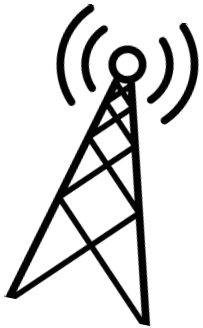
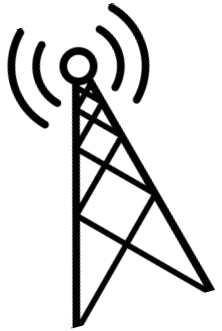


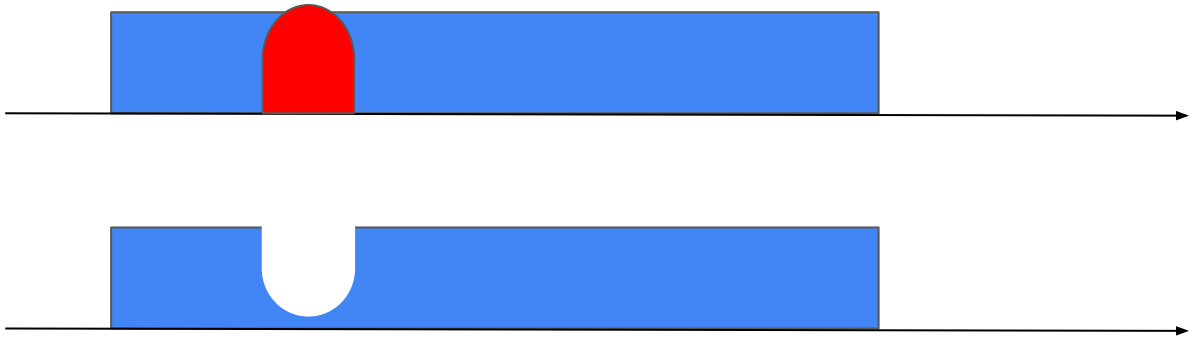
# Signal Avoidance Using 5G

Wesley Chen
Advisor: Professor Predrag



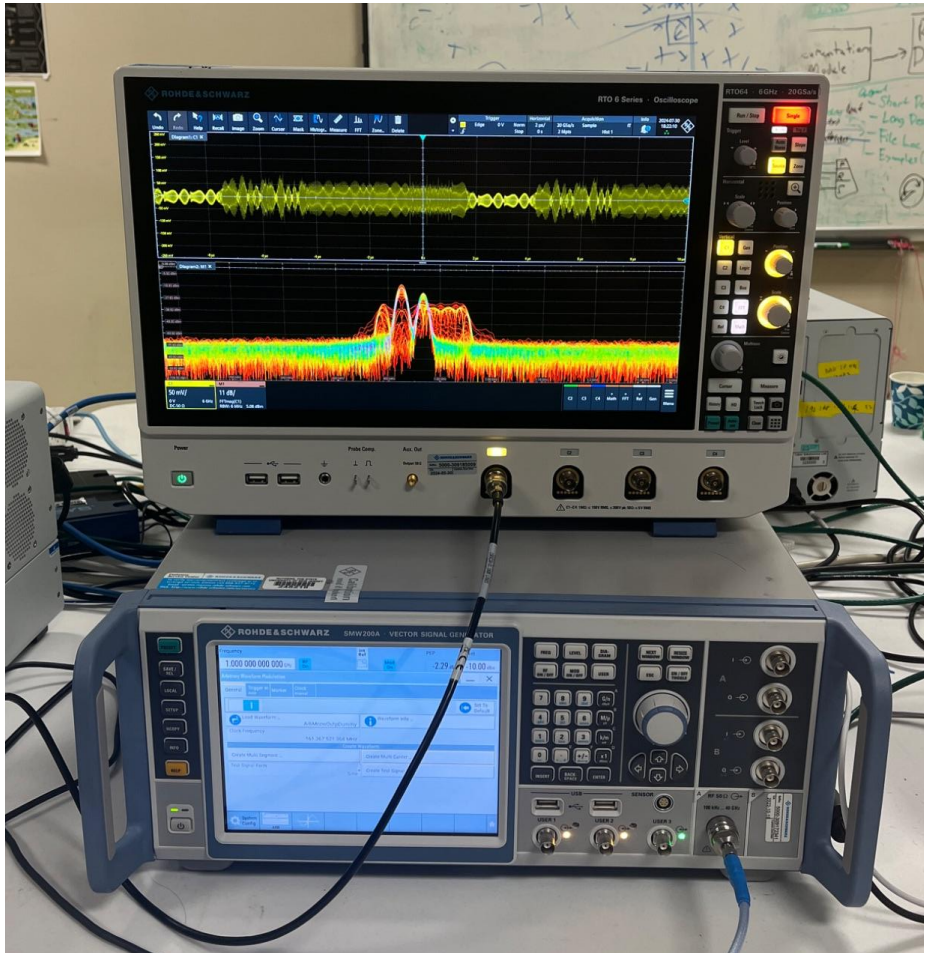
# Overview

- Expand the bandwidth of 5G
- Faster + more channels
- Legacy usage of spectrum
- Goals: develop framework

