Quality improvements to the spectral data acquired from HF multi-static sounding system at the magnetic Equator

V. Vásquez[1], M. Milla[2], K. Kuyeng[1], J. Gonzales[3], D. Scipión[1].

[1] Jicamarca Radio Observatory, Instituto Geofísico del Perú, Lima, Perú.
[2] Sección Electricidad y Electrónica, Pontificia Universidad Católica del Perú, Lima, Perú.
[3] Facultad de Ingeniería Electrónica y Eléctrica, Universidad Nacional Mayor de San Marcos, Lima, Perú.

Abstract

A network of HF radio beacons and receivers for ionospheric sounding has been operating in Peru since 2016. The purpose of this instrument is to measure the group delay, Doppler shift, power, and other parameters in order to estimate the regional plasma density as a function of space and time, this information is crucial for forecasting the occurrence of Spread-F. The HF radar used only one frequency for transmission and reception that generated interference between different transmitter stations in the analyzed spectrum. To improve the quality of the spectral data, changes were made to the operation of the radar. Spectral separation of the transmitted signals was carried out, followed by the implementation of an algorithm that extracts only the signals of interest from the measured spectrum, discarding the noisy areas. The procedure for the changes made to the HF system, along with comparisons of the final data, is shown in this work.

1. Introduction

The HF radar is a multi-static continuous wave radar, and it was composed of three transmitting and six receiving stations, deployed around the center coast and the Andes region of Peru, operating continuously until December 2022. Nowadays, the radar maintains its three transmitting stations but only two receiving stations. Figure N°1.

Since 2016, the three transmitters stations used the same two frequencies: 2.72 MHz and 3.64 MHz modulated with a different pseudorandom code, however, interference from the other transmitters were observed in the obtained spectrum , affecting the signals closer to DC as shown in Figure 2.

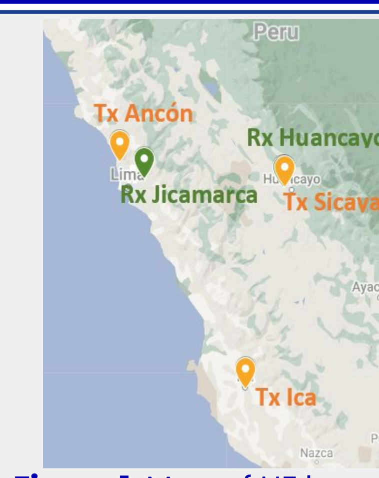

Figure 1. Map of HF beacon stations in Peru.

2. Multi-frequency system in HF radar.

In order to achieve spectral separation and avoid interference from other HF transmitters in the same band, a change was made to the transmission system, by sending multiple frequencies separated by 3.3 Hz in each transmitter station. The frequencies used by each transmitter can be seen in Table 1.

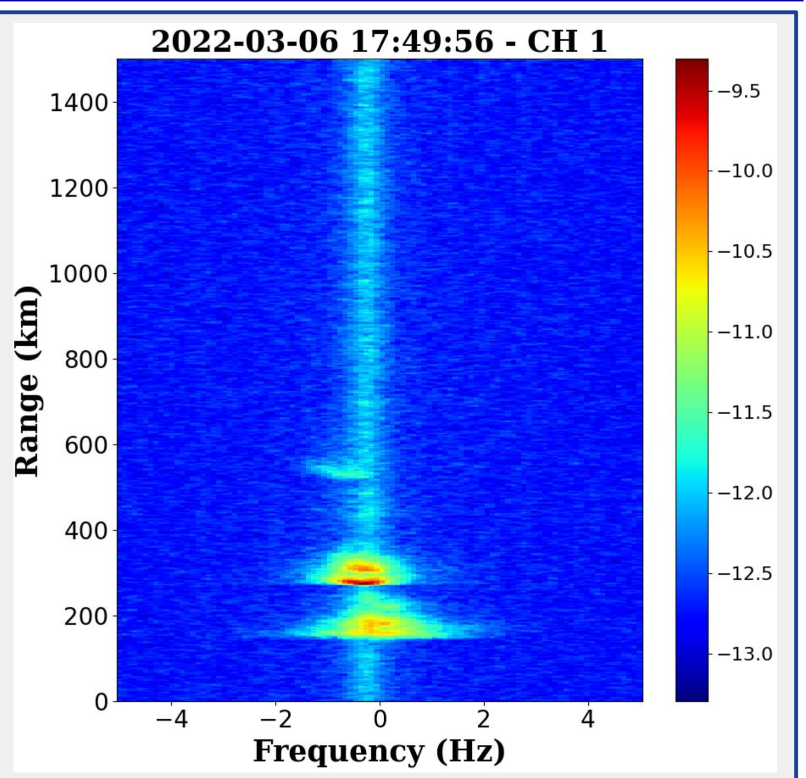

Figure 2. Spectrum Rx: JROA Tx: Sicaya. Freq: 2.72 MHz

Transmitting stations	2.72 MHz Range	3.64 MHz Range	Desviation Frequency
Ancon (code 0)	2722167.9687500	3649902.3437500	463867.1875000
Sicaya (code 1)	2722164.6392718	3649905.6732282	463870.5169782
Ica (code 2)	2722171.2982282	3649899.0142718	463863.8580218

