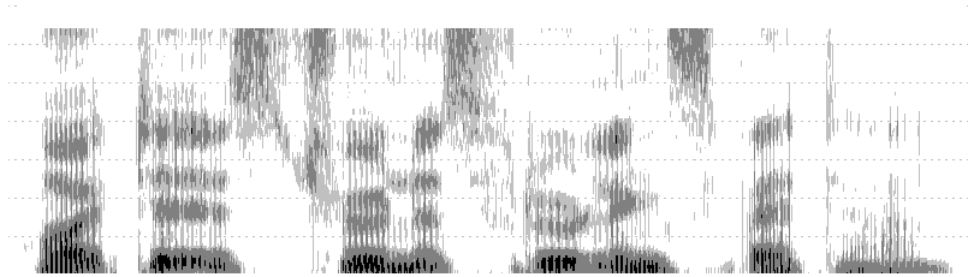
Noise, Signal and Interference

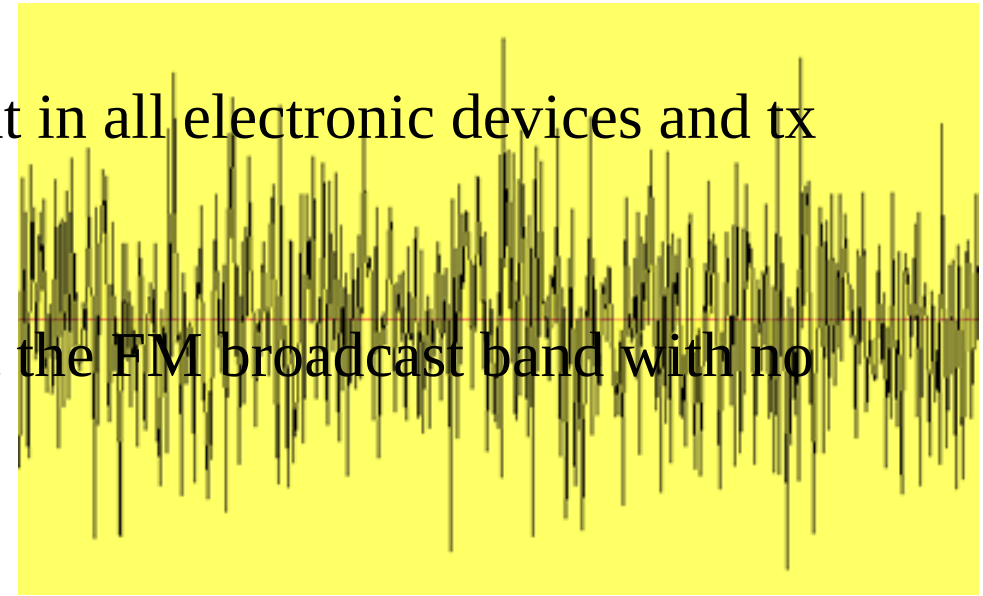


Noise

You never get your pure signal!

Thermal Noise

- Generated by random motion of free electrons and molecular vibration which translate into electric currents
- The random motion results in frequency components evenly distributed over the entire radio frequency spectrum: white noise
- Very small signal present in all electronic devices and tx media, but amplified
- Function of temperature
- Ex: Background noise at the FM broadcast band with no station



Noise

- Man-made Noise
  - Motor's working
  - Car engine spark plugs, cylinder fires, power lines
  - Electric equipments
- Natural Noise
  - Lightening
  - Solar flares
  - Cosmic radio
- Noise level is not the same everywhere
  - It depends on frequency and location