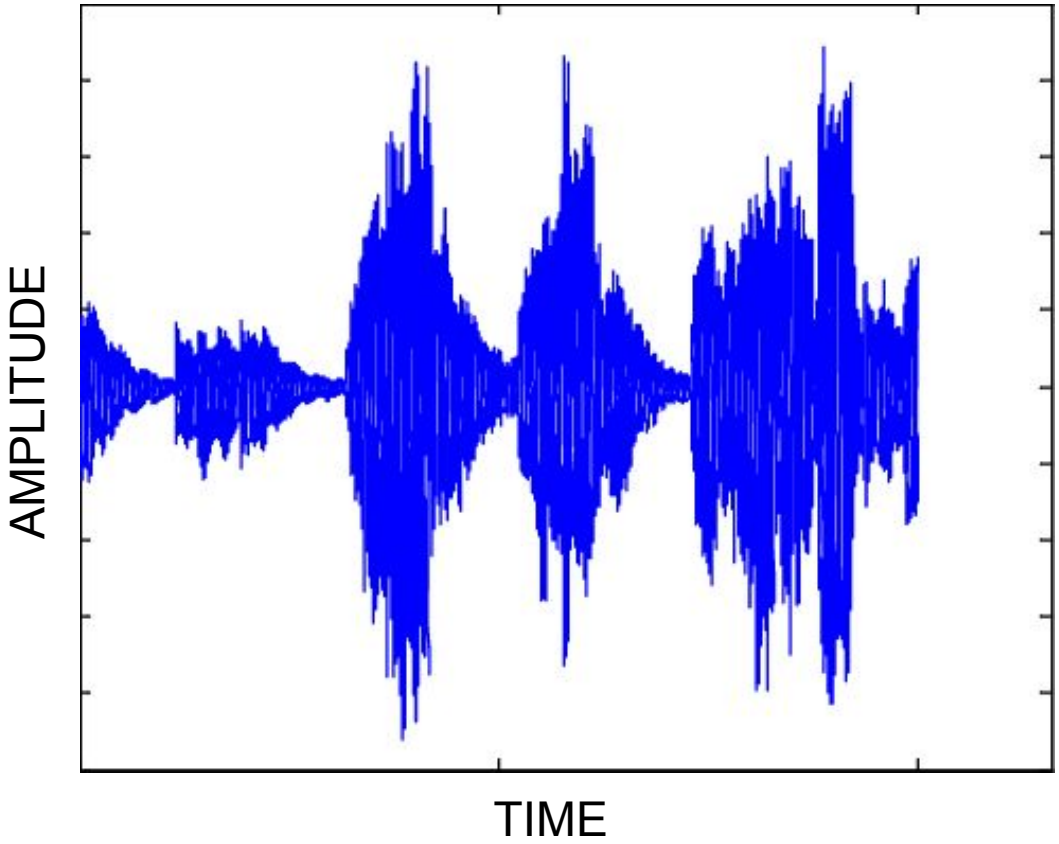


# Devices

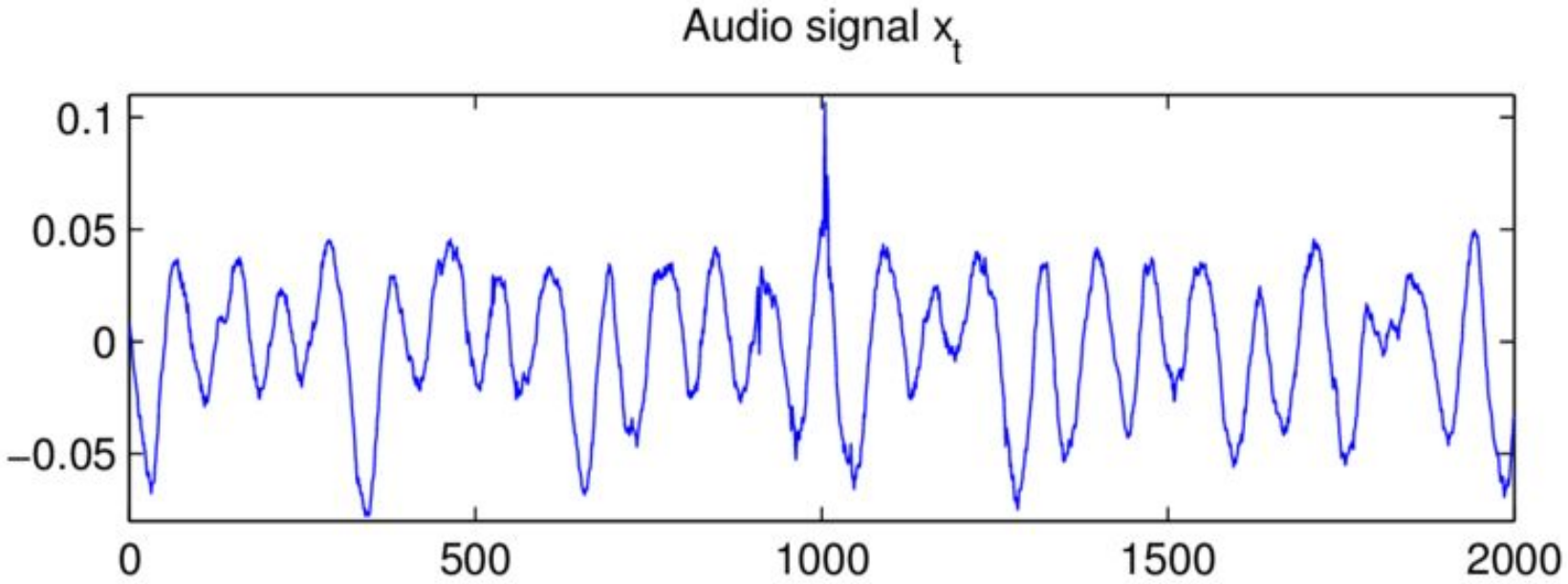
- Signal Generator (bottom)
- Oscilloscope (top)



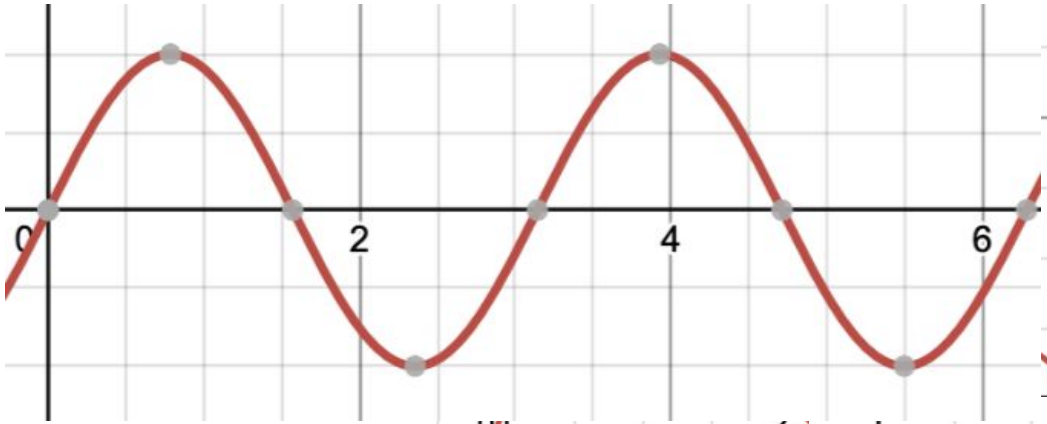
# what is a signal?

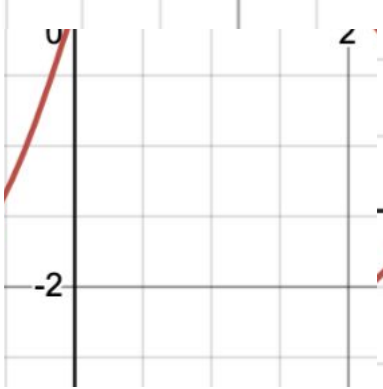


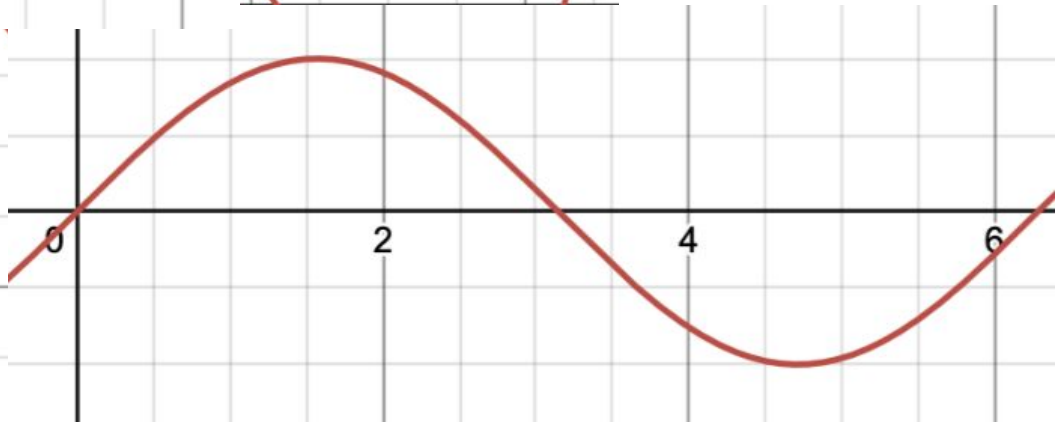
# what is signal?



# what is a signal?

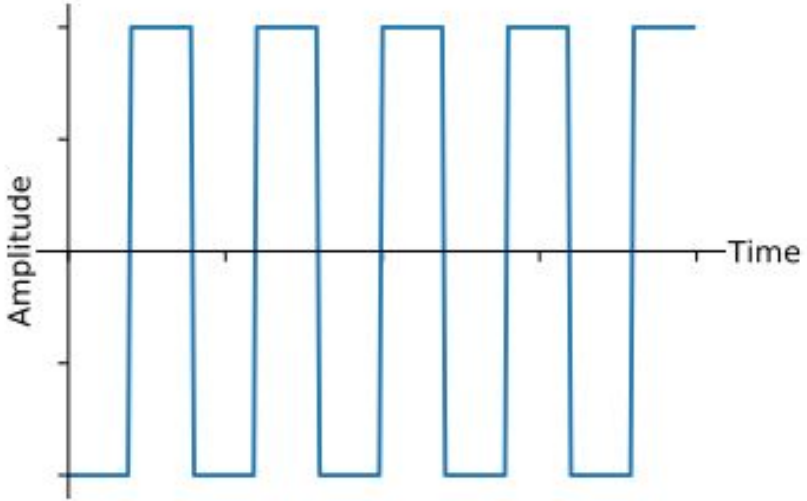


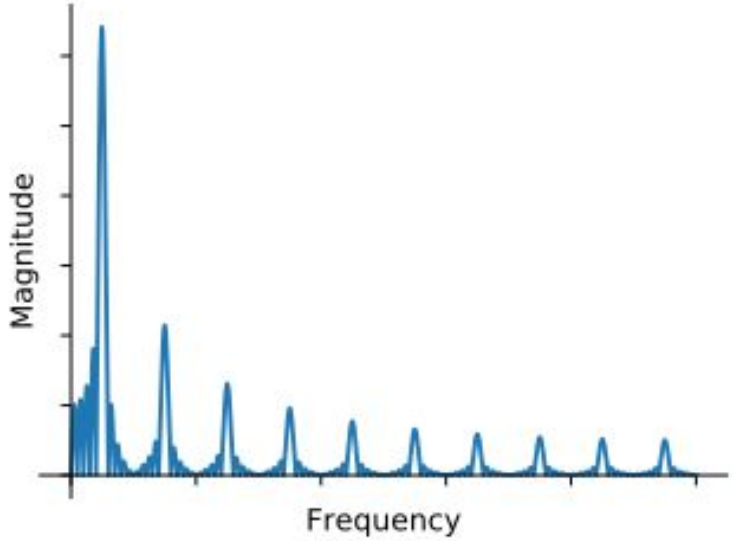



# Frequency Domain

- Signals represented as its constituent frequencies + phases
- Equivalent representation

