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To: UVLBI/DBE groups
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 Subject: Tests of 16MHz DBE

Setup and Procedure:

Tests of the DBE firmware supporting 16MHz wide PFB channels were carried out. One of the goals was to test the compatibility of the DBE 16MHz mode with a VLBA4 backend. The basic setup is shown in Figure 1. The 1PPS signal, taken from the Haystack standards room, was of poor quality and exhibited a lot of ringing. It was cleaned up using the Sample Clock/1 PPS generation board in the DBE, and one of the outputs was sent to the VLBA4 rack. The station 5MHz was input to the VLBA4 rack and one output from the 5MHz distributor was sent to the DBE. The VSI outputs from the DBE were connected to Mark5B+ units, and the VLBA4 recorded on a Mark5A.

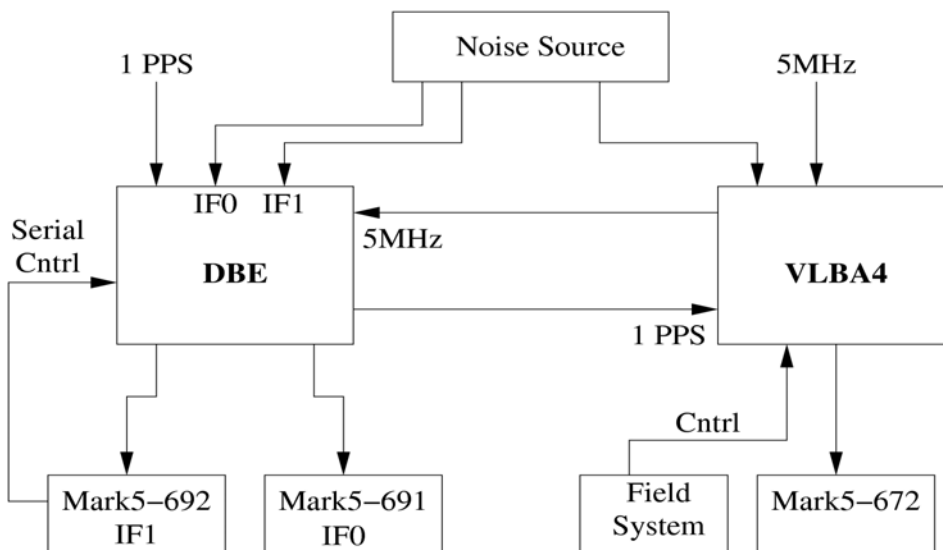


Fig 1: Test setup for VLBA4 - DBE compatibility with 16MHz channels.

The Noise Source setup is shown in Figure 2. The power levels presented to the DBE IF0 and IF1 inputs were -13dBm as calculated from measurements of the bandpass on a spectrum analyzer. Each bandpass was flat to within a few dB. The DBE 1024MHz sample clock is synthesized from the input 5MHz, placing the input noise signal in the 2nd Nyquist zone. The frequency sequence and mapping of DBE channels to VLBA4 Base Band Converters is shown in Figure 3. BBC01 was set to 792.00MHz and BBC14 was set to 1000.00MHz. The Mark4 formatter sampled the LSB of each BBC to match the effective LSB of all the DBE channels.

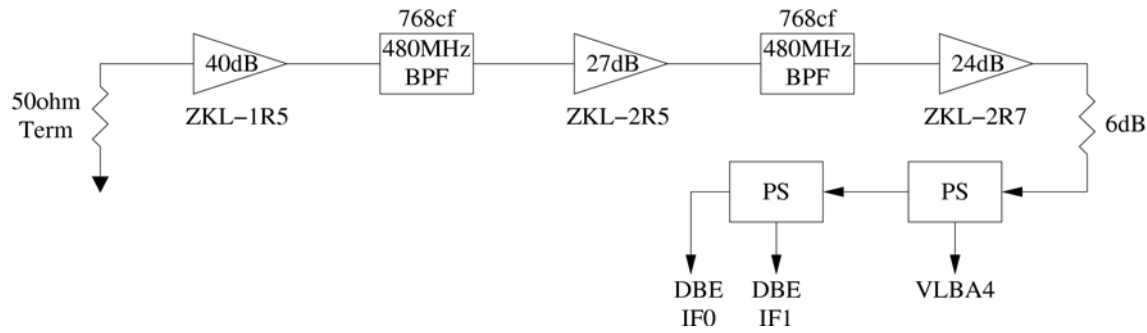


Figure 2: Setup for generating band limited noise for the DBE - VLBA4 test. Power levels presented to the DBE inputs were -13dBm over the 480MHz band.

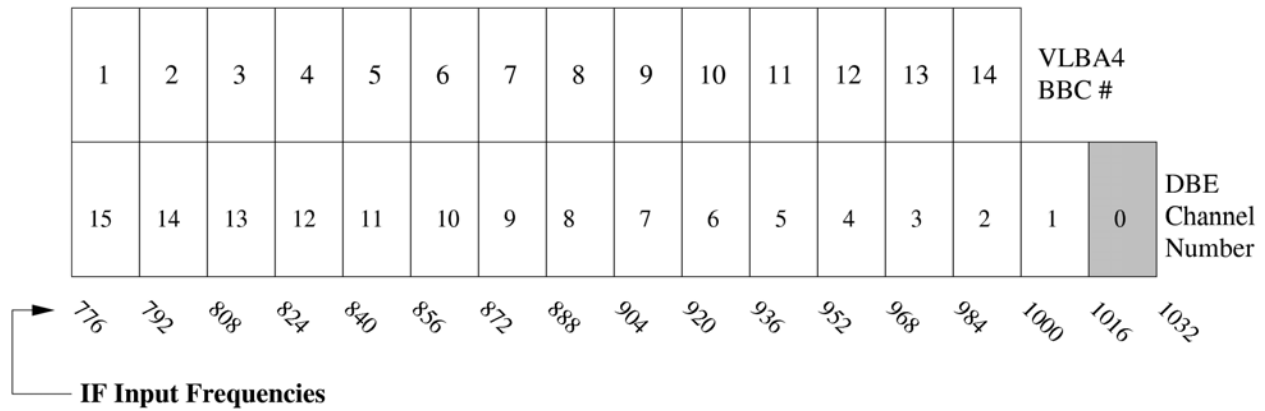


Fig 3: Frequency setup for the DBE - VLBA4 test. The DBE sampled in the 2nd Nyquist zone, resulting in an LSB conversion, so the Mark4 formatter was configured to sample the LSB of the VLBA4 BBC's. Note that DBE channel 0 is bad due to aliasing.

The experiment was recorded with 2-bit sampling, and the VLBA4 rack used Automatic Gain Control to optimize the state counts. The DBE had a single iBOB board, which was used to process both copies of the input IF. Short recordings for each IF were made and corrections to the DBE digital gains determined and applied to optimize the 2-bit state counts. Recordings were made for ~40 seconds on all three recording systems with start times within about 3 seconds of each other. The data were processed on the Mark4 correlator. DBE(IF0) was given the station name HHT, DBE(IF1) is HHT2, and the VLBA4 units is the PICOVEL station.

