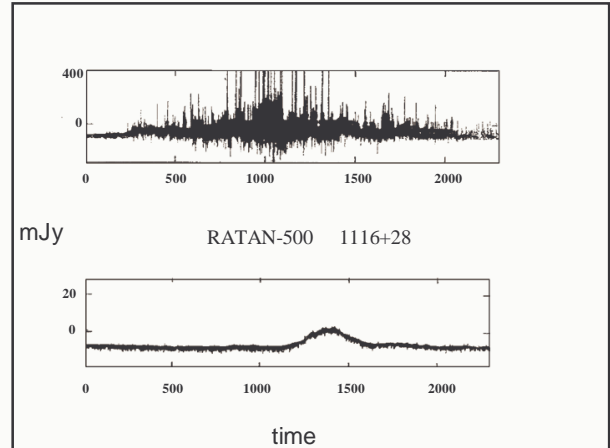


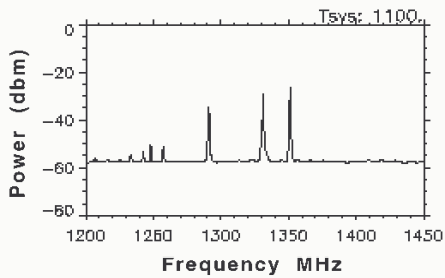
RFI

and how to deal with it

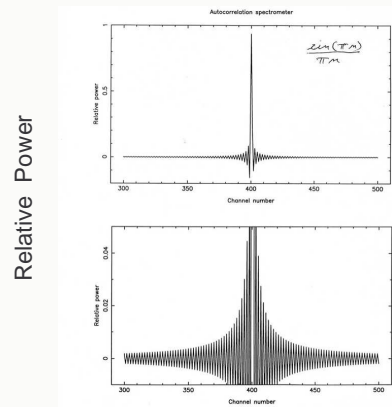
Murray Lewis
(for Rick Fisher)



Hilltop Monitor 1200-1450 MHz



From Autocorrelator spectrometer



RFI and How to Deal with It

- Planning
- Observing Setup
- Data Analysis
- Real-Time RFI Excision

Context

- Generally below 3 GHz
- Arecibo & Green Bank
- Spectral line

Early Planning

General resources of frequency management and RFI control

National Radio Quiet Zone (Green Bank)

Local informal coordination

Radars below 1.4 GHz at Arecibo

Web pages

<http://www.naic.edu/~rfuser/main.html>

<http://www.gb.nrao.edu/nrqz.html>

<http://www.gb.nrao.edu/~rfisher/ipp.html>

Spectrum surveys

<http://www.naic.edu/~rfuser/smarg-plots.html>

<http://www.naic.edu/~rfuser/smarg-vig1.html>

<http://www.gb.nrao.edu/RFI/>

Interference characteristics

Frequency and bandwidth

Intensity distribution

Times of day

Fraction of time to ~one-second resolution

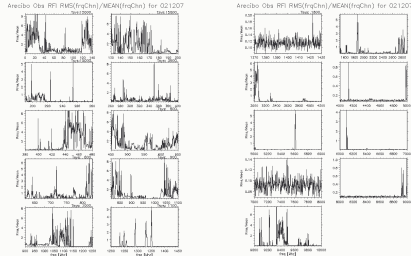
Time-frequency matrix plots

Signal identification

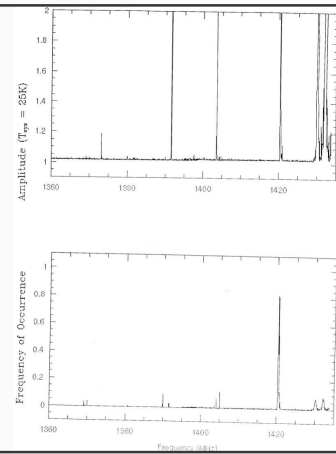
Can any be turned off?

Hilltop-monitor scans

Available on AO Web Page



0 to 10 GHz coverage, as daily averages, rms within a frequency bin, and occupancy versus time



Observing Setup

Dynamic range

Autocorrelation spectrometer

two- or three-bit sampling (bandwidth trade-off)

post-processing convolution (taper) choice

$\sin(\pi n) / \pi n$

Fourier transform spectrometer

multi-bit sampling

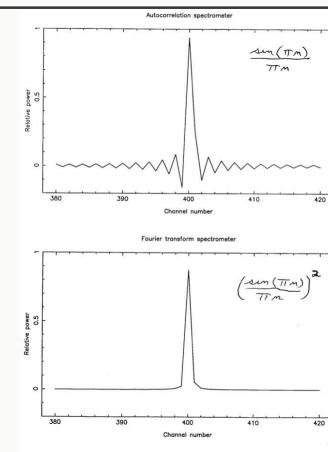
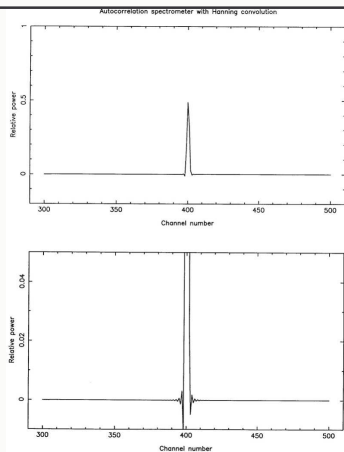
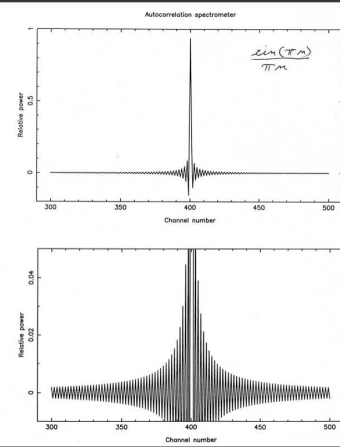
must choose taper at observe time

$[\sin(\pi n) / \pi n]^2$

Time resolution

Will data editing be more effective with shorter integration times?