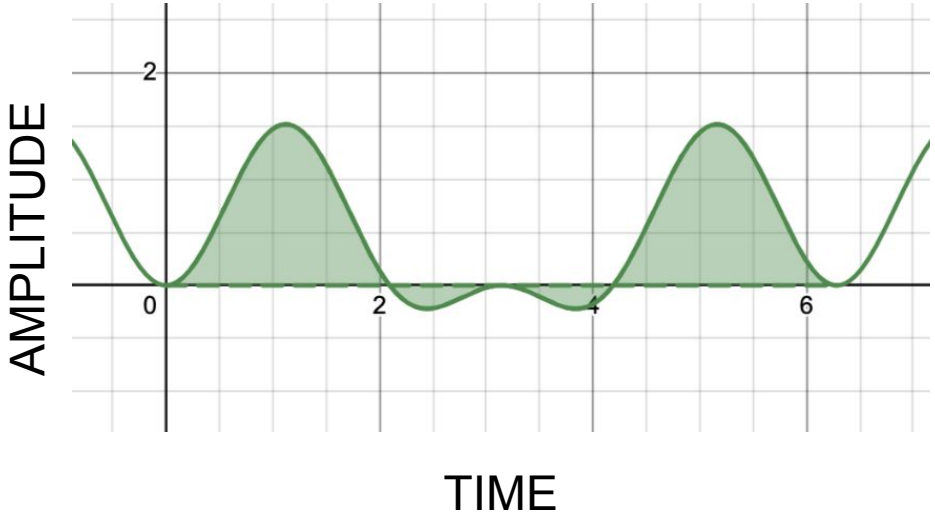


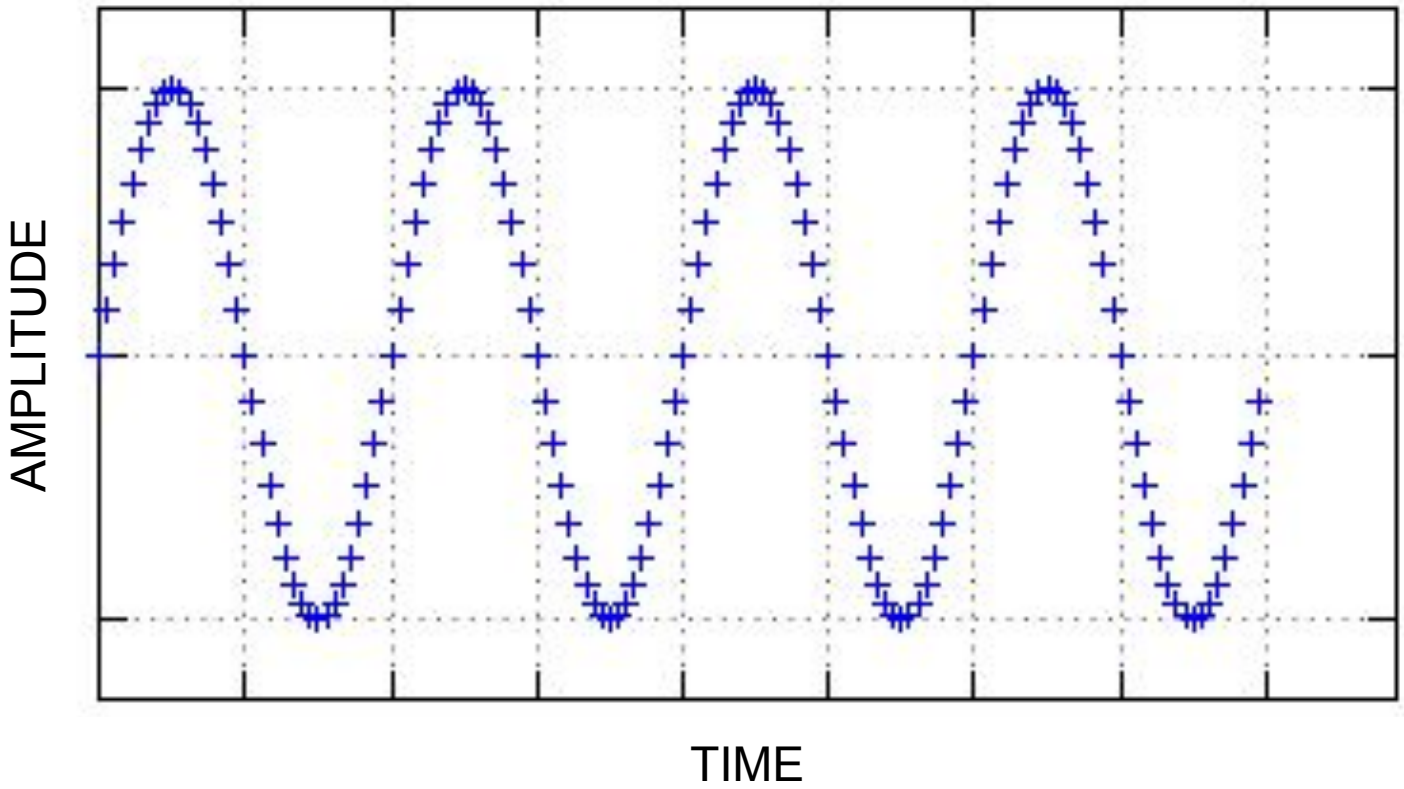
# Conversion from Time to Frequency Domain

