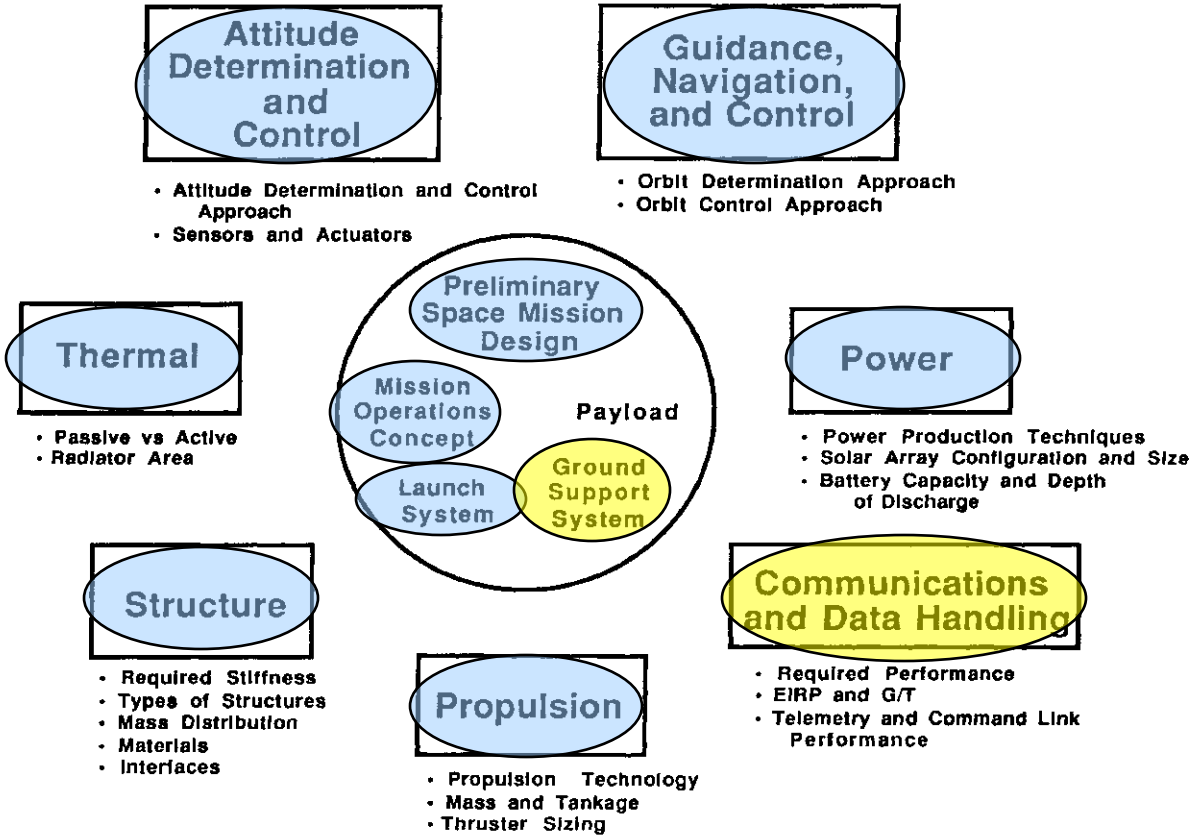
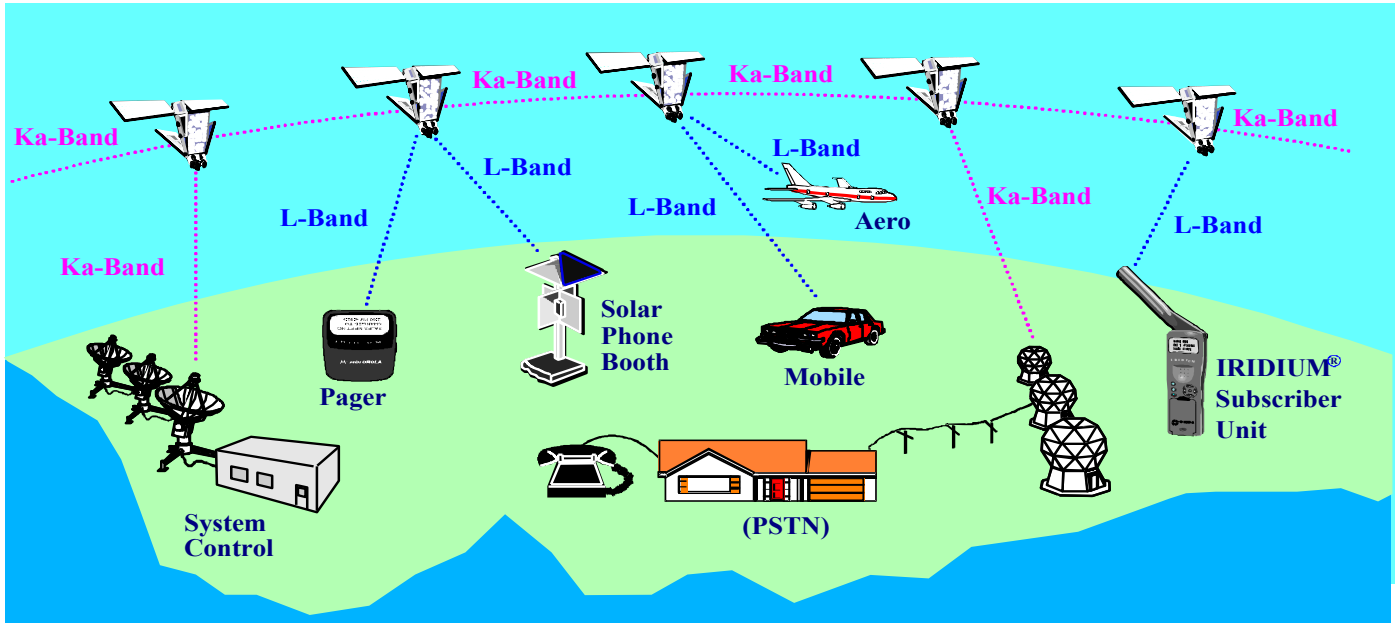
# Telecomunicazioni da/per un satellite

