

MY SUMMER VACATION

CARL HEILES

Astronomy Department, UC Berkeley

THE MOST IMPORTANT TECHNICAL PROBLEM WITH GALFA: THE REFERENCE SPECTRUM

The measured correlator power on-source $P_{bb,ON}$ is

$$P_{bb,ON} = G_{IF}[G_{RF}(T_R + T_A)] \quad (1)$$

G_{IF} is the IF gain (e.g. the baseband filter), G_{RF} the RF gain, T_R the receiver temperature, and T_A the antenna temperature.

To recover T_A we must either measure or eliminate G_{IF} , G_{RF} , and T_R . This is normally done by taking a **reference spectrum**, also known as an **OFF** spectrum. One goes off the source, or goes off frequency, so that $T_A = 0$. Then

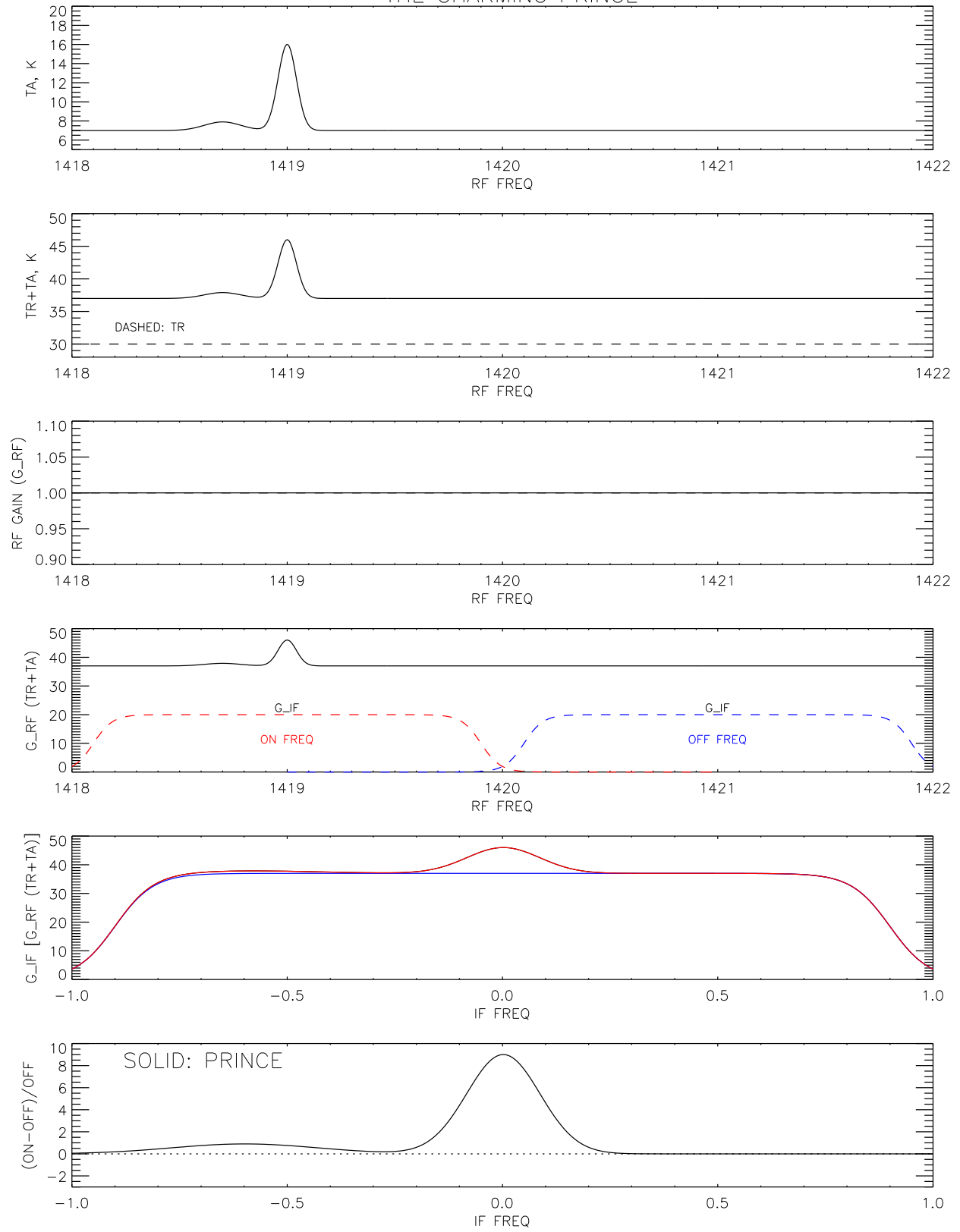
$$P_{bb,OFF} = G_{IF}[G_{RF}(T_R)] \quad (2)$$

and we have the usual

$$\frac{P_{bb,ON}}{P_{bb,OFF}} = \frac{T_R + T_A}{T_R} = 1 + \frac{T_A}{T_R} \quad (3)$$

Make the **standard assumption** that T_R is independent of frequency and you have T_A .

THE CHARMING PRINCE



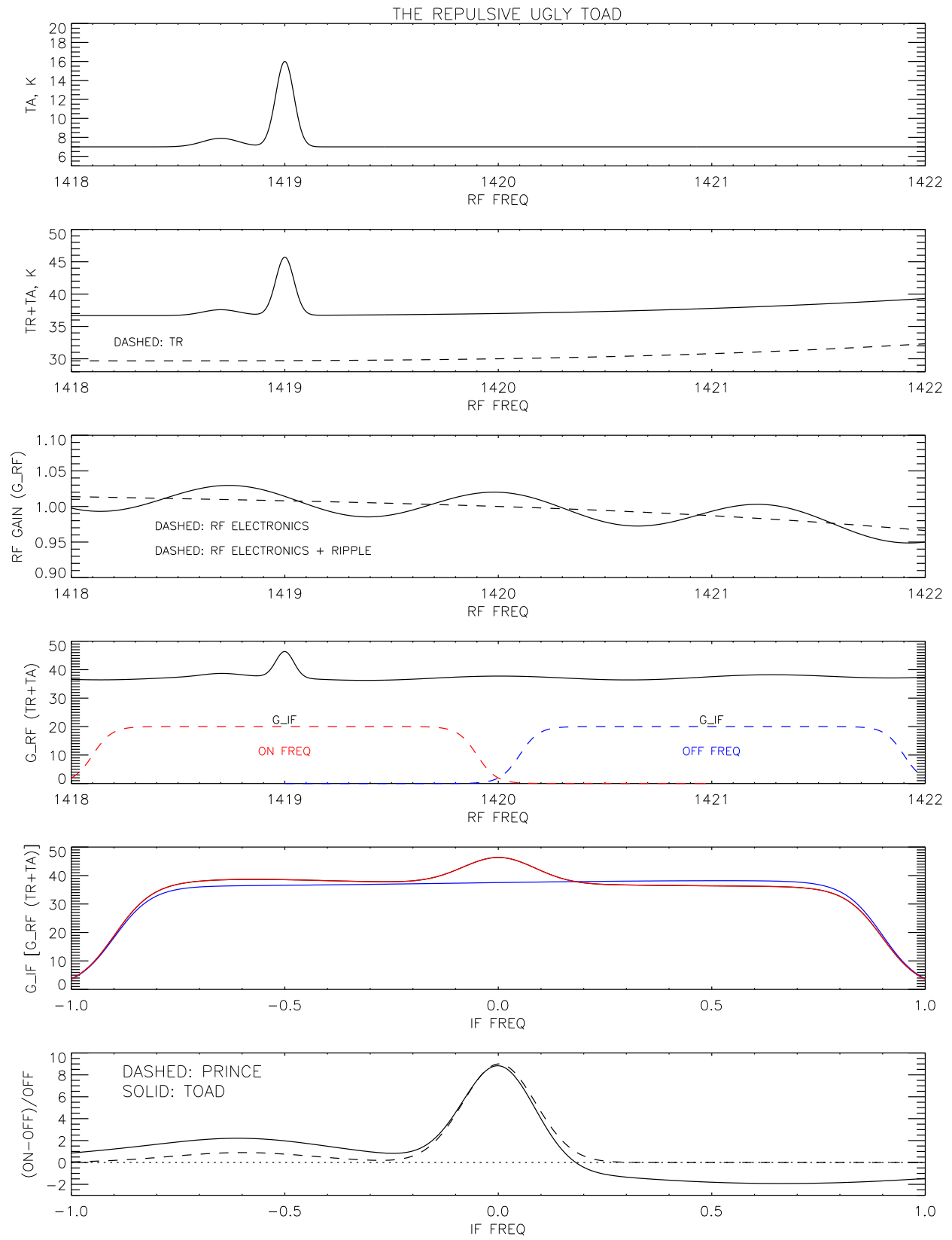
FREQUENCY SWITCHING AT ARECIBO? YOU MUST BE KIDDING...

