Cyclostationary Signal Analysis

Computer generated report.

August 17, 2026

Abstract

This report is computer generated by python code written by Mike Markowski, mike.ab3ap@gmail.com that implements portions of Chad Spooner's CSP blog at cyclostationary.blog. Please fix or report bugs, enhance, and share!

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1 Introduction

This report presents an automated cyclostationary analysis of the signal recorded in the file `wifi-802.11a.mat`. The results and the report itself can be recreated with the command:

```
csp -i wifi-802.11a.mat -o rptwifi -s fsm
```

There are two major steps in cyclostationary analysis:

1. Blind analysis, where the spectrum of interest is studied to efficiently find significant spectral and cycle frequencies. Spectral frequencies are those that a signal is composed of. Cyclic frequencies represent repeating features of a signal like symbol rate, chip rate, and so on, and are useful for both detecting and classifying signals.

2. Spectral Correlation Function (SCF), where only the strongest signals found in the blind study are studied in greater detail.

The mathematics underlying the analysis can be found at the website `https://cyclostationary.blog` by Dr. Chad Spooner. Importantly, when considering real world signals rather than textbook perfect ones, on the page `https://cyclostationary.blog/2016/01/19/textbook-signals/` he says, "Transmitter impairments include phase noise, carrier-frequency drift, symbol-clock jitter, and gain/phase mismatch. These effects typically weaken the cyclostationarity of the signal, but do not typically introduce new periods of cyclostationarity (new cycle frequencies)." Visit the web page for more detail.

The power spectral density of the signal analyzed in this report is displayed in Figure 1.

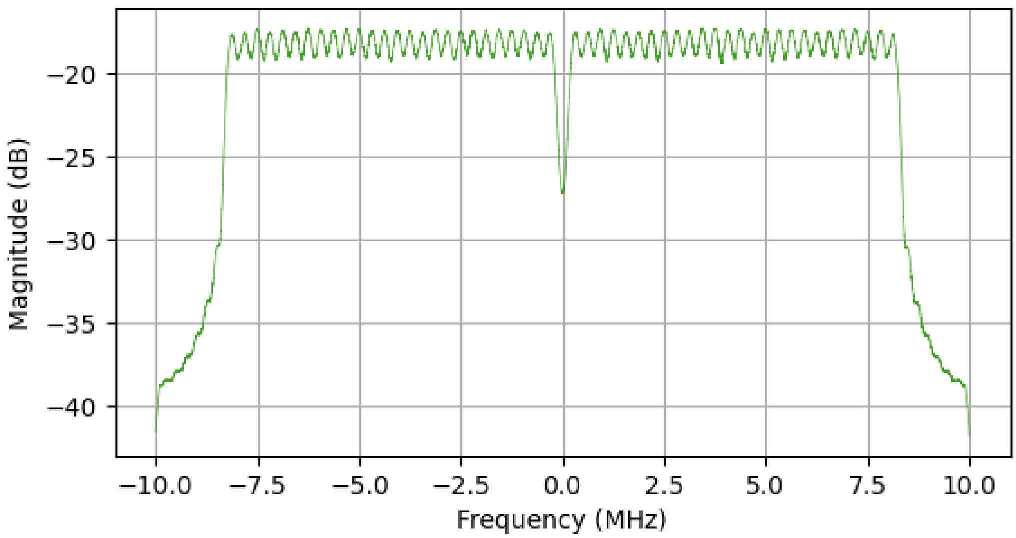

Figure 1: Power spectrum of signal analyzed.

2 SSCA Blind Analysis

Blind cyclostationary analysis is performed over the entire RF spectrum of the recording without knowledge of signals. It provides an estimate of the spectral correlation function (SCF) for many spectral and cycle frequencies. The highest values will be studied in greater detail. The method used here is the SSCA, or Strip Spectral Correlation Analyzer.

A shortcoming of looking at the SCF is that stronger signals will be found but not necessarily weak ones. Spectral coherence, dividing SCFs by appropriately shifted PSDs, normalizes signals to aid comparison. However, it can also be useful to see the strongest signals at a receiver.

