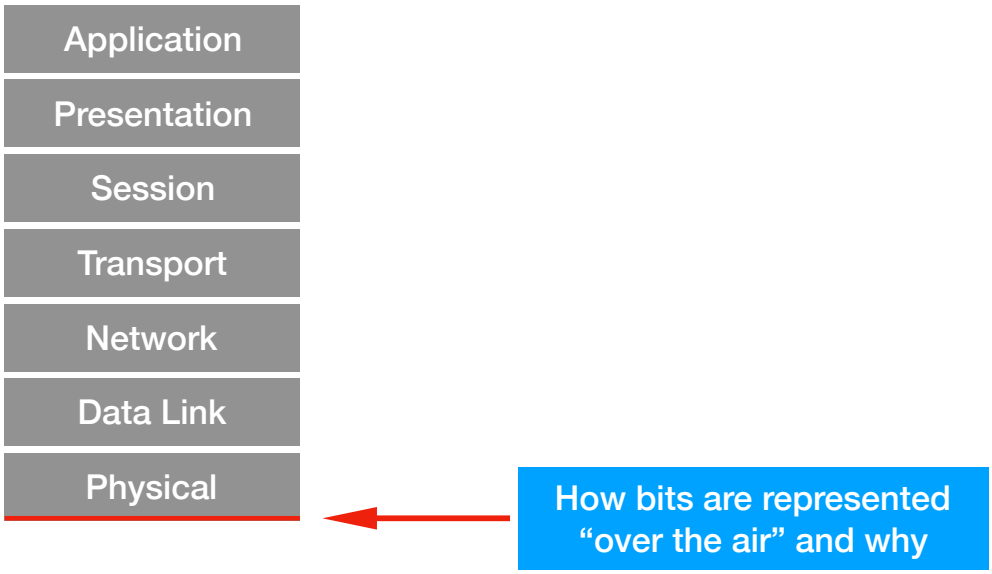
How WiFi Works

Diet Ostry 27 Sept 2018

What I’m going to talk about

OSI Abstract Network Model



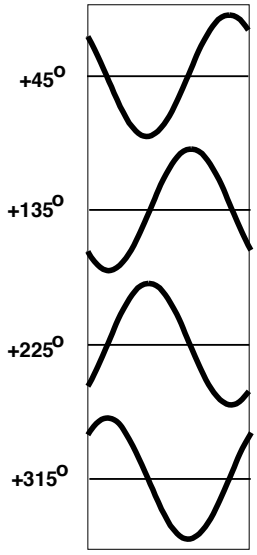
Our goal: Replace the best LAN (Local-Area Network) technology available at that time with a wireless equivalent

Requirements:

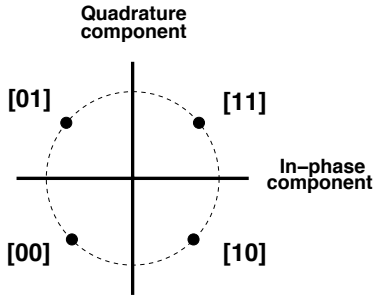
- **fast (~100 Mbps)**
- **wireless**
- **works indoors**
- **short(-ish) range is OK**

A Basic Digital Modulation: QPSK

4 symbols: $s_k(t) = \sqrt{2}\cos(\omega t + \phi_k), \quad \phi_k = 45^\circ,\ 135^\circ,\ 225^\circ,\ 315^\circ$

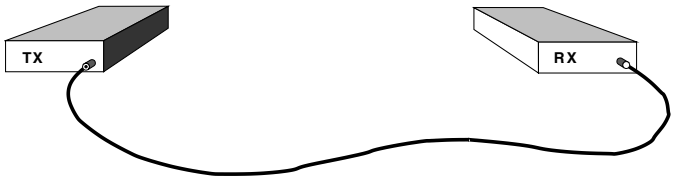


$$
\begin{aligned}
s_0(t) &= \ \ cos(\omega t) - sin(\omega t) \\
s_1(t) &= -cos(\omega t) - sin(\omega t) \\
s_2(t) &= -cos(\omega t) + sin(\omega t) \\
s_3(t) &= \ \ cos(\omega t) + sin(\omega t)
\end{aligned}
$$



