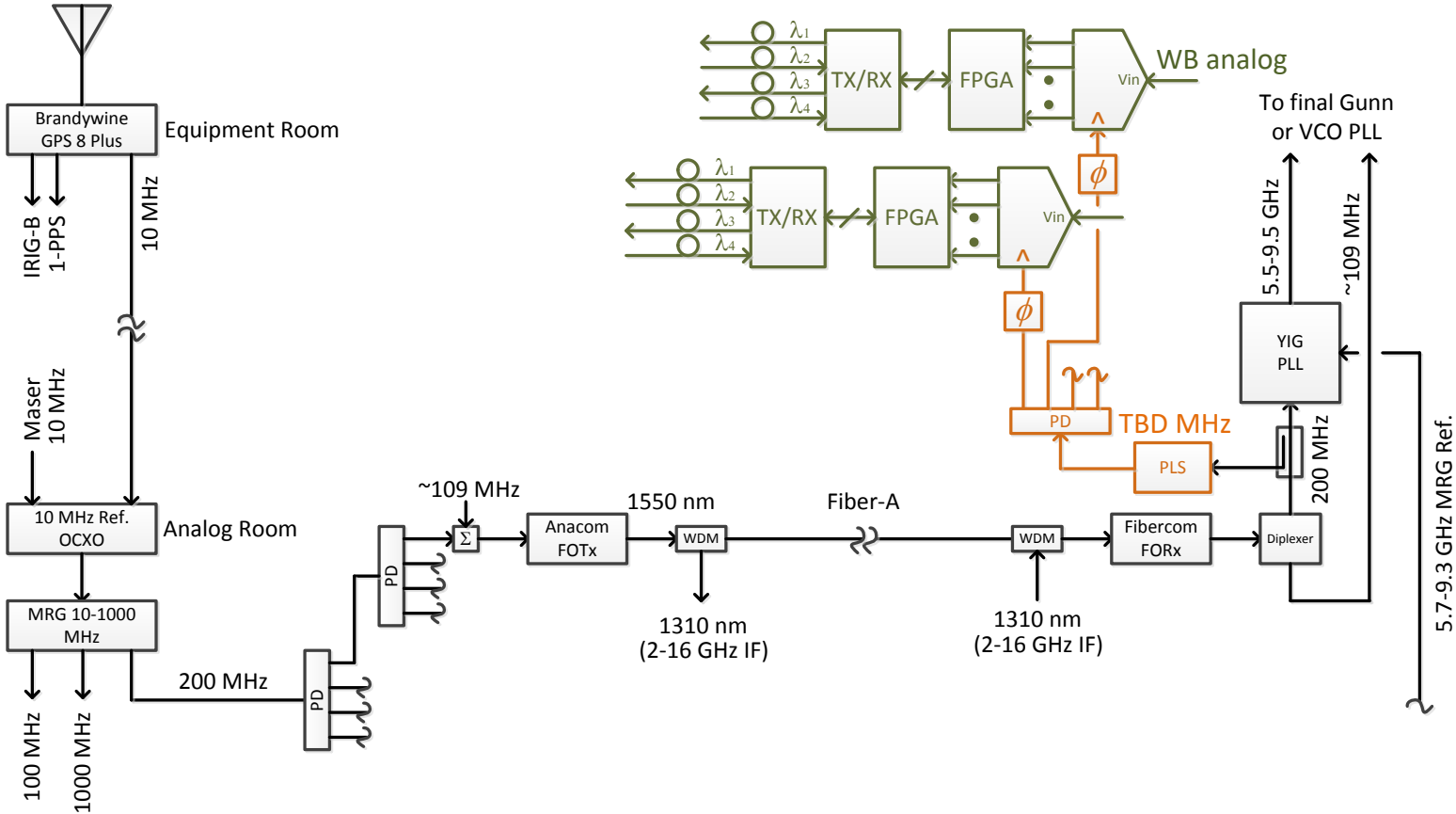
	Digitizing in the Correlator Room	
	Clock Performance	Comments
REFERENCE INPUT		
Frequency, MHz	10.0	Brandywine GPS spec
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec
Waveform type, sine or	Sine or Square	Input to Agilent N5173B
square	-	-
Input impedance	50 Ohms nominal	Input to Agilent N5173B
Input VSWR	Not Available	Input to Agilent N5173B
Coupling, AC or DC	AC	Input to Agilent N5173B
Amplitude, dBm	5 +/- 2	Input to Agilent N5173B
Duty cycle, %	50 +/- 1 (TBR)	Input to Agilent N5173B
Spurs, harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B
Spurs, non-harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B
Phase jitter, integrated from	< 81 (TBR)	< 2.9e-4 degrees rms
1 Hz to 1 MHz, fs rms	-	-
Phase stability, antenna to	Not Applicable	Only 1 reference
antenna, ps	-	-
CLOCK OUTPUT		
Frequency, MHz	2,288.0	Agilent N5173B
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec
Waveform type, sine or	Sine	Agilent N5173B
square	-	-
Output impedance	50 Ohms nominal	-
Output VSWR	1.5:1 (TBR)	Power divider spec
Coupling, AC or DC	AC	-
Amplitude, Vpp	1.0	4.0 dBm into ROACH-2
Duty cycle, %	50 +/- 1 (TBR)	-
Spurs, harmonic, dBc	-55	Agilent N5173B spec
Spurs, non-harmonic, dBc	-66	Agilent N5173B spec
Phase jitter, integrated from	170	0.14 degrees rms
1 Hz to 1 MHz, fs rms	-	-
Phase adjust increment	none	-
degrees	-	-
Phase stability, antenna to	< 5 ps	Calc'd from delta cable
antenna, ps	-	drift