AT ARECIBO, for Galactic HI you CAN-
NOT GET A GOOD OFF spectrum because:

- There is no position where HI is absent, so you can't position switch
- If you frequency switch, the baseline ripple kills you.

Consider baseline ripple as contributing to G_{RF} : the telescope is like a cavity. At Arecibo, the round-trip travel distance is about 300 meters, or 1 μ s; this gives a **BASELINE RIPPLE WITH PERIOD 1 MHZ, EQUIVALENT TO 200 KM/S.**

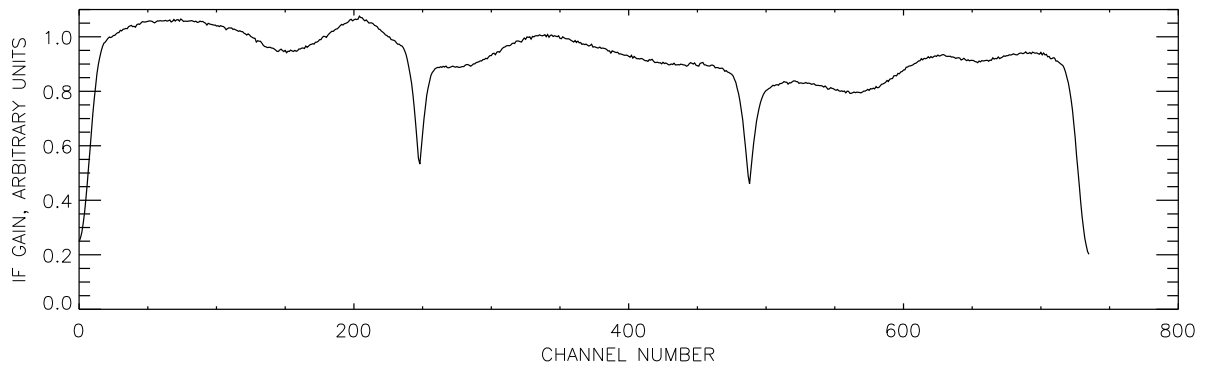
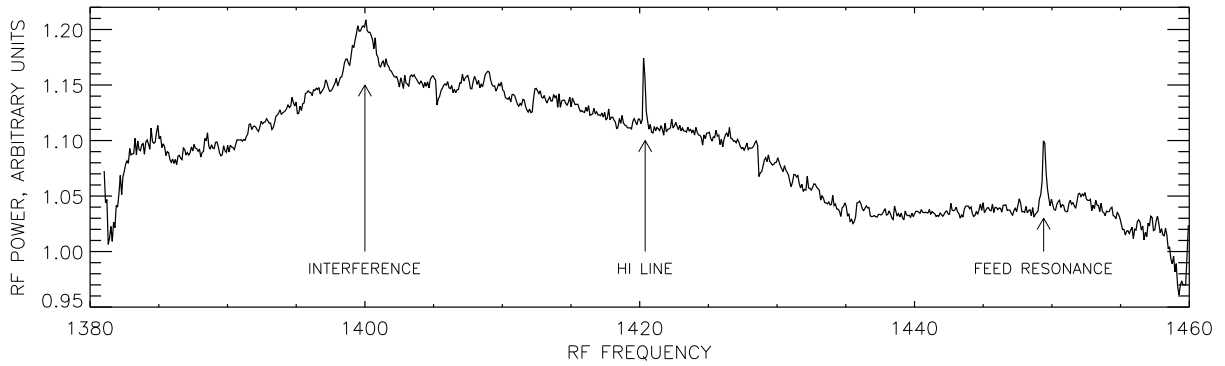
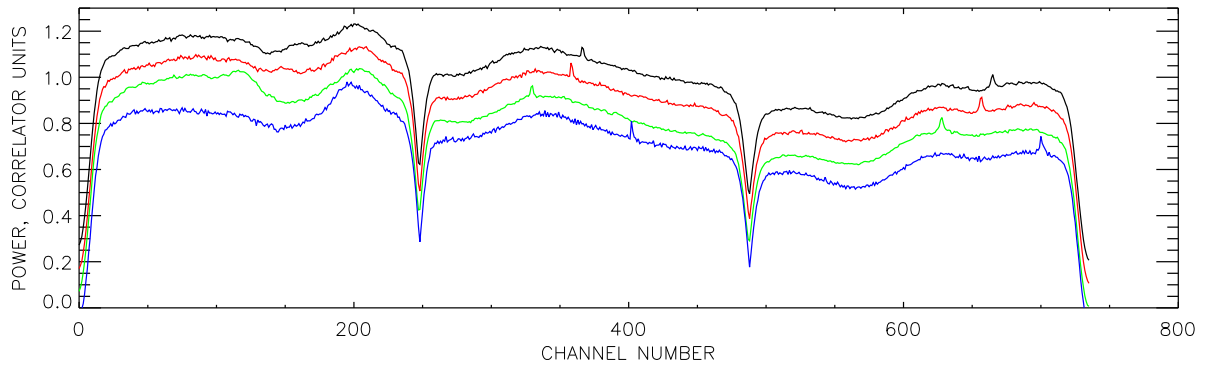
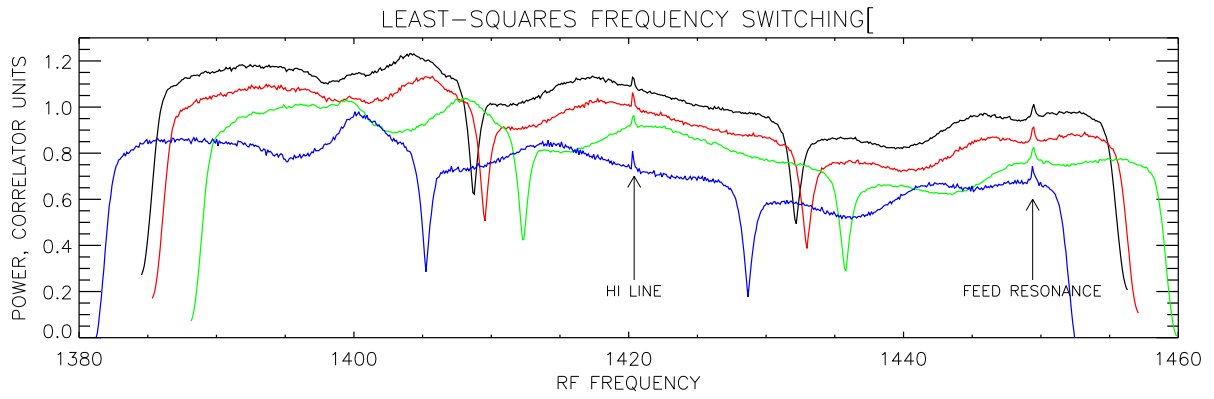
This is comparable to the width of Galactic HI. A serious problem!