# SOTTO-SISTEMI



# Sistemi di comunicazione




- Riceve segnali da Terra / da un altro satellite
- Trasmette segnali a Terra / a un altro satellite

Uplink

Downlink

# Caratterizzazione 1/2

- Servizio
  - Fisso: punto a punto (entrambi fissi)
  - Mobile: punto a punto (uno o entrambi mobili)
  - Broadcasting: punto a multipoint
  - Data relay: space to space
- Copertura
  - Globale
  - Regionale
- Tecnologia
  - RF (Radio Frequenza)
  - Ottica: alte potenzialità per elevate velocità di trasmissione (*data rate)*
- Tipo di accesso
  - Permette S/C di ricevere segnali simultaneamente da più GS

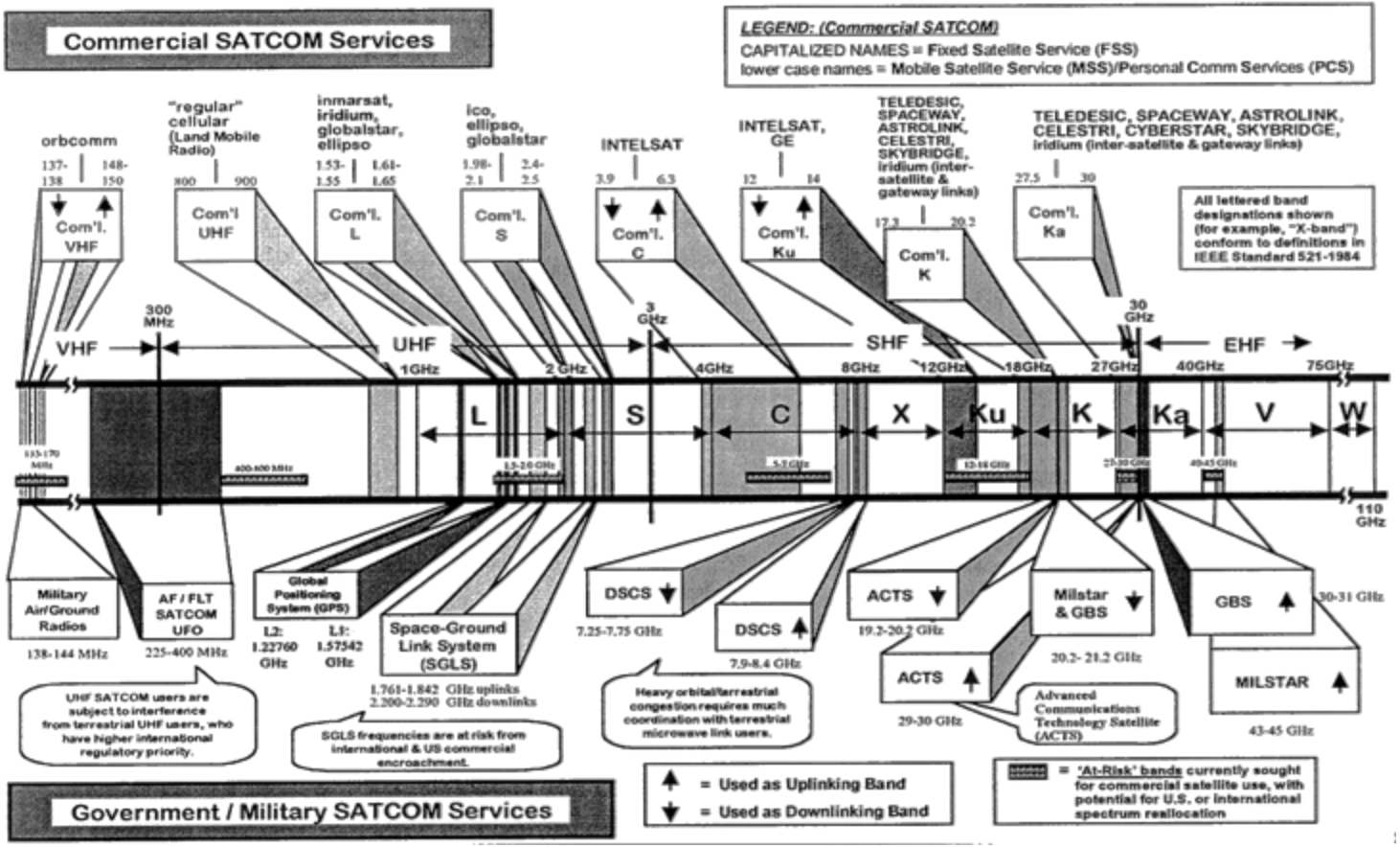
# Caratterizzazione 2/2

- Frequencies

| | | | |
|---|---|---|---|
| – VHF: | 30 - 225 MHz | VHF | little LEO and amateur |
| – UHF: | 225 - 1000 MHz | UHF | primarily military |
| – L-Band: | 1.0 - 2.0 GHz | ↓ | mobile, sound broadcast |
| – S-Band: | 2.0 - 4.0 GHz | ↓ | mobile, sound broadcast |
| – C-Band: | 4.0 - 8.0 GHz | SHF | fixed |
| – X-Band: | 8.0 - 12.4 GHz | ↓ | primarily military |
| – Ku-Band: | 12.4 - 18.0 GHz | ↓ | fixed, TV broadcast, data relay |
| – K-Band: | 18.0 - 26.5 GHz | EHF | fixed and data relay |
| – Ka-Band: | 26.5 - 40.0 GHz | ↓ | fixed and data relay |
| – Q-Band: | 40.0 - 60.0 GHz | ↓ | data relay, military |
| – V-Band: | 60.0 - 75.0 GHz | ↓ | data relay |
| – W-Band: | 75.0 - 110 GHz | ↓ | data relay |

- Signal Modulation Type
  - Analog AM: seldom
  - Analog FM: common in the past
  - Digital: increasingly replacing all others
- Architecture
  - Transparent
  - Regenerative (on-board modulation conversion, forward error correction, storage, and information processing)

# Utilizzo delle frequenze



# Processo di Disegno del Sistema

- Identifica i requisiti
  - Specifica: tipo dati, utenti, locazione utente, quantita' di dati, Ground Station, tempi di accesso, ritardi di trasmissione, disponibilita'...
- Verifica il possibile utilizzo di altri sistemi
  - Identifica: collegamenti e posizionamento GS e "processing" gia' in uso
  - Considera l'uso di satelliti/GS "relay"
- Determina il data rate
  - $n_{campioni} \cdot n_{bit/campione}$
- Disegna il collegamento
  - Seleziona: frequenza, modulazione, attenuazioni, puntamento...
- Disegna l'antenna
  - Seleziona: tipo, dimensioni, massa, guadagni, potenza …
- Documenta le ragioni della scelta

# Data Rate

Data Rate: numero di bit di informazioni al secondo che devono essere trasferiti lungo il collegamento

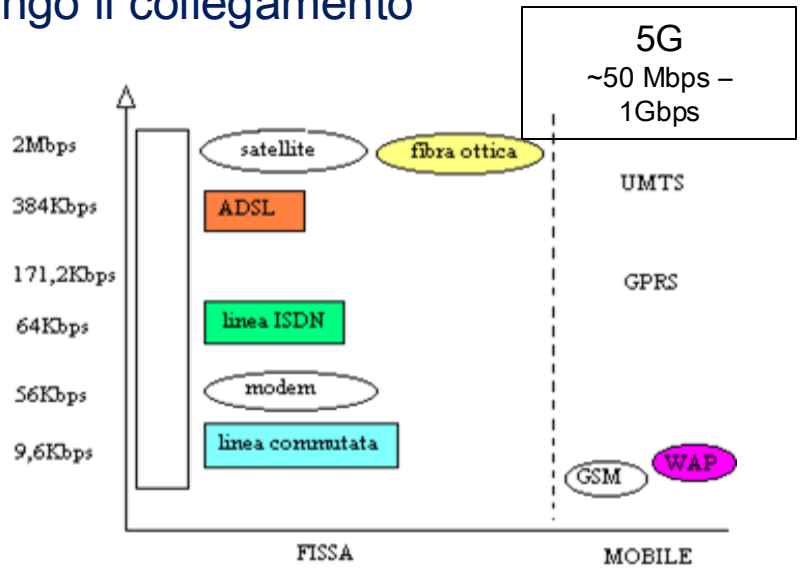
Sistemi digitali: segnali analogici campionati e quantizzati !

