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Sensing FM

A P Nicholson

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Research problem – anomalies inside spectral bands

Convert high-data rate complex signal processing to low-data event signals

Inherently parallel – multiple RX antennas

Heirarchy of high to low BW loops, data → events conversion

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Sensing the RF spectrum

Toy world – anomalies inside FM band

The toy world model

FM signals on 87 MHz to 107 MHz are known, published, and finite in number.

Carrier frequencies are constant over time.

Known RF tower locations and fixed sets of carrier frequencies per tower (FM stations).

The construction of the RF baseband (modulated on the carrier frequency) is a known standard.

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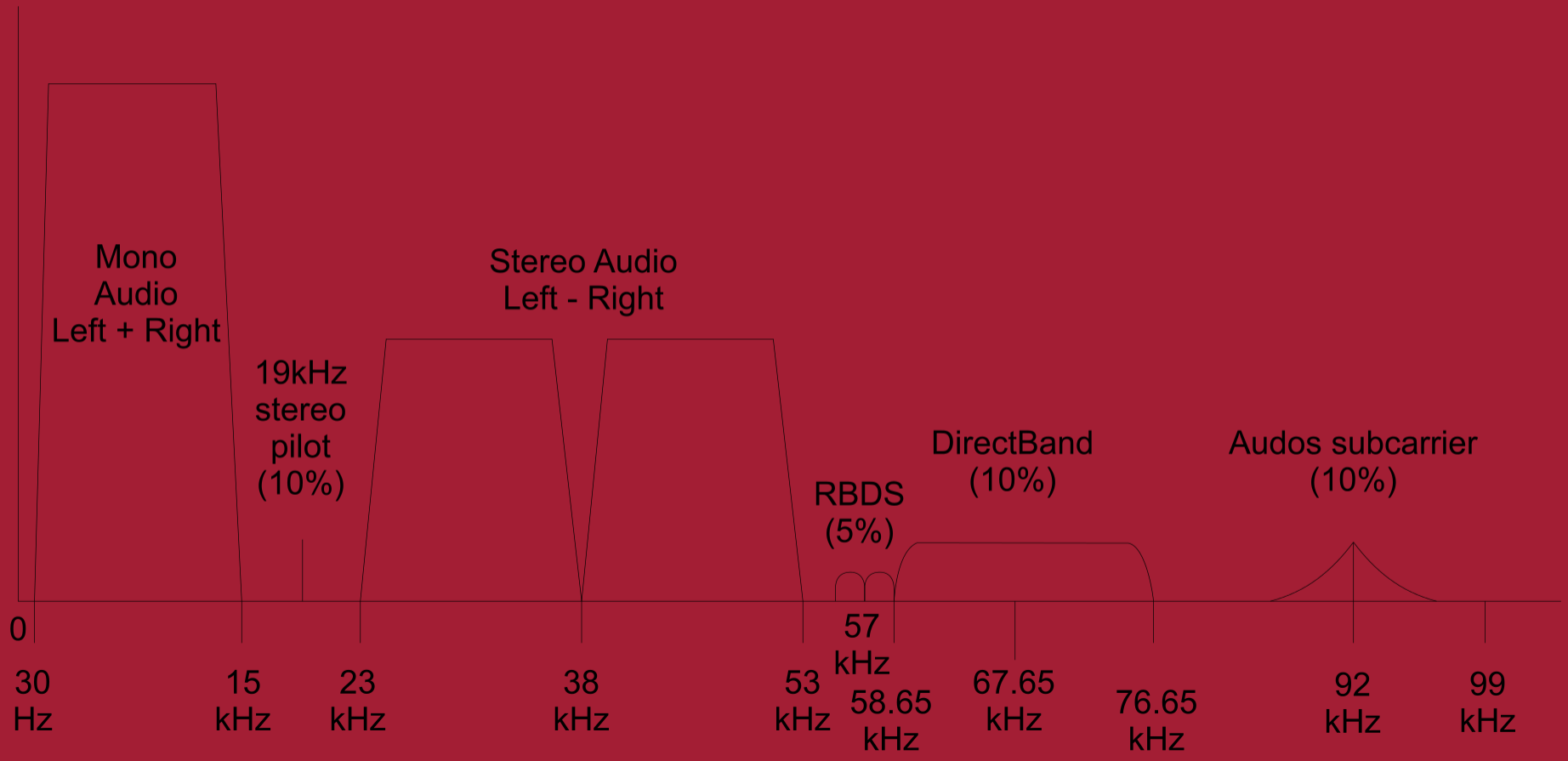