The following graphs are relative to the recording's center frequency, labeled 0 Hz and represent the 500 highest spectral coherences that are greater than a threshold of 0.1. While spectral coherences are plotted, they are colored by their associated spectral correlation function values for added information.

Learn about the SSCA (Strip Spectral Correlation Analyzer) method at `https://cyclostationary.blog/2016/03/22/`

csp-estimators-the-strip-spectral-correlation-analyzer/ and the FAM (FFT Accumulation Method) method at https://cyclostationary.blog/2018/06/01/csp-estimators-the-fft-accumulation-method/.

2.1 SSCA Non-conjugate Spectral Coherences

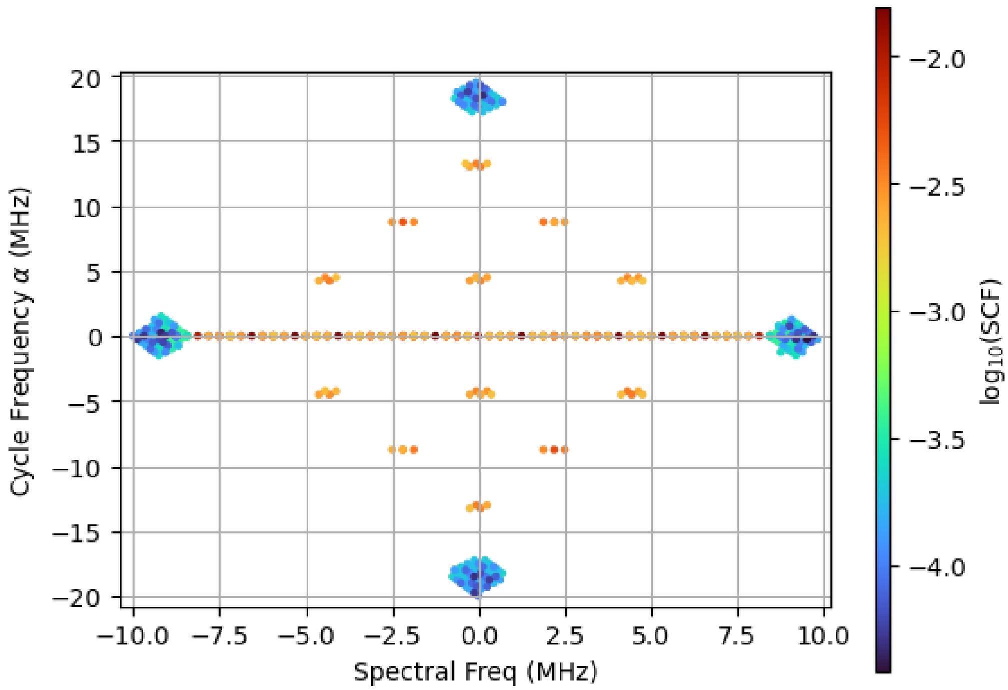

Figure 2: SSCA non-conjugate results.