As fast as 10 spectra per second?
Large data volume



Observing Setup (continued)

Real-time blanking

- 1330/1350 MHz radar at Arecibo
- Iridium 90-millisecond on-off period
- Other? (lightning, ignition noise, etc.)

Receiver filters

Sideband rejection

>100 dB gain in receiver

-100 dBm RFI → 0 dBm (1 volt)

20 K in 10 MHz → -116 dBm

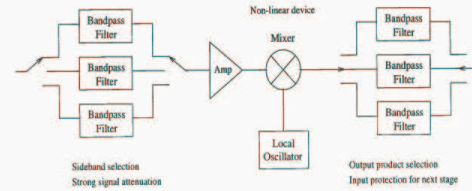
Early filters to protect later receiver stages

Cooled stages overloaded by RFI in main beam

Many mixing and intermodulation products

$$P_{out} \propto P_n^2$$

Think about possible products of known strong signals



$$\text{nb } \sin A * \sin B == 0.5[\cos (A - B) - \cos(A + B)]$$

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Interference characteristics

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Observing Setup (continued)

Optical fibers

Modem noise figure $\approx 5 \times 10^6$ Kelvins

Require about 80 dB of preceding gain

Overload of last pre-amp stage and modem

Data Analysis

Convolution or ACF tapering

Better than Hanning, if required

Manual data editing

Record by record inspection

On-off pair symmetry

Time-frequency matrix display

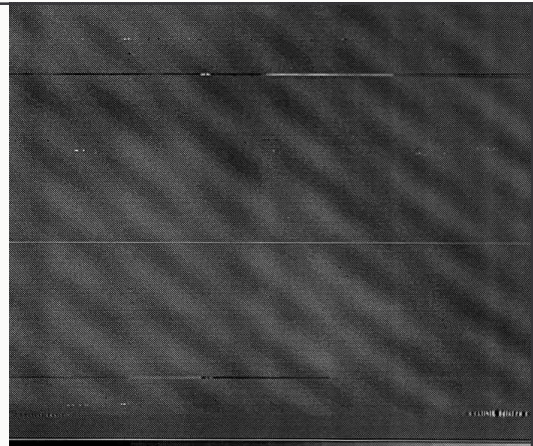
Graphical editing tools

Better picture and visual detection

Data quality measures

Rms, peak, and statistical asymmetry in each spectral channel across records in a scan

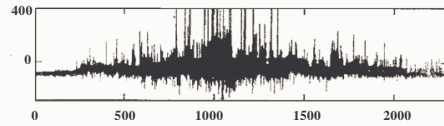
Polarization



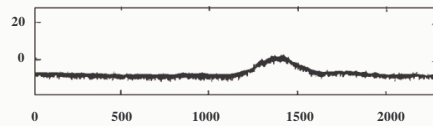
Data Analysis (continued)

Automated editing

- Hard to duplicate manual editing
- Requires substantial differences between RFI and noise
- Threshold detection and deletion
- Median "averaging"
- Requires gain stability and low duty cycle of RFI
- Frequency editing with excess resolution



RATAN-500 1116+28



Diagnostics and Reporting

Objective: where is the RFI source and what is it?

- Internal to receiver
- Local
- Distant transmitter

Timely reporting is often very helpful.

Be as specific and informative to engineers as possible

- Frequency
- Bandwidth and intensities (example spectra)
- Time, duration, and any periodicities
- Dependence on telescope position
- Polarization (same or different intensities, variability)
- Observing parameters (integration time, switching mode, LO setting, filter selections, etc.)

Real-Time RFI Excision

Temporal Blanking

Cancellation

Null-Steering

Post-Correlation Cancellation

(All benefit from added information)

Active field of research

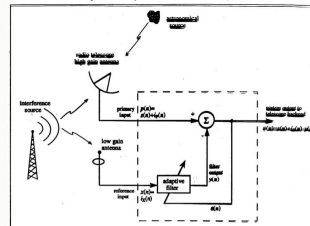
<http://www.atnf.csiro.au/SKA/intmit>

Real-Time RFI Excision

Added information

Signal properties

Concept of Adaptive Interference Cancellation



An ideal adaptive interference canceling system for use on a radio telescope is shown above. The telescope receiver, located at the prime focus, forms the primary input to the canceler. This input consists of the desired astronomical signal, $s(n)$, entering through the main beam, as well as undesired interference, $i_p(n)$, entering through the telescope sidelobes. A second receiver connected to an low-gain antenna forms the reference input, $i_s(n)$, to the canceler. This input consists of only the interference, $i_s(n)$, which is uncorrelated with the astronomical signal but correlated in some unknown way with the interference in the primary channel. In the reference channel, the interference is filtered to produce the output, $y(n)$, that is a close replica to $i_p(n)$. This filter output is subtracted from the primary input, $s(n) + i_p(n)$, to produce the system output, $e(n)$. Minimizing the total output power in $e(n)$ will minimize the output interference power in $e(n)$.

Real-Time RFI Excision (continued)

Null-steering

Similar to adaptive cancellation

Same signal-to-noise requirements

Single dish with auxiliary antennas

Multi-element arrays

Possible astronomical signal degradation

Post-correlation cancellation

Phase preserved in correlation process

Best when correlation with good RFI reference channel

After data recorded

Can try different parameters

Less computationally intensive

Requires large correlator

Small but active research field

<http://www.atnf.csiro.au/SKA/intmi/>