Primary User Authentication of Cognitive Radio Network using Underlay Waveform

Rohit Chakravarthy, Kaiyu Huang, Lin Zhang and Zhiqiang Wu

Outline

1. Spectrum Congestion
2. Cognitive Radio
3. Primary Users & Secondary Users
4. Primary User Emulation Attack
5. Current research & limitations
6. PU Authentication System Model
7. Results
8. Conclusions

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

- FEDERAL EXCLUSIVE
- FEDERAL/NON-FEDERAL SHARED
- NON-FEDERAL EXCLUSIVE

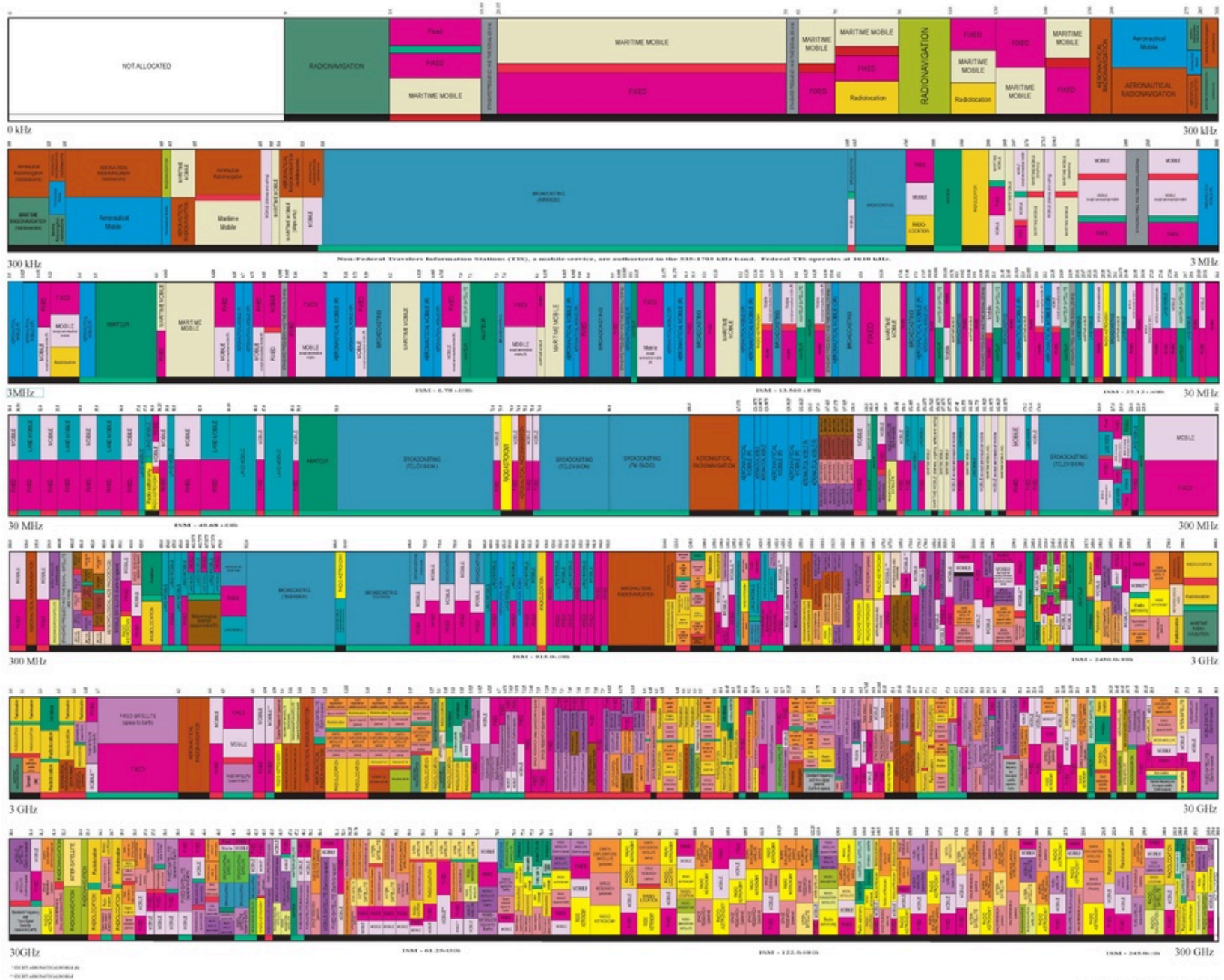
ALLOCATION USAGE DESIGNATION

ASSIGNCE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic supplement to the Table of Frequency Allocations and the U.S. Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

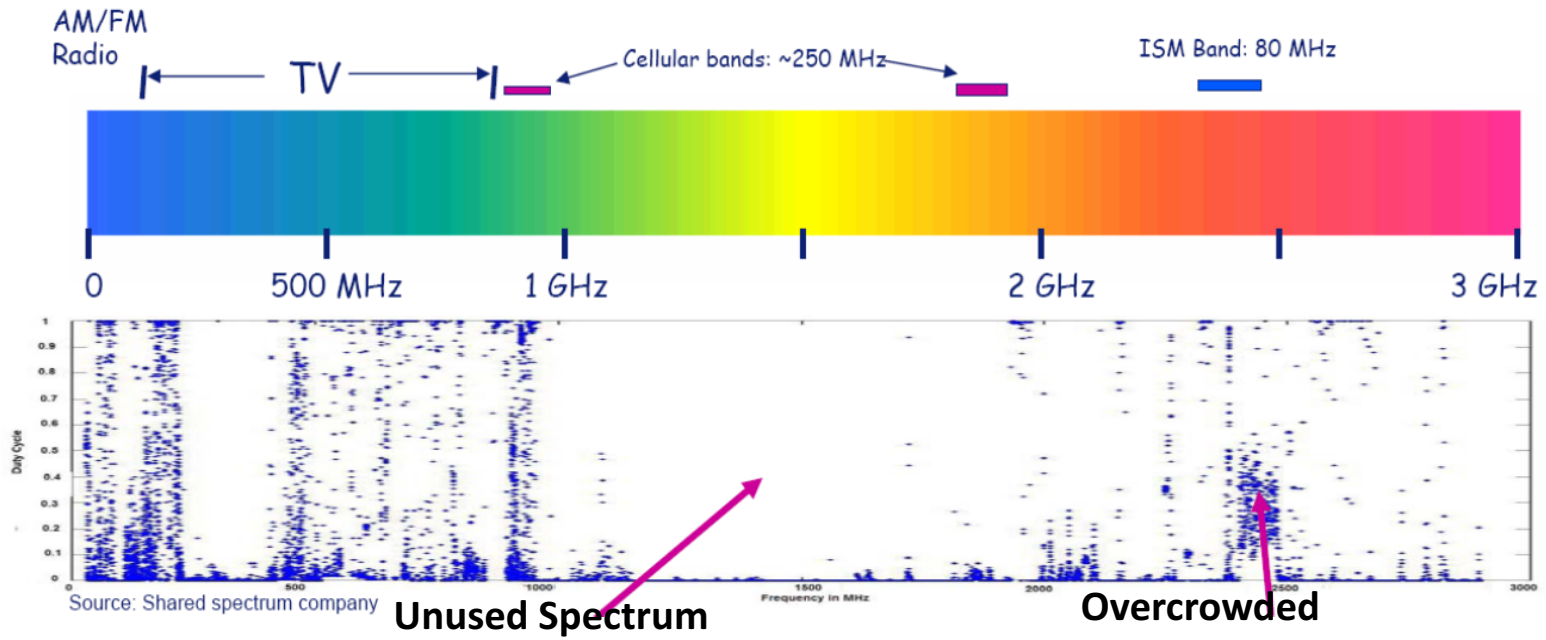
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