SMA Sampling in the Receiver Cabin

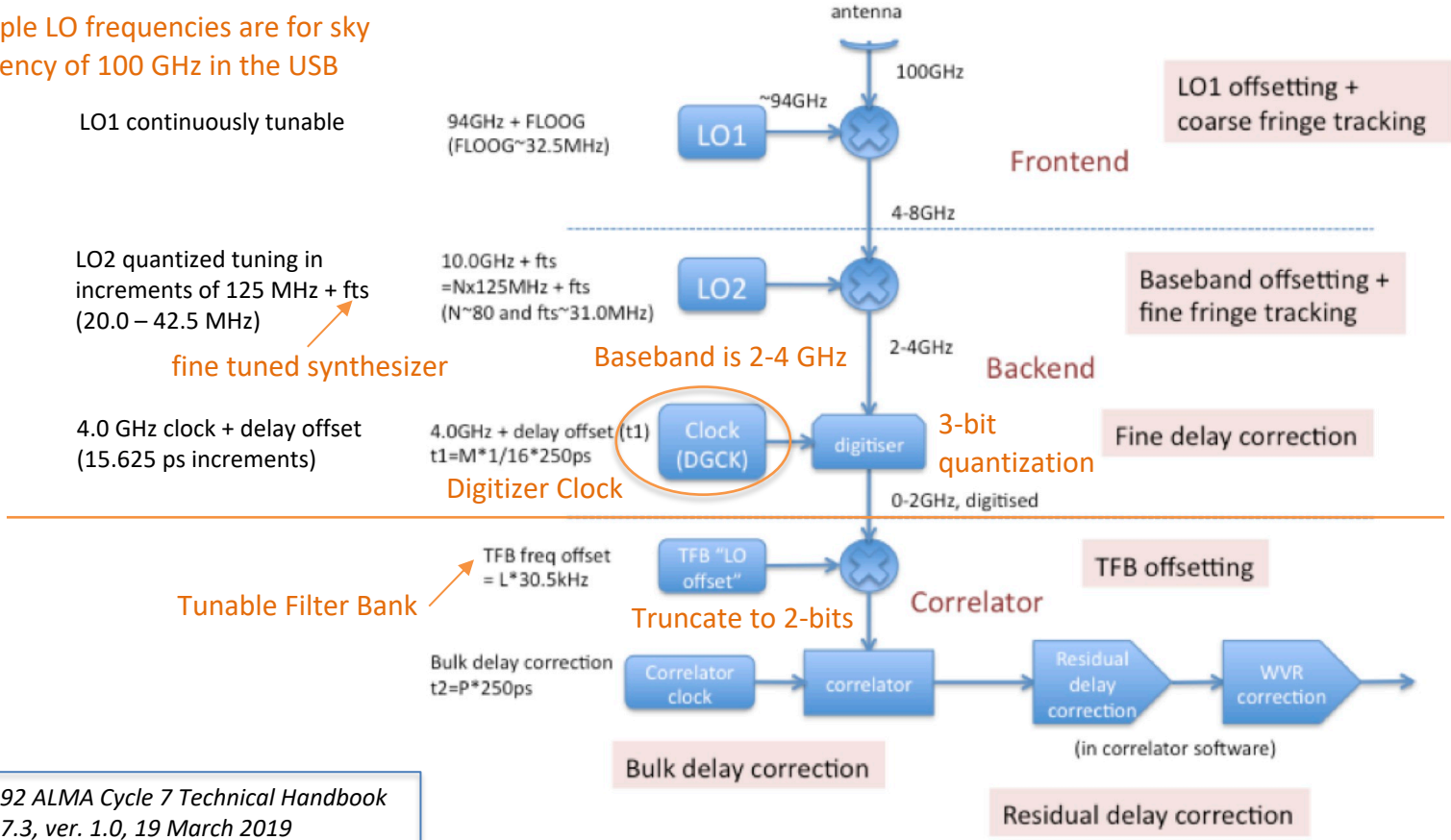


SMA Sampling in the Receiver Cabin (cont'd)



ALMA Summary of Operation

Example LO frequencies are for sky frequency of 100 GHz in the USB



Pg 192 ALMA Cycle 7 Technical Handbook
Doc 7.3, ver. 1.0, 19 March 2019

ALMA Digital Clock Assembly