Results:

The basic results are given in the attached fringe plots (Figs 4-6 are auto correlations and Figs 7-9 are cross correlations). A-priori, one would expect that the auto correlations would have amplitudes very close to 10,000 and have zero phase. One would also expect that when the two DBE channels are correlated against each other the amplitude would similarly be close to 10,000, but with a delay offset due to unequal cable delays. We note here a few characteristics of the fringe plots that contrast with these expectations, and which merit further investigation.

1. The HHT2-HHT2 auto correlation has rms phase variation between frequency channels of 0.9 degrees, which is much higher than one would expect given the $\text{snr}=105331$. This could be due to varying state counts in each channel, but this is probably not likely given that the sampler statistics appear to be set very close to their optimal levels.
2. All three auto correlations have non-zero phase (HHT-HHT=-1.3 degrees, HHT2-HHT2=6.4 degrees, PICO-PICO=1.7 degrees).

3. On the HHT-HHT2 cross correlation, the amplitude is ~8500, 15% less than the expected 10,000.
4. On the HHT-HHT2 cross correlation, there also appears to be a dip in the phase across the full bandpass. Channel 'a' is -136.7 degrees, while channel 'h' near the middle of the band is -142.5 degrees, and at the far end of the band, channel 'n' is back up to -131.6 degrees. Such a variation in phase could possibly be due to crosstalk between the two DBE IF DSP pipelines, or crosstalk in the ADC board. This could be tested by repeating the experiment using separate iBOB boards for each IF. Alternatively, at such high correlation coefficients, quantization errors could cause errors in both amplitude and phase if not corrected for. Since there is no fringe rate a fixed phase offset in a given frequency channel can result in a constant loss due to quantization error.
5. Part of the reason for the low HHT-HHT2 amplitude is due to the fact that 'fourfit' normalizes auto and cross correlations differently. When the HHT station data is copied to another disk module and HHT is correlated against HHT but in cross correlation mode, the amplitude is also lower than expected (~9050). Figs 10-12 show this test in which the stations labeled HHT and HHT2 are both actually copies of data from HHT (DBE IF0).
6. On the VLBA4-DBE cross correlations there is a phase signature across the single bands that results in an asymmetric single-band delay function. This is probably either due to VLBA BBC filters, or a "bit-slip" type problem in the station units of the Mark4 correlator.

Next Experiments:

To investigate further, a few tests are planned:

1. Introduce an LO offset by slightly changing the frequency reference input to the two DBE's. This can be done by sending 10MHz to one and 10MHz + 0.1Hz to the other. This will produce a fringe rate that will average out the effects of quantization error.
2. The 'fourfit' code will be examined to find the reason for non-zero phases and non-zero delays for auto correlations.