JANUARY 2016



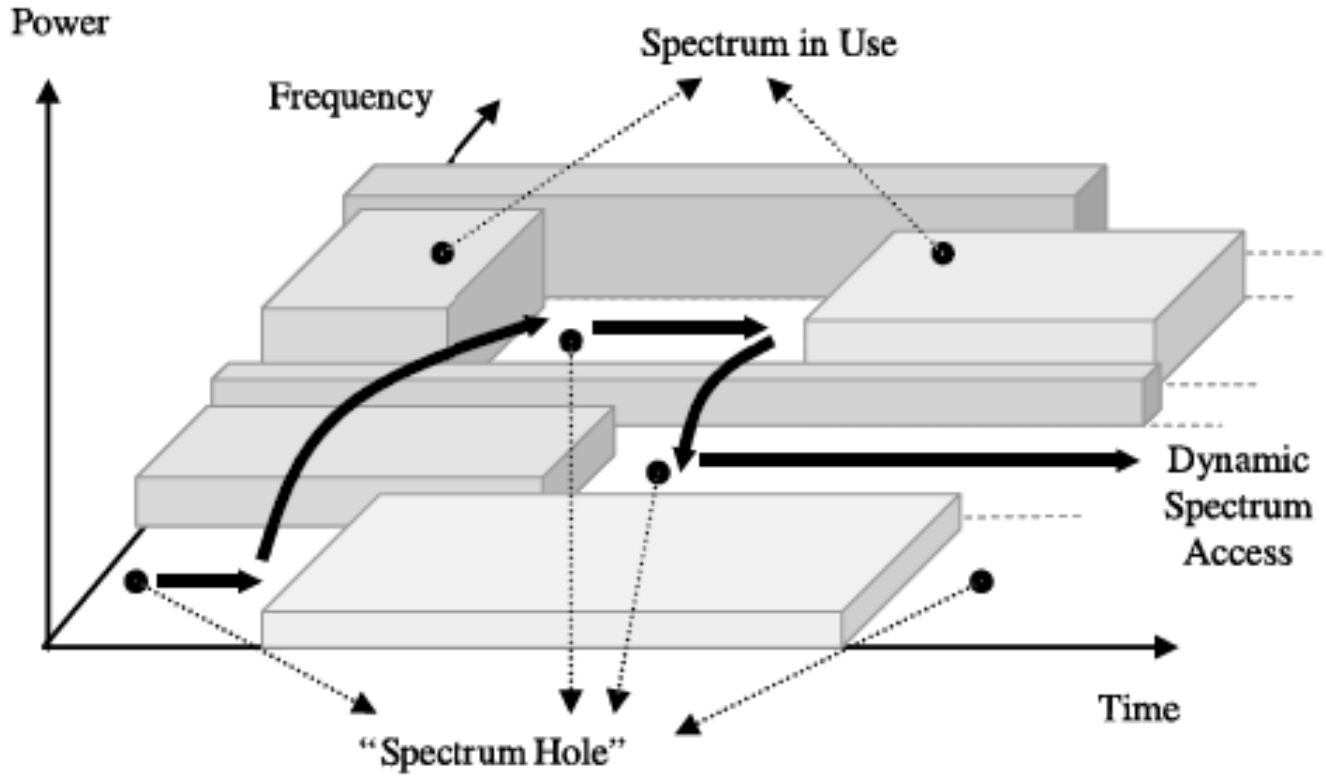
Spectrum Congestion Problem

- Overcrowding of spectrum due to an increased number of users, increased number of spectrum based devices, and higher frequencies/data rates
- Real problem comes down to inefficient usage of the spectrum rather than a lack of spectrum itself



Cognitive Radio

An intelligent radio or system that senses the spectrum and is aware of its operational environment and can be trained to dynamically and autonomously adjust its radio operating parameters accordingly

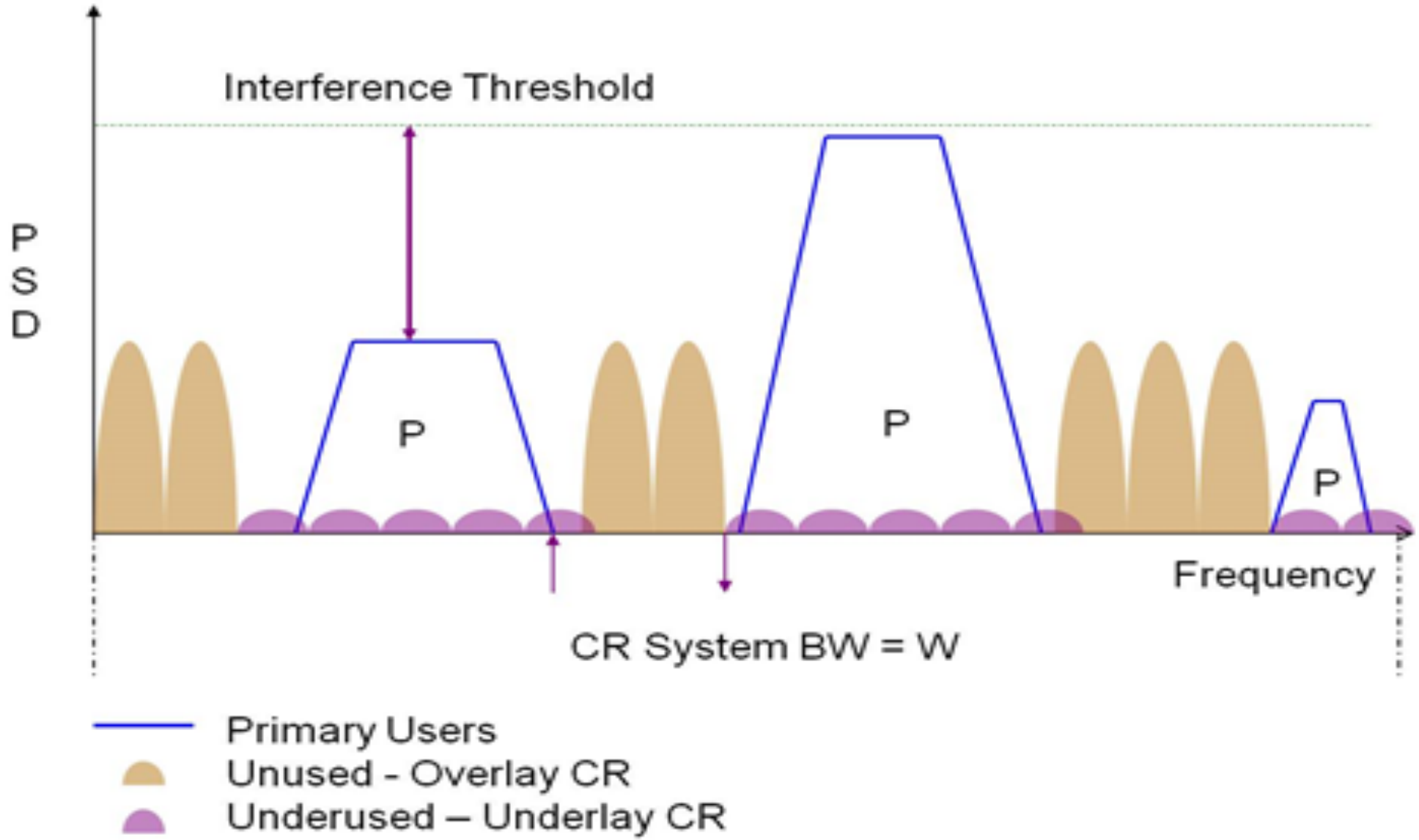


Primary Users & Secondary Users

- Primary User (PU)
  - The intended user in a CR network
  - Principal access to the spectrum

- Secondary User (SU)
  - Opportunistic user using the spectrum on a non-interference basis but in cooperation with the PU
  - Can only use the spectrum when PU grants access or not present

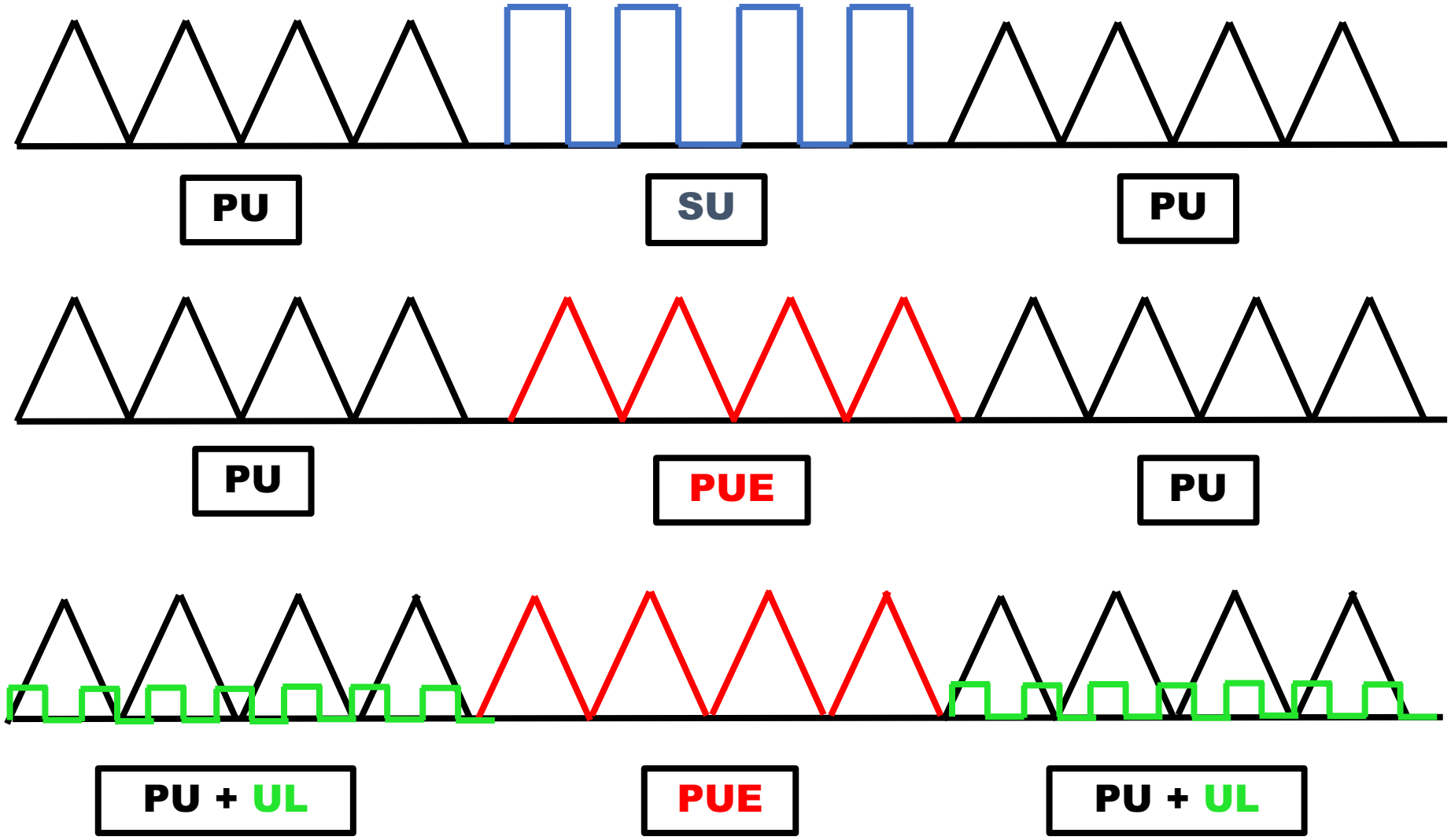
Primary Users & Secondary Users (cont.)



