

Software Defined Radio based Mixed Signal Detection in Spectrally Congested and Spectrally Contested Environment

Kaiyu Huang, Yang Qu, Zhiping Zhang
Vasu Chakarvarthy, Lin Zhang and Zhiqiang Wu

Wright State University
Air Force Research Laboratory
Sun Yat-sen University

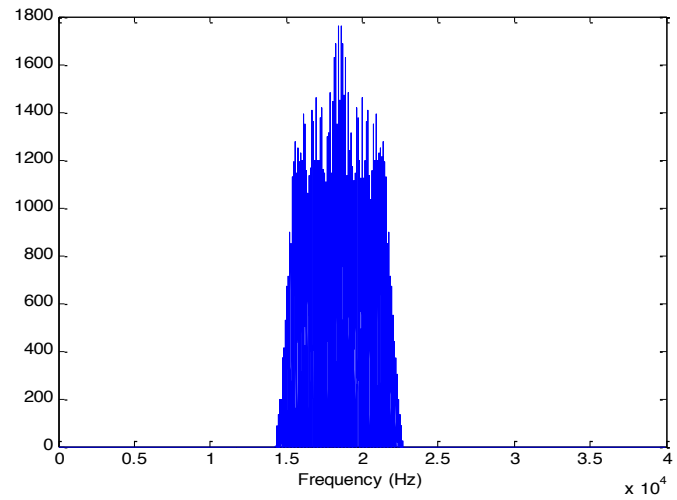
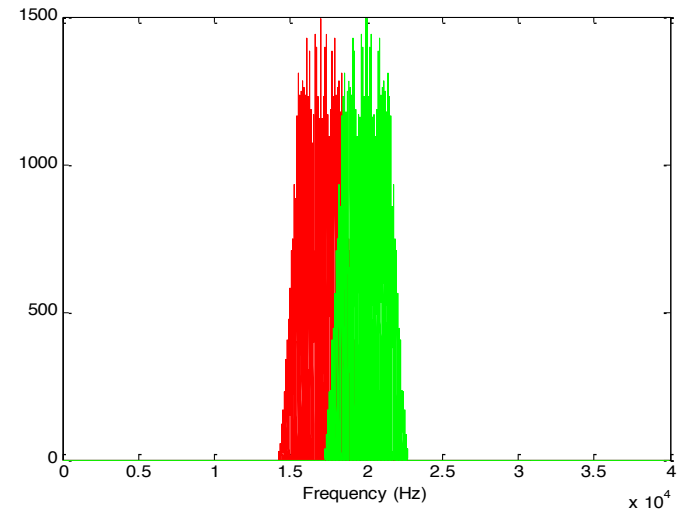
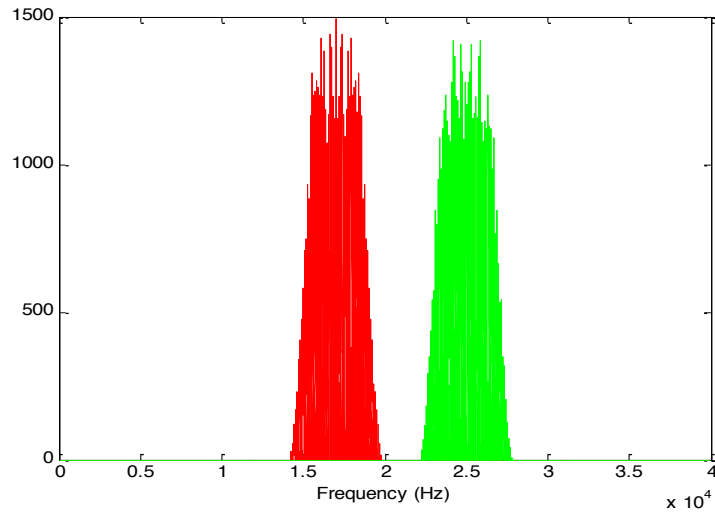
Acknowledgement

- Ohio Federal Research Network (OFRN)
Project “Intelligent Channel Sensing based
Secure Cross Layer Cognitive Networking for
Resilient Space Communication”
- NASA Glenn
- AFRL
- ONR
- NSF

Outline

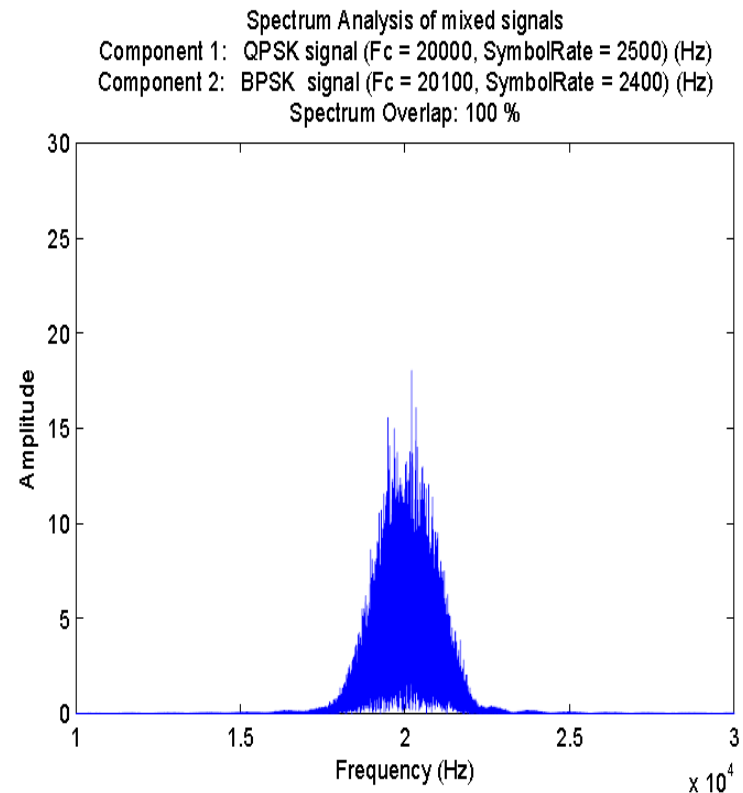
- Motivation
- Cyclostationary Analysis/SCF of Mixed Signal
- Software Defined Radio Implementation
- SDR based Mixed RF Signal Generator
- SDR based Mixed RF Signal Detector
- Examples
- Conclusions

Motivation

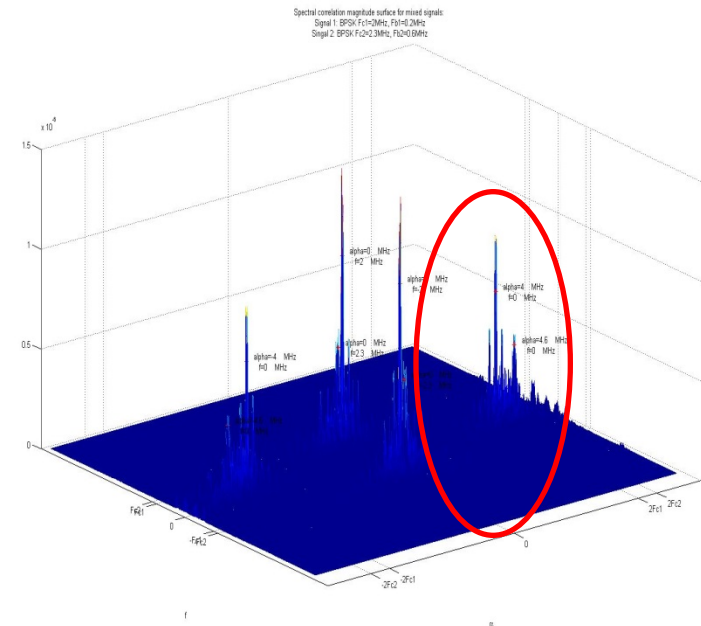
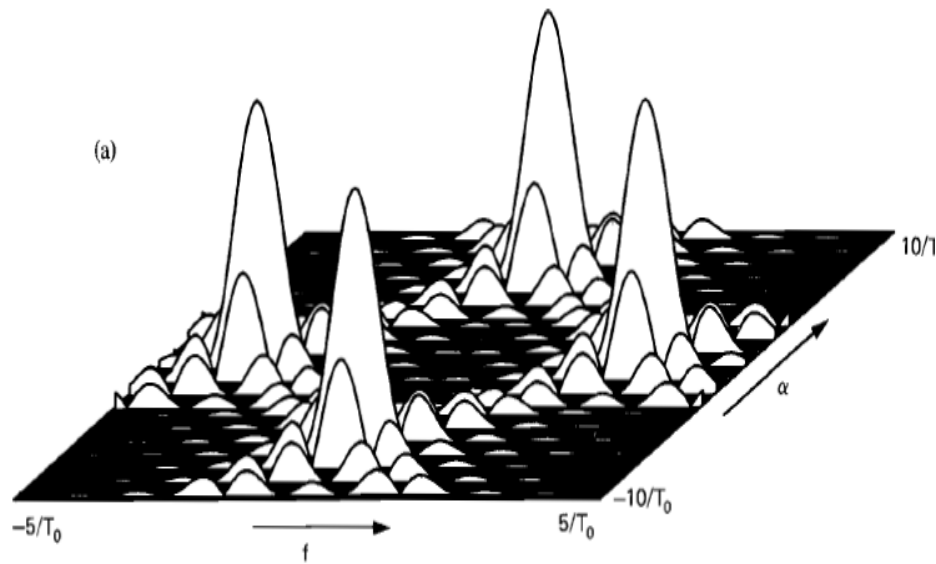