NRAO150.szthru, 219-2015_rev, II
HHT2 - HHT2, fgrou p C, pol LL

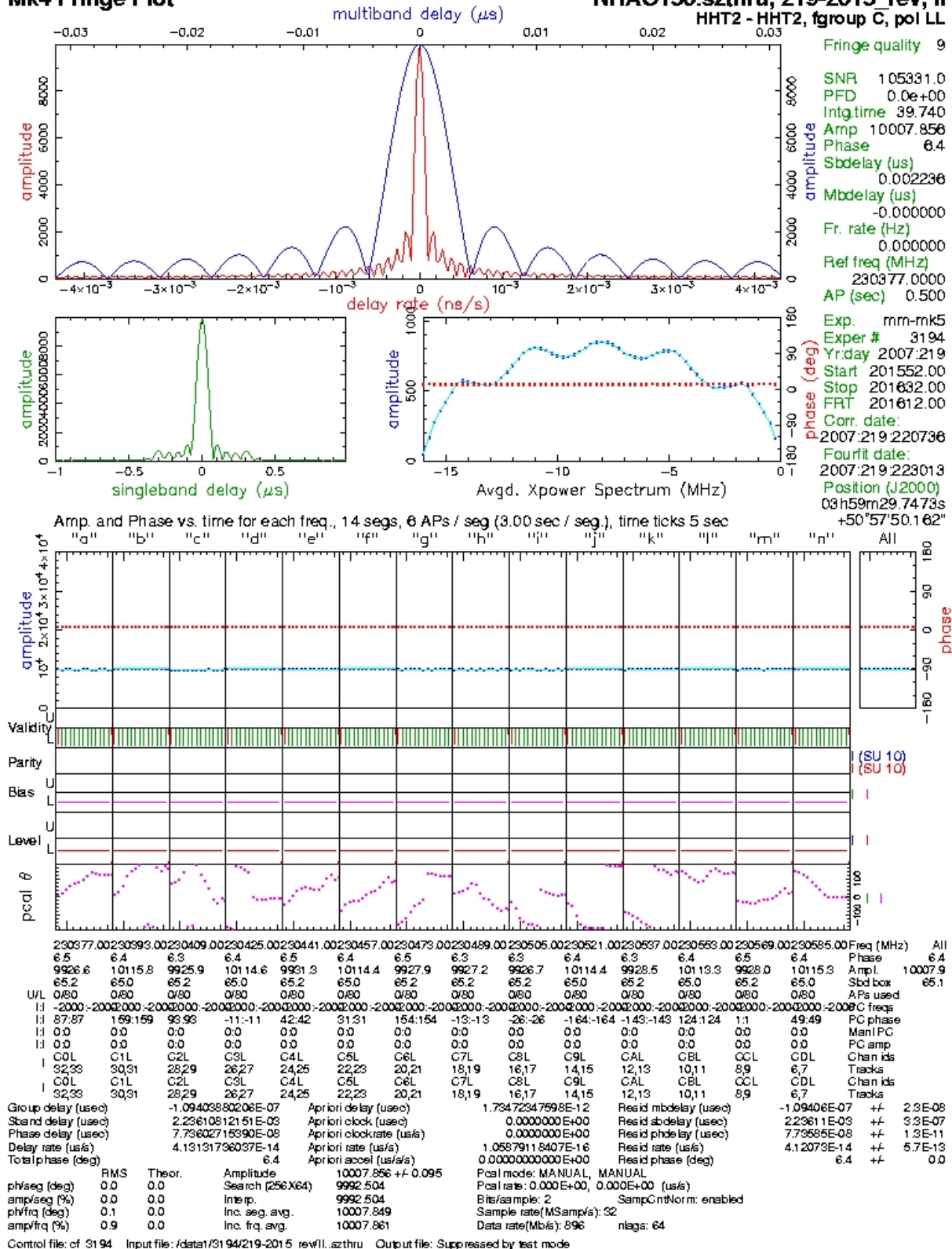


Fig 5 Autocorrelation of DBE IF1

NRA0150.szthru, 219-2015 rev, PP

PICOVEL - PICOVEL, fgroup C, pol LL

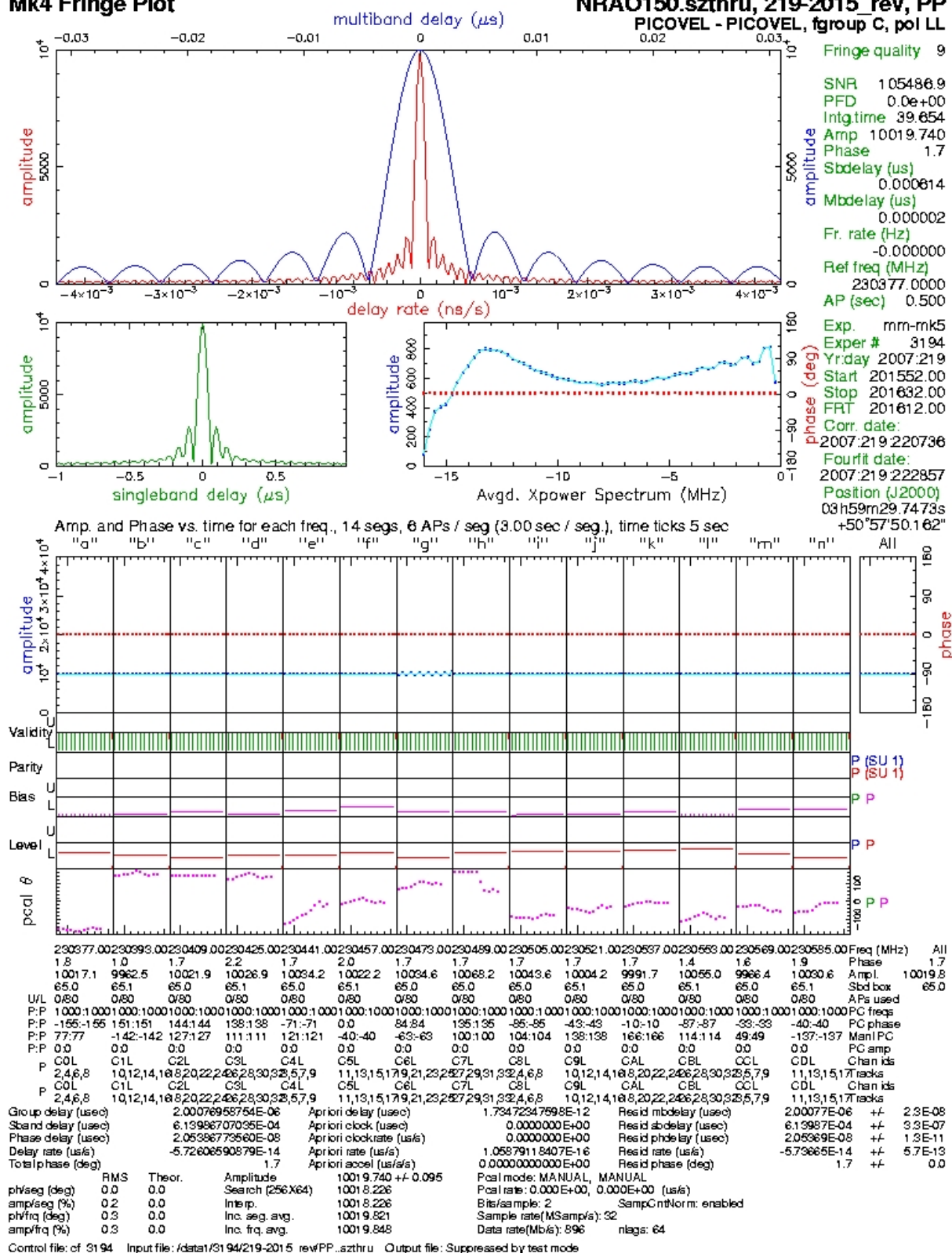
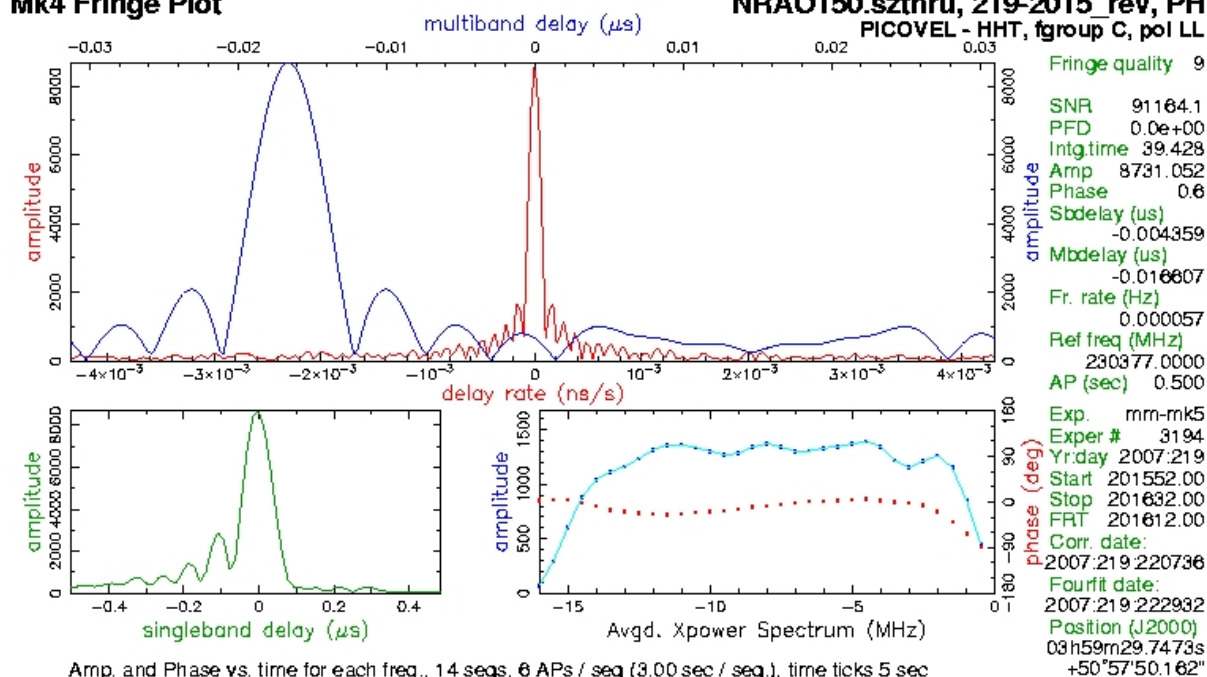


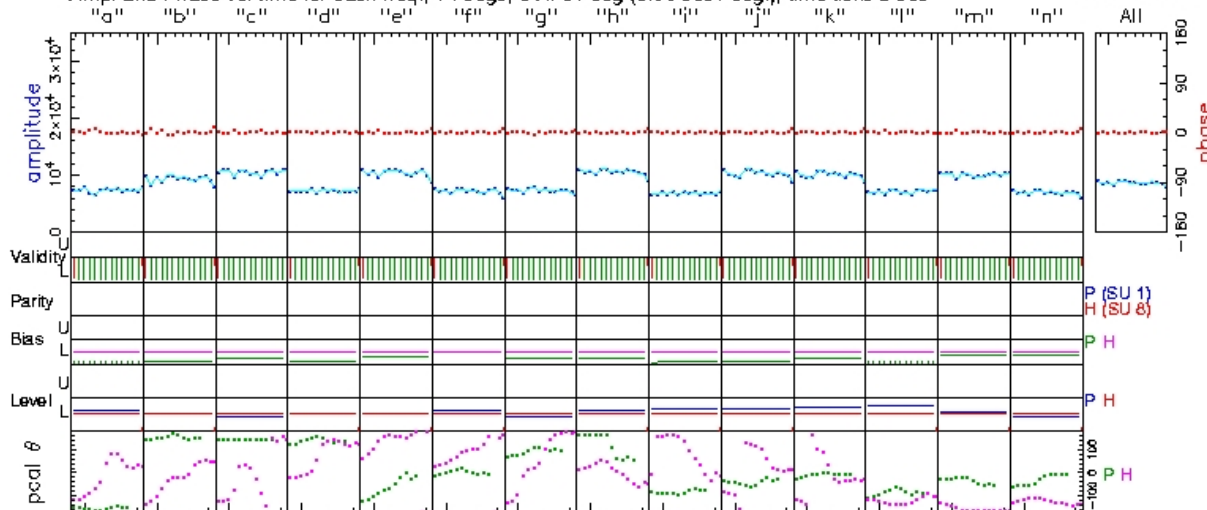
Fig 6 Autocorrelation of VLBA4 recording.