Noise

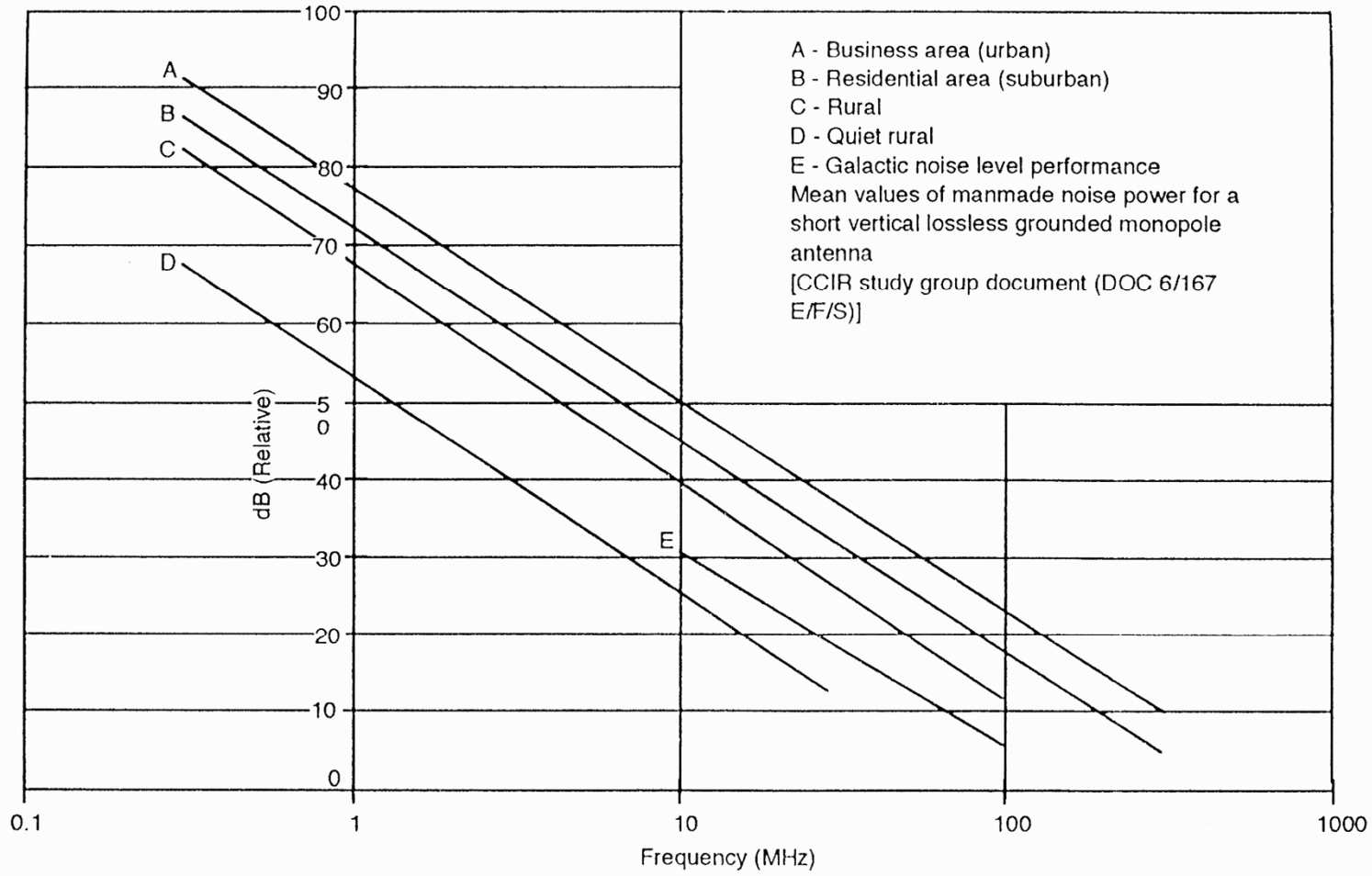


Figure 1.3 Mean value of man-made noise power in mobile surroundings. After [3].