Pg 199 ALMA Cycle 7 Technical Handbook
Doc 7.3, ver. 1.0, 19 March 2019

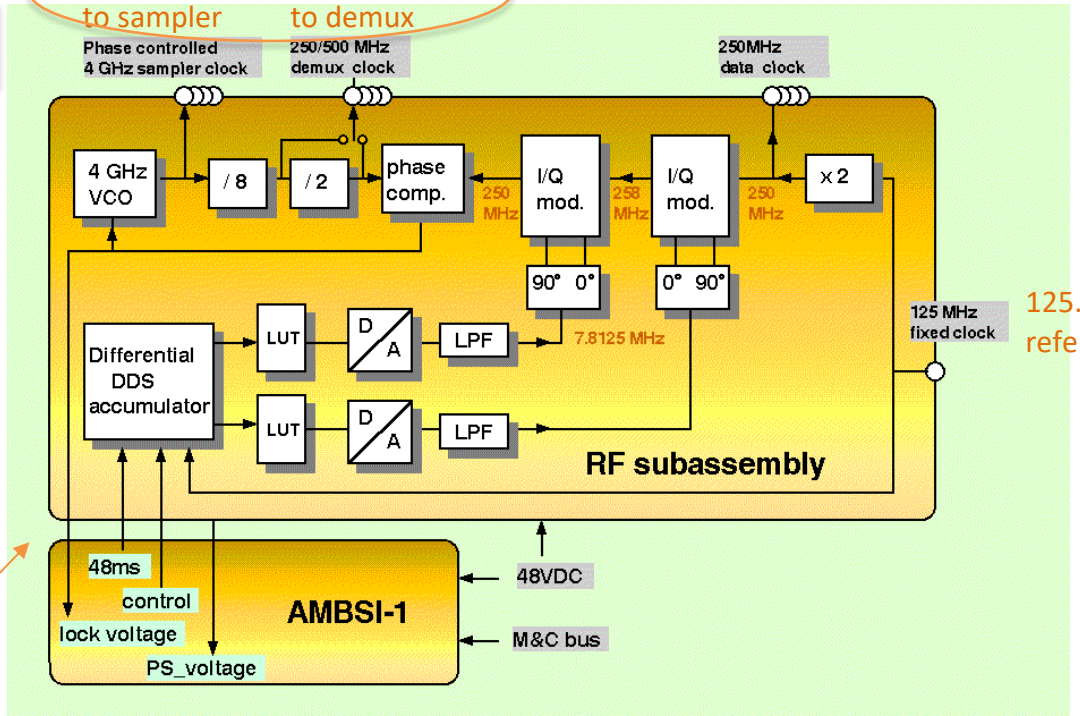
Fine delay corrections are handled by the DGCK that feeds the corrections into the four DTS modules in each antenna. The delay correction resolution of the fine delay is 1/16 of the 4GHz ADC clock.

