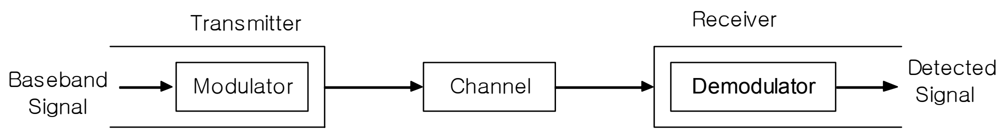
Radio Frequency Integrated Circuits

Modulation

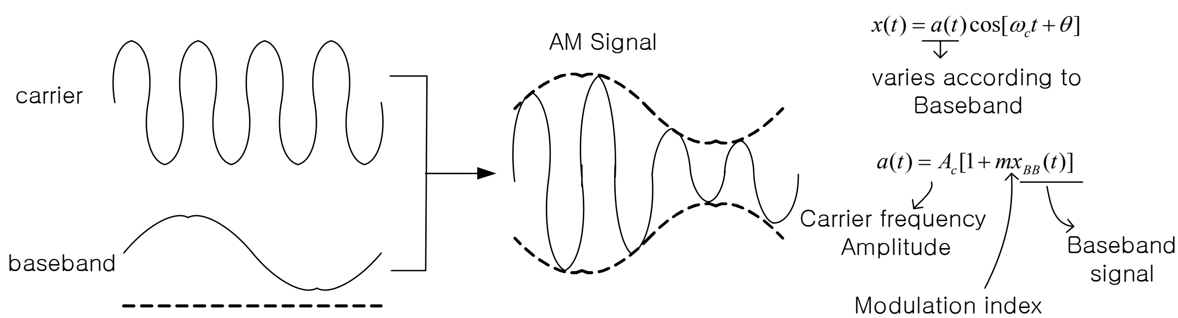


Modulation ⟶ Varying certain parameter of a carrier according to the baseband signal

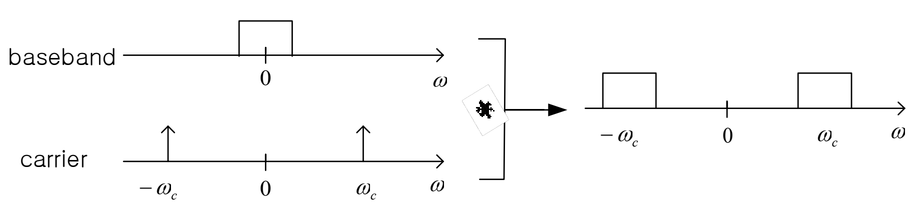
* Assume a sinusoidal carrier

$$\chi(t) = a(t)\cos[\omega_c t + \theta(t)]$$

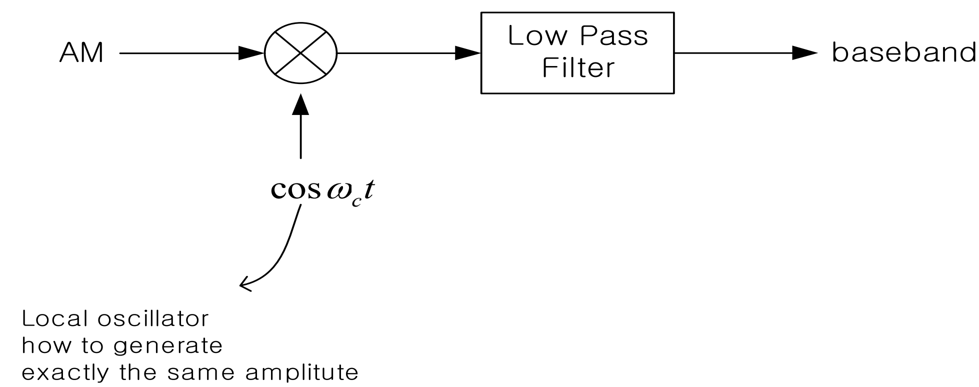
Amplitude modulation (AM):



