Introduction

Radio frequency interference (RFI) is a problem for microwave remote sensing of Earth. Although frequency allocations are set aside for passive sensing, RFI can still degrade measurement quality. In some cases, radiometer bandwidth exceeds allocated spectrum to reduce measurement uncertainty or spectrum allocations are shared, forcing microwave radiometer to co-exist with terrestrial sources. Low level RFI is particularly detrimental as it can be concealed as natural variability leading to flawed scientific results. RFI detection algorithms have been developed to address the problem. Research into other algorithms is needed to improve upon the sensitivity of existing detection algorithms to various types of RFI. The Sparse Component Analysis (SCA) has been investigated to determine its sensitivity to continuous wave (CW) RFI.

Sparse Component Analysis (SCA)

SCA is a blind source separation method which seeks to extract N unknown sources from P observations where P > N. The sources need to have disjoint supports.

\[ x(t) = A s(t) \]

where

- \( x(t) \) = observations (known)
- \( A \) = mixing matrix (unknown)
- \( s(t) \) = sources

No RFI

\[ x(t) = a_{11} a_{12} a_{13} \left( \begin{array}{c} n_1 \\ n_2 \\ r \end{array} \right) \]

\[ \mathcal{H}_0^2: \ x(t) = a_{11} a_{12} a_{13} \left( \begin{array}{c} n_1 \\ n_2 \\ r \end{array} \right) \]

RFI

\[ x(t) = a_{11} a_{12} a_{13} \left( \begin{array}{c} n_1 \\ n_2 \\ r \end{array} \right) \]

\[ \mathcal{H}_1^2: \ x(t) = a_{11} a_{12} a_{13} \left( \begin{array}{c} n_1 \\ n_2 \\ r \end{array} \right) \]

Where

- \( n_1 \) = Radiometer horizontal polarization
- \( n_2 \) = Radiometer vertical polarization
- \( r \) = Radio frequency interference (RFI)

SCA in Practice

Each source is transformed to a sparse representation in another domain.

Mixing matrix \( A \) is estimated using the sparse coefficients obtained in the transformation.

The sources are separated in the transformed domain using the coefficients of observations and the estimated mixing matrix \( A \).

The sources are finally reconstructed in the time domain.

RFI Detection

- The detection criterion is the median of the absolute value of the reconstructed sources, \( s(t) \) in time.
- The output of SCA are three reconstructed sources in time, \( c_1(t), c_2(t), c_3(t) \) where \( t = 1, 2, 3 \), N.
- The median of the absolute value of each reconstructed source (median\(|c_i(t)|, n = 1, 2, 3 \) is evaluated. If all medians are greater than a given threshold, RFI is present.

Simulation Model

\[ p_{RFI} = p_{RFI} a_{11} a_{12} a_{13} \left( \begin{array}{c} n_1 \\ n_2 \\ r \end{array} \right) \]

\[ \mathcal{H}_1: \ x(t) = a_{11} a_{12} a_{13} \left( \begin{array}{c} n_1 \\ n_2 \\ r \end{array} \right) \]

\[ \text{INR}_R = \text{INR}_R + 3 \text{dB} \]

Separation and Reconstruction

Separation

Coefficients of sources

Source 1

Source 2

S1 actual

S2 actual

S1 reconstructed

S2 reconstructed

Conclusion

- Monte Carlo simulations with 1000 time samples are used, along with the structured dictionary and Orthogonal matching pursuit (OMP) algorithm for joint sparse representation, the weighted histograms for matrix estimation and binary masking for source separation.
- Figure shows the performance results of SCA for detection of CW RFI with INR, ranging from -15 dB to 2.5 dB.
- The results shows perfect to near perfect detection for INR greater than -12.5 dB and very good detection at -12.5 dB and -15 dB.
- Results show that detection works for relatively large INR for CW RFI.

Reference