“Typical spectrum of composite baseband FM signal”

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Toy world – anomalies inside FM band

The hardware setup

Use a SDR dongle connected to PC to collect I/Q samples in 2 MHz BW around a centre frequency. Sample rate 2.048MS/s

Scan the band of frequencies in 87 MHz to 107 MHz. 10 scans per region of interest.

Uses a TCP/IP model to communicate with the SDR via “rtl_sdr” package, using tcp_ip server “rtl_tcp”. Matlab uses tcp/ip sockets to talk to “rtl_tcp” instead of to SDR directly.

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Sensing the RF spectrum

MATLAB sensing – outer loop of event generation.

Outer loop does the following across the entire FM spectrum:

Sets gain / sample rate / frequency of SDR – centre frequency on 2 MHz slice.

Takes 2^18 I/Q samples (convert to complex number for FFT processing) per band

Do 64 FFTs using 2^12 samples per band.

Keep a running average of FFTs across the entire FM spectrum.

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Outer loop event detection:

Do findpeaks on averaged power spectrum using a set of high and low adaptive minimum peak height → threshold the power in observed signals.

(minpeakdistance 200kHz, meanpeakwidth 2*freq_step : FM signal broadcast specs)

Estimate noise floor using average of power spectrum, with peaks removed.

Adapt our threshold peak heights to keep number of peaks to reasonable number, without going below noise floor.

Map discovered signal peak to known FM stations → Classify peak into either known or unknown station.

emit EVENT (freq of peak, power, time, region, threshold, known?)

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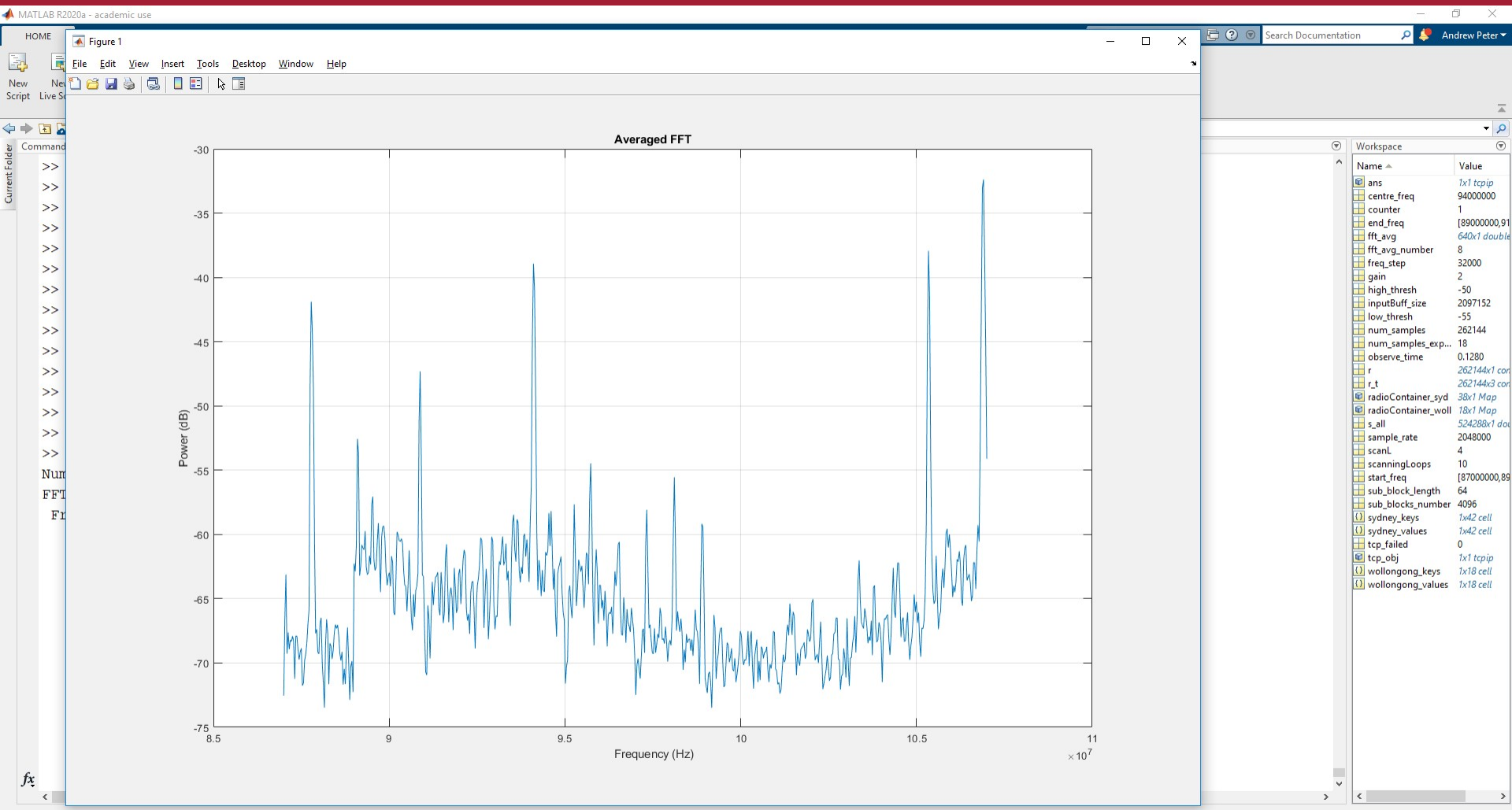

