Academia Sinica, Institute of Astronomy & Astrophysics
Hilo Operations

Subject:
Preliminary Test Results for Wideband IF-1 System, Antenna 2

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I. IF System Description

An upgraded Antenna IF assembly [1] (J. Test, P. Yamaguchi) was installed permanently into antenna 2's IF-1 position on August 15th. This assembly provides an IF bandwidth coverage of approximately 2 – 12 GHz. The 3.5 – 6.5 GHz K&L bandpass filter was removed from the IF-1 path of the BDA [2] (bandwidth doubler assembly) to permit transmission of the wider signal bandwidth. An upgraded C1DC [3] (D. Kubo, S. Ho) designed to process the 2 – 12 GHz signal was installed into rack AR1, position A7, and maintains the function of the legacy system. A partially populated BDC [4] (block down converter) chassis was installed into the mini rack for down conversion of the 7.85 - 10.35 GHz and 9.65 - 12.15 GHz portions of the receiver spectra down to 0.00 - 2.50 GHz for subsequent digitization. An LO [5] assembly was temporarily put in place to generate the 7.85 GHz and 12.15 GHz LOs required by the BDC. Andrew Heliax FSJ1P-50A-xxB cables of specified lengths were used to interconnect the new hardware. *Fig. 1* represents the hardware configuration.

The antenna 2 receiver was tuned to 230 GHz with a cryostat output of -29.5 dBm (R. Chilson). The Antenna IF assembly was initially aligned to provide +10 dBm into the Emcore fiber optic transmitter with the receiver looking at the ambient load (XmitPower = 5.7V on monitor I-page) on August 15th, but was subsequently increased to +15 dBm on August 23rd. The Emcore fiber transmitter has an input 1 dB compression point (P1dBc) of approximately +23 dBm. All spectral measurements contained within this memo were performed using an Agilent E4407B spectrum analyzer with resolution bandwidth of 3 MHz and video bandwidth of 3 kHz.

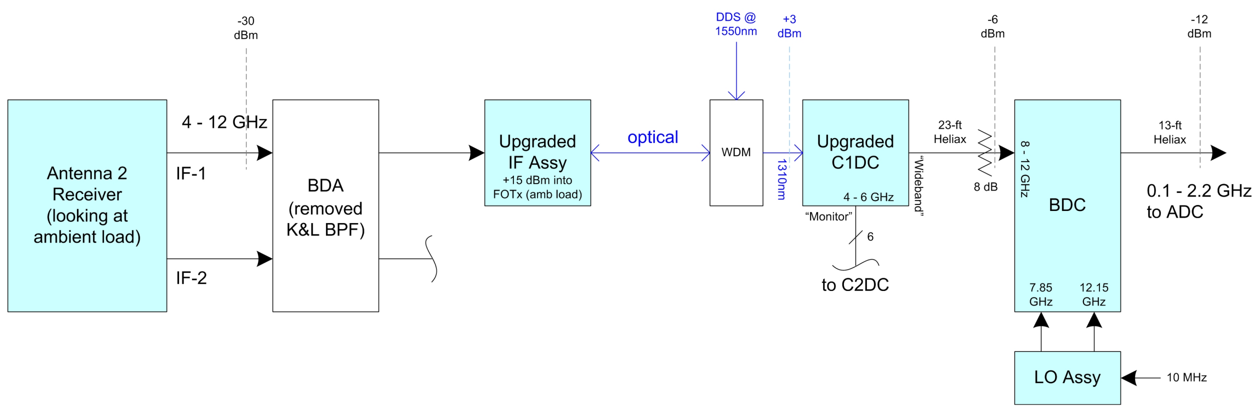

Fig. 1 A2-IF1 Test Configuration. Tests were performed using the upgraded 200 GHz receiver looking at the ambient load in the cabin. Unless otherwise stated, this figure represents the hardware configuration for test results described herein.

II. Magnitude versus Frequency Response

Receiver to C1DC Output: *Fig. 2* shows the frequency response through the stock A2-IF1 hardware path (prior to upgrade) from the receiver output to the C1DC Monitor test point output. The BDA assembly was bypassed for this test. *Fig. 3* depicts the transfer function through the upgraded hardware consisting of a new antenna IF-1 assembly and new C1DC chassis. Note this new IF transmission system provides access to the full 3 – 12 GHz receiver output spectrum at the C1DC Wideband SMA output connector.

