Microwave Systems

Microwave Engineering
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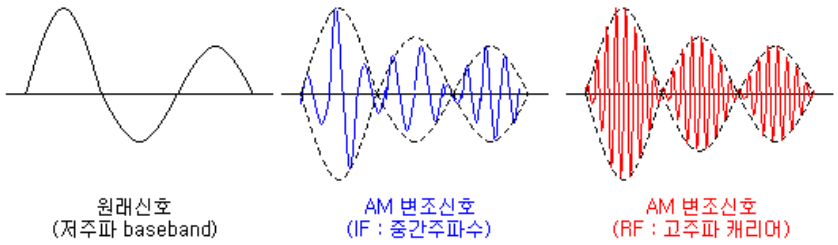
1. Microwave Systems

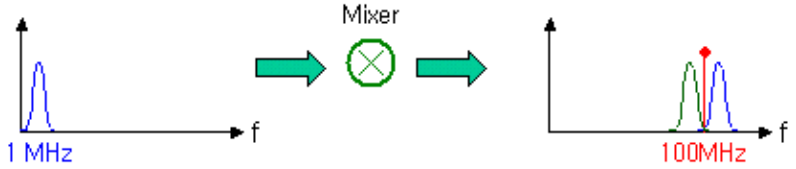
Transmission

- Information
  - Channel bandwidth
  - Base band
  - Inefficient wave radiation
- Modulation – center frequency

출처: RFDH.com



Time domain



Frequency domain

Why's modulation need?

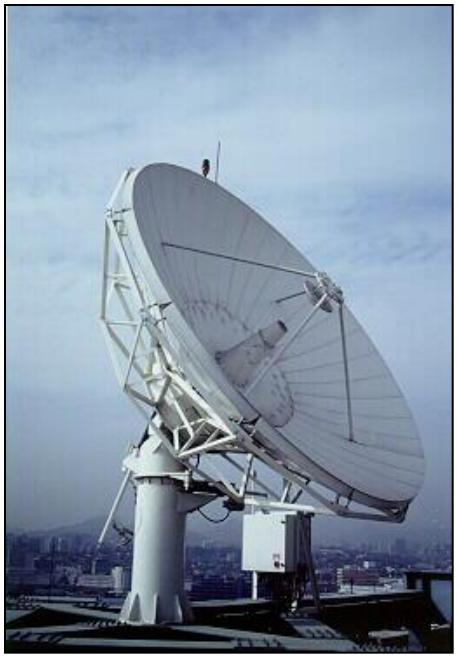
- Transmission efficiency
  - Multiplexing
  - Antenna length: wavelength
  - Wave radiation: comparison with DC