NRAO150.szthru, 219-2015 rev, PH

PICOVEL - HHT, fgroup C, pol LL



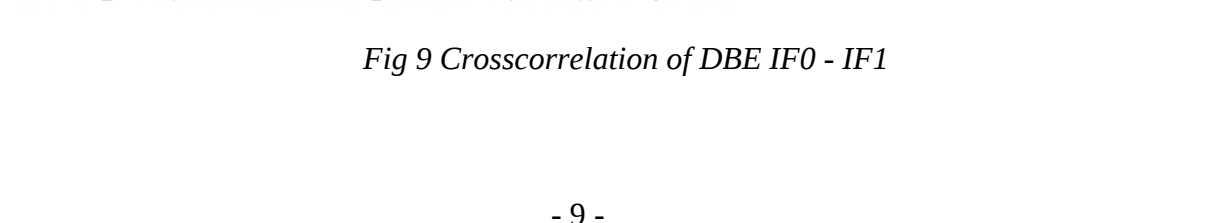
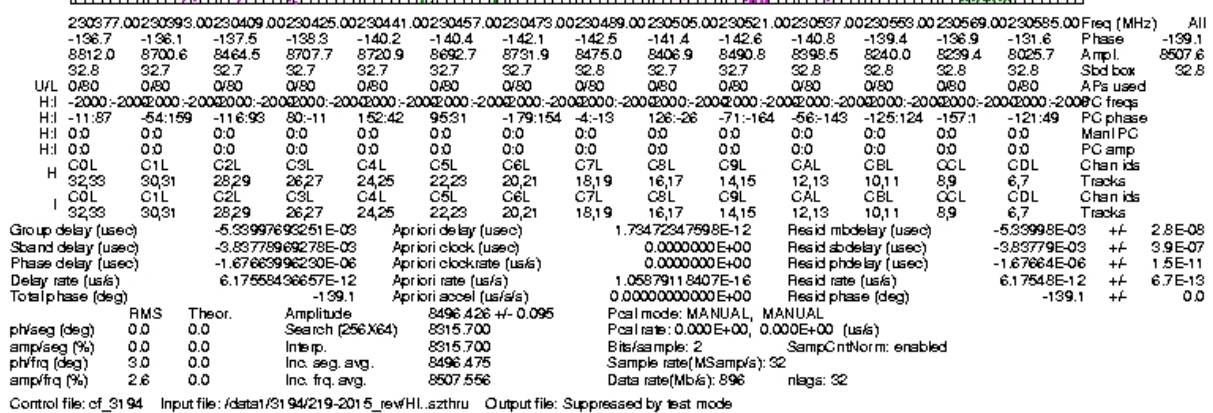
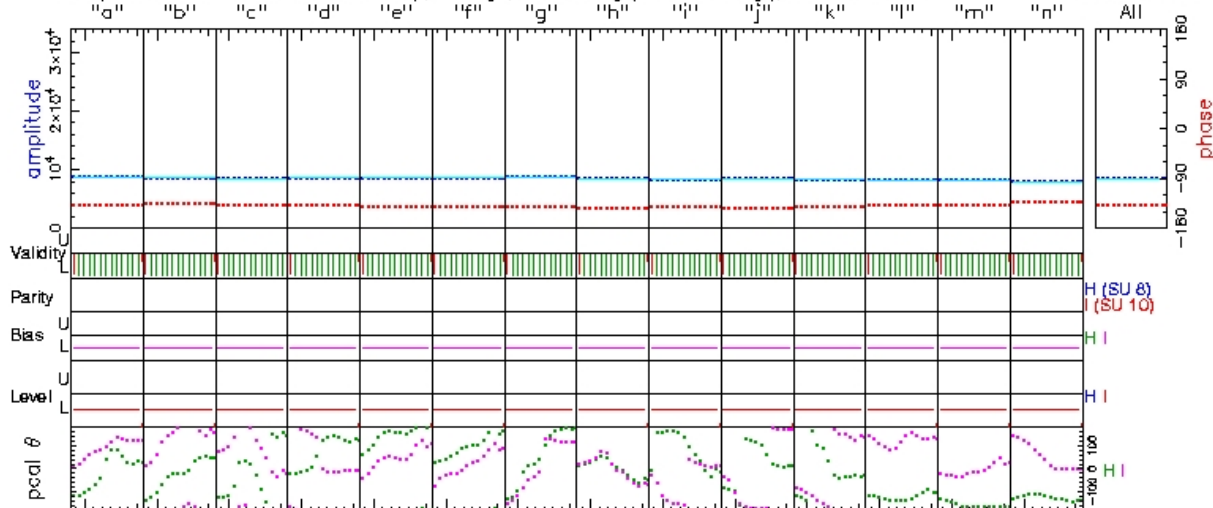
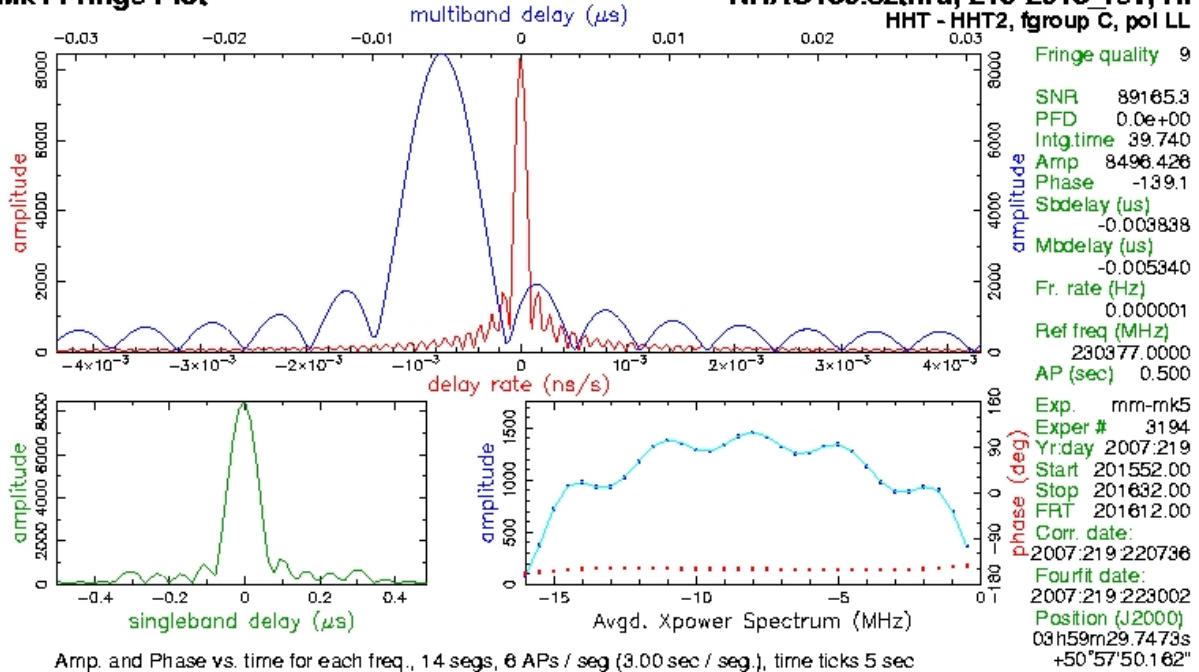
Amp. and Phase vs. time for each freq., 14 seqs, 6 APs / seq (3.00 sec / seq.), time ticks 5 sec