**circuito vocale telefonico:**

$n_{campioni}$=8000 campioni/s $n_{bit/campione}$

8 bit/campione

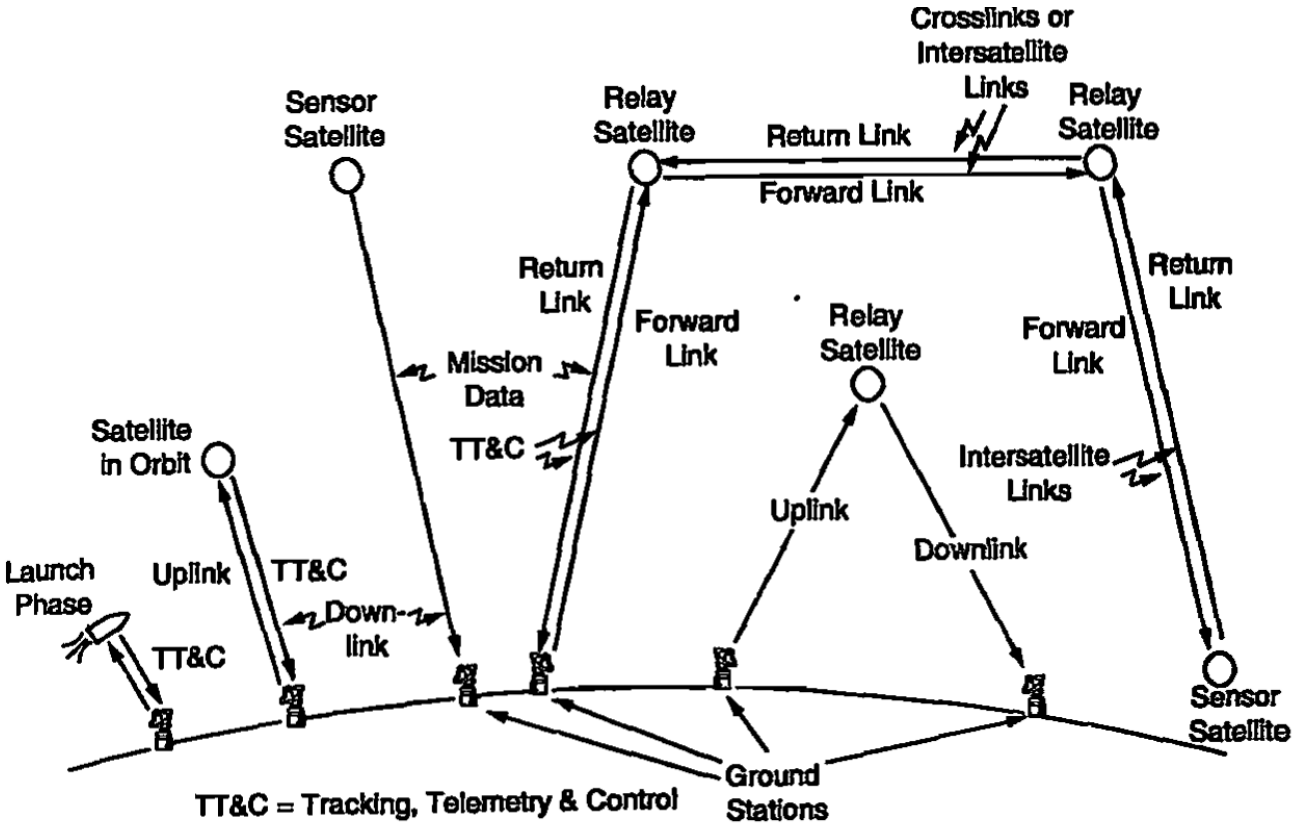
$\Rightarrow$ data rate = 64 kbps




Teorema del campionamento:
un segnale analogico con $f_{max}$ puo' essere ricostruito completamente da campioni presi ogni $1/(2\ f_{max})$ secondi

Esempio: musica di alta qualita' $f_{max}$=20 Hz, CD player lavorano con un sample di 44.1 Hz

# Communication Architecture



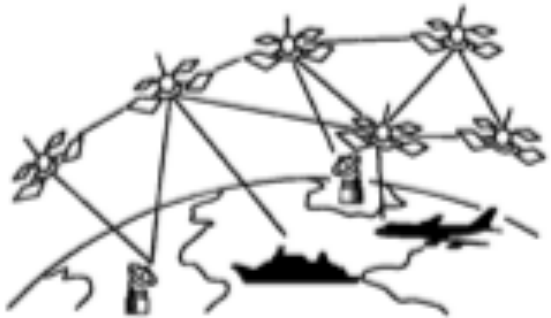
# Communication Link vs Architettura

A. Store and Forward

B. Geostationary Orbit

C. Molniya Orbit

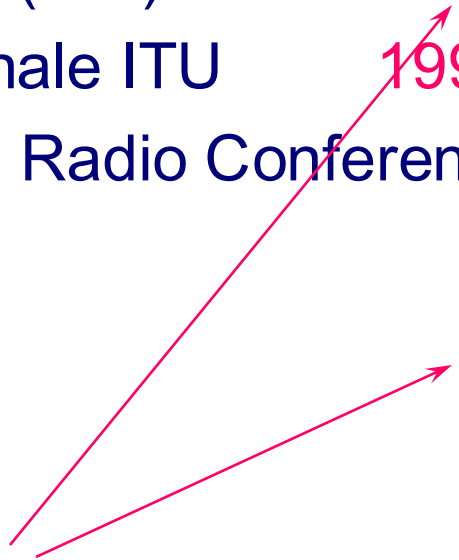
D. Crosslink in Communication Satellite System



E. Low-altitude, Crosslinked Comsat Network

# Procedura di richiesta della frequenza

- Richiesta nazionale: FCC (usa) 1990
- Italia: richiesta internazionale ITU 1992
- ITU: World Administrative Radio Conferences (WARC) 1992
- ITU: pubblica le regole 1995

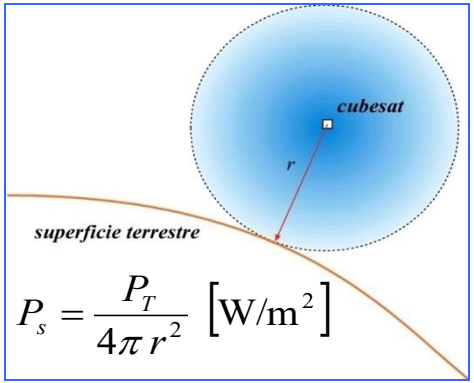


IRIDIUM

# Un po' di teoria…

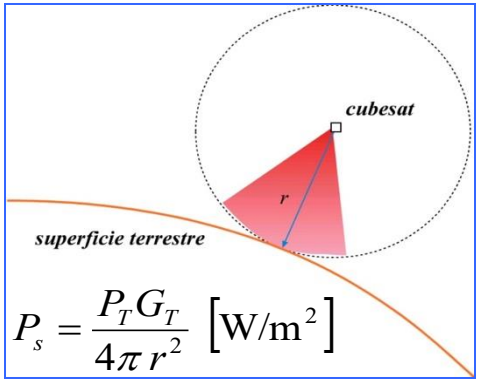
Trasmissione:

(esempio downlink)




$$P_s = \frac{P_T}{4\pi r^2} \left[\mathrm{W/m^2}\right]$$

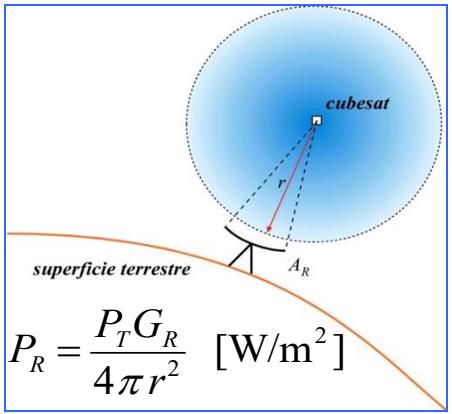
Antenna isotropa



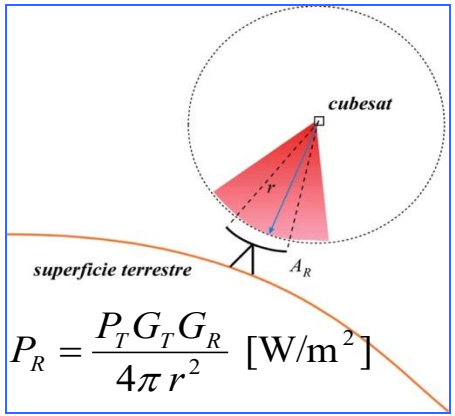

$$P_s = \frac{P_T G_T}{4\pi r^2} \left[\mathrm{W/m^2}\right]$$

Antenna direttiva

Ricezione:

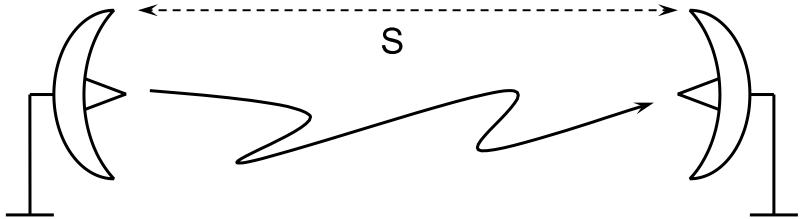



$$P_R = \frac{P_T G_R}{4\pi r^2} \left[\mathrm{W/m^2}\right]$$




$$P_R = \frac{P_T G_T G_R}{4\pi r^2} \left[\mathrm{W/m^2}\right]$$

# Analisi del collegamento




- Energy per bit ($E_b$), Noise density ($N_o$):

$$E_b = P\,L_l\,G_t\,L_s\,L_a\,G_r / R = EIRP\,L_s\,L_a\,G_r / R$$

figura di merito trasmettitore

$$N_o = k\,T_s \quad \text{(thermal energy)}$$

$$E_b/N_o = EIRP\,L_s\,L_a\,(G_r/T_s) / kR$$

figura di merito ricevitore

$$= (EIRP + L_s + L_a + G_r + 228.6 - R - T_s)\ dB$$

=10 Log()

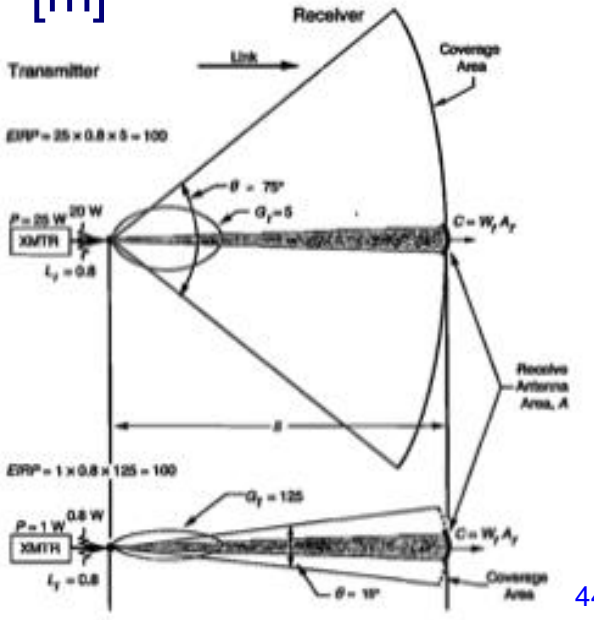
- Trasmettitore: P=potenza, $L_l$=line loss, $G_t$=guadagno
- Ricevitore: $G_r$=guadagno, $T_s$=noise temperature
- Sistema: R=data rate, $L_s$ =space loss, $L_a$=path loss

# Caratteristiche di un'antenna

Circular antenna beam

- Guadagno di picco: G
  - $G \cong \pi^2 D^2 \eta / \lambda^2$
- Half power width alla frequenza f (GHz): $\theta$
  - $\theta = 21 / fD$ (gradi) $\Leftrightarrow$ $D = 21 / f\theta$ [m]

$\Rightarrow G \cong \eta\,(21\pi 10^9/c\theta)^2$



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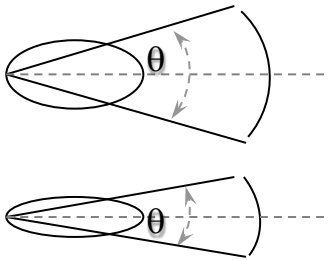



coverage area →

figure of merit →

| | | antenna 1 | antenna 2 |
|---|---|---|---|
| f | (GHz) | 0.500 | |
| λ | (m) | 0.600 | |
| η | | 0.58 | |
| L | | 0.8 | |
| P | (W) | 25 | 1 |
| θ | (gradi) | 75 | 15 |
| D | (m) | 0.560 | 2.800 |
| $G_t$ | | 5 | 125 |
| EIRP ($PLG_t$) | | 100 | 100 |