Power in dB

$10\ log_{10}X = $ x dB

X	x (dB)
1	0
2	3
3	5
5	7
10	10
20	13
100	20

x dB = $10\ log_{10}X$

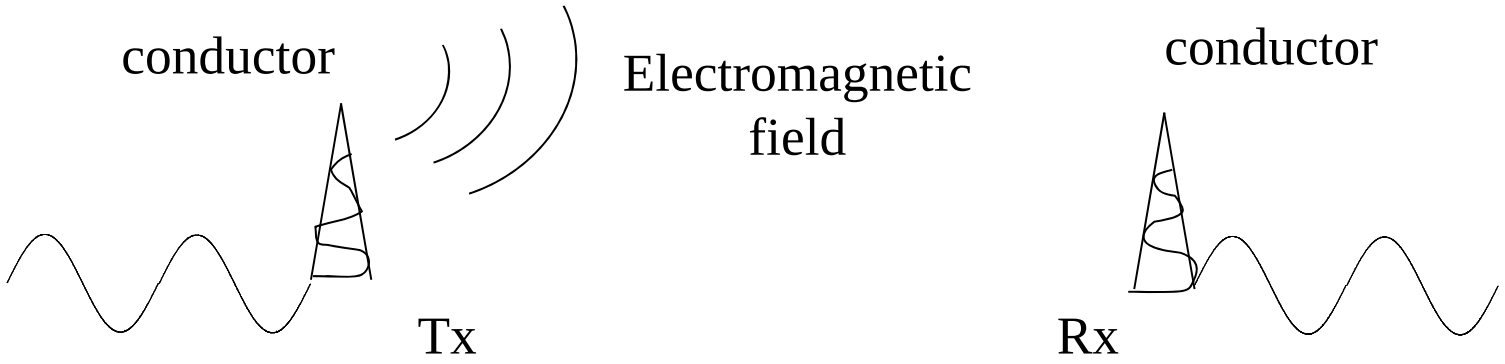
dBW = $10\ log_{10}$P (watt)

dBm = $10\ log_{10}$P (mW)

(1W = 1000mW = 30dBm)

Signal

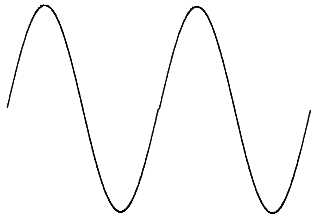
How to send information?



Signal

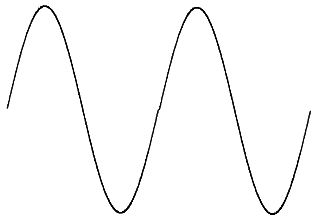
Information can be encoded by sign wave: A *sin* (ωt +ϕ)