Mixed Signal Detection/Identification

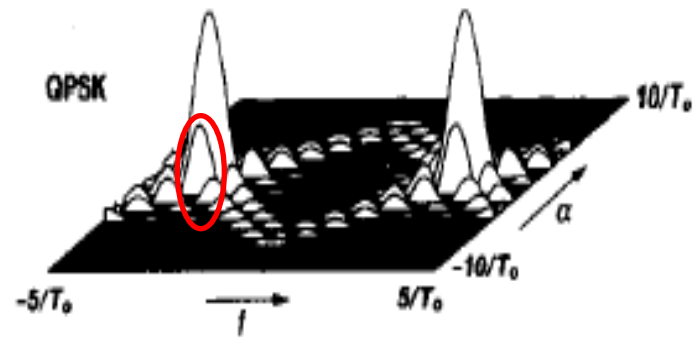
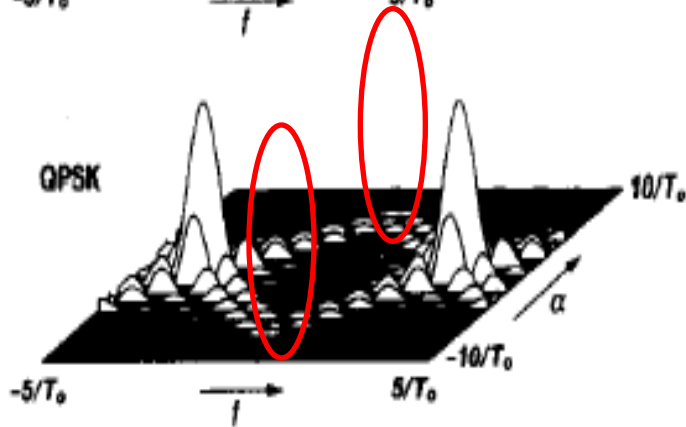
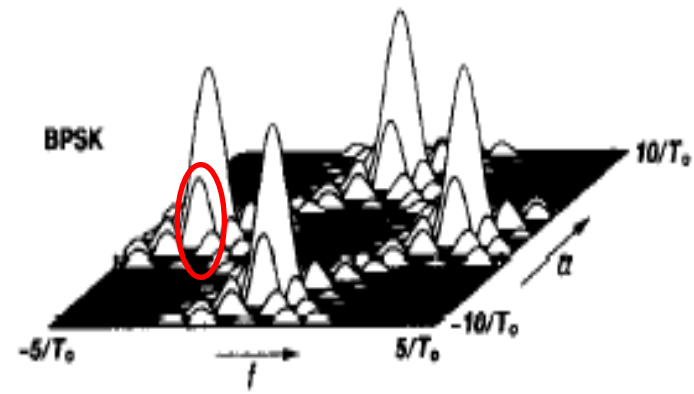
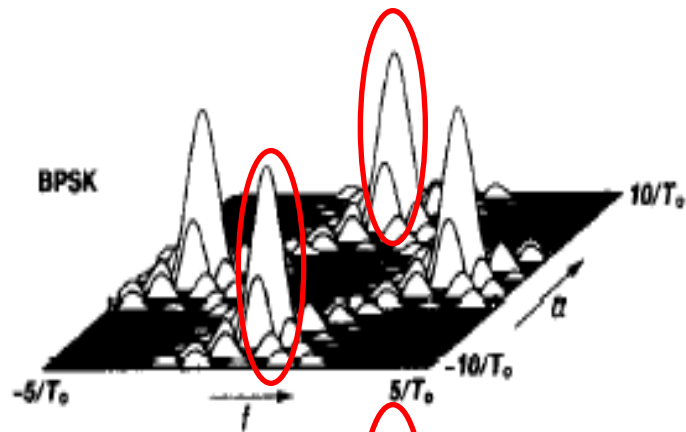
- Mixed signal: multiple signal components with significant spectrum overlap
- Spectrally congested and contested environment
- Cognitive radio and dynamic spectrum access network



Spectral Correlation Function (SCF)



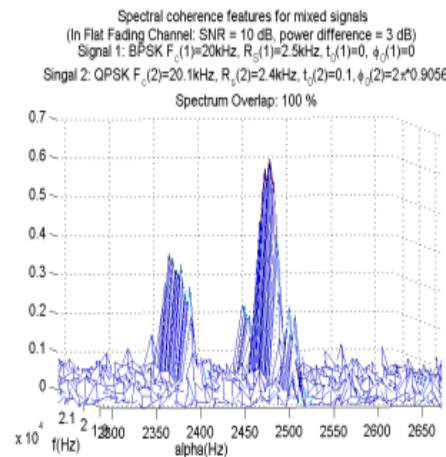
SCF and SOF of Mixed Signals with Higher-order Modulations



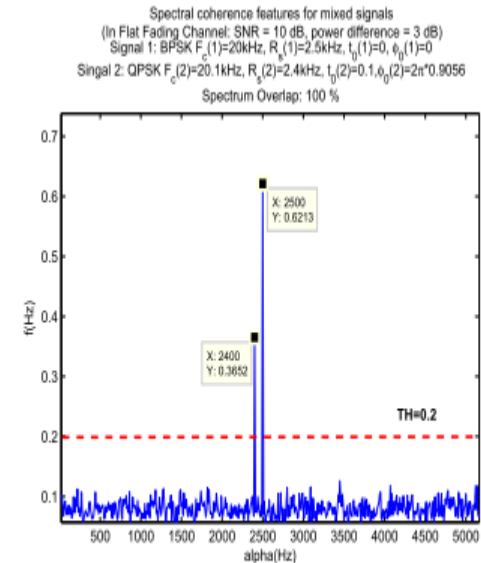
SOF based Mixed Signal Detection and Symbol Rate Estimation

Three-step algorithm to detect signals

1. Estimate the mixed signal's carrier frequency \hat{f}_c and null-to-null bandwidth \hat{B} through spectrum analysis.
2. Calculate the SOF around $\hat{B}/2$ for a cyclic frequency span of \hat{B} with fine resolution.
3. Identify the number of signals and estimate