Spectral efficiency: 2 bits/sec/Hz i.e. 1 symbol/sec/Hz

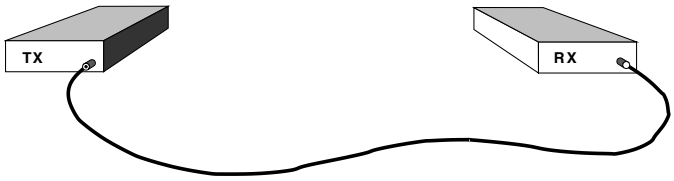
via cable/fibre

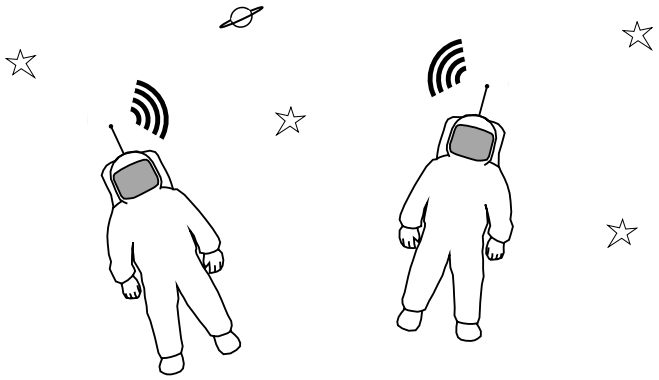


100 Mbps ?

100 Mbps ?

via cable/fibre

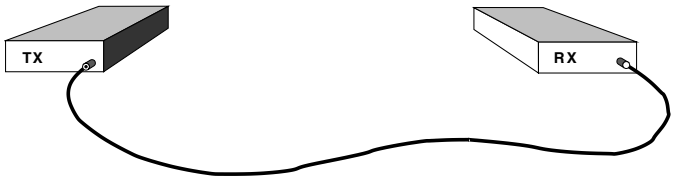




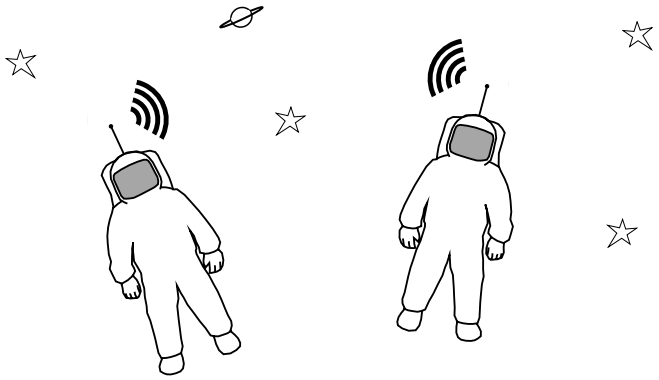
in free space

100 Mbps ?

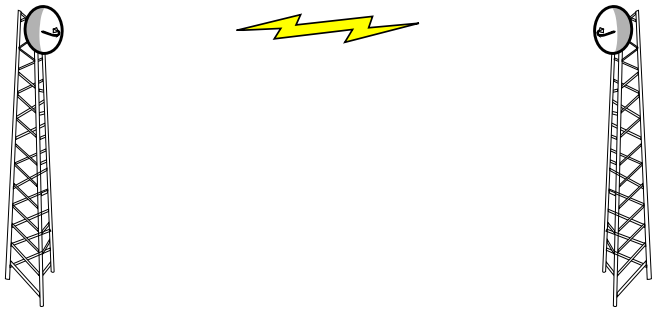
via cable/fibre



in free space

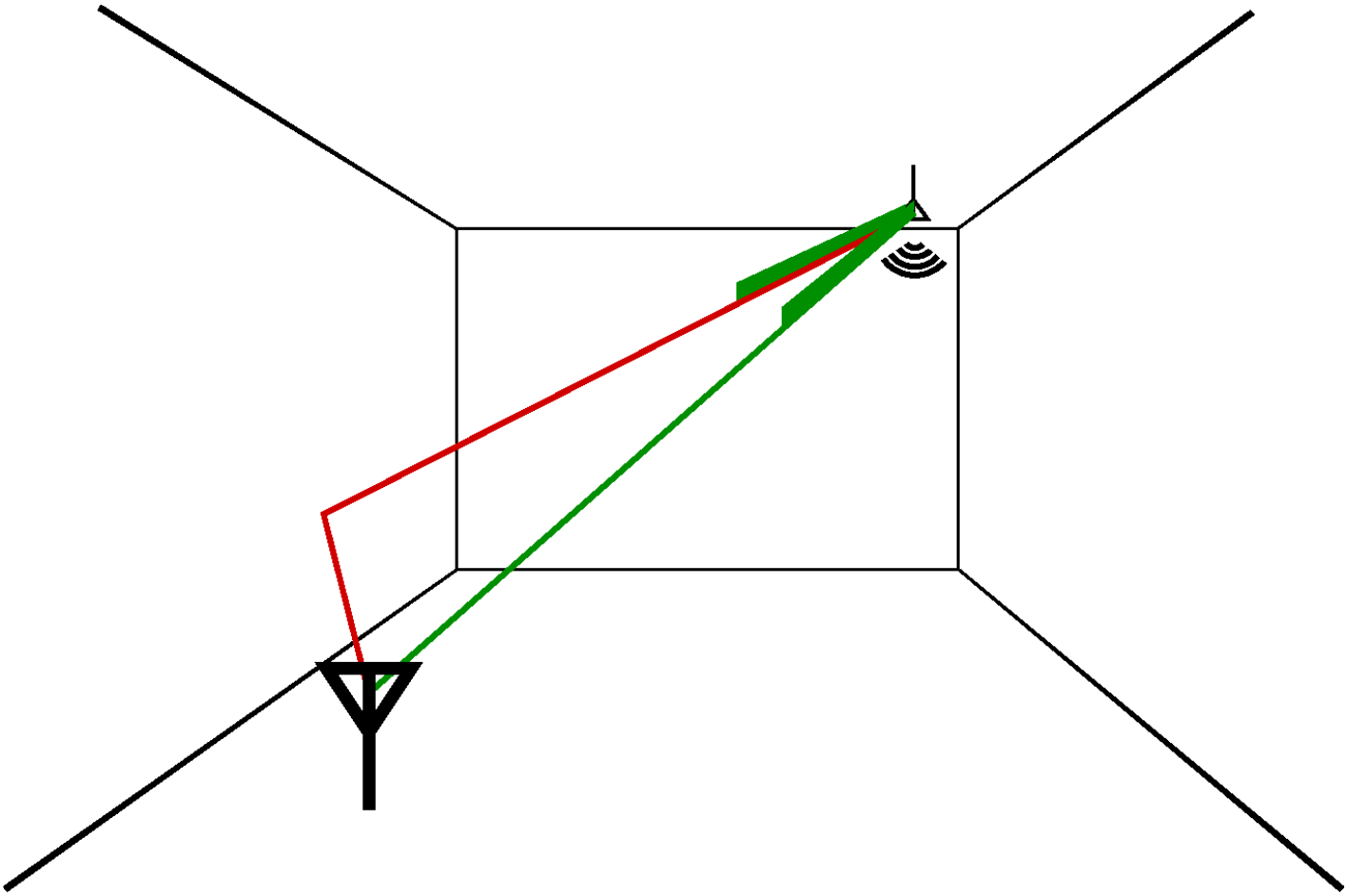


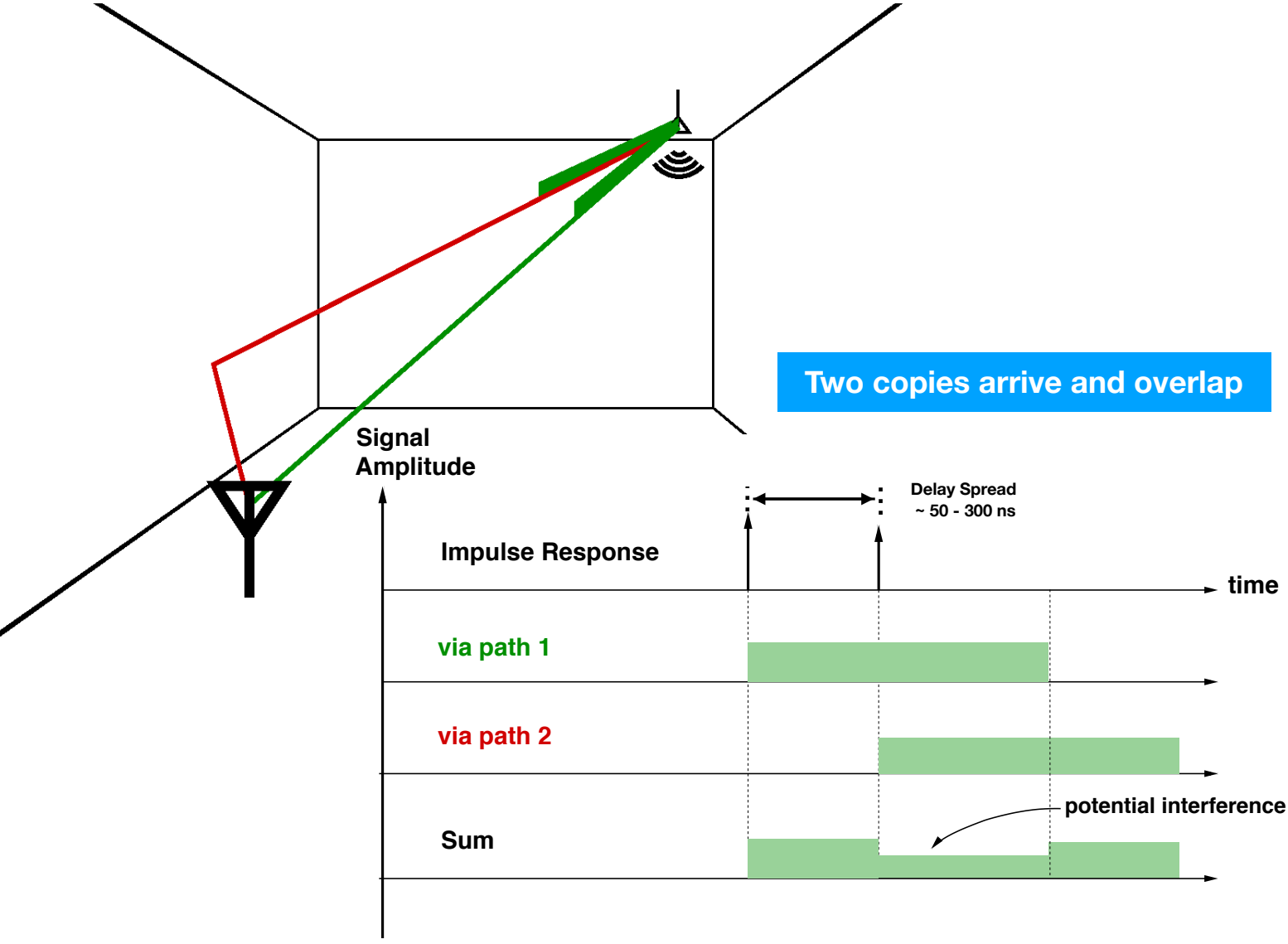
pencil beam



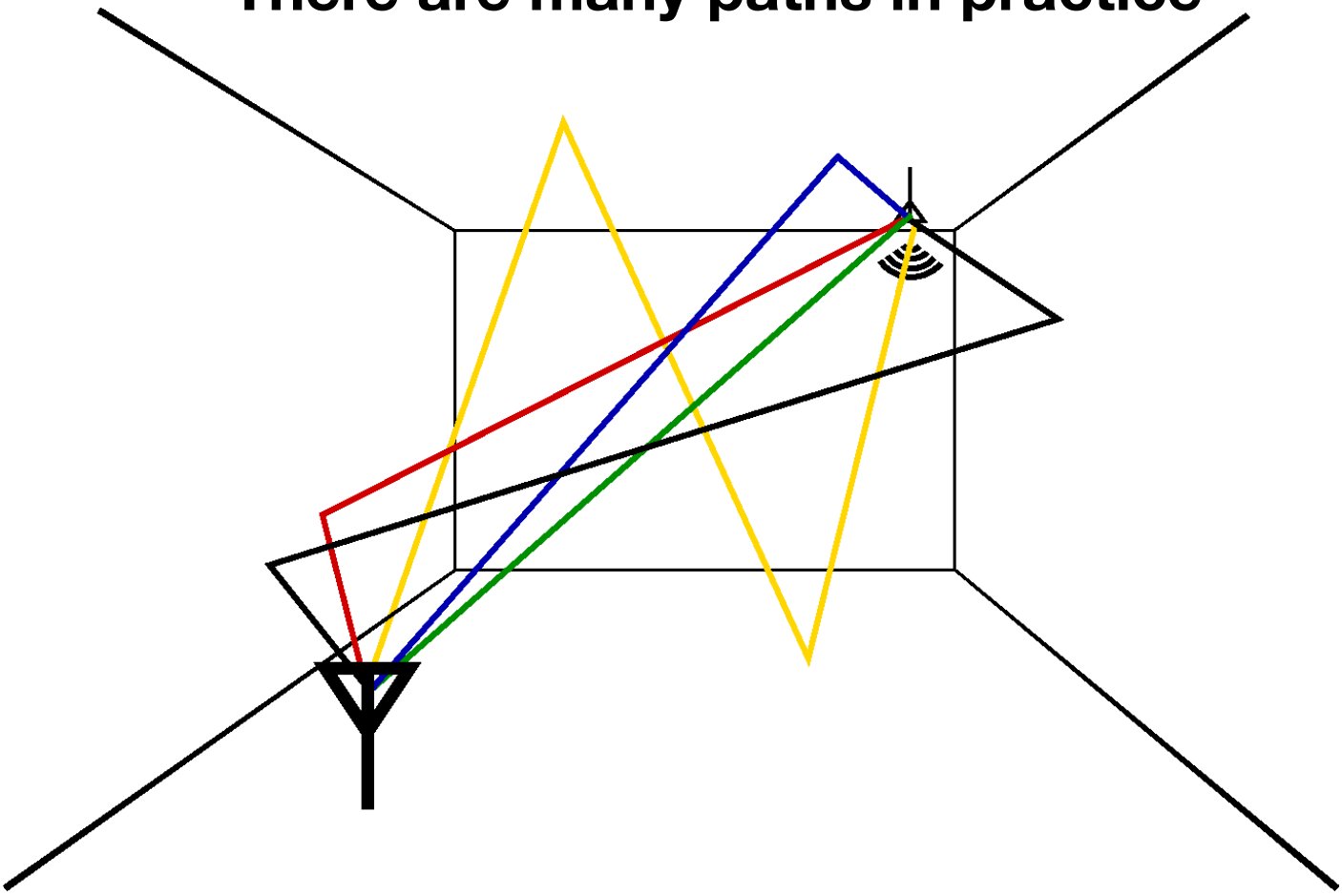

~2 Mbps
CSIRO Lindfield site aggregation proposal

The problem is Multipath

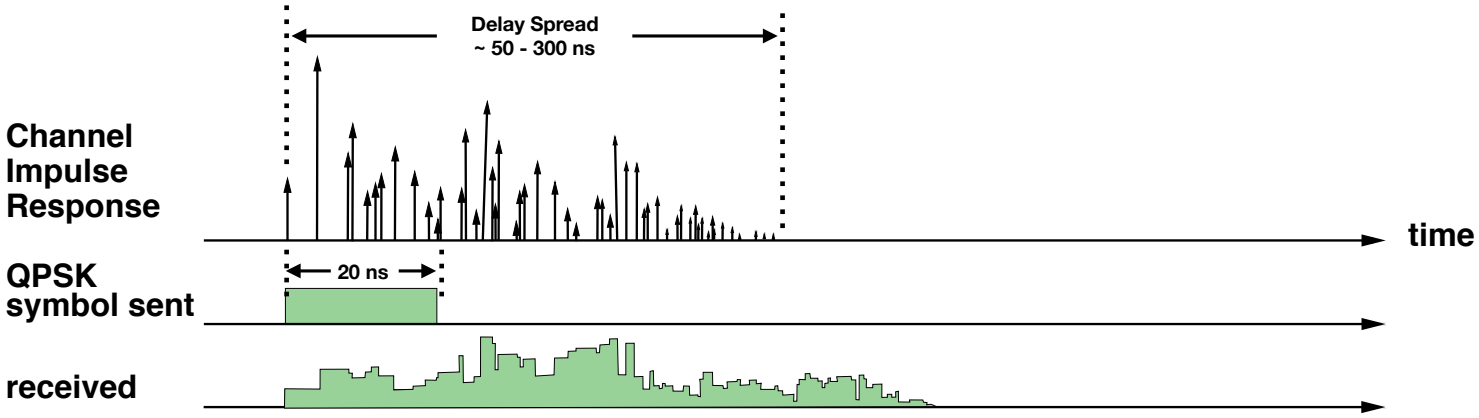



Two copies arrive and overlap
Signal
Amplitude
Delay Spread
~ 50 - 300 ns
Impulse Response
time
via path 1
via path 2
potential interference
Sum

There are many paths in practice



Effect of Multi-path on QPSK symbols



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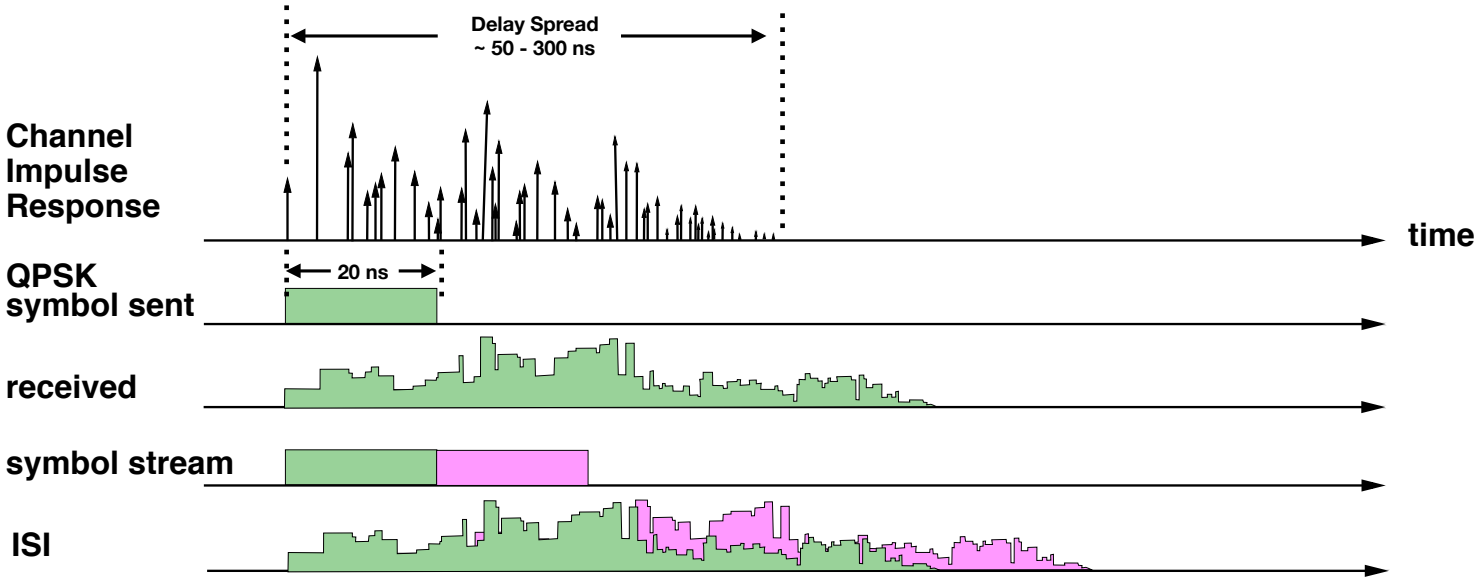