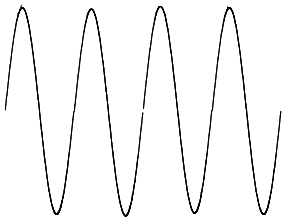
vary the amplitude



Same frequency

vary the frequency

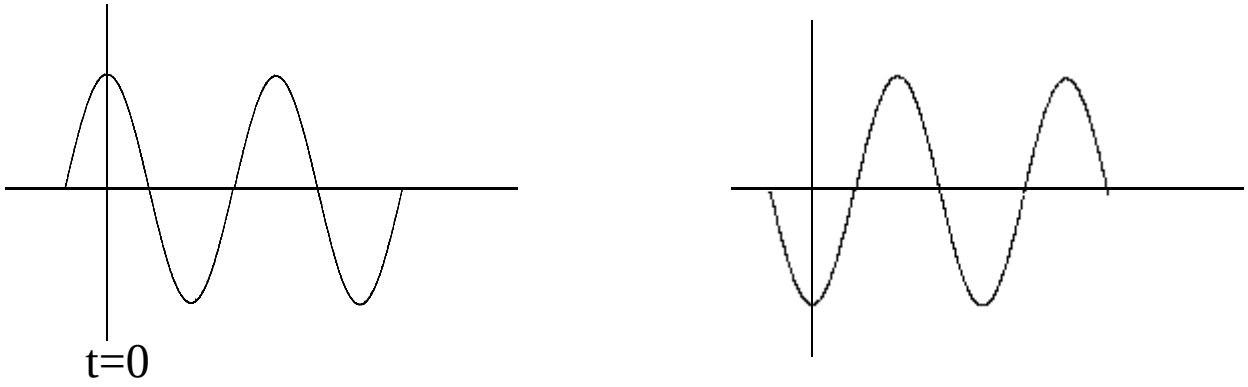




Same amplitude

Signal

vary the phase

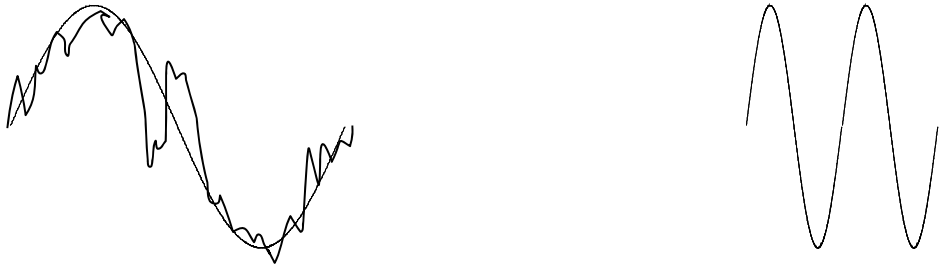


Theoretically infinite information can be encoded by sign wave

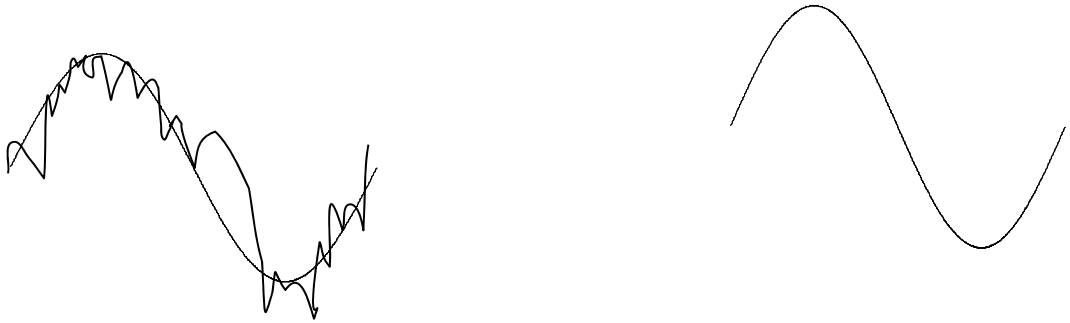
Noise affects amplitude, frequency and phase

Amplitude + Noise

Frequency + Noise



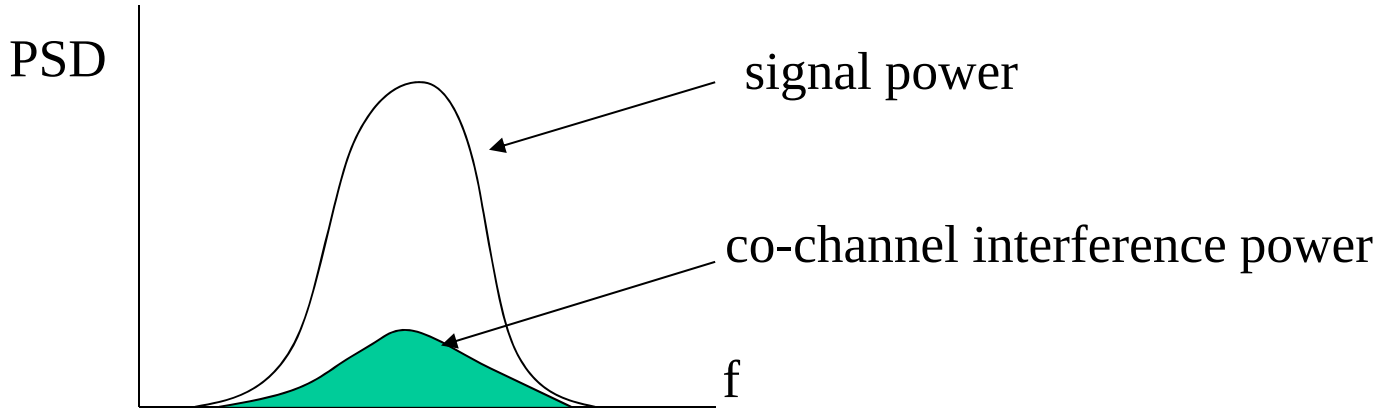
Phase + Noise



Interference

Co-channel interference:

- Between signals that use the same frequency
- To reduce co-channel interference, sufficient physical isolation is required

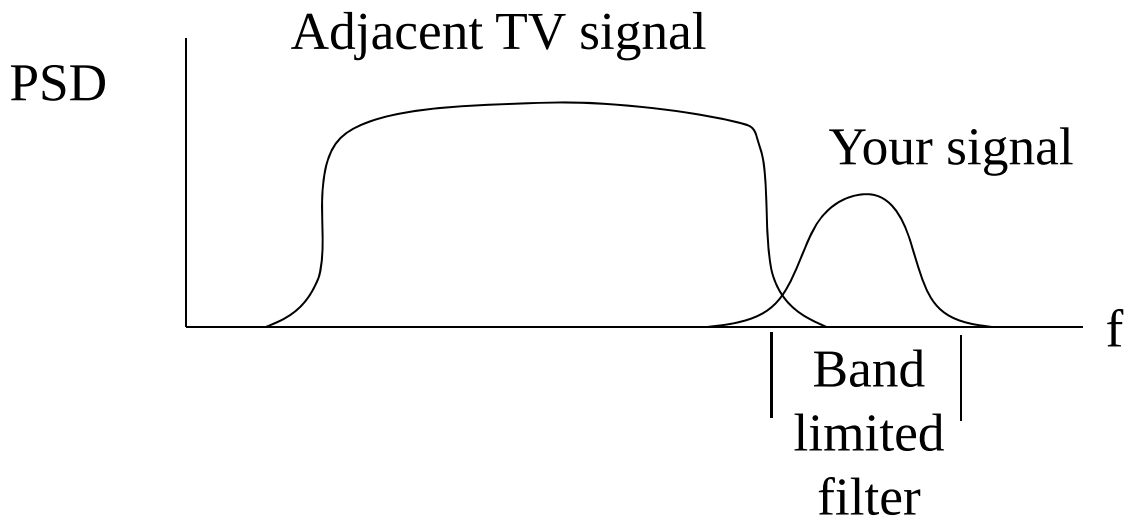


Interference

Adjacent channel interference

Interference from signals adjacent in frequency to the desired signal

It results from imperfect receiver filter which allows nearby frequency to leak into the pass band