15.625 psec or 22.5 degree increments

Pg 9, ALMA Back End Digital Clock Assembly, BEND-53.04.00.01-006-A-DSN, 2006-10-12

4.0 GHz clock to sampler

250 MHz clock to demux



125.0 MHz reference clock

Figure 1 Functional block diagram of the DGCK

	SMA				ALMA (66 ANTENNAS)	
	Digitizing in the Correlator Room		Digitizing in the Receiver Cabin		Digitizing in the Receiver Cabin	
	Clock Performance	Comments	Clock Requirements	Comments	Clock Requirements	Comments
REFERENCE INPUT						
Frequency, MHz	10.0	Brandywine GPS spec	200.0	YIG PLL reference	125.0	-
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec	1.0E-06	Brandywine GPS	1.0E-06	ALMA GPS
Waveform type, sine or	Sine or Square	Input to Agilent N5173B	Sine	YIG PLL reference	Sine	Sine
square	-	-	-	-	-	-
Input impedance	50 Ohms nominal	Input to Agilent N5173B	50 Ohms nominal	Input to Clock PLL	50 Ohms nominal	Input to DGCK assy
Input VSWR	Not Available	Input to Agilent N5173B	</= 1.5:1 (TBR)	Input to Clock PLL	< 1.9:1	Input to DGCK assy
Coupling, AC or DC	AC	Input to Agilent N5173B	AC	Input to Clock PLL	AC	Input to DGCK assy
Amplitude, dBm	5 +/- 2	Input to Agilent N5173B	0 +/- 2 (TBR)	Input to Clock PLL	6 nominal	Input to DGCK assy
Duty cycle, %	50 +/- 1 (TBR)	Input to Agilent N5173B	50% +/- 1%	Input to Clock PLL	50 +/- 1 (TBR)	Input to DGCK assy
Spurs, harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B	< -30 (TBR)	Input to Clock PLL	TBD	Input to DGCK assy
Spurs, non-harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B	< -40 (TBR)	Input to Clock PLL	TBD	Input to DGCK assy
Phase jitter, integrated from	< 81 (TBR)	< 2.9e-4 degrees rms	TBD	Need to measure	TBD	-130 dBc @ 10 kHz
1 Hz to 1 MHz, fs rms	-	-	-	-	-	-
Phase stability, antenna to	Not Applicable	Only 1 reference	TBD	How to measure?	TBD	Stabilized by fiber LLC
antenna, ps	-	-	-	-	-	-
CLOCK OUTPUT						
Frequency, MHz	2,288.0	Agilent N5173B	TBD	-	4000.0	4 outputs
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec	1.0E-06	Brandywine GPS spec	1.0E-06	ALMA GPS
Waveform type, sine or	Sine	Agilent N5173B	Sine	-	Sine	-
square	-	-	-	-	-	-
Output impedance	50 Ohms nominal	-	50 Ohms nominal	-	50 Ohms nominal	-
Output VSWR	1.5:1 (TBR)	Power divider spec	< 1.6:1 (TBR)	-	< 1.5:1	-
Coupling, AC or DC	AC	-	AC	-	AC	-
Amplitude, Vpp	1.0	4.0 dBm into ROACH-2	TBD	-	0 +/- 1.5	-
Duty cycle, %	50 +/- 1 (TBR)	-	50 +/- 1 (TBR)	-	TBD	Not specified
Spurs, harmonic, dBc	-55	Agilent N5173B spec	< -30 (TBR)	-	< -25	-
Spurs, non-harmonic, dBc	-66	Agilent N5173B spec	< -40 (TBR)	-	< -65	-
Phase jitter, integrated from	170	0.14 degrees rms	TBD	-	TBD	-80 dBc @ 10 kHz
1 Hz to 1 MHz, fs rms	-	-	-	-	-	-
Phase adjust increment	none	-	TBD	-	22.5	Max 5 changes per 48
degrees	-	-	-	-	-	ms timing interval
Phase stability, antenna to	< 5 ps	Calc'd from delta cable	TBD	Dependent on 200 MHz	TBD	Stablilized by fiber LLC
antenna, ps	-	drift	-	stability		so probably small