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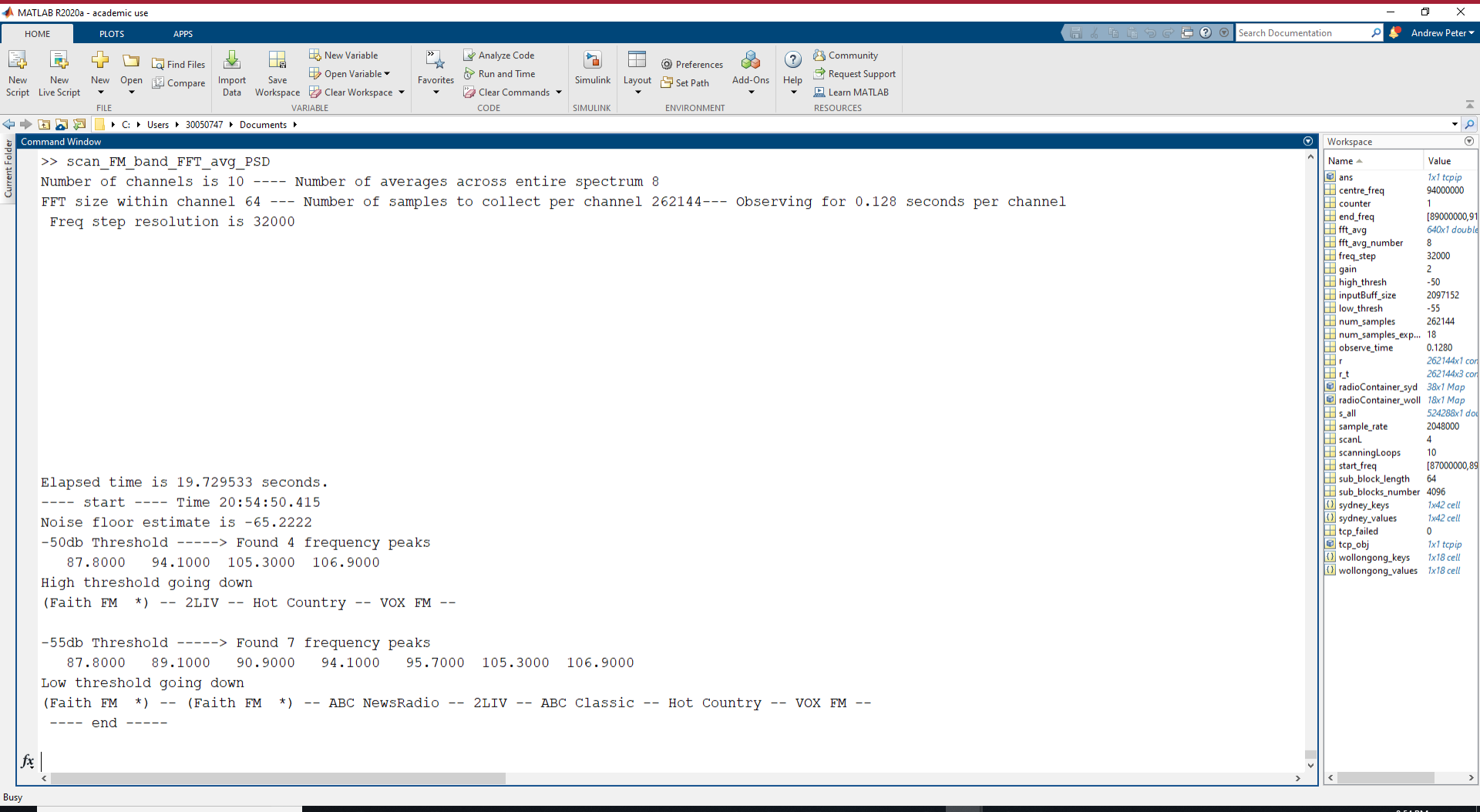