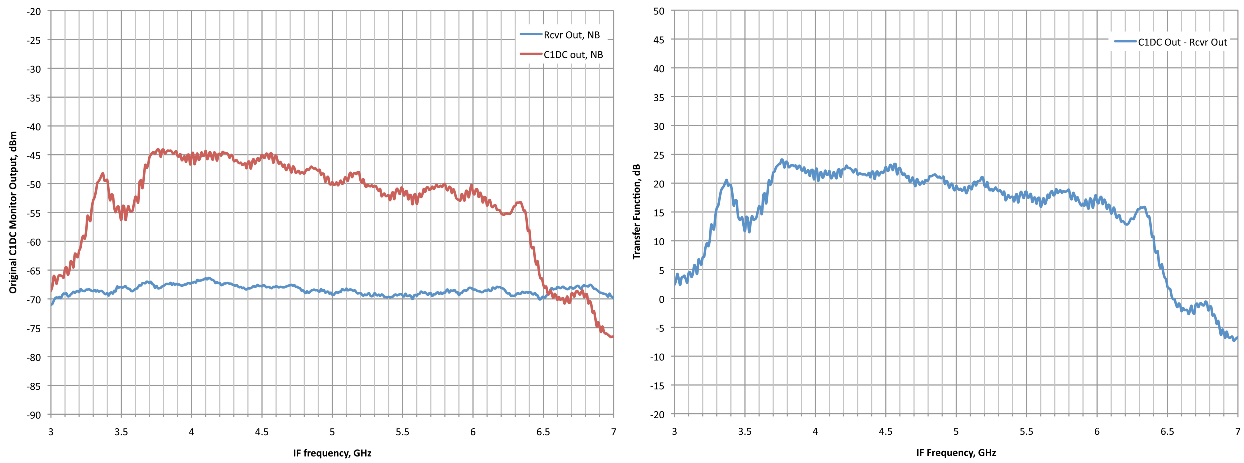

Fig. 2 Stock C1DC Output Spectra. The left panel shows the receiver noise output as measured in the antenna cabin (blue trace) and C1DC Monitor output (maroon trace). Note the approximate -6 dB gain slope across the 4 - 6 GHz noise and is consistent with historical data. The right panel shows the transfer function from the receiver output to the C1DC Monitor output with a system gain of approximately 20 dB at 5 GHz. The BDA in the antenna cabin was bypassed for this test.

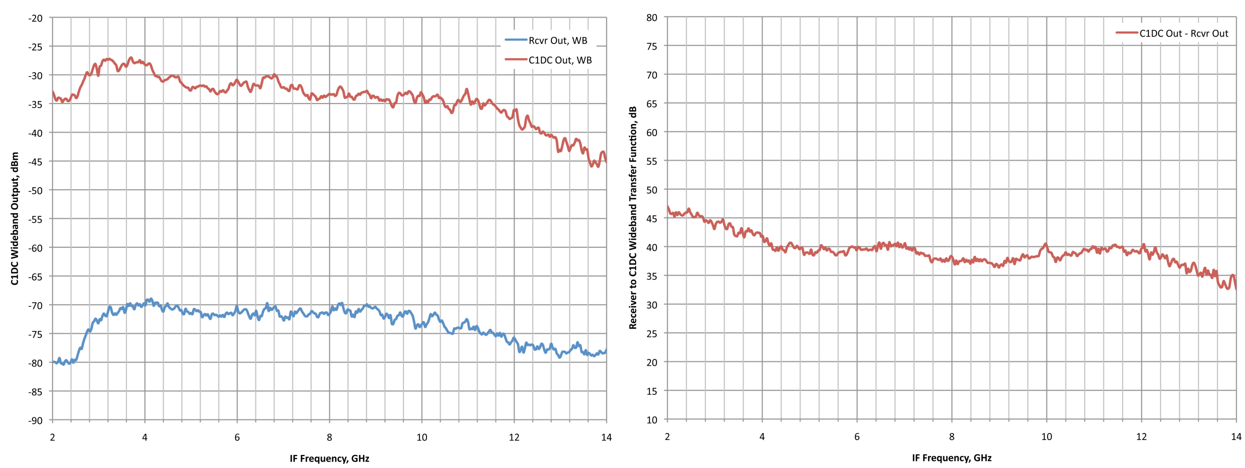

Fig. 3 Upgraded C1DC Output Spectra. The left panel shows the receiver noise output as measured in the antenna cabin (blue trace) and C1DC Wideband output (maroon trace). The right panel shows the transfer function from the receiver output to the C1DC Wideband output with a system gain of approximately 37 dB at 8 GHz. The BDA was bypassed for this test.

