Interference Canceling for Improved Coexistence Between Passive and Active Radio Systems

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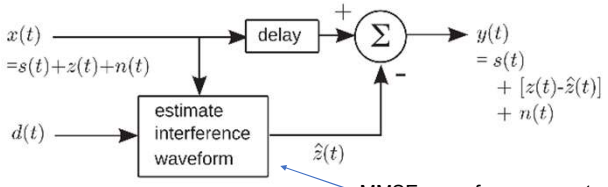
Background & Objectives

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

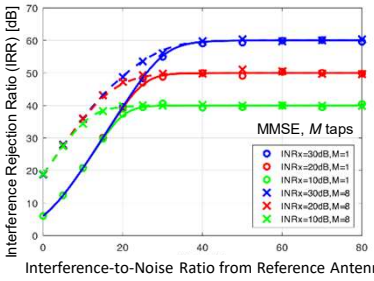


d(t): Auxilliary "reference" antenna, or Parametric signal model

MMSE, waveform parameter estimation, combinations

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

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 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

Detection

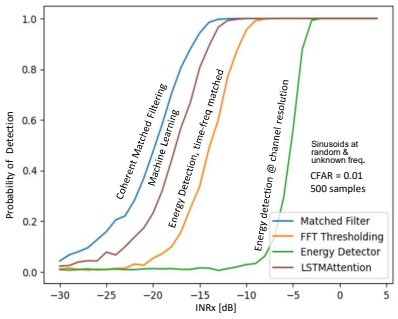
Detection is essential – canceler must not be allowed to operate unless interference is present and IRR can be improved

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



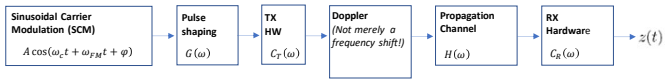
Data Acquisition & Sharing

- "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/

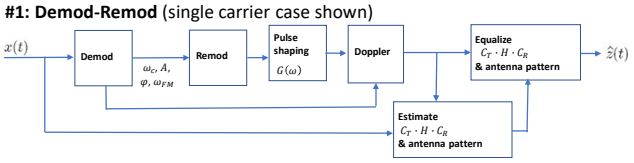
Parametric Approaches

Signal model:

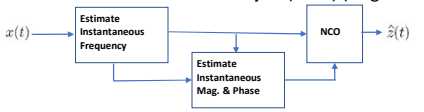


Two Parametric Strategies:

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

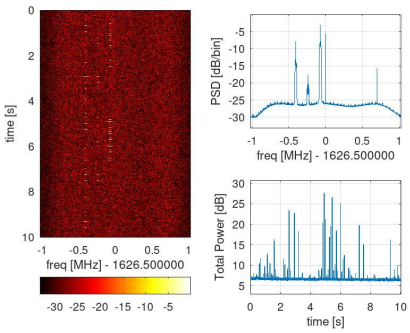


#2: Short Time Sinusoidal Analysis (STSA) (single carrier case shown)



Update period $L << F_s / B$
i.e., over a period in which the bandwidth of the signal is not apparent
Knowledge of modulation not required.

Case Study: Iridium

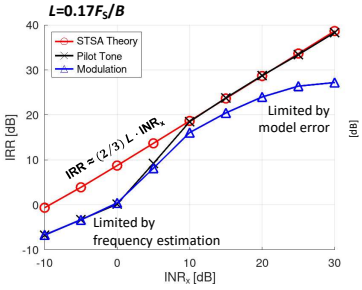


Each signal:
- ***B* = 31.5 kHz bandwidth**
- **20.32 ms bursts:**
  - **2.56 ms pilot tone**
  - **0.48 ms BPSK sync**
  - **17.28 ms QPSK data**

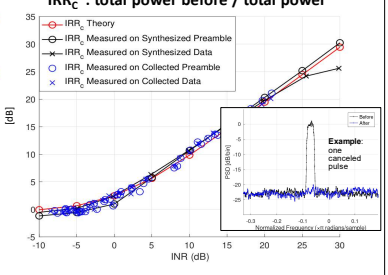
This structure facilitates comparison of performance when the STSA assumption does vs. does not strictly apply

STSA:
- ***L* << F_s/*B* = 65 samples; Will use *L* = 0.17F_s/*B* = 11**

Theory vs. Simulation
L*=0.17F_s/*B



10 s recorded data → ~ 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_x : 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/