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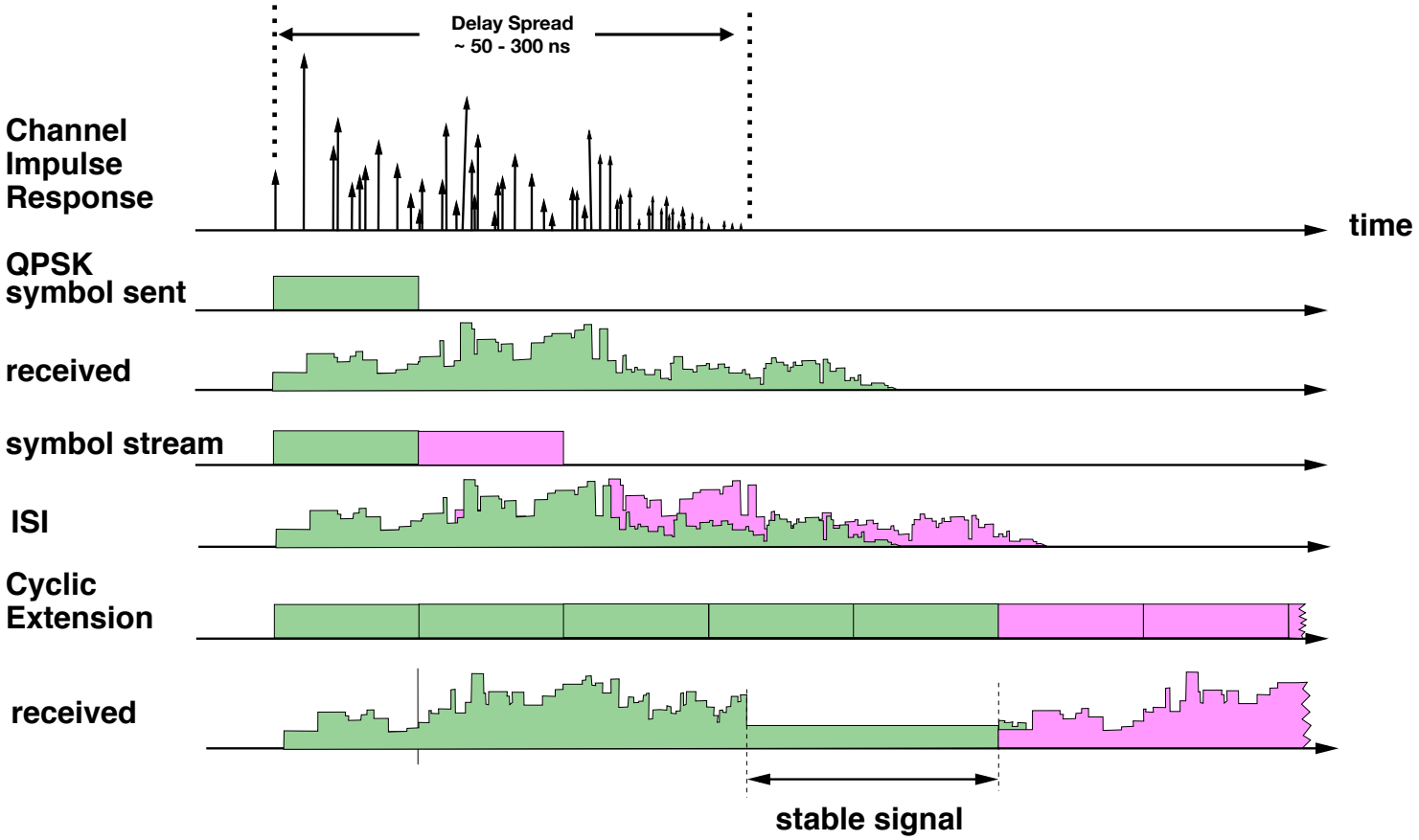
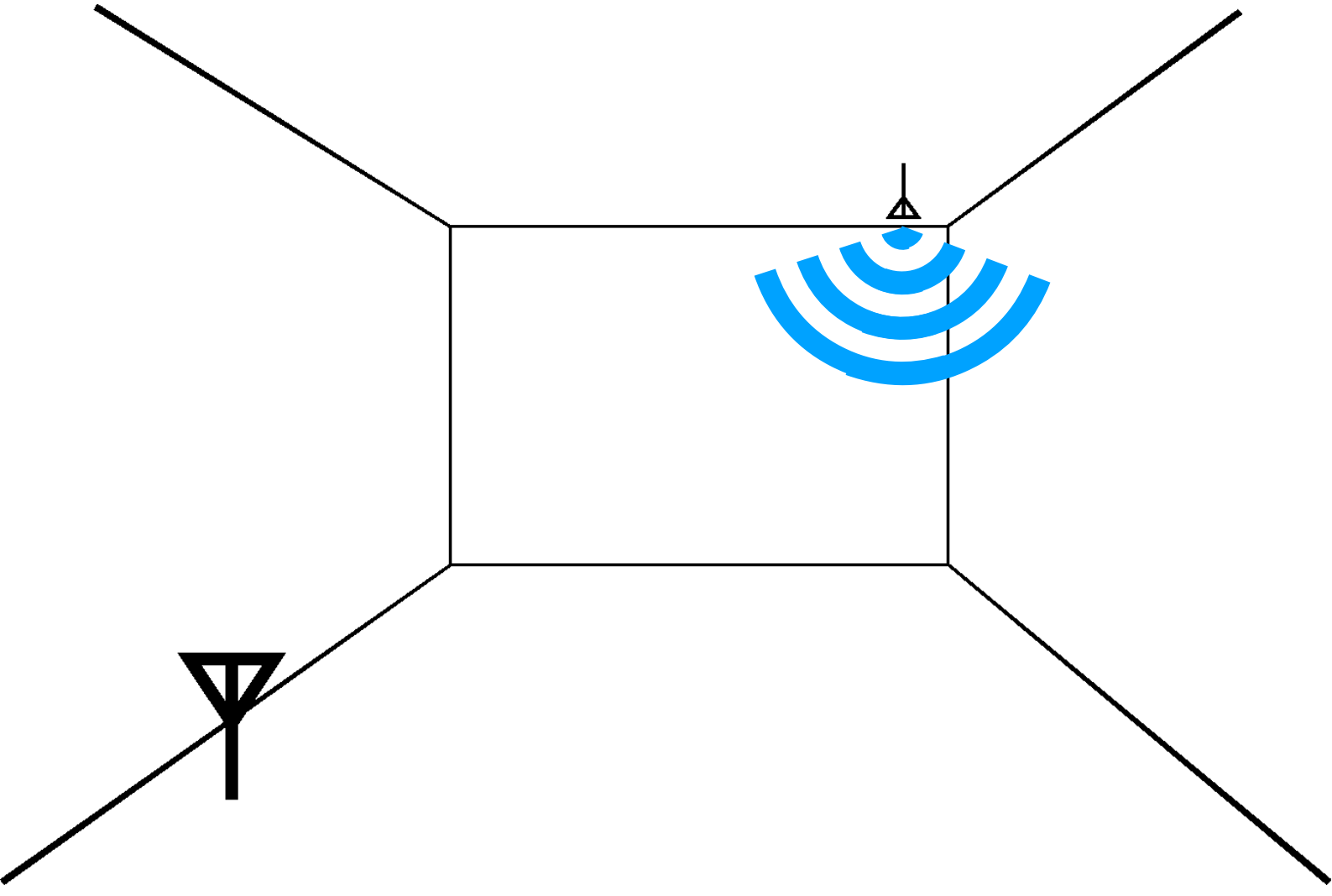


Frequency Response of the Link



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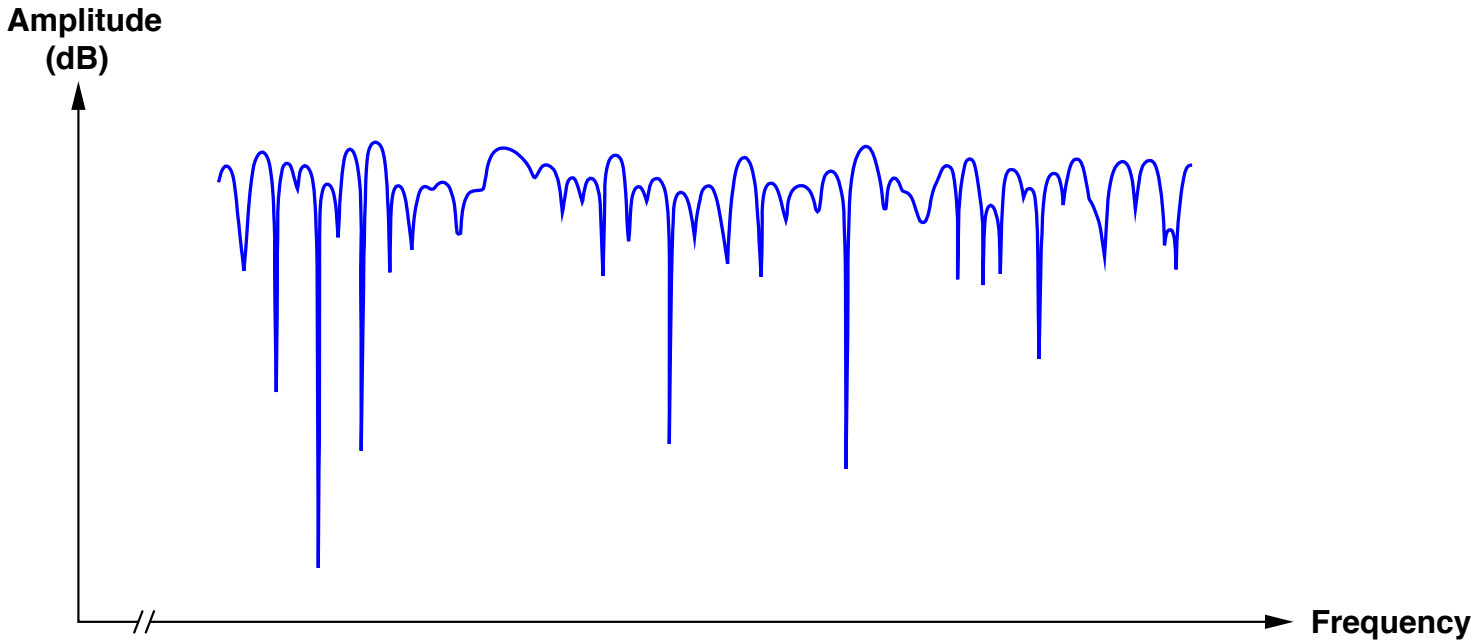
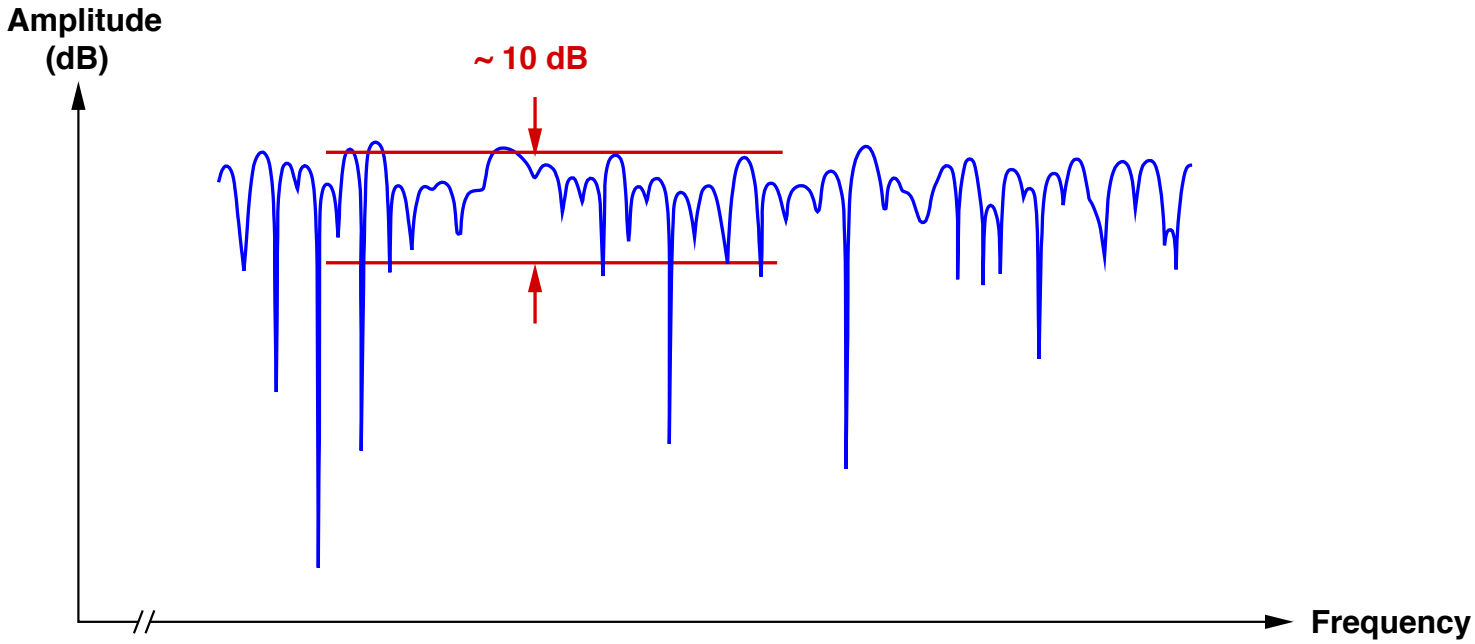


(This is a Rayleigh process if there is no line-of-sight signal)

Frequency Response of the Link



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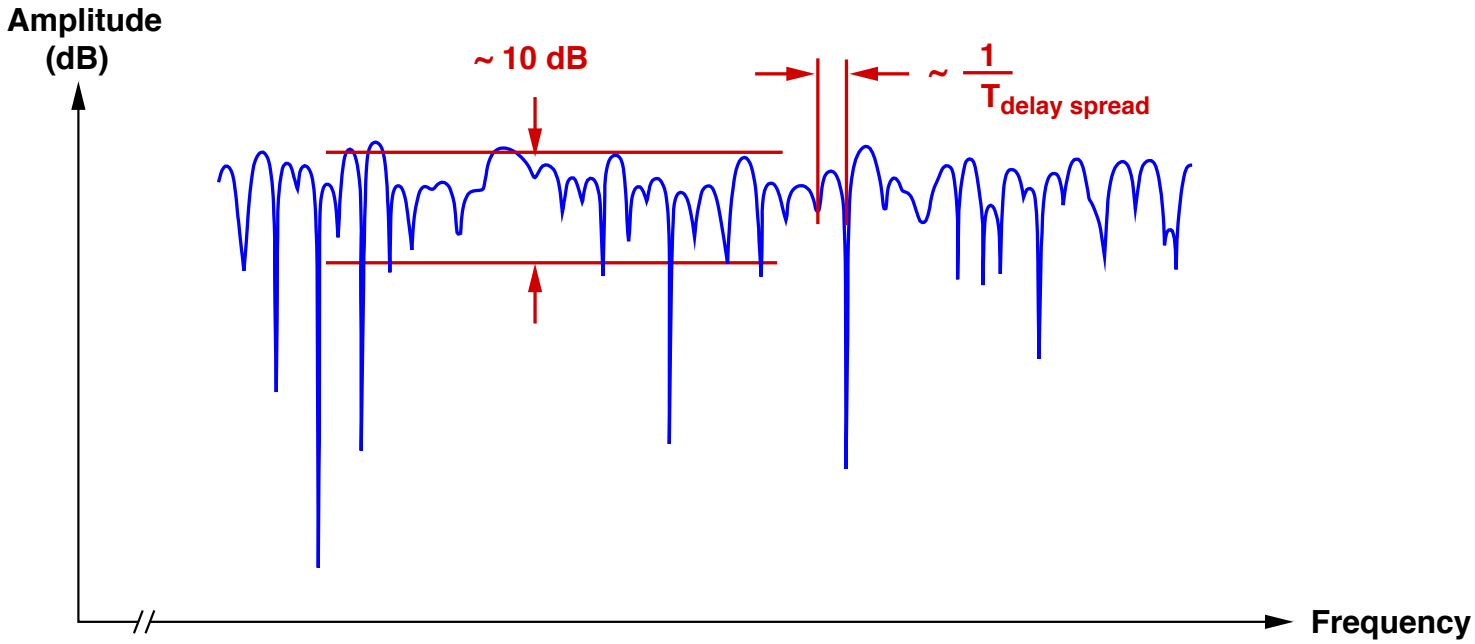