$$g(t) = S(t) \cdot \sin(w_1 t)$$


$$\frac{1}{2\pi}\int_0^{2\pi} g(t)dt = \frac{f_1}{2}$$

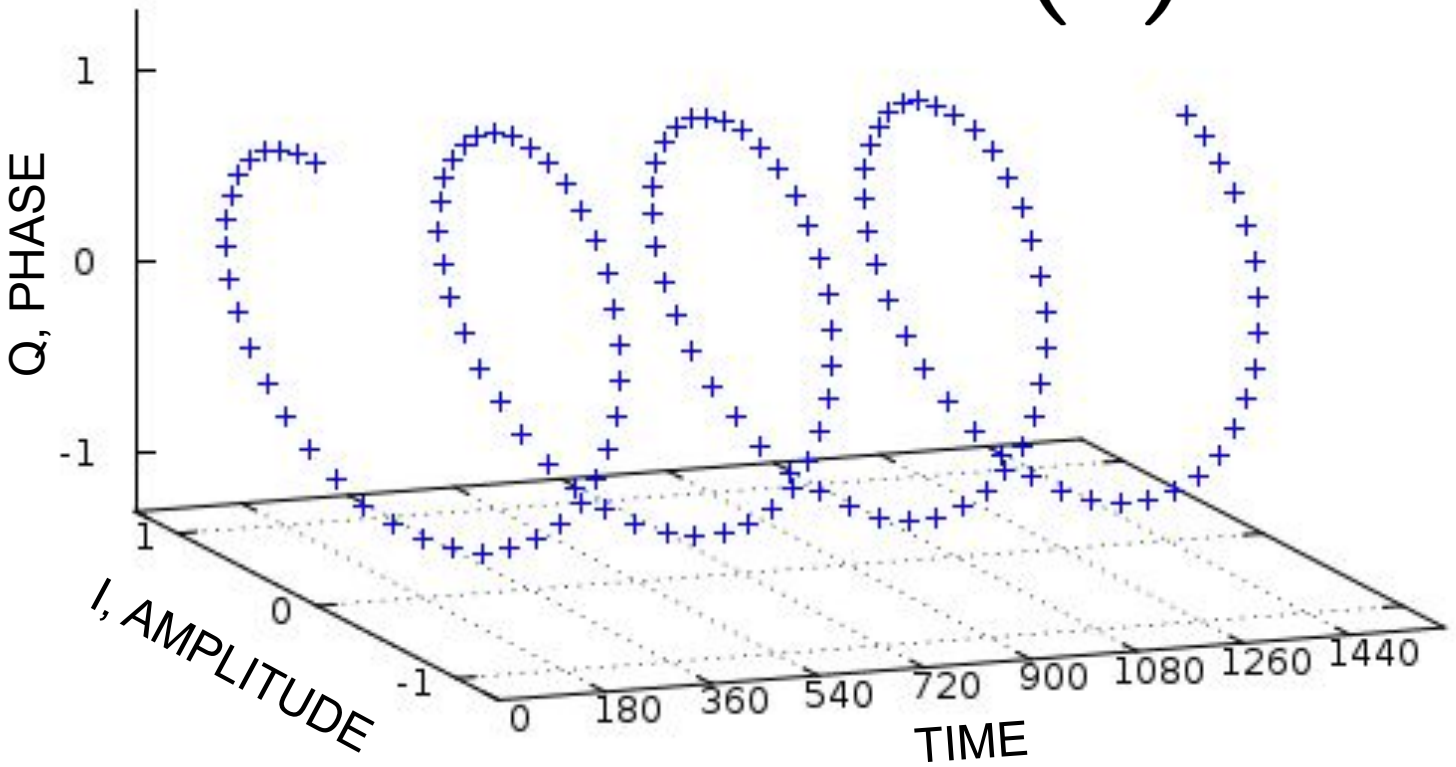


# The Real Plane

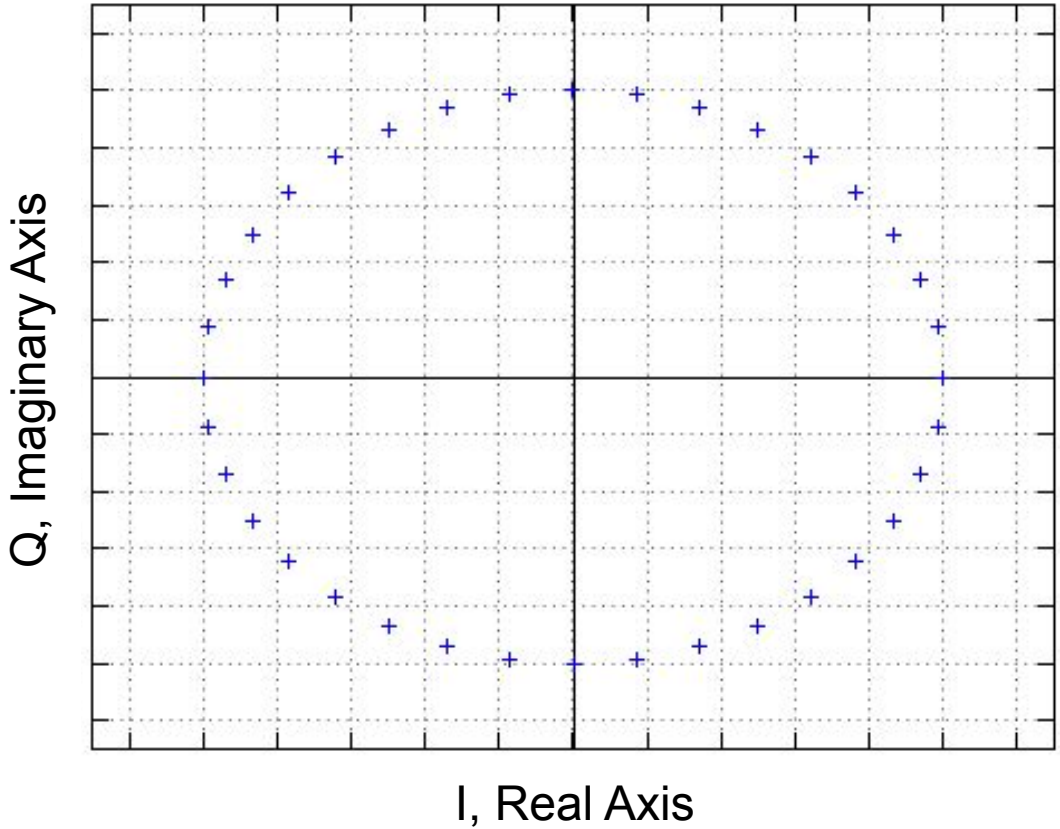


# A 3 Dimensional Plane

$$I(t) + Q(t)i$$



# The Imaginary Plane



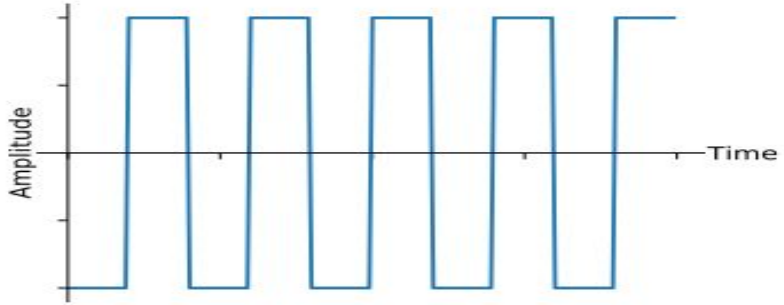
# Modulation

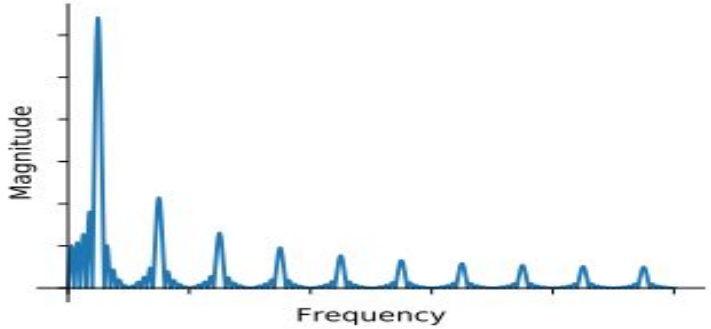
- real and imaginary parts times high frequency sine/cos
- imaginary signals don’t exist in real world

