Spectral Requirements and Interference Excision in Broadband Radio Telescopes

Dynamic range

Digital signal processing assumes linearity

Noise power to max power margin
fiber modem: \( kTB = -43 + \log(BW \text{ in GHz}) \) dBm
common amplifiers prefer max of -10 to 0 dBm

Digital conversion range (6 dB per bit)

Frequency resolution

Gaps between RFI signals (\( \leq 0.1\% \) resolution desirable)

Time resolution

Adaptive canceling time scales (milliseconds)

Radar? (microseconds)
peak power 30 dB above average

RFI excision options

Blanking (time or frequency)

Coherent cancellation

Null-steering

Post-correlation

Self interference!!
Four-Meter Antenna Temperature of Sun and Strong RFI

RFI power averaged over 10% bandwidth

- TV, main beam
- Audio Satellite main beam
- TV, 0 dBi
- Audio Satellite, 0 dBi

Log(Antenna Temperature in K) vs. Log(Frequency in GHz)
Flux Density of Sun and Strong RFI

RFI power averaged over 10% bandwidth

- TV
- Audio Satellite

Log(Flux Density in Jy) vs. Log(Frequency in GHz)

- Active Sun
- Quiet Sun
ARSR-3 RADAR Spectrum, clip: F fraction: 1

ARSR-3 RADAR Spectrum, blanked 150 us, 0.95 - 1.25 sec
Real-Time RFI Excision

Added information

Signal properties

Better sample of RFI

Optimized weak RFI detection

Blanking

1 to 1000 milliseconds

Detection (and tracking) task

Non-contiguous-samples spectrometers?

Cancellation

Adaptive filter

High signal-to-noise reference RFI sample

Complex delay compensation and tracking

Parametric

A priori signal knowledge of signal

Solution and tracking of limited number of parameters

E.g., delay, phase, Doppler, intensity of GLONASS
Figure 2

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, \( x(n) \), to the canceler. This input consists of only the interference, \( i_x(n) \), 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 real time.
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/intmit