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MATLAB R2020a - academic use

HOME PLOTS APPS

Search Documentation | Andrew Peter

New Script | New Live Script | New | Open | Find Files | Compare | Import Data | Save Workspace | New Variable | Open Variable | Clear Workspace | Favorites | Analyze Code | Run and Time | Clear Commands | Simulink | Layout | Preferences | Set Path | Add-Ons | Help | Community | Request Support | Learn MATLAB

FILE VARIABLE CODE SIMULINK ENVIRONMENT RESOURCES

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Command Window

```
Low threshold going down
(Faith FM  *) -- (Faith FM  *) -- ABC NewsRadio -- 2LIV -- ABC Classic -- Hot Country -- VOX FM --
 ---- end -----

Elapsed time is 19.074750 seconds.
---- start ---- Time 20:57:25.714
Noise floor estimate is -65.6802
-51db Threshold -----> Found 5 frequency peaks
   87.8000   90.9000   94.1000  105.3000  106.9000
High threshold going down
(Faith FM  *) -- ABC NewsRadio -- 2LIV -- Hot Country -- VOX FM --

-56db Threshold -----> Found 8 frequency peaks
  Columns 1 through 7
   87.8000   89.1000   90.9000   94.1000   95.7000   98.1000  105.3000
  Column 8
  106.9000
Low threshold going down
(Faith FM  *) -- (Faith FM  *) -- ABC NewsRadio -- 2LIV -- ABC Classic -- i98FM -- Hot Country -- VOX FM --
 ---- end -----
```

Workspace

Name	Value
ans	1x1 tcpip
centre_freq	94000000
counter	1
end_freq	[89000000,91
fft_avg	640x1 double
fft_avg_number	8
freq_step	32000
gain	2
high_thresh	-50
inputBuff_size	2097152
low_thresh	-55
num_samples	262144
num_samples_exp...	18
observe_time	0.1280
r	262144x1 cor
r_t	262144x3 cor
radioContainer_syd	38x1 Map
radioContainer_woll	18x1 Map
s_all	524288x1 do
sample_rate	2048000
scanL	4
scanningLoops	10
start_freq	[87000000,89
sub_block_length	64
sub_blocks_number	4096
sydney_keys	1x42 cell
sydney_values	1x42 cell
tcp_failed	0
tcp_obj	1x1 tcpip
wollongong_keys	1x18 cell
wollongong_values	1x18 cell

Busy

Type here to search

8:57 PM 21/09/2020

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Sensing the RF spectrum

MATLAB sensing – inner loop of event generation.