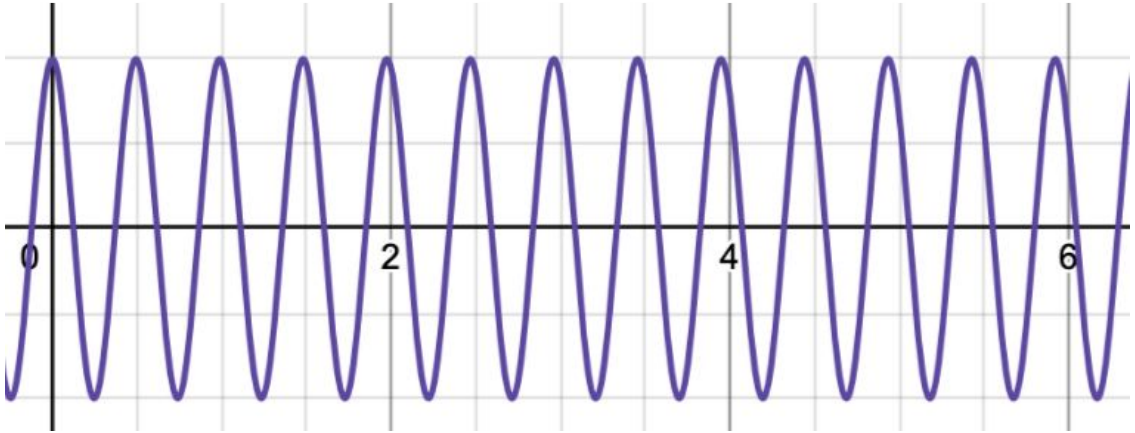
$$I(t) + Q(t)i$$

$$I(t)\sin(wt) + Q(t)\cos(wt)$$

# Modulation

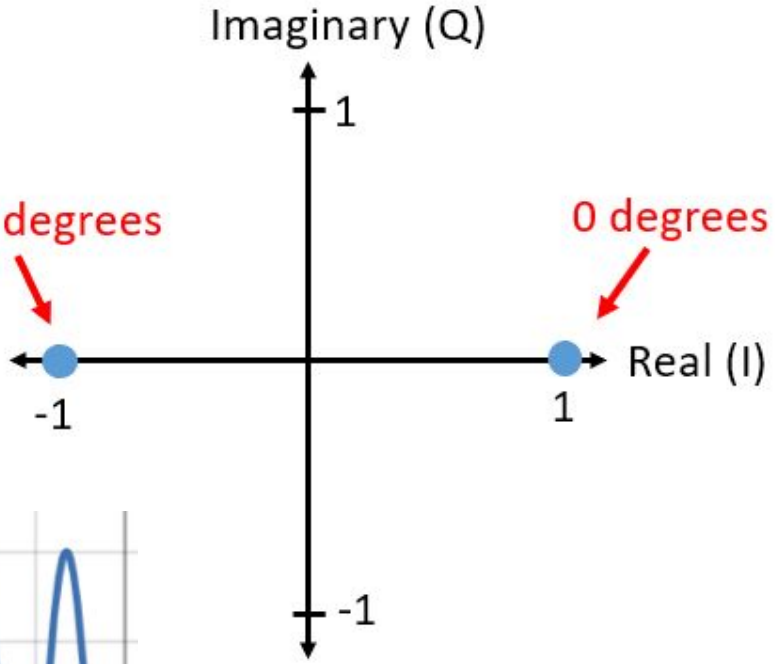


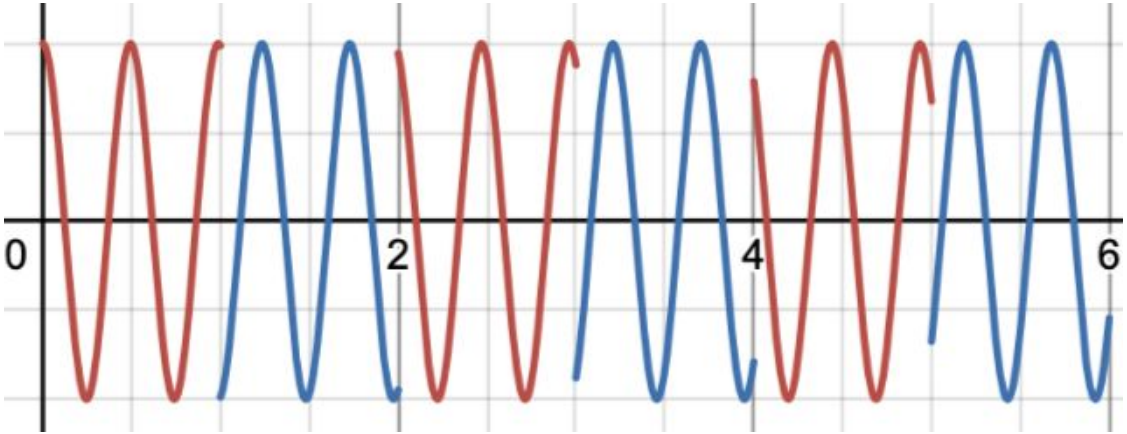



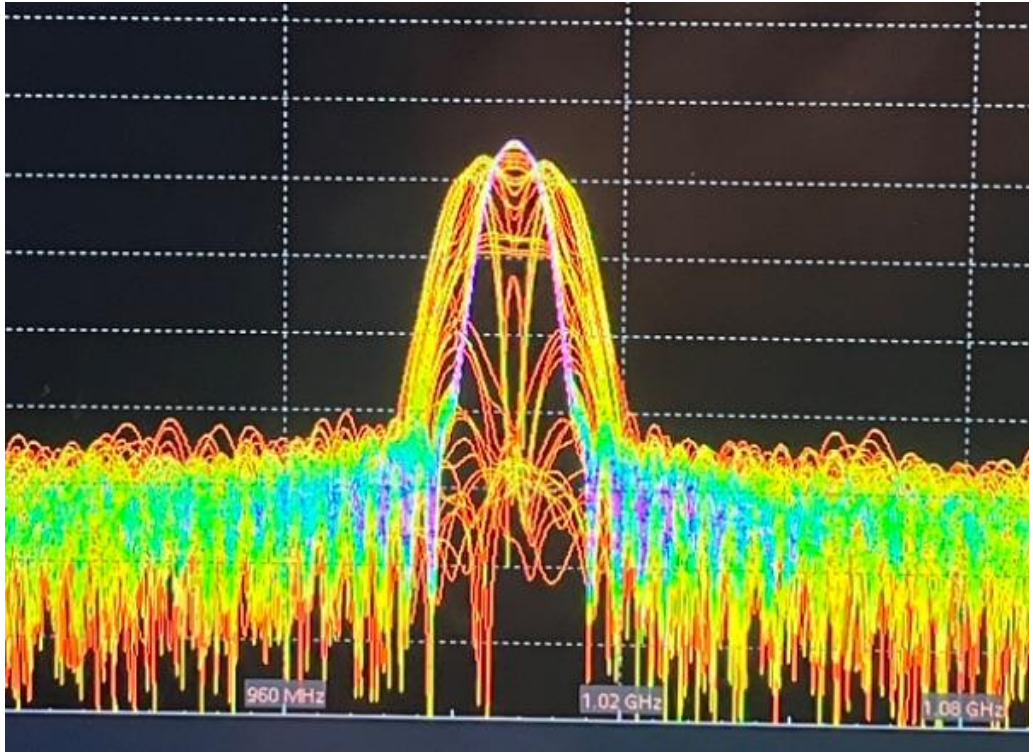



# BPSK

- Binary Phase Shift Keying
- 1 bit symbol
- Other methods: QPSK, QAM, etc.



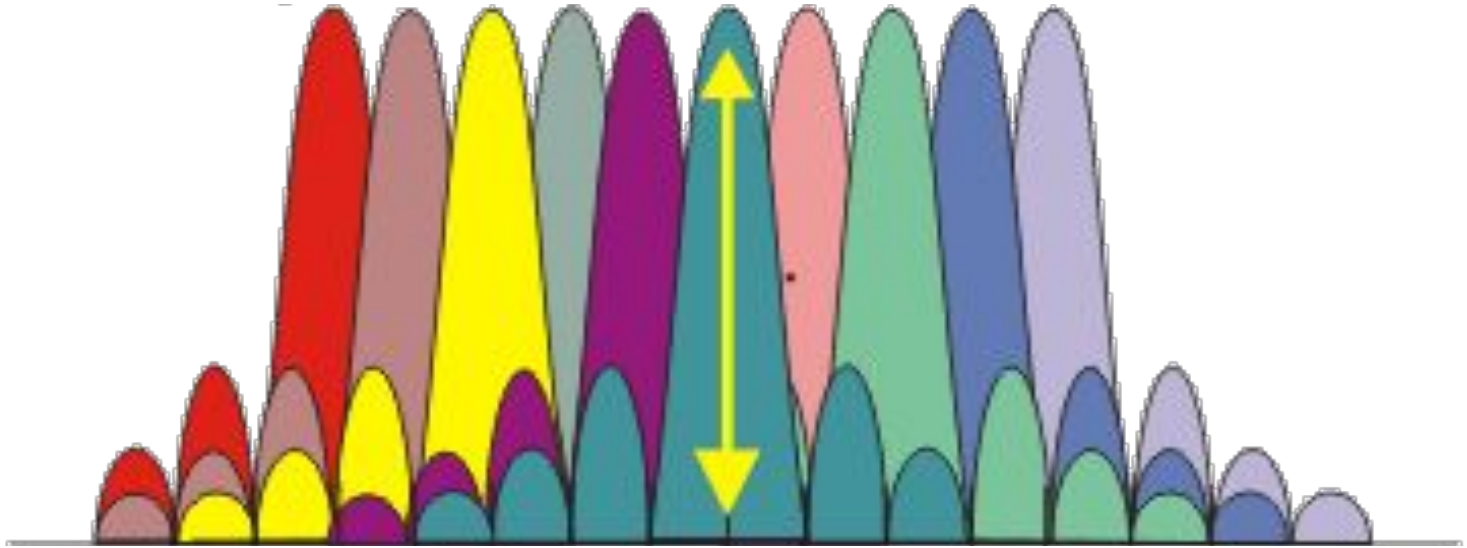



FREQUENCY

```
[0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1]
hiii
```

# OFDM

- Orthogonal Frequency Division Multiplexing
- Each carrier (frequency) contains data