(a) 3-D view



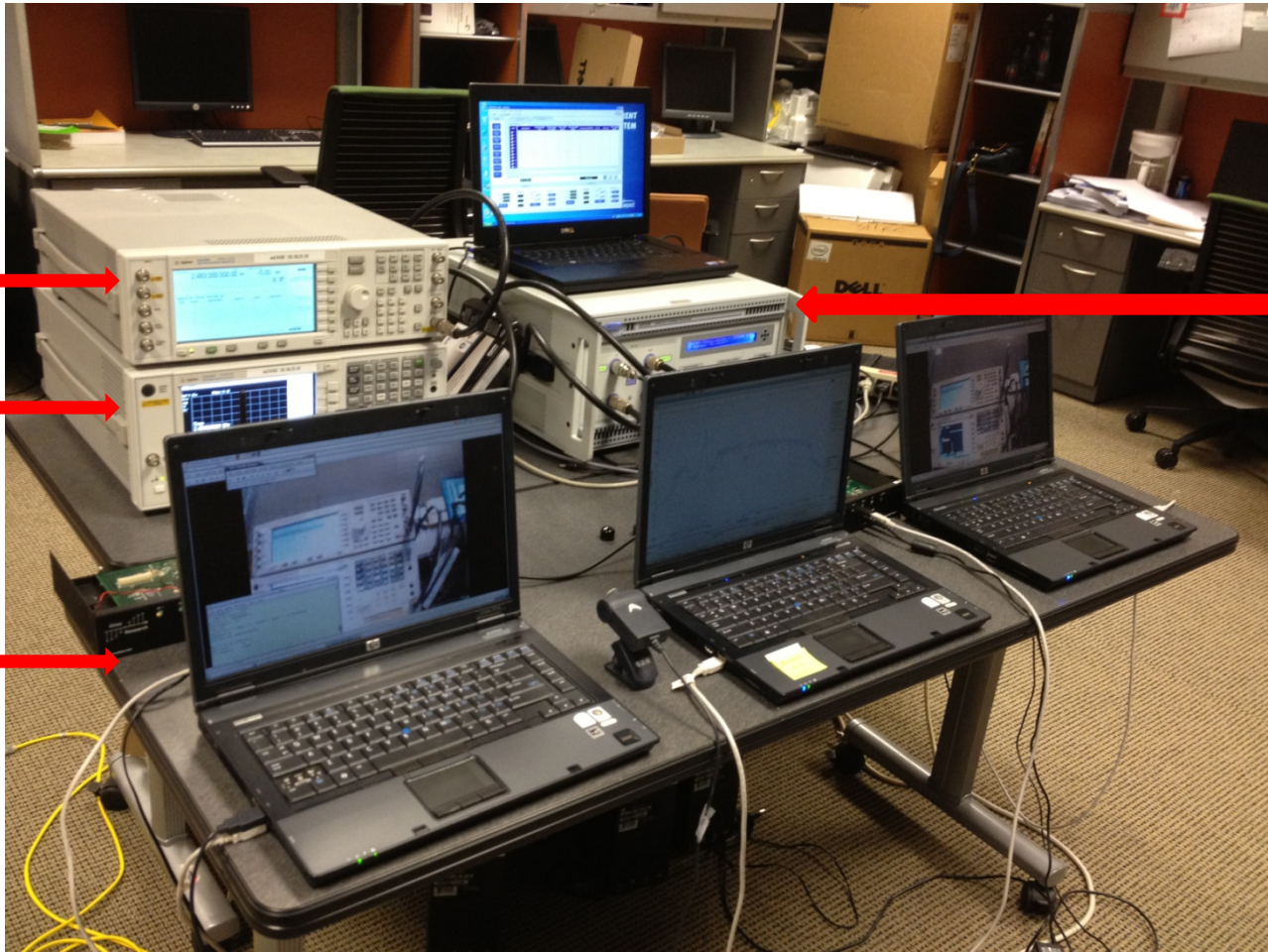
(b) α view

SDR Implementation

Signal
Generator

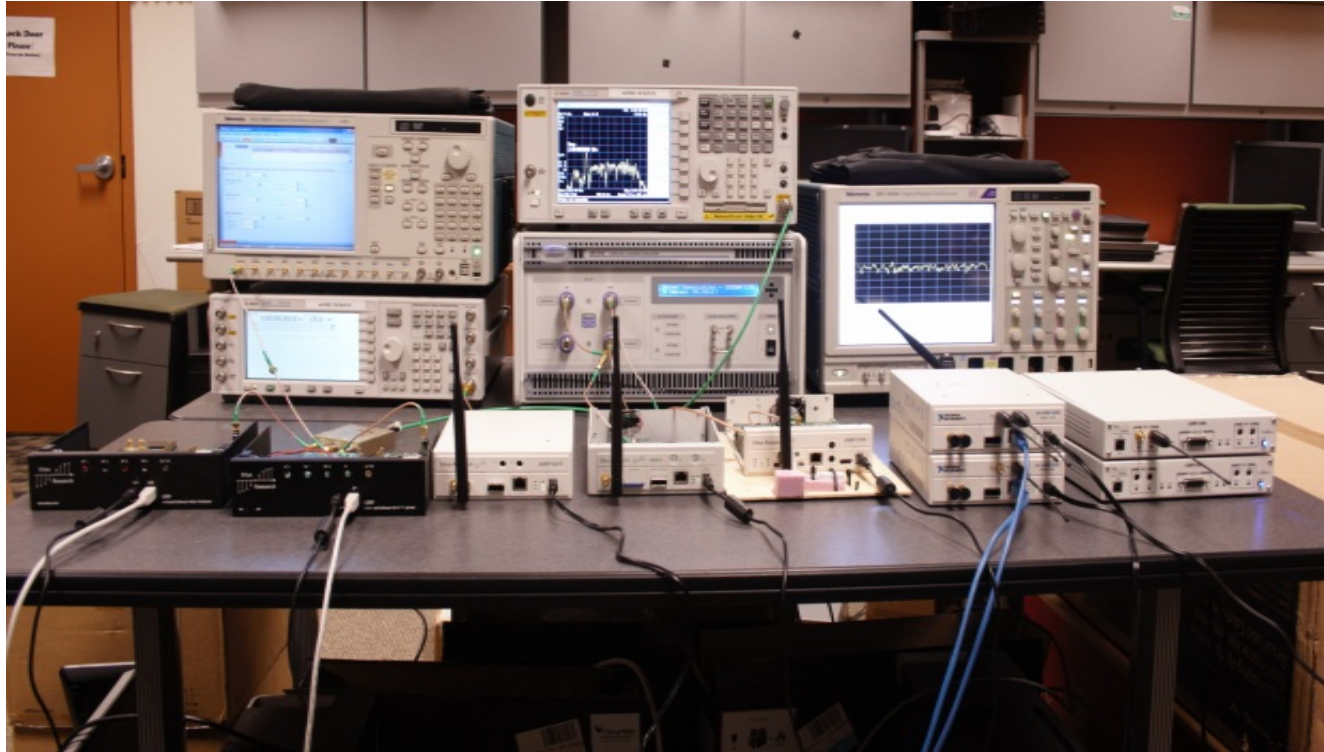
Spectrum
Analyzer

SDR
Software
Suite

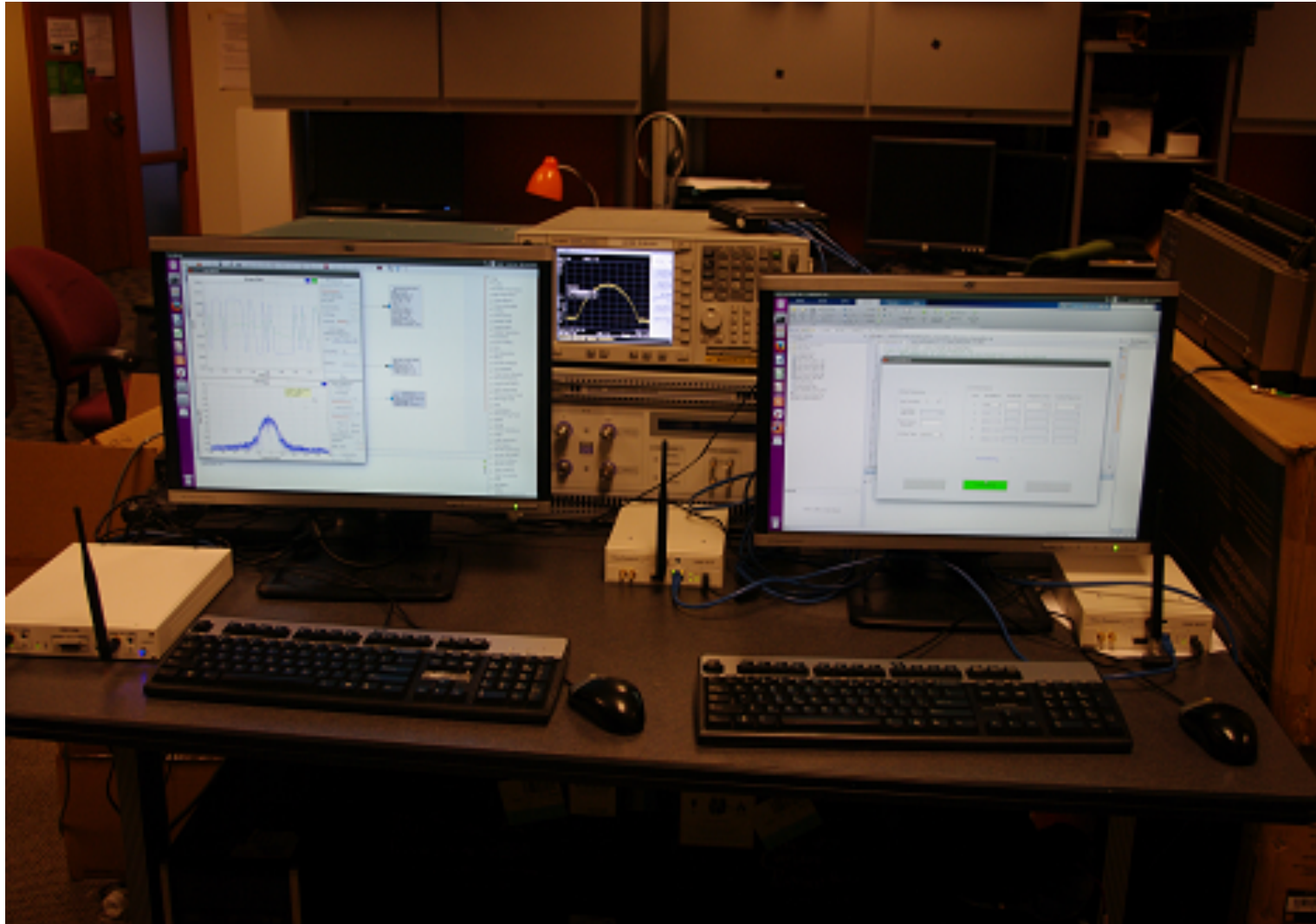


Wireless
Channel
Emulator

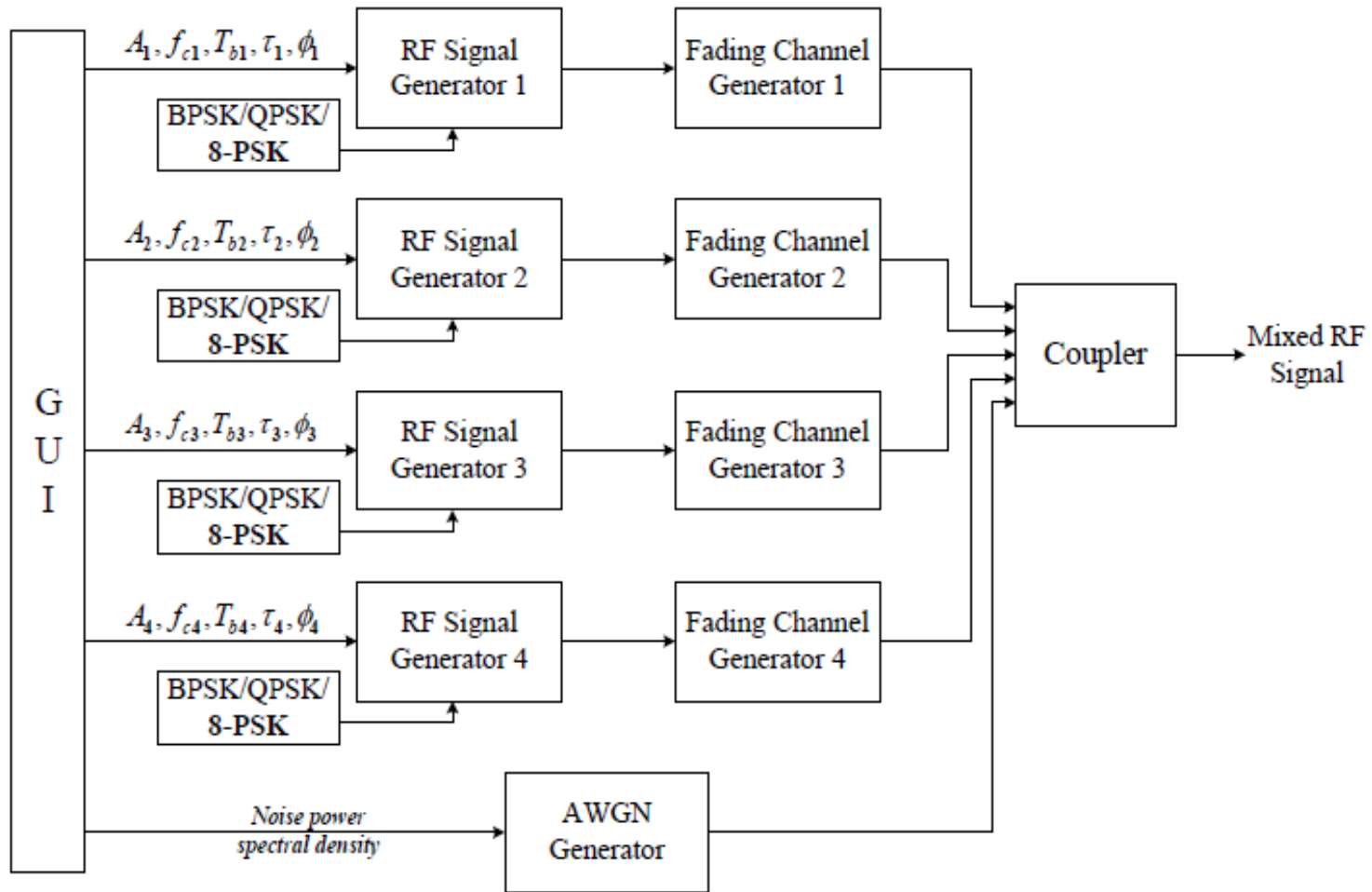
SDR Implementation



SDR Implementation



Mixed RF Signal Generator



SDR based Mixed Signal Generator

Global Parameters

Signal Component Number:

Sampling Rate (Hz):

Lowest RF (Hz):

Transmission Time (s):

Window Type:

Local Parameters

No.	Modulation	Amplitude	Frequency offset (Hz)	Symbol Rate (Hz)	Phase Delay (degree)	Time Delay (ms)
1	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
2	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
3	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
4	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
5	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Setting Parameters

Transmit!

Exit

Pulse Shaping Filter

Global Parameters

Signal Component Number:

Sampling Rate (Hz):

Lowest RF (Hz):

Transmission Time (s):

Window Type:

Local Parameters

No.	Modulation	Amplitude	Frequency offset (Hz)	Symbol Rate (Hz)	Phase Delay (degree)	Time Delay (ms)
1	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
2	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
3	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
4	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