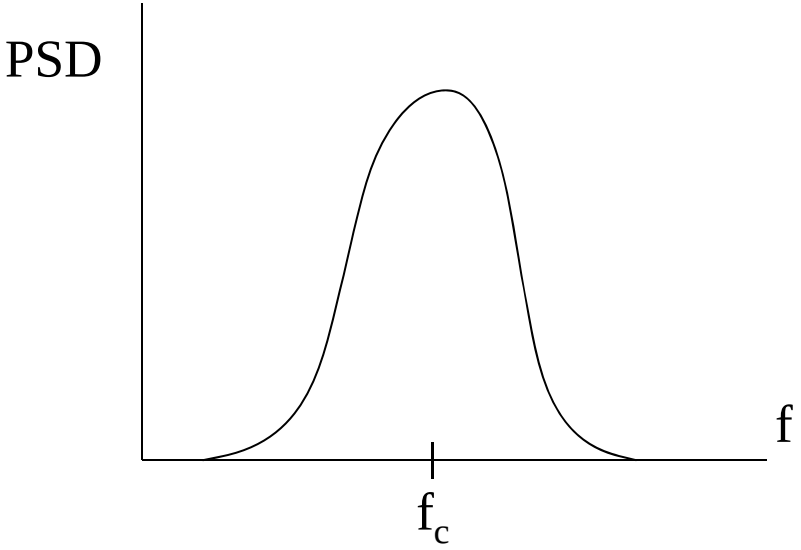
Interference

PSD: where the power is in the signal

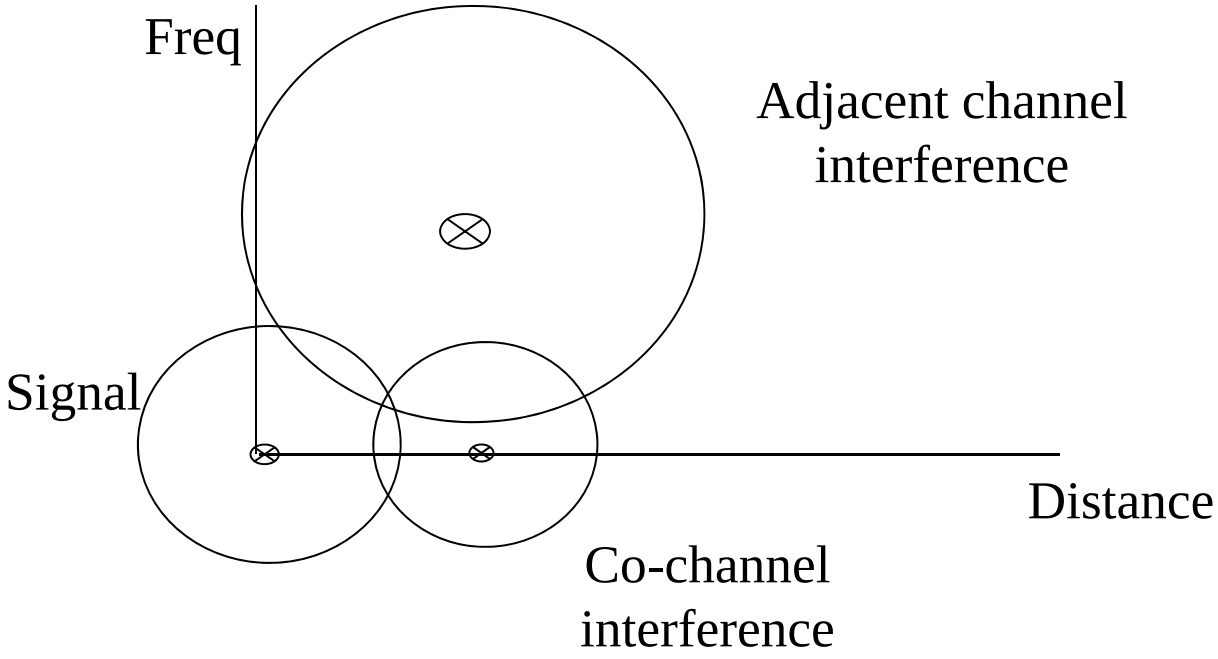
1) shape: bandwidth, how wide is it
2) location: center frequency, f_c
3) size: total Power = total Area