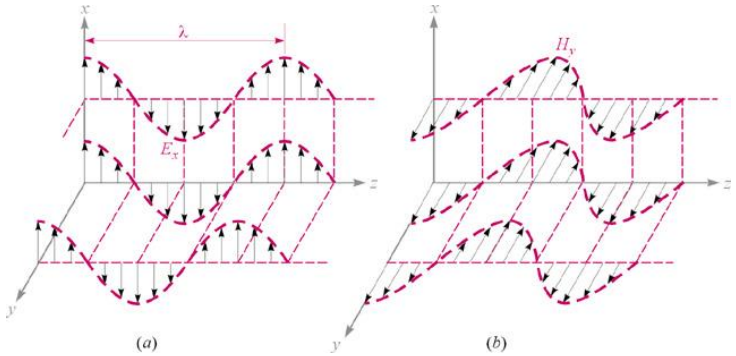
Battery: DC

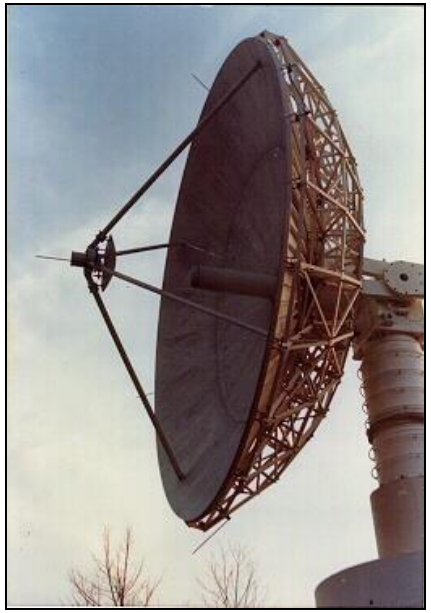
Antenna: AC

Friis power transmission formula

☑ ❑ Microwave radio link







R

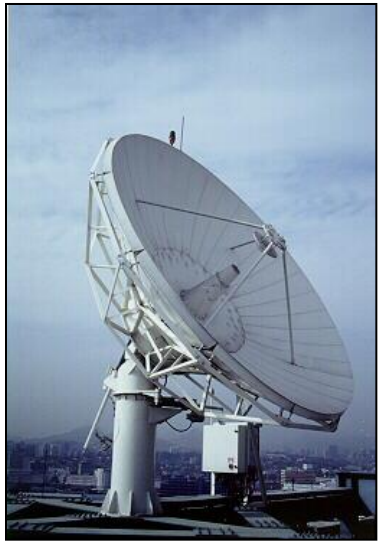
P_t

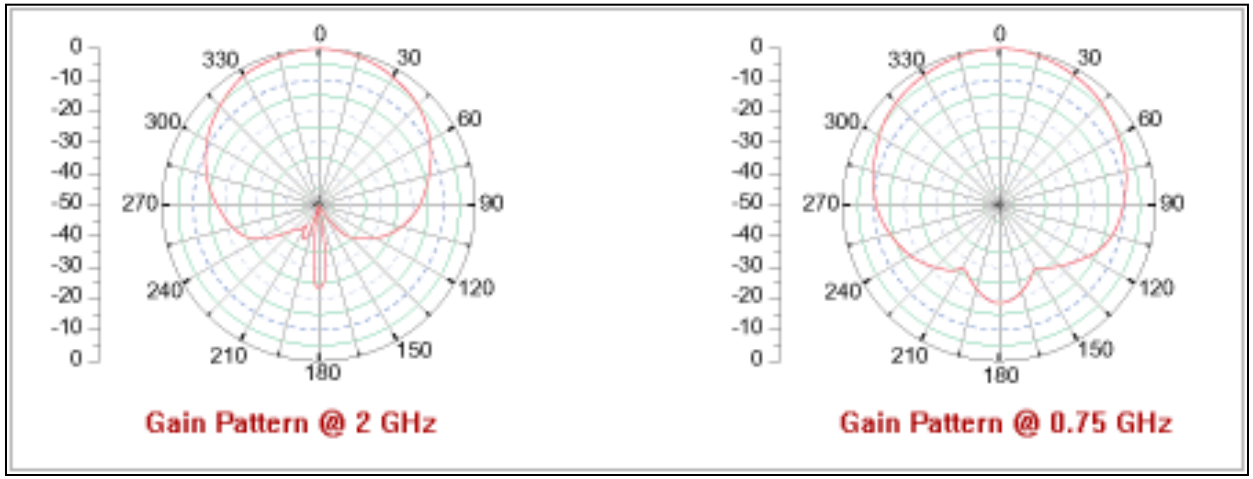
P_r

Friis power transmission formula

- **Power density:** $S = \frac{P_t}{4\pi R^2} G_t \left[W / m^2 \right]$

- **Antenna gain: anisotropic radiation (G > 1)**
  isotropic radiation (G = 1)





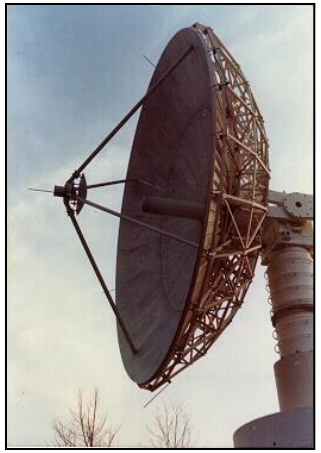
Radiation pattern [dBi]: dB isotropic

Friis power transmission formula

- Received power: $P_r = SA_e$
- Effective area
  - $A_e = \dfrac{\lambda^2 G_r}{4\pi}$

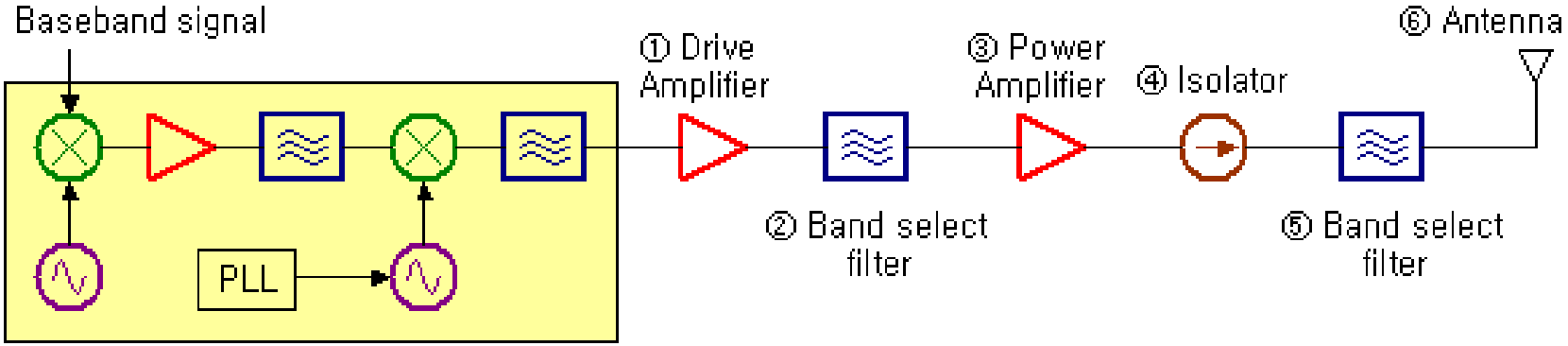
$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2 [W]$$

