Cyclostationary Signal Analysis

Computer generated report.

June 1, 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!

Contents

List of Figures

List of Tables

1 Introduction

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

```
csp -i wifi.mat -o rptWifi
```

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, 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` presented 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). The deviation from IID symbols can arise from the nature of the source message, and from the inclusion of periodically repeated symbols that facilitate receiver operations like synchronization and channel equalization. The deviations from IID symbols can introduce new cycle frequencies relative to the textbook model. Finally, the inclusion of effects related to the access method (frequency-division multiple access, time-division multiple access, code-division multiple access, etc.) can radically add to or change the cycle frequencies and cycle-frequency pattern relative to the textbook signal."

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

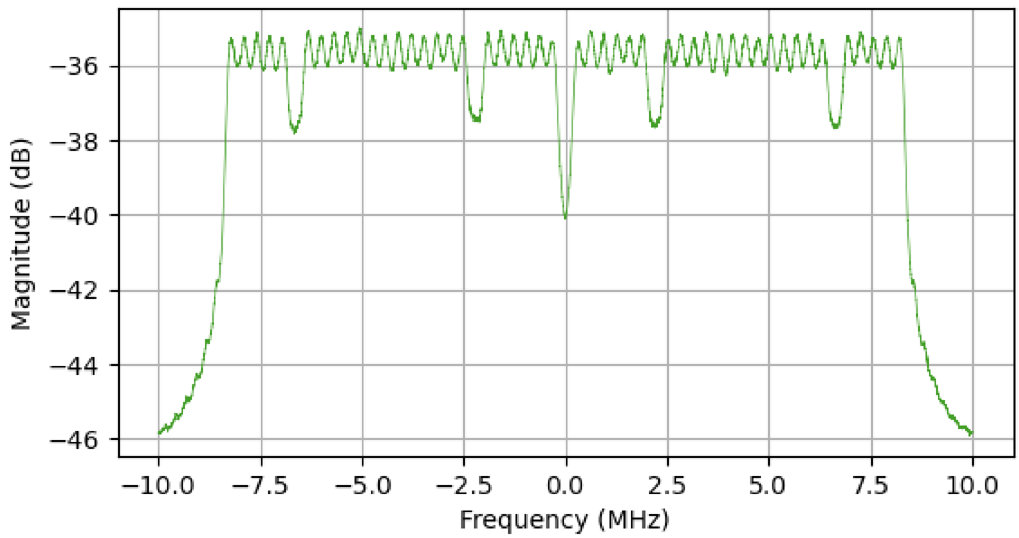

Figure 1: Power spectrum of signal analyzed.

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.