In frequency domain



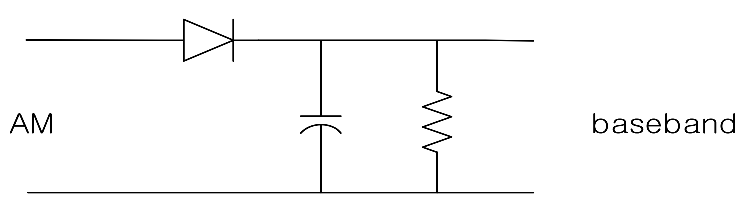
Detection of AM



For small modulation indexes

$$1 + mx_{BB}(t) > 0$$

You can use a simple leaky peak detector for detection



Phase and Frequency Modulation (PM), (FM)

PM: $x(t) = A_C \cos[\,\omega_C t + mx_{BB}(t)]$

m: phase modulation index

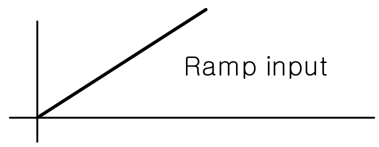
FM: $x(t) = A_C \cos[\,\omega_C t + m\int_{-\infty}^{t} x_{BB}(t)dt\,]$

m: frequency modulation index

excess frequency: $\dfrac{d\theta}{dt}$

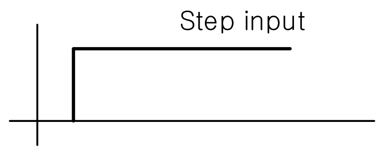
<u>Difference b/w PM & FM</u>

if $x_{BB}(t) = at$

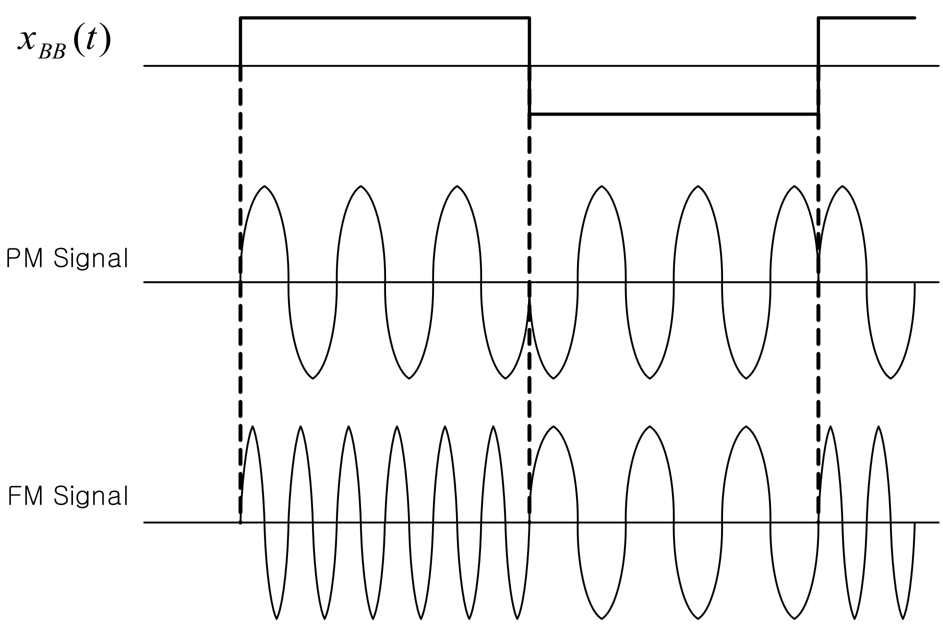


PM Signal: $x(t) = A_C \cos[\underbrace{(\omega_C + \alpha)}_{\text{Shift in carrier frequency}} t]$