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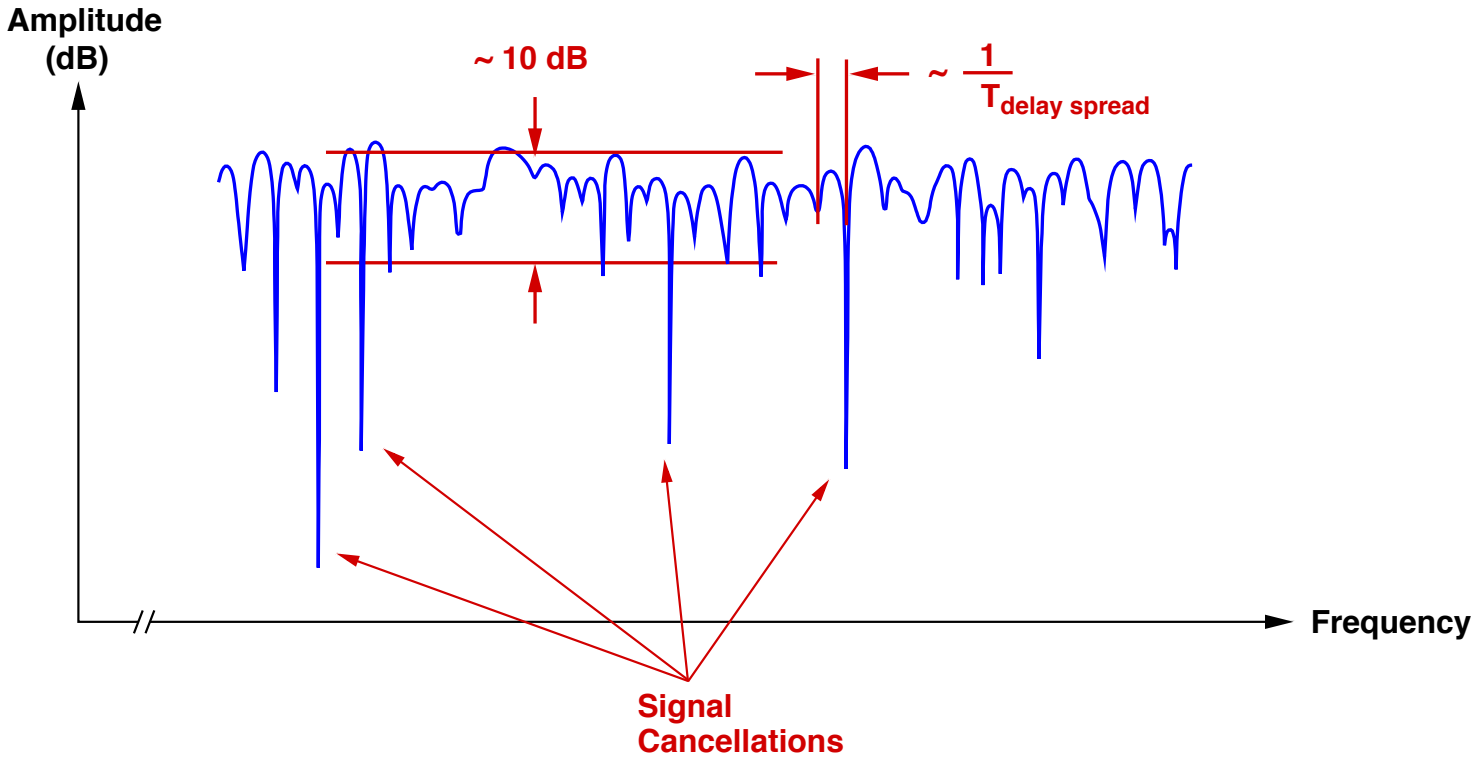
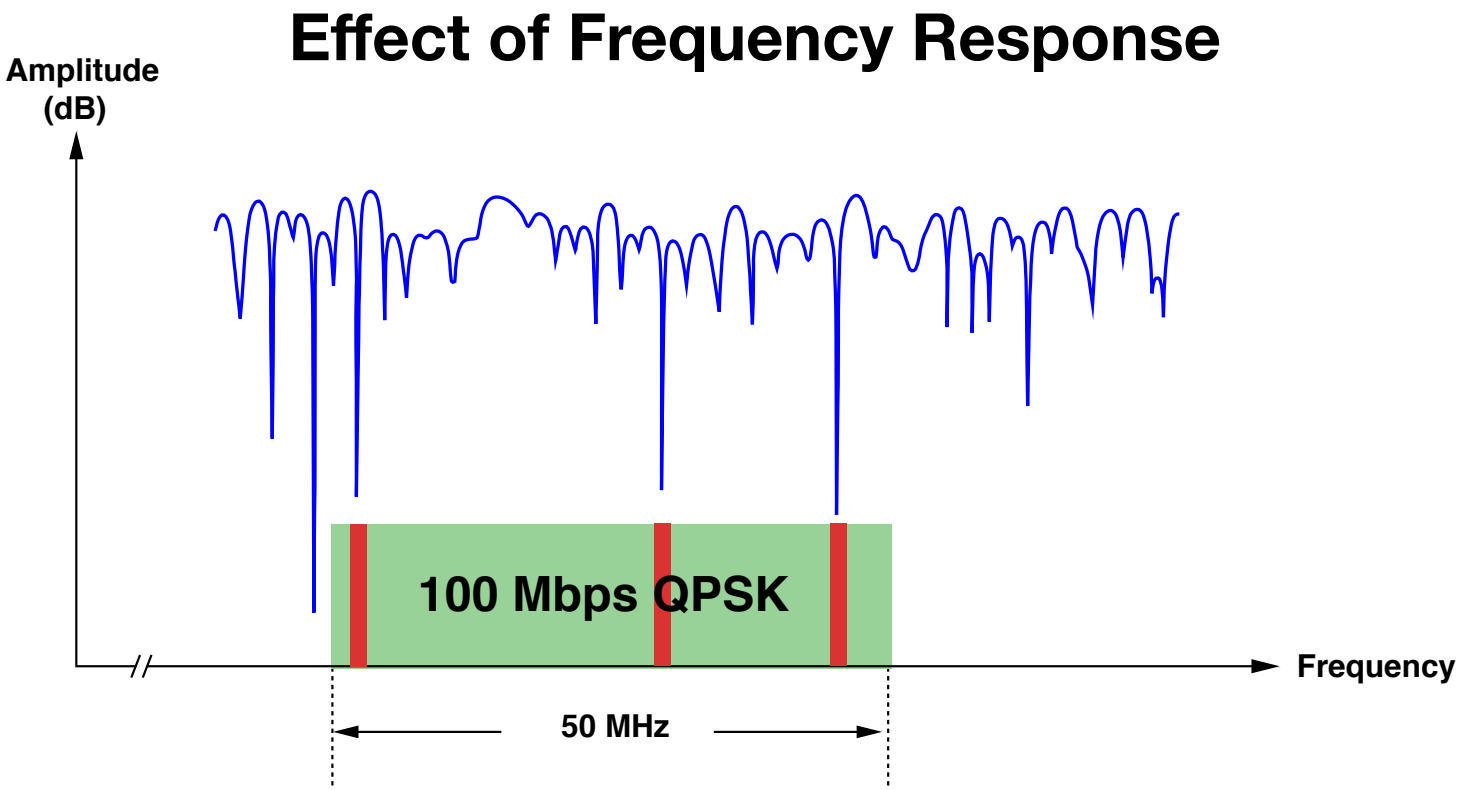
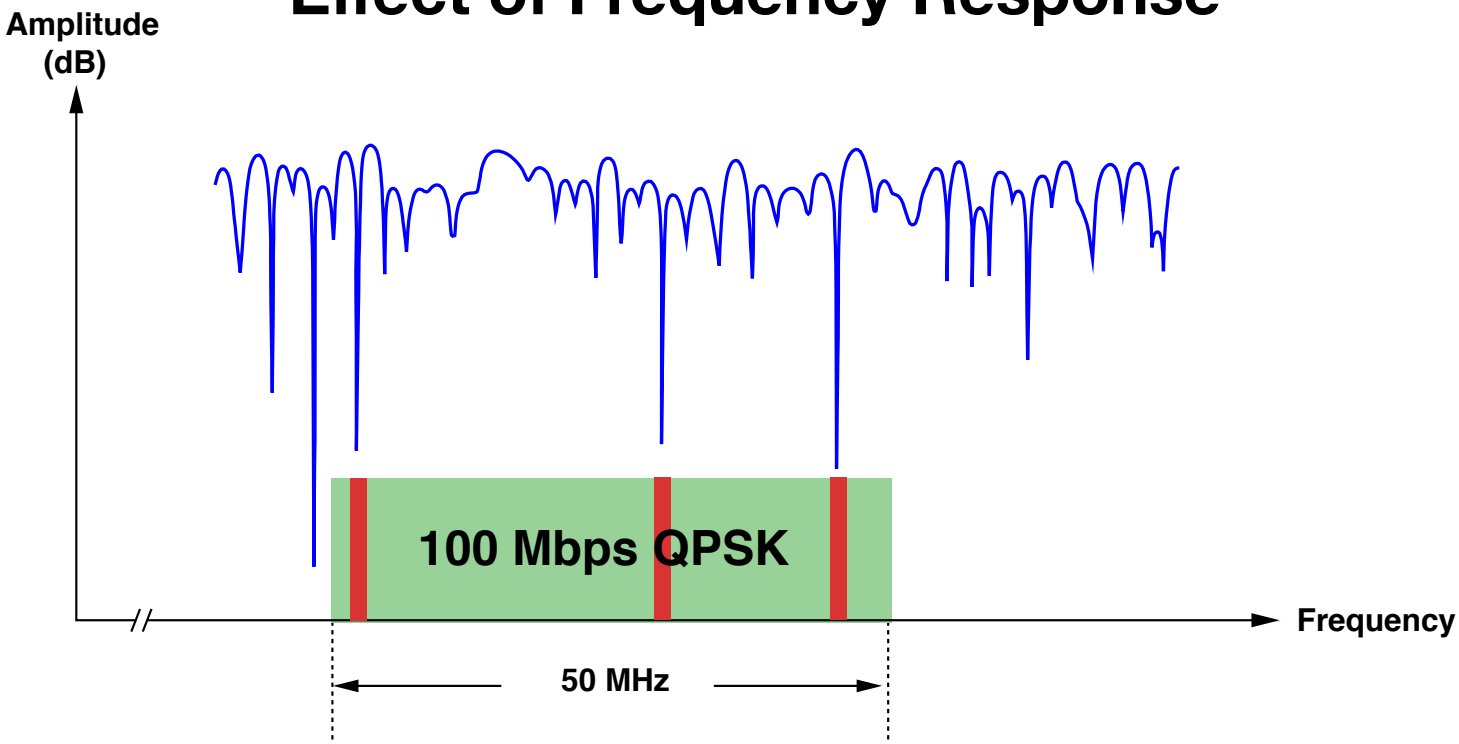


