EVLA Memo #183
Clock Signal Harmonics in EVLA Baselines

Keith Morris, Emmanuel Momjian
September 16, 2014

Introduction

Reports of an interfering signal at 1408MHz (the 11th harmonic of 128MHz, a common EVLA reference signal), beginning in 2009, ultimately led to a search for other harmonics; a pattern of detection of odd harmonics could indicate that a 128MHz square wave is responsible for these in-band interfering signals. This signal was originally believed to be the product of two L301s mixing in the T302 LSC converter. Later tests showed that the 1408MHz signal persisted even when the two L301s were tuned to the same frequency.

Background

When a sinusoidal signal is clipped to create a square wave, as in the EVLA modules where this signal is used as an FPGA clock source, a comb line of odd harmonics is generated. The highest Fourier component f of this comb line is related to the rise time t_r of the resulting square wave by the approximate relation $f \sim 0.34/t_r$. High-speed logic devices in the L305, L302, and DTS modules have rise times on the order of 100s of picoseconds, which could produce harmonics as high as 2 - 3GHz. This allows a focused search. Unfortunately for this test (but fortunately for radio astronomy), only a limited subset of the odd harmonics of 128MHz below 3GHz are detectable using EVLA receivers: 384MHz (3rd harmonic) at P-band, and 1152, 1408, 1664, and 1920MHz in L-band. Of these, the 1152MHz component appeared in some baselines, but was not studied thoroughly, while the 1664MHz component was masked by even stronger interfering signals from external sources.

Method and Results

The quasi-annual RFI Sweep test of July 2013 confirmed the presence of the 1408MHz signal. A second RFI Sweep test, performed in July 2014 reconfirmed this signal, as well as the presence of a 1920MHz signal (the 15th harmonic of 128MHz). We have attempted to quantify the strength of each signal, although it should be noted that these are based on uncalibrated visibilities. Differences in signal strength between polarizations may be regarded as insignificant, due to the lack of calibration, or they may be real symptoms.

The modules that use this signal as an FPGA clock were characterized in the VLA shielded chamber for both shielding effectiveness and radiated emissions. The L302 synthesizer was found to be shielded sufficiently to be within ELVA harmful RFI level thresholds. The DTS (D30x) and Antenna LO Reference Distributor (L305) each showed radiated emissions well above the EVLA harmful level thresholds, and rely on additional shielding from the module racks to comply with the emission requirements. In the event that an electronics module rack does not provide the expected level of shielding, there is some risk of radiated emission from the modules, either internally coupled to the same antenna, or radiatively coupled to other antennas.

In August 2014 we conducted a test for the 384MHz 3rd harmonic. We shifted the standard LO tuning for P-band up in frequency by 23MHz, so that the spectral component under test would not coincide with a subband filter notch. We observed once using 26 antennas, so that autocorrelations would be avialbable on all antennas (excluding two with known problems), and a second time with both the LO and Utility rack doors open on one antenna. The presence or absence of the 384MHz signal was not affected by the state of the rack doors; the 384MHz signal appeared just as strong with the doors open or closed. A full accounting of the affected antennas and the relative strengths of the interfering signals in auto- and cross-correlation is available. Figure 1 shows the locations of the antennas at the time of these observations. The red (1408MHz) and green (1920MHz) boxes indicate the antennas showing the largest interference signal amplitudes.

Figure 1: Antenna locations at the time of the July 2014 RFI sweep, showing geographic relation among affected antennas

Figure 2 shows the 384MHz signal, averaged across all baselines. Figure 3 and Figure 4 show 1408MHz and 1920MHz, respectively, averaging all baselines to ea08.