if $x_{BB}(t) = a$

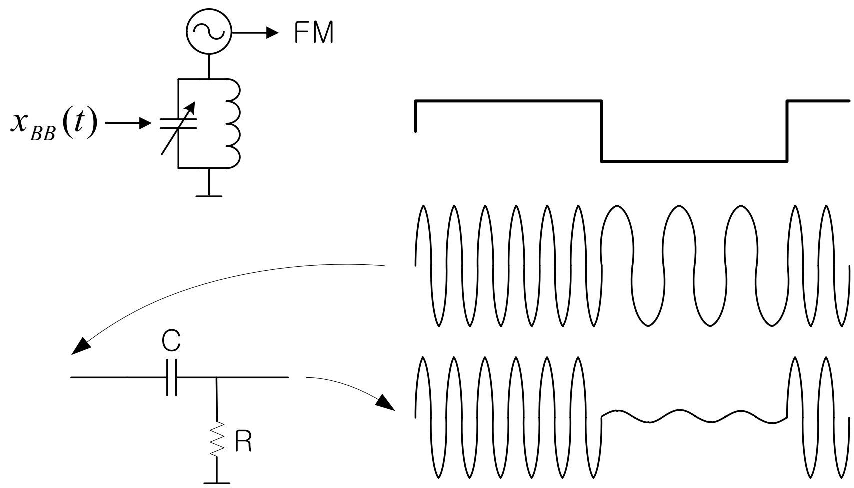


FM Signal: $x(t) = A_C \cos[\underbrace{(\omega_C + \alpha)}_{\text{Shift in carrier frequency}} t]$



→ A voltage controlled oscillator (VCO) is a simple frequency modulator

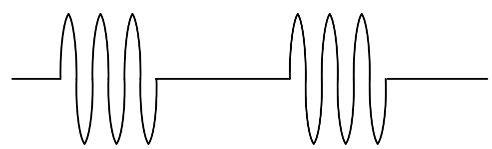
FM demodulator:



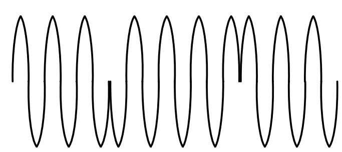
Digital Modulation

Similar to AM, PM, and FM digital modulations are called:

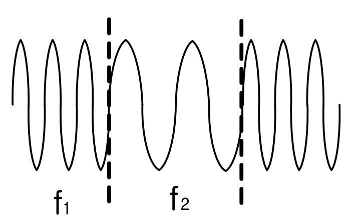
Amplitude Shift Keying (ASK)



Phase Shift Keying (PSK)



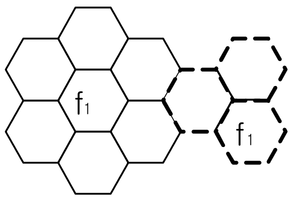
Frequency Shift Keying (FSK)



→ you can have binary and M-ary signalling

Example: Quadrature modulation: QPSK

Cellular System:



available spectrum: e.g. 25MHz around 900MHz

For 100000 users at the same time ⟶ frequency reuse

7-cell reuse pattern

center cell use f_1 ⟶ six cells around it cannot use f_1

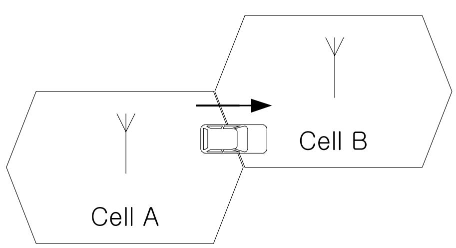
each cell utilizes a group of frequencues

Co-Channel Interference (CCI)

- ➔ How much two cells that use the same frequency interfere with each other
- ➔ CCI depends on the ratio of distance between two co-channel cells to the cell radius and is independent of the transmitted power

In 7-cell reuse pattern
Geometrical ratio = 4.6 ⟶ Signal / CCI = 18 dB

Handoff

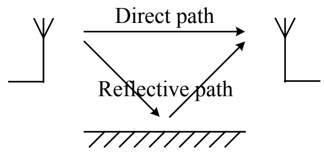


When a mobile receiver is moving from one cell to another the strength of signal A is decreasing while B is increasing The mobile service controller has to handoff the mobile unit from station A to station B (adjacent cell does not use the same group of frequencies)

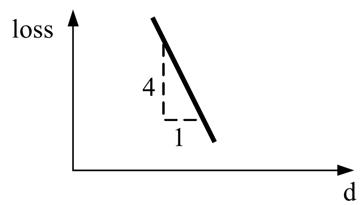
Handoff fails with relatively high probability resulting in dropped calls