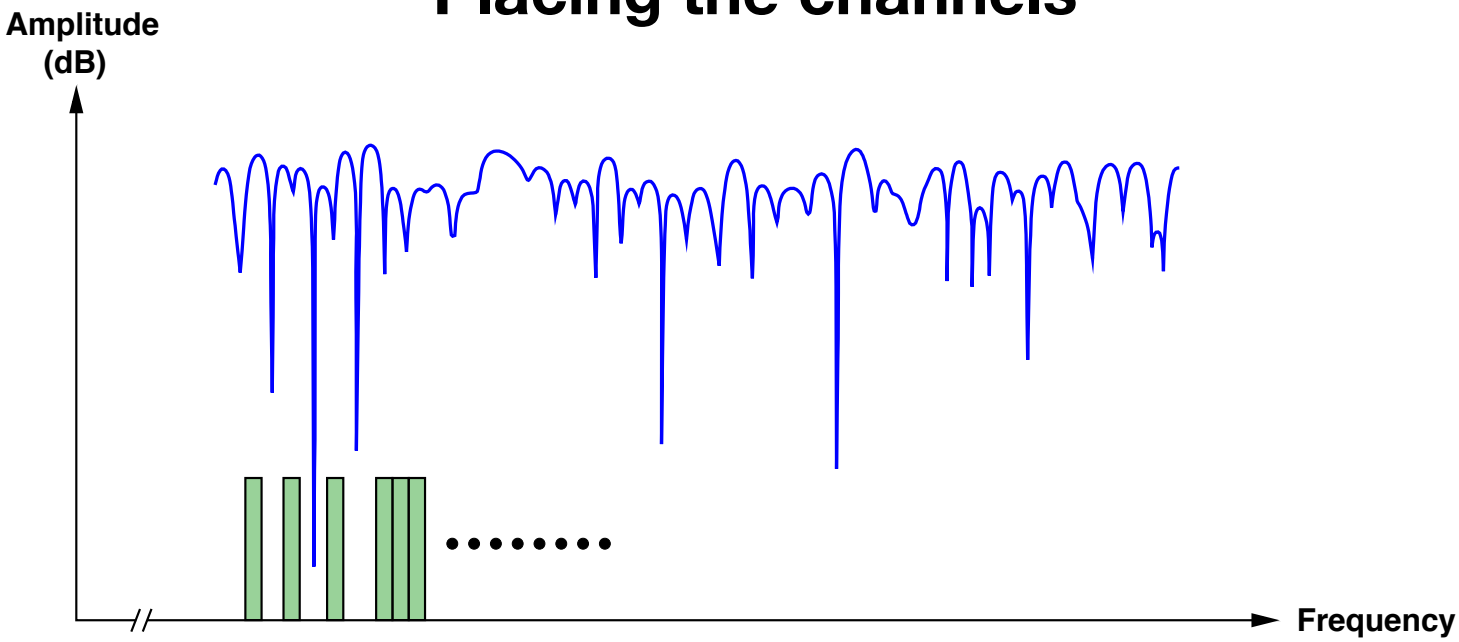

Effect of Frequency Response
Amplitude
(dB)
100 Mbps QPSK
Frequency
50 MHz

Effect of Frequency Response

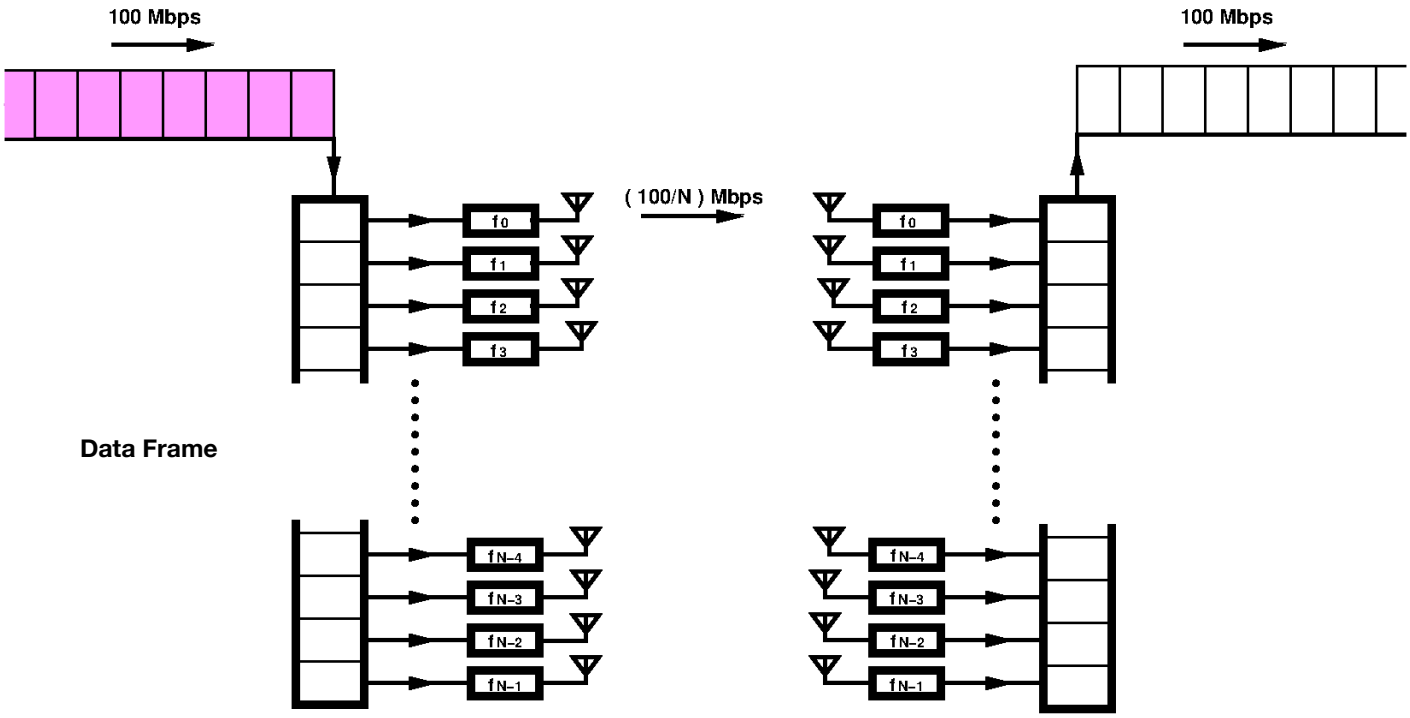


Idea: place narrow–bandwidth signals to avoid nulls

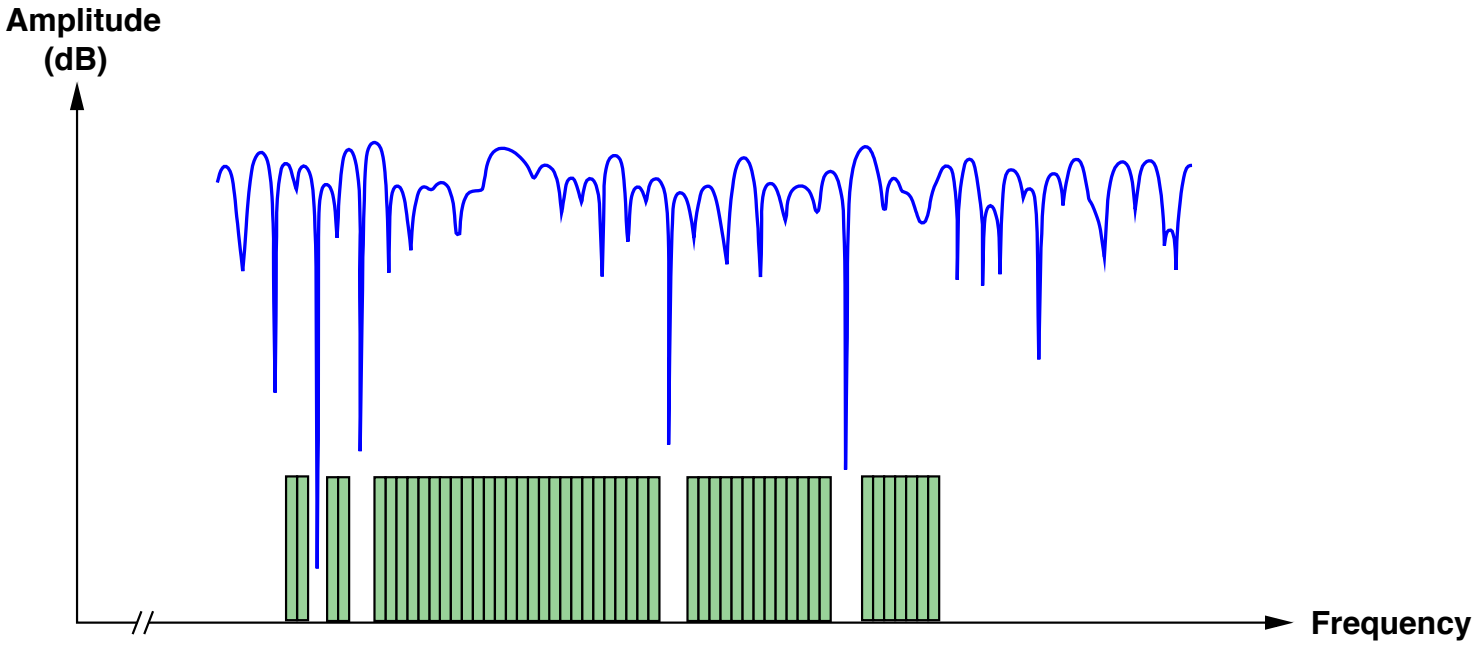
Placing the channels



Sending at N frequencies



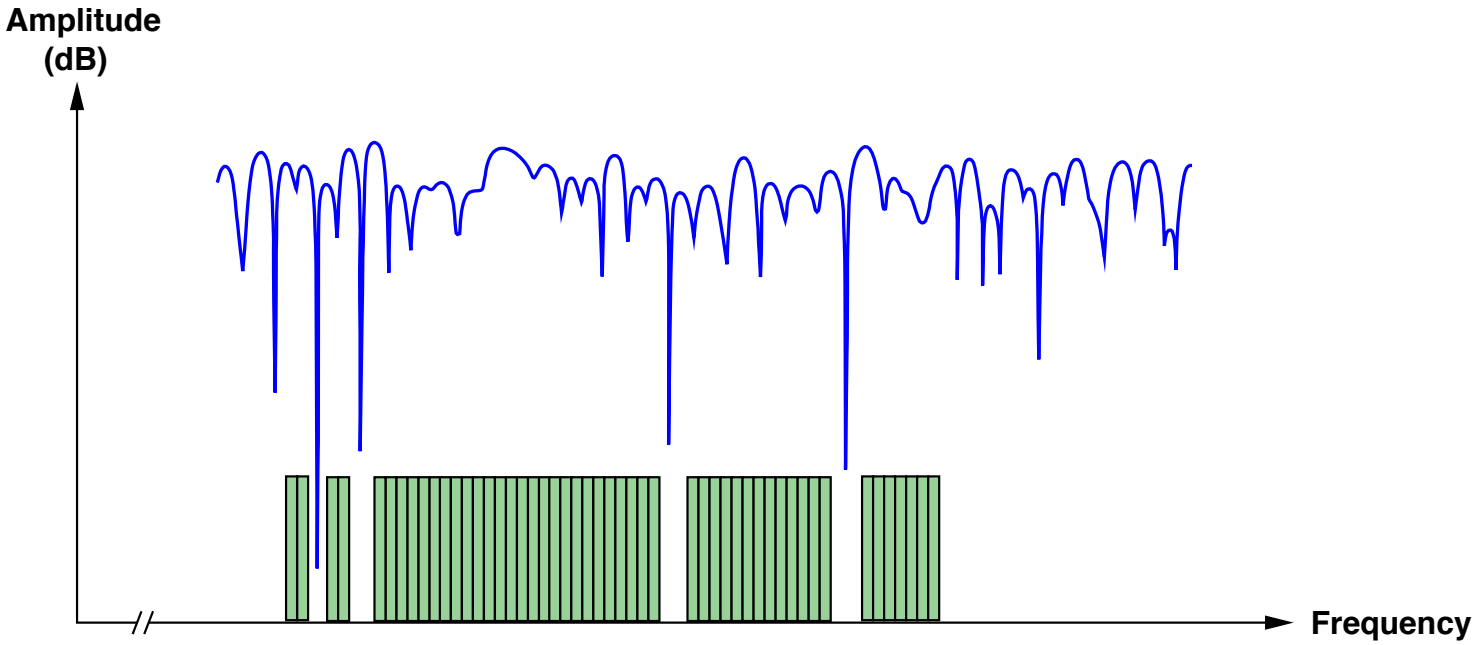
Choosing the frequencies



Idea: Place streams at clear parts of the spectrum

Choosing the frequencies

Problem: large overhead to repeatedly measure the spectrum



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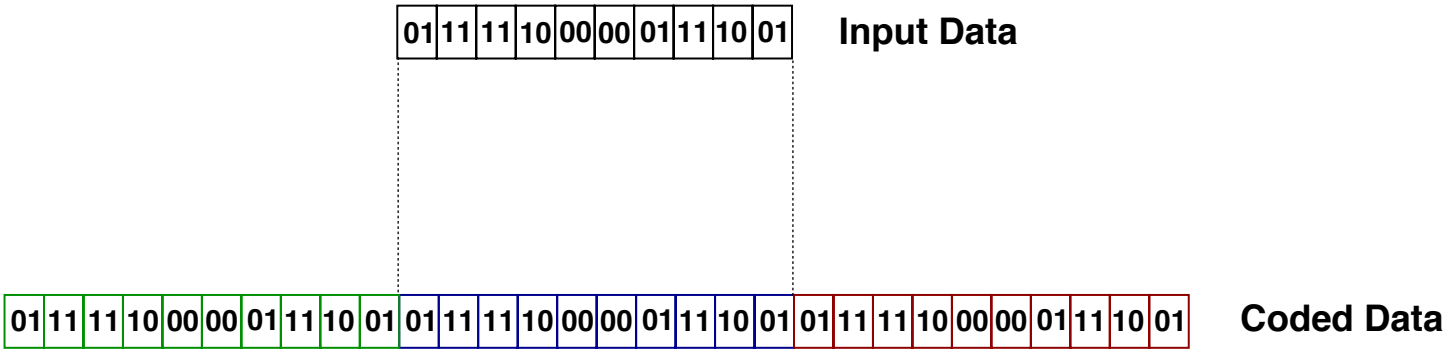
A toy FEC (Forward Error Correction) Code



