Hi Friends

To get you oriented, remember that last summer we performed some observations of the moon. The moon was supposedly illuminated by a transmitter in Belgium emitting Morse code in a narrow-bandwidth signal. That is, a narrow bandwidth signal was generated and then turned on and off to represent the dots and dashes.

We captured data in two phased-array beams (beams 2 and 3) from two different places on the moon separated by about 0.25°. The question we hoped to answer was whether the two beams were sampling 2 points in an interference pattern or whether the interference would be washed out. To put this into another language, our goal was to measure the cross correlation between the two beams. If the correlation is high, then we have successfully proven interference between the beams.

Here is a frequency-calibrated version of the cross correlation waterfall of the two simultaneous beams. I sent you some figures like this yesterday. The fact that we see white streaks is promising. It suggests there is an artificial signal in there, but not necessarily the Moon bounce signal.

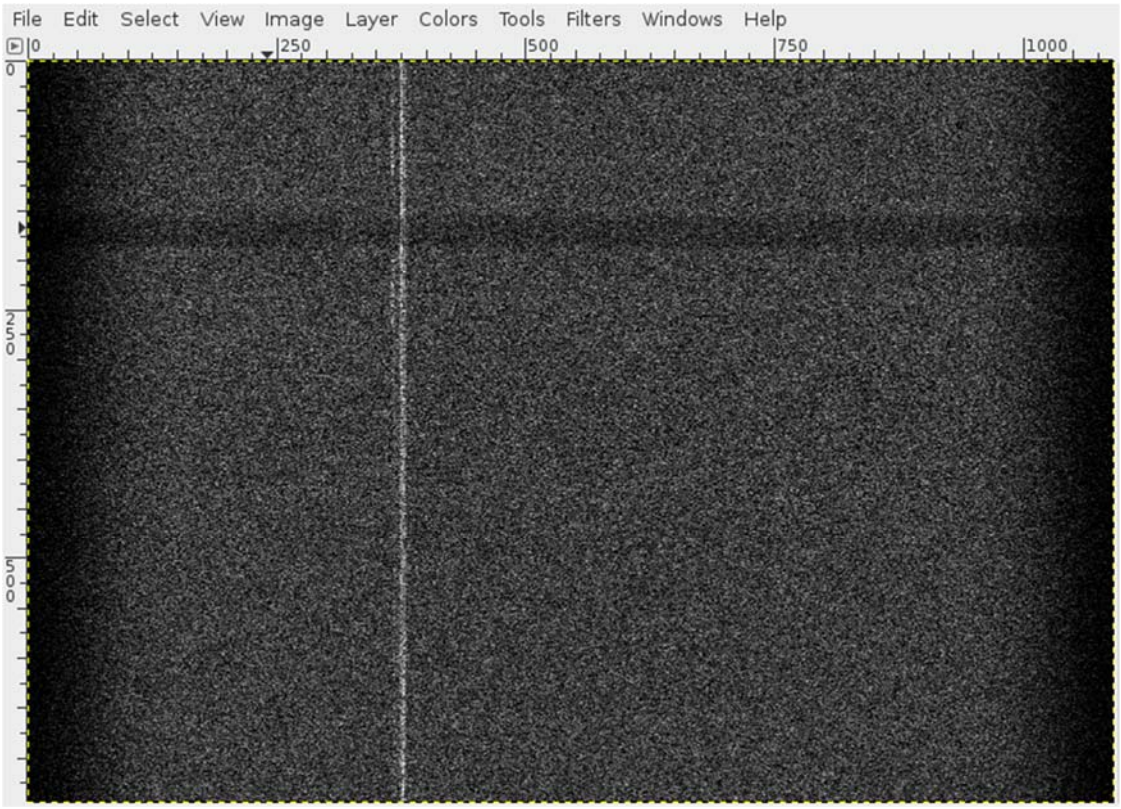

Figure 1: Cross correlation waterfall from the two beams. Time is on the vertical axis and frequency is on the horizontal. Intensity is represented via grayscale, with light values stronger than dark values. Axis scales described in the text.

Fig. 1 is a standard waterfall with frequency on the horizontal and time on the vertical, with early times near the top. We have a total of about 4 minutes of data but only about 1 second is shown here.

