EVLA Memo. 72

EVLA Hardware Modifications in Support of Solar Observing

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Abstract

For the EVLA to support solar observations requires certain hardware modifications to be implemented in the antenna front ends. This memorandum briefly reviews the problem posed by the strong and variable signal produced by the Sun and outlines the hardware solution designed to accommodate strong solar signals. Implementation plans are also discussed and a possible approach to calibrating the instrument is presented.

Introduction

As described in EVLA Memo 70, solar observing imposes special demands on the EVLA. The most immediate concern is to manage the very large signals entering the system, which can saturate various elements unless appropriate measures are taken. Tables 1 and 2, prepared by Bob Hayward, summarize input levels in solar flux units (1 SFU = 10^4 Jy) to various components of the (unmodified) EVLA receiver systems that yield 1% and 1 dB compression, respectively. The way the tables should be read is as follows. Consider the L band in Table 1, first line. The front end goes into 1% compression for an input signal of 63.1 SFU. However, the LSC converter goes into 1% compression at a signal level of only 12.8 SFU (indicated in red). The LSC converter is therefore the limiting element in this case. However, if the LSC-converter 20 db attenuator is switched in (second row), the LSC converter can accommodate 1278 SFU before going into 1% compression, and it is the front end that goes into 1% compression first at 63.1 SFU (indicated in red) and therefore becomes the limiting element. Inspection of Tables 1 and 2 shows that for L, S, and C bands, the front end is the limiting element. X band and the higher frequency bands have no 20 dB attenuator and are limited by either the converter or down converter.

EVLA Memo 70 shows that, unless modifications to the EVLA receivers are introduced, the system will be in compression for even quiet Sun observations in some bands. The system is in compression for essentially all bands for active region observing. Flare-associated emissions will drive the system into strong compression in all bands. Hence, hardware modifications are needed to allow EVLA receivers to accommodate strong solar signals without compression.

Hardware modifications

Paul Lilie has proposed hardware modifications that would allow observations of the quiet and active Sun (Fig. 1). Briefly, two signal paths will be made available during solar observations. One path allows the signal to pass through unmodified EVLA receiver: that is, to the LNA and from there to the post-amplifier, the mixer, etc. The second path uses a coupler to route the signal to a high-compression amplifier and, by means of a transfer switch, to the post-amplifier, etc. A high noise cal will inject a cal signal into either path. The cal amplitude is under control of a cal stepped attenuator. By routing the input signal through the HNA, an additional ~35 dB of dynamic range is gained, sufficient to observe active regions and all but the largest flares (see Memo 70). Although details of the implementation may differ from band to band, the essential elements of the scheme will be the same for all bands.

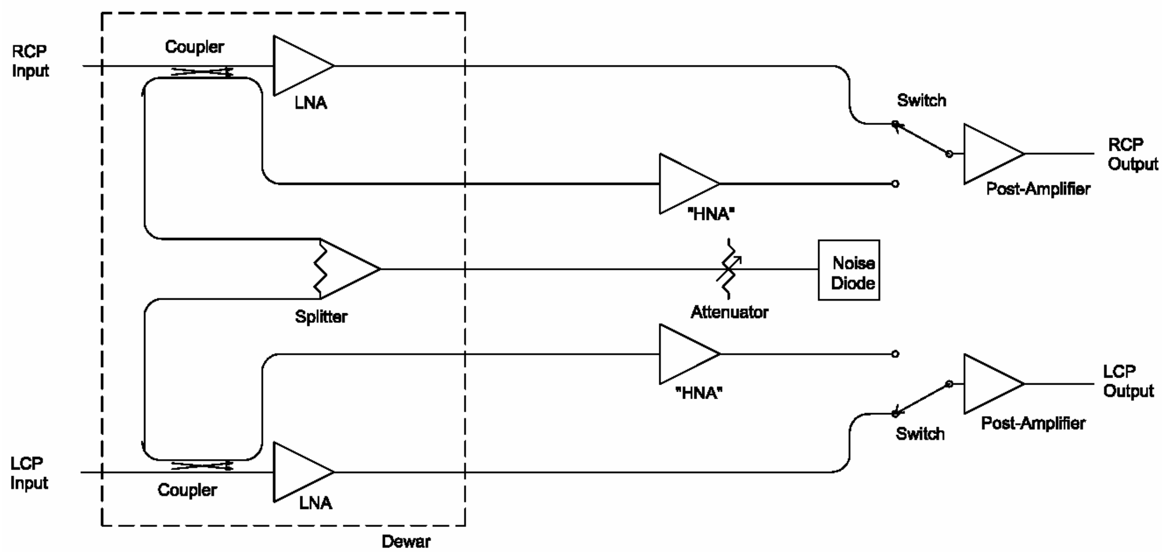

Figure 1

Implementation

Because funding resources are finite, not all bands will be modified as outlined above, at least not initially. Discussions within the NRAO have resulted in the following understanding:

- The L band and one additional band TBD (S, C, X, U, or KA but not K or Q) will be modified as part of the EVLA project.