# Caratteristiche di un'antenna

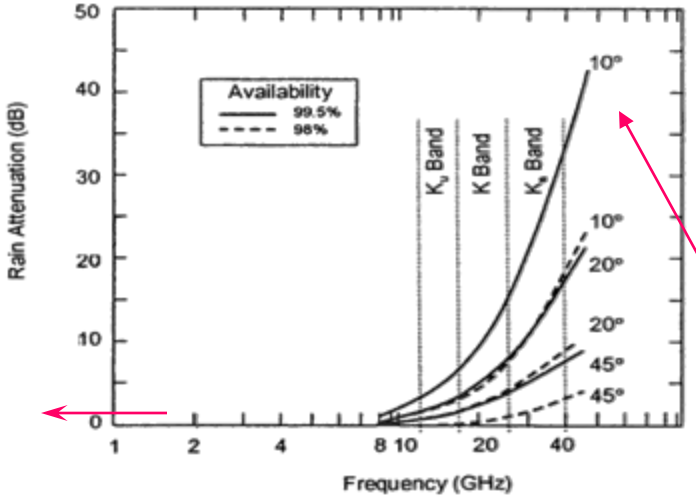
- Guadagno di picco: G

  Circular antenna beam

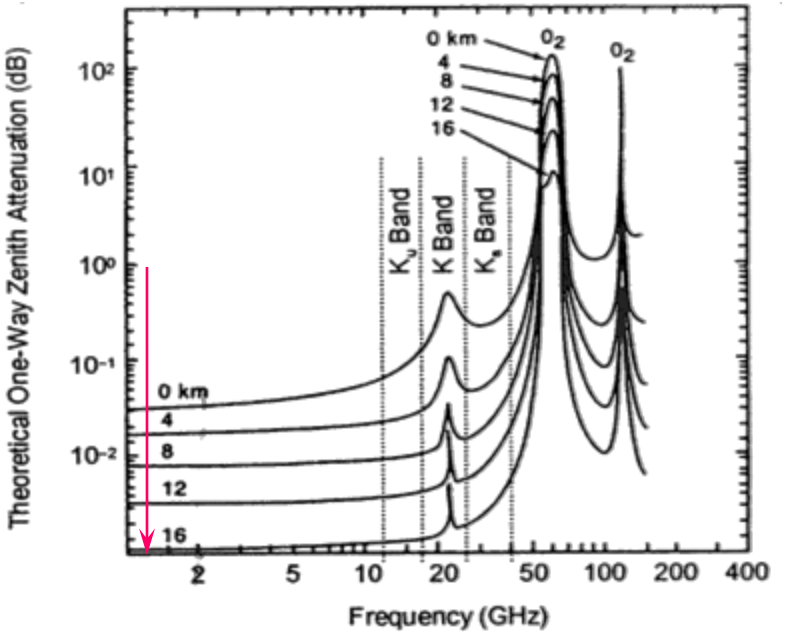
  - $G \cong \pi^2 D^2 \eta / \lambda^2 \Rightarrow G \cong \eta (21\pi 10^9/c\theta)^2$
- Half power width alla frequenza f (GHz): $\theta$
  - $\theta = 21 / fD$ (gradi) $\Leftrightarrow$ $D = 21 / f\theta$ [m]
- Riduzione di guadagno da offset di puntamento *e* (gradi): $L_\theta \Rightarrow G_f = L_\theta G$
  - $L_\theta = -12 (e/\theta)^2$ dB

# Perdite

- Path loss (atmospheric & rain): $L_a$




elevation angle



# Perdite

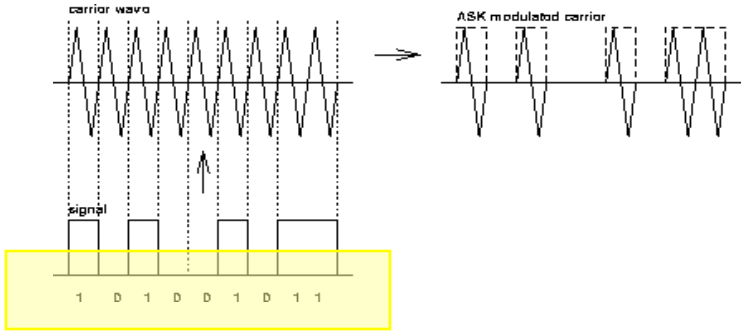
- Noise Temperature: $T_s$
- Space loss: $L_s$
  - $L_s = (\lambda/4\pi s)^2$ s=path length

| | | Downlink | | | Crosslink | Uplink | |
|---|---|---|---|---|---|---|---|
| Frequenza (GHz) | | **0.2** | 2-12 | 20 | 60 | **0.2-20** | 40 |
| System Noise Temperature | (K) | **221** | 135 | 424 | 682 | **614** | 763 |
| System Noise Temperature | (dB-K) | **23.4** | 21.3 | 26.3 | 28.3 | **27.9** | 28.8 |