- Friis transmission formula



Microwave transmitter (Tx)

☑ ❑ **Up-conversion: frequency**



f_{BB} $f_{LO} \pm f_{BB}$ $f_{LO} \pm f_{BB}$

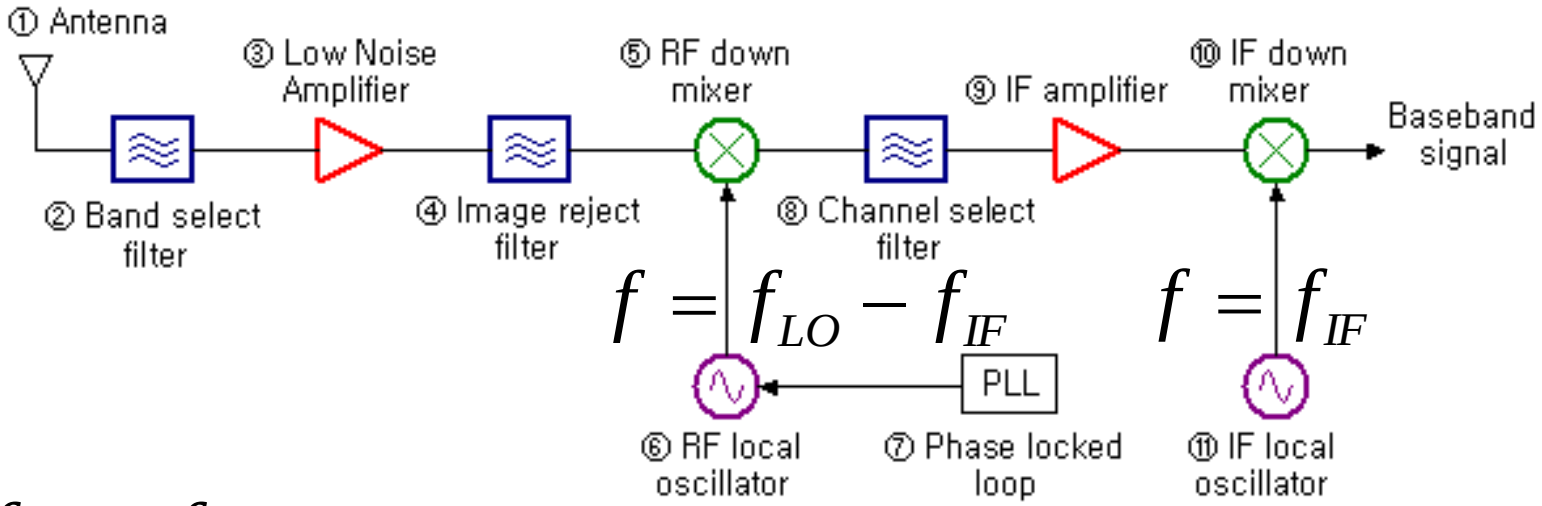
출처: RFDH.com

☑ $$\cos(x)\cos(y) = \frac{1}{2}\left(\cos(x+y) + \cos(x-y)\right)$$

Microwave receiver (Rx)

