

Interference Canceling for Improved Coexistence Between Passive and Active Radio Systems

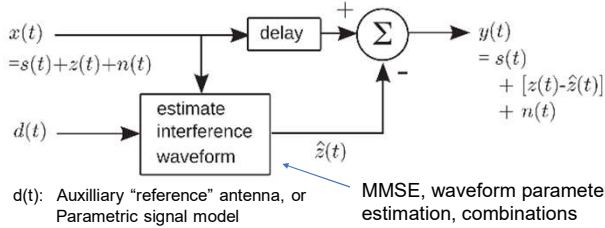


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Background & Objectives

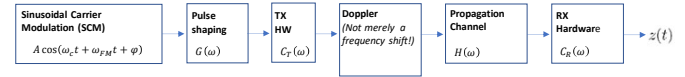
Working toward a look-through capability for radio telescopes via feed-forward coherent time-domain canceling (FF-CTC):



YouTube Video: "Techniques for Observing in the Presence of Satellite Interference" (Background)

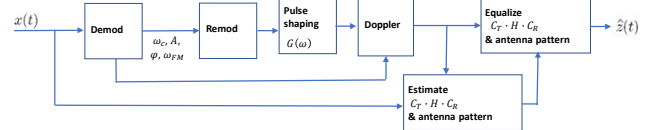
Parametric Approaches

Signal model:

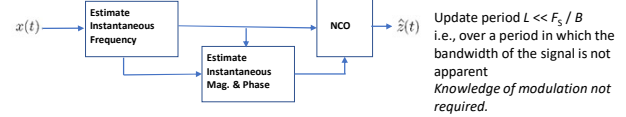


Two Parametric Strategies:

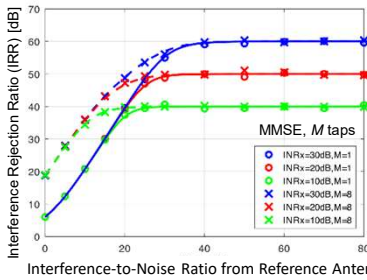
#1: Demod-Remod (single carrier case shown)



#2: Short Time Sinusoidal Analysis (STSA) (single carrier case shown)



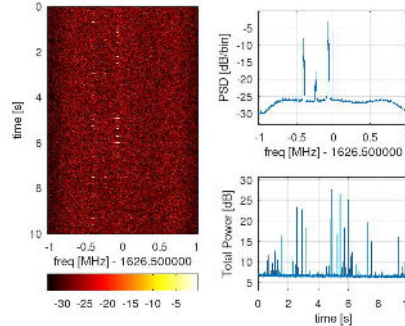
Reference Antenna Approach



- We have worked out accurate expressions for performance with respect to INRs and M for a variety of MMSE-based techniques
- Need a reference antenna that delivers $\text{INR} > 20$ dB (best IRR, low noise injection)
- Astronomy signal must not be significant in reference antenna output

Ellingson & Buehrer (2022), *PASP*, DOI: 10.1088/1538-3873/ac9b92

Case Study: Iridium



- Each signal:
- $B = 31.5$ kHz bandwidth
 - 20.32 ms bursts:
 - 2.56 ms pilot tone
 - 0.48 ms BPSK sync
 - 17.28 ms QPSK data

This structure facilitates comparison of performance when the STSA assumption does vs. does not strictly apply

- STSA:
- $L \ll F_s / B = 65$ samples; Will use $L = 0.17 F_s / B = 11$

Detection

Detection is essential - canceler must not be allowed to operate unless interference is present and IRR can be improved

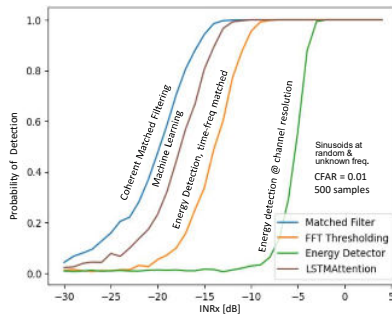
Machine learning outperforms every technique considered except coherent matched filtering (i.e., matched to waveform)

Machine learning method demonstrated here is "LSTM with Attention", found to be best performer in this application

Other high-performing machine learning methods evaluated:

- TSSequencer
- Inception/Xception plus
- Minirocket and other Rocket classifiers

Difference between the high-performing machine learning methods is small



Data Acquisition & Sharing



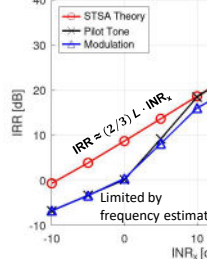
- "Small Aperture Telescope Testbed" (SATT)
- 2 x portable 21 dBi grid paraboloid on az-el mount for sidereal and/or LEO satellite tracking
- Radiometric and/or interferometric detection of continuum astrophysical sources throughout L-band for meaningful interference mitigation experiments



Repository of publicly-available data:
Repoman-rfcap
<https://ellingsonvt.info/rfcap/>

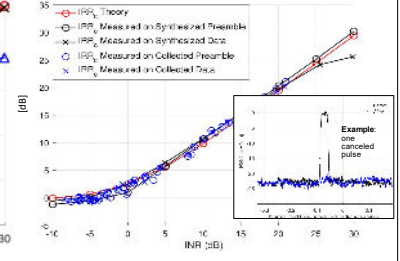
Theory vs. Simulation

$L=0.17F_s/B$



10 s recorded data $\rightarrow \sim 100$ bursts

"IRR_c": total power before / total power



Findings:

- Parametric methods better at low INR, reference antenna methods better at high INR
- Impact of low INR: Poor detection, frequency estimation limited, "noise eating"
- Importance of stationarity; esp. antenna pattern (Sengupta & Ellingson (2023), *IEEE Int'l Ant & Prop. Sym.*)

Work in Progress

- Performance in *bona fide* astrophysical observations (see "SATT", left); characterization especially with respect to "toxicity"
- Exploiting source-cited receivers to improve reference channel INR
- Exploiting existing array architecture to improve reference channel INR

More Information



Project updates, publications, videos, education & outreach:
VT Radio Astronomy Interference Mitigation Project Web Site
<https://ellingsonvt.info/raim/>