

# An Implementation of Digital Communication Through Audio Signals

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## Problem Statement

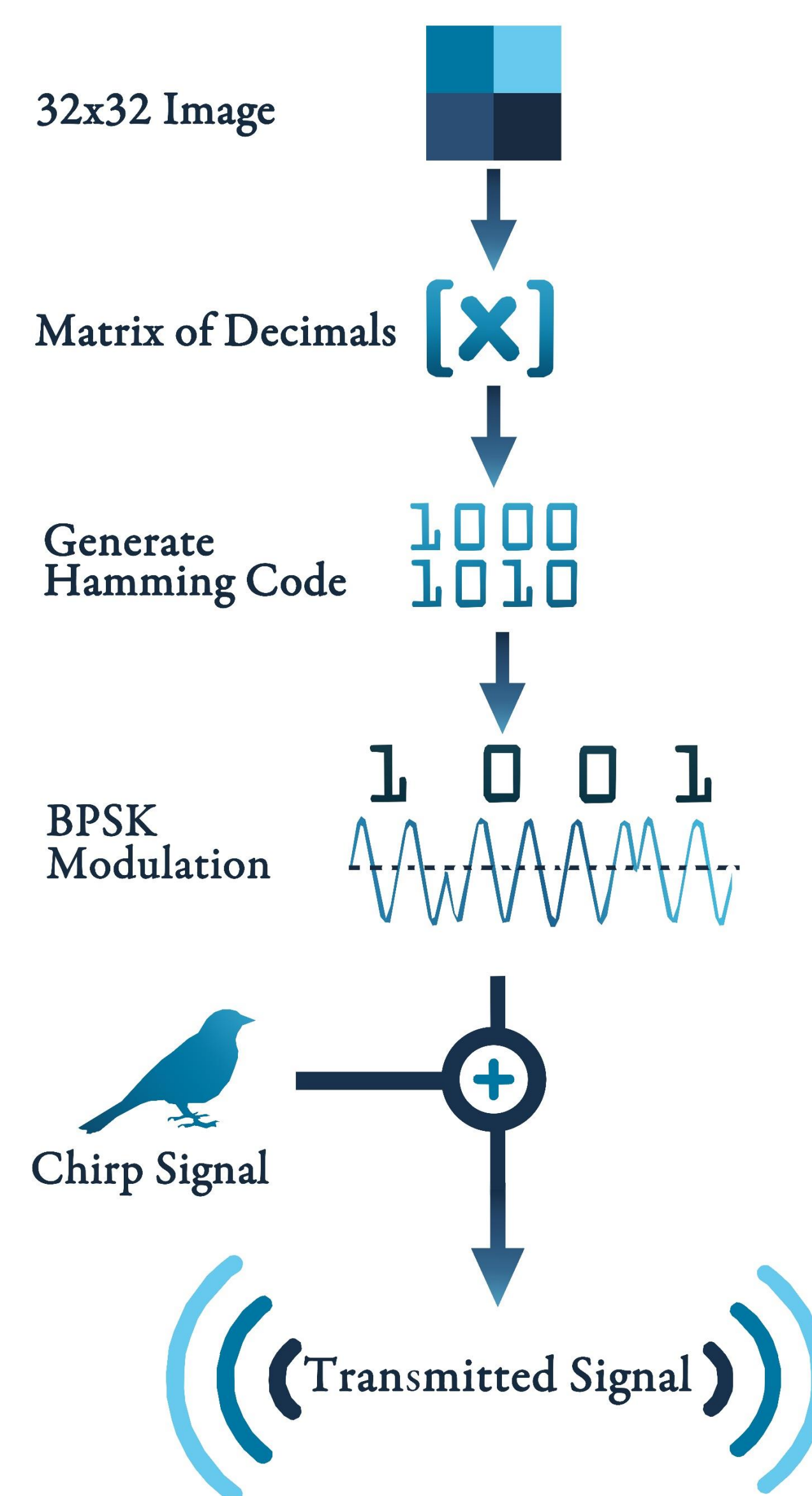
- Implement a communication scheme to send an image between laptops with minimal error
  - Utilize only MatLab, speakers, and microphones
  - Employ modulation schemes, error correcting code, sampling, and methods to optimize communication in the environment