❑ Down-conversion: frequency

출처: RFDH.com

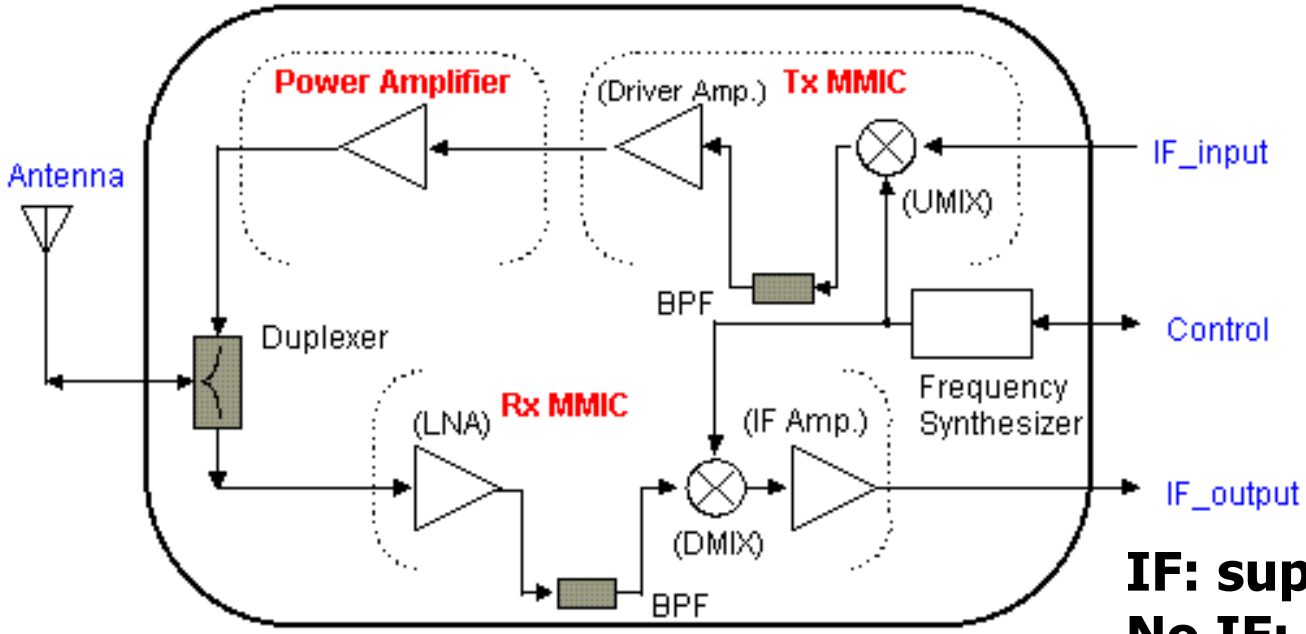


$f_{LO} \pm f_{BB}$ $\quad f_{IF} \pm f_{BB}$ $\quad f_{BB}$

$$\cos(x)\cos(y) = \frac{1}{2}\left(\cos(x+y) + \cos(x-y)\right)$$

Microwave transceiver

- Duplexer: bandpass filter or switch
  - Loss, tx suppression, channel selection