Receiver to BDC Output: The transfer functions for the low (7.85 – 10.35 GHz) and high (9.65 – 12.15 GHz) bands are provided in *Fig. 4* and *Fig. 5*, respectively. The maroon/purple traces in both figures represent the signals entering the ADCs for digitization. The purple portions of the traces highlight the 0.15 – 2.15 GHz desired spectra scheduled to be processed by the correlator. The sample rate for the E2V ADC board is currently selected to be 4.576 GHz (88th harmonic of 52 MHz clock) and defines a Nyquist frequency limit of 2.29 GHz. The two maroon plots of the left panel show the signal to be attenuated by approximately 15 dB at 2.3 GHz and rolling off at a rate of

~14 dB/100 MHz. This should be sufficient to prevent aliasing of the signal near the band edge, particularly if the channels beyond 2.15 GHz are discarded.

Referring back to the low band response in *Fig. 4*, the baseband output signal has a linear gain slope component of -1.6 dB with a maximum power variation of 5.7 dBpp. The high band response in *Fig. 5* shows a linear gain slope component of -0.8 dB with a maximum power variation of 7.3 dBpp.

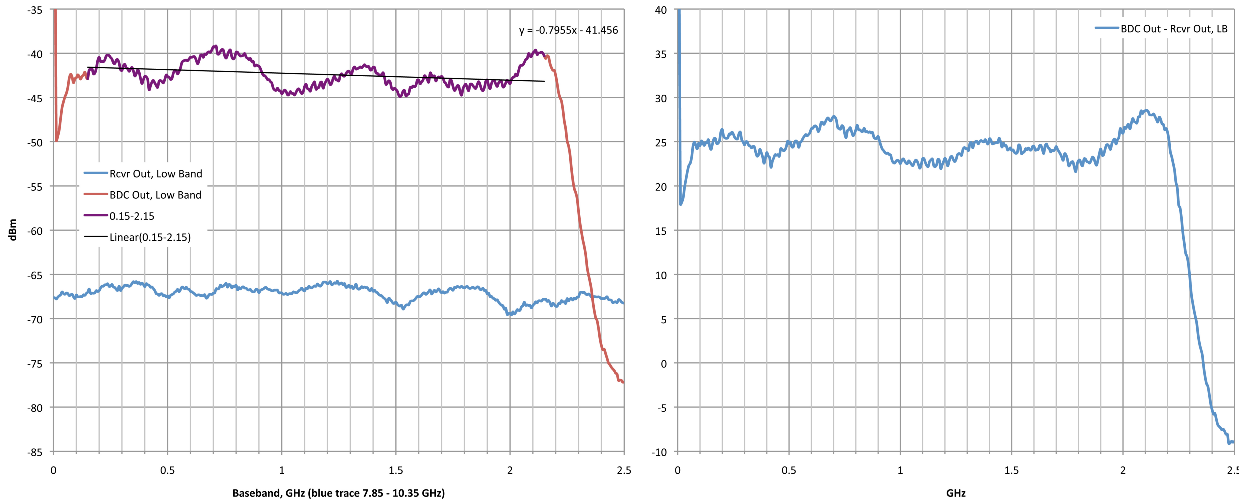

Fig. 4 BDC Output Spectrum, Low Band. The blue trace on the left panel shows the receiver noise output from 7.85 – 10.35 GHz plotted against baseband frequency for direct comparison. The LO used for down conversion is 7.85 GHz. The maroon/purple trace represents the down converted BDC output with the purple portion highlighting 0.15 – 2.15 GHz. The right panel shows the transfer function from the receiver output to the BDC baseband output and indicates a system gain of about 23 dB at 1 GHz. The BDA was included for this test.