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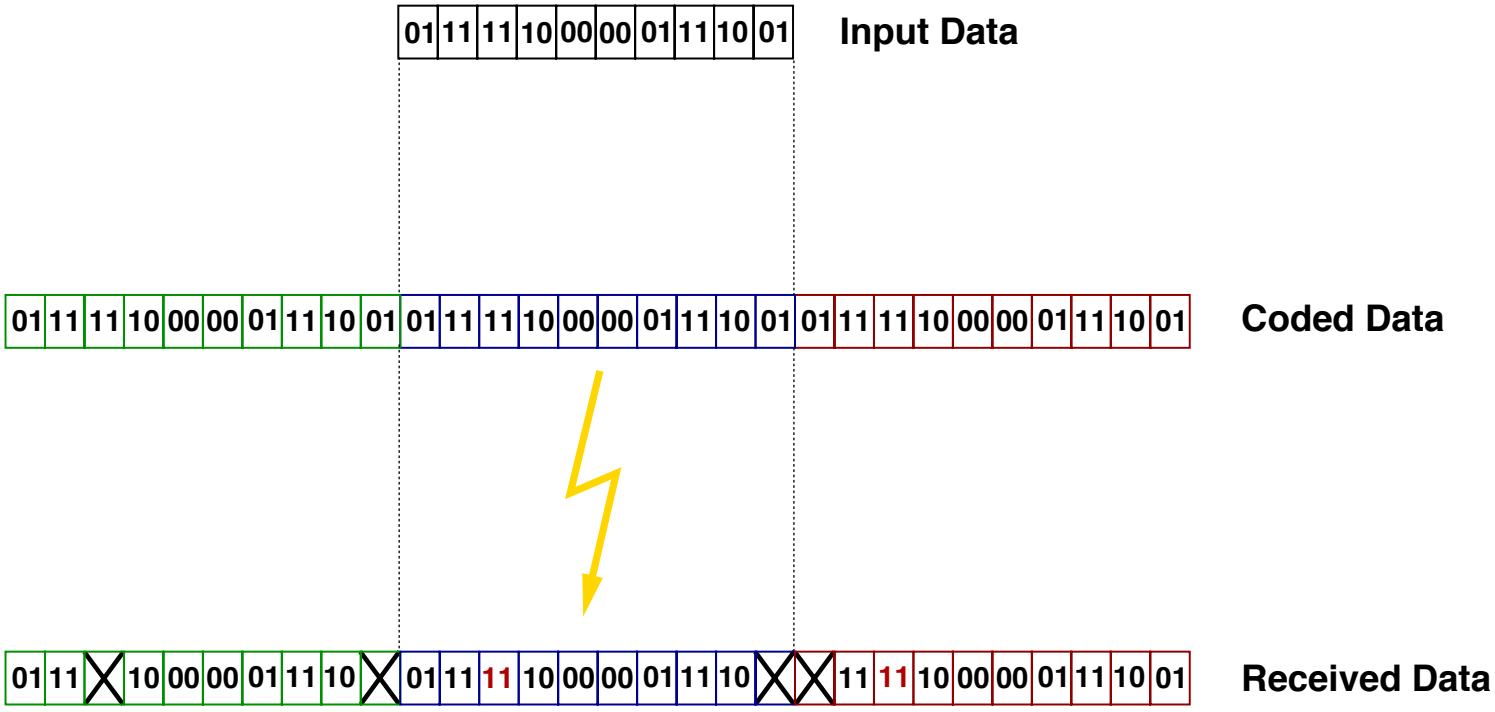

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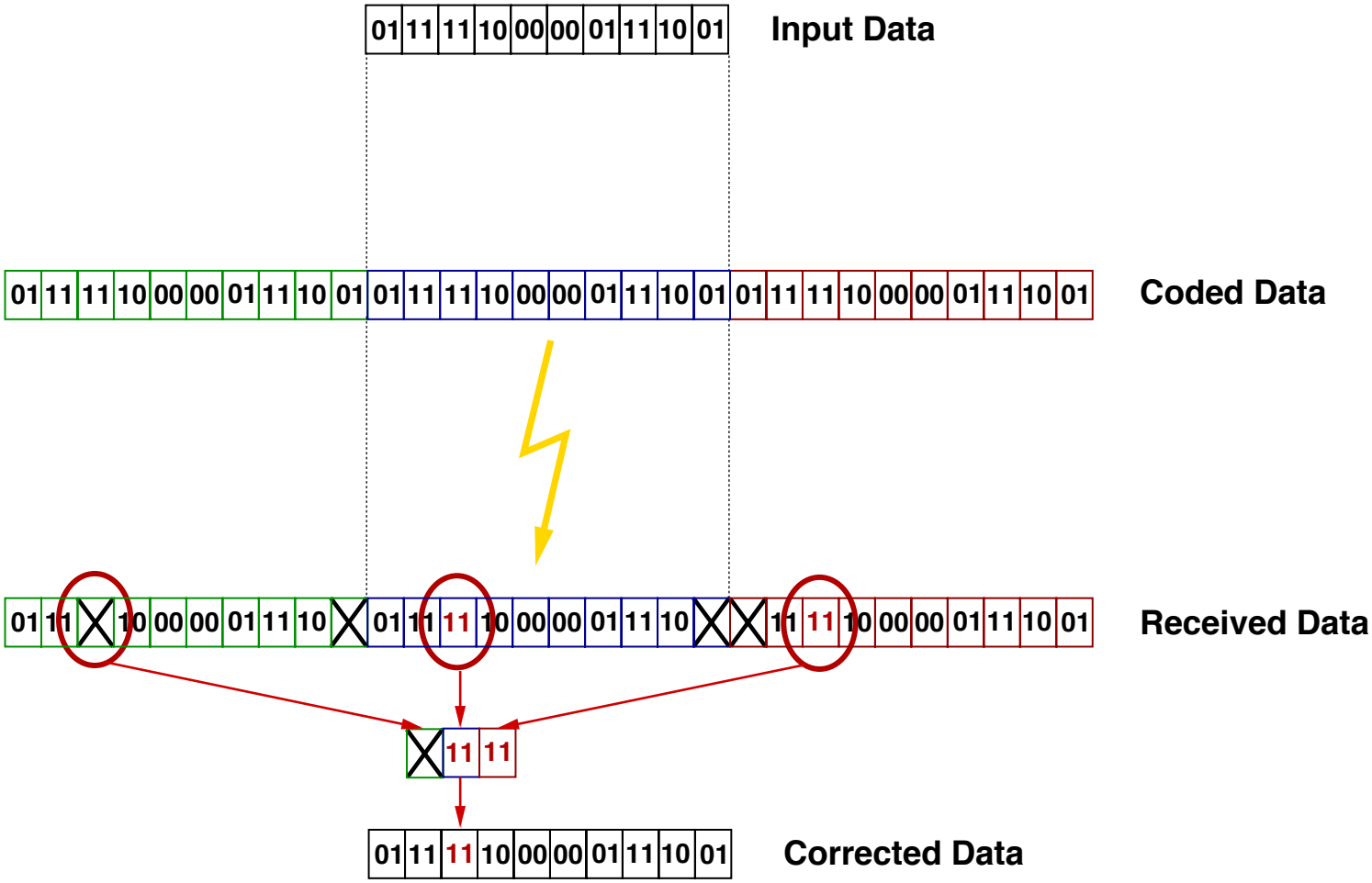

Choosing the frequencies

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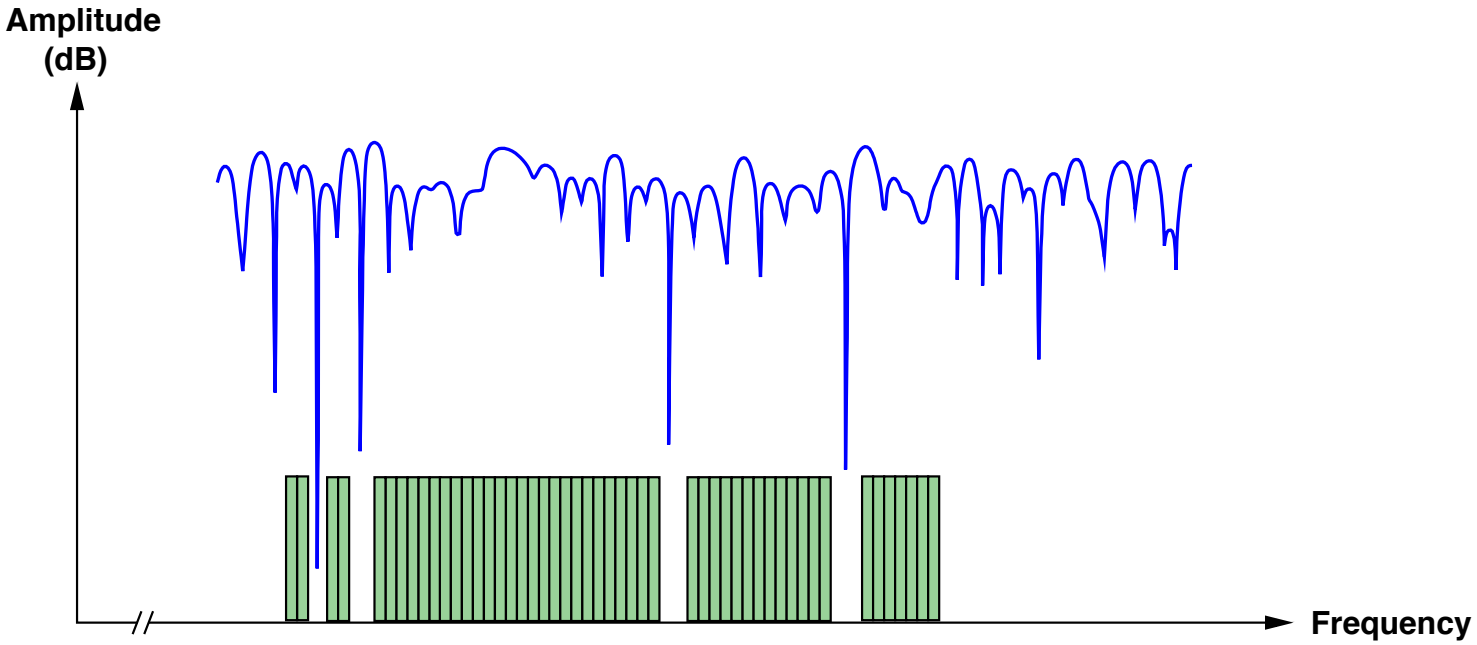
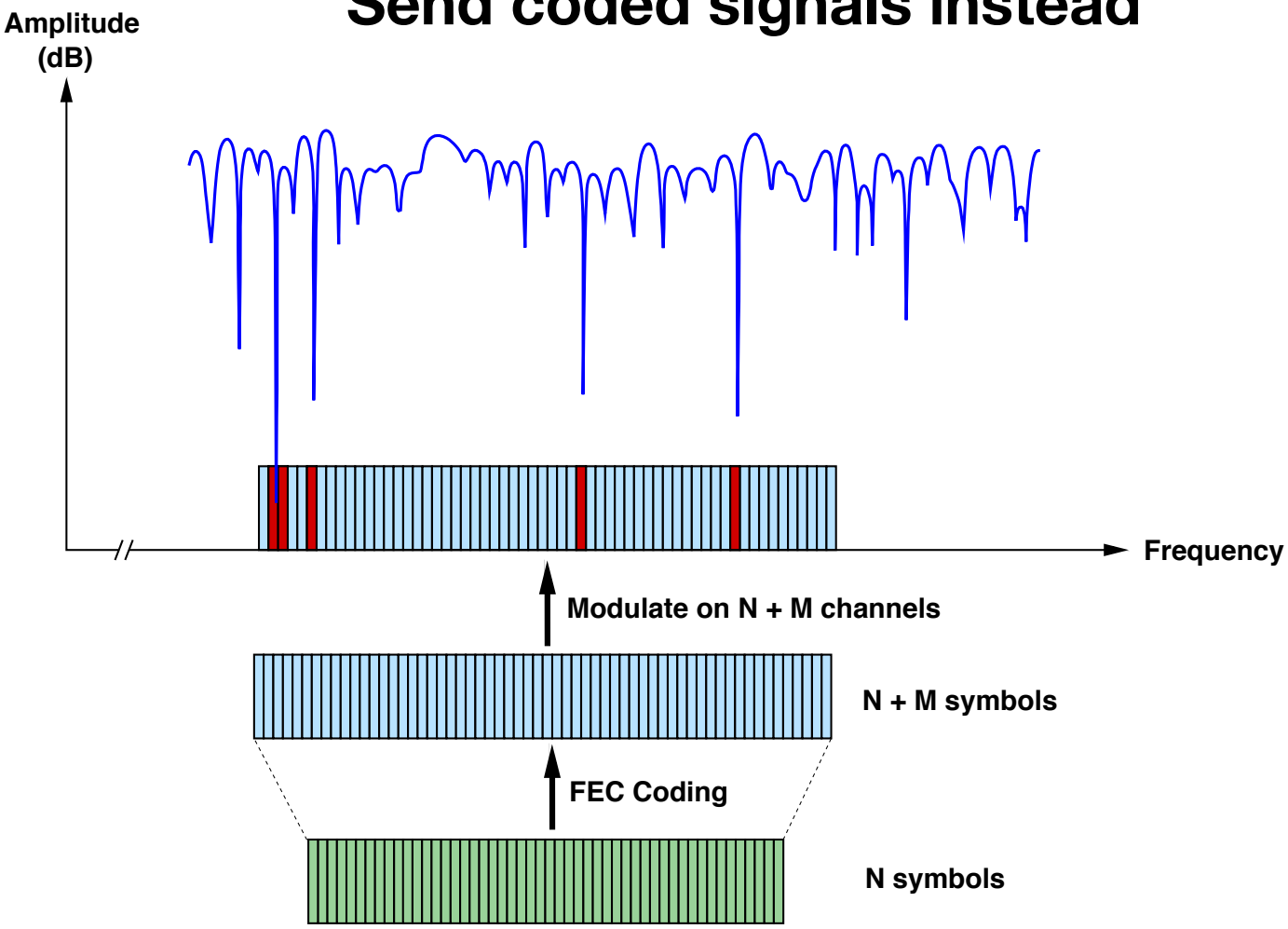