References

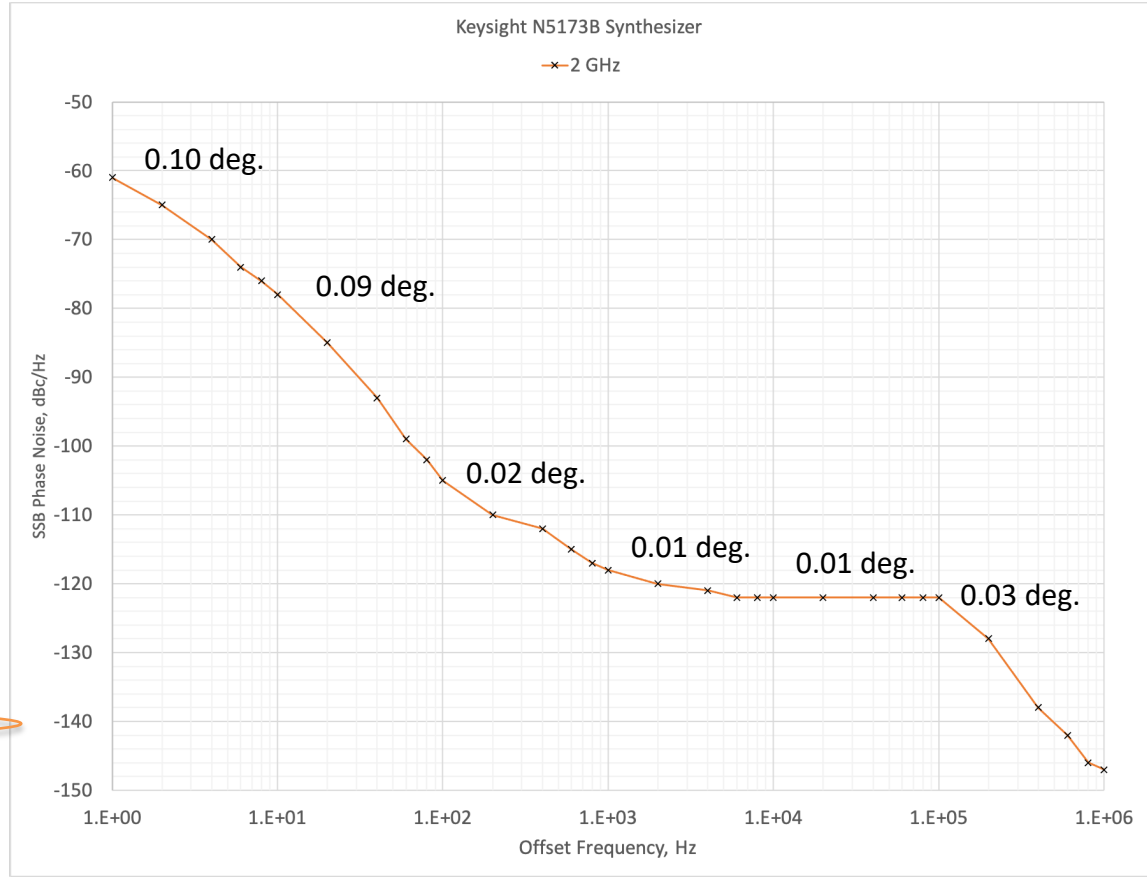
ALMA Cycle 7 Technical Handbook, 2019-03-19
https://almascience.nrao.edu/documents-and-tools/cycle7/alma-technical-handbook/view