230377.00230993.00230409.00230425.00230441.00230457.00230473.00230489.00230505.00230521.00230537.00230553.00230569.00230585.00															Freq (MHz)	All													
	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	Phase	8731.1												
	75793.5	9417.7	10587.0	7287.2	15053.4	7256.1	7359.8	10669.8	6561.1	10990.3	10181.0	7174.7	10418.2	7034.4	Ampl.	8731.1													
	32.7	33.5	33.0	32.7	32.6	32.0	32.5	33.1	32.0	32.5	32.8	32.4	33.1	32.4	Sbd box	32.7													
U/L	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	0/80	APs used														
P/H	1000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	-2000	P C frags													
P-H	-155	-11	151	-54	144	-116	138	-80	-171	-152	0.95	84	-179	135	-4	-85	-126	-43	-71	-10	-56	-87	-125	-33	-157	-40	-121	PC phase	
P-H	-77	-11	-142	-10	127	0	111	0	121	-10	-43	0	100	0	104	0	138	0	166	0	114	0	49	0	-137	0	ManI PC		
P-H	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	PC amp	
P	C0L	C1L	C0L	C2L	C9L	C4L	C5L	C6L	C7L	C8L	C9L	CAL	CBL	CCL	CDL	Chan	kids												
	2,46,8	10,12,14,18	8,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,72,74,76,78,80,82,84,86,88,90,92,94,96,98,100	11,13,15,17,19,21,23,25,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55,57,59,61,63,65,67,69,71,73,75,77,79,81,83,85,87,89,91,93,95,97,99,101,103,105,107,109,111,113,115,117,119,121,123,125,127,129,131,133,135,137,139,141,143,145,147,149,151,153,155,157,159,161,163,165,167,169,171,173,175,177,179,181,183,185,187,189,191,193,195,197,199,201,203,205,207,209,211,213,215,217,219,221,223,225,227,229,231,233,235,237,239,241,243,245,247,249,251,253,255,257,259,261,263,265,267,269,271,273,275,277,279,281,283,285,287,289,291,293,295,297,299,301,303,305,307,309,311,313,315,317,319,321,323,325,327,329,331,333,335,337,339,341,343,345,347,349,351,353,355,357,359,361,363,365,367,369,371,373,375,377,379,381,383,385,387,389,391,393,395,397,399,401,403,405,407,409,411,413,415,417,419,421,423,425,427,429,431,433,435,437,439,441,443,445,447,449,451,453,455,457,459,461,463,465,467,469,471,473,475,477,479,481,483,485,487,489,491,493,495,497,499,501,503,505,507,509,511,513,515,517,519,521,523,525,527,529,531,533,535,537,539,541,543,545,547,549,551,553,555,557,559,561,563,565,567,569,571,573,575,577,579,581,583,585,587,589,591,593,595,597,599,601,603,605,607,609,611,613,615,617,619,621,623,625,627,629,631,633,635,637,639,641,643,645,647,649,651,653,655,657,659,661,663,665,667,669,671,673,675,677,679,681,683,685,687,689,691,693,695,697,699,701,703,705,707,709,711,713,715,717,719,721,723,725,727,729,731,733,735,737,739,741,743,745,747,749,751,753,755,757,759,761,763,765,767,769,771,773,775,777,779,781,783,785,787,789,791,793,795,797,799,801,803,805,807,809,811,813,815,817,819,821,823,825,827,829,831,833,835,837,839,841,843,845,847,849,851,853,855,857,859,861,863,865,867,869,871,873,875,877,879,881,883,885,887,889,891,893,895,897,899,901,903,905,907,909,911,913,915,917,919,921,923,925,927,929,931,933,935,937,939,941,943,945,947,949,951,953,955,957,959,961,963,965,967,969,971,973,975,977,979,981,983,985,987,989,991,993,995,997,999,1001,1003,1005,																									

Fig 7 Cross correlation VLBA4-IF0

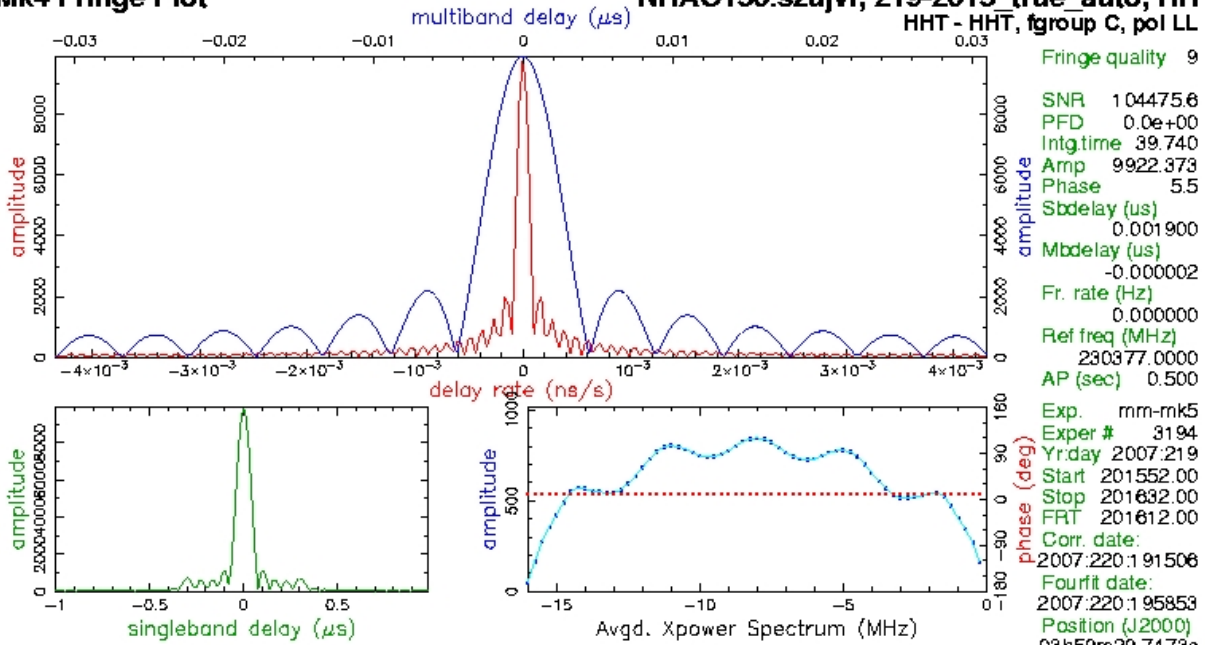
NRAO150.szthru, 219-2015_rev, HI
HHT - HHT2, fgroup C, pol LL