2.2 SSCA Conjugate Spectral Coherences

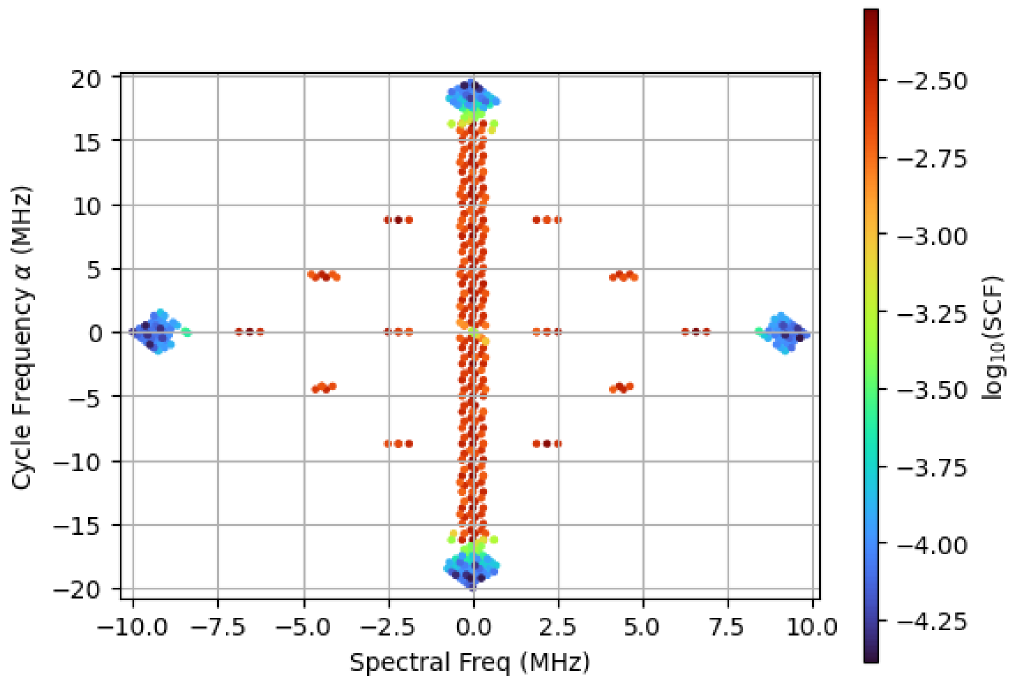

Figure 3: SSCA conjugate results.

3 Cycle Frequencies

From blind analysis results, cycle frequencies with the largest SCFs will be studied in more detail. These strongest describe important properties of the signal, like symbol rate, sub-carrier spacing, pilot tones, cyclic prefix duration, and others. After being ranked and retrieved from blind analysis results, the cycle frequencies and SCF peak values for non-conjugate and conjugate are plotted.

3.1 Non-conjugate

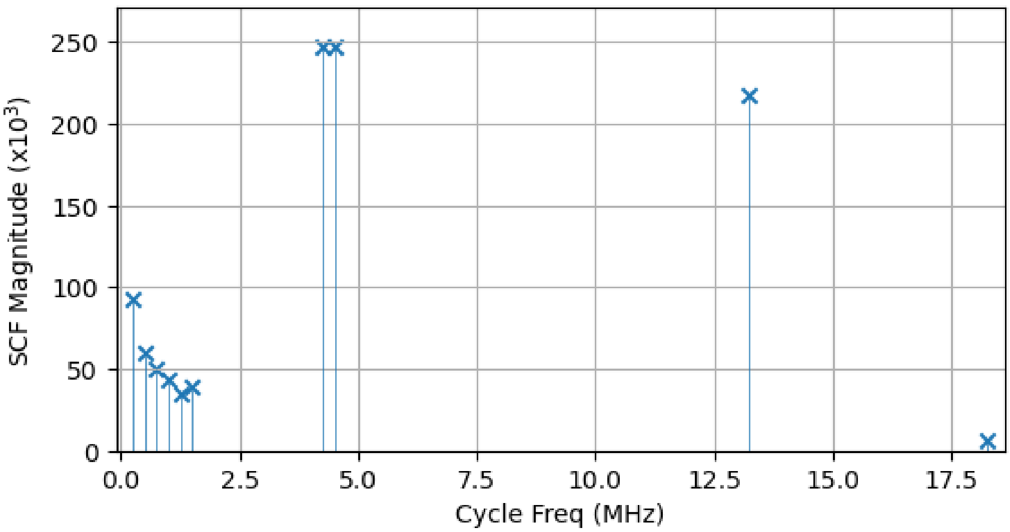

Figure 4: Non-conjugate cycle frequencies.

Cycle (MHz)	*SC (x10^{-3})*
0.2500	993.8
0.5000	975.2
0.7500	944.1
1.0000	901.6
1.2500	840.5
4.2500	750.2
4.5000	742.0
1.5000	722.8
18.2500	715.3
13.2501	658.7

Table 1: Table of non-conjugate cycle frequencies.