2.1 SSCA Non-conjugate Spectral Coherences

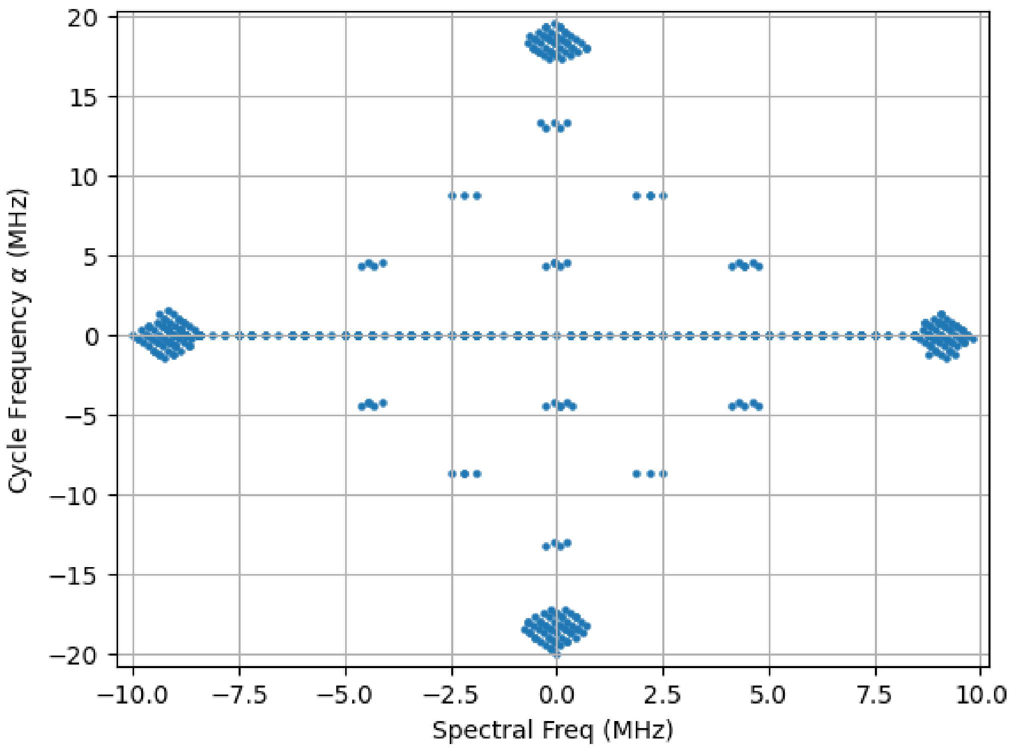

Figure 2: SSCA non-conjugate results.

2.2 SSCA Conjugate Spectral Coherences

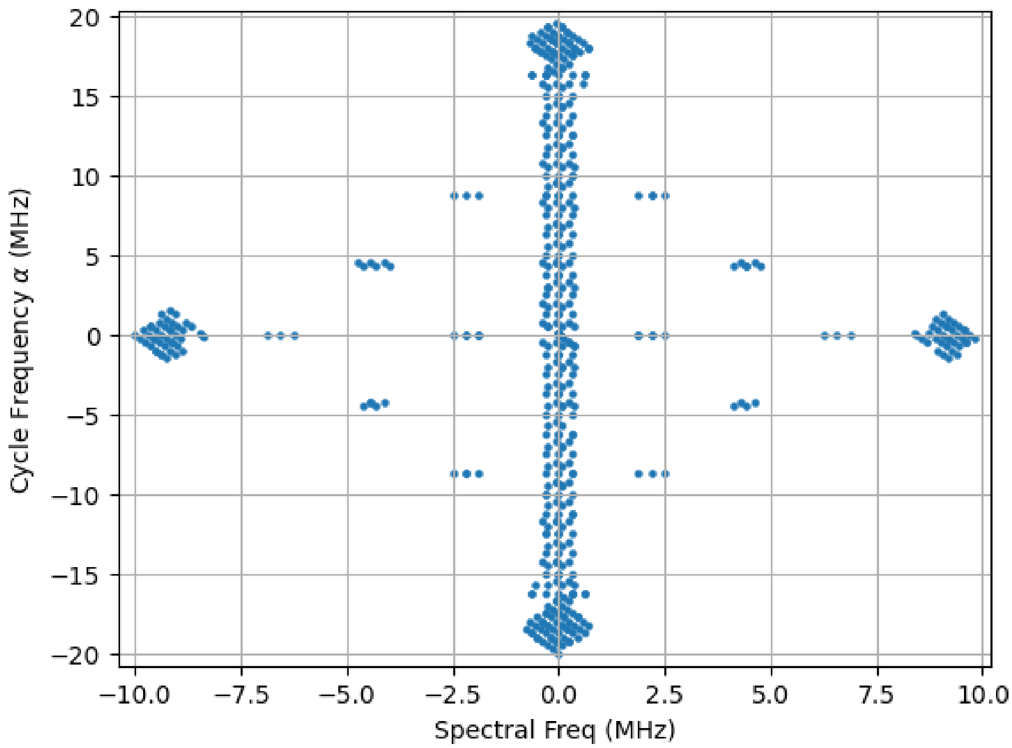

Figure 3: SSCA conjugate results.