$$P = V^2_{RMS}/R$$

Ex. FM Broadcast



Co-channel, adjacent channel interference

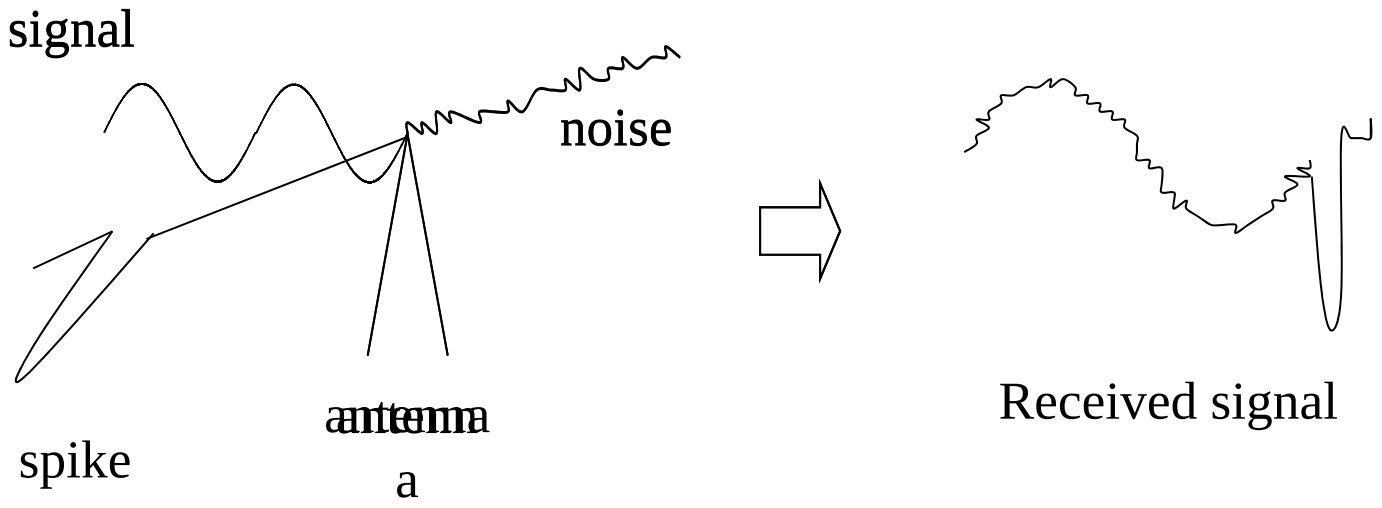


Signal, Noise, Interference

Independent in propagation and attenuation before
a conductor

They are additive at the Rx, Not in the air

Interference prevents infinite number of information

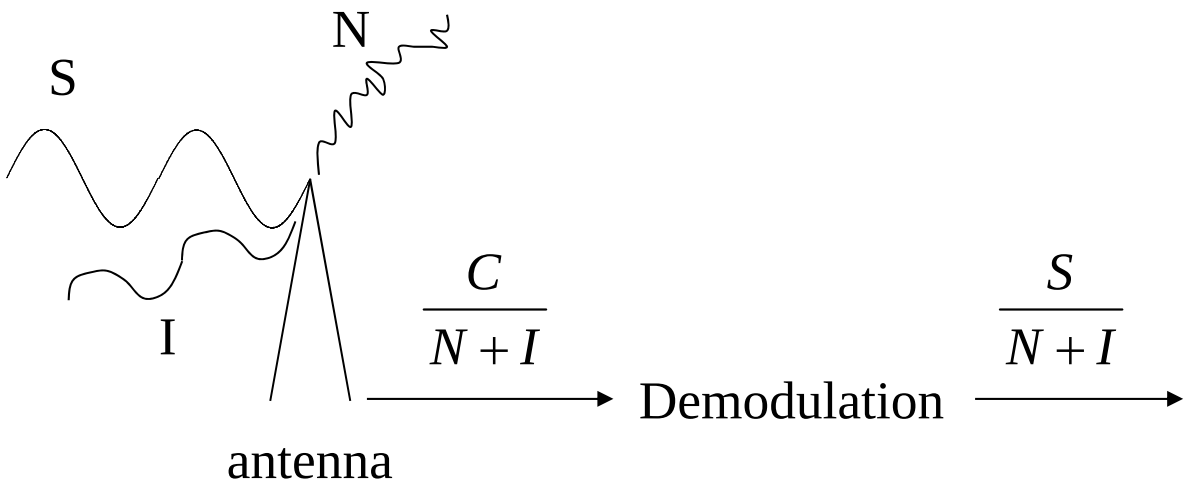


Signal, Noise, Interference

S/N depends on where it is measured

C/(N+I): at antenna before demodulation

S/(N+I): after demodulation



Channel Capacity

Maximum Error-free data rate