3.2 Conjugate

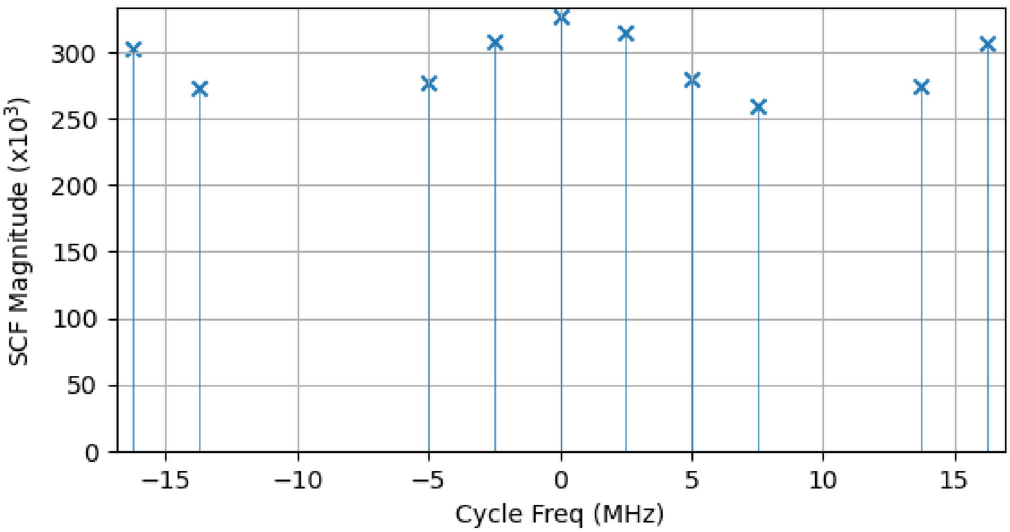

Figure 5: Conjugate cycle frequencies.

Cycle (MHz)	*SC* ($x10^{-3}$)
0.0000	909.8
16.2500	884.6
-16.2500	882.6
2.5000	855.2
-2.5000	849.5
5.0000	777.6
-5.0000	769.3
13.7501	749.0
-13.7501	748.0
7.4999	692.6

Table 2: Table of conjugate cycle frequencies.

4 Spectral Coherence

After the blind detection presented above, spectral coherence (SC) values below a threshold of 0.1 are dropped and the remaining are ranked by strongest SCF. The following graphs show spectral coherence curves for the top 10 cycle frequencies from the ranking. The SCFs are calculated with the Frequency Smoothing Method, which is divided by the PSD (Power Spectral Density) to obtain the spectral coherence curves. The SCF uses absolute signal strength and the SC is used for normalized comparison. Finally, those 10 curves those are plotted in the graphs in this section.

As before, spectral frequencies are relative to center frequency and labeled zero. Symmetric values about the vertical axis are ignored, as is the PSD ($\alpha = 0$) in the non-conjugate case.

The spectral coherence function is described in detail at `https://cyclostationary.blog/2016/01/08/the-spectral-coherence-function/`.