Primary Users Emulation Attack

- “Intruder” who tries to interfere and occupy the vacant spectrum of the PU intended for SU
- Impersonates PU by mimicking distinctive characteristics and features
- SU assumes PU is still occupying the spectrum when in reality PUE Attack is occurring
- CR left vulnerable to PUE attack thus losing spectrum to intruder
- Poor spectrum utilization

Primary Users Emulation Attack (cont.)



Current PUE research and limitations

1. Energy & Cyclostationary methods
2. Location based approaches
3. Cooperative sensing
4. Cryptography

Above methods are ineffective to identify PUE attacks or require high computational complexity

PU Sensing Methods in literature

- Energy Detection
  - Usage of an energy detector in signal detection to identify the presence of a PU
  - Problem – Just detection of energy levels is not sufficient enough to differentiate PU from PUE

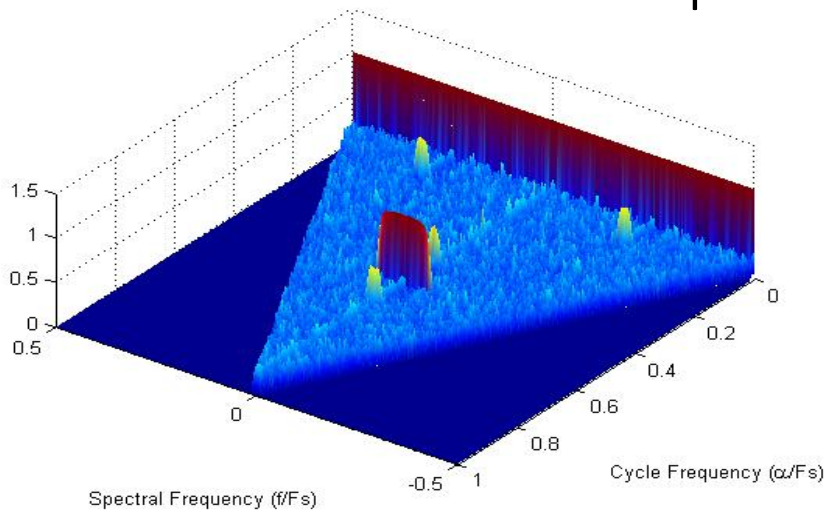
- Match-filter detection
  - Correlates a shifted version of the PU waveform and compares the output of the filter with the predetermined signal
  - Problem – requires perfect knowledge of PU, and moreover a PUE can just use a repeater to imitate PU

- Cyclostationary Signal Processing (CSP) Detection
  - Extracts distinct features of PU signal and performs detection based on those special features
  - Can distinguish PU from noise
  - Extraction of features still possible under varying Signal to Noise Ratio (SNR) using embedded information in PU signal that are non-existent in noise
  - Problem – high computational complexity

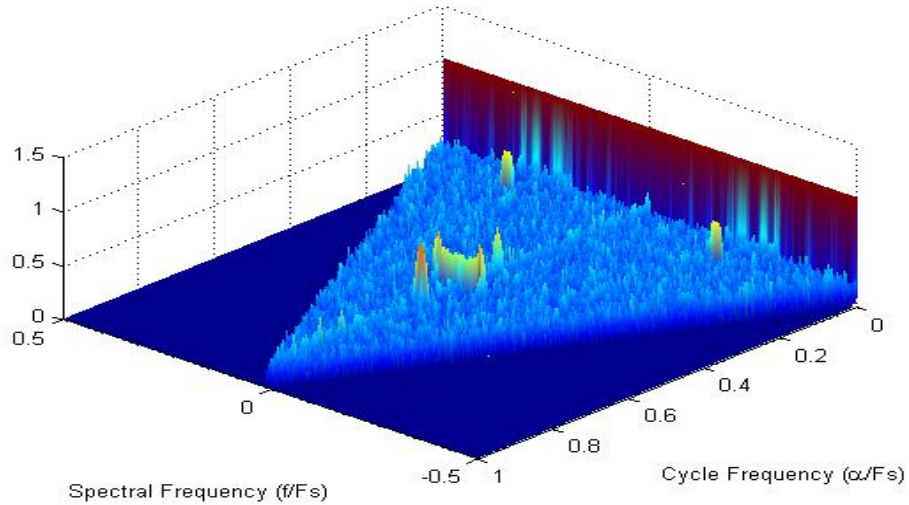
What is Cyclostationary Signal Processing?

Cyclostationary Signal Processing (CSP) is a statistical signal processing technique which exploits the inherent features and properties of a modulated signal such as modulation, symbol rate, chip rate, etc.