Idea: Place streams at clear parts of the spectrum

Send coded signals instead



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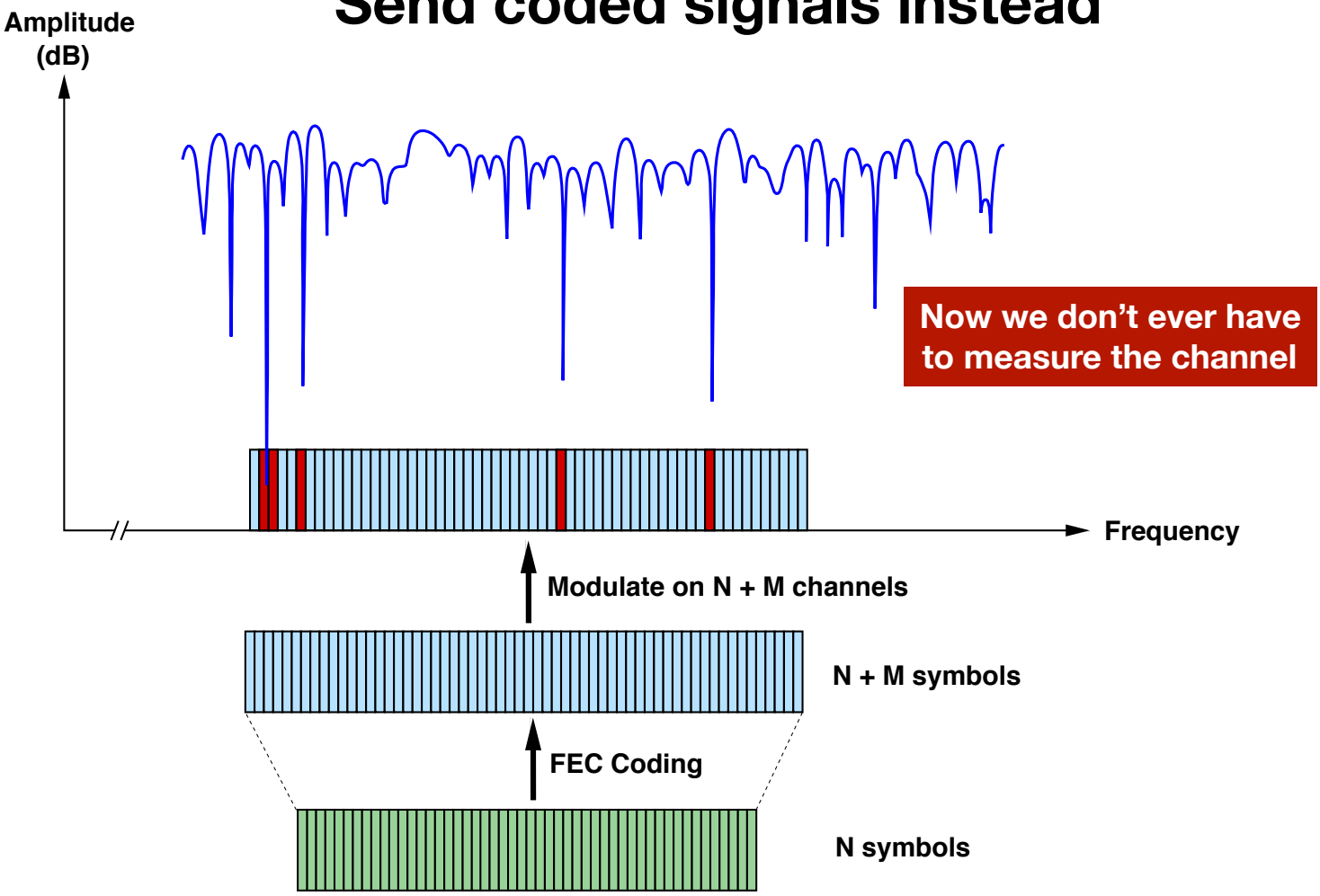
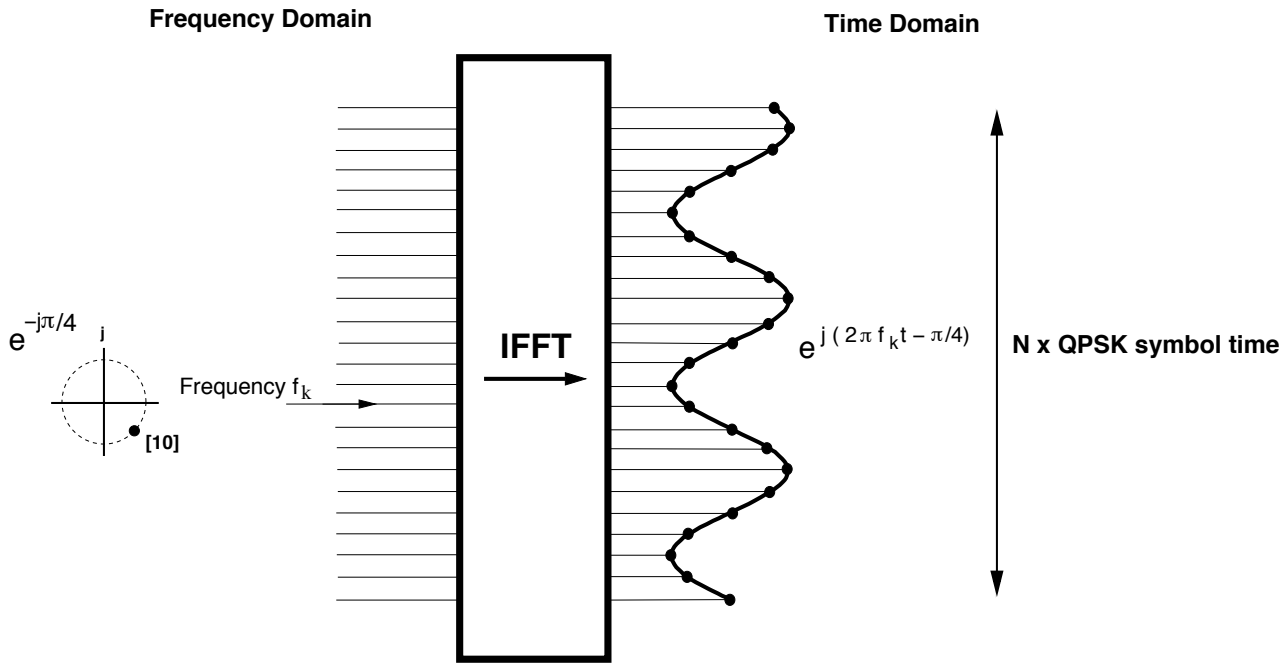


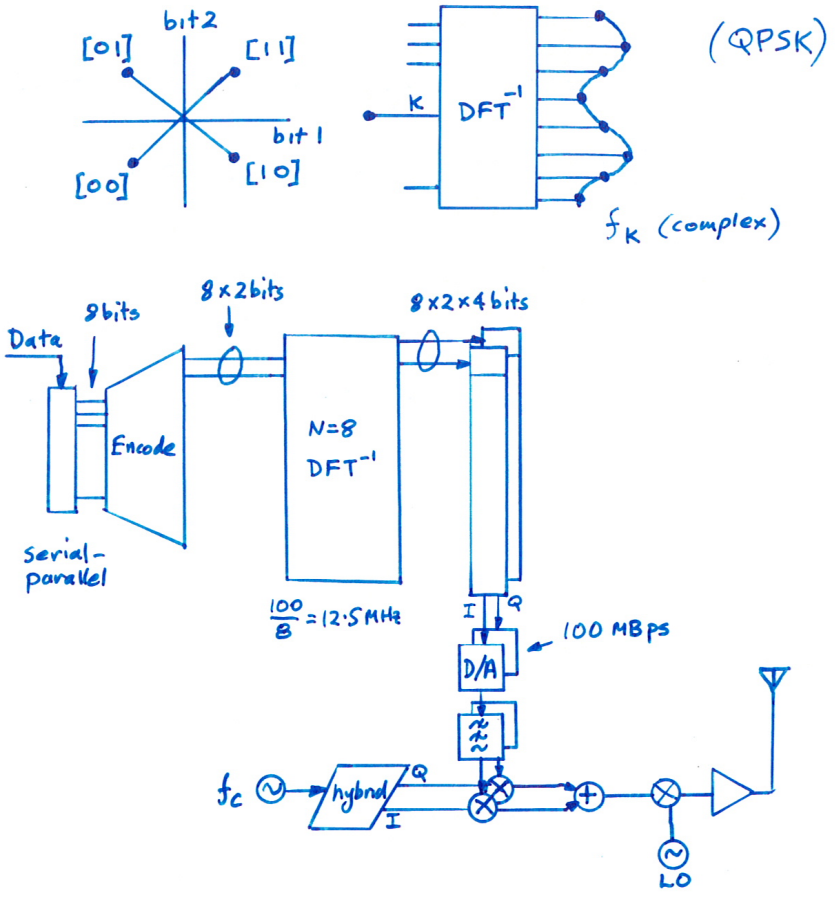
How do we generate all the signals?



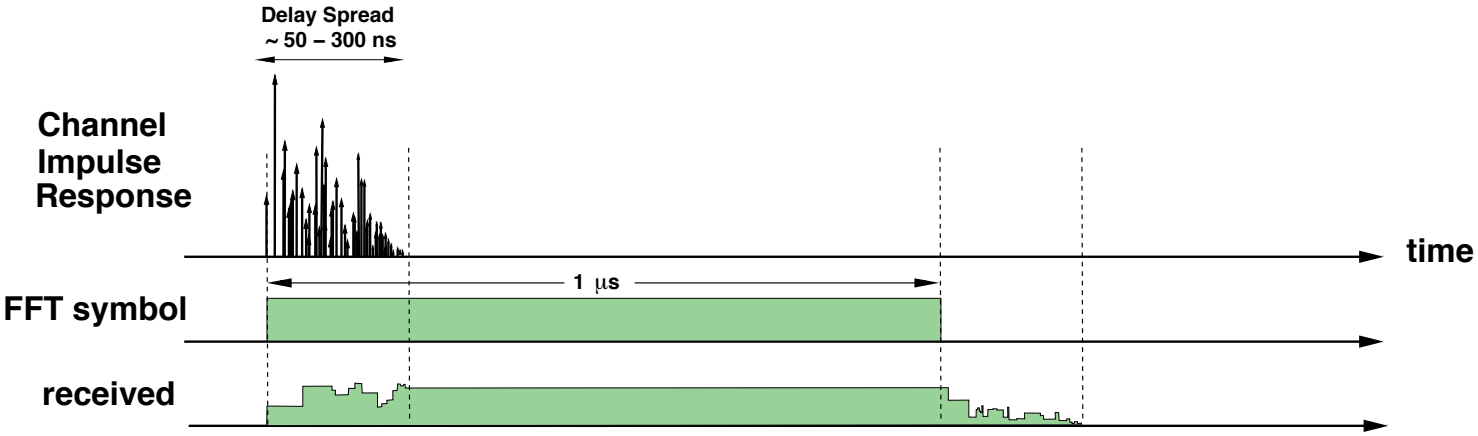
IFFT Implements N parallel QAM Modulators at regularly spaced frequencies