**CAN WE KISS THE TOAD?
LEAST-SQUARES FREQUENCY
SWITCHING (LSFS)**

**BY TAKING MEASUREMENTS AT
SEVERAL LO FREQUENCIES, and
PROPERLY ANALYZING THEM WITH
A LEAST SQUARES FIT:**

**LSFS ALLOWS SEPARATION OF THE
IF AND RF TERMS**



TIME STABILITY OF G_{IF}

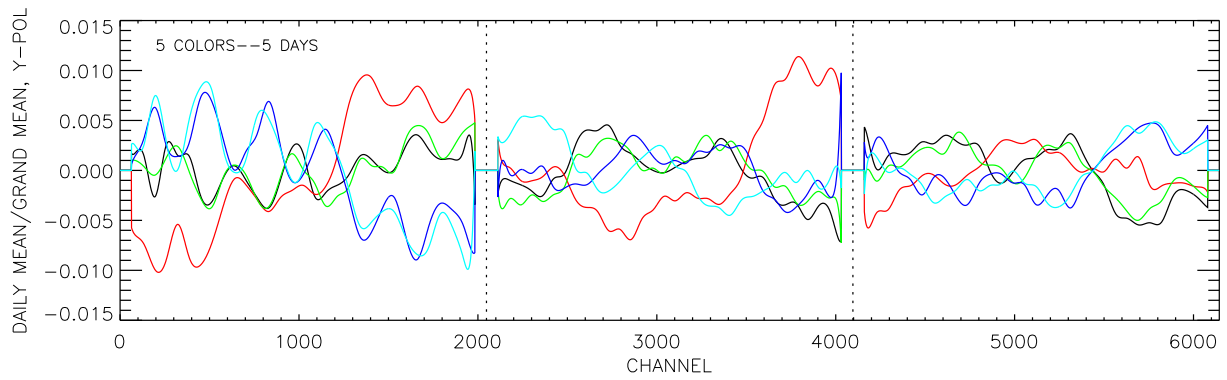
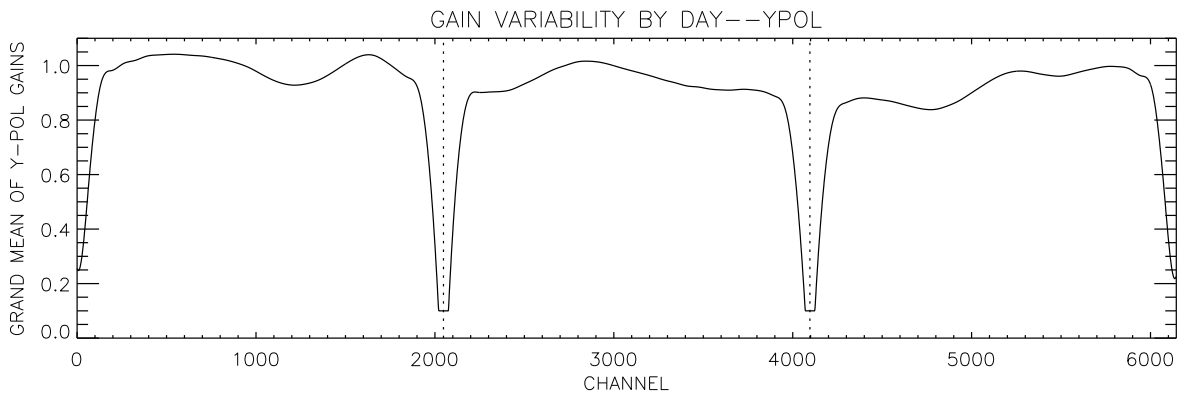
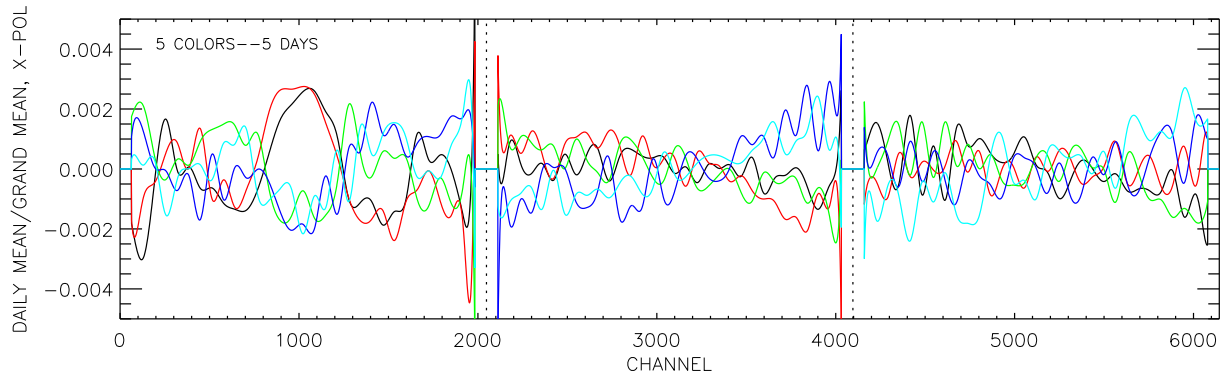
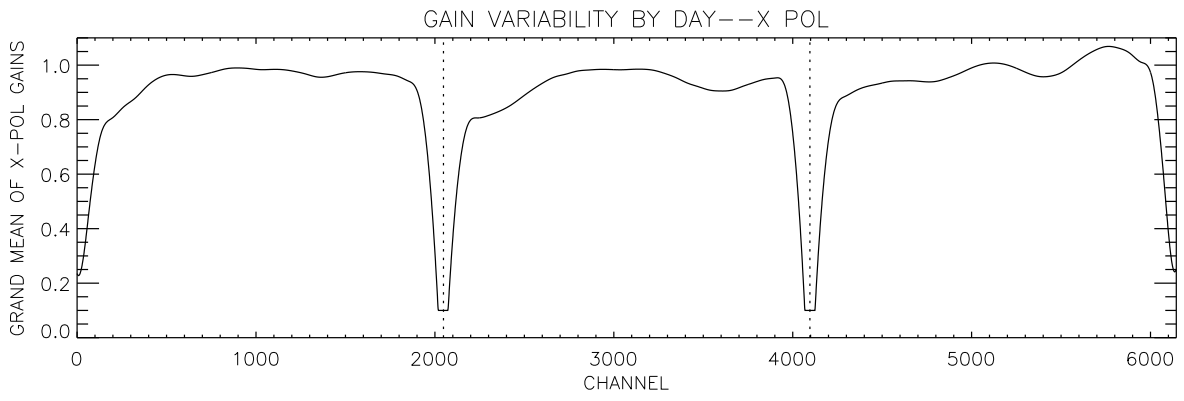
The IF term is G_{IF} .

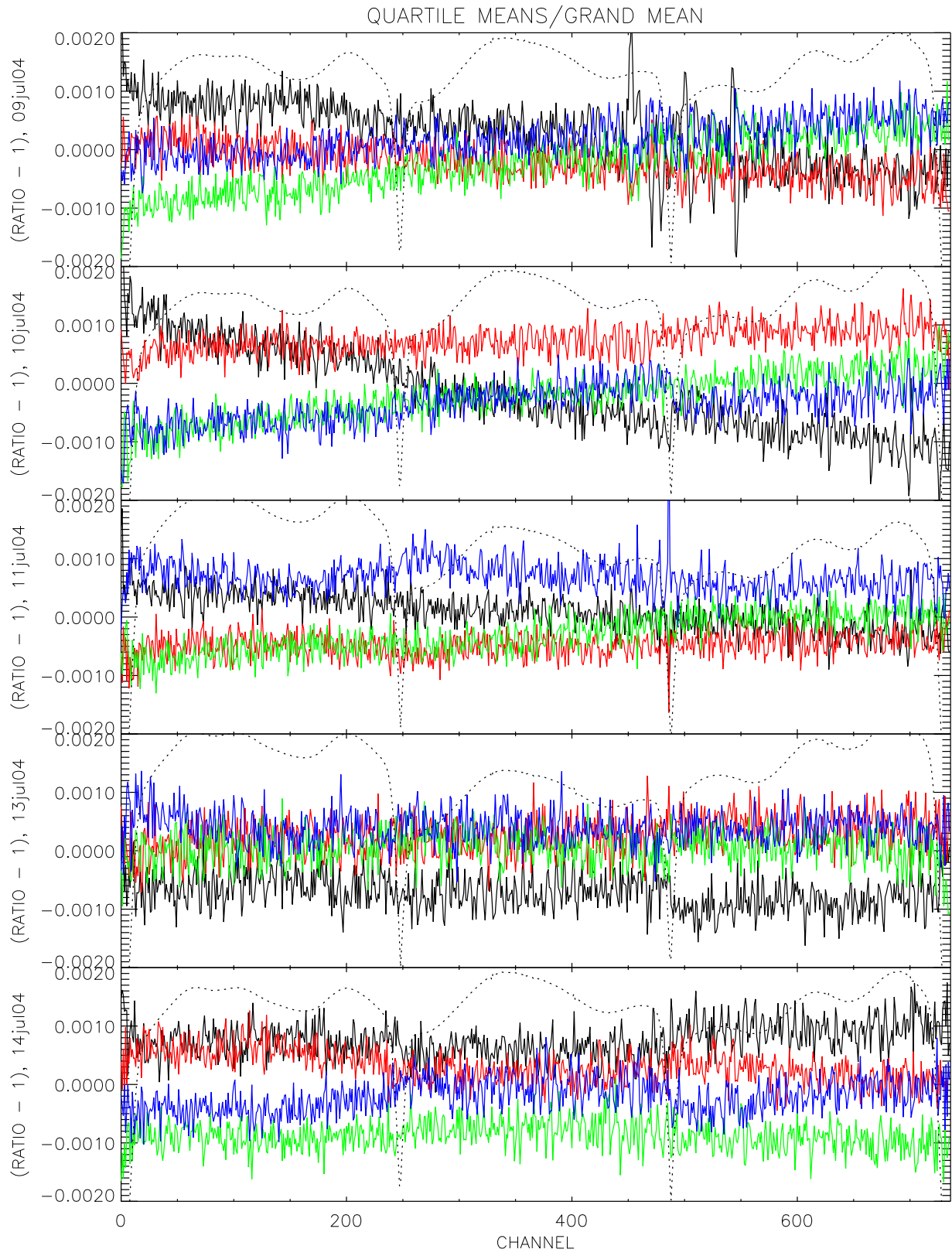
IF THIS IS STABLE, WE CAN MEASURE IT INFREQUENTLY—A HUGE ADVANTAGE!

As it happens:

- **G_{IF} IS RATHER STABLE DURING THE DAY** if the attenuators are left unchanged.
- **G_{IF} CHANGES LOTS FROM DAY TO DAY** as the attenuators are changed.

Because G_{IF} is constant during a day, we measure it once with a fairly long integration and apply it to all of that day's data.