3 Cycle Frequencies

Cyclostationary analysis discovers the following cycle frequencies in the signal, ranked highest to lowest by SCF.

3.1 Non-conjugate

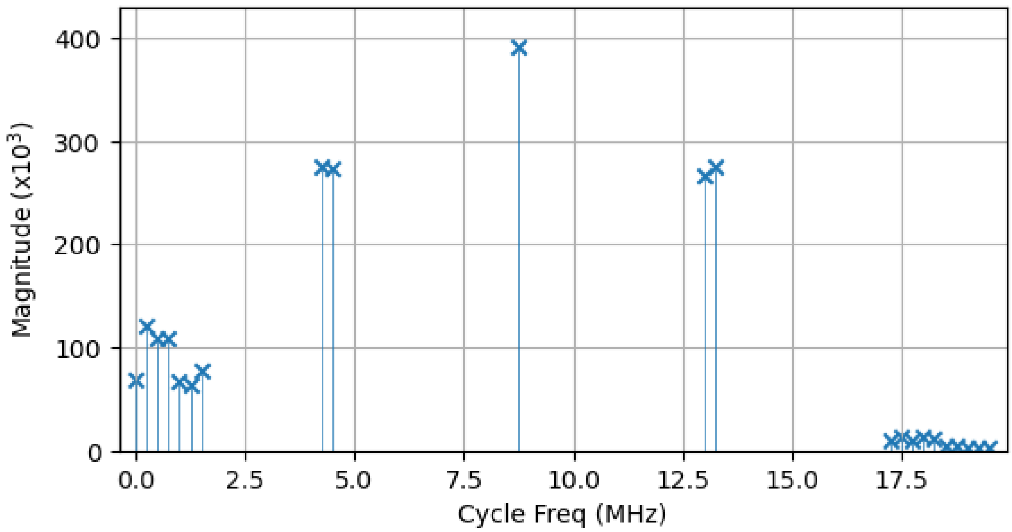

Figure 4: Non-conjugate cycle frequencies.

Cycle (MHz)	*Max SCF (x10^3)*
8.750	391.3
4.250	275.2
13.250	274.6
4.500	274.2
13.000	266.0
0.250	121.4
0.750	109.5
0.500	108.6
1.500	77.0
0.002	68.1
1.000	67.4
1.250	64.3
17.500	14.1
18.000	13.2

18.250	11.0
17.750	10.7
17.250	9.7
18.750	4.7
18.500	4.1
19.250	2.9

Table 1: Table of non-conjugate cycle frequencies.

3.2 Conjugate

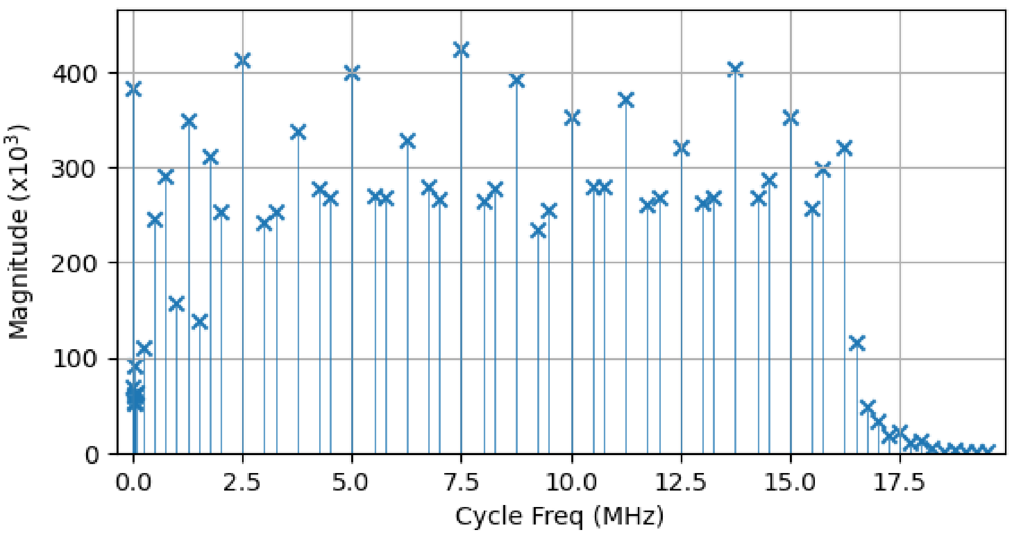

Figure 5: Conjugate cycle frequencies.