ALMA Back End Digitizer Clock Assembly, Hardware Description, BEND-53.04.00.01-006-A-DSN, 2006-10-12
http://edm.alma.cl/forums/alma/dispatch.cgi/bedrr/showFile/101960/d20061116212255/No/2006-10-12BEND-53.04.00.01-006-A-DSN.pdf

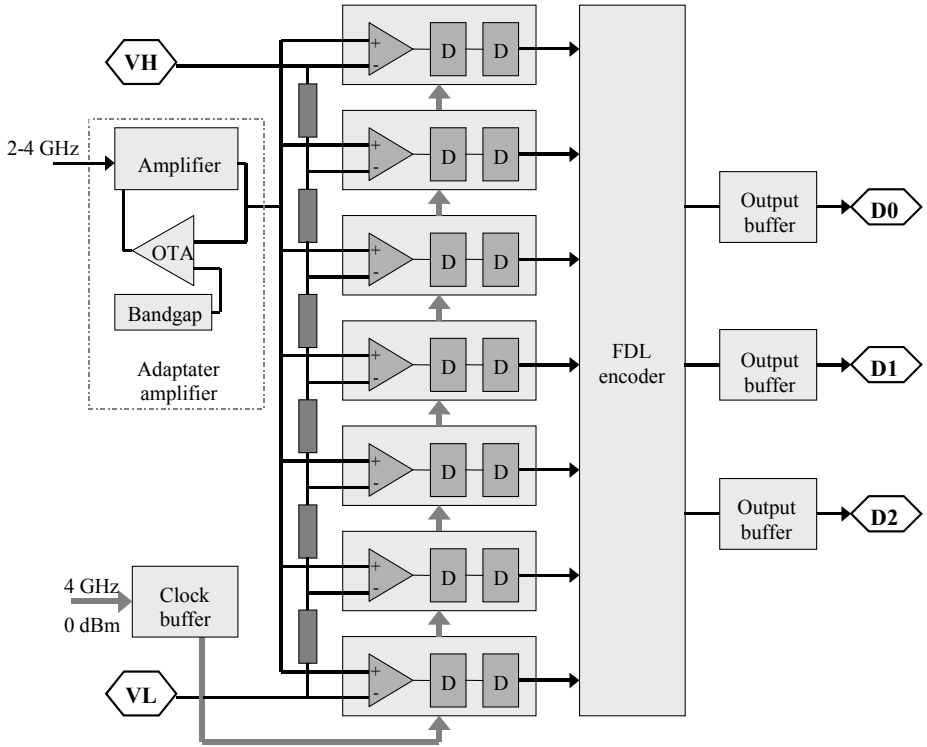
Extra Slides

Agilent N5173B Phase Noise at 2 GHz

	Digitizing in the Correlator Room	
	Clock Performance	Comments
REFERENCE INPUT		
Frequency, MHz	10.0	Brandywine GPS spec
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec
Waveform type, sine or	Sine or Square	Input to Agilent N5173B
square	-	-
Input impedance	50 Ohms nominal	Input to Agilent N5173B
Input VSWR	Not Available	Input to Agilent N5173B
Coupling, AC or DC	AC	Input to Agilent N5173B
Amplitude, Vpp (dBm)	5 +/- 2	Input to Agilent N5173B
Duty cycle, %	50 +/- 1 (TBR)	Input to Agilent N5173B
Spurs, harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B
Spurs, non-harmonic, dBc	< -40 (TBR)	Input to Agilent N5173B