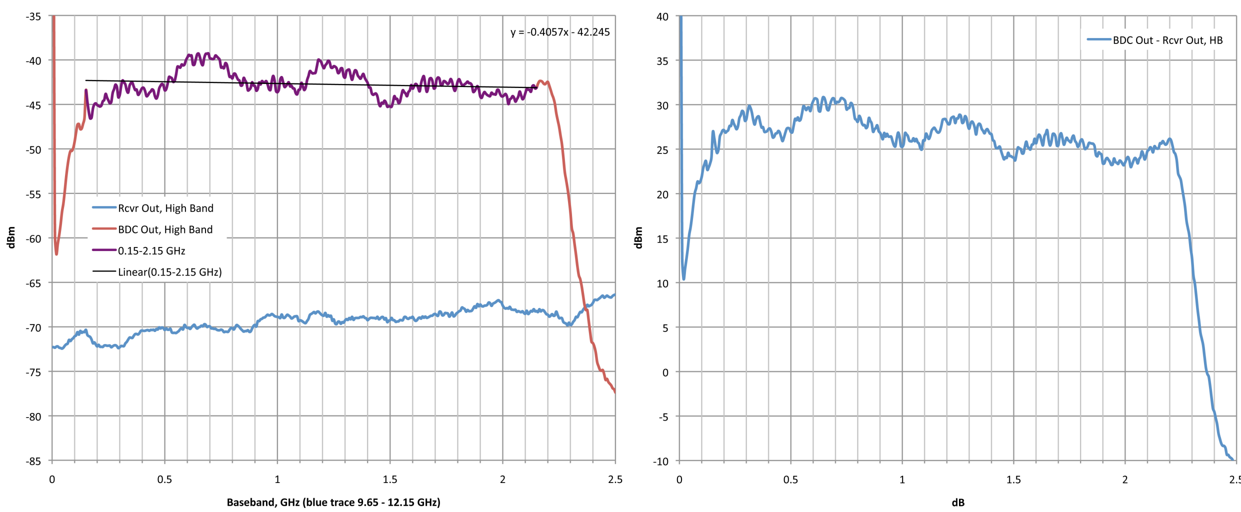

Fig. 5 BDC Output Spectra, High Band. The blue trace on the left panel shows the receiver noise output from 12.15 – 9.65 GHz plotted against baseband frequency for direct comparison. Note the spectral reversal of this blue trace due to the high side LO of 12.15 GHz. The maroon/purple trace represents the down converted BDC output spectrum with the maroon portion highlighting 0.15 – 2.15 GHz. The right panel represents the transfer function from the receiver output to the BDC baseband output and indicates a system gain of about 26 dB at 1 GHz. The BDA was included for this test.

III. Output Signal to Noise Ratio vs. Frequency

Signal to noise ratio (SNR) measurements were conducted at the C1DC and BDC outputs by capturing the output signals with the receiver activated then deactivated. The deactivated condition represents the IF system noise floor up to the measurement point.

Receiver to C1DC Monitor Output SNR: *Fig. 6* represents the SNR measurements taken at the new C1DC Monitor output port for the 4 – 6 GHz legacy system. The right panel shows the SNR (Signal – Noise, dB) value of ~23 dB at 5 GHz. This result is considered pessimistic because the noise floor measurement (maroon trace) was very close to the spectrum analyzers noise floor.

