# POST-DETECTION INTERFERENCE REJECTION AND WEAK BURST DETECTION IN TIME-FREQUENCY SPECTROGRAMS

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## ABSTRACT

In the frame of a radio search for extrasolar planets, we analyze dynamic spectra obtained with an acousto-optical spectrograph connected to the UTR-2 decameter array in Kharkov, attempting to reach maximum sensitivity. Data consist of two dynamic spectra, made of 10000 consecutive spectra acquired over 100 msec and 300 channels each, and covering the same 10-MHz band simultaneously observed from ON and OFF source beams. From this time-frequency spectrograms, algorithms first recognize and mask interference-contaminated pixels, based on statistical analysis and ON/OFF cross-correlations. Then spectral integration is perfomed for increasing the S/N ratio, before statistical detection of weak bursts.

## INSTRUMENTS AND OBSERVATIONS

The observation system consists of the T-shaped UTR-2 array (Kharkov, Ukraine). It can observe in the range 7-35 MHz, with effective areas about 60000 $m^2$ for the NS branch and half for the EW branch. Pointing is achieved through phasing and gives the telescope a multi-beam capacity [1]. The receiver used is an Acousto-Optical Spectrograph (AOS), which allows to perform multi-channel observations simultaneously within two identical 10-MHz bands (in 330 channels/band), fed by two different beams from UTR-2. One beam ("ON") aims at the target source, and the other ("OFF") is shifted by 1°. One acquisition file corresponds to ~15 minutes of continuous observation at ~100 msec/spectrum, or 10000 consecutive pairs of spectra. During this time-interval, the AOS stability is better than 2-3%. Observations are preferably performed at night, for minimum contamination by man-made RF, and for high elevation of the source, minimizing the perturbations due to ionospheric propagation.

## METHOD OF ANALYSIS AND SIMULATIONS

One acquisition thus consists of a pair of frequency-time arrays (10 MHz $\times$ ~15 min) recorded simultaneously from the ON and OFF beams. These dynamic spectra are severely contaminated, even in the nighttime, by two main types of intense interference : terrestrial lightning (broadband spikes) and man-made RFI (fixed frequency bands). These spurious signals must be identified and eliminated in order to reconstruct a broad clean band before spectral integration. Although much work has been done on interference immunity, real-time processing of narrowband observations, and post-processing of radio maps, very few results are reported on the processing of broadband dynamic spectra. The simultaneity of ON and OFF observations is obviously a decisive advantage of our observation procedure, because many of the above interference enter both beams and are thus correlated in the ON and OFF dynamic spectra.

The procedure of analysis we have developed involves the following steps :

(1) Pre-processing, to prepare the data for identification of interference and signal detection.

(2) Interference identification, through local and global frequency-time statistical analysis of dynamic spectra, together with high-pass filtering of the data.

(3) Tests of signal "gaussianity" which justifies and measures the quality of step (2).

(4) Frequency integration and signal detection (broadband spikes) over the noise background.

The detailed procedure is described in [2]. It has been tested on simulated dynamic spectra, included both a useful "signal" and various kinds of interference. The simulations reveal that the various steps applied in the interference identification (and subsequent elimination) are very complementary to each other. None is enough alone to perform a satisfactory cleaning of the dynamic spectra. But the whole procedure is at present still too "severe", in that it must remove twice as many pixels as the polluted ones to eliminate all of the interference. The detection of weak broadand signal spikes requires optimization between maximum efficiency and minimum number of false alarm detections. The whole processing of 10000 pairs of dynamic spectra presently requires ~1 hour computation time on a medium-size workstation.

## PRELIMINARY RESULTS AND PERSPECTIVES

When applied to real data (search for radio emission from known candidate exoplanets and from Saturn's atmospheric lightning) this method allowed to increase the sensitivity of the observations from 25 Jy before interference elimination and frequency integration to ~5 Jy after it. Tentative detection of the radio signature of Saturnian lightning was performed as a test, and marginally achieved, while the search for radio exoplanets has still negative results. However, the above sensitivity, when compared to theoretical predictions [3] suggest hat this search is not unrealistic.

Future or ongoing improvements of the method include :

- performing statistical analyses based on median values rather than on average to decrease the susceptibility to spurious data points ;
- include predicted dedispersion before weak broadand signal spikes detection ;
- use longer integration times together with "OFF3 channel providing a gain monitoring ;
- use of a digital receiver more stable than an AOS ;
- operate UTR-2 in correlation EW $\times$ NS mode to reuce confusion ;
- pursue a systematic monitoring of candidate exoplanets discovered by radial velocity (or occultation) techniques.

Future large low frequency phased arrays such as LOFAR should provide more sensitivity and real-time interference elimination, but the above algorithms may still be useful for reaching the sky noise limit independent of oserving conditions.

## REFERENCES


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