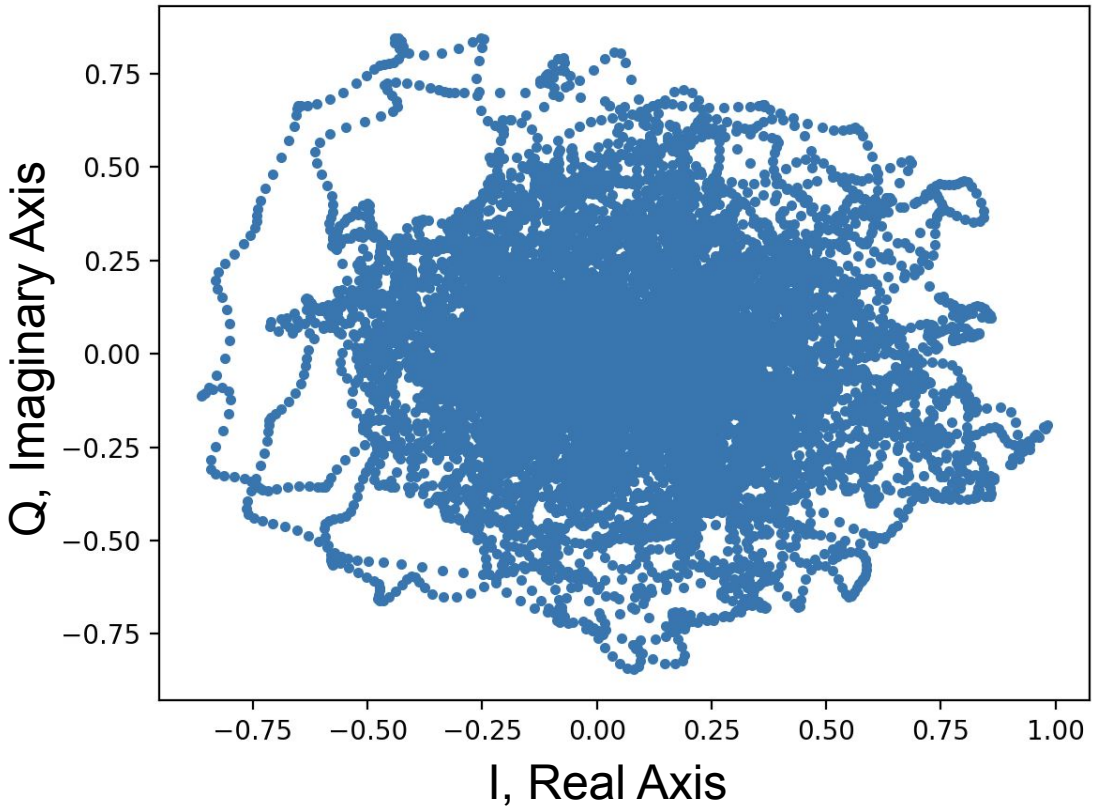


Synchronization

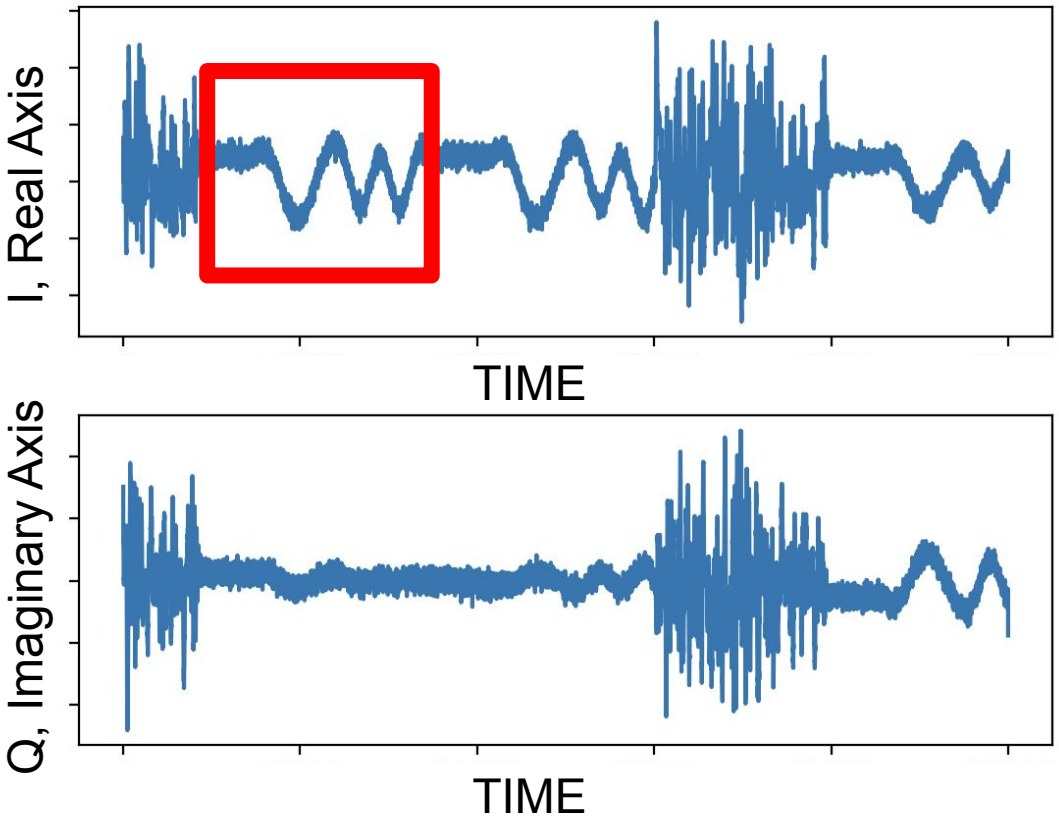
$$S(t) = I(t)\sin(wt) + Q(t)\cos(wt)$$

$$S(t) \cdot \sin(wt) \rightarrow low\,pass\,filter \rightarrow I(t)$$

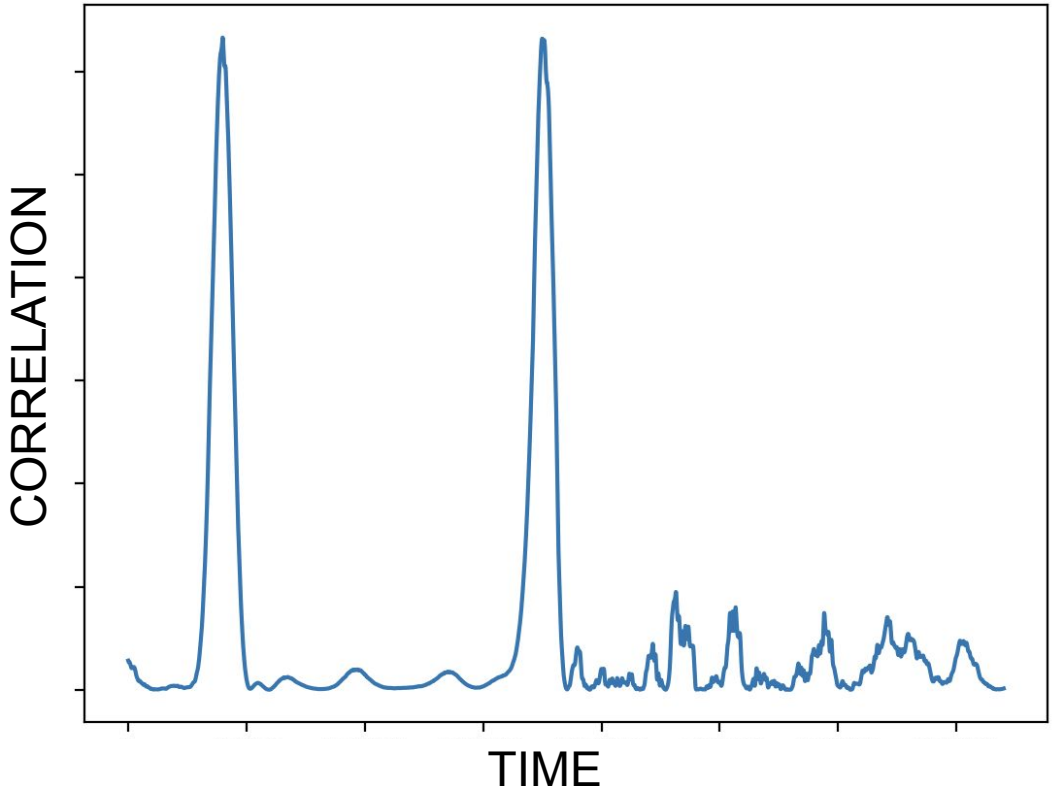
# Synchronization: initial IQ plot



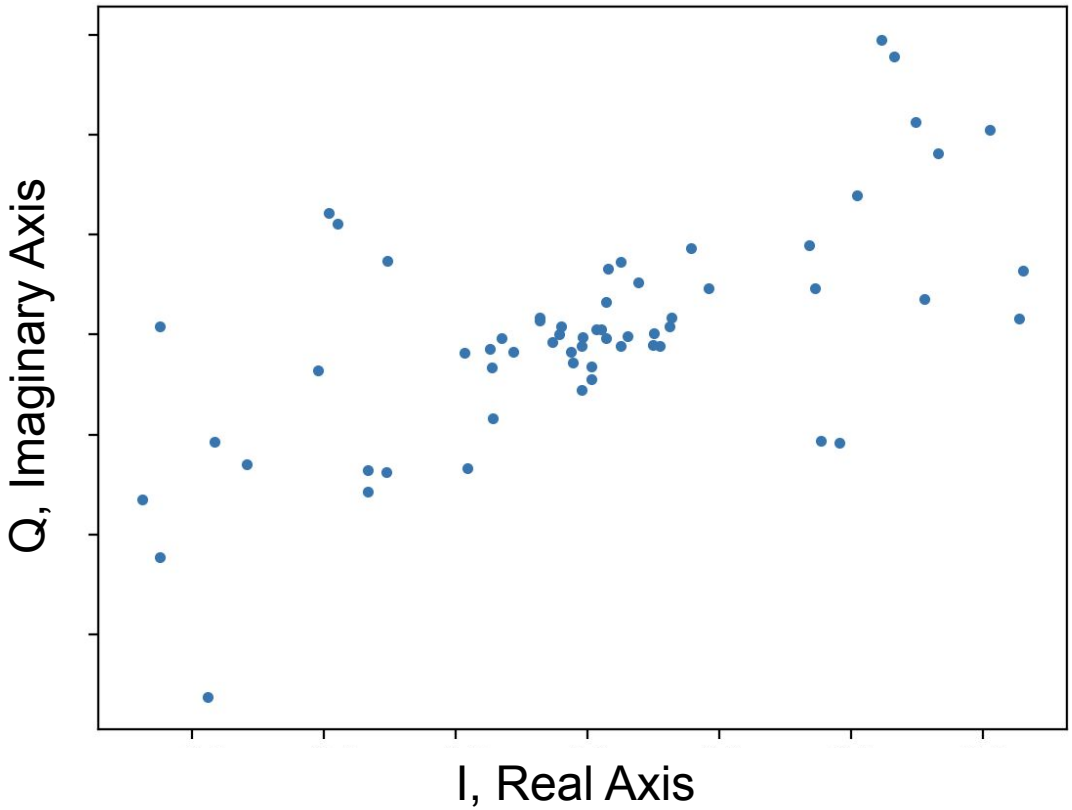
# Barker Codes - Pseudo Random Bits

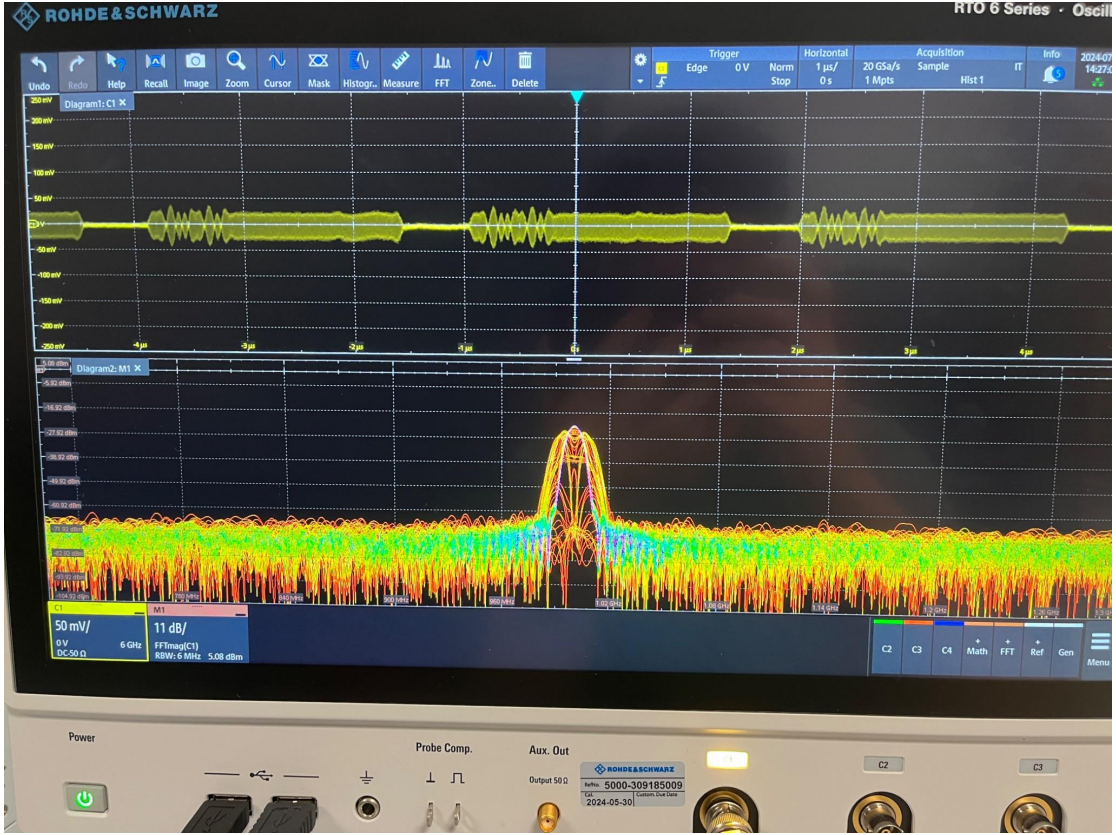


# Synchronization: correlation with Barker Codes

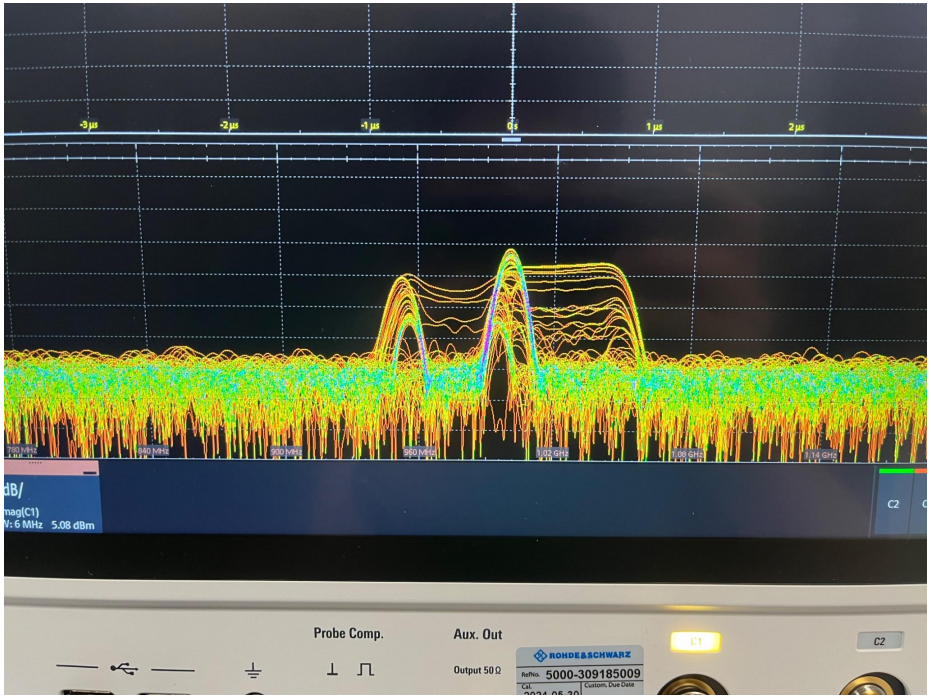


# Synchronization: cleaned up IQ plot





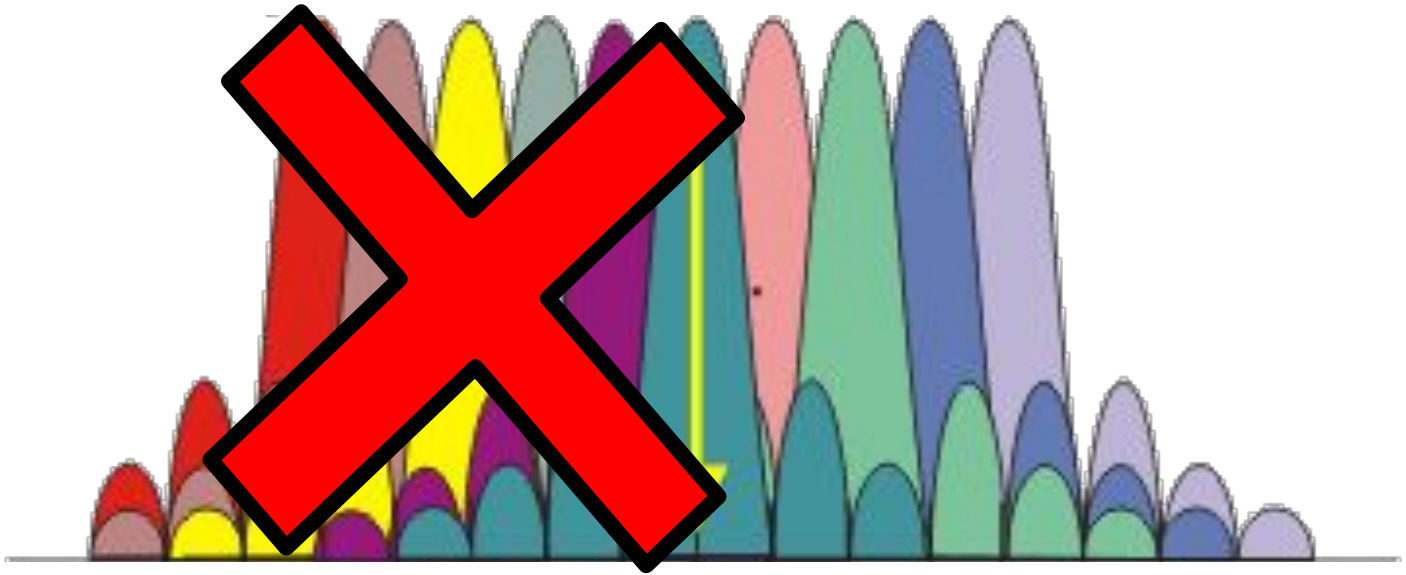