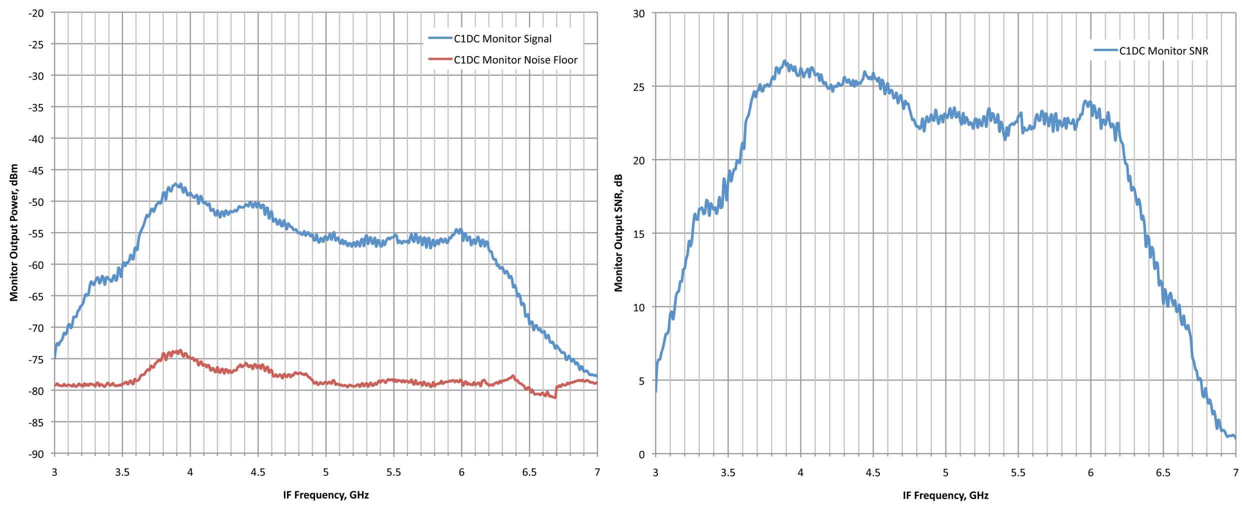

Fig. 6 C1DC Monitor Output SNR. The blue trace on the left panel depicts the C1DC Monitor signal output spectrum for the normal 4 – 6 GHz IF signal with the receiver output looking at the ambient load. The maroon trace represents the IF system noise floor with the receiver deactivated. The right panel represents the SNR of the C1DC Monitor output with a value of ~23 dB (pessimistic, see text) at 5 GHz.

Receiver to BDC Output SNR: *Fig. 7* shows the measurement results for the low band (7.85 – 10.35 GHz) BDC output SNR tests. The results indicated in the right panel show a SNR of ~25.5 dB at 1.0 GHz. A separate measurement using a power meter resulted in -12.0 dBm and -39.0 dBm for signal and noise, respectively, and an overall SNR of 27 dB which is relatively close to the previous value of ~25.5 dB.

Fig. 8 shows the measurement results for the high band (9.65 – 12.15 GHz) BDC output SNR tests. The maroon noise plot in the left panel has significant slope due to higher IF system gain at higher frequency and compensates for the opposite receiver output slope over this band. The results indicated in the right panel show a SNR of ~22 dB at 1.0 GHz. A separate measurement using a power meter resulted in -12.0 dBm and -34.6 dBm for signal and noise, respectively, yielding an overall SNR of 22.6 dB. Note that the 12.0 GHz LO used by the BDA is clearly visible in the baseband spectrum at 150 MHz (12.0 – 12.15 = 0.15 GHz spur).

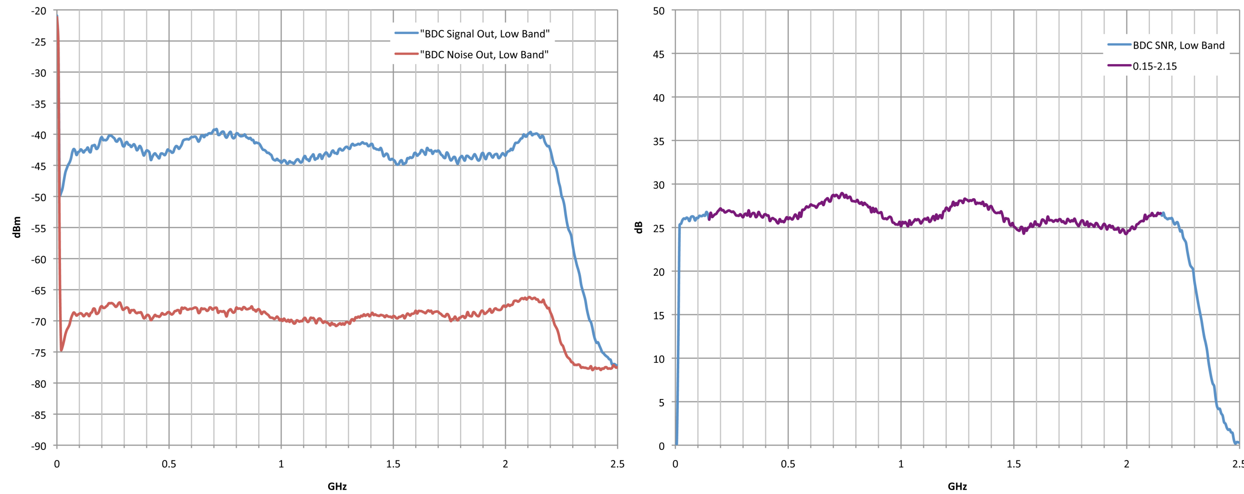

Fig. 7 BDC Output SNR, Low Band. The blue trace on the left panel depicts the BDC noise output spectrum for the low band (7.85 – 10.35 GHz) with the receiver output activated. The maroon trace represents the IF system noise floor with the receiver deactivated as seen at the BDC output. The right panel represents the SNR with the purple portion highlighting 0.15 – 2.15 GHz and a value of ~25 dB at 1 GHz.