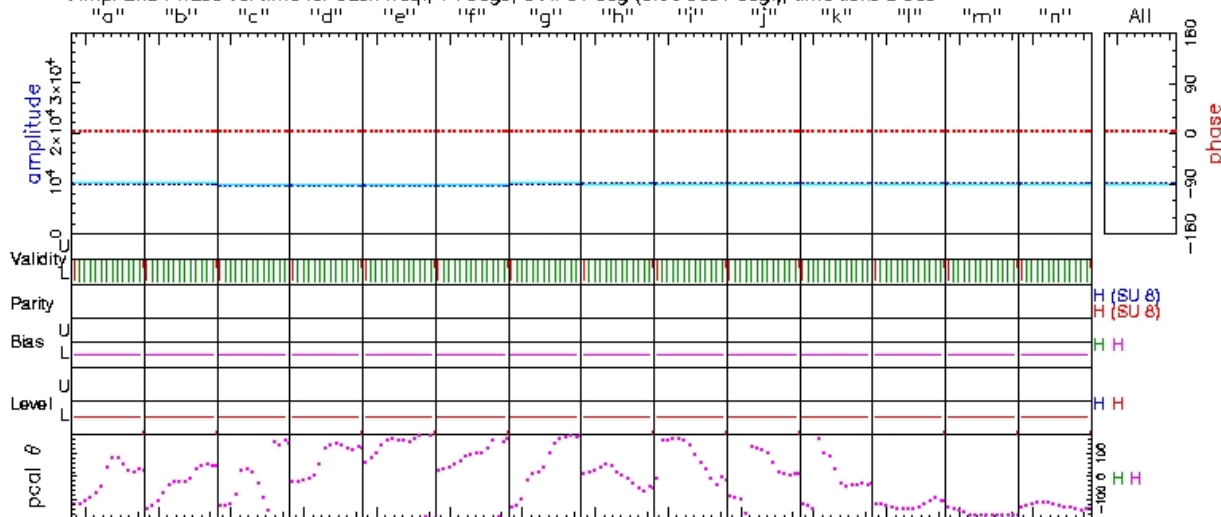
Mk4 Fringe Plot

NRAO150.szujvf, 219-2015 true_auto, HH

HHT - HHT, tgroup C, pol LL



Amp. and Phase vs. time for each freq., 14 segs, 6 APs / seg (3.00 sec / seg.), time ticks 5 sec