Phase jitter, integrated from	< 80 (TBR)	< 2.9e-4 degrees rms
1 Hz to 1 MHz, fs rms	-	-
Phase stability, antenna to	Not Applicable	Only 1 reference
antenna, ps	-	-
CLOCK OUTPUT		
Frequency, MHz	2,288.0	Agilent N5173B output
Frequency accuracy, ppm	1.0E-06	Brandywine GPS spec
Waveform type, sine or	Sine	Agilent N5173B
square	-	-
Coupling, AC or DC	AC	-
Amplitude, Vpp	1.0	4.0 dBm into ROACH-2
Duty cycle, %	50 +/- 1 (TBR)	-
Spurs, harmonic, dBc	-55	Agilent N5173B spec
Spurs, non-harmonic, dBc	-66	Agilent N5173B spec
Phase jitter, integrated from	170	0.14 degrees rms
1 Hz to 1 MHz, fs rms	-	-
Phase adjustment, degrees	none	-
Phase stability, antenna to	< 5 ps	Calc'd from delta cable
antenna, ps	-	drift



Sampler Chip Block Diagram



Digitizer Sampler Chip Block Diagram
BEND-53.01.02.01-003-A-DWG, 2004-04-08

Data Transmission System Transmitter

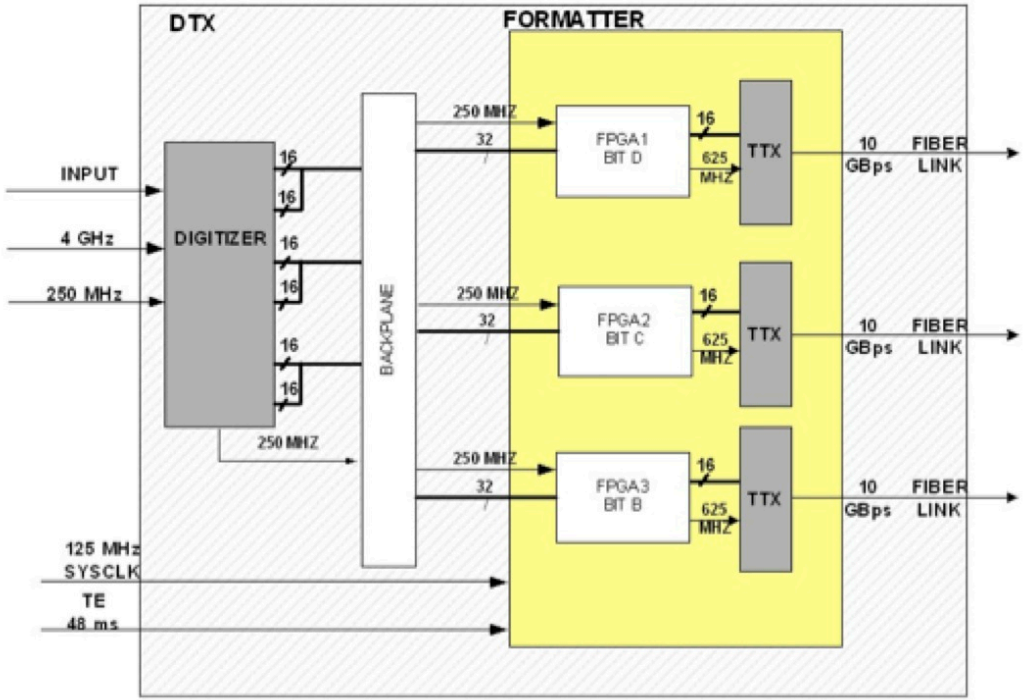


Figure B.8: The Data Transmission System Transmitter (DTX) module, as used in each antenna.