⟶ 2nd generation cell phones measure received signal from different base stations to perform the handoff

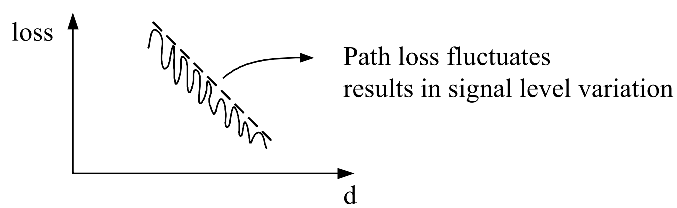
Path loss and multi-path fading



In crowed area loss profile is proportional to d^4 (d: distance)



because of multi path fading this loss fluctuates

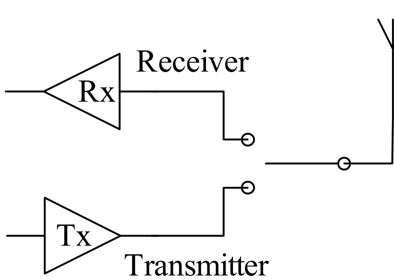


for both transmitter and receiver,

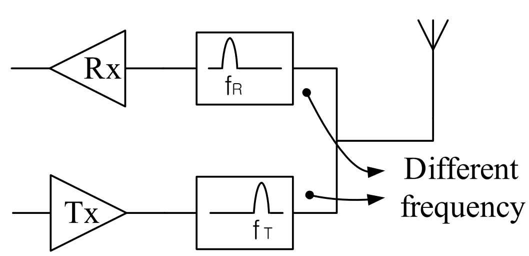
output power and dynamic range must be chosen such that they accommodate these signal fluctuations

Multiple Access Techniques

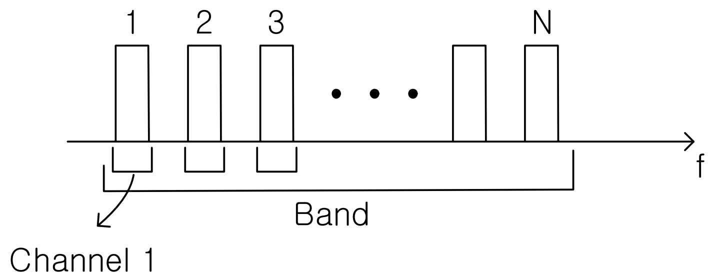
Time Division Duplexing (TDD)



Frequency Division Duplexing (FDD)



Frequency Division Multiple Access (FDMA)

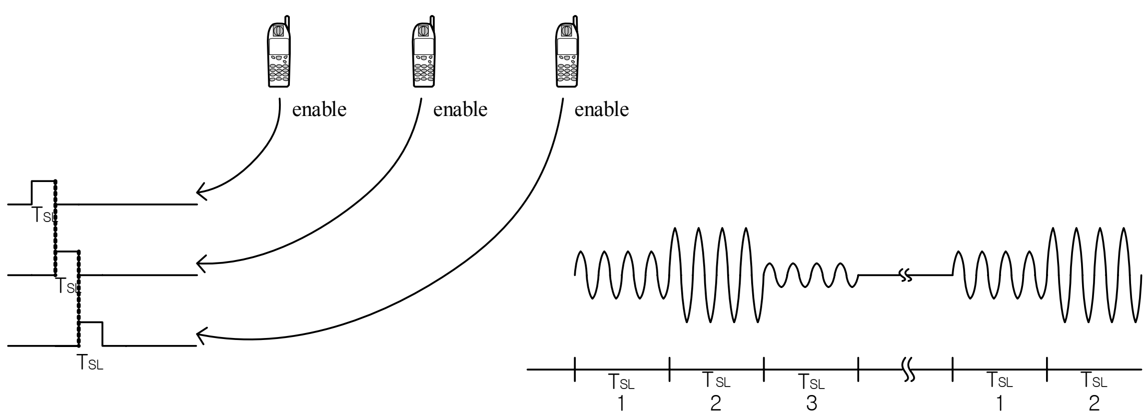


FDMA ⟶ relatively simple

$$\text{\# of simultaneous users} = \frac{\textit{total available frequency band}}{\textit{width of each channel}}$$