5	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Setting Parameters Transmit! Exit

Modulation Type

Global Parameters

Signal Component Number:

Sampling Rate (Hz):

Lowest RF (Hz):

Transmission Time (s):

Window Type:

Local Parameters

No.	Modulation	Amplitude	Frequency offset (Hz)	Symbol Rate (Hz)	Phase Delay (degree)	Time Delay (ms)
1	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
2	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
3	QPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
4	8PSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
5	16QAM	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Setting Parameters Transmit! Exit

Other Parameters

Global Parameters

User Number:

Sampling Rate (Hz):

Transmission Time (s):

Window Type:

Local Parameters

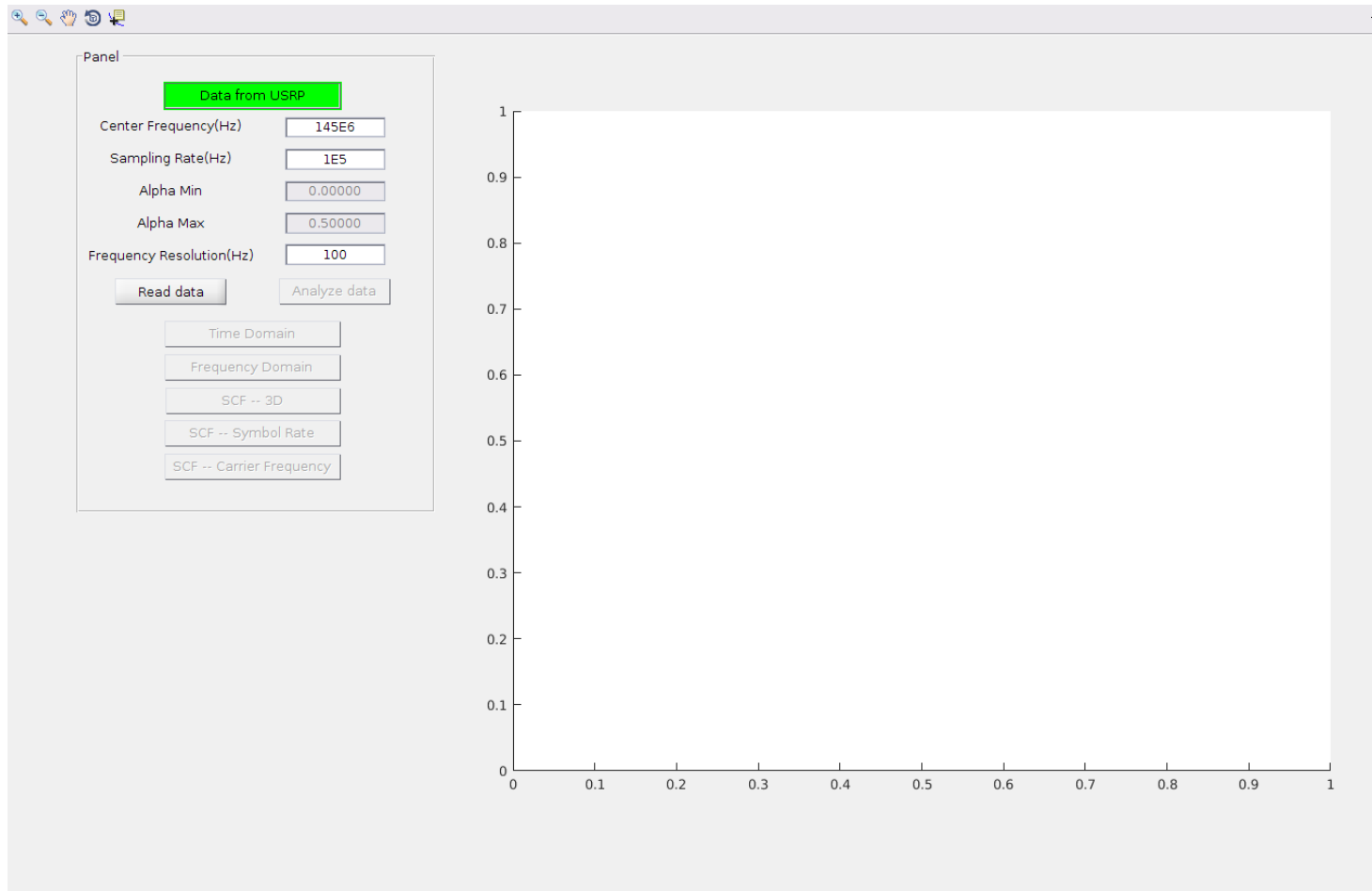
User	Modulation	Amplitude	Frequency (Hz)	Symbol Rate (Hz)
1	<input type="text" value="BPSK"/>	<input type="text" value="1"/>	<input type="text" value="2.450e9"/>	<input type="text" value="1e4"/>
2	<input type="text" value="QPSK"/>	<input type="text" value="2"/>	<input type="text" value="2.4503e9"/>	<input type="text" value="2e4"/>
3	<input type="text" value="8PSK"/>	<input type="text" value="3"/>	<input type="text" value="2.4497e9"/>	<input type="text" value="3e4"/>
4	<input type="text" value="BPSK"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
5	<input type="text" value="BPSK"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Setting Parameters