Table 1. HF Radar Frequencies (Hz).

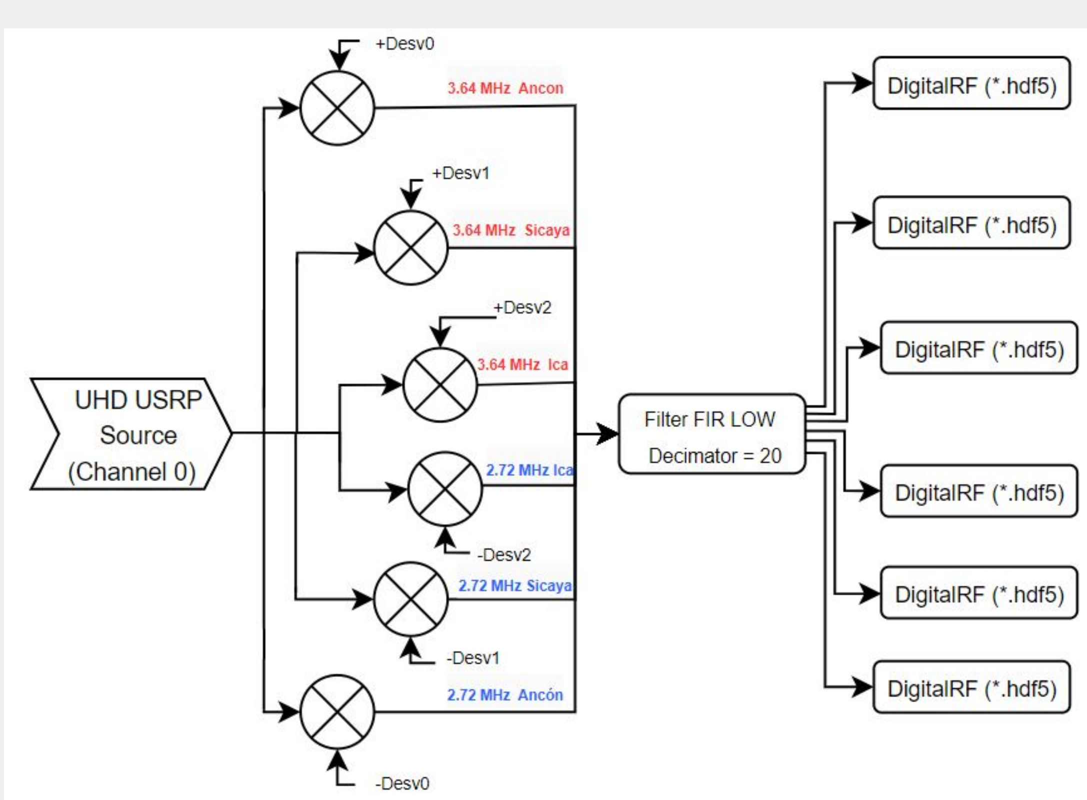

Figure 3. Diagram of the HF radar receiver system developed in GNURadio.

It was possible to identify and spectrally separate the signals coming from a given station, displacing the cross-talk in frequency but not eliminating it, as you can see in Figure 4.