Note the scales on top and left. Across the top, 1 pixel = 1000 Hz. Across the left, 1 pixel = 0.001 sec. Notice the inverse relationship?

A few notes on Fig. 1. On the website of the Moon-bounce project, the transmission frequency is stated to be 1.296 GHz. From the center frequency of the observation, the triplet just above column 400 has a frequency of 1295648000 Hz or 1.295648 GHz. We don't know if the difference is just a Doppler shift or if this indicates that the identified signal is not from the transmitter.

To interpret this data we need to do some quantitative analysis. For any old signal blasting into your telescope, you will generally see it no matter where you point. However, if the signal is coming from a random direction, then generally the correlation observed between the two beams will average down with the noise over time. On the other hand, if the signal is coming from the Moon, then the signal between the two beams will add up in phase. To make a quantitative comparison I collapsed waterfalls like the one above into line graphs:

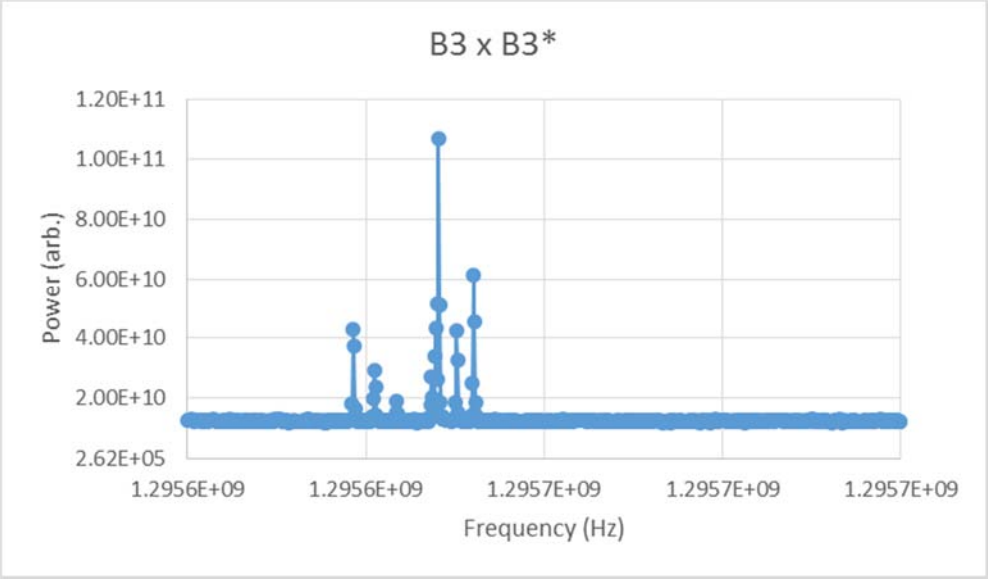

Figure 2: Correlation of beam 3 with itself (aka autocorrelation). This is a measure of the total signal entering the telescope. The spectrum for beam 2 is essentially the same, meaning that a similar amount of power is coming in both beams.