CORRECTING FOR THE IF GAIN G_{IF}

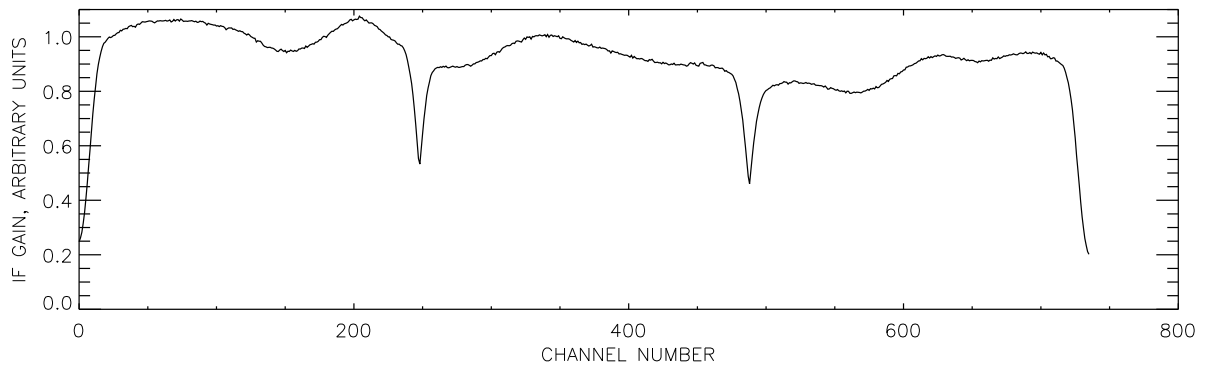
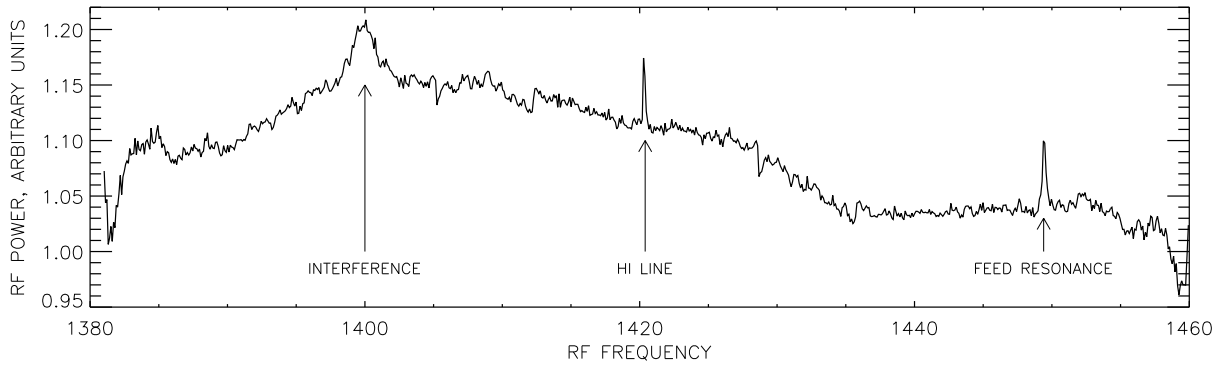
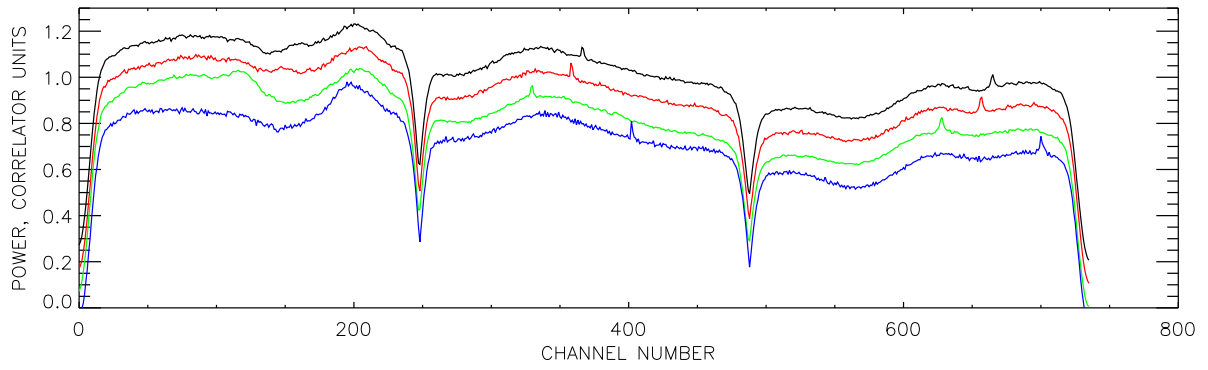
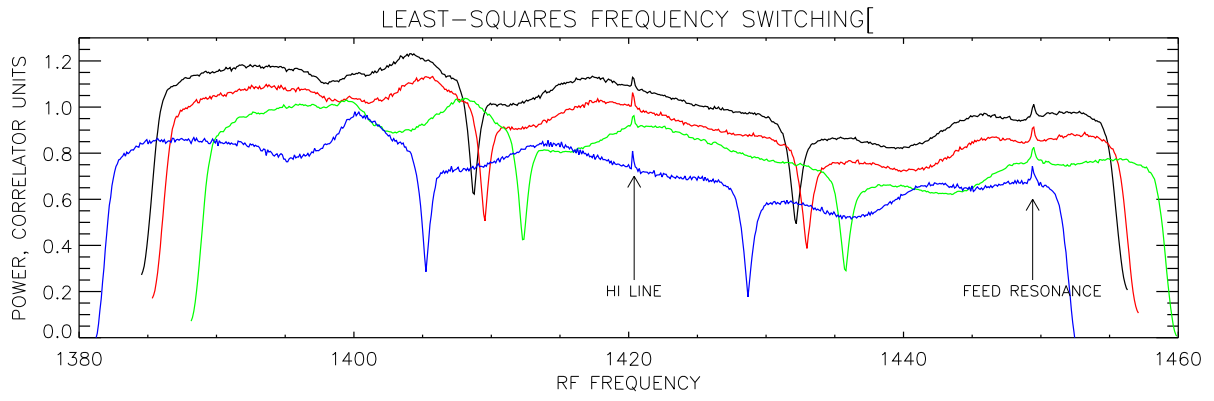
For a given day we derive G_{IF} .

After dividing by all of that day's spectra by G_{IF} , we are left with

EACH SPECTRUM =

$$P_{bb,ON} = G_{RF}(T_R + T_A)$$

The LSFS specrum we showed is this quantity, averaged over time. Look at it again...



CORRECTING FOR THE IF GAIN G_{IF}

There seems to be lots of **NOISE** on this spectrum.

**BUT THIS NOISE IS REALLY BASE-
LINE RIPPLE!**

IT IS PRODUCED BY G_{RF}

We need to measure G_{RF} . It consists of two portions:

1. The slowly-varying “RCVR/FEED” portion.

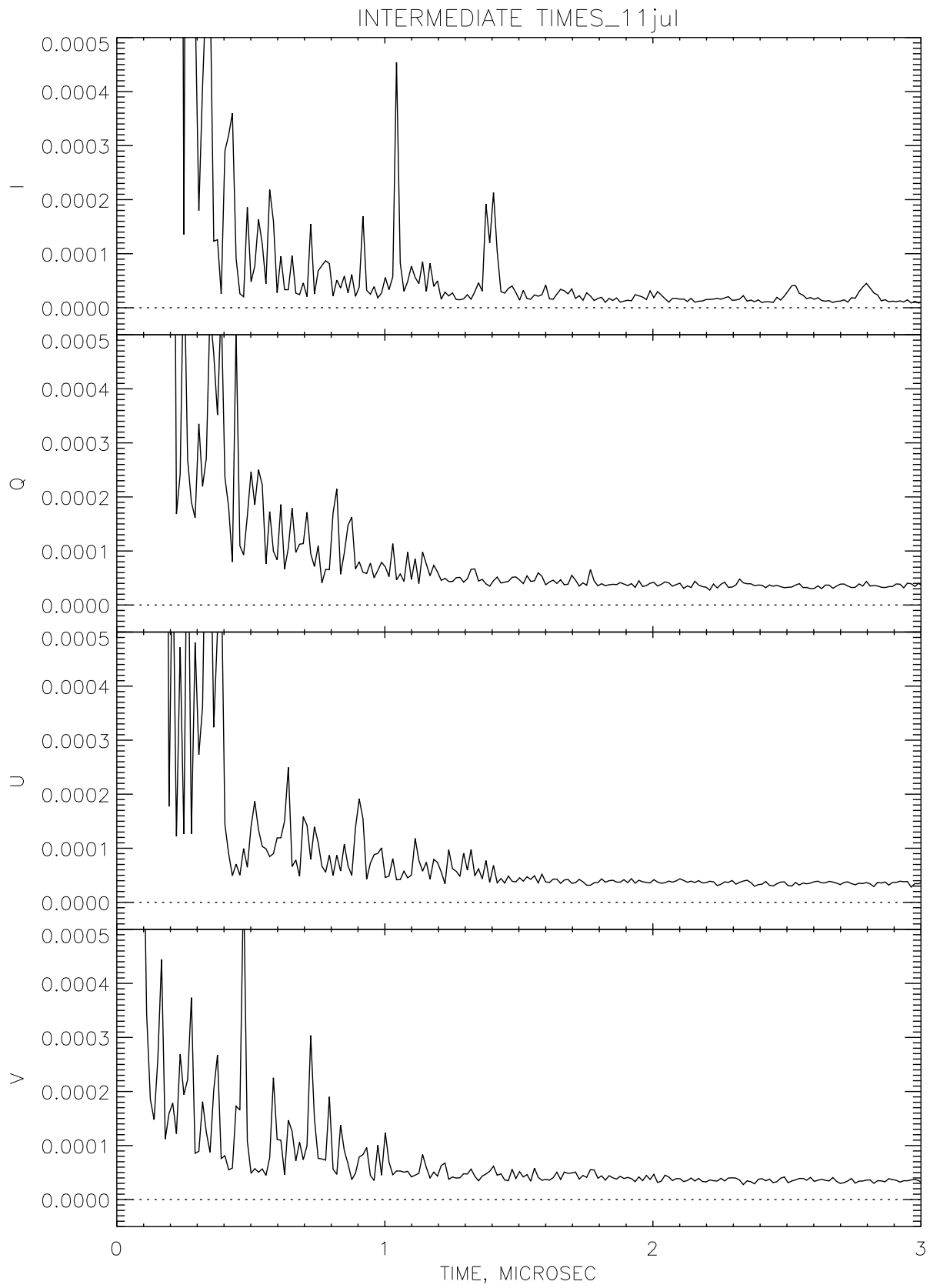
We neglect this for now. It varies slowly with both frequency and time, so it can be calibrated.

