Lecture 6 (part 1):
Wireless Communication Systems

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Key Idea of TARF

Surface Vibration → RADAR

Acoustic

Underwater speaker
How Can We Decode?
- ON-Off
- FMD (not clearly legible)
- FSK

- 1000 1000 1000 1000 1000 1000 1000
Decoding Information

Underwater Speaker

RADAR

Angle Variation

100Hz

100Hz

200Hz

200Hz

Rx

Rx

Bit 0

Bit 1

Surface Vibration

Tx: 100Hz

Tx: 200Hz
Decoding Information

RADAR

Underwater Speaker

Angle Variation

Surface Vibration

Bit 0

Bit 1

Rx

100Hz

200Hz

Rx

100Hz

200Hz

Tx: 100Hz

Tx: 200Hz
Standard Modulation Schemes?

The wireless channel

Mathematics & Physical Interpretation

Upconversion & Downconversion

Modulation & Demodulation
Implementation

**Receiver**
Custom made FMCW Millimeter-Wave RADAR
- Center Frequency: 60GHz
- Bandwidth: 3GHz
- Antennas: 23dBi Gain Horn Antennas

*Radar acts as daughterboard to a USRP(N210) software radio*

**Transmitter (low power)**
Electro-Voice UW30 Underwater Loudspeaker
- Center Frequency: 150Hz
- Bandwidth: 100Hz

**Pre-amplifiers**
- OSD 75W Compact Subwoofer Amplifier
- Pyle 300W Stereo Receiver
Implementation

**Receiver**
Custom made FMCW Millimeter-Wave RADAR

**Transmitter** (low power)
Underwater Loudspeaker
Different Evaluations

Water Tank

Swimming Pool

Swimming Pool with swimmers

Acoustic Transmitter

RADAR

RADAR

Acoustic Transmitter
Throughput Results

Experiment: Vary the Power and Depth of Underwater Transmission

Signal-to-Noise Ratio (dB) vs. Throughput (bps)
Throughput Results

**Experiment:** Vary the Power and Depth of Underwater Transmission

![Throughput Graph](image-url)
Throughput Results

Experiment: Vary the Power and Depth of Underwater Transmission

![Graph showing throughput results with signal-to-noise ratio (dB) on the x-axis and throughput (bps) on the y-axis. The graph compares three modulation methods: 16QAM, QPSK, and BPSK, with BPSK being more sensitive to signal-to-noise ratio changes.]
Throughput Results

Experiment: Vary the Power and Depth of Underwater Transmission

![Graph showing throughput results for BPSK and QPSK with varying signal-to-noise ratio (dB)].
SNR vs Depth

Signal-to-Noise Ratio (dB)

Depth (m)

1/depth$^2$
Dealing with Waves

**Experiment:** Generate Waves of Peak-to-Peak Amplitudes

Our technology can communicate even in the presence of natural surface waves that are 1,000x larger than the acoustic vibrations.
Receiver Misalignment

Experiment: Vary the Alignment Between the RADAR and the Transmitter