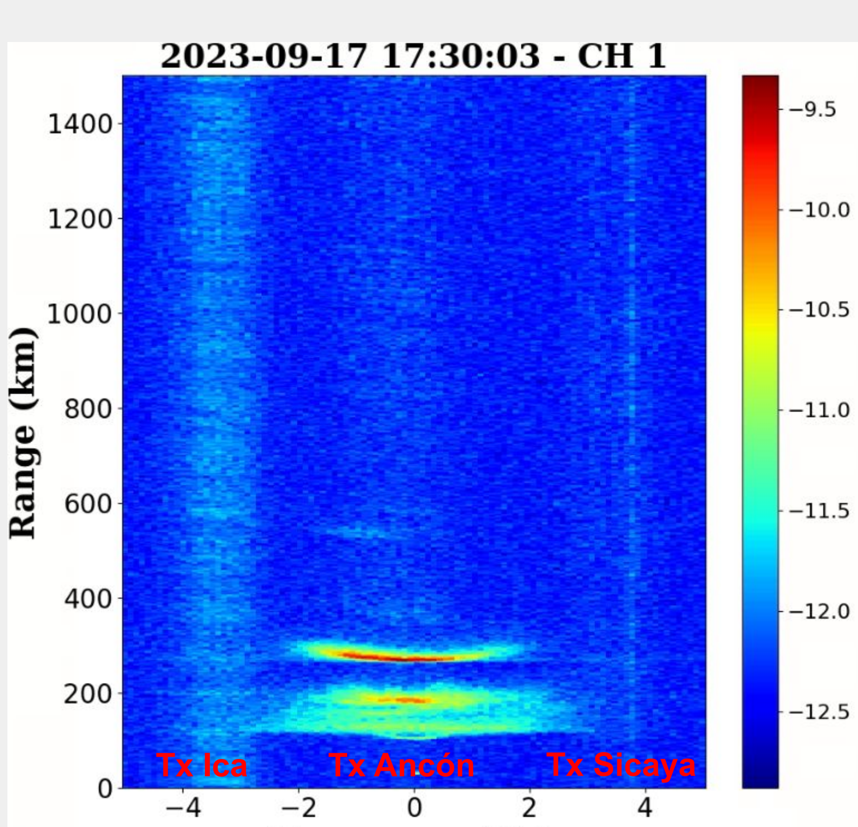

Figure 4. Spectrum Rx: JRO. Tx: Ancón. Freq: 2.72 MHz.

3. Procedure of Clustering and Reduction algorithm

A series of steps were carried out:
Initially, a median filter was applied, followed by the application of a percentile value.
After this, the DBScan algorithm was used.
Finally, the obtained data was filled in because it was dispersed.

Through this series of steps this algorithm is capable of detecting clusters of data in the spectra, classifying them as the coherent echoes of interest, while tagging the remaining sectors as "noise" that will be discarded.

