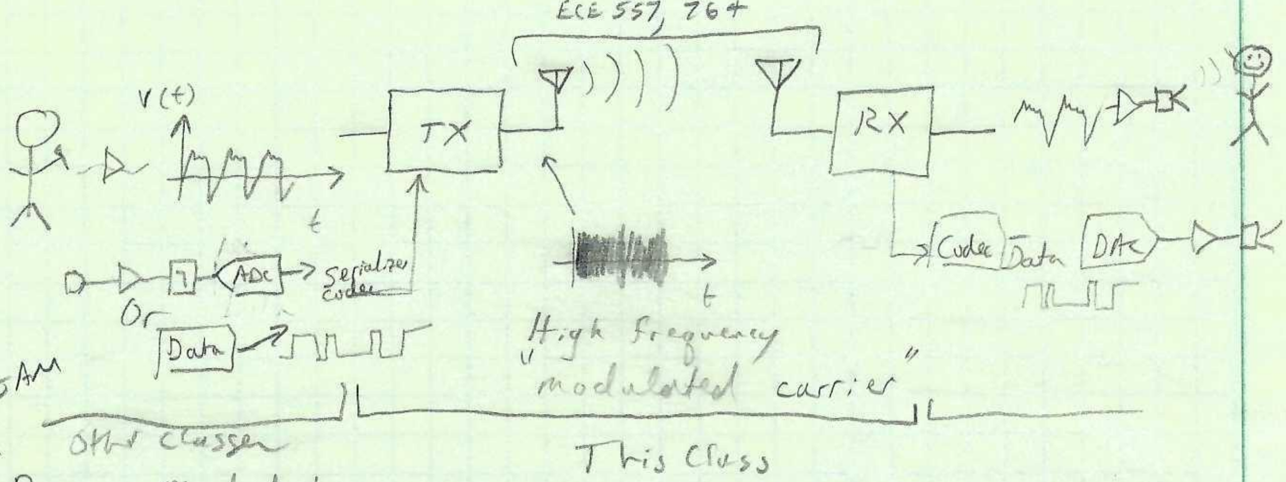
Course Intro

- Self / Class
- Syllabus — Show radios made in prev semesters + commercial SMD boards
- Demo (pg 3) – Signal generators, scopes, ~~&~~ spectrum analyzers & Antennas
- Radio, modulation, frequencies, & applications

Radio Transmission Fundamentals

(For those who havent had 660 ...)



Demo

100 MHz FM → 27 MHz AM

→ 1.5 MHz AM

Basic Modulations

CW and OOK — Continuous wave; on-off keying

data morse code / (E.g. Key Fob)

AM (Amplitude Mod)

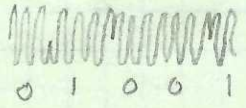
voice // early television, Aircraft comm

This class → FM & FSK (...)

FM Broadcast

ECE 660

- FSK "
  Data / digitized voice, E.g. Bluetooth
- PM & PSK (including BPSK, etc.)



data

- Varriants QPSK, QAM, π/4 QPSK, MSK, OFDM, etc, etc...

Cell phones

Why use high freq carrier & modulation?

("instead of hooking amplified signal to antenna directly")

- Allows practical antenna sizes
- Allows "frequency multiplexing"
  (multiple channels / services / customers)

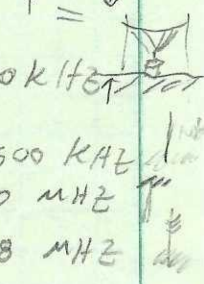
Demo: (Show FM Broadcast band & other bands/signals on Spec An – with radio on same channel. Point out antennas

NXT PG!

Some Radio Services & Frequency examples (Licensed & unlicensed)

Early Apps (1901 - 1950...)

Service	"Band"	Freqs
Early Wireless Telegraph & Voice	LF	< 300 kHz
AM Broadcast	MF	550 - 1600 KHZ
Shortwave	HF	2 - 30 MHZ
FM	VHF	88 - 108 MHZ



Some Current Apps

Broadcast	↑	FM	VHF	88 - 108 MHZ
	ECE 662	Cable TV (guided)	L band	5 - 1500 MHZ
	↓	Sat Radio	S band	2.3 GHZ
	ECE 764 ↓	Sat TV	K band	12 GHZ