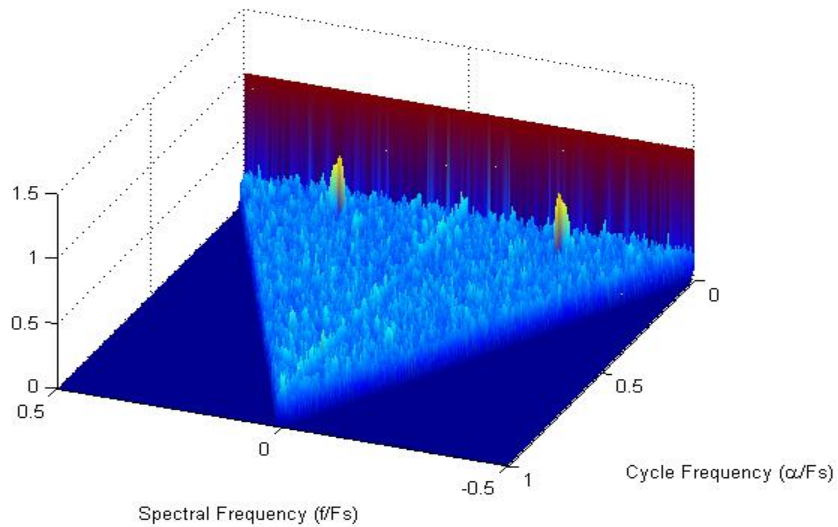
Spectral Correlation Function



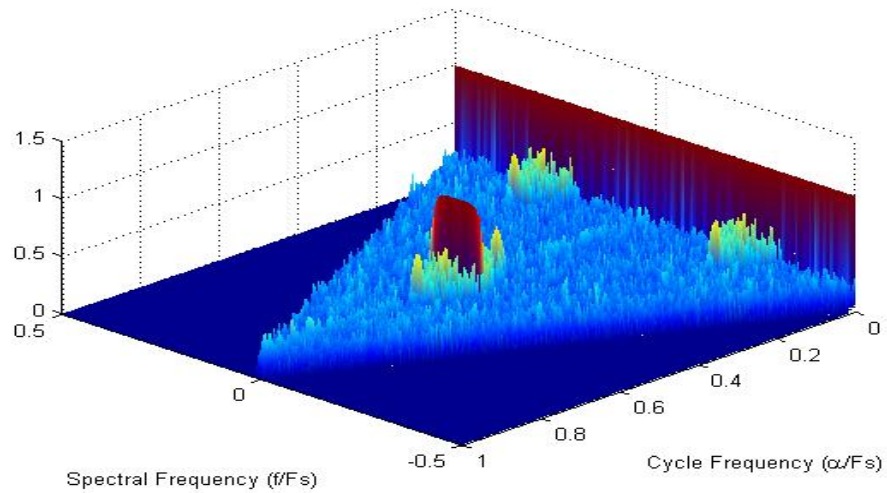
BPSK - AWGN



BPSK - Fading

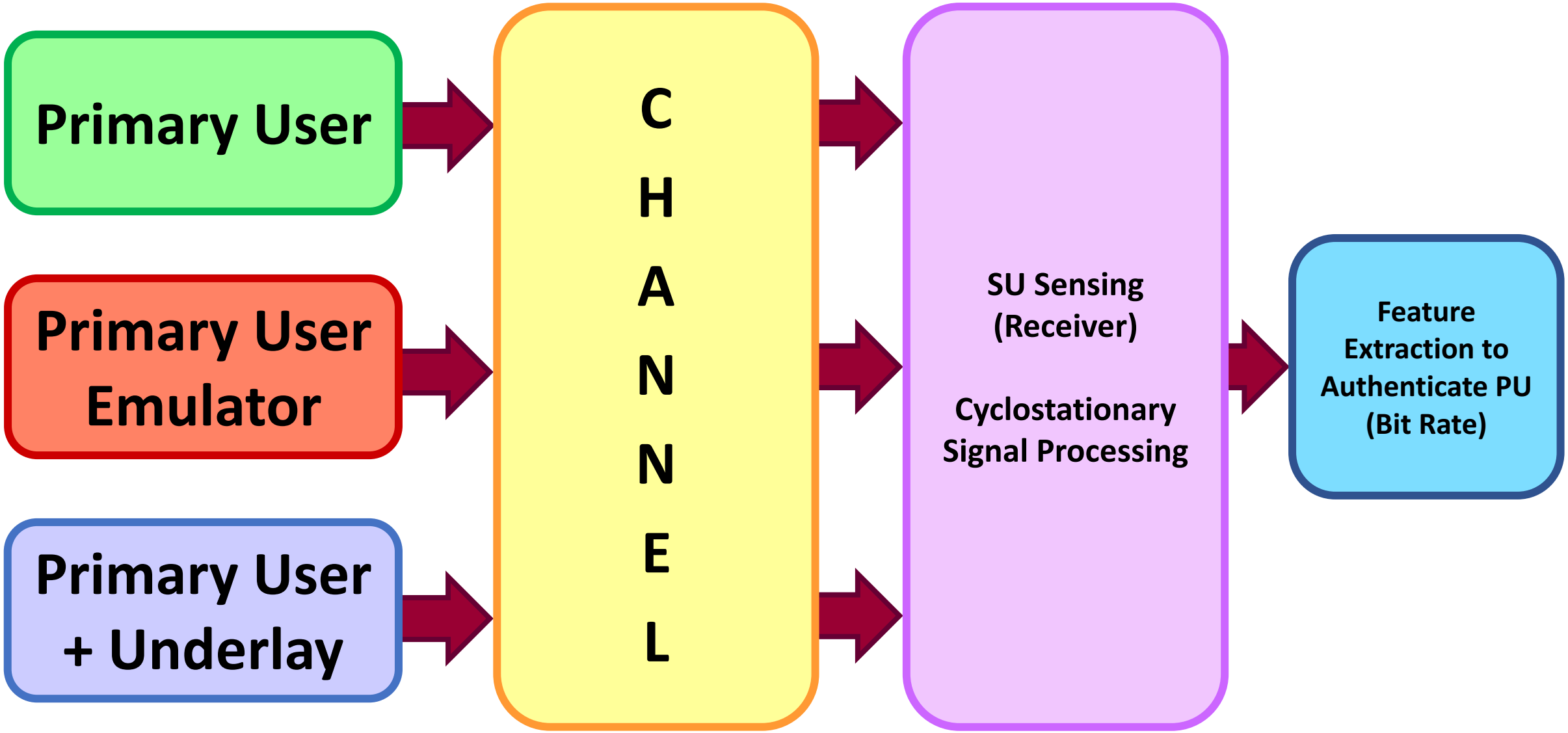


QAM



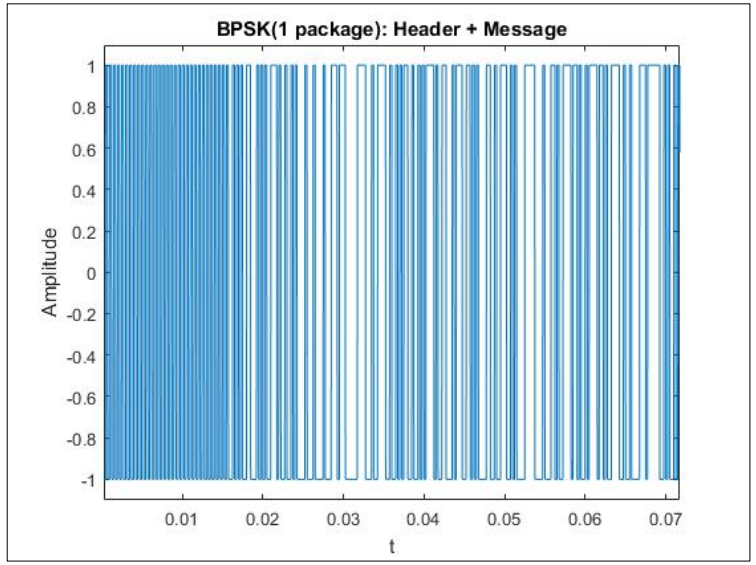
DS-CDMA

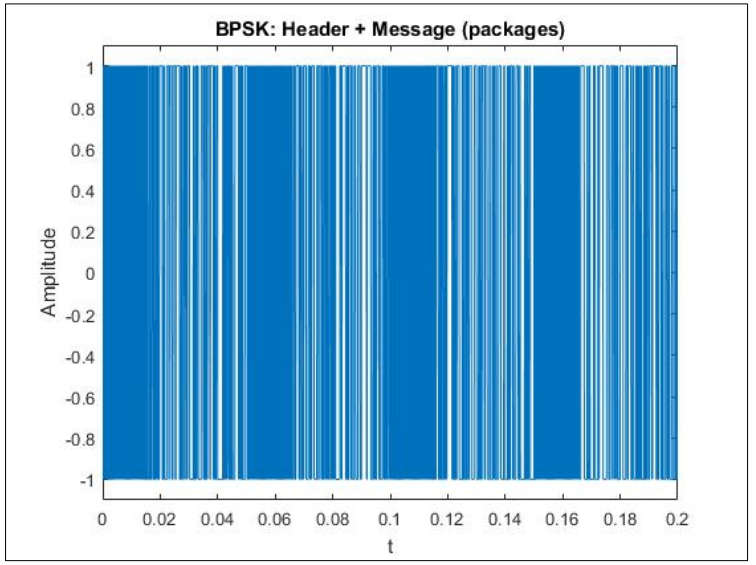
PU Authentication System Model

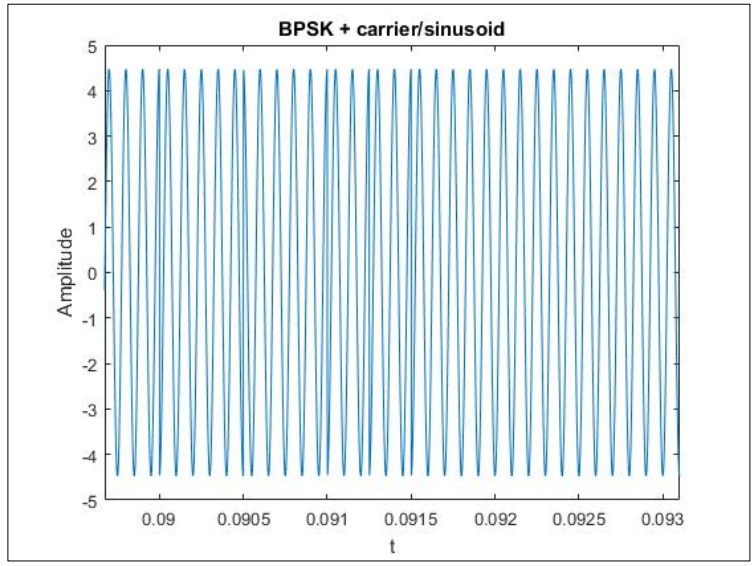


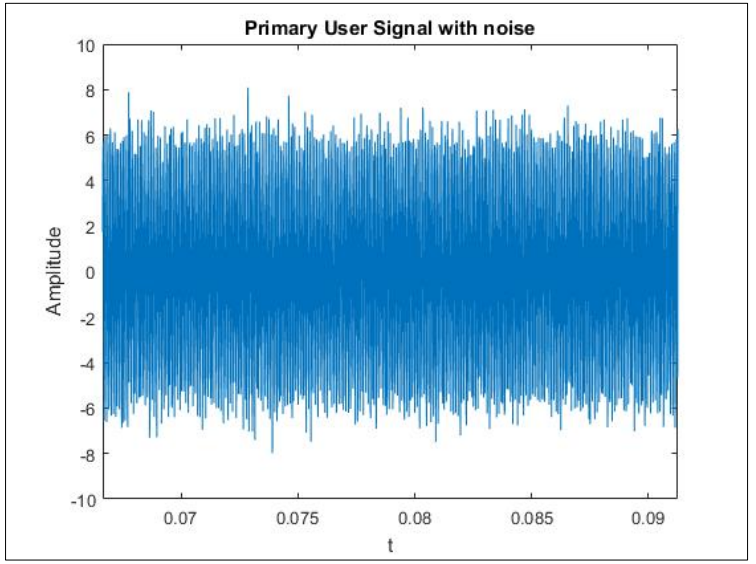
PU Authentication System Model

Generation of PU Signal in Time Domain:



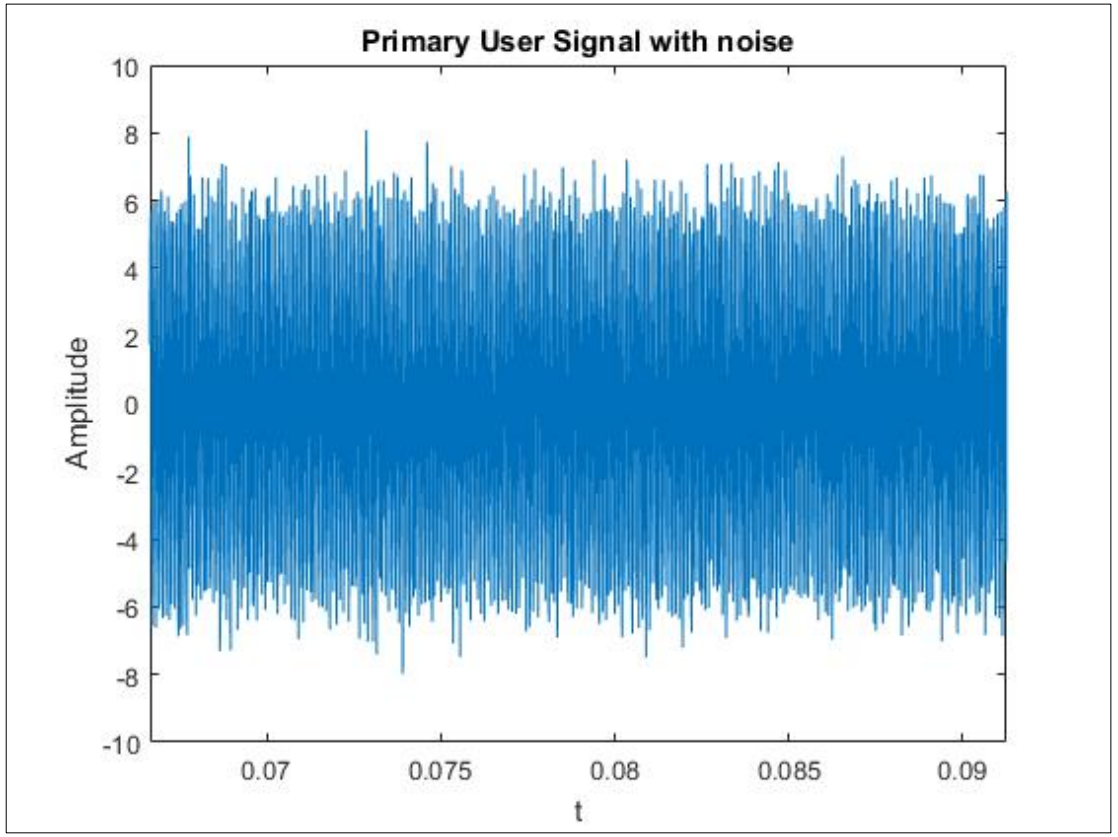


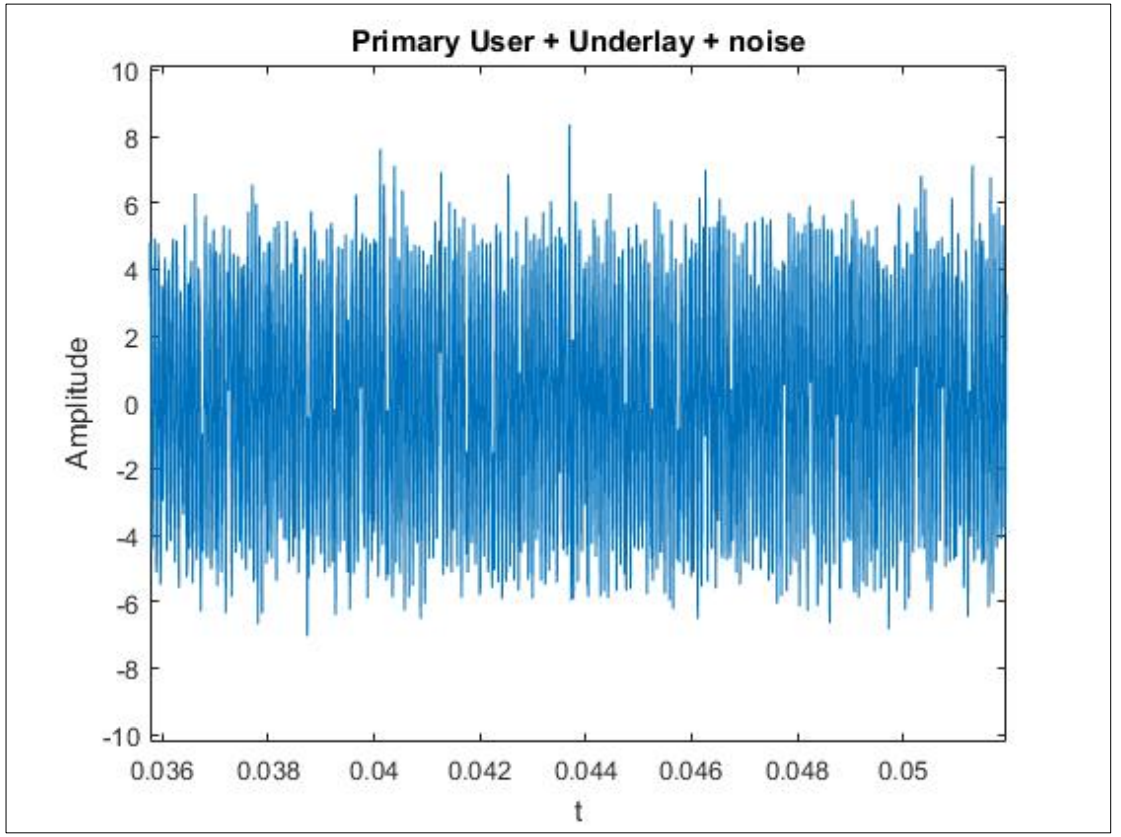




PU Authentication System Model

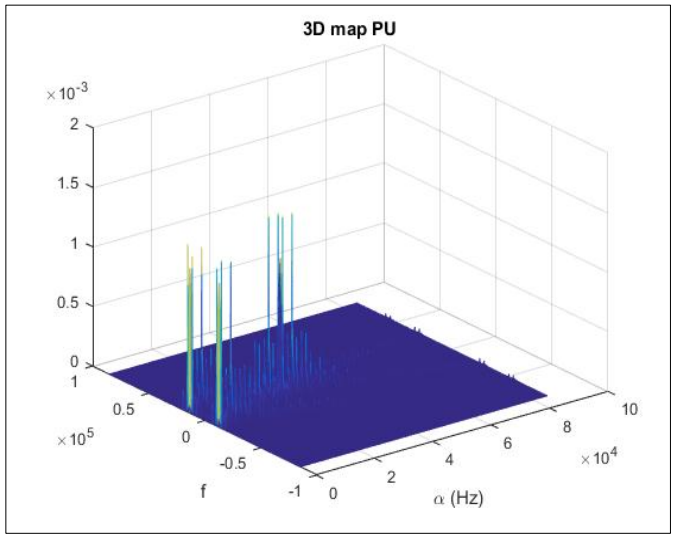
PU vs. PU + Underlay in Time Domain

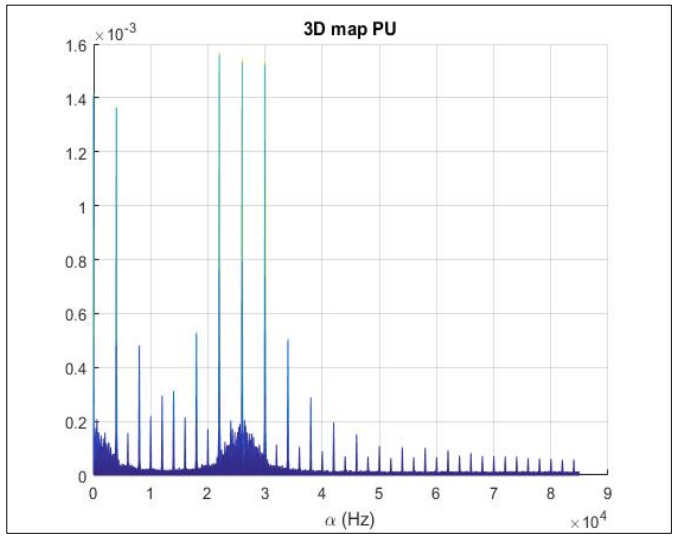


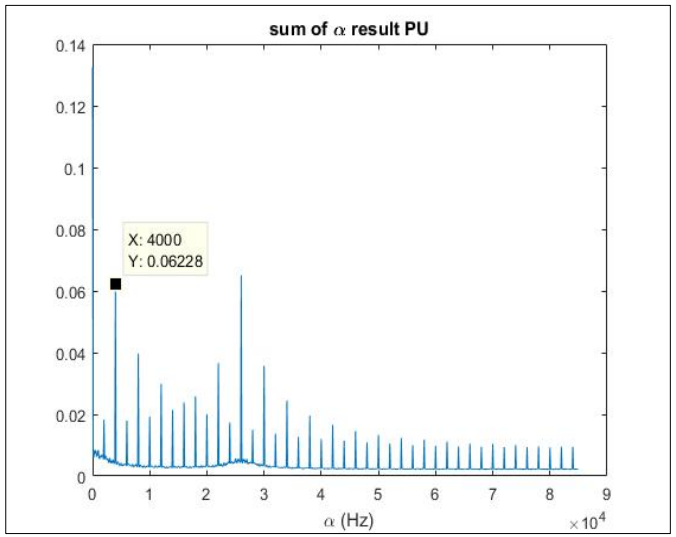


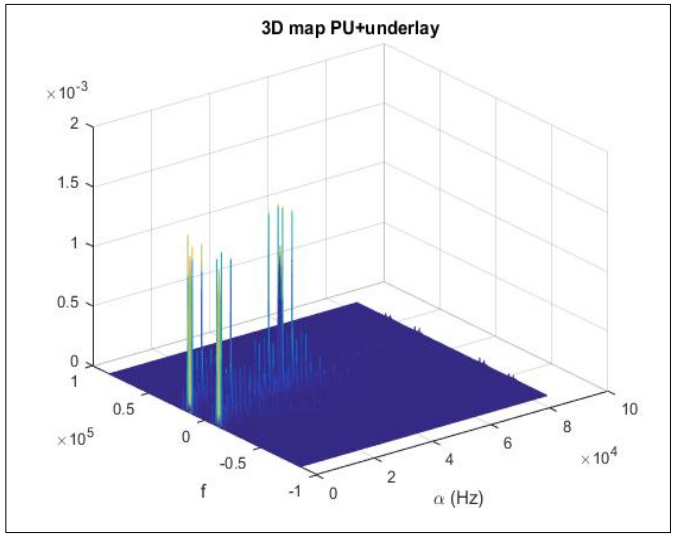
PU Authentication System Model