# Modulazione 1/4

## Amplitude Shift Keying

$s(t) = f(t) \sin(2\pi f_c t + \phi)$

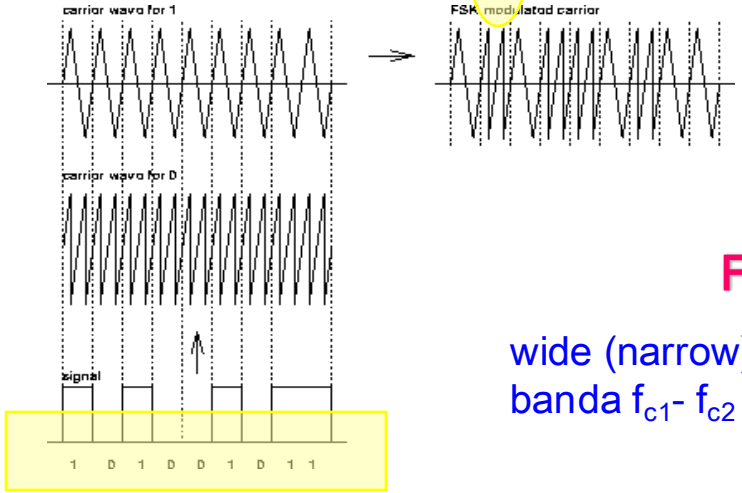



**ASK**

larghezza di banda inalterata

## Frequency Shift Keying

$s(t) = f_1(t) \sin(2\pi f_{c1} t + \phi) + f_2(t) \sin(2\pi f_{c2} t + \phi)$




**FSK**

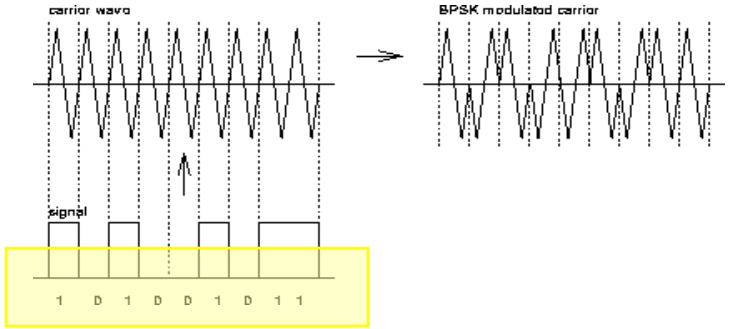
wide (narrow) band:
banda $f_{c1}$- $f_{c2}$ >> banda $f_1(t)$ - $f_2(t)$