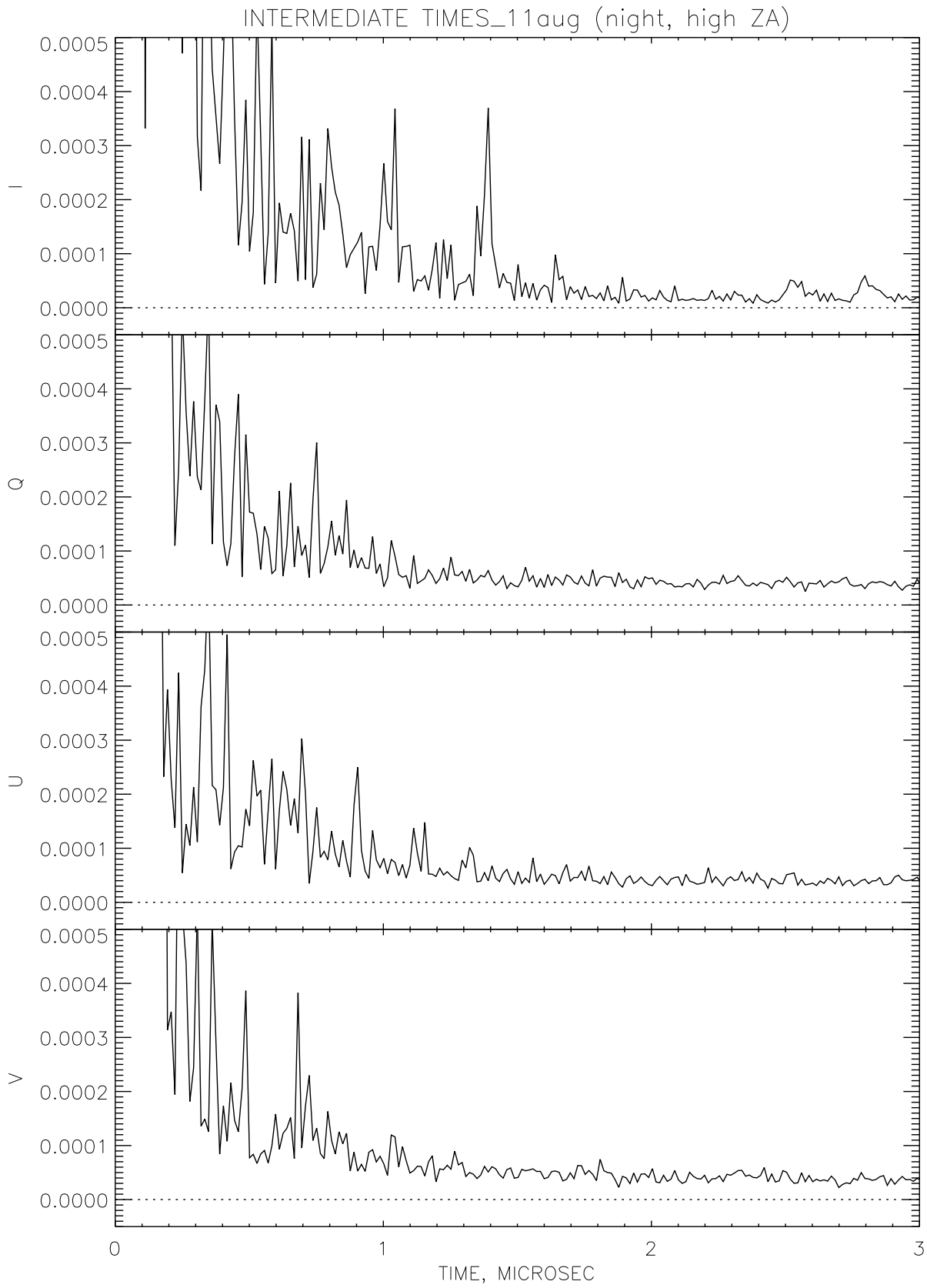
2. The RAPIDLY-VARYING RIPPLE portion.

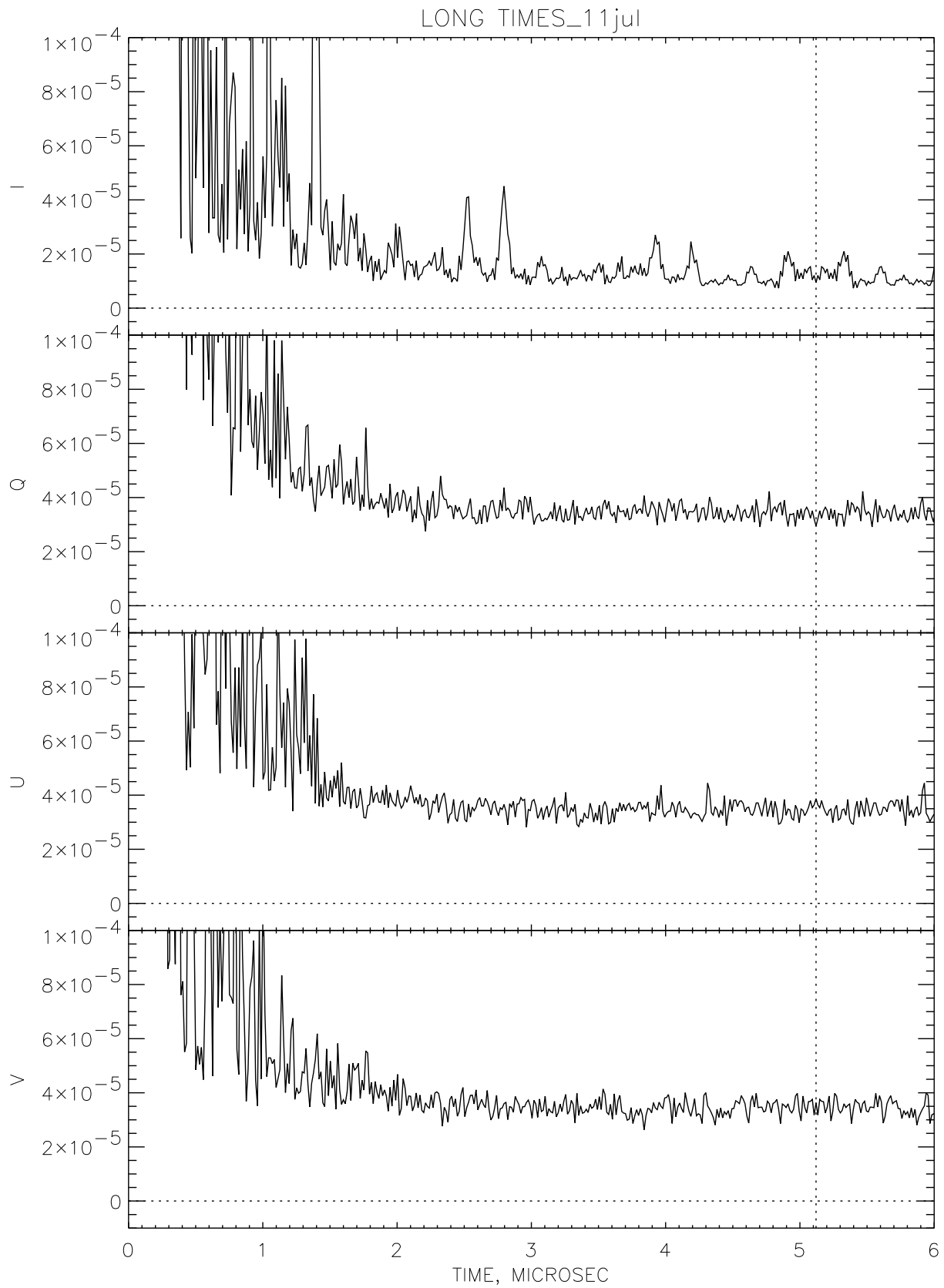
It changes fairly rapidly with **BOTH TIME AND FREQUENCY**.