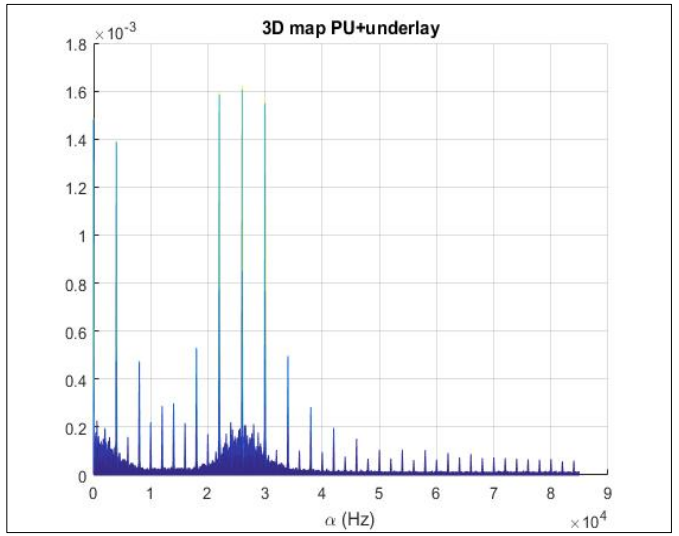
Results of CSP for PU & PU + Underlay

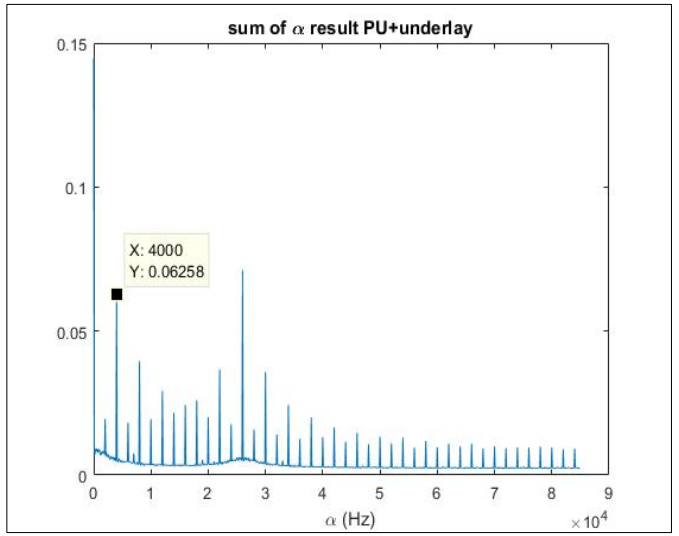






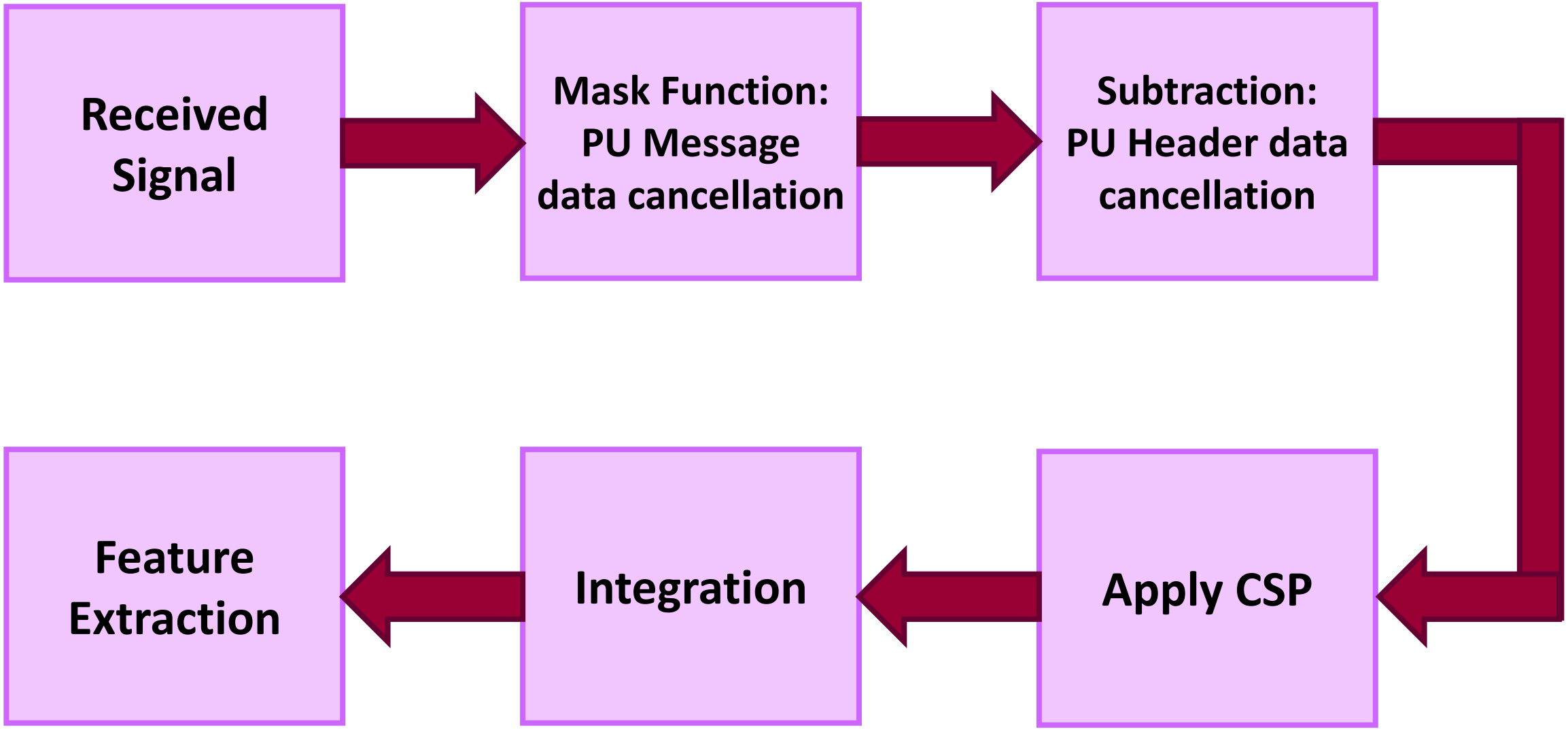




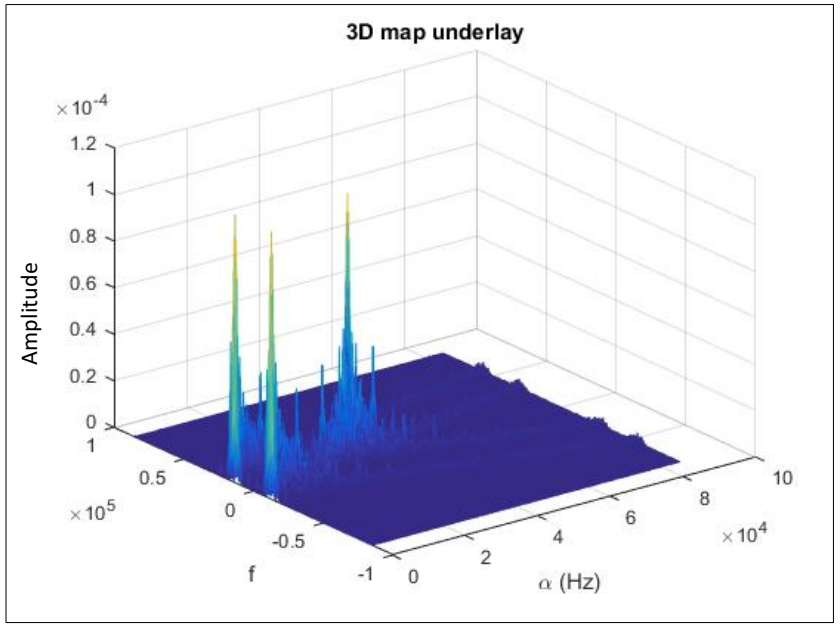


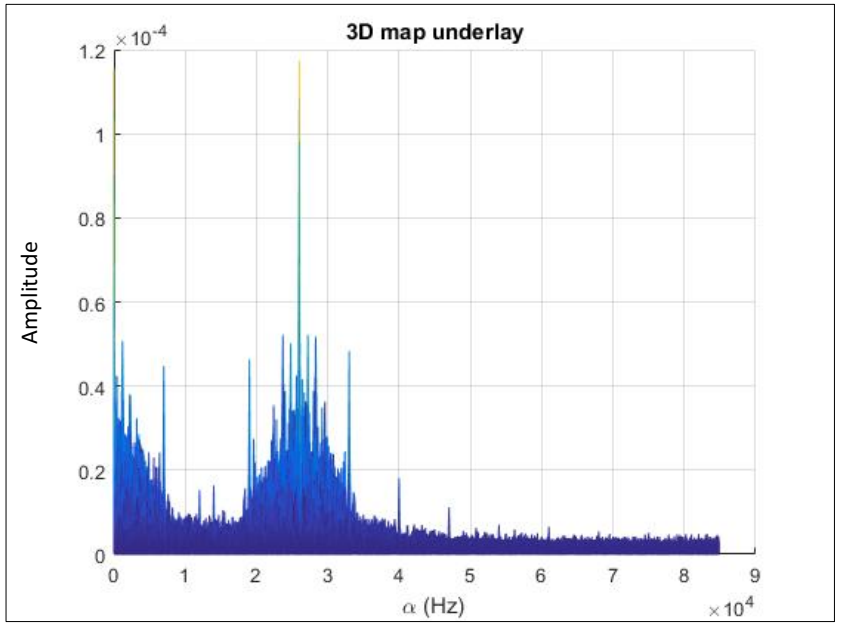
PU Authentication System Model

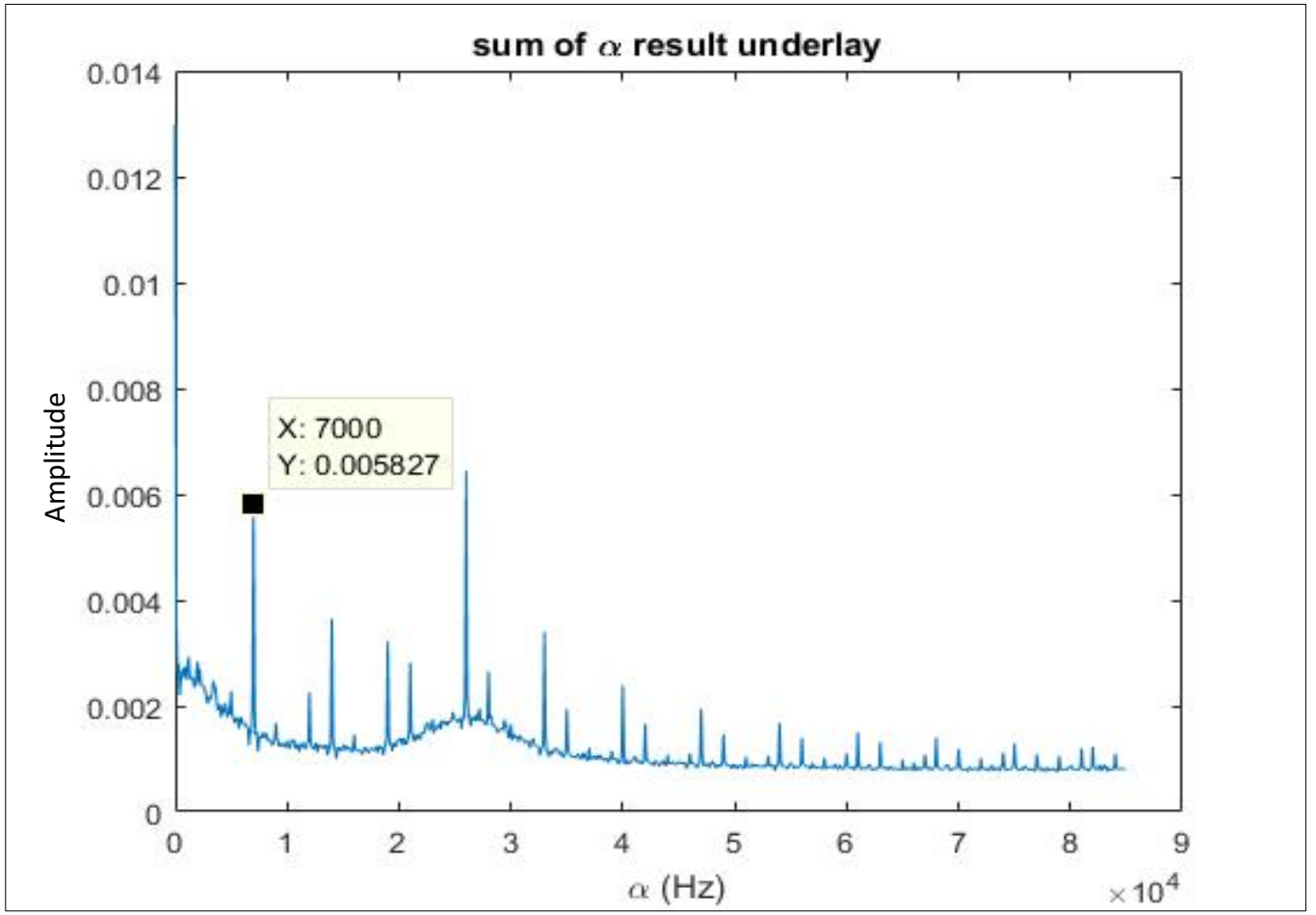