230377.00230393.00		230409.00230425.00		230441.00230457.00		230473.00230489.00		230505.00230521.00		230537.00230553.00		230569.00230585.00		230601.00230617.00		230633.00230649.00		230665.00230681.00		230697.00230713.00		230729.00230745.00		230761.00230777.00		230793.00230809.00		230825.00230841.00		230857.00230873.00		230889.00230905.00		230921.00230937.00		230953.00230969.00		230985.00231001.00		231017.00231033.00		231049.00231065.00		231081.00231097.00		231113.00231129.00		231145.00231161.00		231177.00231193.00		231209.00231225.00		231241.00231257.00		231273.00231289.00		231305.00231321.00		231337.00231353.00		231369.00231385.00		231401.00231417.00		231433.00231449.00		231465.00231481.00		231497.00231513.00		231529.00231545.00		231561.00231577.00		231593.00231609.00		231625.00231641.00		231657.00231673.00		231689.00231705.00		231721.00231737.00		231753.00231769.00		231785.00231801.00		231817.00231833.00		231849.00231865.00		231881.00231897.00		231913.00231929.00		231945.00231961.00		231977.00231993.00		232009.00232025.00		232041.00232057.00		232073.00232089.00		232105.00232121.00		232137.00232153.00		232169.00232185.00		232201.00232217.00		232233.00232249.00		232265.00232281.00		232297.00232313.00		232329.00232345.00		232361.00232377.00		232393.00232409.00		232425.00232441.00		232457.00232473.00		232489.00232505.00		232521.00232537.00		232553.00232569.00		232585.00232601.00		232617.00232633.00		232649.00232665.00		232681.00232697.00		232713.00232729.00		232745.00232761.00		232777.00232793.00		232809.00232825.00		232841.00232857.00		232873.00232889.00		232905.00232921.00		232937.00232953.00		232969.00232985.00		233001.00233017.00		233033.00233049.00		233065.00233081.00		233097.00233113.00		233129.00233145.00		233161.00233177.00		233193.00233209.00		233225.00233241.00		233257.00233273.00		233289.00233305.00		233321.00233337.00		233353.00233369.00		233385.00233401.00		233417.00233433.00		233449.00233465.00		233481.00233497.00		233513.00233529.00		233545.00233561.00		233577.00233593.00		233609.00233625.00		233641.00233657.00		233673.00233689.00		233705.00233721.00		233737.00233753.00		233769.00233785.00		233801.00233817.00		233833.00233849.00		233865.00233881.00		233897.00233913.00		233929.00233945.00		233961.00233977.00		233993.00240009.00		240025.00240041.00		240057.00240073.00		240089.00240105.00		240121.00240137.00		240153.00240169.00		240185.00240201.00		240217.00240233.00		240249.00240265.00		240281.00240297.00		240313.00240329.00		240345.00240361.00		240377.00240393.00		240409.00240425.00		240441.00240457.00		240473.00240489.00		240505.00240521.00		240537.00240553.00		240569.00240585.00		240601.00240617.00		240633.00240649.00		240665.00240681.00		240697.00240713.00		240729.00240745.00		240761.00240777.00		240793.00240809.00		240825.00240841.00		240857.00240873.00		240889.00240905.00		240921.00240937.00		240953.00240969.00		240985.00241001.00		241017.00241033.00		241049.00241065.00		241081.00241097.00		241113.00241129.00		241145.00241161.00		241177.00241193.00		241209.00241225.00		241241.00241257.00		241273.00241289.00		241305.00241321.00		241337.00241353.00		241369.00241385.00		241401.00241417.00		241433.00241449.00		241465.00241481.00		241497.00241513.00		241529.00241545.00		241561.00241577.00		241593.00241609.00		241625.00241641.00		241657.00241673.00		241689.00241705.00		241721.00241737.00		241753.00241769.00		241785.00241801.00		241817.00241833.00		241849.00241865.00		241881.00241897.00		241913.00241929.00		241945.00241961.00		241977.00241993.00		242009.00242025.00		242041.00242057.00		242073.00242089.00		242105.00242121.00		242137.00242153.00		242169.00242185.00		242201.00242217.00		242233.00242249.00		242265.00242281.00		242297.00242313.00		242329.00242345.00		242361.00242377.00		242393.00242409.00		242425.00242441.00		242457.00242473.00		242489.00242505.00		242521.00242537.00		242553.00242569.00		242585.00242601.00		242617.00242633.00		242649.00242665.00		242681.00242697.00		242713.00242729.00		242745.00242761.00		242777.00242793.00		242809.00242825.00		242841.00242857.00		242873.00242889.00		242905.00242921.00		242937.00242953.00		242969.00242985.00		243001.00243017.00		243033.00243049.00		243065.00243081.00		243097.00243113.00		243129.00243145.00		243161.00243177.00		243193.00243209.00		243225.00243241.00		243257.00243273.00		243289.00243305.00		243321.00243337.00		243353.00243369.00		243385.00243401.00		243417.00243433.00		243449.00243465.00		243481.00243497.00		243513.00243529.00		243545.00243561.00		243577.00243593.00		243609.00243625.00		243641.00243657.00		243673.00243689.00		243705.00243721.00		243737.00243753.00		243769.00243785.00		243801.00243817.00		243833.00243849.00		243865.00243881.00		243897.00243913.00		243929.00243945.00		243961.00243977.00		243993.00244009.00		244025.00244041.00		244057.00244073.00		244089.00244105.00		244121.00244137.00		244153.00244169.00		244185.00244201.00		244217.00244233.00		244249.00244265.00		244281.00244297.00		244313.00244329.00		244345.00244361.00		244377.00244393.00		244409.00244425.00		244441.00244457.00		244473.00244489.00		244505.00244521.00		244537.00244553.00		244569.00244585.00		244601.00244617.00		244633.00244649.00		244665.00244681.00		244697.00244713.00		244729.00244745.00		244761.00244777.00		244793.00244809.00		244825.00244841.00		244857.00244873.00		244889.00244905.00		244921.00244937.00		244953.00244969.00		244985.00245001.00		245017.00245033.00		245049.00245065.00		245081.00245097.00		245113.00245129.00		245145.00245161.00		245177.00245193.00		245209.00245225.00		245241.00245257.00		245273.00245289.00		245305.00245321.00		245337.00245353.00		245369.00245385.00		245401.00245417.00		245433.00245449.00		245465.00245481.00		245497.00245513.00		245529.00245545.00		245561.00245577.00		245593.00245609.00		245625.00245641.00		245657.00245673.00		245689.00245705.00		245721.00245737.00		245753.00245769.00		245785.00245801.00		245817.00245833.00		245849.00245865.00		245881.00245897.00		245913.00245929.00		245945.00245961.00		245977.00245993.00		246009.00246025.00		246041.00246057.00		246073.00246089.00		246105.00246121.00		246137.00246153.00		246169.00246185.00		246201.00246217.00		246233.00246249.00		246265.00246281.00		246297.00246313.00		246329.00246345.00		246361.00246377.00		246393.00246409.00		246425.00246441.00		246457.00246473.00		246489.00246505.00		246521.00246537.00		246553.00246569.00		246585.00246601.00		246617.00246633.00		246649.00246665.00		246681.00246697.00		246713.00246729.00		246745.00246761.00		246777.00246793.00		246809.00246825.00		246841.00246857.00		246873.00246889.00		246905.00246921.00		246937.00246953.00		246969.00246985.00		247001.00247017.00		247033.00247049.00		247065.00247081.00		247097.00247113.00		247129.00247145.00		247161.00247177.00		247193.00247209.00		247225.00247241.00		247257.00247273.00		247289.00247305.00		247321.00247337.00		247353.00247369.00		247385.00247401.00		247417.00247433.00		247449.00247465.00		247481.00247497.00		247513.00247529.00		247545.00247561.00		247577.00247593.00		247609.00247625.00		247641.00247657.00		247673.00247689.00		247705.00247721.00		247737.00247753.00		247769.00247785.00		247801.00247817.00		247833.00247849.00		247865.00247881.00		247897.00247913.00		247929.00247945.00		247961.00247977.00		247993.00248009.00		248025.00248041.00		248057.00248073.00		248089.00248105.00		248121.00248137.00		248153.00248169.00		248185.00248201.00		248217.00248233.00		248249.00248265.00		248281.00248297.00		248313.00248329.00		248345.00248361.00		248377.00248393.00		248409.00248425.00		248441.00248457.00		248473.00248489.00		248505.00248521.00		248537.00248553.00		248569.00248585.00		248601.00248617.00		248633.00248649.00		248665.00248681.00		248697.00248713.00		248729.00248745.00		248761.00248777.00		248793.00248809.00		248825.00248841.00		248857.00248873.00		248889.00248905.00		248921.00248937.00		248953.00248969.00		248985.00249001.00		249017.00249033.00		249049.00249065.00		249081.00249097.00		249113.00249129.00		249145.00249161.00		249177.00249193.00		249209.00249225.00		249241.00249257.00		249273.00249289.00		249305.00249321.00		249337.00249353.00		249369.00249385.00		249401.00249417.00		249433.00249449.00		249465.00249481.00		249497.00249513.00		249529.00249545.00		249561.00249577.00		249593.00249609.00		249625.00249641.00		249657.00249673.00		249689.00249705.00		249721.00249737.00		249753.00249769.00		249785.00249801.00		249817.00249833.00		249849.00249865.00		249881.00249897.00		249913.00249929.00		249945.00249961.00		249977.00249993.00		250009.00250025.00		250041.00250057.00		250073.00250089.00		250105.00250121.00		250137.00250153.00		250169.00250185.00		250201.00250217.00		250233.00250249.00		250265.00250281.00		250297.00250313.00		250329.00250345.00		250361.00250377.00		250393.00250409.00		250425.00250441.00		250457.00250473.00		250489.00250505.00		250521.00250537.00		250553.00250569.00		250585.00250601.00		250617.00250633.00		250649.00250665.00		250681.00250697.00		250713.00250729.00		250745.00250761.00		250777.00250793.00		250809.00250825.00		250841.00250857.00		250873.00250889.00		250905.00250921.00		250937.00250953.00		250969.00250985.00		251001.00251017.00		251033.00251049.00		251065.00251081.00		251097.00251113.00		251129.00251145.00		251161.00251177.00		251193.00251209.00		251225.00251241.00		251257.00251273.00		251289.00251305.00		251321.00251337.00		251353.00251369.00		251385.00251401.00		251417.00251433.00		251449.00251465.00		251481.00251497.00		251513.00251529.00		251545.00251561.00		251577.00251593.00	
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NRAO150.szujvf, 219-2015_true_auto, II
HHT2 - HHT2, fgroup C, pol LL