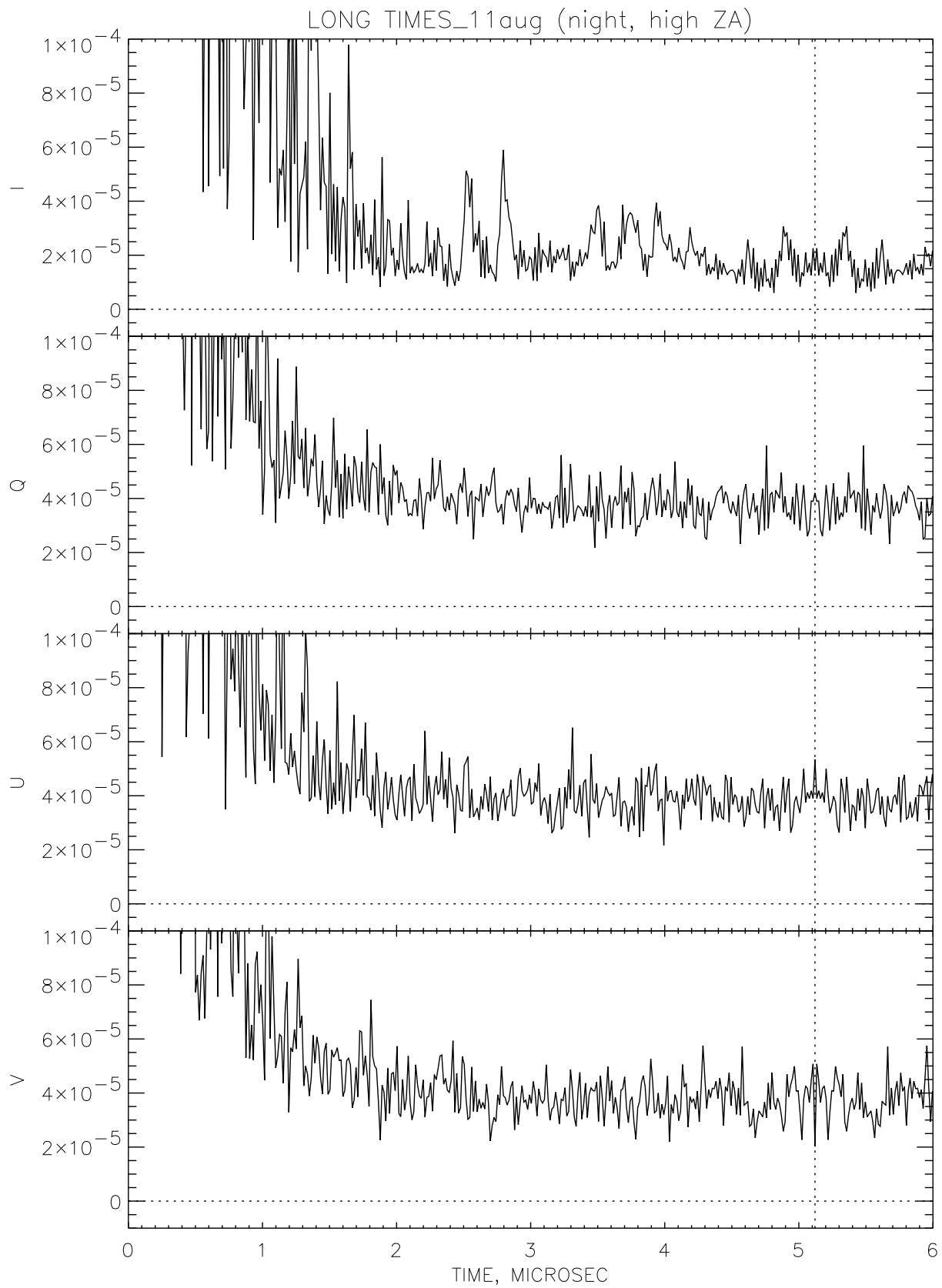
IT MUST BE CALIBRATED ON SOMETHING LIKE A MINUTE-BY-MINUTE BASIS.

The ripple is produced by reflections of the signal, with the return reflection delayed by some time and interfering with the original signal. These time delays can be determined by Fourier techniques.









SOME IMPORTANT SUMMARY CONCLUSIONS CONCERNING RIPPLES

Our most important conclusion:

**OBSERVERS REPORT THAT BASE-
LINE RIPPLE CAUSES MUCH MORE
TROUBLE IN THE LATE AFTER-
NOON THAN AT NIGHT. YET...**

**THE RIPPLE POWER AT NIGHT IS
COMPARABLE TO THAT IN THE
LATE AFTERNOON!!**

We conclude that the trouble arises because the ripple **VARIES WITH TIME**, and the moving Sun contributes significantly—**BUT NOT OVERWHELMINGLY**—to the ripple power at some times of day.

Another conclusion:

RIPPLES ARE PRODUCED BY MORE THAN ONE SET OF REFLECTIONS.

There are significant reflections at $\sim 1, 1.4, 2.5, 2.8, 3.9, 4.2, 4.9 \mu\text{s}$. These correspond to one-way reflection distances ranging from 155 to 735 meters.

155 meters is roughly the feed-to-bowlbottom distance.

Most of the longer times make little physical sense in terms of Arecibo's physical structure. Yet they exist, and they repeat.

And a note: Our time resolution is high, $\sim 0.01 \mu\text{s}$, because our total bandwidth is ~ 78 MHz. Using a wide bandwidth is essential to get the time resolution, and hence the detectability, of the Fourier peaks.

AND ONE MORE THING:

**RIPPLES ARE NOT SIGNIFICANTLY
POLARIZED**

CAN WE REALLY KISS THE TOAD???

We will determine G_{RF} by **MAKING SIMULTANEOUS WIDE-BANDWIDTH (~ 80 MHz) SPECTRA** with our normal narrow ~ 7 MHz spectra. The Berkeley FPGA spectrometers allows this.

- **THE WIDE BANDWIDTH SUPPLIES THE FOURIER COMPONENTS OF THE RIPPLE**
- **THE NARROW BANDWIDTH MEASURES THE HI.**
- **WE SUBTRACT THE FOURIER COMPONENTS OF THE RIPPLE FROM THE HI SPECTRUM.**

IMPORTANT POINT: THIS DOES NOT AFFECT THE HI LINE SHAPE.

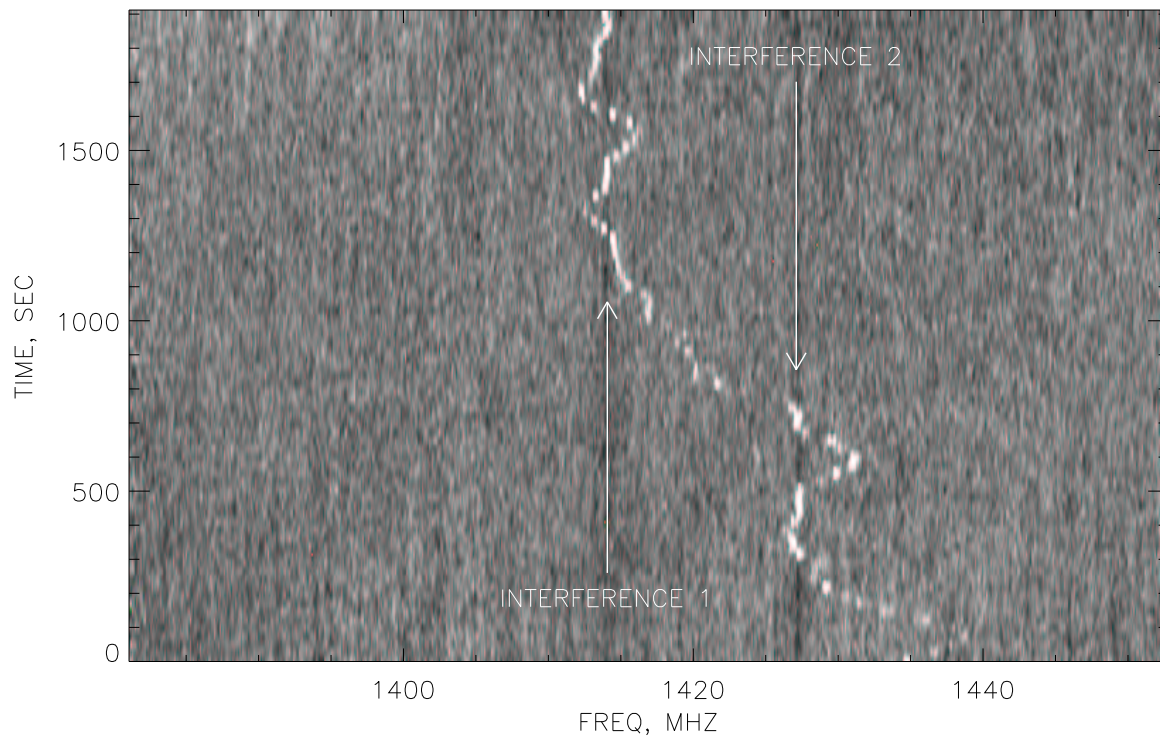
We DO NOT ZERO OUT the Fourier coefficients at the ripple frequencies. Rather, we determine their amplitude and phase and subtract them, thus subtracting the ripple—**AND ONLY THE RIPPLE.**

JUST HOW POLARIZED IS INTERFERENCE, ANYWAY???