## Motivation

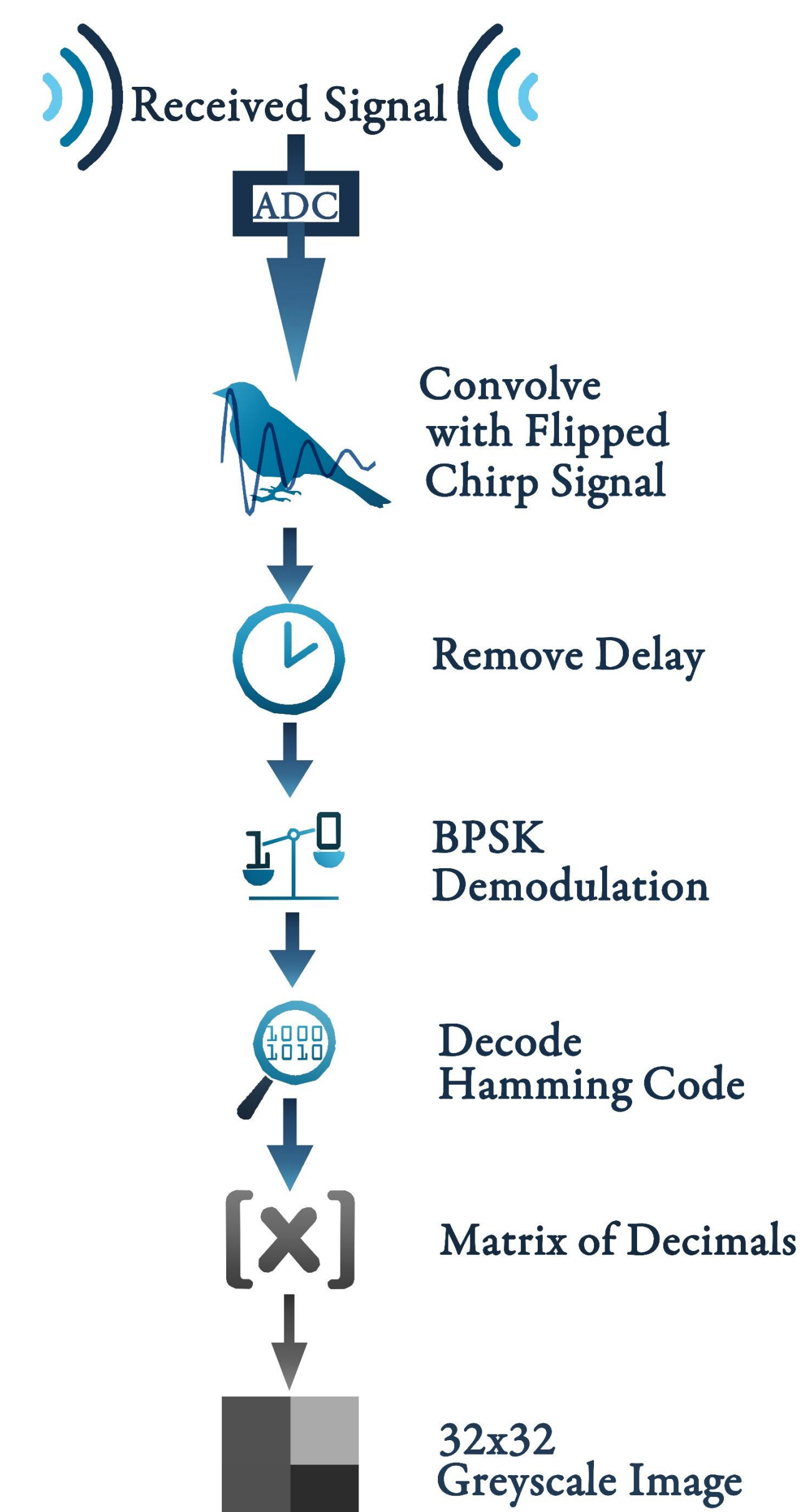
- Low error digital communication has become crucial in the modern era
- Devices (ex: cell phones) are often restricted by memory limitations
- Users may find themselves unable to accomplish a task (ex: taking a photo) due to insufficient available storage
- This communication scheme demonstrates how data can be sent to and stored at an external memory location, then returned to the user upon request without error