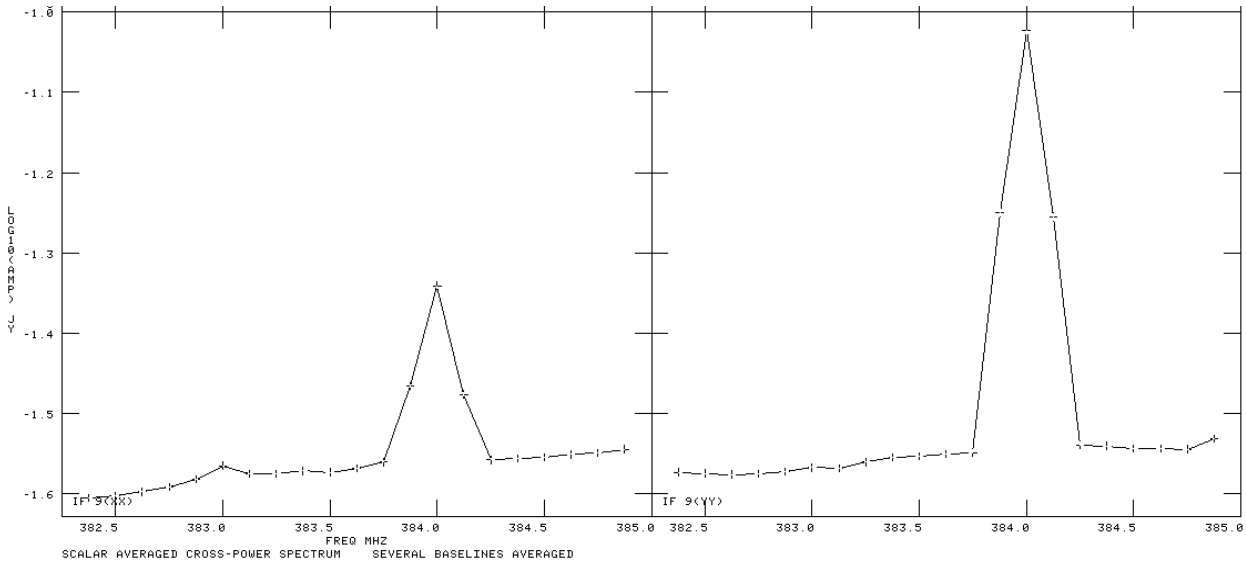

Figure 2: Signal at 384MHz, average of all baselines

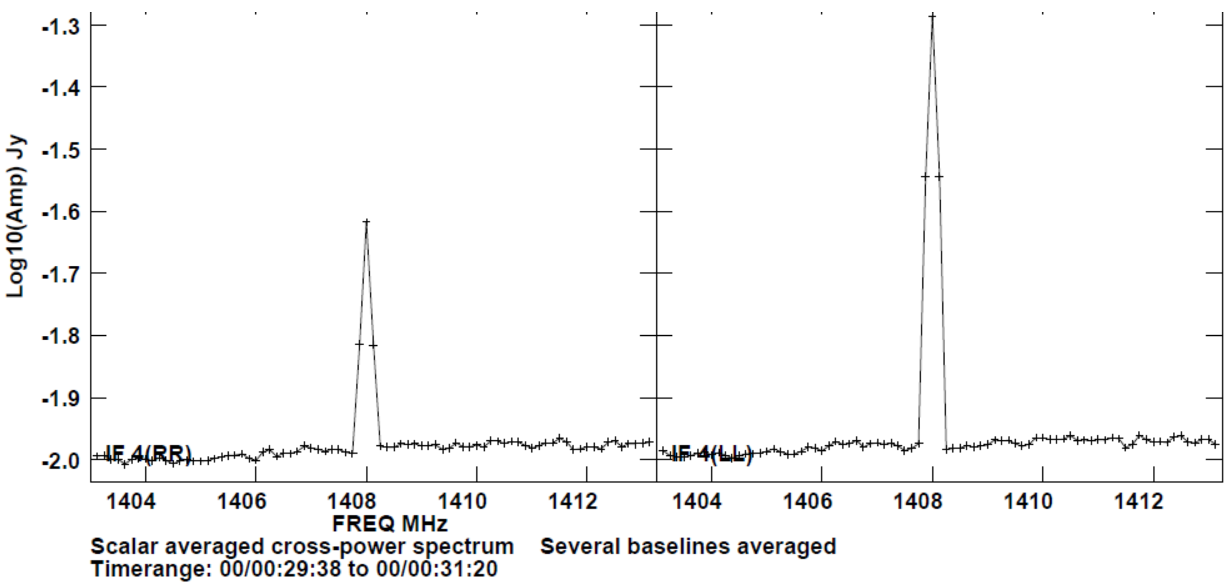

Figure 3: Signal at 1408MHz, all baselines to ea08

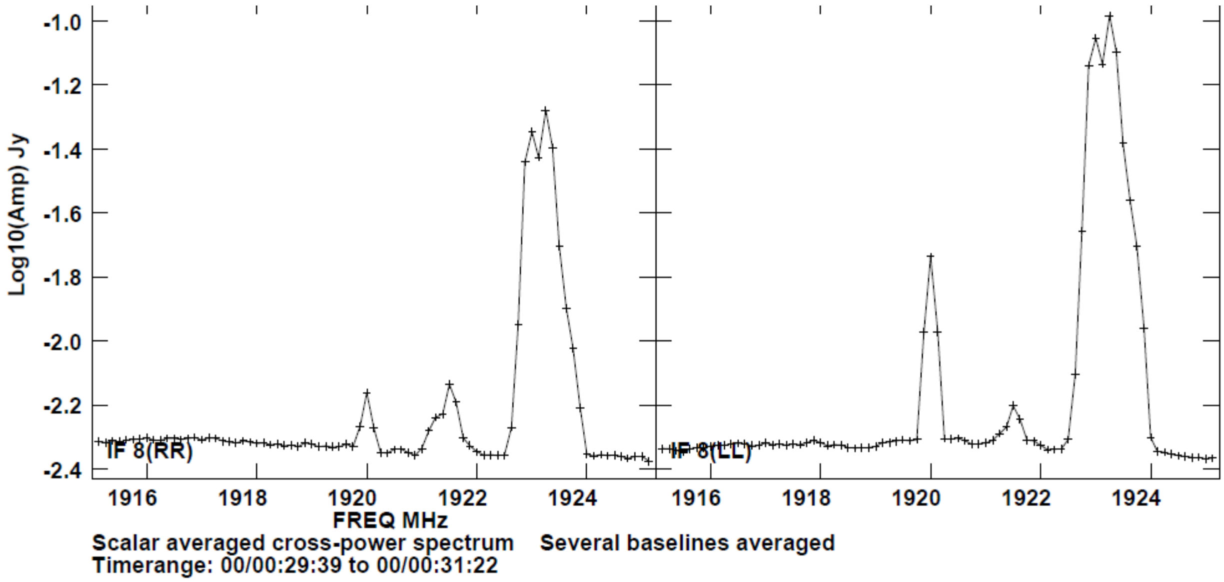

Figure 4: Signal at 1920MHz, all baselines to ea08

Recommendations

One immediate action that can be taken is add (at least) these three signals – 384MHz, 1408MHz, and 1920MHz, but possibly all odd harmonics of 128MHz up through S-band -- as known interfering signals.

As far as mitigation, try to distinguish between radiation from a common source and internal self-contamination. If this is the result of some aggressor antenna radiating to victim antennas, then perhaps a geographic coincidence will be apparent. If this is due to internal self-contamination within an antenna, then there is some evidence that the LO and Utility racks have compromised shielding. Visually inspect and test seals on rack doors and repeat the RFI sweep observation.

Acknowledgements

The authors wish to express appreciation to Dan Mertely, for providing the module shielding reports and invaluable assistance with the P-band observation.