Cycle (MHz)	*Max SCF ($x10^3$)*
7.500	424.4
2.500	413.8

13.750	404.0
5.000	399.5
8.750	393.4
11.250	371.4
10.000	352.9
15.000	352.3
1.250	349.3
3.750	339.1
6.250	328.1
12.500	321.7
16.250	320.9
1.750	312.7
15.750	297.8
0.750	291.6
14.500	287.1
10.500	280.2
6.750	280.1
10.750	279.3
8.250	278.2
4.250	277.2
5.500	270.1
13.250	268.8
4.500	268.6
12.000	268.4
5.750	268.1
14.250	268.0
7.000	267.5
8.000	264.4
13.000	263.4
11.750	261.1
15.500	256.6
9.500	254.8
3.250	253.2
2.000	252.6
0.500	245.8
3.000	241.6

9.250	234.2
1.000	156.6
1.500	139.0
16.500	115.7
0.250	110.6
0.040	91.8
0.012	68.6
0.078	63.7
0.026	60.7
0.032	59.7
0.048	54.9
0.058	51.6
16.750	47.7
17.000	33.6
17.500	21.2
17.250	17.8
18.000	11.9
17.750	11.6
18.250	5.9
18.750	2.6
18.500	2.3
19.250	1.8
19.500	1.8
19.000	1.6

Table 2: Table of conjugate cycle frequencies.

4 Spectral Coherence

After the blind detection presented above, the following graphs show spectral coherence curves for the 10 cycle frequencies with the highest SCF (not SC) values. The SCFs are calculated with the Time Smoothing Method, which is then divided by the PSD (Power Spectral Density) to obtain the spectral coherence (SC) curves. Only those with values above a threshold of 0.1 are retained. Finally, the top 10 of 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.