4.1 Non-conjugate

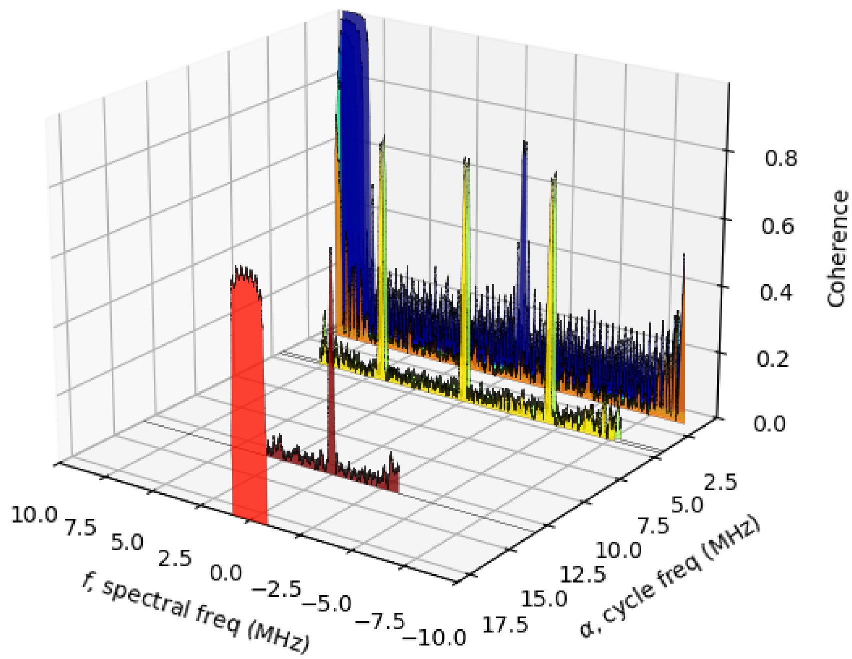

Figure 6: Top 10 non-conjugate SC curves.

4.2 Conjugate

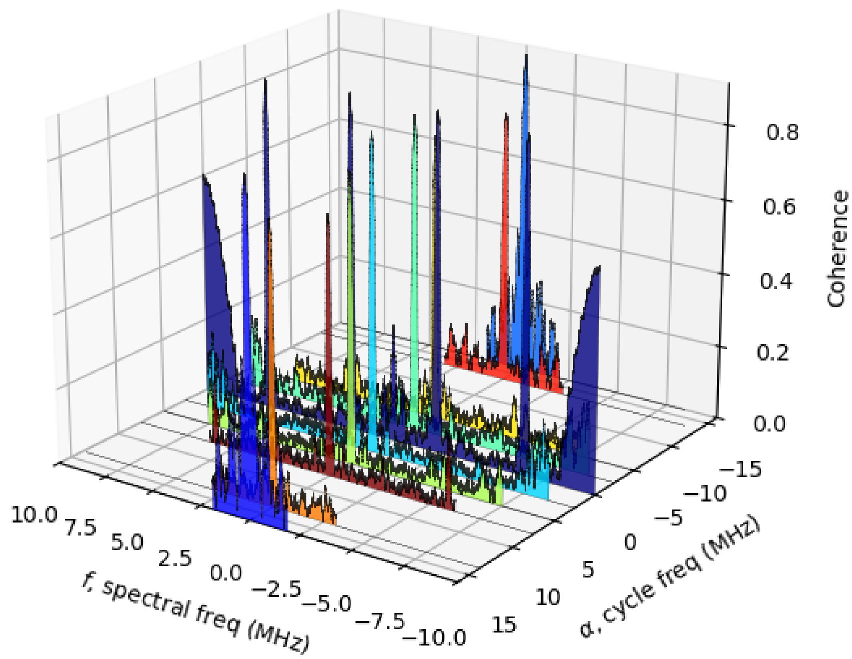

Figure 7: Top 10 conjugate SC curves.

5 Spectral Correlation Function, Frequency Smoothing Method

As previously described, the spectral correlation function (SCF) is calculated for a small number of cycle frequencies discovered by a blind search. The SCF curves presented in the following graphs are chosen as described in Section 4. The difference is that SCFs are plotted, not spectral coherences, and only the top 5 are presented. SCFs are calculated using the Frequency Smoothing Method with a smoothing window 1112 samples wide.

Both types of CSP estimators are described at `https://cyclostationary.blog/2015/11/20/`

`csp-estimators-the-frequency-smoothing-method/`, the time smoothing method, and also at `https://cyclostationary.blog/2016/03/22/csp-estimators-the-strip-spectral-correlation-analyzer/`, the frequency smoothing method.

