Design and Demonstration of an Interference Suppressing Microwave Radiometer

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RFI Issues for Microwave Radiometers

- A microwave radiometer is a sensitive receiver measuring naturally emitted thermal noise power within a specified bandwidth.

- Human transmission in many bands is prohibited by international agreement; these are the “quiet bands” ideal for radiometry.

- L-band channel quiet band is 1400-1427 MHz: larger bandwidth would improve sensitivity if RFI can be addressed. No quiet band available for C-band radiometers.

- Even within quiet bands, RFI has still been observed - possibly due to filter limitations or intermodulation products.

- Many interferers are localized either in time or frequency: should be relatively easy to detect and remove with an appropriate system.
Outline

- Design of an RFI suppressing radiometer
- Description of our implementation
- Experiment description
- Initial results
Typical radiometer is a very “slow” instrument: power received is integrated up to msec scales by analog system before being digitized.

Typical radiometer has a single, large bandwidth channel: susceptible to narrow band interference.

Our design uses a digital receiver to allow much more rapid sampling of incoming data; this rapid sampling improves the ability to mitigate temporally localized RFI.

Our design also performs a 1024 point FFT operation; improves ability to mitigate spectrally localized RFI.

Processor must operate in real time so that final data rate can be reduced to a manageable level; implement processor in hardware (FPGA’s).
System Block Diagram

Antenna → Low-noise front end → Analog Downconverter → ADC → Digital Downconverter

Asynchronous Pulse Blanker → 1024 point FFT → Frequency domain blanker (not yet implemented)

Integration → Data Recording/Control
Example: Time Blanking of an ATC Radar

- Time domain results:
  - Direct path Multi-path?
  - APB “Blanking” decision

- Effect of varying APB threshold in frequency domain:
  - “Max held” spectra
  - Averaged spectra
Digital Back-End

- System design includes digital IF downconverter (DIF), asynchronous pulse blanker (APB), FFT stage, and SDP operations
- Dual channel implementation completed
- Most blocks on separate boards to simplify testing and reconfiguration
- Microcontroller interface via ethernet for setting on-chip parameters
- Second prototype uses Altera "Stratix" FPGA’s: approx 10000 LE, $260
- Designs for all components complete; DIF, APB, FFT, SDP, and capture card initial implementations functioning
Current Digital Back-End Implementation

- Modular form used for processor boards: note microcontrollers
- EEPROM's on each card for autoprogramming of FPGA's on power-up
Experiments at OSU

- Experiments designed to demonstrate radiometric accuracy in the presence of interference
- Observations of a large water tank; external cal sources are ambient absorbers and a sky reflector
- Highly accurate ground-based radiometry is tough due to contributions from objects not under view, including reflections
- Keep cal targets exactly the same size as pool to reduce these effects; observations of pool as ambient temp varies also

- Initial tests in existing RFI; artificial RFI to be added as tests progress
Antenna/Front End Unit

- Front end Tsys approx. 200K neglecting antenna

Temperature control used to maintain internal standards; rest of system not temperature controlled

Terminator total power within 0.01 dB over ~1 hour after noise diode stabilization
Dual Channel Downconverter

- One channel is ~1325-1375 MHz, other is ~1375-1425 MHz

- Downconverter, digital receiver, computer, and thermal control systems in rack inside lab

- Working with system gain ~70 dB at present: moves –94 dBm in 100 MHz to –24 dBm; this triggers 4-5 ADC bits
Pool and Cal Targets

- Water pool is approximately 16’ x 32’ by 6” deep; use saline water to decrease skin depth and eliminate sub-pool contributions
- Absorbers are 12” (a few 18”) to cover the area; mounted on “racks” that can be placed on pool by a team of 2-4 people
- Reflectors are foil covered foam

- Temperature of pool, absorbers, and ground around pool all recorded; salinity of pool checked for each experiment
Pool and Cal Targets

Absorbers: Assume $T_b = T_{phys}$

Reflectors: Assume $T_b = T_{ref} \sim T_{sky}$?

Water: $T_b \sim T_{wat} + Q T_{ref}$

Possible background contributions make precise calibration tough; data analysis to sort out these effects currently in progress.
Current Experiment Results

- Hardware integration period 21 msec, switched every 1.33 secs through front end states, every 5 seconds through receiver mode

Horizontally polarized data, absorber observation

Radar at 1331 MHz apparent, along with other more CW RFI

Blanker reduces radar effects, as well as saturation problems in FFT computation
Initial Calibrated Brightnesses

- Water observation using absorber/reflective cal, horizontal pol

Blanker dramatically reduces influence of radar at 1331 MHz

CW RFI in band not affected by blanker

Some spectral features remain in blanker on data; caused by calibration issues

Absolute value near expected water brightness

Working to improve calibration/accuracy of this experiment
Total Power Measurement Vs. Time

- Water observation using absorber/reflector cal, horizontal pol

Radar causes periodic huge change in total brightness; also a calibration bias through effect on absorber/reflector

Blanker greatly reduces these effects

Frequency domain blanker implemented in software; simple threshold of brightness data

Narrowband RFI not a major impact on total power in this experiment
Digital receivers have the potential to greatly improve radiometer performance in the presence of RFI: essentially a using a more capable receiver

Many options available beyond those chosen in our implementation; our basic algorithms still show reasonable initial performance

Still working to refine demonstration; improve accuracy to be able to demonstrate suppression of smaller RFI effects

We have also operated an L-band RFI monitoring system in aircraft experiments to gather data in a wider range of environments

Our system will be operated in C-band aircraft experiments in 2004 to explore suppression performance and to gather C-band RFI environment data