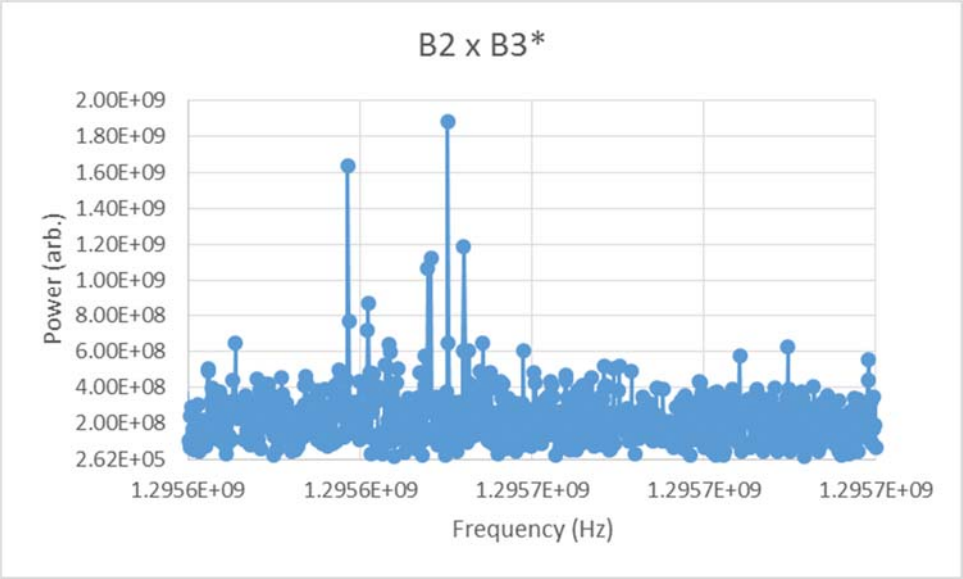

Figure 3: Similar to Fig. 2, this graph shows unnormalized cross-correlation between beams 2 and 3.

You can already tell from the high noise Fig. 3 that something is wrong. These graphs were generated by computing the complex average of 3700 one-millisecond spectra. If the signals were correlated then I would expect that the peaks would have similar values between Figs. 2 and 3. But if they do not correlate (there is no interference pattern) then I expect the cross correlation peaks should be down by approximiately a factor of sqrt(3700) = 60.8. By comparing the vertical-axis scales between the two figures we see a drop by almost exactly this amount in the cross correlation. This indicates that the signals don't correlate.

As a final test, I computed the classic correlation-coefficient between the two beams with proper normalization. The result is shown in Fig. 4.

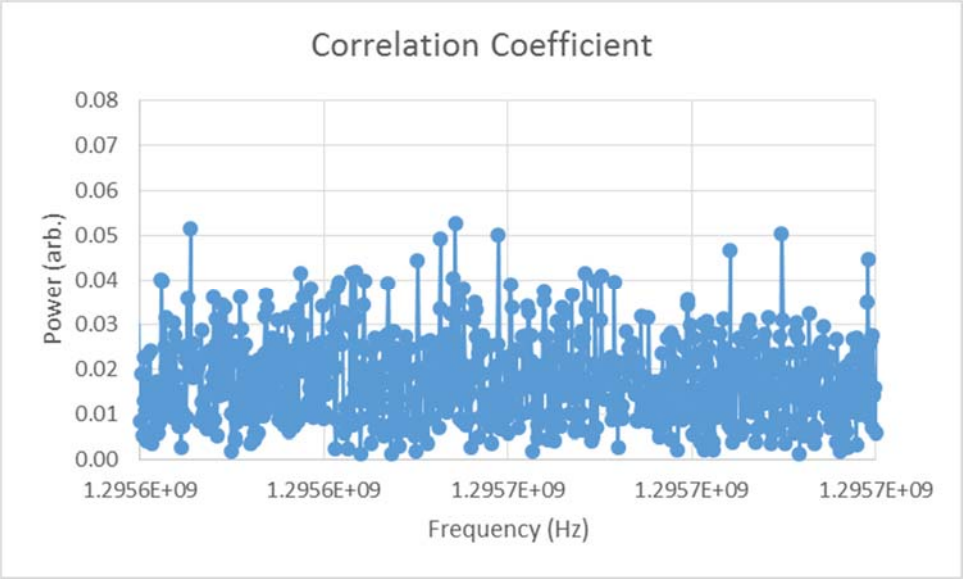

Figure 4: Normalized cross correlation coefficient between two beams. For no interference, the expected noise level is 0.05 at the 3-sigma level. We see no evidence for any interference between the two beams.

Conclusion

Jon said that there was something strange about this data and that we should do the experiment again. I agree. But before doing that, I wanted to work out the processing strategy using the data we have. I've done that now. I'm actually pleased with this outcome because it is a good example of a null result. That is, the signal in the waterfalls is NOT coming from the Moon, but from some other direction hence is radio interference from Earth.

Jon and I will talk about repeating these measurements on another day. I'll keep you posted.

Gerry

On 11/18/2016 9:59 AM, Gerald Harp wrote:

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>> Haven't heard from you, I see atafx was never started. The moon
>> beamformer data is in obs@tumulus:~/gharp/moonbf. 16 bit real/16 bit
>> im, signed. Centered on 1295.8192MHz, BW 1.092267MHz. About 4 minutes
>> worth.
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