Theoretical limit by Shannon: $W log_2(1+S/N)$

In a typical wireless data system, with 30 kHz/ch

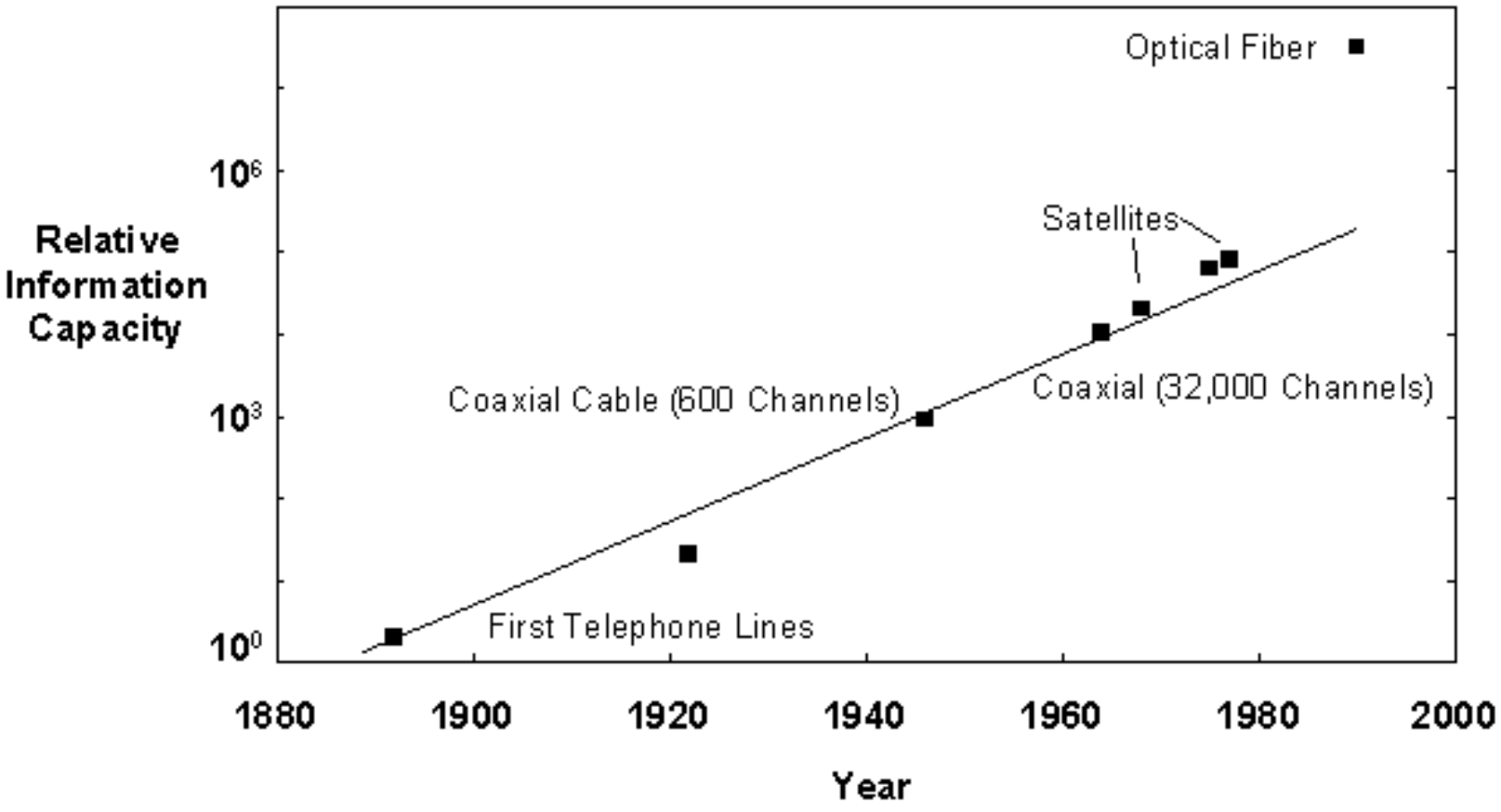
Shannon	Fact
180kbps/30kHz	16.2kbps/10kHz user ch

Ex) S/(N+I) = 18dB with W = 10kHz

Channel capacity = 60 kbps

Practical USDC channel rate = 16.2 kbps

Channel Capacity



Summary

Noise, interference and signal are additive at the receiver

Noise and interference affects signal's amplitude, frequency and phase

Noise and interference prevent infinite number of information

Channel capacity by Shannon: $W log_2(1+S/N)$