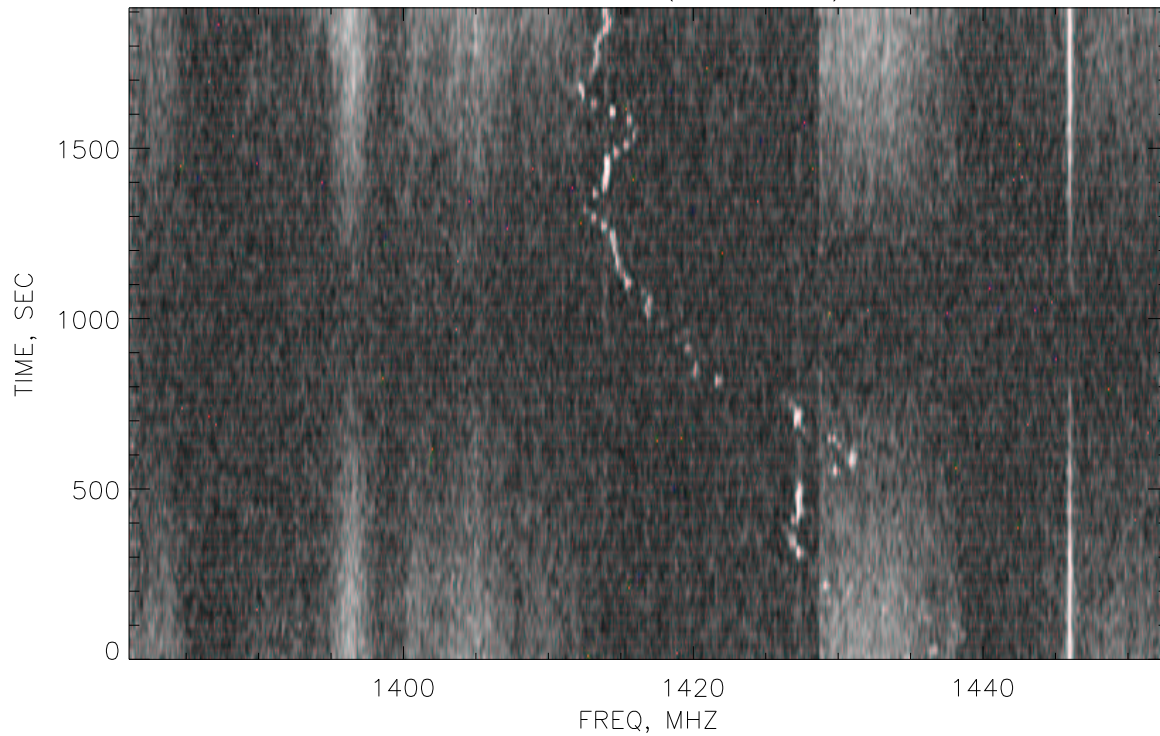
Desh has suggested that interference is partially polarized. If so, the polarized Stokes parameters can be used to determine the presence of interference.

We show some data to illustrate the character of interference. We conclude that interference is partially polarized, so the polarized Stokes parameters are useful diagnosing interference. However, they cannot be used to REMOVE the interference.