- One or two additional bands will be modified through the use of contingency funds. Hence $2 \le n \le 4$ bands will be modified as part of the EVLA project.

- However, the necessary "hooks" needed to allow future modification will be designed into each band.

- Any bands that are not modified as part of the EVLA project initially, or from contingency funds, will only be modified if some additional source of funding becomes available.

Unfinished business

While the hardware modifications outlined above will allow the Sun to be observed, additional work is needed to specify requirements for the EVLA monitor and control system, and to define solar observing modes, so that they can be implemented in the online software system. In addition, requirements for offline software will need to be defined, and algorithms identified and implemented, in order to handle the special calibration procedures needed for solar observations.

Barry Clark has suggested a possible approach for calibrating the complex gain of the antennas when the signal passes through the HNA. The scheme relies on two assumptions:

- That the HNA will supply sufficient power to the synchronous detector and sampler that they operate in their nominal range, even when the VLA is pointed at cold sky
- That the relative complex gain between the LNA path and the HNA path varies slowly with time

Calibration of the LNA path employs the same procedures as non-solar observations. What remains is to calibrate the complex gain of the HNA path relative to the LNA path. The proposed procedure is to divide the array into two groups of antennas, A and B, each containing roughly half of the antennas, and to point at a normal (but rather strong) calibrator. Then,

1. Make measurement with standard setup, group A and B with receivers R and L through the LNA. Calculate, for each antenna, the complex gain of the R receiver relative to the L receiver, using only the baselines between the A and B groups.
2. Make measurement with group A, receiver R through the HNA, receiver L through the LNA. If the HNA is 50 db worse than the LNA, the SNR on RR on baselines between group A and group B will be 25 db worse than in step 1. So it is like calibrating on a 30 mJy source instead of a 10 Jy source, but still, a minute, or at most two, should result in an accurate calibration of the gain through the R HNA path relative to the L LNA path. But, since we know from 1. the relative complex gain of the L LNA path and the R LNA path, we now know the relative complex gain of the R HNA path relative to the R LNA path.

3. Repeat with the group A receiver R set to go through the LNA, L through the HNA.
4. Repeat with the group B receiver R going through the HNA.
5. Repeat with the group B receiver L going through the HNA.

Then, for observing the sun, you point at the sun through the HNA and the nearby phase calibrator through the LNA, and apply the relative gains determined above to the calibrator data before using it to calibrate the solar data.

It may be possible to perform steps 2 and 3 at the same time (and 4 and 5 at the same time), relying on interpolating between normal observations of the calibrator, which saves time, but the procedure above is a little more conservative.

We thank Rick Perley, Barry Clark, Bob Hayward, and Peter Napier for discussions leading to the hardware solution and implementation plan described in this memo.

Table 1

Unmodified EVLA Receiver System when Observing the Sun
T_{Sys} and Equivalent SFU (assume 1 SFU = 1330°K)
For 1% Compression
(*Italics = LSC Converter 20 dB Attenuator Inserted*)

Freq Band	Front-End		LSC or UX Converter		Down Converter	
	T_{Sys}	SFU	T_{Sys}	SFU	T_{Sys}	SFU
L	84,000	63.1	17,000	12.8	29,000	21.8
	84,000	*63.1*	*1,700,000*	*1278*	*2,900,000*	*2180*
S	33,000	24.8	7,800	5.9	13,200	9.9
	33,000	*24.8*	*780,000*	*586*	*1,320,000*	*992*
C	23,500	17.7	6,000	4.5	9,500	7.1
	23,500	*17.7*	*600,000*	*451*	*950,000*	*714*
X	23,500	17.7	-	-	5,400	4.1
Ku	19,000	14.3	4,400	3.3	3,900	2.9
K	8,500	6.4	5,000	3.8	5,000	3.8
Ka	8,500	6.4	5,000	3.8	6,900	5.2
Q	1,360	1.0	6,500	4.9	7,700	5.8

Table 2

Unmodified EVLA Receiver System when Observing the Sun

T_{Sys} and Equivalent SFU (assume 1 SFU = 1330°K)

For 1 dB Compression

(*Italics = LSC Converter 20 dB Attenuator Inserted*)

Freq Band	Front-End		LSC or UX Converter		Down Converter	
	T_{Sys}	SFU	T_{Sys}	SFU	T_{Sys}	SFU
L	1,330,000	1000	270,000	203	460,000	346
	1,330,000	*1000*	*27,000,000*	*20,300*	*46,000,000*	*34,586*
S	530,000	398	125,000	94.0	210,000	158
	530,000	*398*	*12,500,000*	*9,398*	*21,000,000*	*15,789*
C	370,000	278	95,000	71.4	150,000	113
	370,000	*278*	*9,500,000*	*7,143*	*1,500,000*	*11,278*
X	370,000	278	-	-	86,000	64.7
Ku	300,000	226	70,000	52.6	63,000	47.4
K	135,000	102	78,000	58.6	78,000	58.6
Ka	135,000	102	80,000	60.1	110,000	82.7
Q	23,000	17.3	105,000	79.0	123,000	92.5