Results in insufficient capacity in crowed areas

Time Division Multiple Access (TDMA)



To avoid loss of data TDMA transceivers store data in $T_F - T_{SL}$ second and then send the burst of TDMA signal in T_{SL} second

TDMA systems use A/D and store data digitally

Code Division Multiple Access (CDMA)

Both FDMA&TDMA try to keep the signals not interfering with each other either in frequency domain or time domain

→ signals are orthogonal in one of these domains

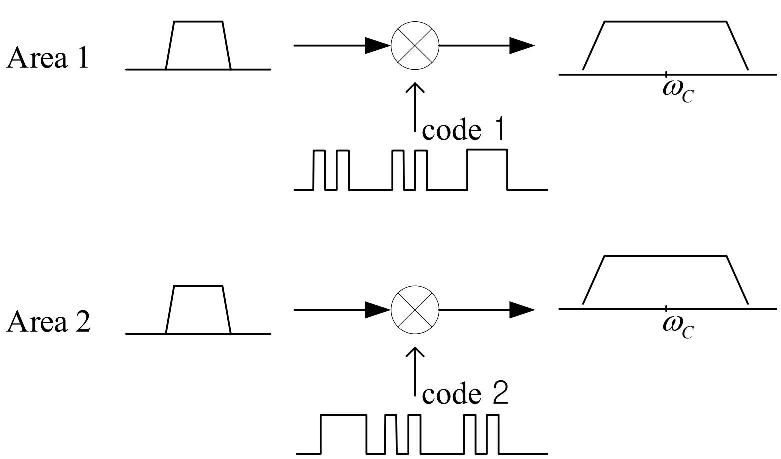
→ CDMA allows complete overlap of signals in both frequency and time
both employs "orthogonal messages" to avoid interference

→ Imagine that in this room
every group of students speak in a different language
if the level of all languages is about the same you can tune to only one language and receive the data!

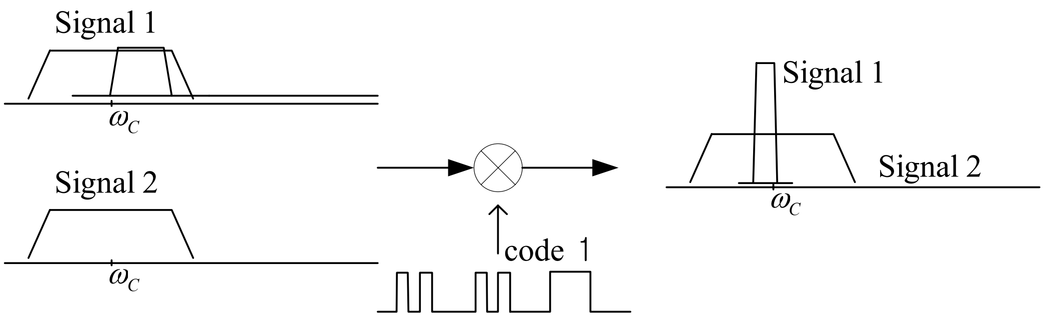
→ in CDMA different languages are crested by orthogonal digital codes
at the start of communication, each transmitter/receiver pair are assigned a certain code

→ baseband data is translated to that code before modulation

by coding the signal → spread the spectrum



At the receiver, you de-spread the desired signal

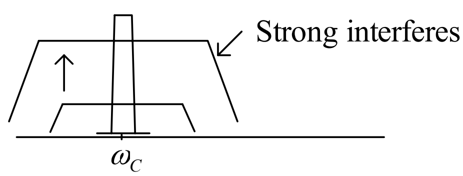


When they are many users all other signals form a white noise

→ CDMA has a soft limitation in the number of users

Number of users↑ → noise floor↑ (linearly with two number of users)