4.1 Non-conjugate

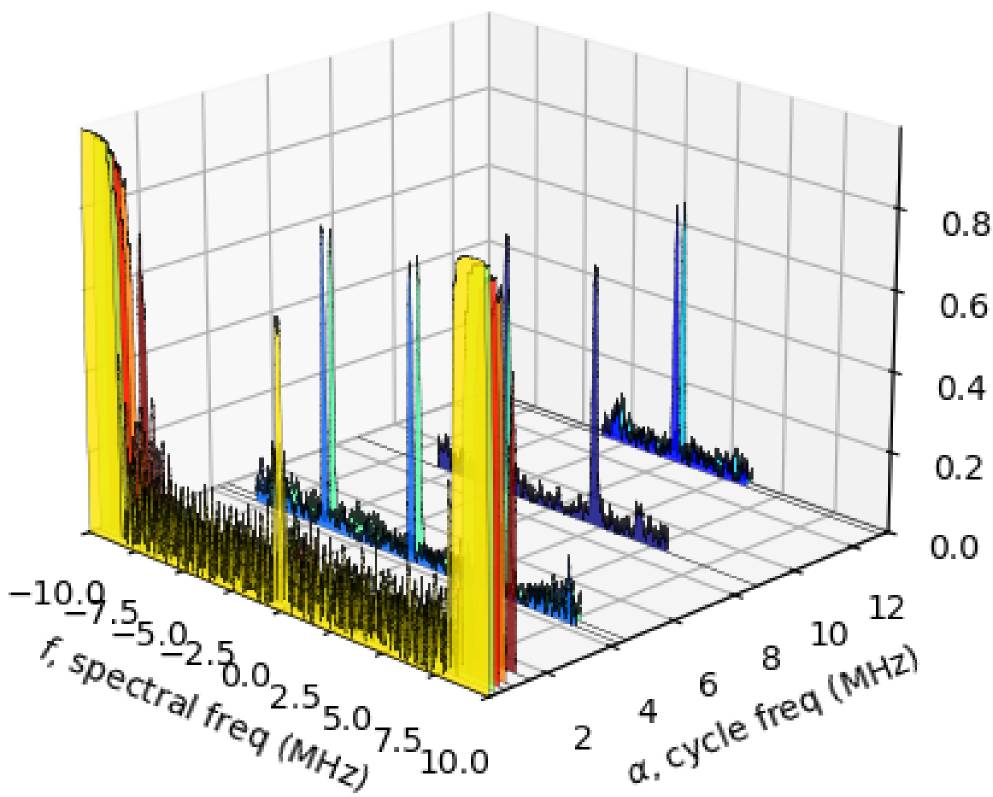

Figure 6: Top 10 non-conjugate SC curves.

4.2 Conjugate

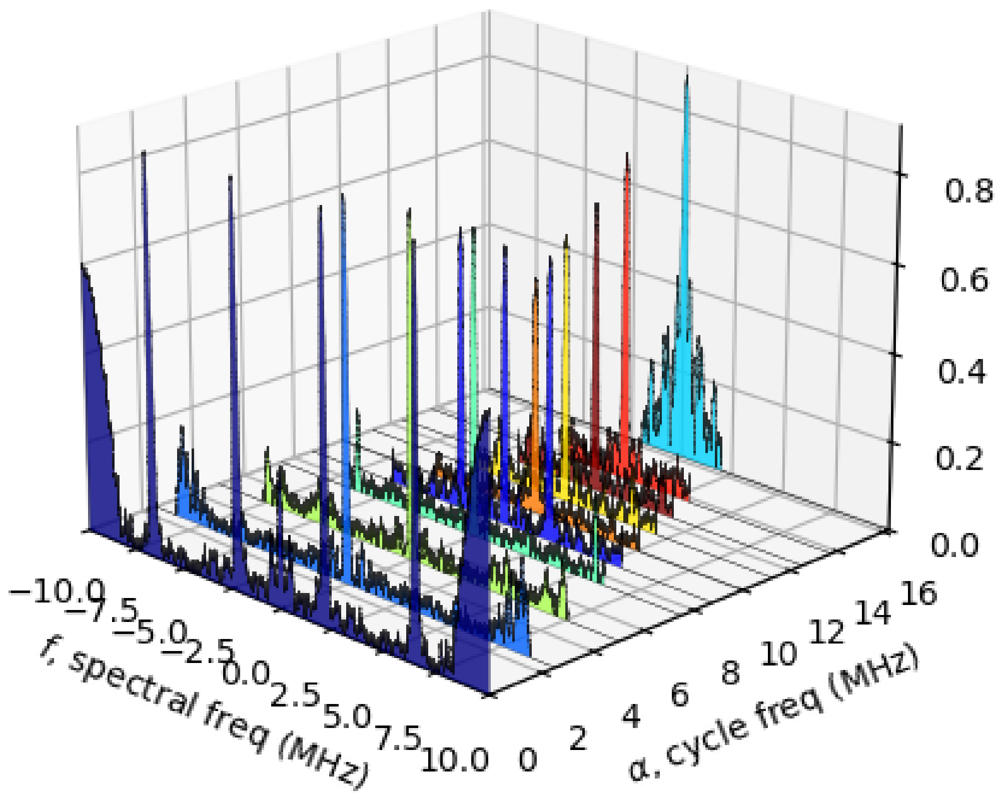

Figure 7: Top 10 conjugate SC curves.

5 Spectral Correlation Function, Time 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 fig:sc. The difference is that SCFs are plotted, not spectral coherences, and only the top 5 are presented. SCFs are calculated using the Time Smoothing Method with an analysis block size of 512 samples.