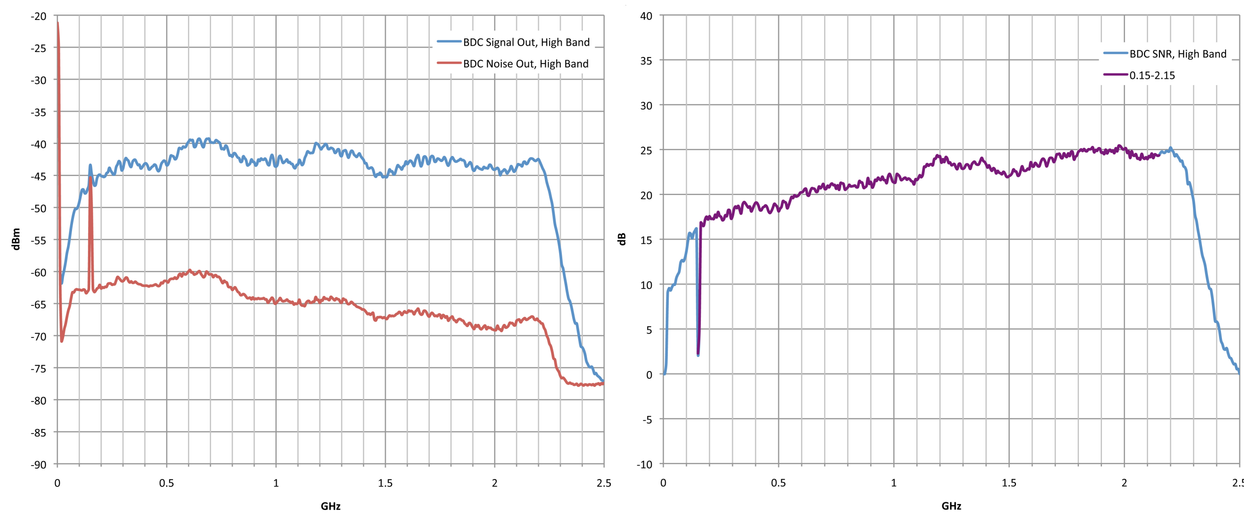

Fig. 8 BDC Output SNR, High Band. The blue trace on the left panel depicts the BDC noise output spectrum for the high band (12.15 – 9.65 GHz) with the receiver output connected and looking at the ambient load. The maroon trace represents the IF system noise floor with the receiver deactivated. Note the spur at 150 MHz which corresponds to the 12.0 GHz BDA LO (12.0 – 12.15 = 0.15 GHz) leakage. The slope of the noise floor is caused by the higher IF channel gain WRTo frequency. The right panel shows the SNR with the purple portion representing 0.15 – 2.15 GHz.

The SNR values of ~25.5 and ~22 dB for the low and high bands, respectively, were conducted with the receiver looking at the ambient load. During observations the receiver will be looking at a cold sky and will result in ~5 dB (Y-factor of 3.2) less signal power and will in turn reduce the SNR values to ~20.5 and ~17 dB for low and high bands, respectively. Furthermore, the ambient load SNR near the upper IF frequency of 12 GHz (150 MHz at baseband) is already low at 17 dB and will drop to 12 dB during observations.

IV. IF System Linearity, Receiver Output to BDC Output

An Agilent 8494B (DC – 18 GHz) variable step attenuator was inserted between the cryostat output and the BDA within the antenna cabin. This step attenuator provided manual adjustments in precise 1 dB increments from 0 – 11 dB (minimum insertion loss at 0 dB setting was -1.1 dB). A power meter was used to measure the BDC output power relative the step attenuator settings. The left panel of *Fig. 9* shows the linearity performance of the entire wideband IF system from the cryostat output to the BDC baseband low and high band outputs. Note the very linear performance over the range tested. The right panel shows the monitor page XmitPower and C1DC IF Power WRTo the IF power provided to the BDA located in the antenna.