## Project Overview

### Transmission



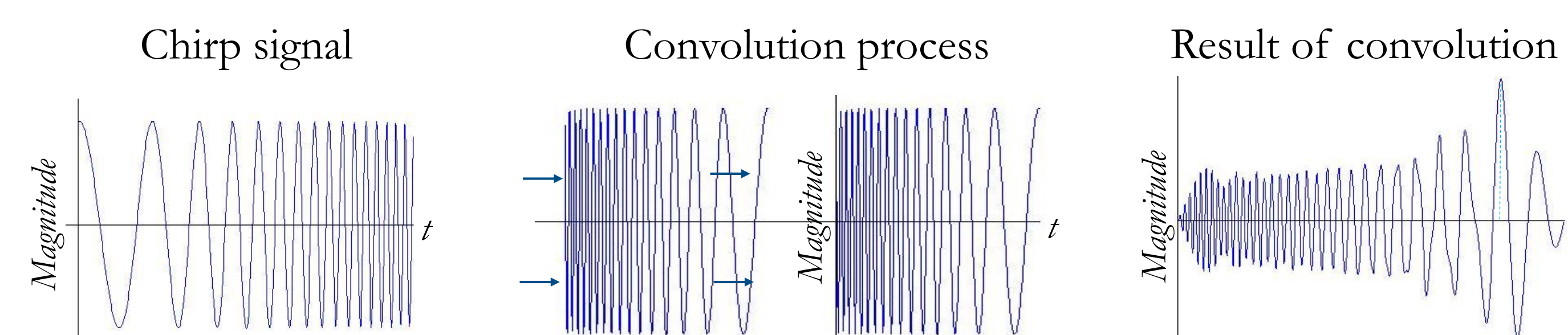
### Reception



## Theory & Methods

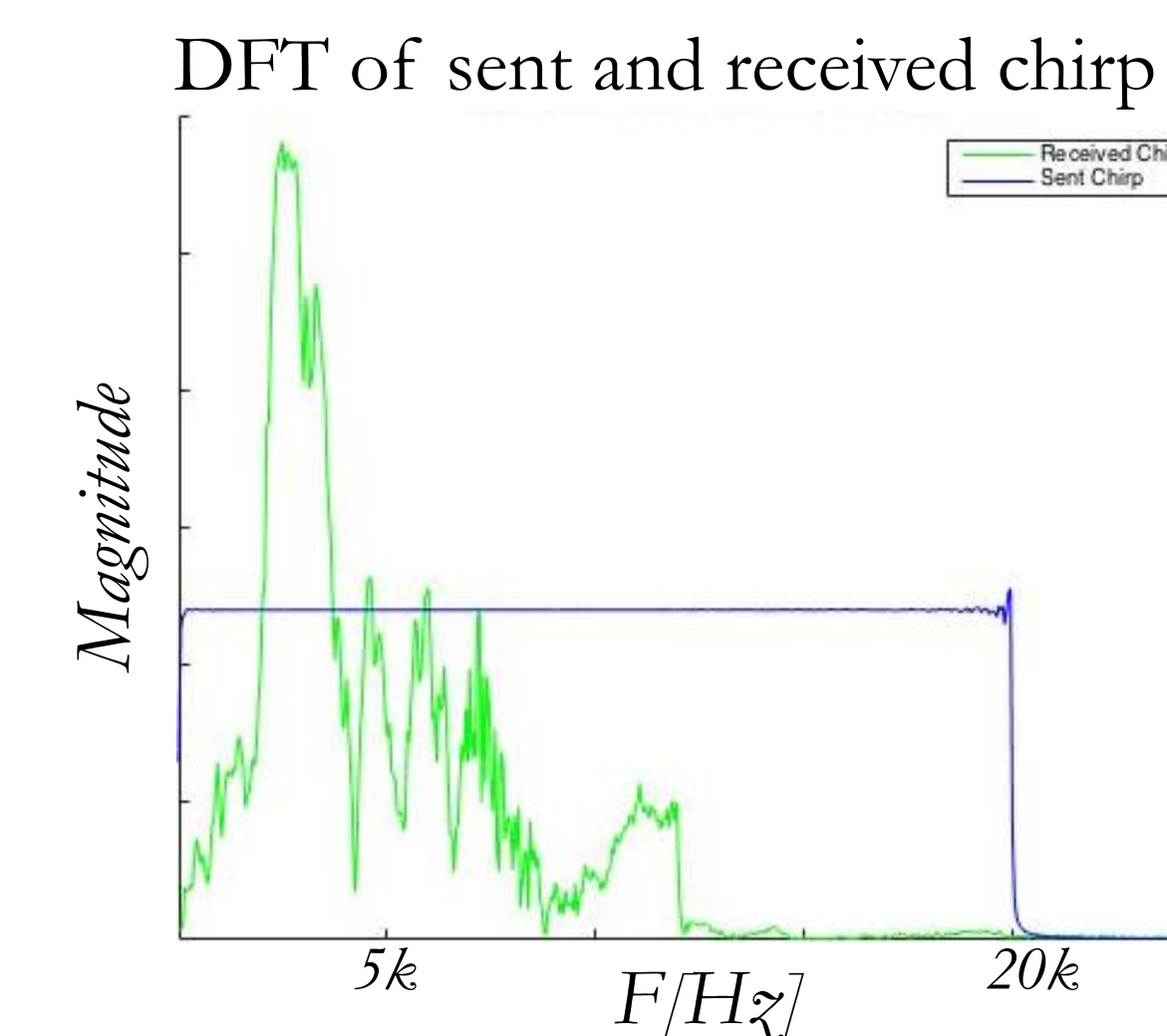
### Chirp

- Chirp at the beginning of the sent signal enabled receiver to detect when the significant audio signal began
- Detected by convolution



### Sounding the Channel

- DFT of the sent and received chirp indicated frequency response of the environment
- Large magnitude in received signal's DFT indicated low attenuation of those frequencies, making them good choices for carrier frequencies



### BPSK

#### Modulation

- Matrix of sine waves was created at the carrier frequency
- Diagonal matrix of  $\pm 1$ , representing the coded bits, was created
- Multiplied together, these matrices resulted in the vector to be sounded

$$\begin{aligned} bpskTone &= \sin(2\pi F_c t); \\ bpskTones &= repmat(bpskTone, 1, numberofbits); \\ signs &= diag((-1).^codedbits, 0); \\ x &= bpskTones * signs; \end{aligned}$$

#### Demodulation

- Audio signal was sampled at more than twice the highest frequency
- Inner product was taken of each windowed bit and  $\pm \sin(2\pi F_c t)$
- The larger inner product determined if a 1 or 0 was sent