```
[0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1]
hiii
```




```
[0 0 0 0 0 1 0 1 0 1 0 0 0 0 1 1 0 0 1 0 1 1 1 0 1 1 1 0 0 0 0 0 1 0 1 0 0
 1 1 0 1 0 0 0 0 1 0 1 1 1 0 1 1 1 0 0 0 0 0 1 0 1 0 0 1 1 0 0 1 1 0 1 0 1
 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
hi winlab
```

# Goal Refresher

- How do signal interact?



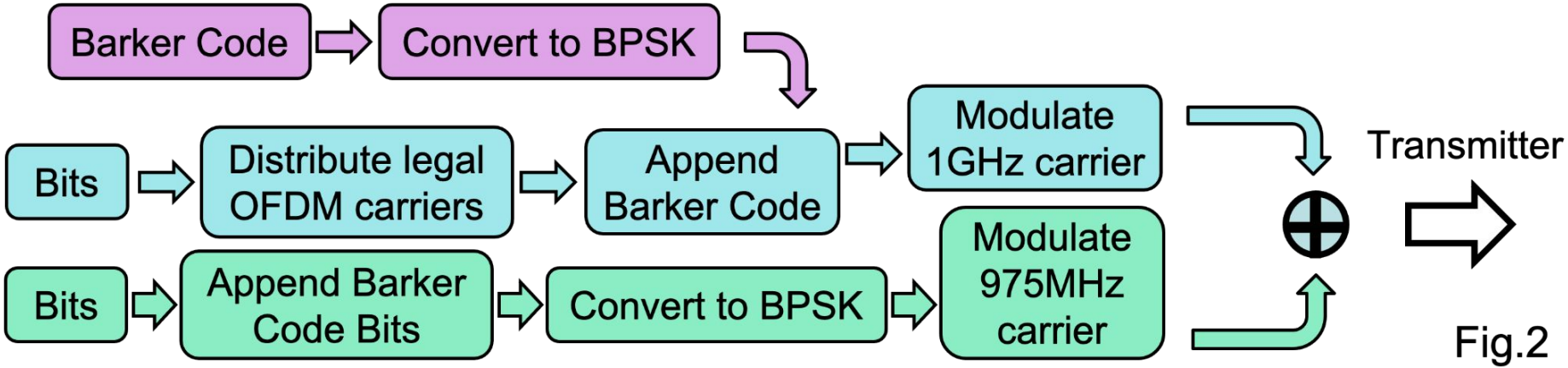

Barker Code
Convert to BPSK
Bits
Distribute legal OFDM carriers
Append Barker Code
Modulate 1GHz carrier
Transmitter
Bits
Append Barker Code Bits
Convert to BPSK
Modulate 975MHz carrier