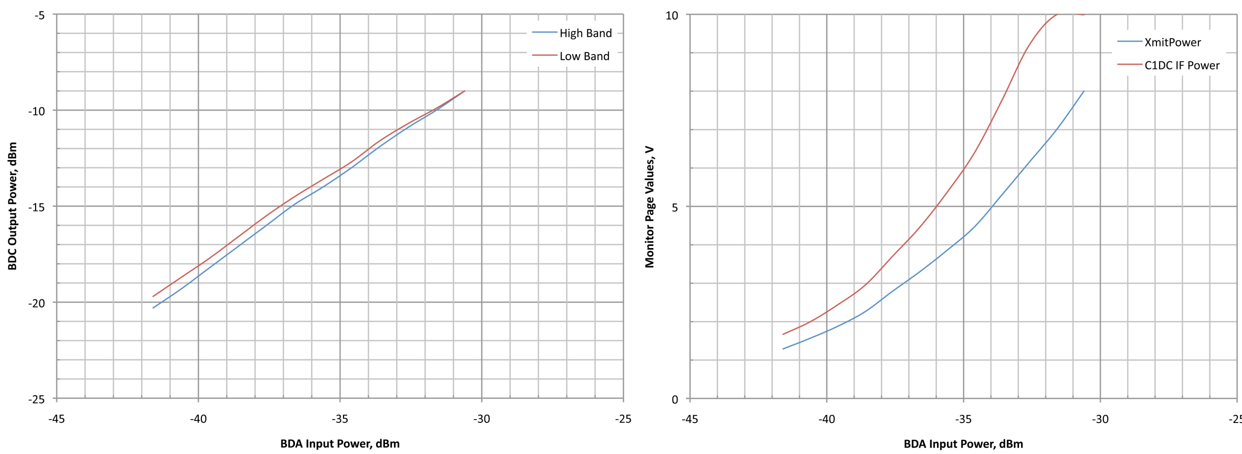

Fig. 9 IF System Linearity. Left panel - BDC baseband output power vs. BDA input power. Right panel – XmitPower (monitor I-page) and C1DC IF Power (monitor f-page) values vs. BDA input power.

IV. Summary

The installation of the upgraded Antenna IF assembly and C1DC into the IF-1 path of antenna 2 has shown to maintain the present legacy 4 – 6 GHz IF signal bandwidth to the existing correlator without incident. This upgraded hardware has expanded the IF transmission bandwidth from 4 – 6 GHz to approximately 3 – 12 GHz (refer to left panel of *Fig. 3*). The 3 – 12 GHz IF signal is available at the upgraded C1DC "Wideband" SMA(f) connector output at a level of -4 dBm +/- 6 dB (ambient load), with the actual level being dependent on the fiber loss.

A partially populated BDC chassis capable of processing two IFs from a single antenna was temporarily installed into the mini rack located adjacent to DR7 in the correlator room. The wideband IF signal from the upgraded C1DC located in AR1-A7 was routed to the BDC input using 23-feet of FSJ1-50 Heliax coaxial cable. All measurements for the two baseband outputs from the BDC were conducted at the end of a 13-foot FSJ1-50 coaxial cable which would normally connect to a ROACH2 motel chassis located in DR7. Measurement results are as follows:

Magnitude vs. frequency flatness:	5.7 dBpp for low band 7.3 dBpp for high band
Output Signal-to-Noise Ratio:	25.5 dB at 1 GHz for low band, ambient load 22.0 dB at 1 GHz for high band, ambient load, degrades with higher IF
Power linearity:	No noticeable signal compression over ranged tested

The test data collected for this memo is available in [6] and [7] in Excel format.

References:

[1] Upgraded Antenna IF design information:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/IF_Module_SN101_ALL.pdf

[2] Bandwidth Doubler Assembly (BDA) design information:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/Bandwidth_Doubler_Assembly.pdf

[3] Upgraded C1DC design information:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/C1DC_BDC_2012feb1.pdf

[4] Block Down Converter (BDC) design information:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/BDC_design_2011dec15.pdf

[5] LO chassis design information:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/WB_LO_Distribution_Diagram.pdf

[6] Raw Excel data for wideband IF tests:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/IF_upgrade_tsts_2012aug22a.xlsx

[7] Raw Excel data for wideband IF tests:
https://www.cfa.harvard.edu/twiki/pub/SMAwideband/IfLo/IF_upgrade_new_tsts_2012aug23.xlsx