Pg 200 of ALMA Cycle 7 Technical Handbook
Doc 7.3, ver. 1.0, 19 March 2019

Recent developments in digitizer technology

Table from **Benjamin Quertier's** presentation at ESO workshop (June 2019)
Micram ADC2 loaned and tested at LAB at 40 GSps (beyond the data sheet)
Challenges: calibrating interleaving cores, spurious tones; specs still a niche market

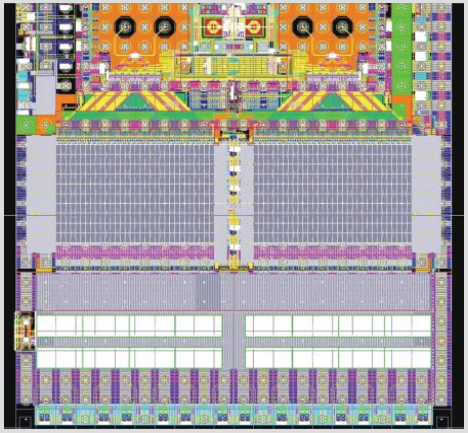
	HMCAD5831	ASNT7123	ADC2	AD6B40G	PMCC_56SAR
Company	Analog Device	Adsantec	Micram	Alphacore	Pacific µchip
Bandwidth	20GHz	16GHz	25GHz	20GHz	28GHz
Sampling Freq.	26GSps	16GSps	34GSps	40GSps	56GSps
Resolution	3 bits	4 bits	6 bits	6 bits	8 bits
Power	4.2W	4.3W	12W	TBD	0.5W
Architecture	single core	single core	2 cores	2 cores	64 cores
Output interface	6 lanes	4 lanes	24 lanes	24 lanes	64 lanes
Package	QFN	CQFP	Module	Chip-On-Board	BGA
Availability	Discontinued	Yes	Yes	2020	Q2 2020
Tested at LAB	Yes	Yes	Yes	Not yet	Not yet

T. Hunter, ALMA Front-end & Digitizer Tech Rqmts to Enable ALMA 2030 Development Roadmap

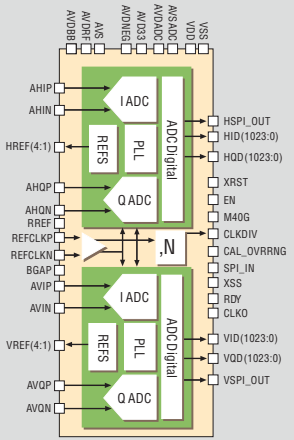
Smithsonian Receiver Lab Lunch Talk - March 10, 2021 9

56GSa/s 8-bit Analog-to-Digital Converter

8-bit quantization
Differential analog input, 1 Vpp full-scale
15 GHz -3 dB bandwidth (min.)
56 GSa/sec
1.75 GHz input clock reference
Internal 14 GHz VCO/PLL per I/Q ADC pair
SNDR 40 dB @ 1 GHz, 36 dB @ 17 GHz
Output rate – 128 samples x 8-bits, 437.5 MHz



56GSa/s ADC Two-Channel Version Using CHAIS Architecture



56GSa/s ADC Four-Channel Version

https://www.fujitsu.com/downloads/MICRO/fma/pdf/56G_ADC_FactSheet.pdf
https://www.fujitsu.com/downloads/MICRO/fma/pdf/56G_techback.pdf