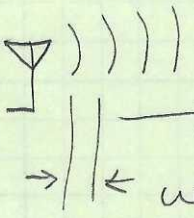
Personal & Public Service Comm

"Ham" Radio	HF, VHF/UHF, microwave
CB/MURS	27 & 151 MHZ
FRS	467 MHZ
Public Service (Police, etc)	150, 900, etc. MHZ
Cell Phones	800, 1800 MHZ etc.
WLAN	2.4 & 5.x GHZ

Other

UWB	3 - 10 GHZ
Radar, Space Comm	0.4 – 77 GHZ

Wavelengths & Antenna Size



↙ Represents peaks of sinewaves

EM Fields
⟶ propogats away at speed c

→| |← wavelength $\lambda = c \cdot \underbrace{\frac{1}{f}}_{T = \text{period of one cycle}}$

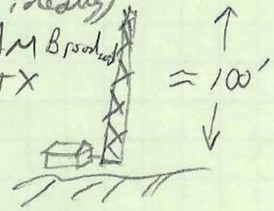
Example wavelengths

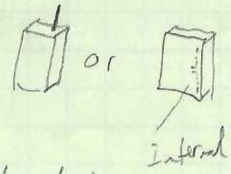
f	λ
1 KHz	300 km
1 MHz	300 meters
1 GHz	300 mm (30 cm) ≈ 11"

NOTE

For good efficiency, Antenna size must be $\gtrsim \frac{1}{10} \lambda$ ($\lambda/2$ for dipole, $\lambda/4$ for monopole ideally)

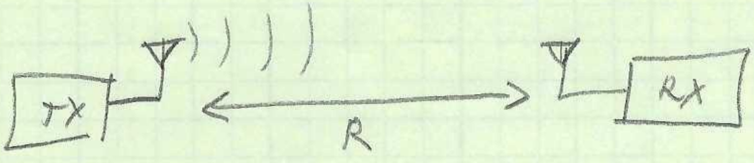
	f	λ	λ/4
	1 MHz	300m	75m
"Micro wave" [	1 GHz	0.3M	7.5cm
MmWave Band ⟶	100GHz	3mm	0.75mm





Link Budgets & Received Power

Recall comm system



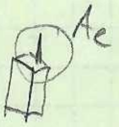
Let TX power be P_t watts

Then, , power density at range R is

$$\rho = \frac{P_t G_t}{\underbrace{4\pi R^2}_{\text{Area of sphere w/ radius } R}} \left(\frac{W}{m^2}\right)$$

← Directivity gain of antenna

Receiver intercepts small fraction of power determined by its antenna's "effective Aperture" area A_e



$$\boxed{A_e = \frac{\lambda^2}{4\pi} G_A} \approx \frac{1}{10}\lambda^2 \quad \text{for monopole or dipole}$$

Example: $P_t = 1$ Watt, $G_t = 1$ ("isotropic" radiator)

$R = 10$ km

$$\Rightarrow \rho = 8E-10 \ W/m^2$$

$$A_e\Big|_{1GHz} \approx \frac{1}{10}\left(\frac{\overset{c}{3E8}}{\underset{f}{1E9}}\right)^2 = 0.009m$$

So RX power is

$$P_r = \rho A_e = \underline{7pW}\,!$$

At 1 km, this would be 700 pW

At 1 m, 0.7 mW

NOTE

These powers are typically given in "dBm"

$$\boxed{dBm = 10 \log \left(\frac{P}{1 mW} \right)}$$

R	P_r	P_{dBm}
1 m	0.7 mW	−1.5
1 km	0.7 nW	−61.5
10 km	7 pW	−91.5

CAUTION

In General,

$$P_r = \frac{P_t G_t}{4 \pi R^n} A_e \quad \text{OR} \quad \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 (R)^A}$$

with $2 < n < 5$!

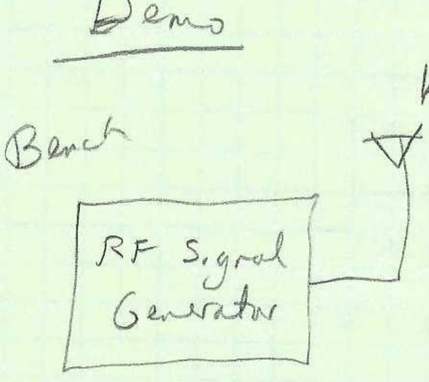
$n = 2$ in "Free space"

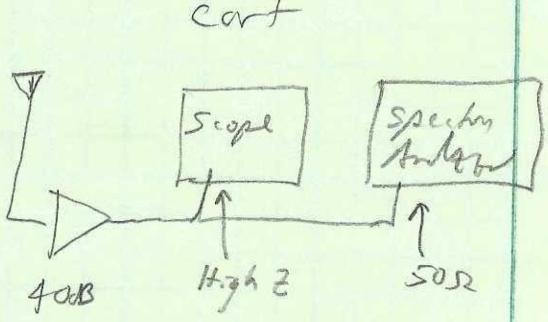
$n = 4$ is often used for terrestrial environments

So P_r may be very weak!