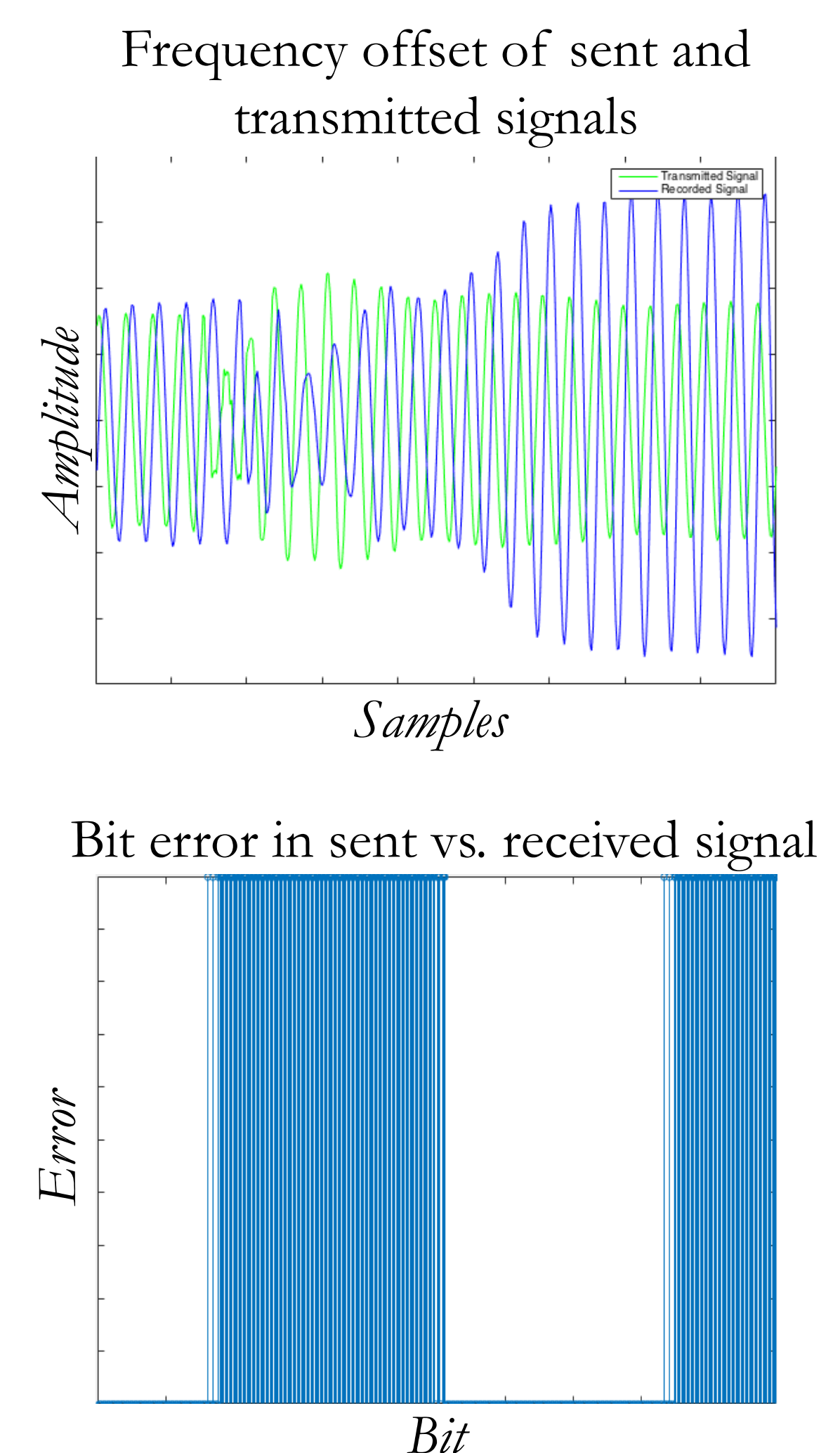
$$\begin{aligned} \text{if } \text{dot}(Tone', \sin(2\pi F_c t)) > \text{dot}(Tone', -\sin(2\pi F_c t)) \\ \text{codedrcvMSG} &= [\text{codedrcvMSG } 0]; \\ \text{else} \\ \text{codedrcvMSG} &= [\text{codedrcvMSG } 1]; \\ \text{end} \end{aligned}$$

## Results

### Problems Faced

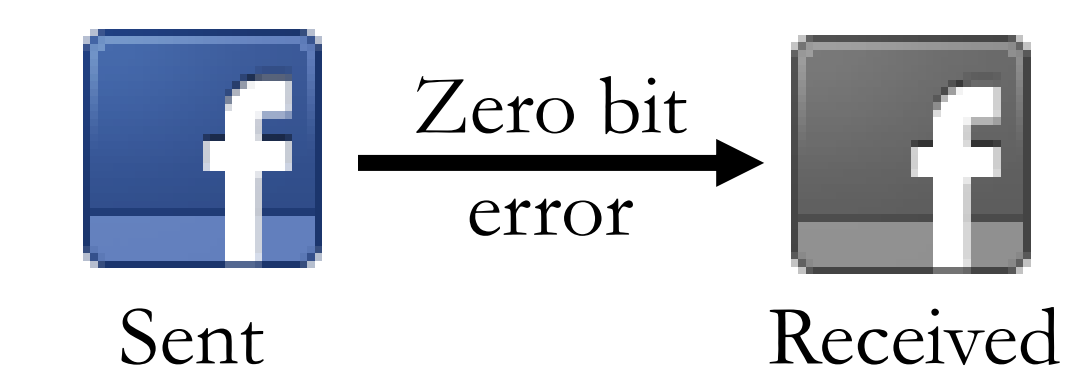
#### Mismatched Laptop Sampling Rates

- The built-in speakers and microphones of different laptop models had different sampling rates
- Resulted in the received audio signal's frequency being distorted
- This distortion delayed the frequency response of the received signal
  - Eventually caused decoding scheme to break down
- Designed our two-way communication scheme to mitigate this effect



### Successful Communication

- By sending the recorded audio signal back to the transmitter laptop, the frequency distortion caused by the built-in sound systems was diminished
- Observed successful communication of an image using audio signals, with consistent zero bit error in low noise environments



## Conclusions

- This communication scheme can be used to store images in a secondary computer until requested by primary computer, at which point they can be returned with little to no error
- Computer sound systems should have equal sampling rate characteristics to reliably send images one way

## Acknowledgements

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