Power Control is very important in CDMA



⟶ Received signal levels are controlled to be within 1dB of each other

Power control also reduces the average power dissipation of the mobile unit

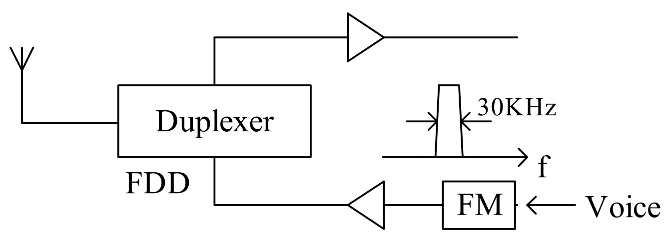
Wireless Standards

→ **Advanced Mobile Phone Service (AMPS)**

FDMA with Analog FM, 30kHz channels

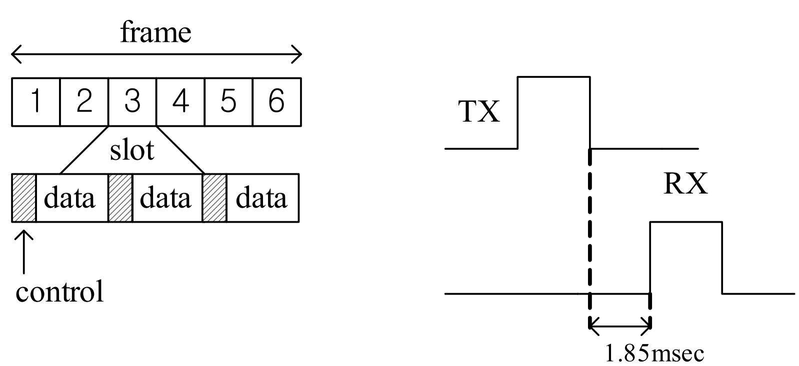
Receiver band: 869 ~ 894 MHz

Transmitter band: 824 ~ 849 MHz



→ **North American Digital Standard (NADC)**

same as above except it uses QPSK instead of FM

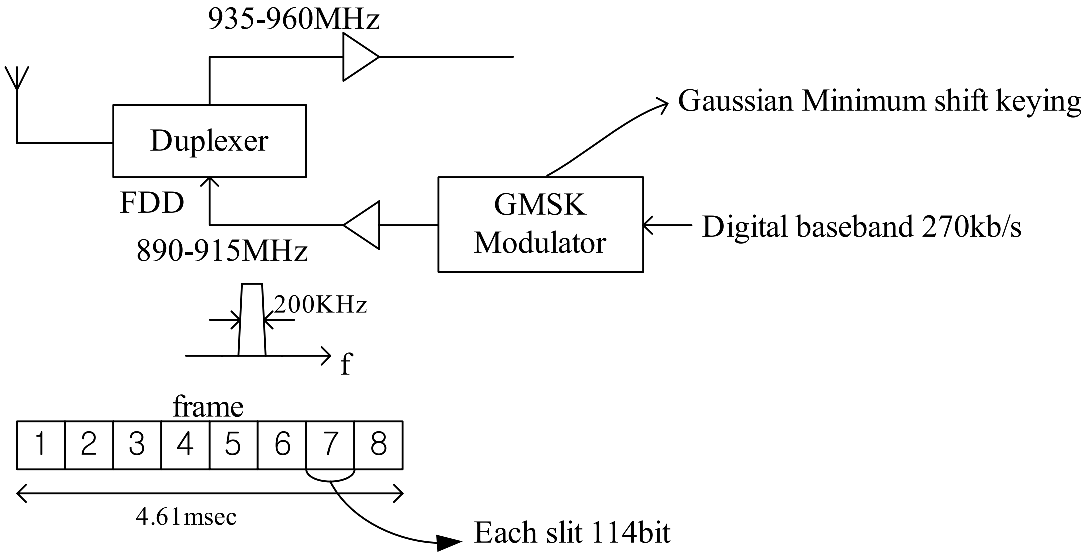


→ **Global System for Mobile Communication (GSM)**

GSM is European standard

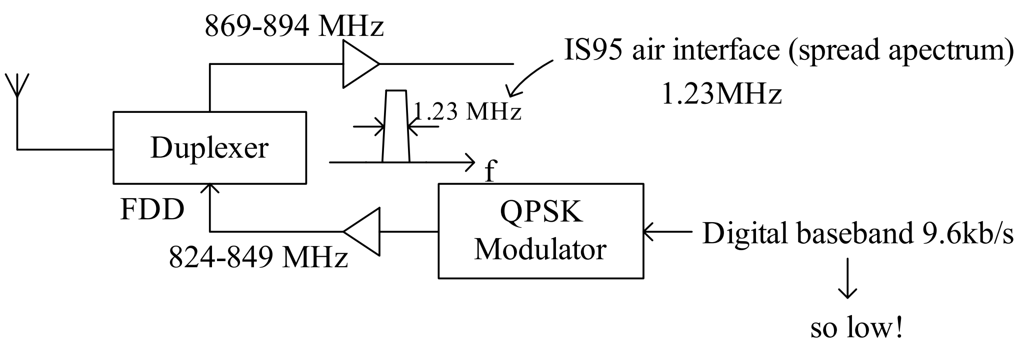
GSM is TDMA with FDD (Frequency Division Duplexing)

Supports: fax, ISDN, …

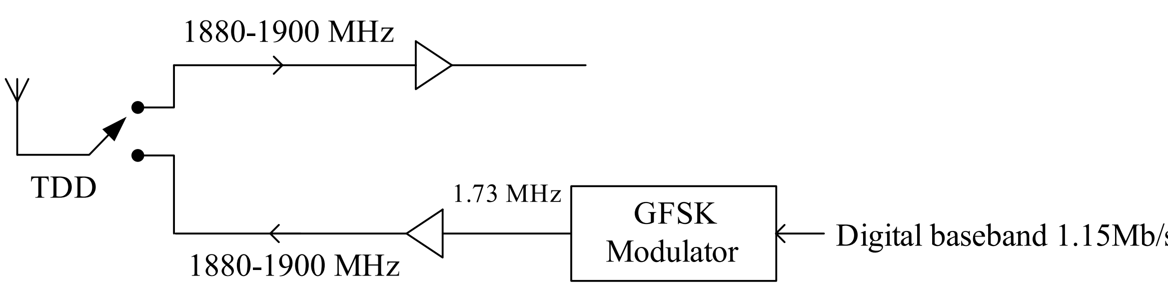


-1000 user per channel

→ **<u>Qualcomm CDMA</u>**