PU Authentication Algorithm featuring PU Signal Cancellation technique:



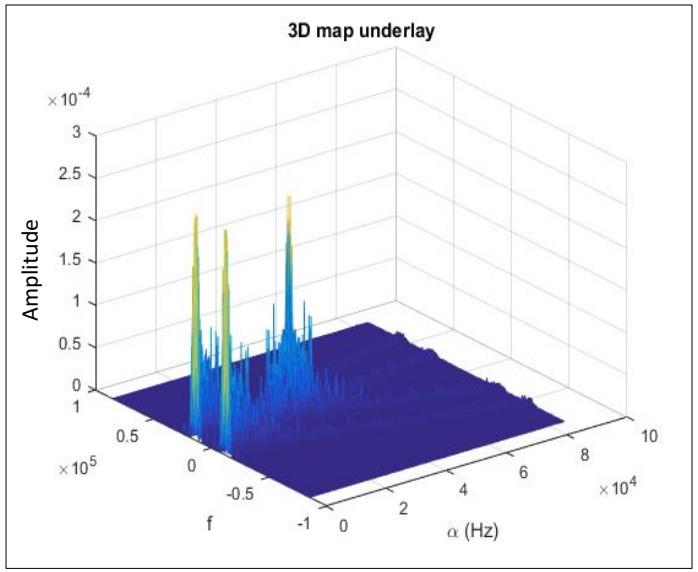
Results

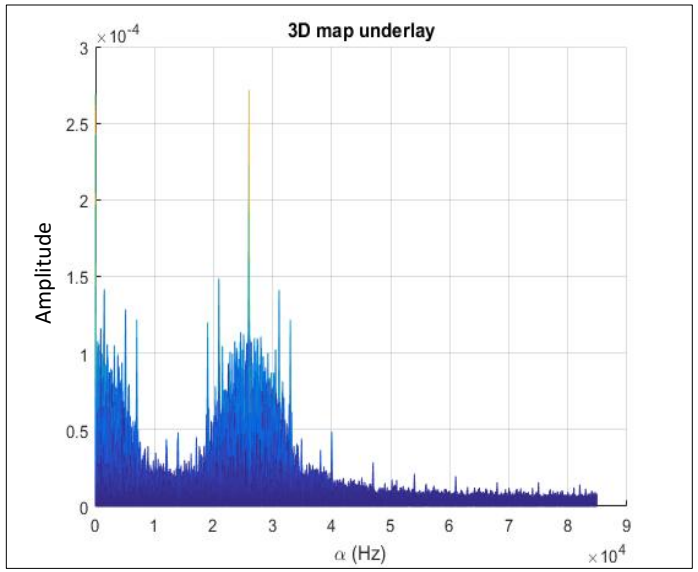

3D map underlay
Amplitude
f
α (Hz)

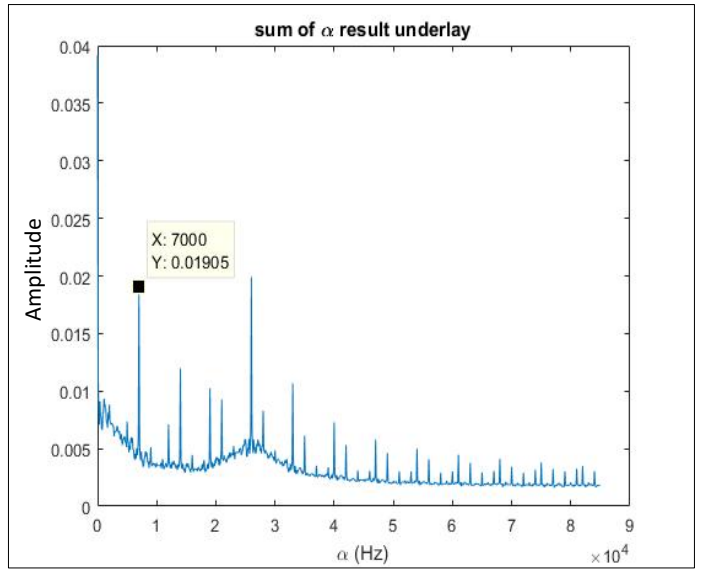

3D map underlay
Amplitude
α (Hz)


sum of α result underlay
Amplitude
X: 7000
Y: 0.005827
α (Hz)