Inner loop does the following across discovered frequencies (from events from outer loop), which could be asynchronously to outer loop on another SDR dongle:

Sets gain / sample rate / frequency of SDR

Takes 2^19 I/Q samples (convert to complex number for FFT processing) per peak

Do the spectral correlation function (2-D FFT of time lag product of the signal with itself)

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Spectral correlation function is a 2D FFT of time-lagged signal with itself.

Zero-time lag is just FFT of x^2 – power spectral density.

Can choose range of the time lags to analyse.

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Inner loop event detection:

Findpeaks on the SCF function : e.g can you find the 19 kHz pilot tone ?

Emit EVENT ((freq of peak, power, time, region, threshold, known?), (pilot?))

Can expand to other features inside FM baseband – e.g RDS Radio Data System, which is inserting digital streams in conventional FM baseband.

→ Real-time event processing to discern anomalies, e.g “pirate FM station”

e.g an event which contains on-going transmission from an unknown station with a pilot tone

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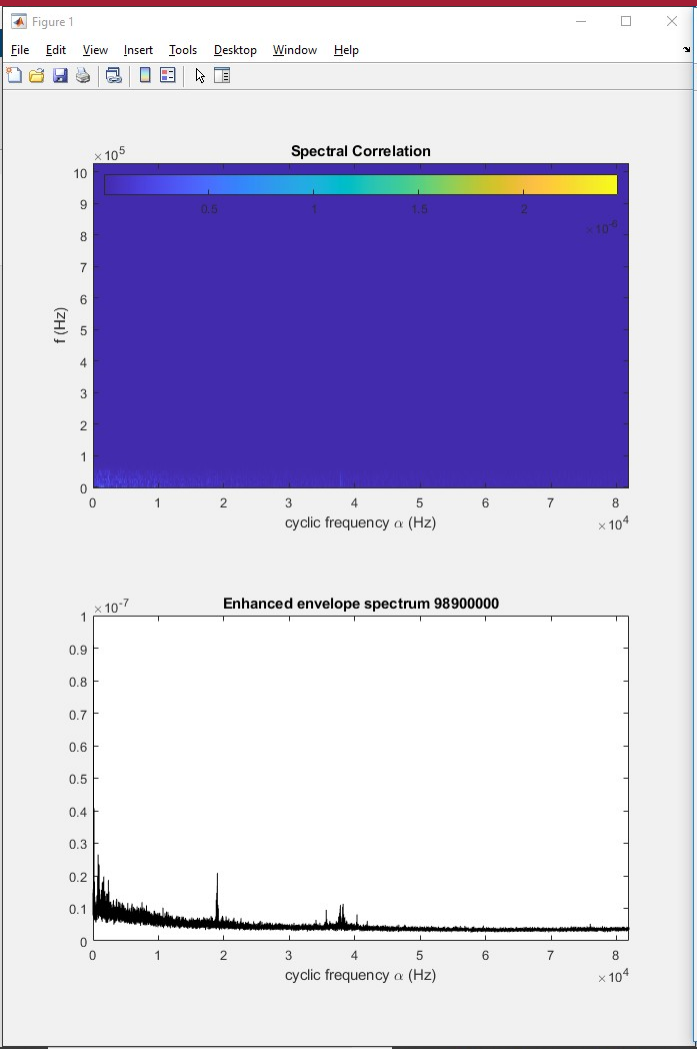