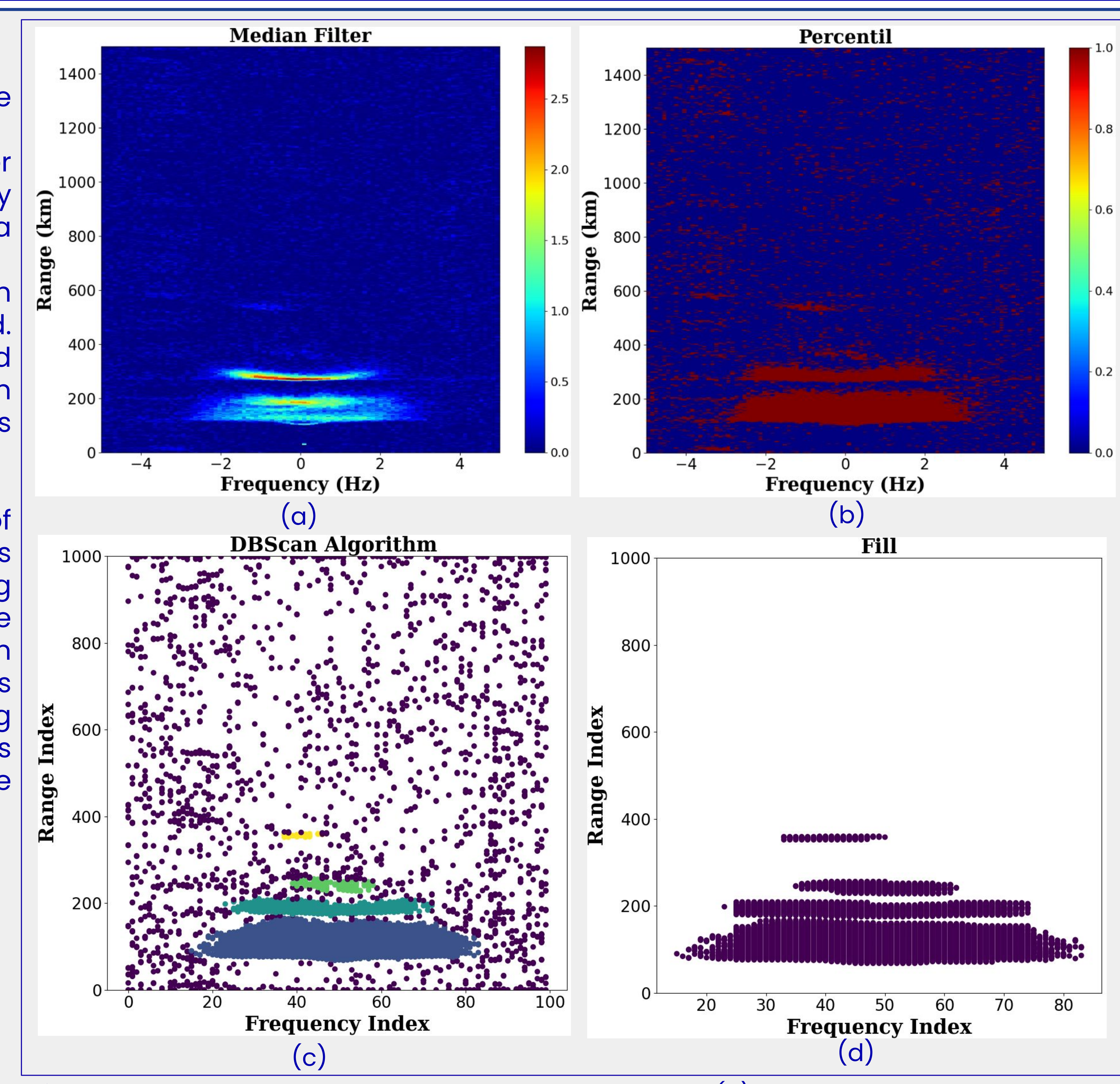

Figure 5. Procedure of Clustering and Reduction algorithm. (a) Median Filter applied to original spectrum. (b) Percentile of highest values of spectral power. (c) DBSCAN Algorithm. (d) Data Fill.

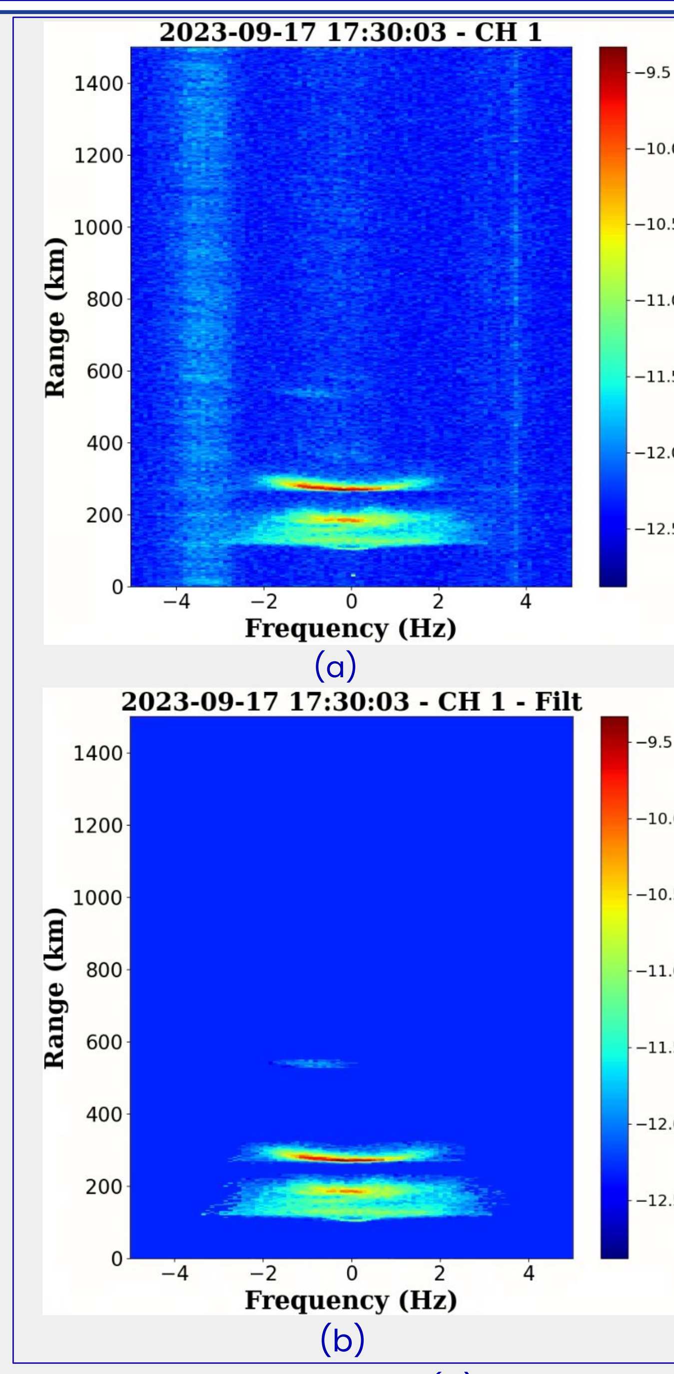

Figure 6. Spectrum (a) Original , (b) Final Result.