출처: RFDH.com

IF: superheterodyne
No IF: direct conversion

Uplink and downlink

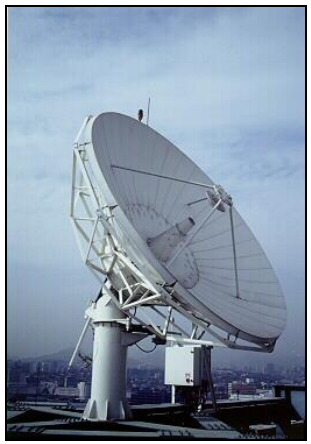
$R = 40{,}000[km]$

$P_t = 10[\mathrm{W}]$

$f_d = 12[\mathrm{GHz}]$

$\theta_{3\mathrm{dB}} = 2^\circ$

$\eta = 0.55$



$P_t = 100[\mathrm{W}]$

$f_u = 14[\mathrm{GHz}]$

$4m$ diameter dish

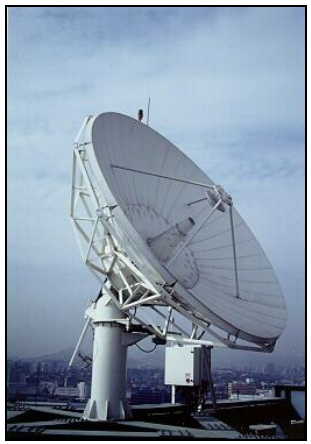
$\eta = 0.6$

Uplink calculation

$$P_r = \text{EIRP} - L_{\text{FS}} + G_r[\text{dB}]$$

$$D_r = \frac{4\pi}{\theta_1 \theta_2}$$

$$G_r = \eta D_r$$



$$\text{EIRP} = P_t G_t$$

$$D_t = \frac{4\pi}{\lambda^2} A_e$$

$$G_t = \eta D_t$$

$$L_{\text{FS}} = \left(\frac{4\pi R}{\lambda} \right)^2$$

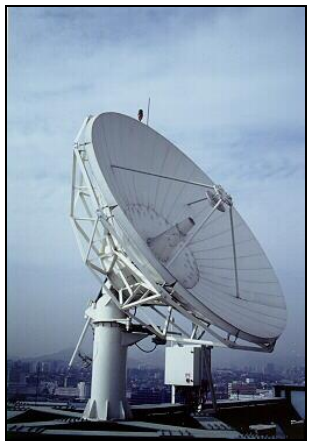
Downlink calculation

$$P_r = \text{EIRP} - L_{\text{FS}} + G_r[\text{dB}]$$

$$\text{EIRP} = P_t G_t$$

$$D_t = \frac{4\pi}{\theta_1 \theta_2}$$

$$G_t = \eta D_t$$



$$D_r = \frac{4\pi}{\lambda^2} A_{\max}$$

$$G_r = \eta D_r$$

$$L_{\text{FS}} = \left(\frac{4\pi R}{\lambda} \right)^2$$

Thermal Noise or Johnson Noise

- ❑ Thermal noise: white noise, Nyquist formula

$$P_n = kTB$$

$$N = N_0 B$$

$$T = \frac{N}{kB}$$

- Noise power
- Noise temperature

Carrier to noise ratio

- C/No: related to carrier to noise ratio
- G/T: Figure of merit

Carrier to noise ratio

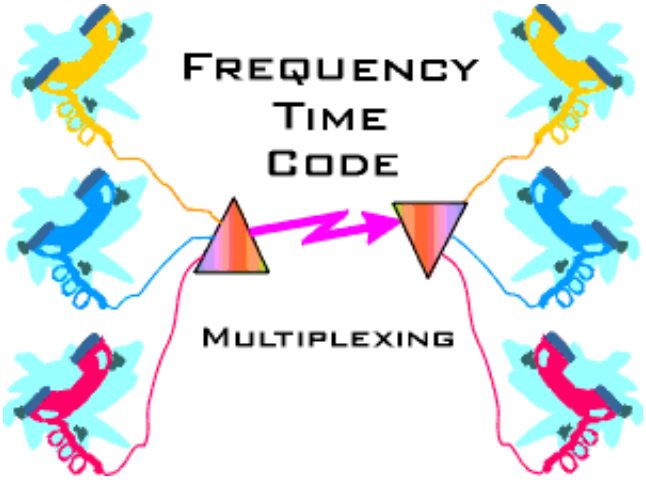
$$\frac{C}{N} = \frac{C}{N_0 B} = \frac{C}{TkB}$$

G/T: sensitivity of receiver

$$C = \mathrm{EIRP} - L_{\mathrm{FS}} + G_r [\mathrm{dB}]$$

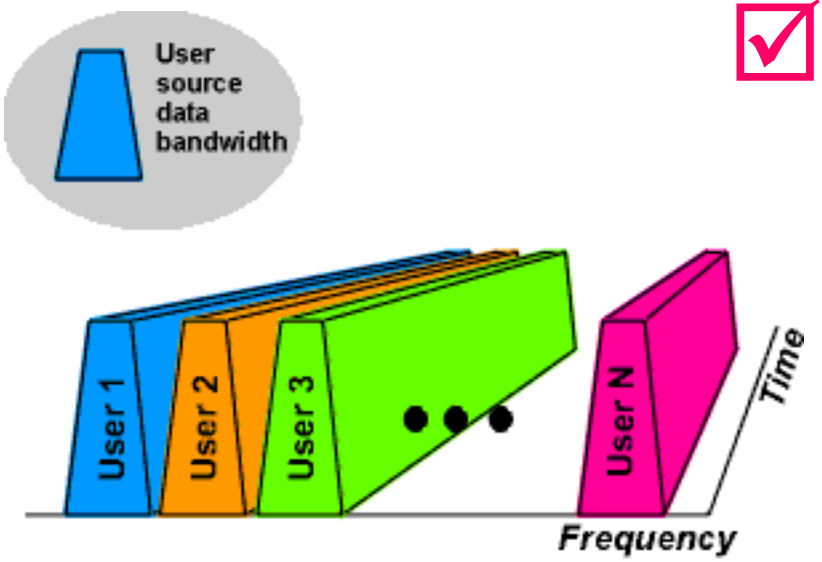
Multiplexing: resources

- FDM (Frequency Division Multiplexing)
- TDM (Time Division Multiplexing)
- CDM (Code Division Multiplexing)



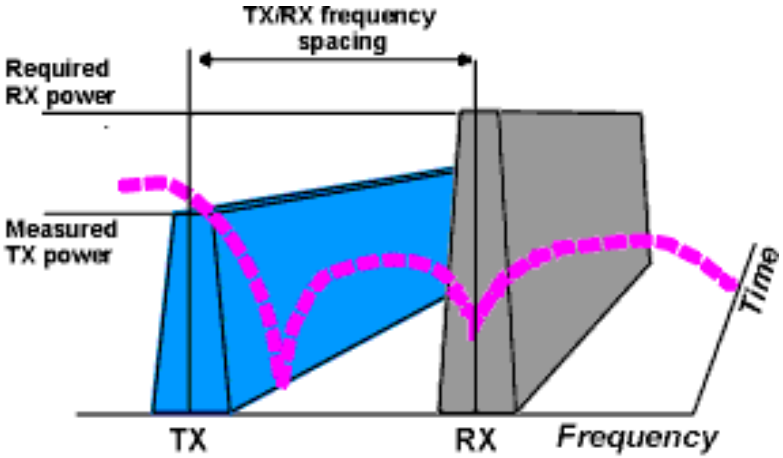
Communication

FDMA (FDM Access)