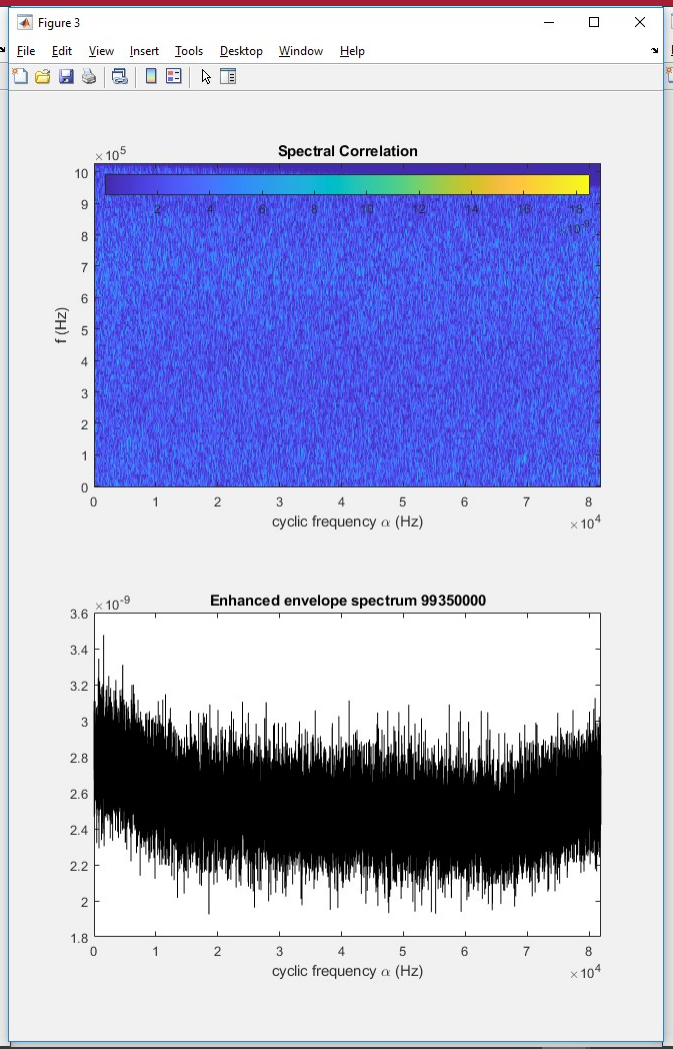

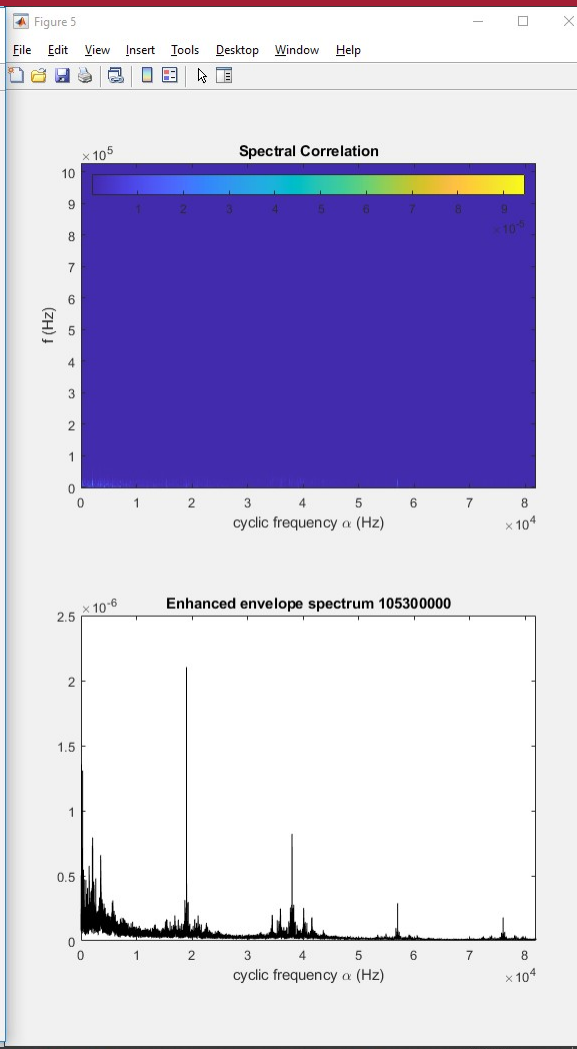

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MATLAB scripts →

scan_FM_band_FFT_avg_PSD.m (outer)
Demo_Fast_SC.m (inner)

https://github.com/neuromorphicsystems/neuromorphic-rf-scene-analysis

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Going further :

Build multiple SDR sensing station → make outer/inner loops parallel

Navigating by FM scene → analyse region events over time & power level changes of stations etc

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