Transmit!

Exit

Mixed Signal Detector



Case 1: Signals without Overlap

Global Parameters

Signal Component Number:

Sampling Rate (Hz):

Lowest RF (Hz):

Transmission Time (s):

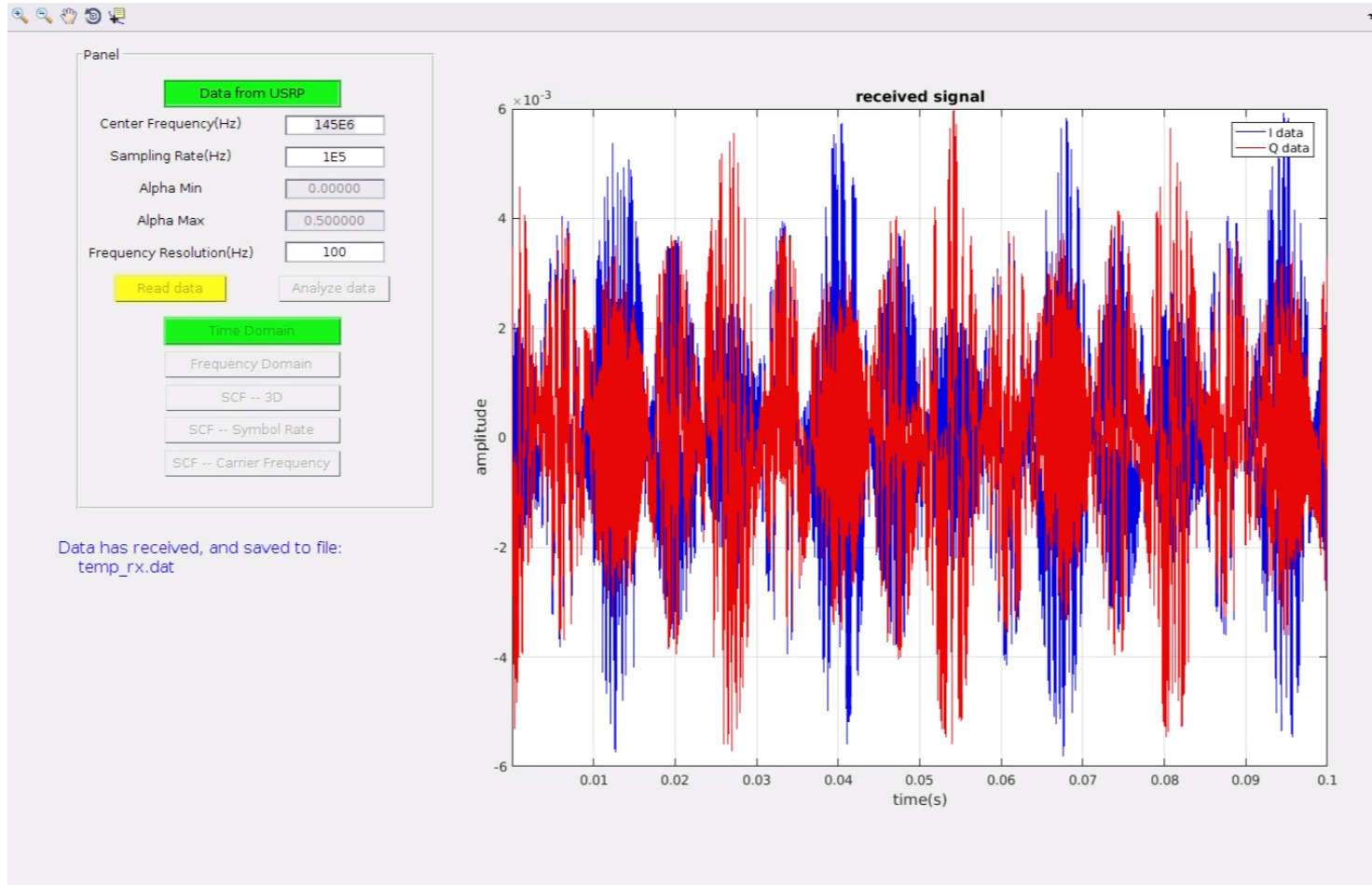
Window Type:

Local Parameters

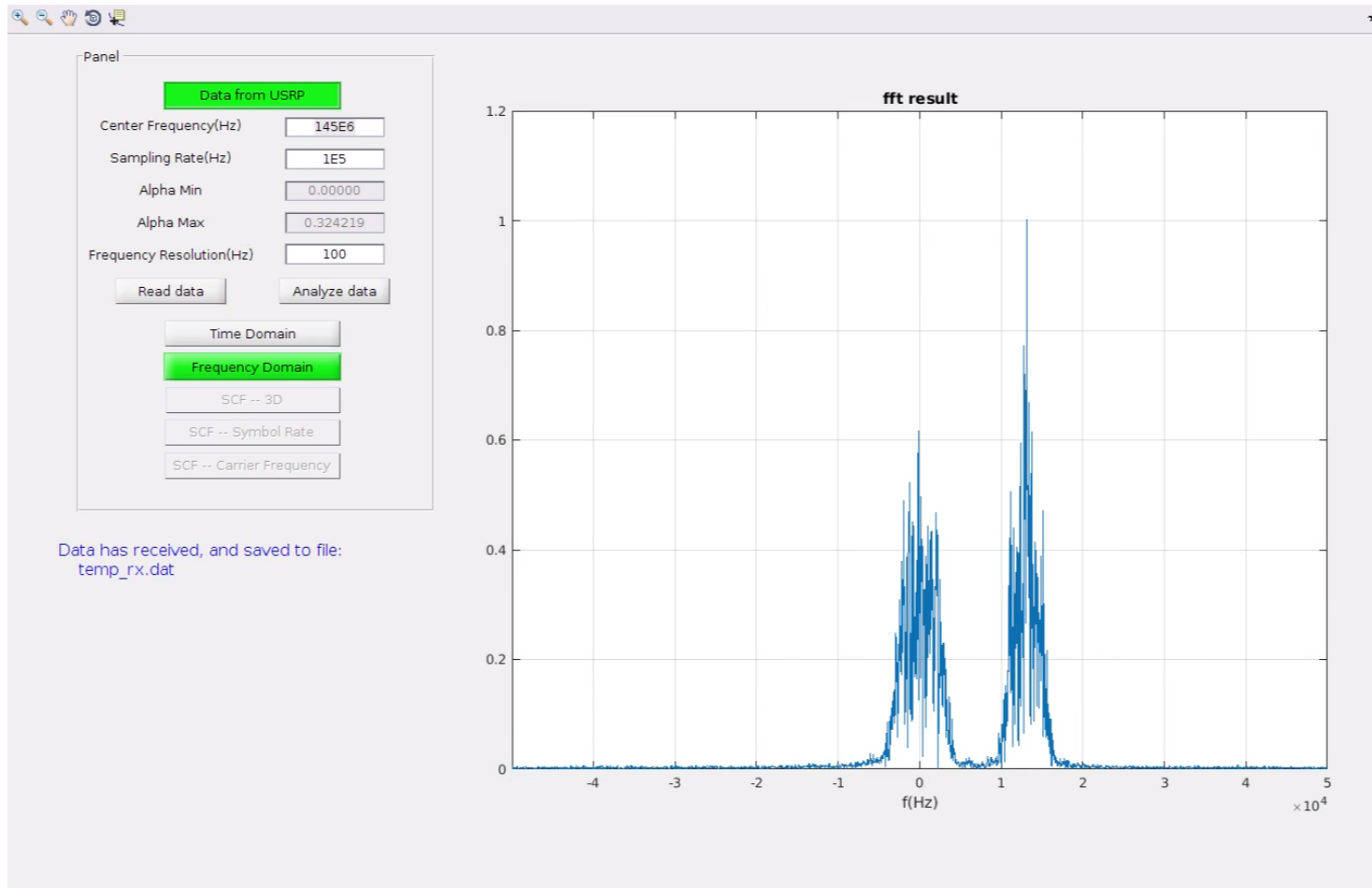
No.	Modulation	Amplitude	Frequency offset (Hz)	Symbol Rate (Hz)	Phase Delay (degree)	Time Delay (ms)
1	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="5e3"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
2	BPSK	<input type="text" value="1"/>	<input type="text" value="1.3e4"/>	<input type="text" value="7e3"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
3	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
4	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
5	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Transmitting...