Frequency division multiple access

- Resource: frequency
- Guard band
- Simple transceiver
- Interference

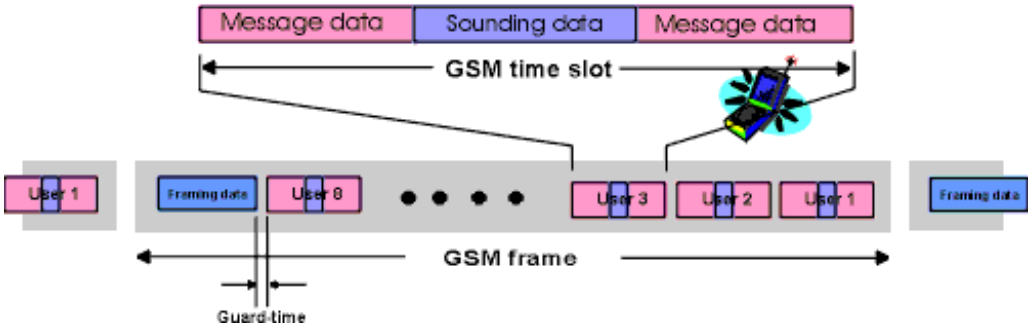


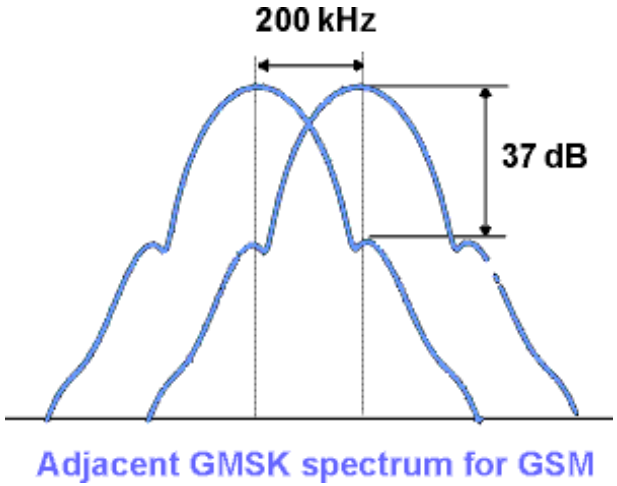
Power control issues with selective fading

TDMA (TDM Access)