August 1991

DFT Modulator



Multitone in the Time Domain



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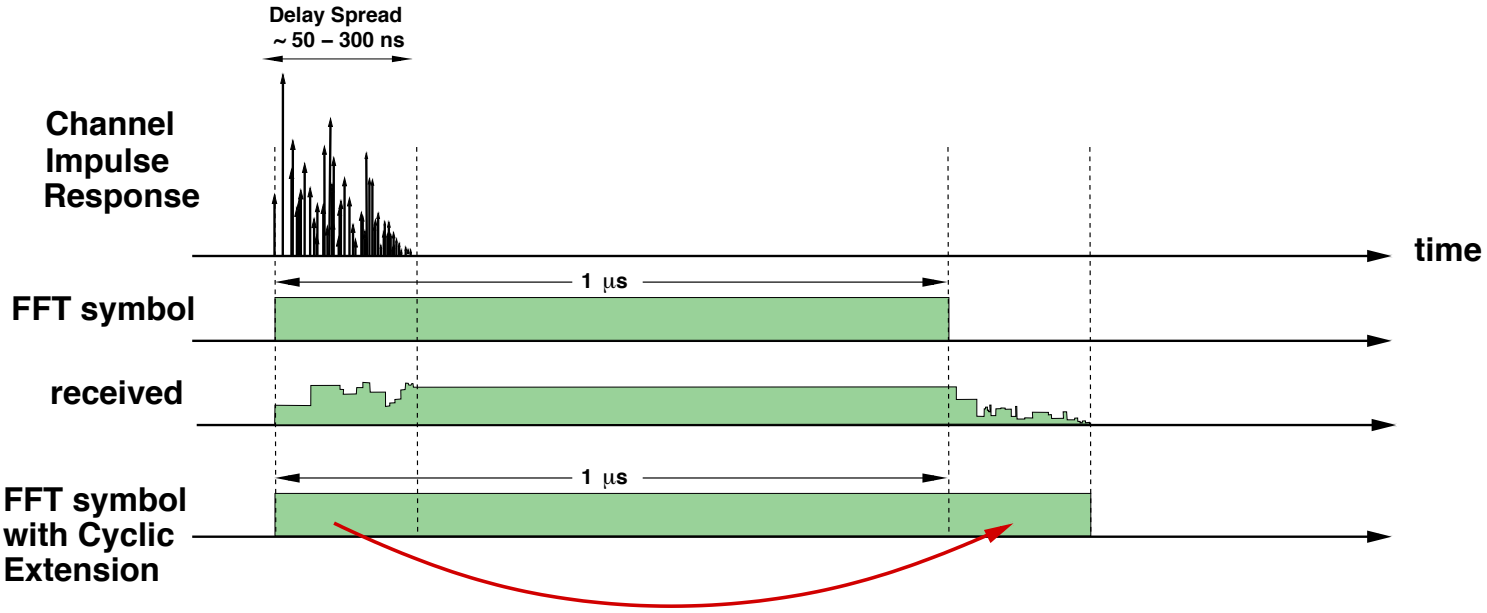

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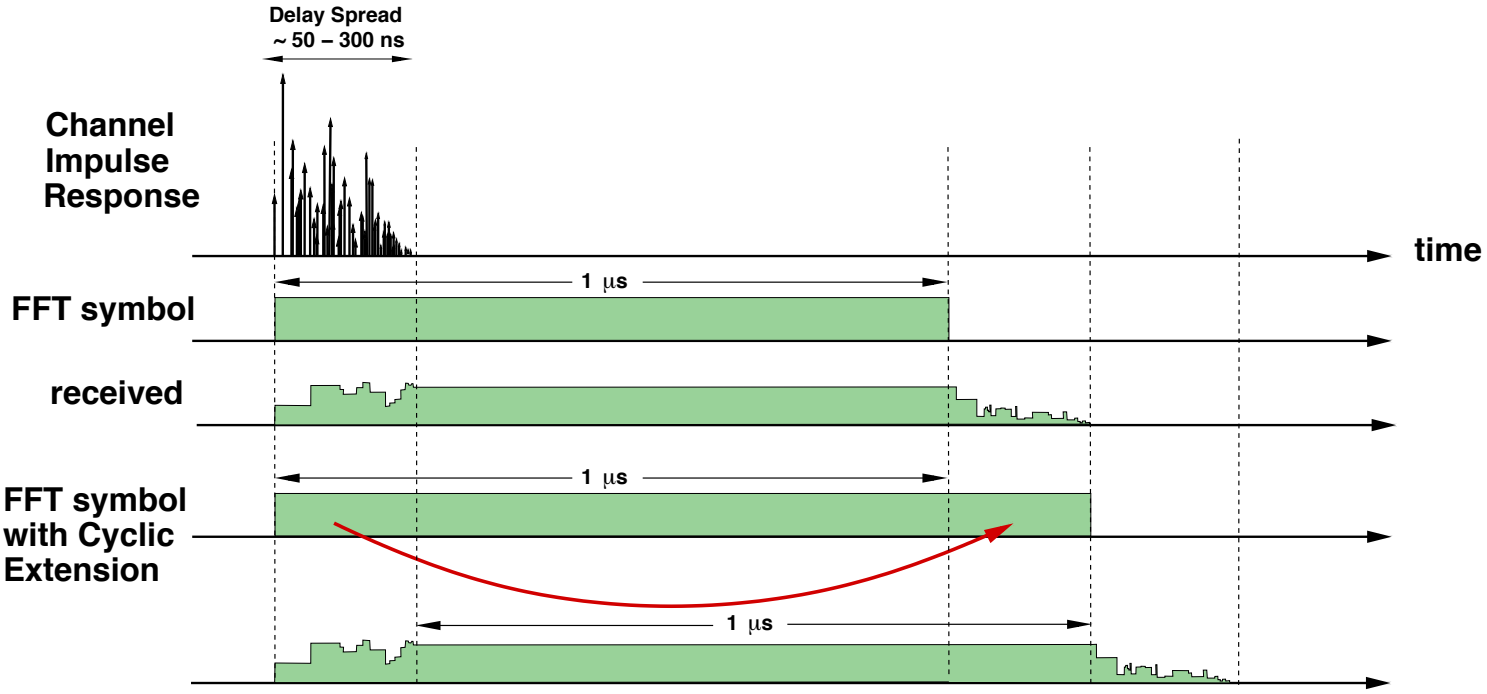

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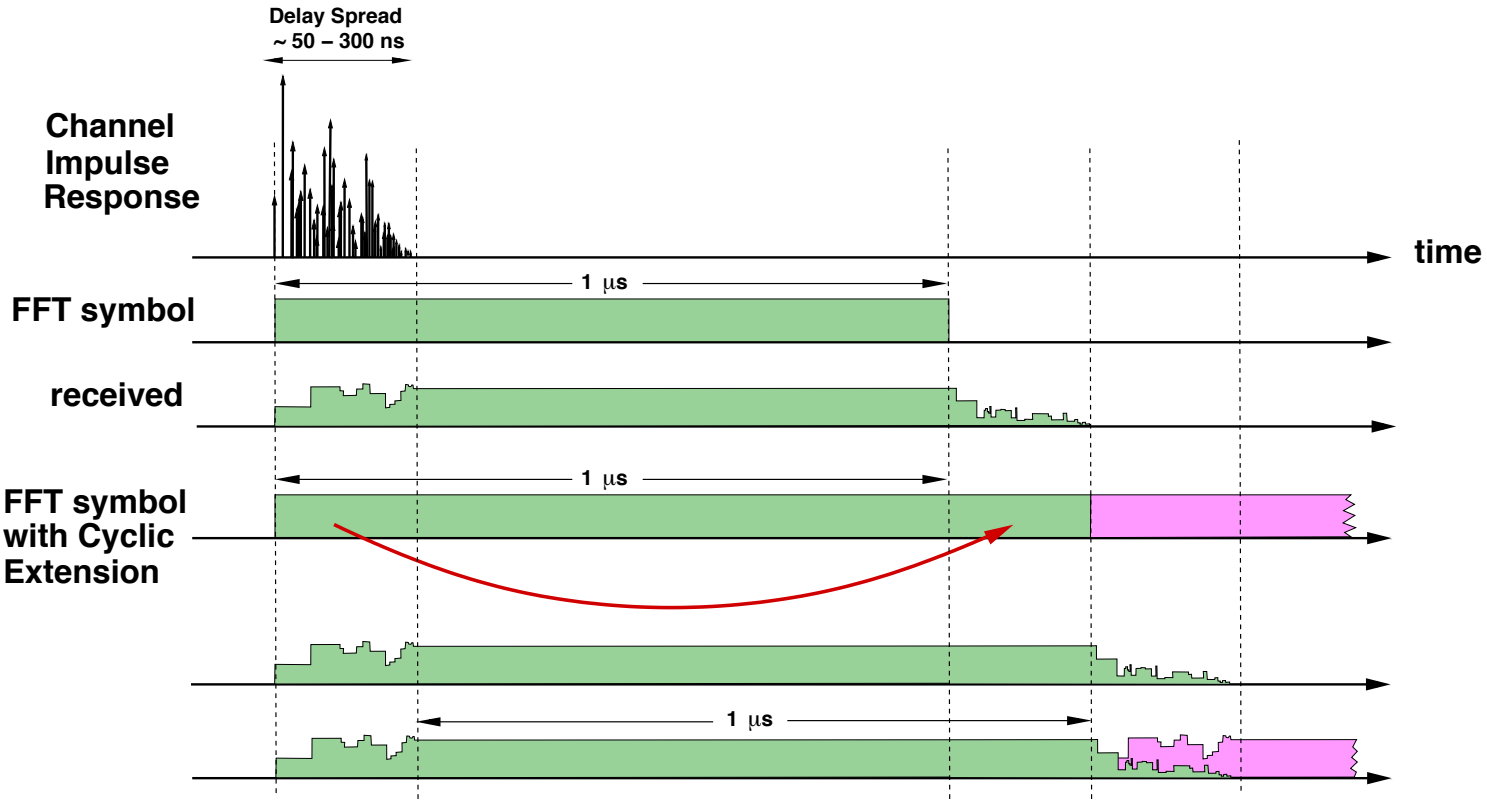
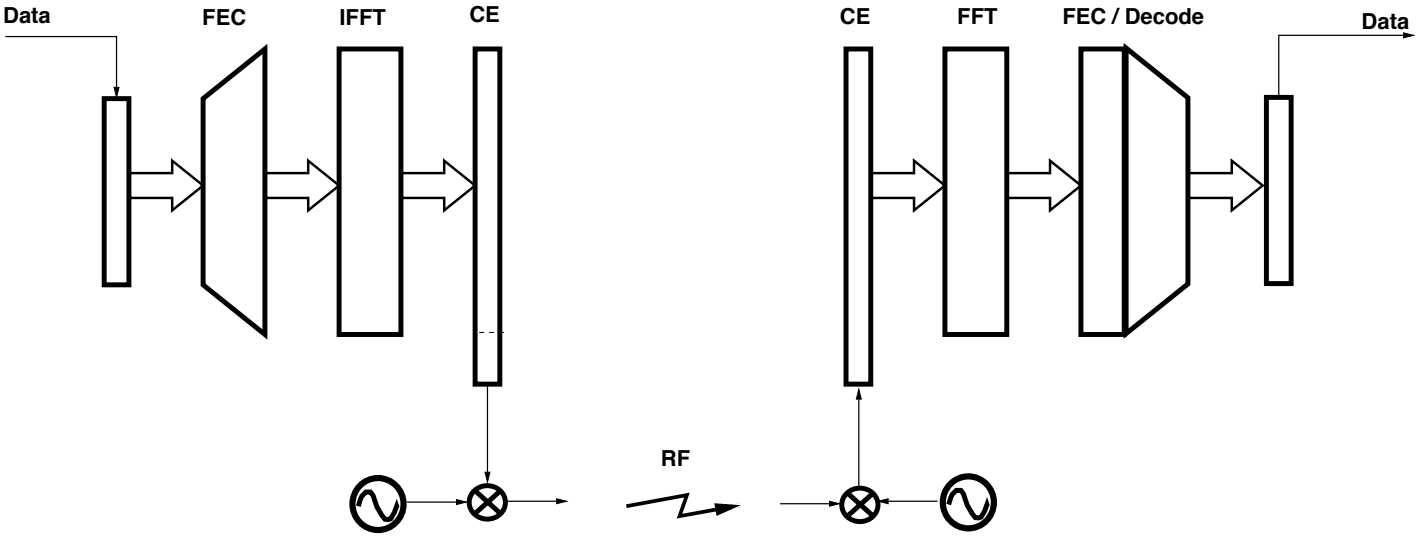


Simplified System



The Core Ideas

MTM — Multi-tone Modulation
Multiplex the data stream into many slower streams and transmit them in parallel at different frequencies

FEC — Forward Error Correction
Apply coding before transmission to prepare for losses
→ *Never need to measure the channel*

FFT — Fast Fourier Transform
Efficient generation of multi-tone modulation

CE — Cyclic Extension
Corrects time-smearing of the multi-tone symbols

WiFi !