4. Comparisons of final parameters

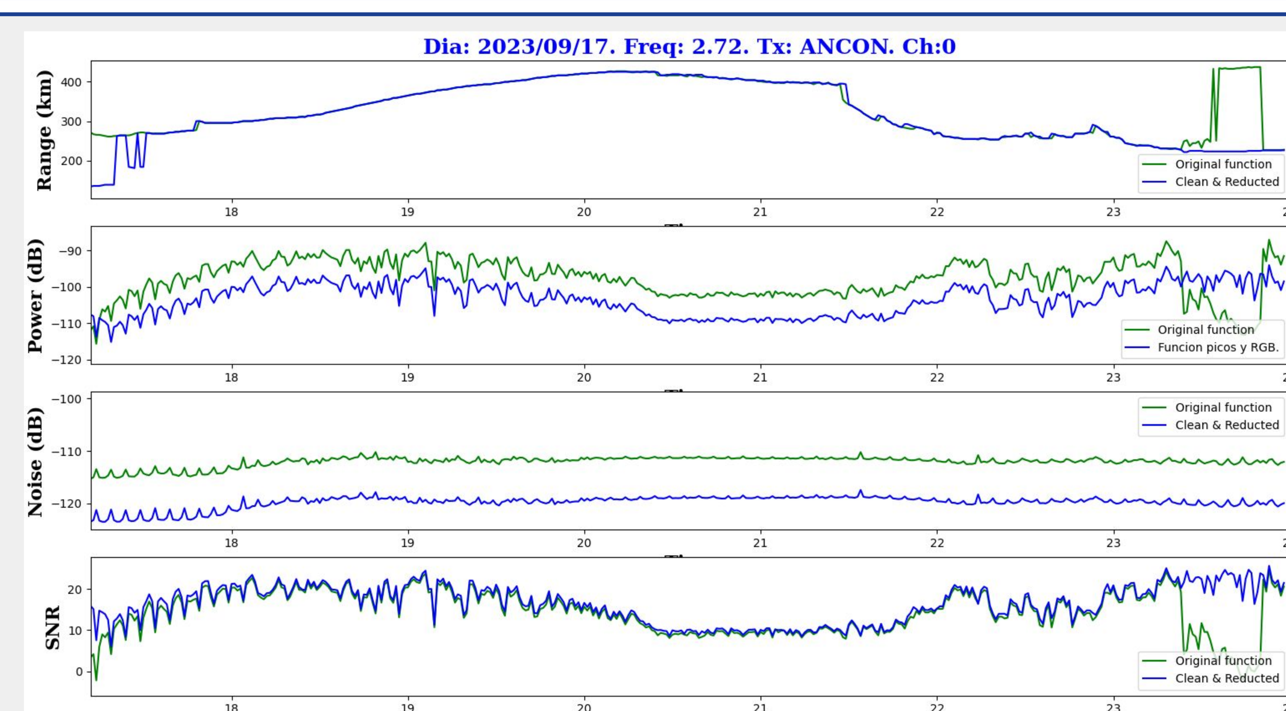

Figure 7. Comparison of the spectral data original (green) vs. filtered (blue). (a) Heights (b) Power. (c) Noise. (d) SNR. Hour: 17 to 24 hours

- In the Figure 7.b the new power level slightly decreases, this is because the previous power level accounted for the interferences from the other transmitters.
- The noise level is significantly reduced as it is obtained without considering the interferences. (Refer to Figure 7.c)
- These changes result in a slight increase in the Signal-to-Noise Ratio (SNR) levels, as demonstrated in Figure 7.d.

5. Conclusions

- The signals from each transmitter in the spectral data were successfully extracted, free from interference caused by other transmitters and without any cross-talk.
- The developed algorithm effectively reduced the noise level in the HF system.
- As a result, a slight increase in the Signal-to-Noise Ratio (SNR) value was achieved, as the algorithm allows for the extraction of low significant noise values.
- Additionally, the implementation of this algorithm resulted in a significant reduction in the storage size of the spectra, reducing it by approximately 75%.

6. References

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7. Acknowledgments

The Jicamarca Radio Observatory is a facility of the Instituto Geofisico del Peru operated with support from the NSF AGS-1732209 through Cornell University. We also thank the support of Ciencia Internacional, a peruvian non-profit civil association that supports the operation of the Jicamarca Radio Observatory.

email: roj-op02@igp.gob.pe