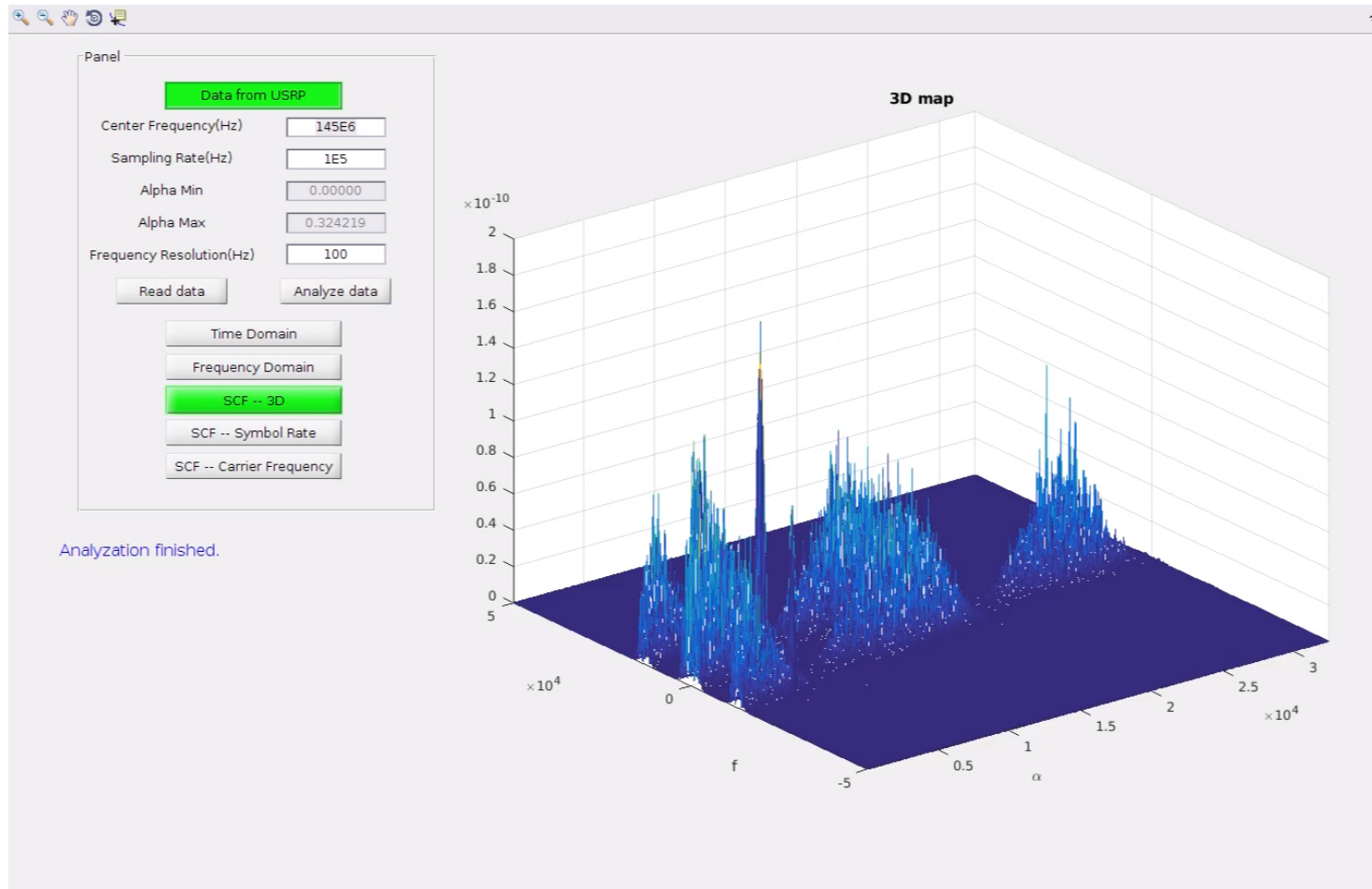
Case 1: Signals without Overlap



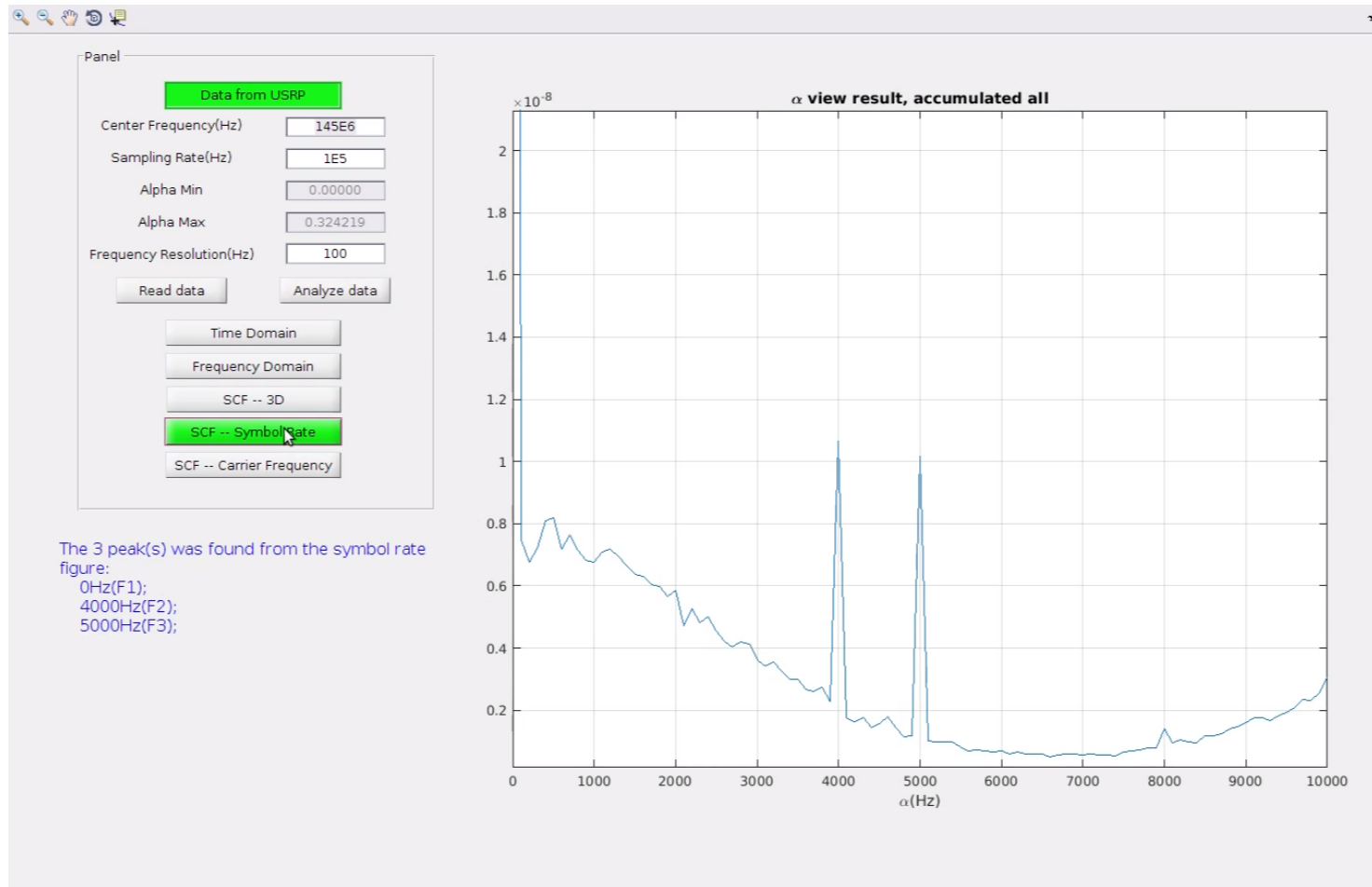
Case 1: Signals without Overlap



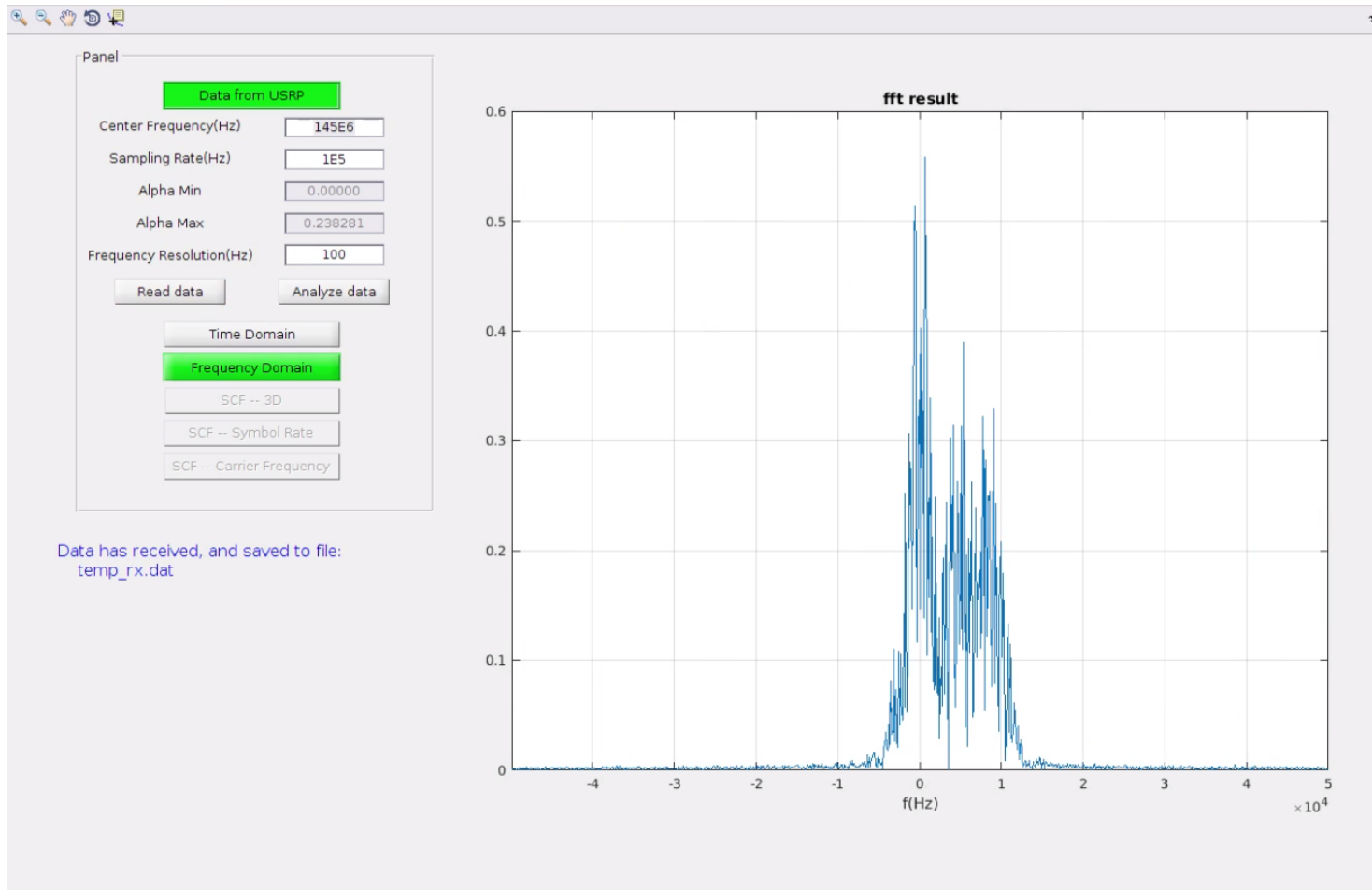
Case 1: Signals without Overlap



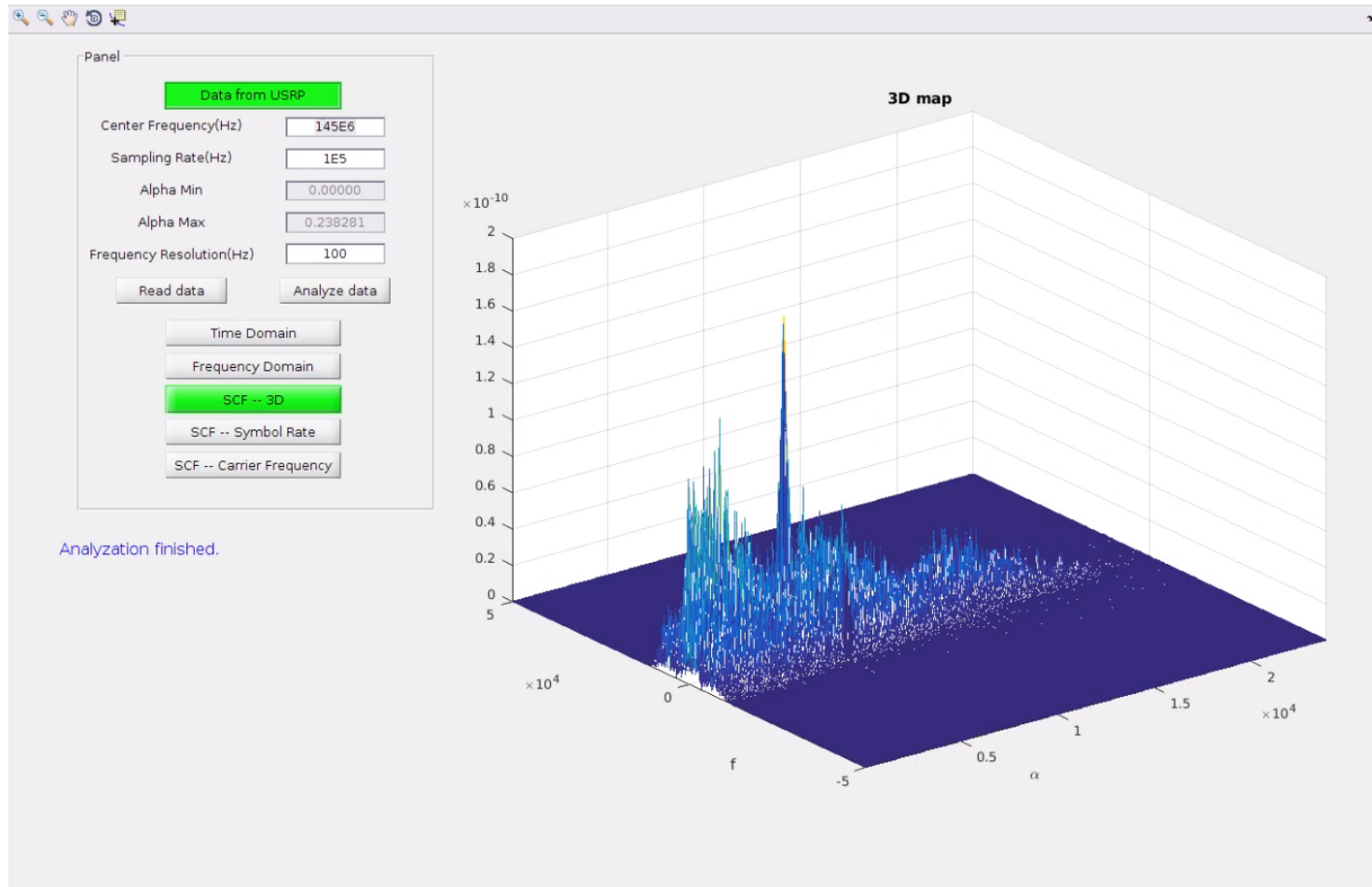
Case 1: Signals without Overlap



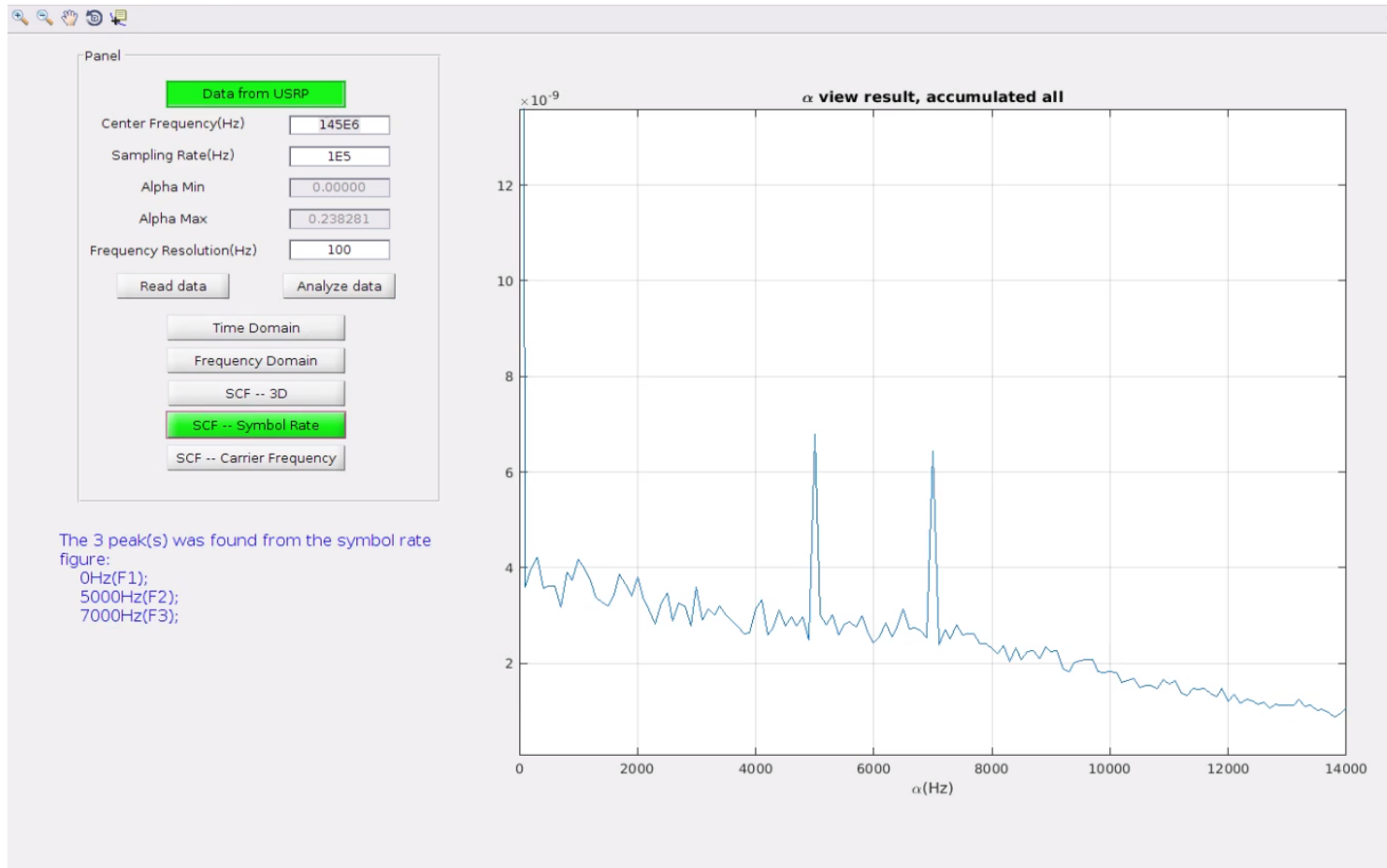
Case 2: Signal with Significant Overlap



Case 2: Signal with Significant Overlap



Case 2: Signal with Significant Overlap



Case 3: 3 Signals Mixed Together

Global Parameters

Signal Component Number:

Sampling Rate (Hz):

Lowest RF (Hz):

Transmission Time (s):

Window Type:

Local Parameters

No.	Modulation	Amplitude	Frequency offset (Hz)	Symbol Rate (Hz)	Phase Delay (degree)	Time Delay (ms)
1	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="4e3"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
2	QPSK	<input type="text" value="1"/>	<input type="text" value="10e3"/>	<input type="text" value="5e3"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
3	8PSK	<input type="text" value="1"/>	<input type="text" value="16.5e3"/>	<input type="text" value="7e3"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
4	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
5	BPSK	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="1"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

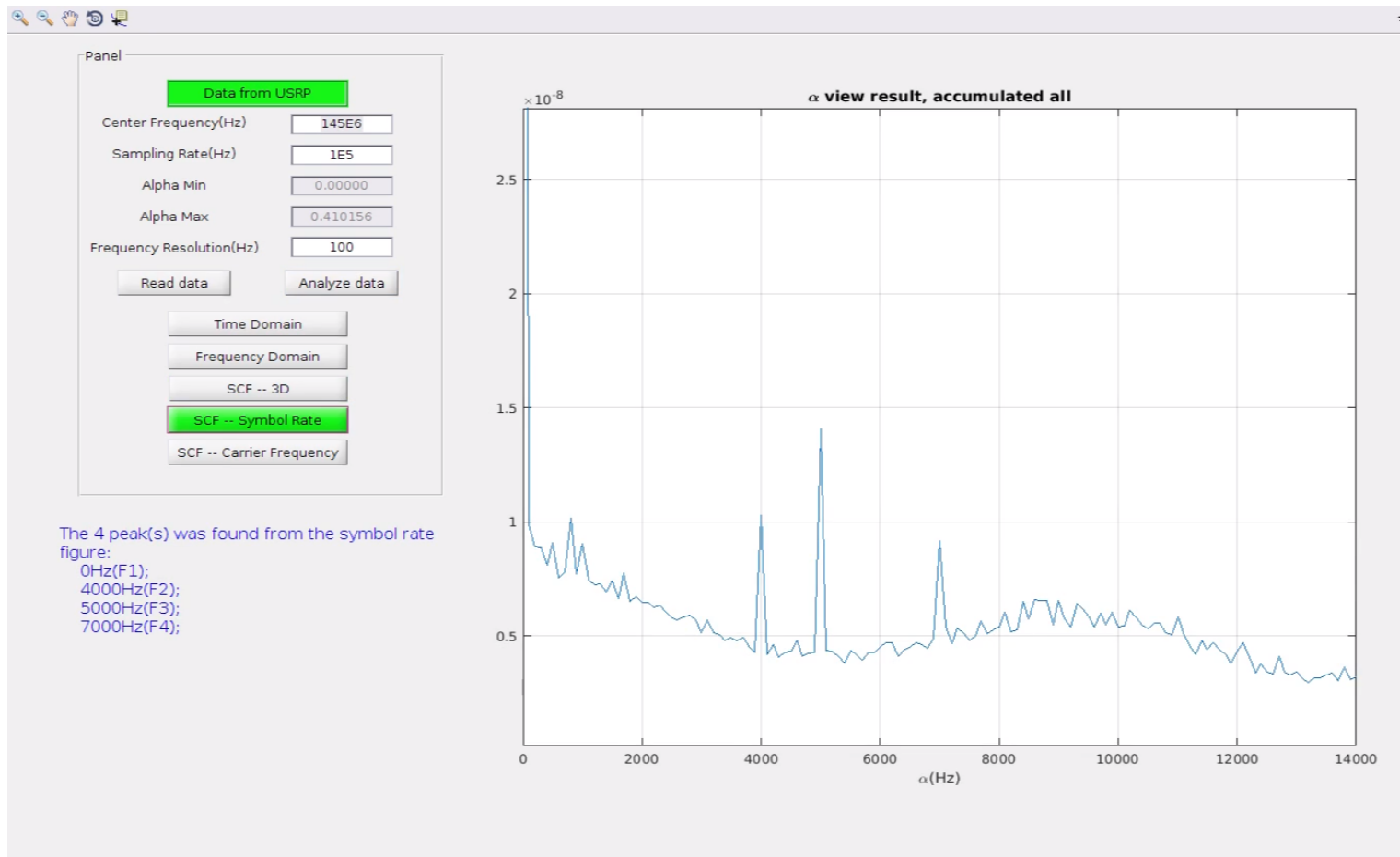
Transmitting...

Setting Parameters

Transmitting

Exit

Case 3: 3 Signals Mixed Together



Conclusions

- Cyclostationary Analysis based Mixed Signal Detection
- SDR Implementation and Demonstration
- SDR Mixed RF Signal Generator
- SDR Mixed RF Signal Detector