Fig.2

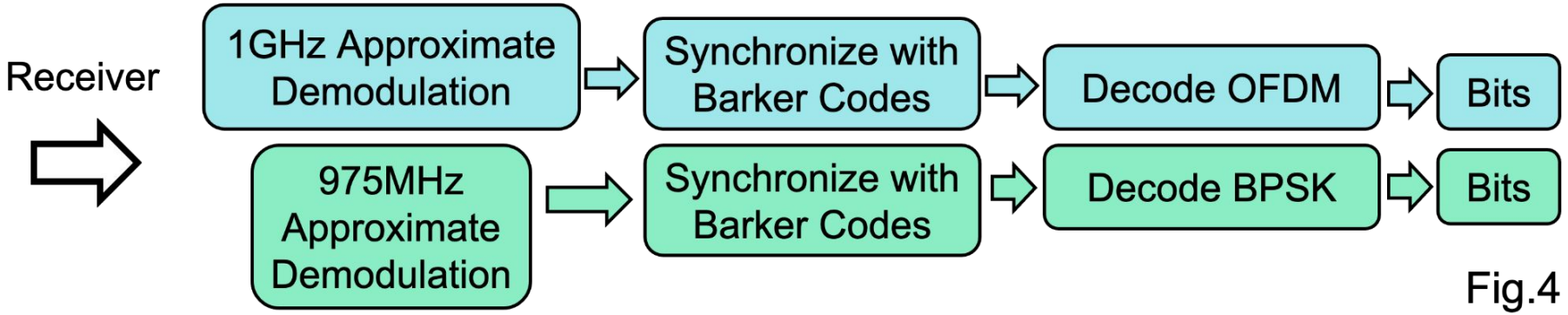
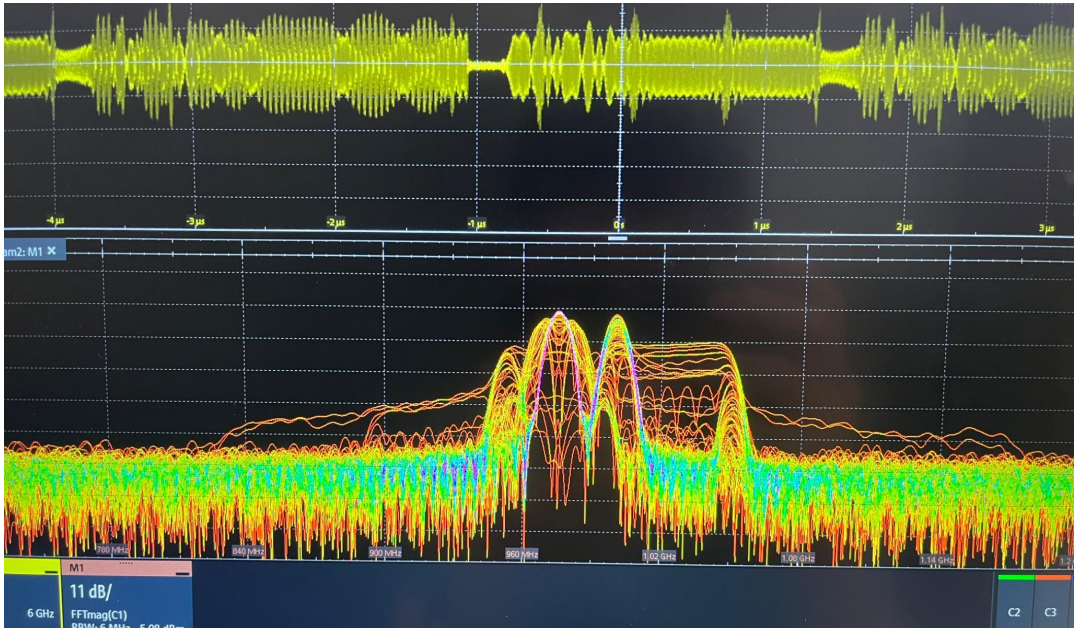

Receiver
1GHz Approximate Demodulation
Synchronize with Barker Codes
Decode OFDM
Bits
975MHz Approximate Demodulation
Synchronize with Barker Codes
Decode BPSK
Bits

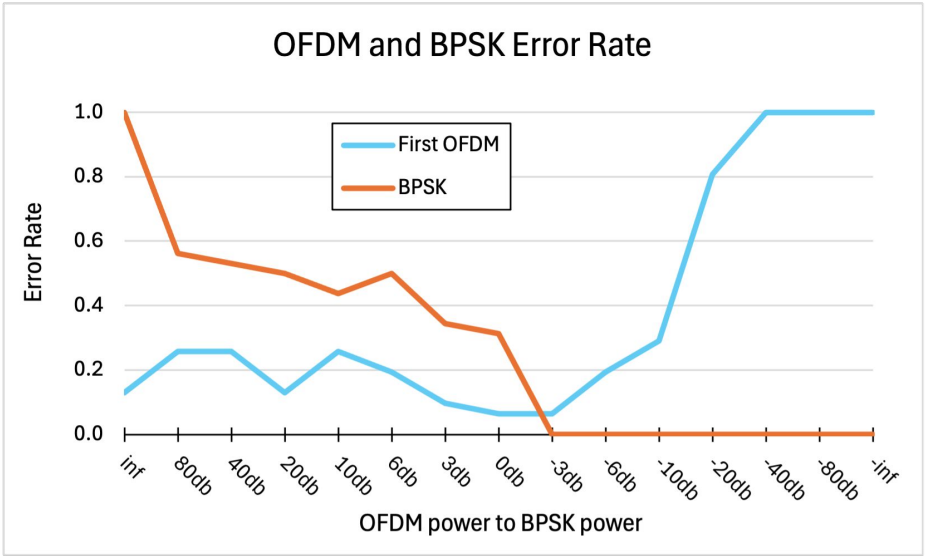
Fig.4

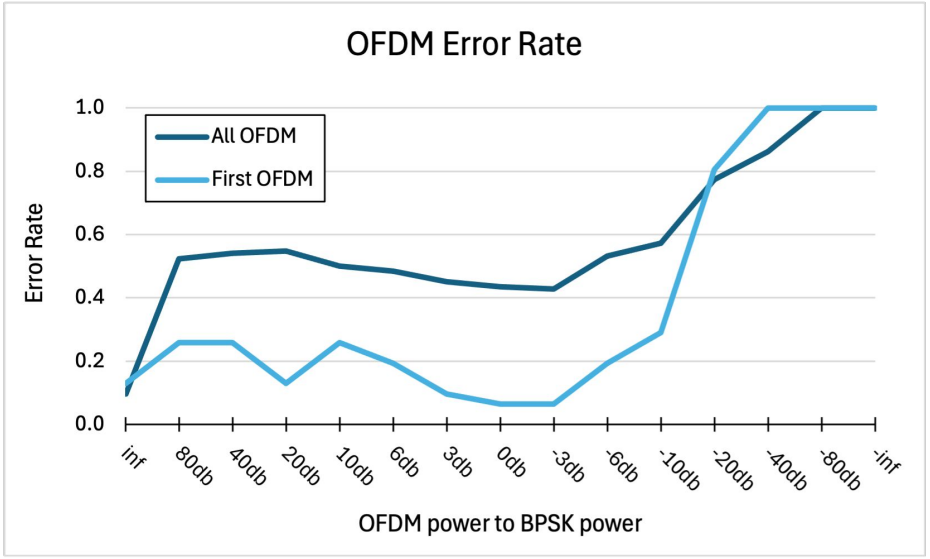



```
[1 0 0 0 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1]
hhhhhh hh
```

```
[0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1]
hiii
```

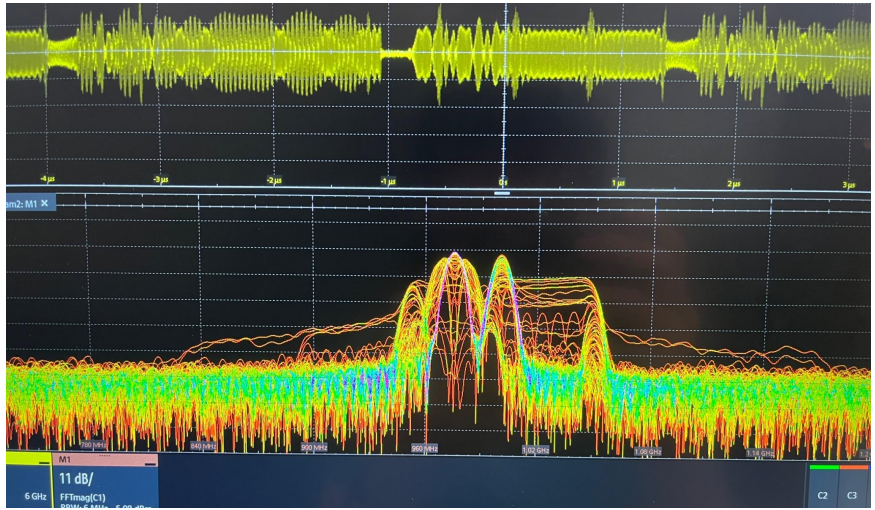
# Error Rates


OFDM and BPSK Error Rate
Error Rate
1.0
0.8
0.6
0.4
0.2
0.0
First OFDM
BPSK
inf
80db
40db
20db
10db
6db
3db
0db
-3db
-6db
-10db
-20db
-40db
-80db
-inf
OFDM power to BPSK power


OFDM Error Rate
Error Rate
1.0
0.8
0.6
0.4
0.2
0.0
All OFDM
First OFDM
inf
80db
40db
20db
10db
6db
3db
0db
-3db
-6db
-10db
-20db
-40db
-80db
-inf
OFDM power to BPSK power

# Future

- Projects can be built on top of this framework to test signal avoidance techniques
- ie adding a buffer between the two signals



# THANKS SO MUCH