& range is << implied for $n = 2$

Demo





27.125 MHz CB
100 MHz FM
151.820 MHz MURS
467.5625 MHz FRS
902-928 FHSS commercial radios
900, 1800 MHz Cellphone

Setup Sig Gen for AM, 50% depth at 27 MHz
Demo old walkie talkie AM
Switch to 100 MHz, 151 MHz, 467 MHz, 915 MHz
units

Why nothing on scope @ > 100 MHz ?

Demo 2-way Radios
- CB, MURS, FRS, Ham Radio, Digital WalkieTalkie, Cellphone

FCC Rules & Regulations / Handout

Bands and Applications (wikipedia pg / Handout)

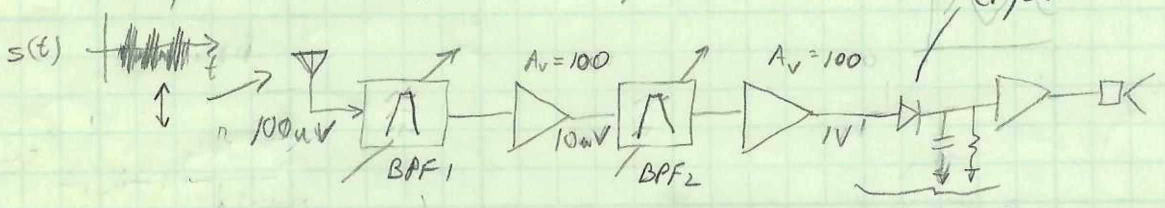
Receiver Design

Requirements:

- Amplify signal (to level suitable for demodulator ckts)
- Separate from other signals (filter)
- Demodulate to recover voice/data

(Show Spectrum Display) Explain dB scale 10dB = 10X power
20dB = 100 X power

SOLUTION 0: Early Tuned RF "AM" RX Design:

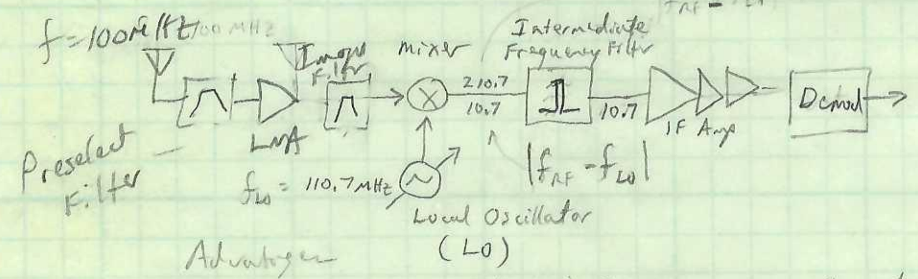


Problems:

- Multiple tuning adjustments
- Poor selectivity (can't make filters narrow or sharp enough) ← due to limited "Q"
- Difficult to amplify at high frequencys (Amp GBW, stability!!)
- Stability issue (prone to oscillate)

★ Show patent 147,147

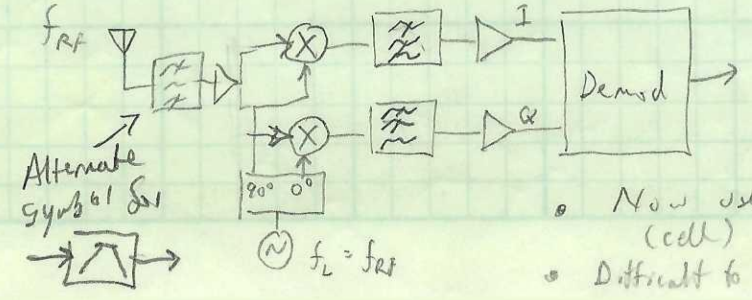
Solution 1: "Superheterodyne" RX (Convert f_{RF} to lower frequency 1st)



Advantages

- Fixed tuned (IF) filter, sharper than at RF (better "selectivity")
- Tuned by varying LO frequency only (single adjustmt)
- Amplification done at low frequency
  (Easier / better stability)

Solution 2: "Zero-IF" or "Direct Conversion" architecture



Show Papers

- Now used in most wideband system (cell)
- Difficult to make work well for narrowb