Downlink Transmit Beamforming

Single-Carrier Acoustic Communication in a Simulated Noisy Environment

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February 2024

Outline

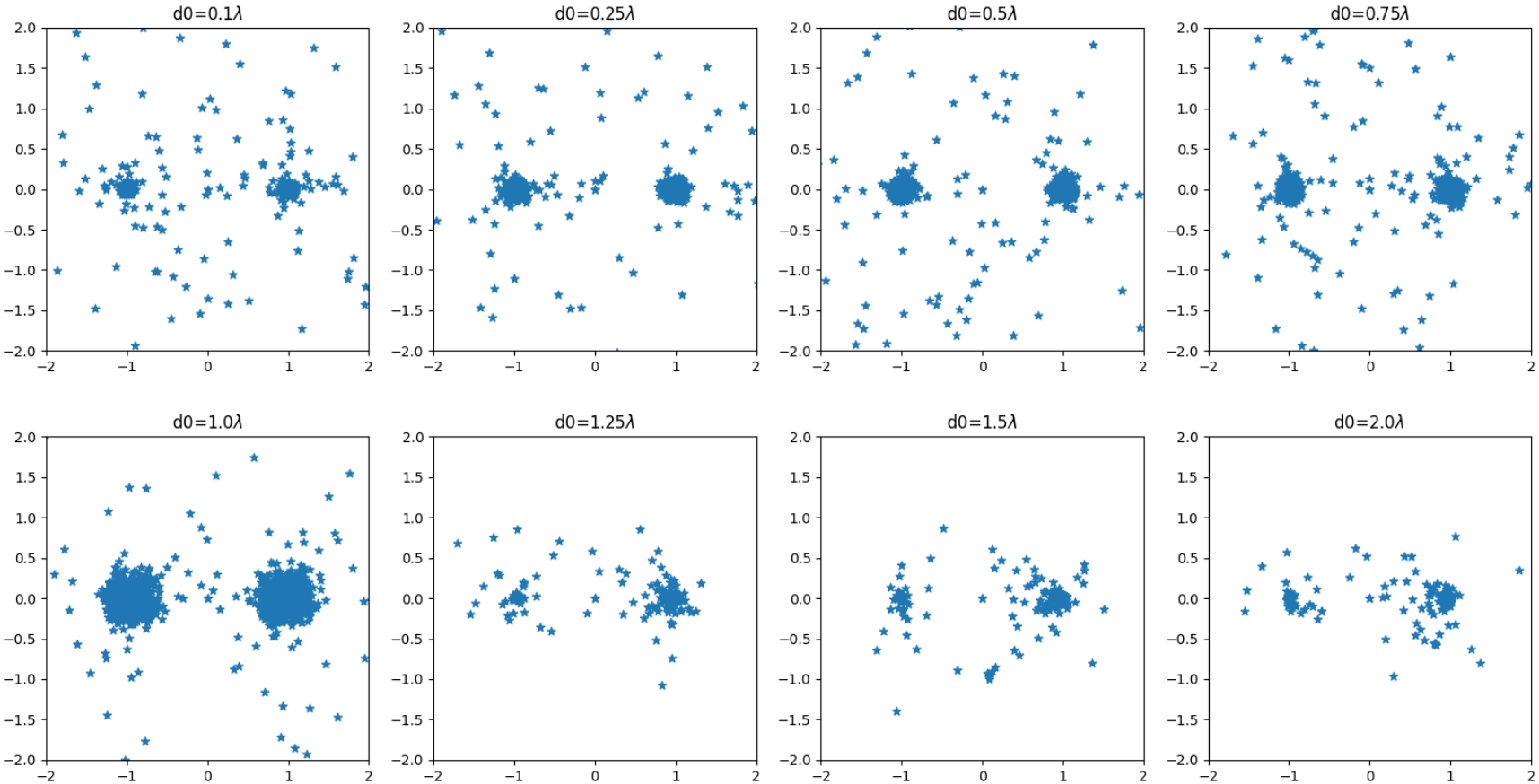
Communication System

BPSK Transmitter/Receiver initialized with following parameters:

Parameter	Symbol	Value
Center Frequency	f_c	16 kHz
Sampling Frequency	f_s	48 kHz
Symbol Rate	R	3000 Symbols/s
Samples per Symbol	N_s	16
# of Array Elements	M	12
Wavespeed	v	343 m/s
Feedforward Filter Length	$K_1 + 1$	20
Feedback Filter Length	K_2	4
RRC Roll-off	α	0.5
Fractional Spacing	$N_s F_s$	4
Number of Training Frames	N_T	4
Number of Total Frames	N_{rep}	16

Element Spacing Analysis

- Constellation Diagram for element spacing as factor of wavelength λ for 16kHz at 20 dB
- One reflection in channel, 12-element RX



Uplink Cross-Correlation

- Received signal formed by delay-and-sum method
- 12-Element Base Station with one reflection, beamforming applied

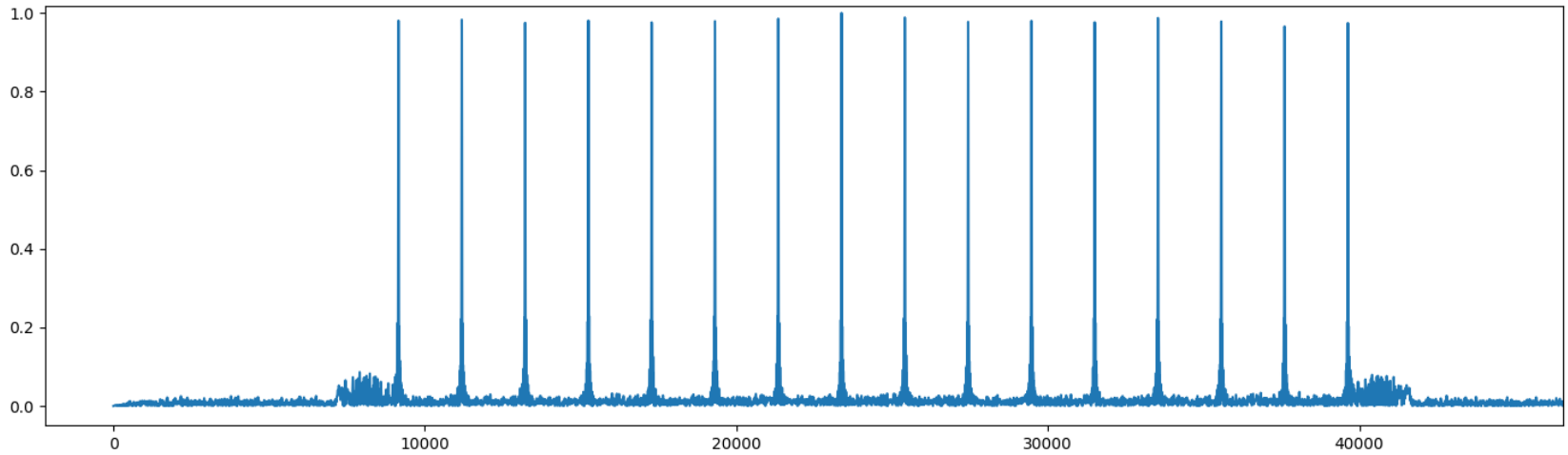


Figure: Cross-Correlation for Uplink Signal at 8 dB

DFE Framework

Following receiver architecture from [1]:

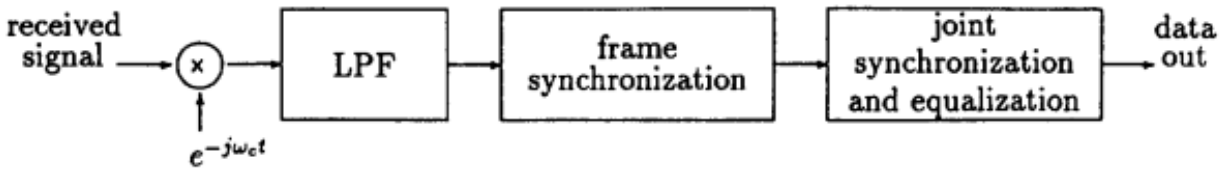


Figure: Receiver approach from [1]

Currently implemented with Recursive-Least Squares algorithm:

$$c_n = \sum_{i=0}^{n} 2\lambda^{n-i} e[i]\boldsymbol{u}[n]_i \tag{1}$$

DFE Initial Results

- Constellation Diagram for SNR from 8-20 dB
- One reflection in channel, 12-element RX

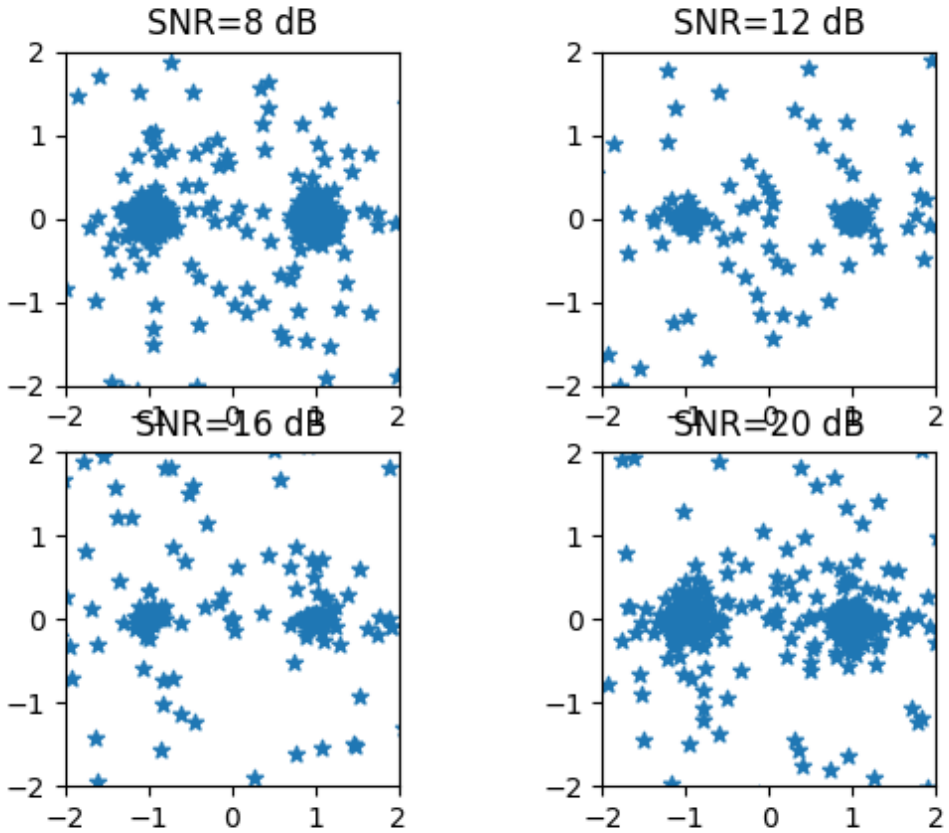
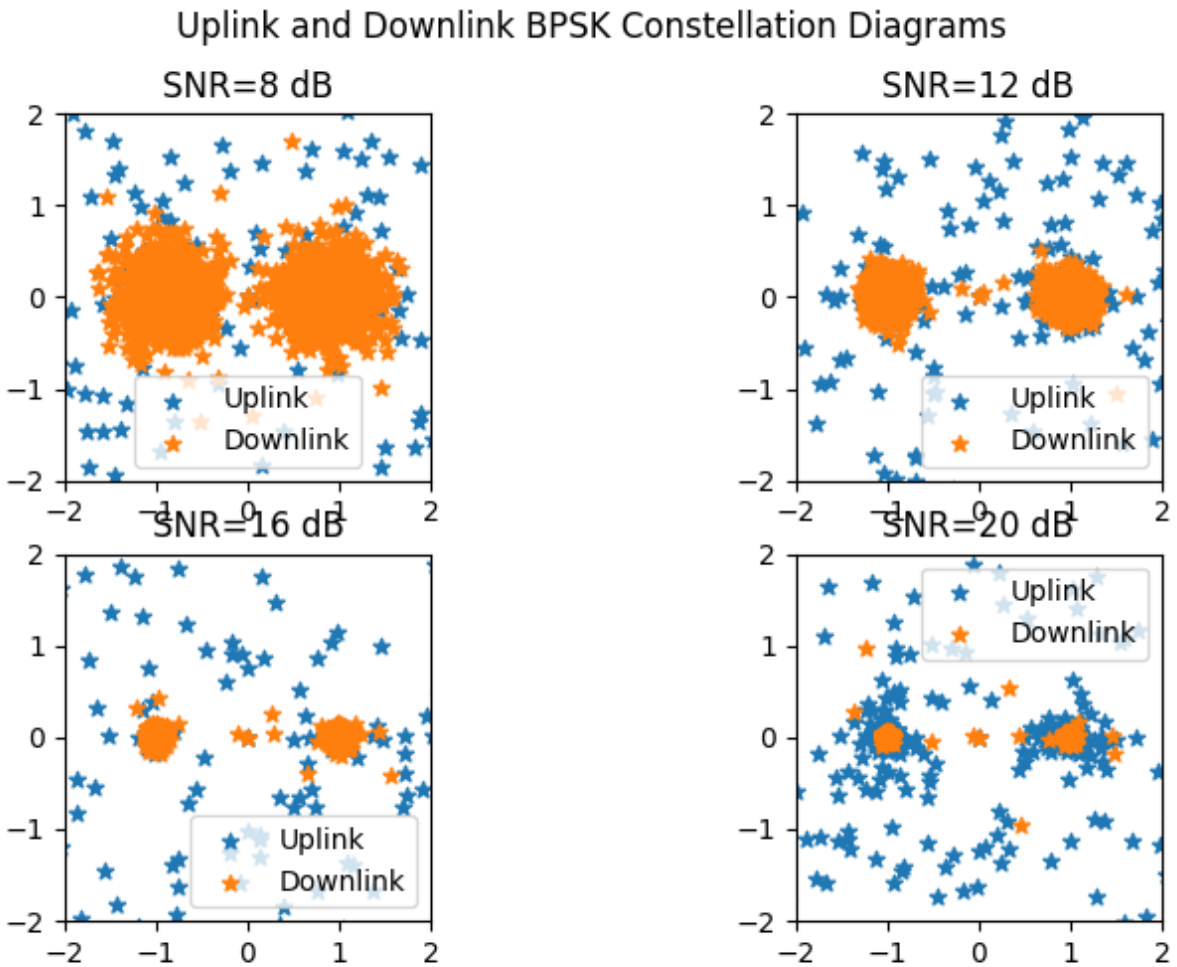


Figure: Constellation Diagram for Uplink

Downlink

- Steering vector applied at base station
- Single-channel DFE at user
- Same two-path (single-reflect) channel



S (Theta)