5.1 Non-conjugate

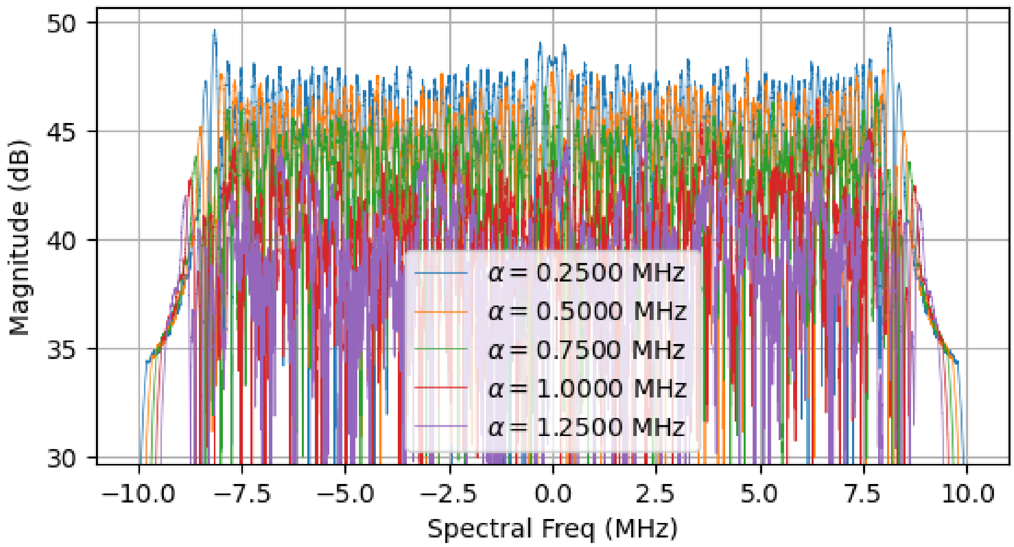

Figure 8: Non-conjugate SCF.

5.2 Conjugate

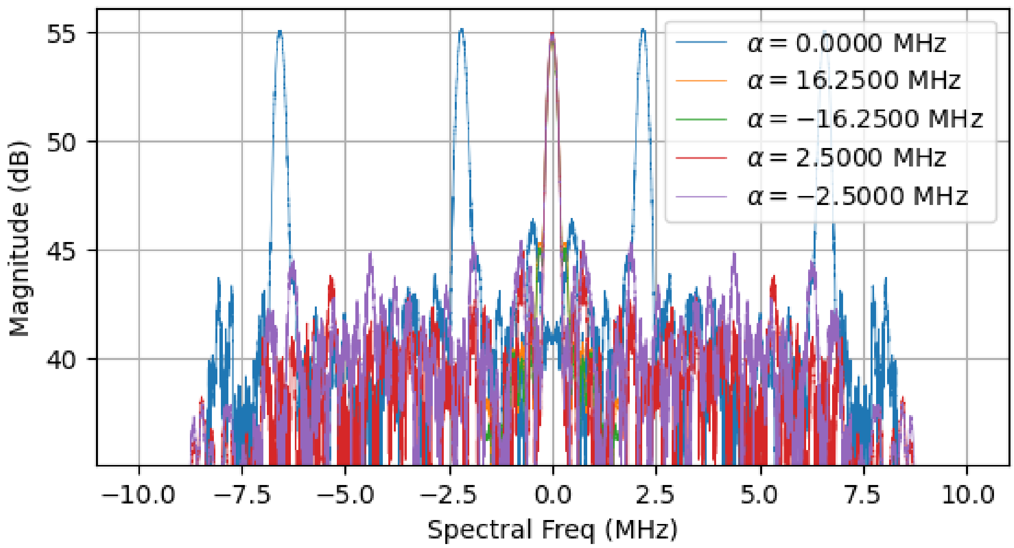

Figure 9: Conjugate SCFs for top cyclic frequencies, α.

6 Document Information

Cyclostationary analysis and data plotting presented in this document were created by a program written in python and required 3.1 sec of processing time. The program generated the LaTeX input document collecting results and providing basic descriptions. This can be used as a starting point for an in-depth analysis, for example, explaining the reasons for observed cycle frequencies.