- Resource: time
- Guard time
- Complicated transceiver

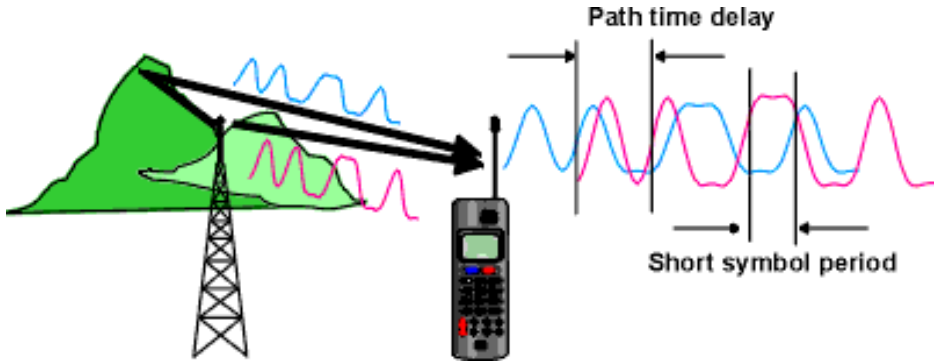
GSM TDMA data and frame structure





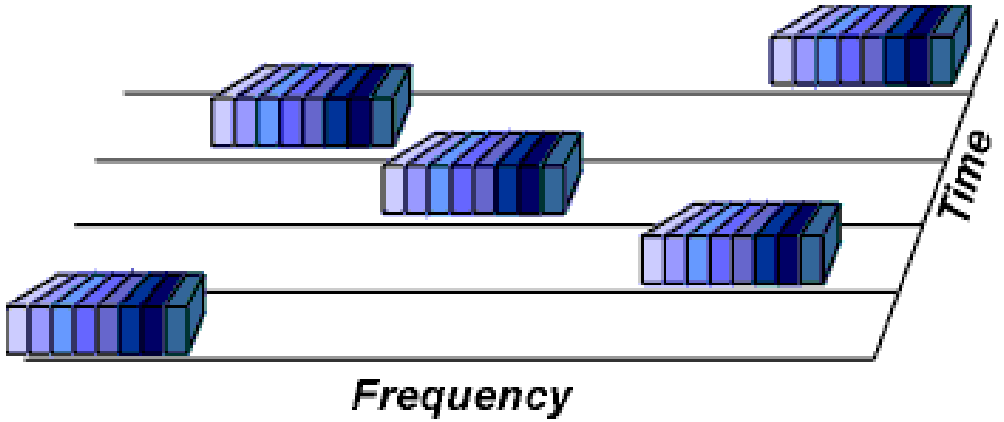
Adjacent GMSK spectrum for GSM

GSM: Global System for Mobile commo



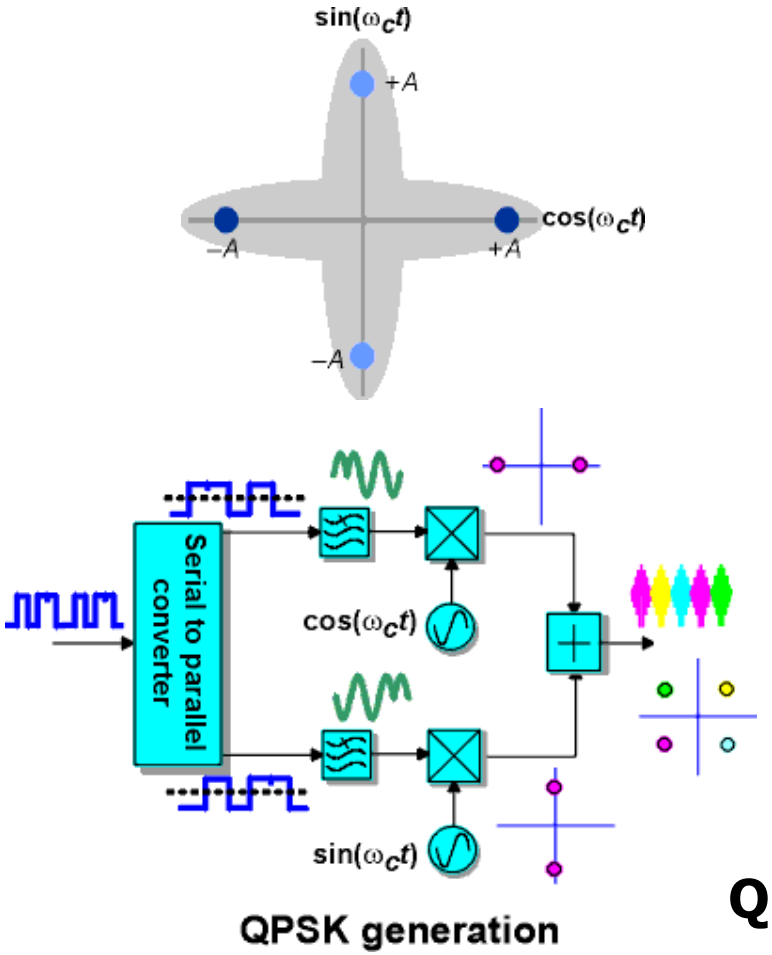
FH(Frequency Hopping)-CDMA

- Resource: code
- Precise clock
- Very complicated transceiver
- Bluetooth, military applications