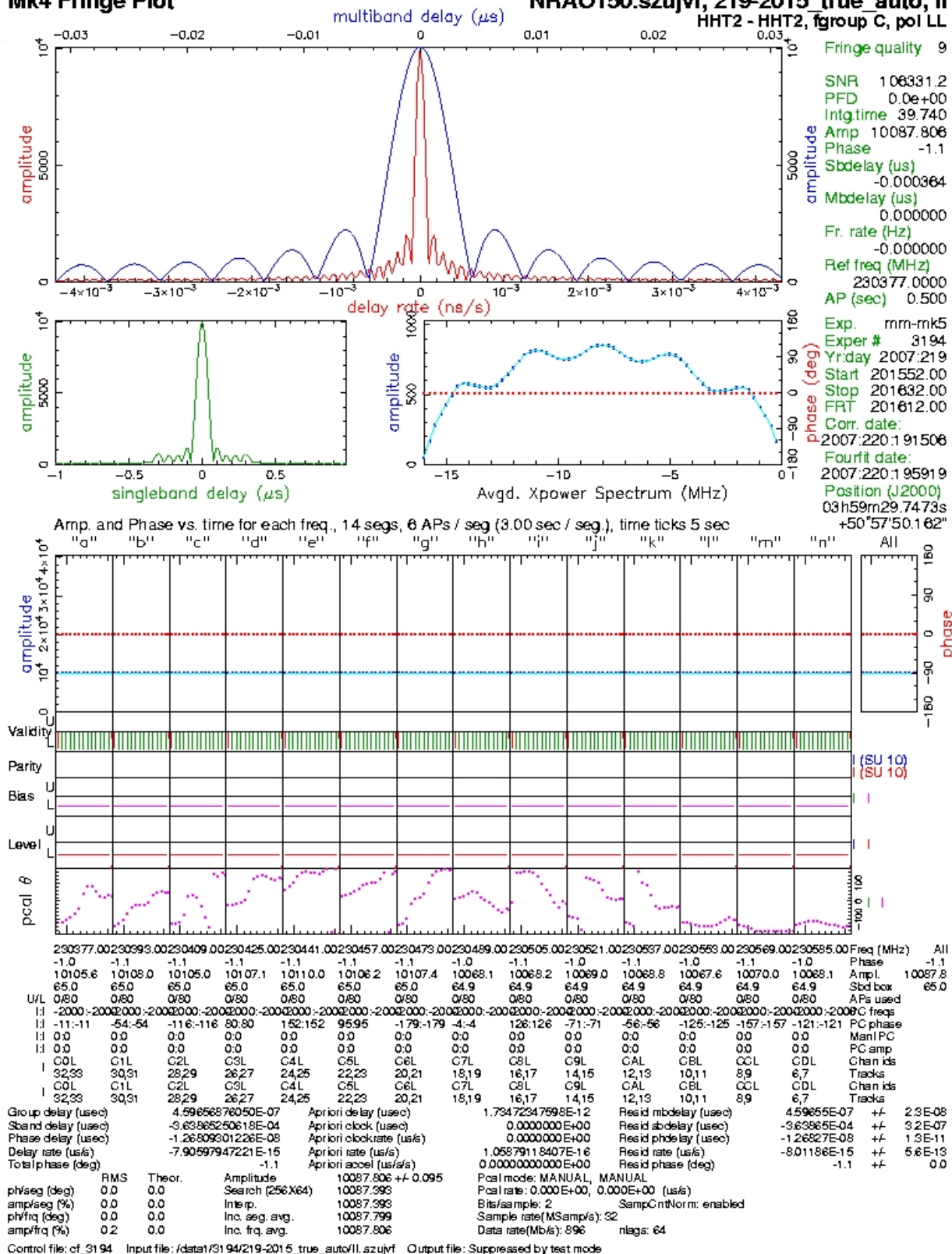


Fig 11: Auto correlation of DBE (IF0) using data copied to a separate file and renamed to station HHT2.

NRAO150.szujvf, 219-2015 true auto, HI

HHT - HHT2, fggroup C, pol LL

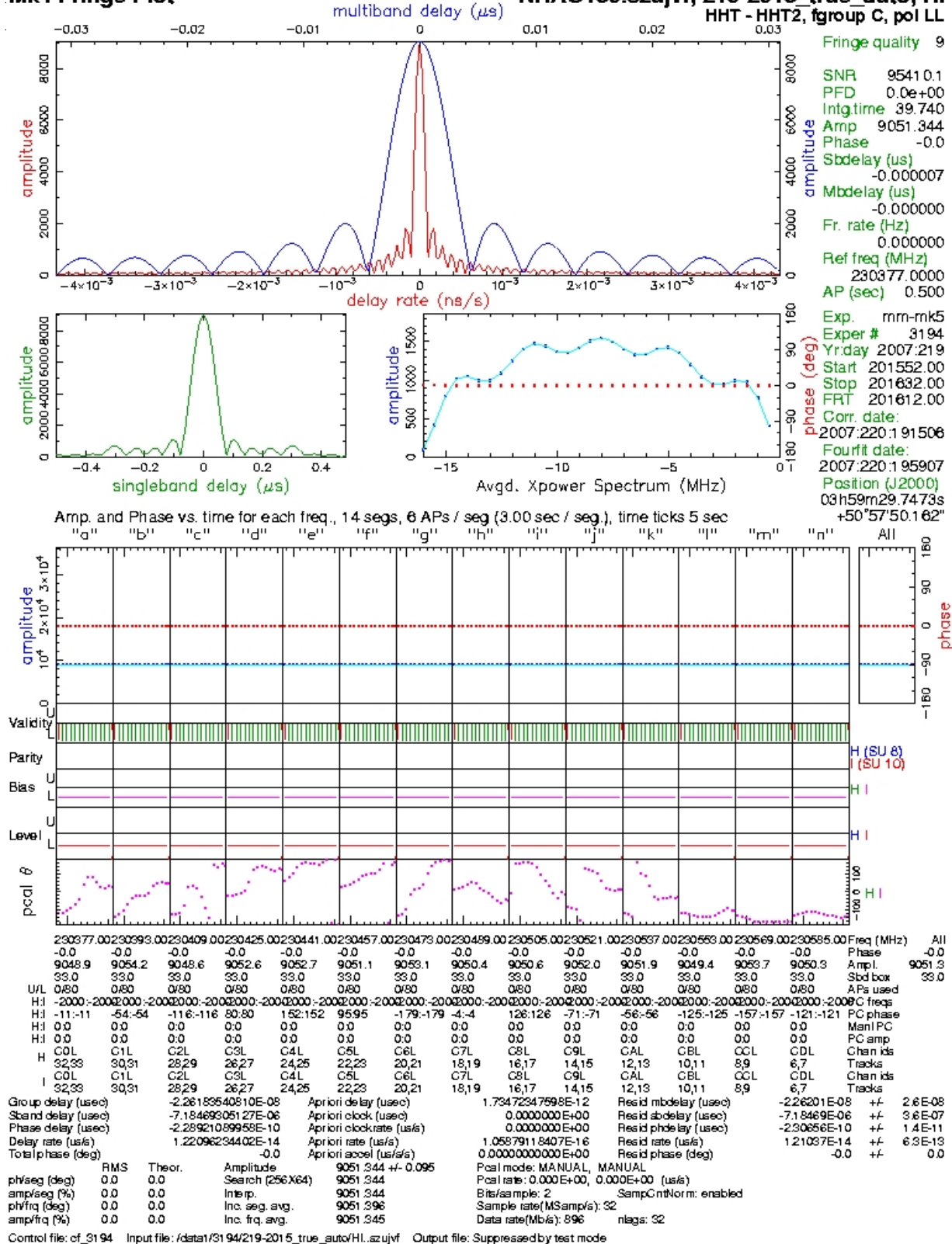


Fig 12: Auto correlation of DBE (IF0) but fooling the correlator into thinking it's doing a cross-correlation to see what the difference in normalization is.