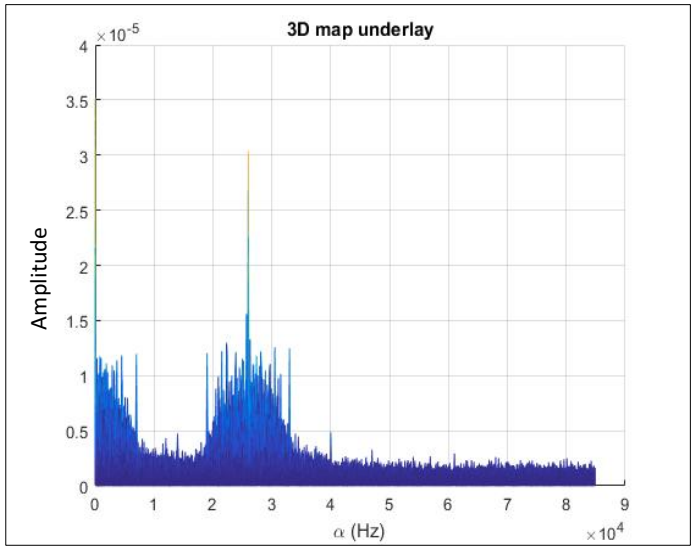
Results: Varying SNRs for Underlay

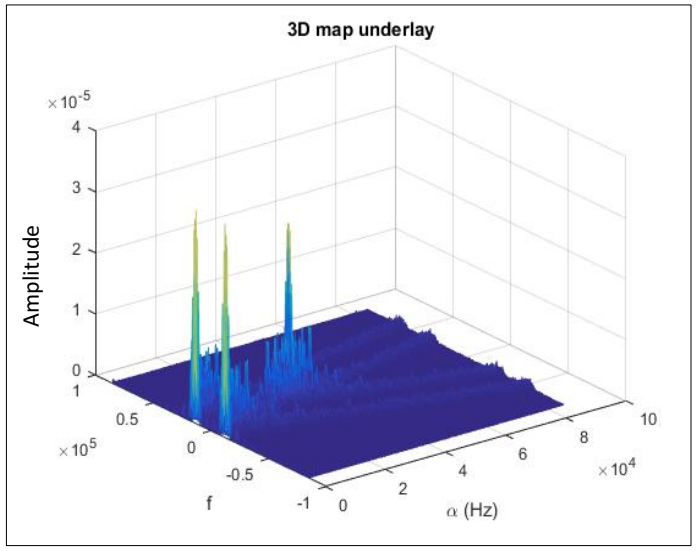


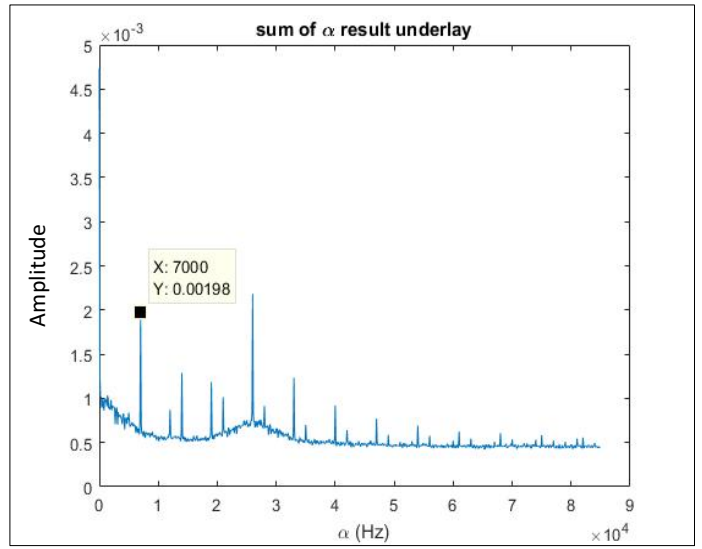




Underlay SNR = 10dB

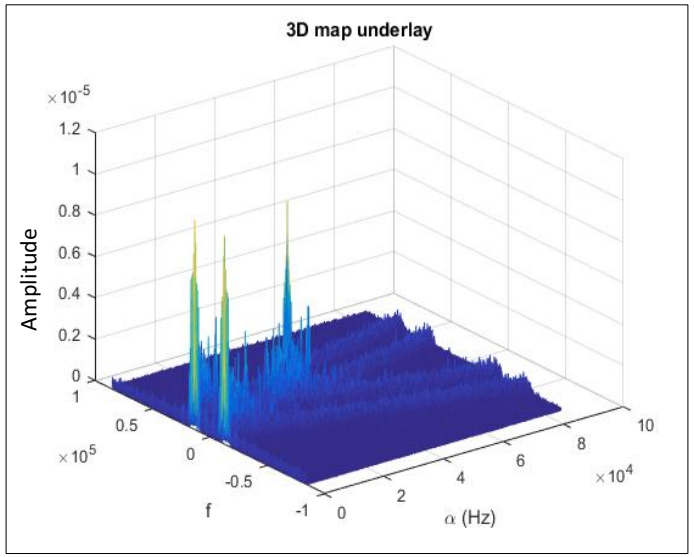


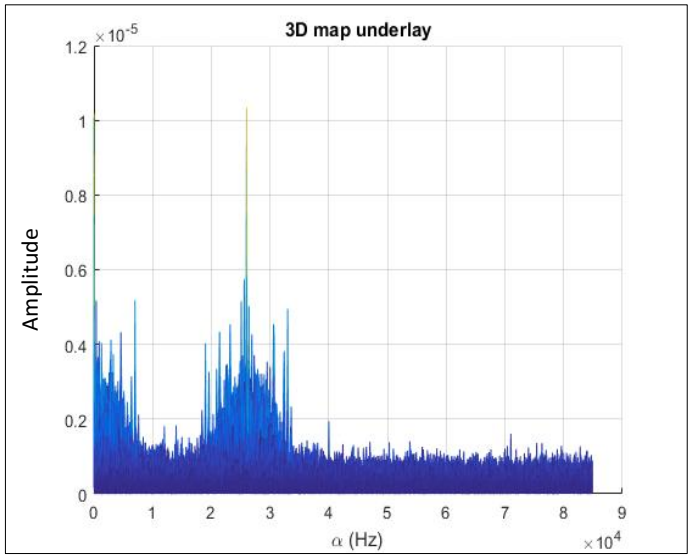


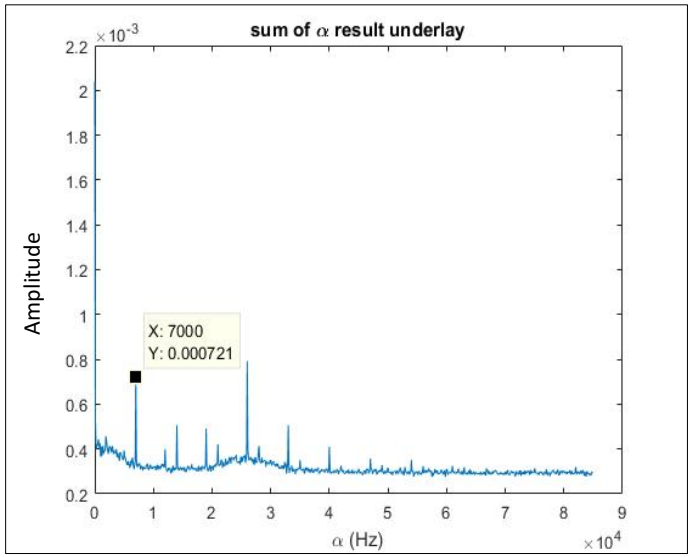


Underlay SNR = -10dB

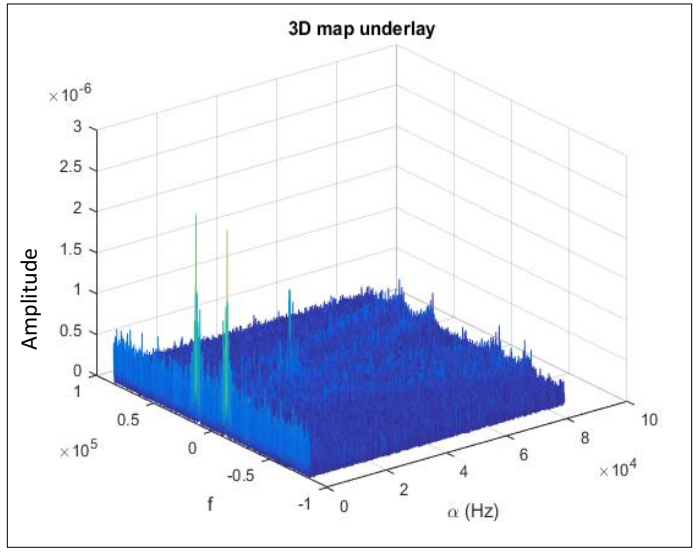
Results: Varying SNRs for Underlay

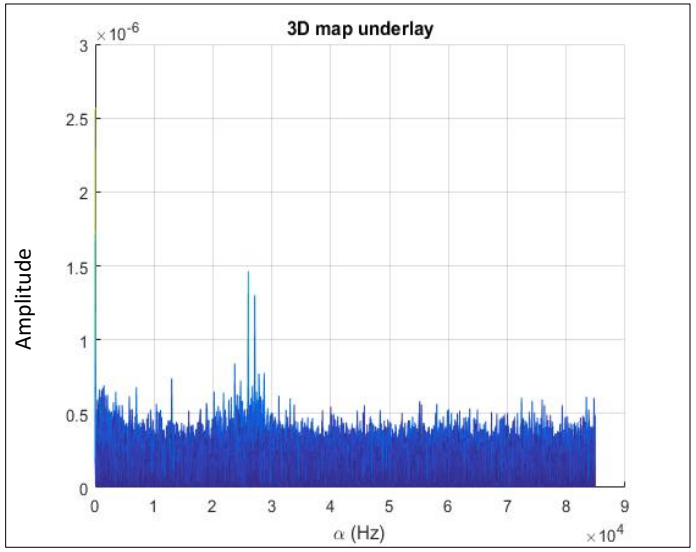


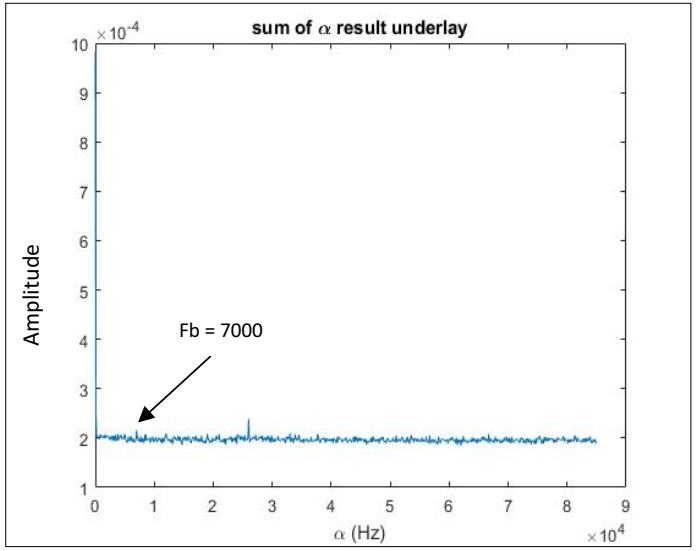




Underlay SNR = -20dB







Underlay SNR = -40dB

Conclusions

- Superimposition of covert underlay waveform was essential to authenticate PU from PUE
- Presence of underlay waveform was not visible in both time and CSP domain
- Knowledge of underlay waveform in combination with novel technique to extract underlay waveform was key
- Post-CSP Integration allowed clear identification of bit frequency to authenticate PU

Novelties & Contributions

- Superimposition of Underlay waveform onto Primary User Header
- Creating a CSP based algorithm featuring PU Signal Cancellation to extract underlay and authenticate PU

Questions?