→ **<u>Digital European Cordless Telephone (DECT)</u>**



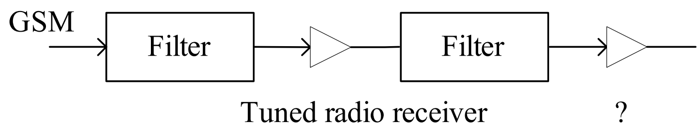
There are many more wireless standards WCDMA → 1.8GHz …

Assume:

GSM detection:

Channel BW: 200 KHz

Carrier frequency: 900 MHz

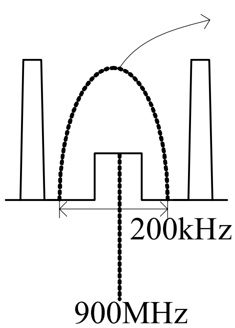


In order to tune to a channel, filter that you need

$$Q_{filter} \approx \frac{f_{carrier}}{f_{BW}} = \frac{900\times10^3}{200} = 4500$$

Not only you need a high Q, it has to be a variable filter (tunable)

→ Main problem is that you need to attenuate the adjacent channel

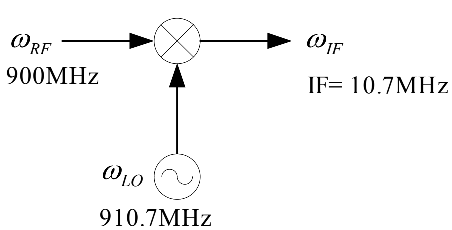


$Q_{filter} \approx 10^7 \leftarrow$ impossible

tunable

independent of temp!

→ Use mixer to reduce the specs (Q) of the filter



$$Q_{filter} \approx \frac{f_{IF}}{f_{BW}} = \frac{10.7\times10^3}{200} = 53.5$$

In this case it does not need to be tunable

as you change LO frequency to go from one channel to the next