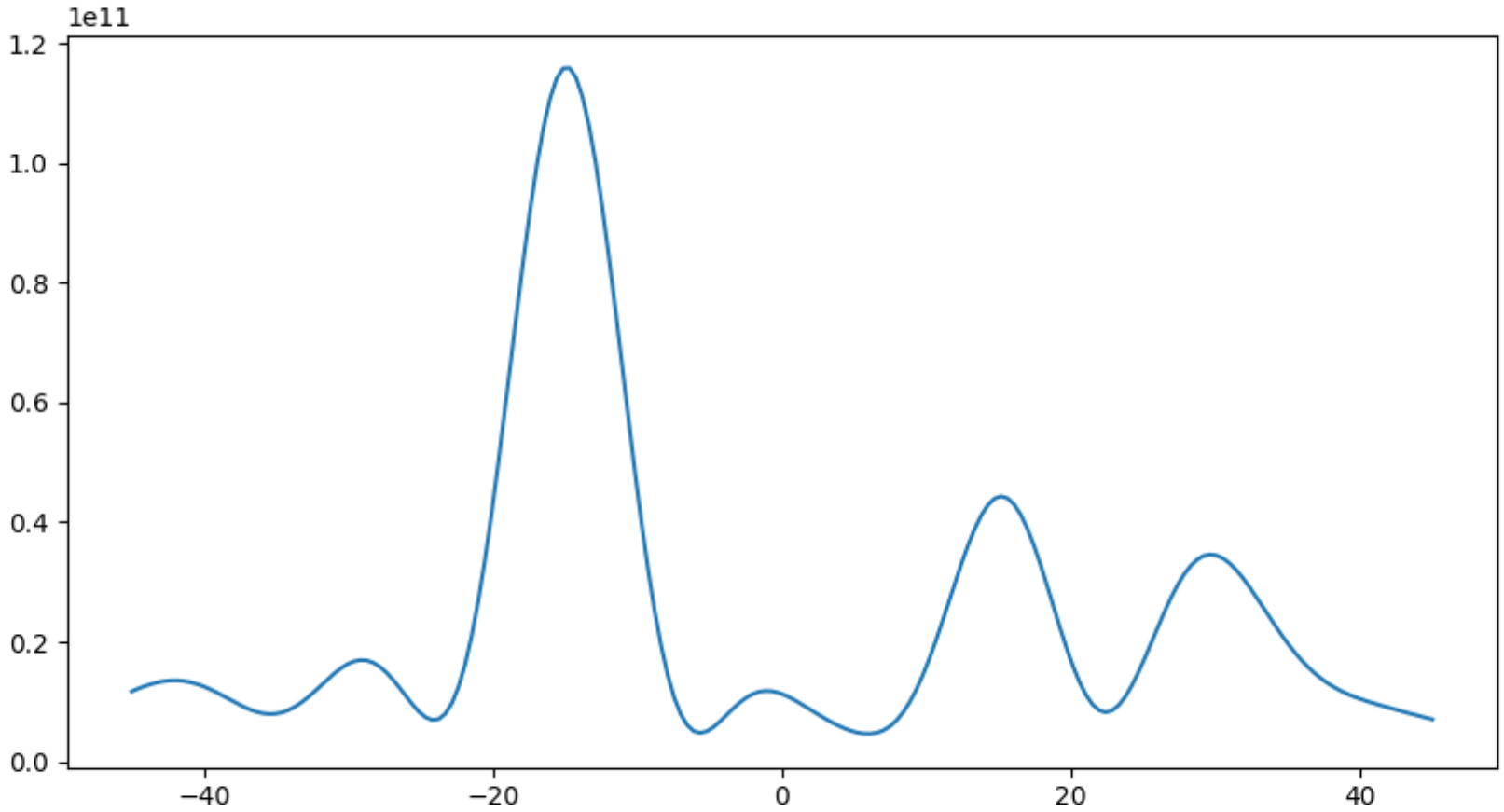


Figure: S (Theta) at Base Station

Downlink MSE

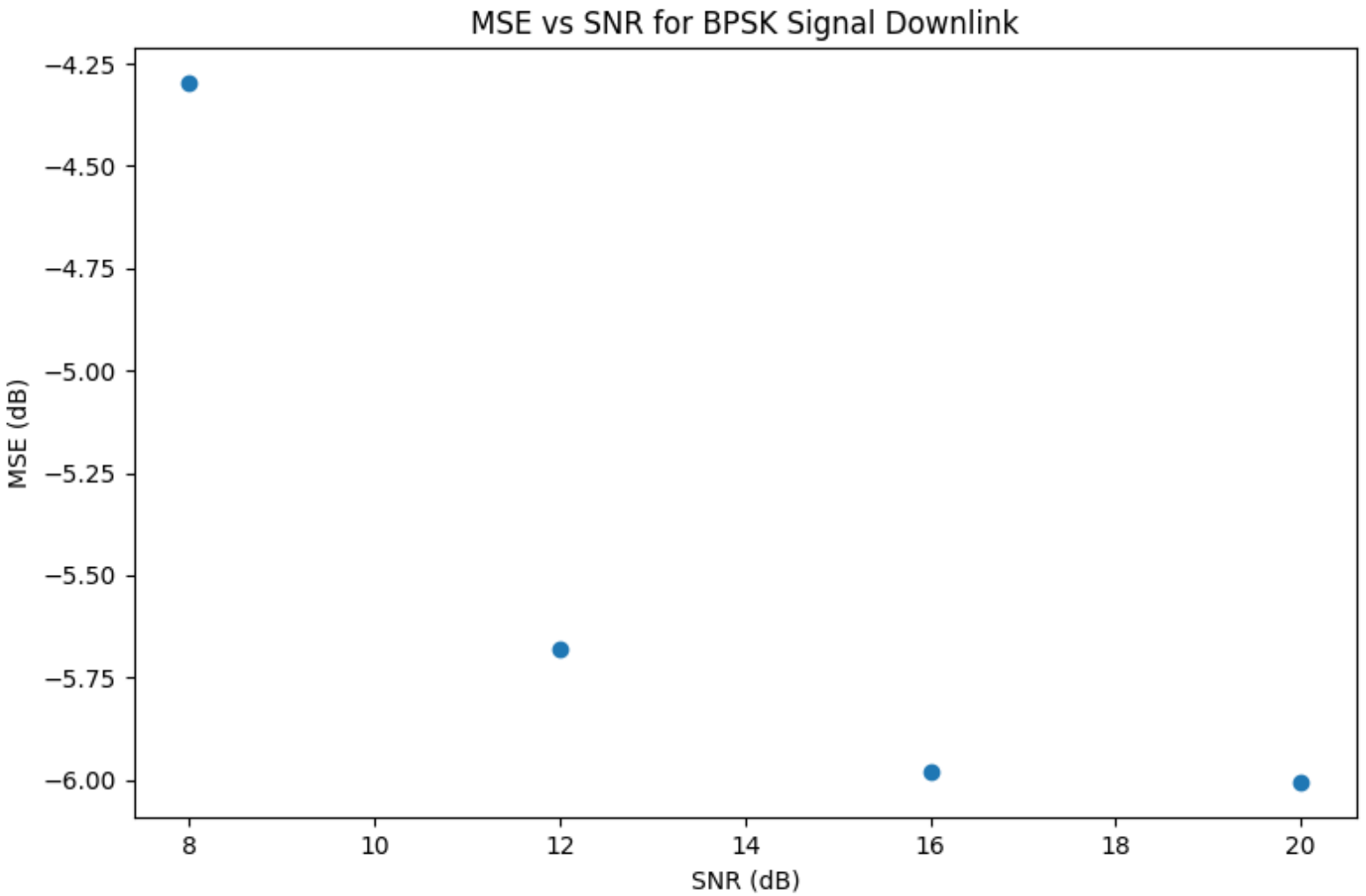


Figure: MSE for Downlink

Next Steps

- Open Air test
- Improve uplink DFE - multichannel?
- Analyze number of taps, element spacing, etc.


M. Stojanovic, J.A. Catipovic, and J.G. Proakis.
Phase-coherent digital communications for underwater acoustic channels.
IEEE Journal of Oceanic Engineering, 19(1):100–111, 1994.