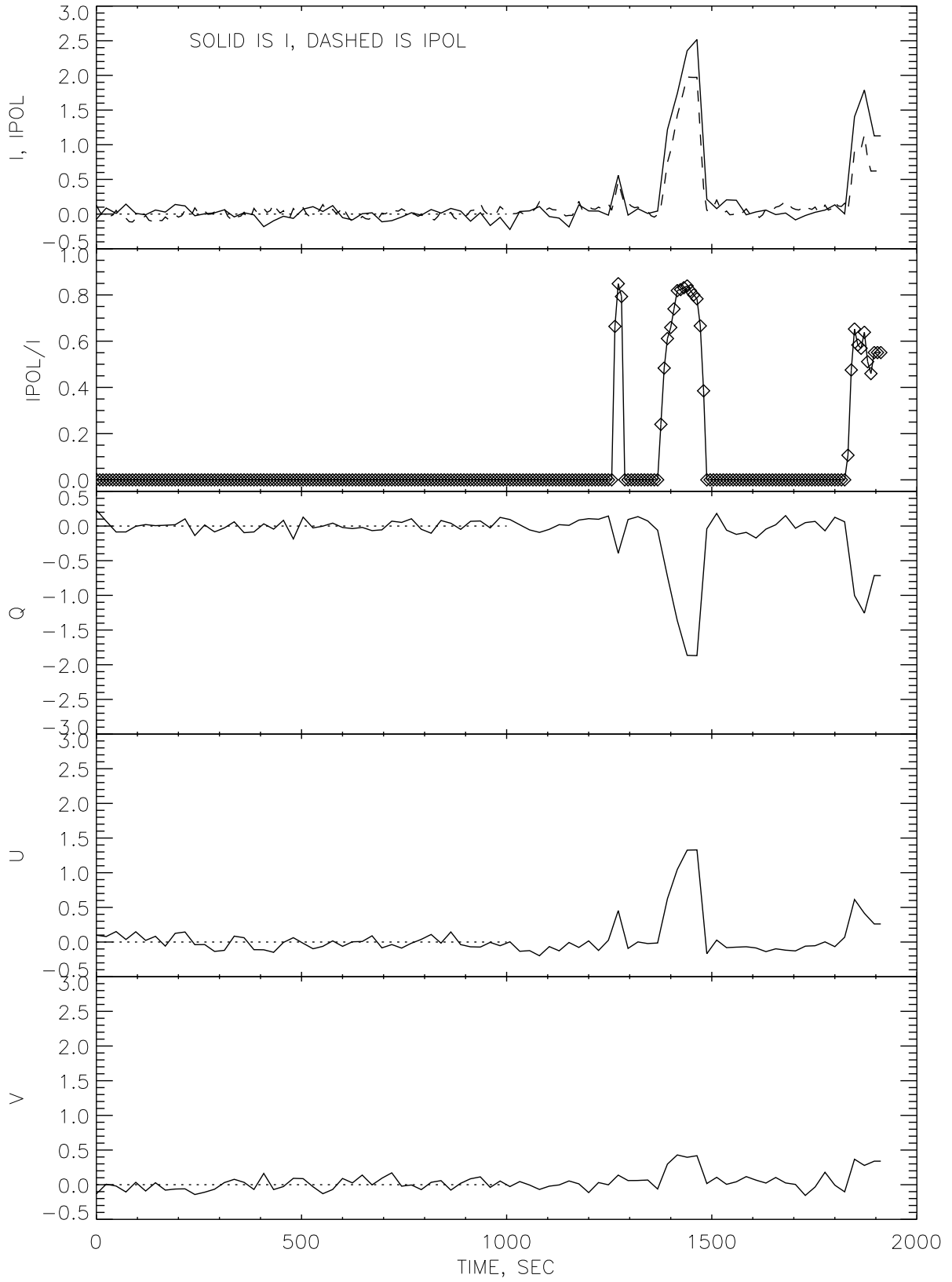
STOKES I



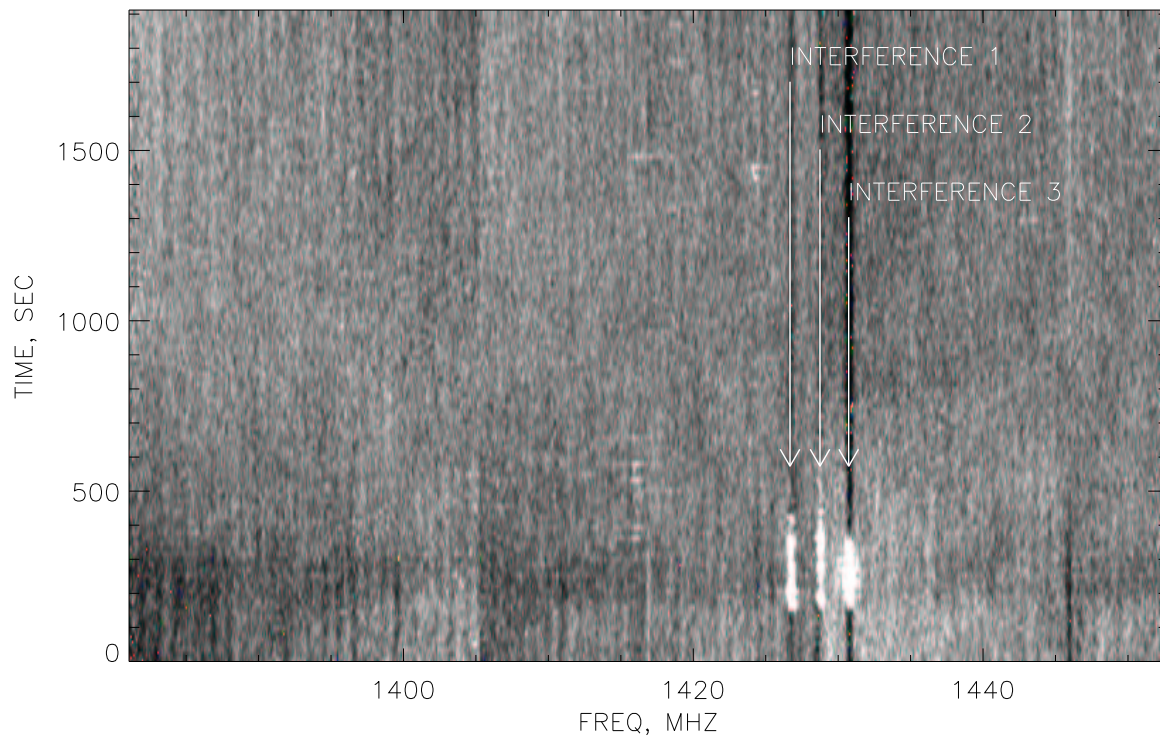
$$\text{IPOL} = \text{SQRT}(Q^2 + U^2 + V^2)$$



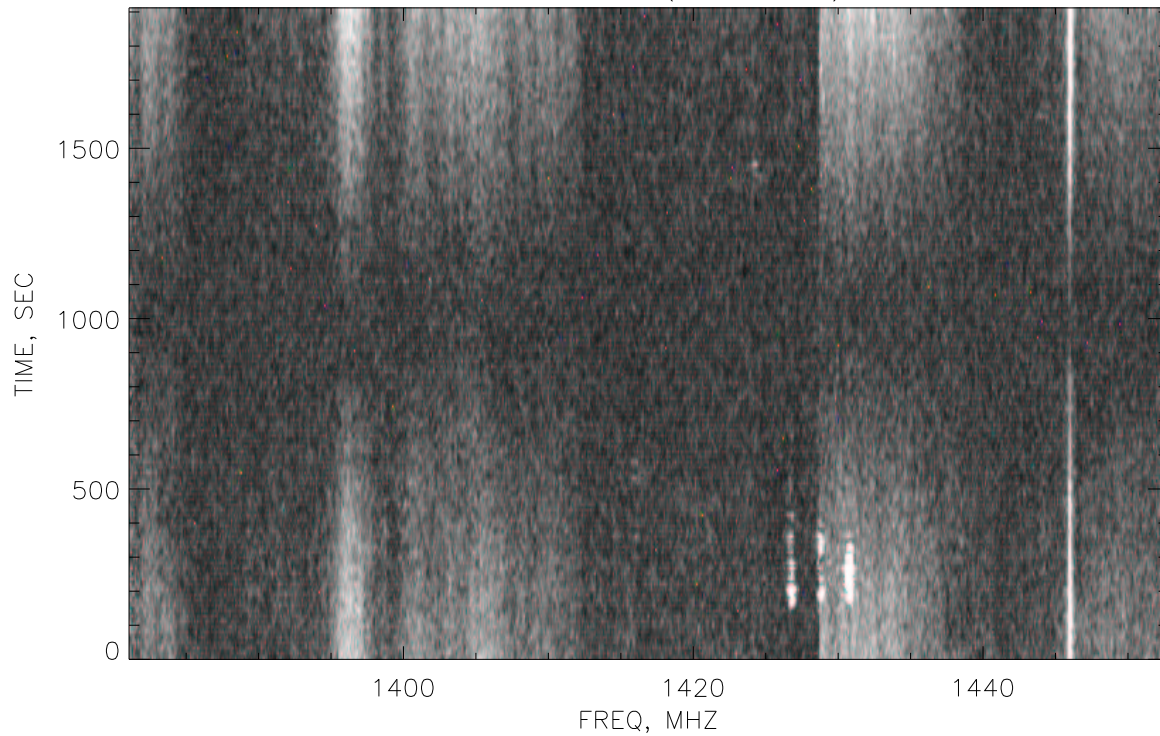
INTERFERENCE 1



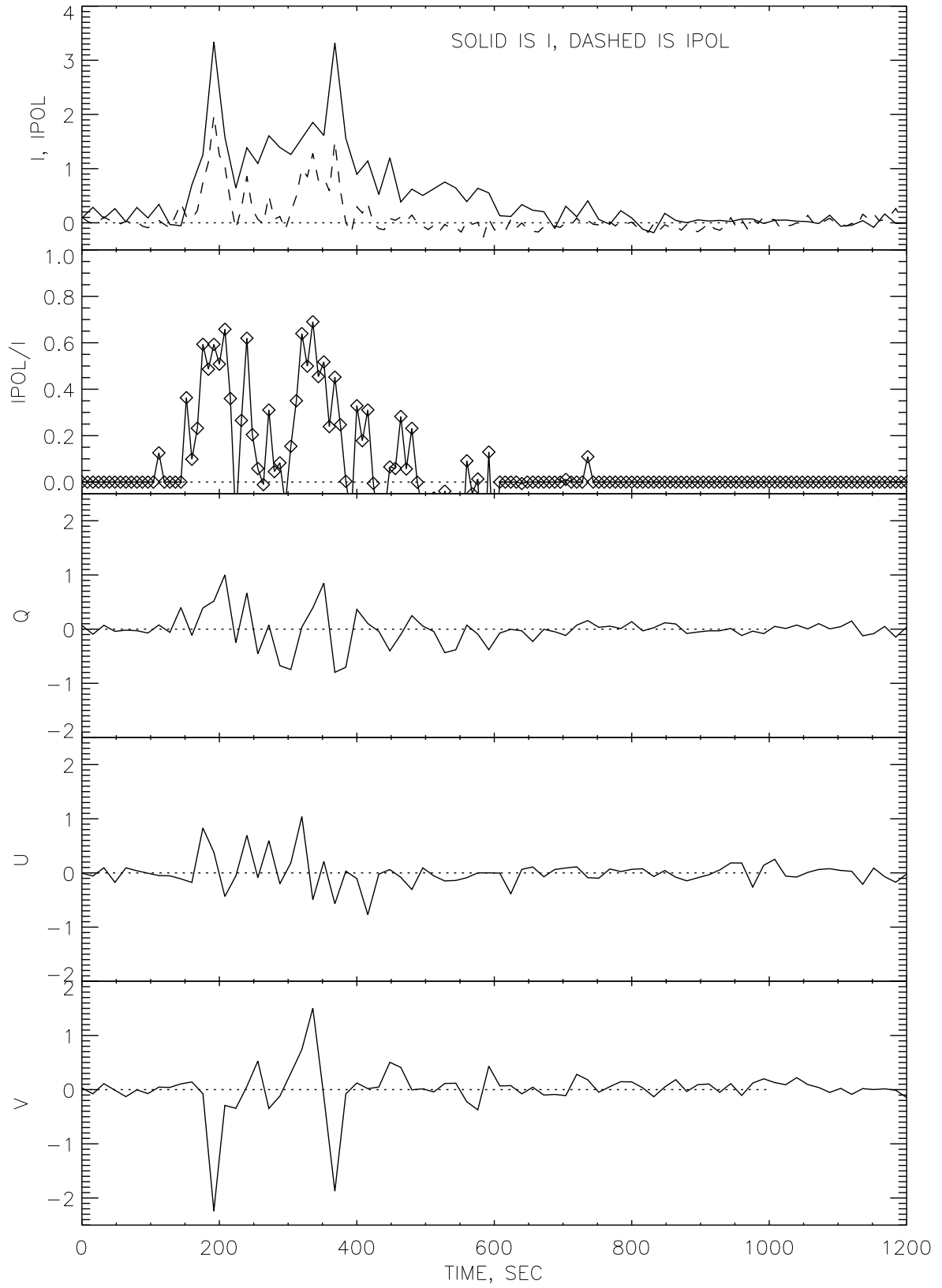
STOKES I



$$\text{IPOL} = \text{SQRT}(Q^2 + U^2 + V^2)$$



INTERFERENCE 2



ALFA PERFORMANCE AT OH

We obtained spider-scan calibration data while ALFA was tuned for OH. Our observations refer to a 100 MHz band covering 1625 to 1725 MHz.

ALFA PERFORMANCE 1625-1725 MHz