# Modulazione 2/4

## Phase Shift Keying

$s(t) = \sin(2\pi f_c t + \phi(t))$

$\phi(t)$: 0 → 0; $\pi$ → $\pi/2$, $\pi$, $3\pi/2$




**PSK**

**BPSK**

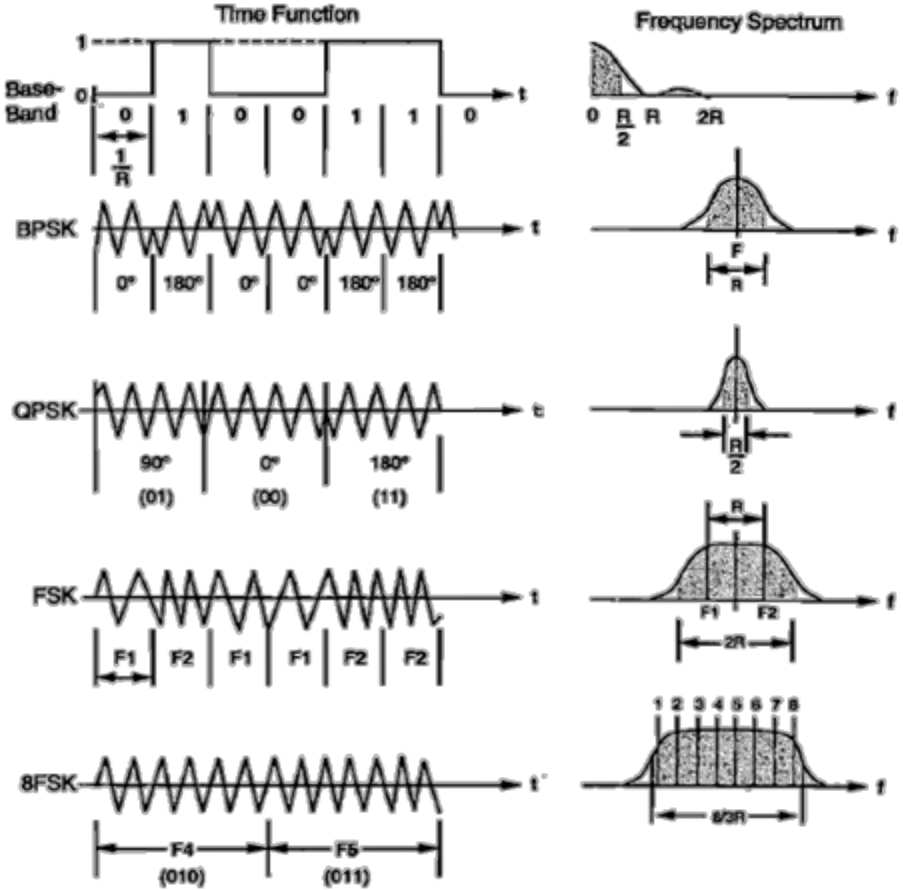
**QPSK**

**MPSK**

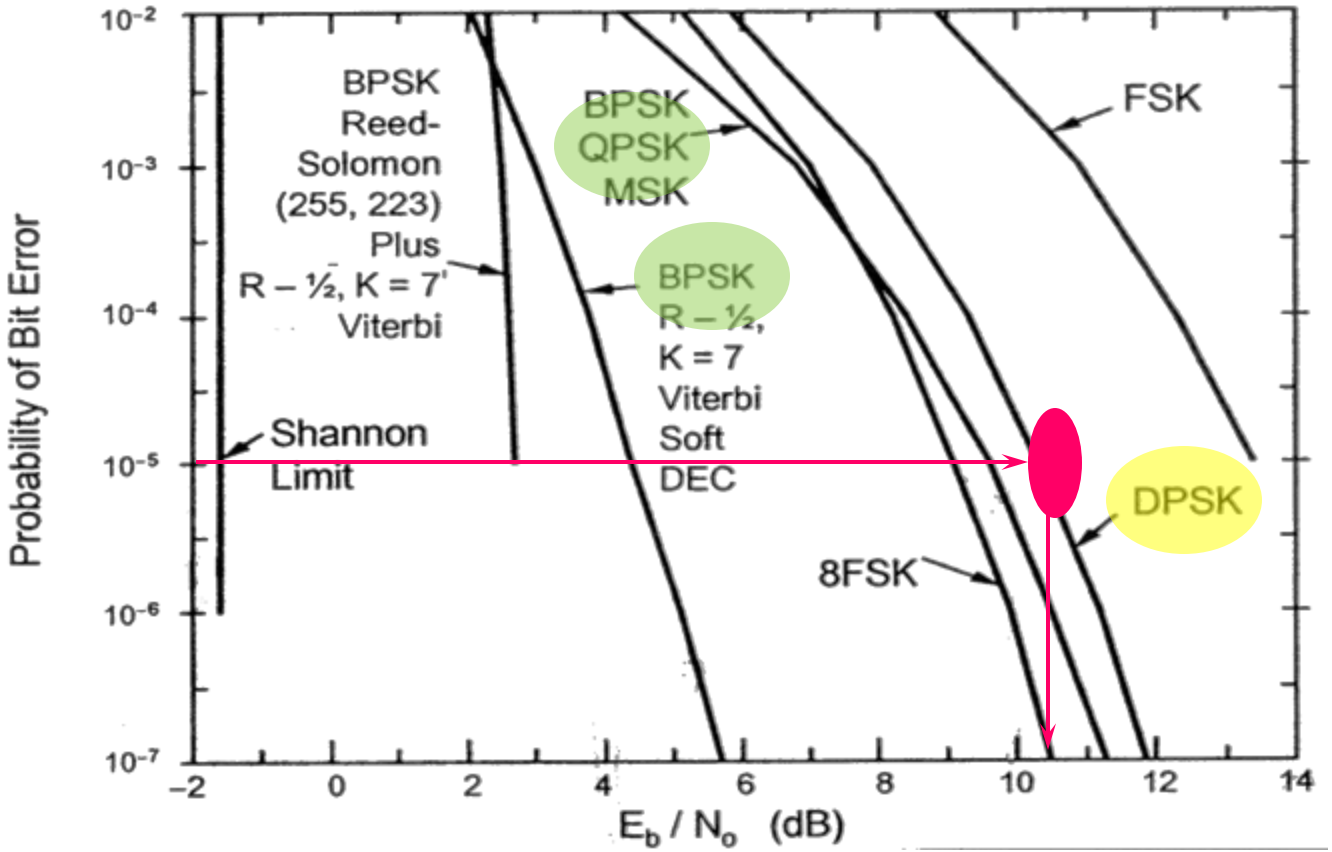
M fasi: $2\pi m/M$
m=0,1,... M-1

Signaling rate: numero di volte in cui cambia il parametro del segnale (A, f, $\phi$). Misura: baud
ASK, FSK, PSK: bit rate = signaling rate
QPSK, MPSK: bit rate > signaling rate

# Modulazione 3/4



# Modulazione 4/4




Phase/Frequency Shift Keying

# Esempio

- Downlink analysis
  - f=2.2 GHz, R=17 Mbps, bit err rate=$10^{-5}$
  - Trasmitter: P=13 dB, $L_l$=-1 dB, $G_t$=1.4 dB, $e_t$=70°
  - $L_s$=-… dB (h=1000 km), $L_a$=-0.5 dB
  - Receiver: $G_r$=39.1 dB, $e_r$=0.2°, $T_s$=135 K
  - $\eta$=0.55
  - PSK
  - $\Rightarrow E_b/N_o = (EIRP+L_s+L_a+G_r+228.6-R-T_s)$ dB
  - $\Rightarrow$ Margine = $(E_b/N_o) - (E_b/N_o)_{required}$ – perdite
- Uplink analysis …

# Esercizio (downlink)

| **Orbit & Geometry** | | |
|---|---|---|
| Altitude | 600 | km |
| Inclination | 60 | deg |
| Min. elevation angle | 10 | deg |

| **Link** | | |
|---|---|---|
| f | 12.6 | GHz |
| Modulation | QSPK | |
| Implementation loss | 2 | dB |

| **Requirements** | | |
|---|---|---|
| R | 28.8 | Gbps |
| Bit error rate | 1.0E-05 | |
| Margin | 3.5 | dB |

| **S/C** | | |
|---|---|---|
| Antenna efficiency | 0.55 | |
| Pointing error | 0.2 | deg |
| Transmitter Line Loss | 3 | dB |
| Antenna diameter | 1 | m |

| **Ground Station** | | |
|---|---|---|
| Antenna diameter | 4 | m |
| Antenna efficiency | 0.65 | |
| Pointin error | 0.04 | deg |
| Noise Temperature | 135 | K |
| Increase Noise due to rain | 174.55 | K |

Evaluate the power of the S/C transmitter!!!

$E_b/N_o = (EIRP+L_s+L_a+G_r+228.6-R-T_s)$ dB

$EIRP = P + L_l + G_t$