5.1 Non-conjugate

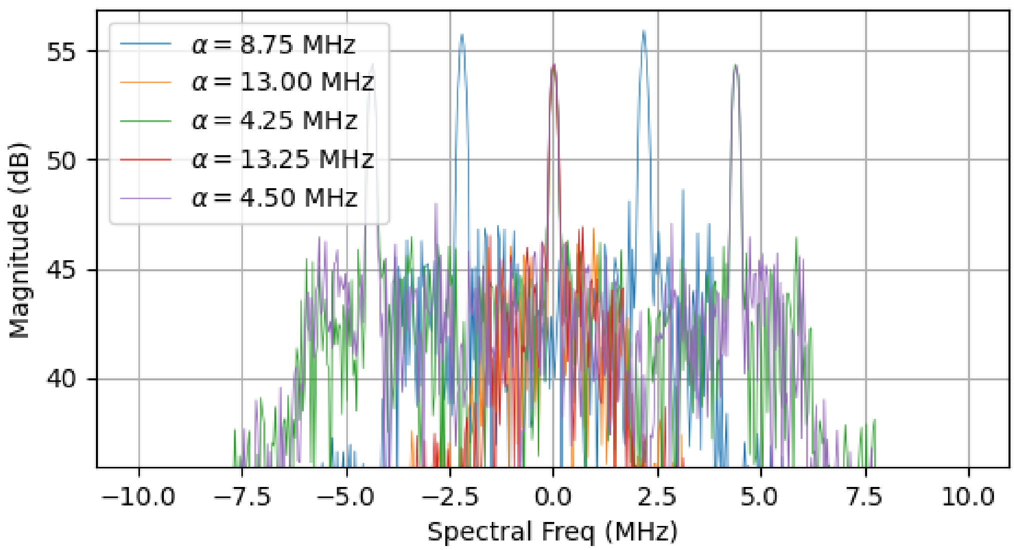

Figure 8: Non-conjugate SCF.

5.2 Conjugate

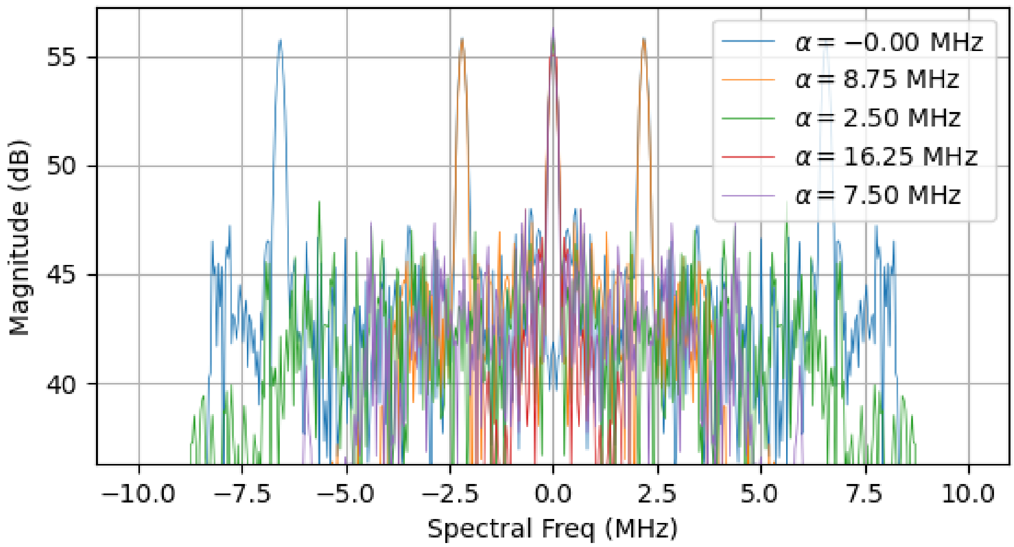

Figure 9: Conjugate SCFs for top cyclic frequencies, α.

6 Document Information

Cyclostationary analysis and data plotting presented in this document were created by a program written in python and required 3.8 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.