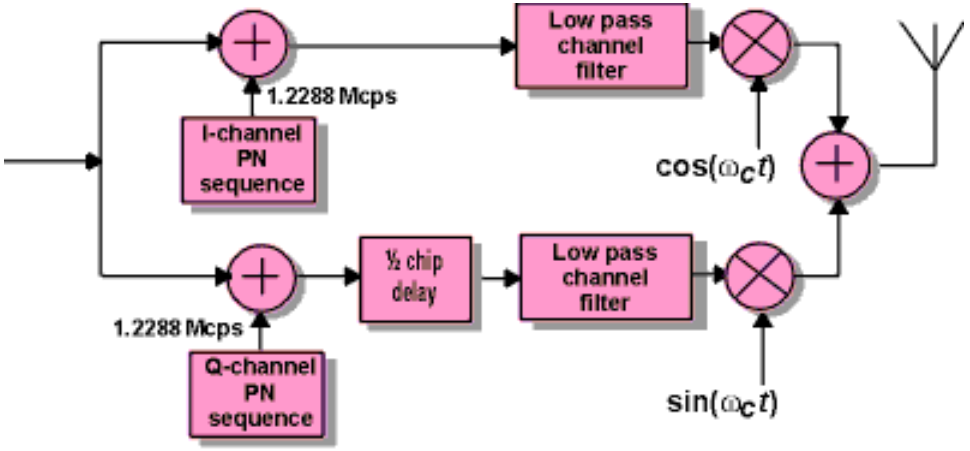


Frequency hopping with GSM

DS(Direct Sequence)-CDMA



QPSK generation



Offset-QPSK Modulator for IS-95 CDMA

QPSK: Quadrature Phase Shift Keying

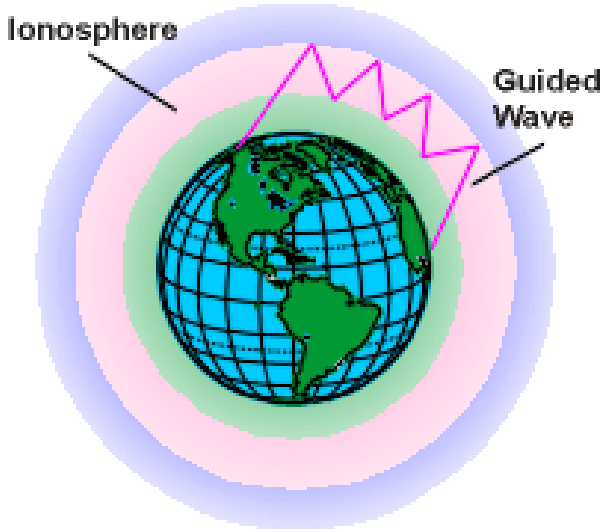
2. Applications

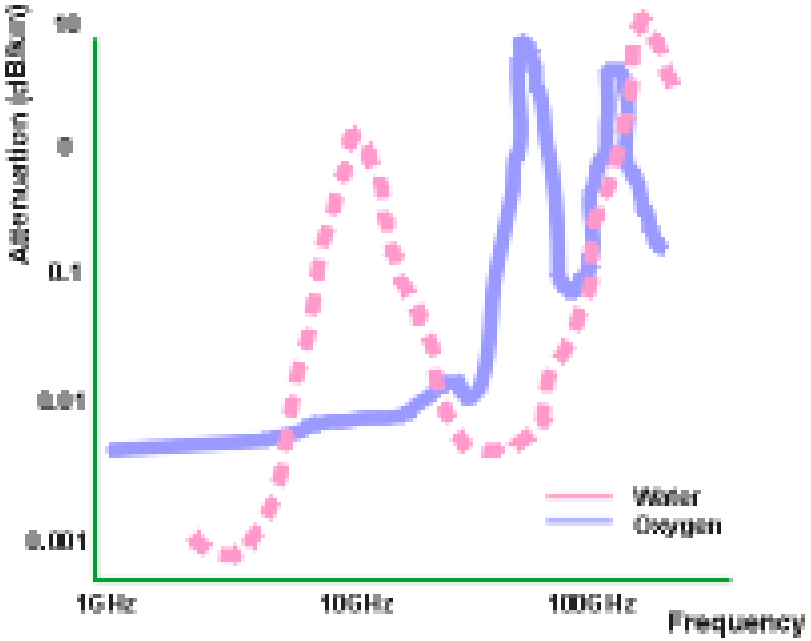
Frequency spectrum

Name	Frequency[Hz]	Wavelength	Application
EHF	30G-300G	1cm-1mm	Car radar
SHF	3G-30G	10cm-1cm	Radar, satellite
UHF	300M-3G	1m-10cm	TV, PCS, IMT2000
VHF	30M-300M	10m-1m	FM, TV
HF	3M-30M	100m-10m	Shortwave AM, HAM
MF	300k-3M	1km-100m	AM
LF	30k-300k	10km-1km	Navigation
VLF	3k-30k	100km-10km	Submarine, navigation
ELF	30-300	10000km-1000km	Submarine

2. Applications

Attenuation





☑ **HF application**

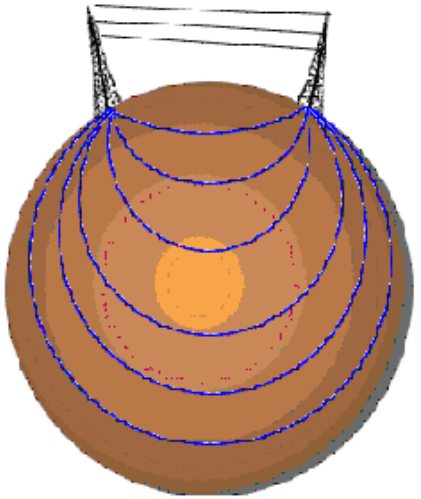
☑ **Attenuation by water and oxygen**

2. Applications

ELF application

- Skin depth: long wavelength
- Long antenna: 104km at USA
- Unidirectional communication
- Slow bit rate: redundancy
- Information: code table

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} = \frac{1}{\alpha}$$



2. Applications

EHF application

- Short antenna
- Absorption: air, water(60 GHz)
- Anti-collision radar: 76 GHz
- ITS: Intelligent Transport System

Radar

ITS