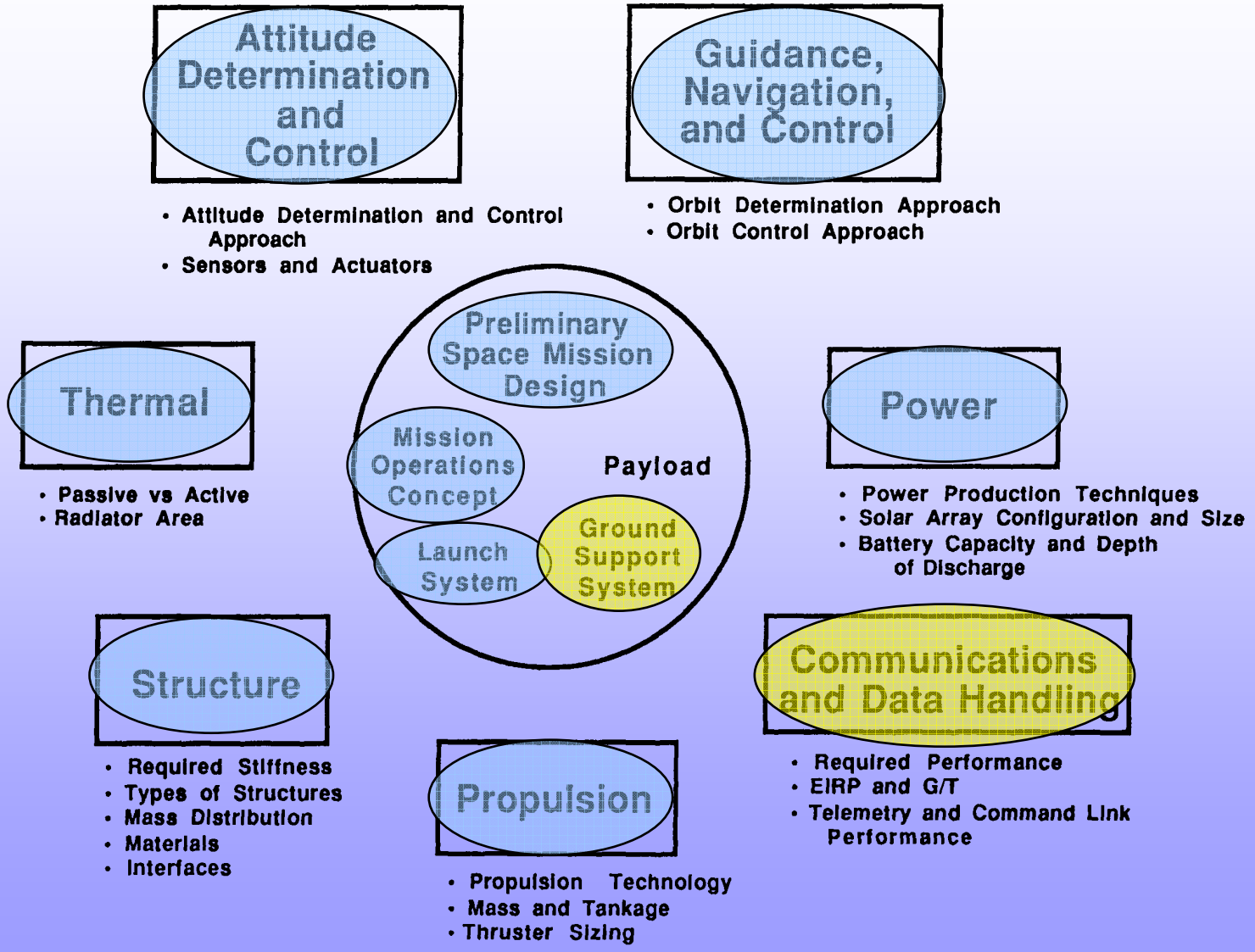
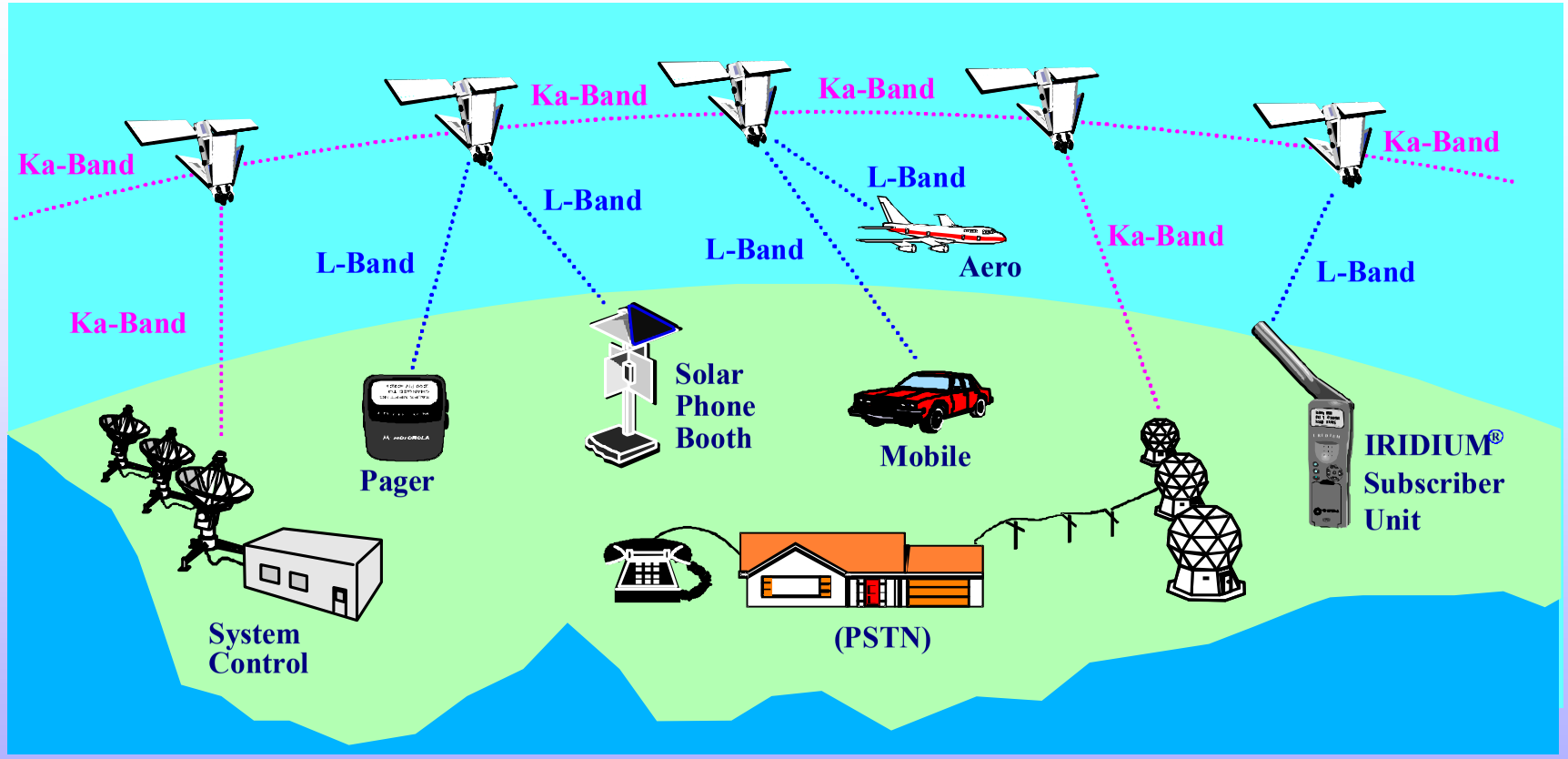
Telecomunicazioni da/per un satellite

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
  - Ottica: alte potenzialita' per elevate data rate
- Tipo di accesso
  - Permette S/C di ricevere segnali simultaneamente da piu' GS

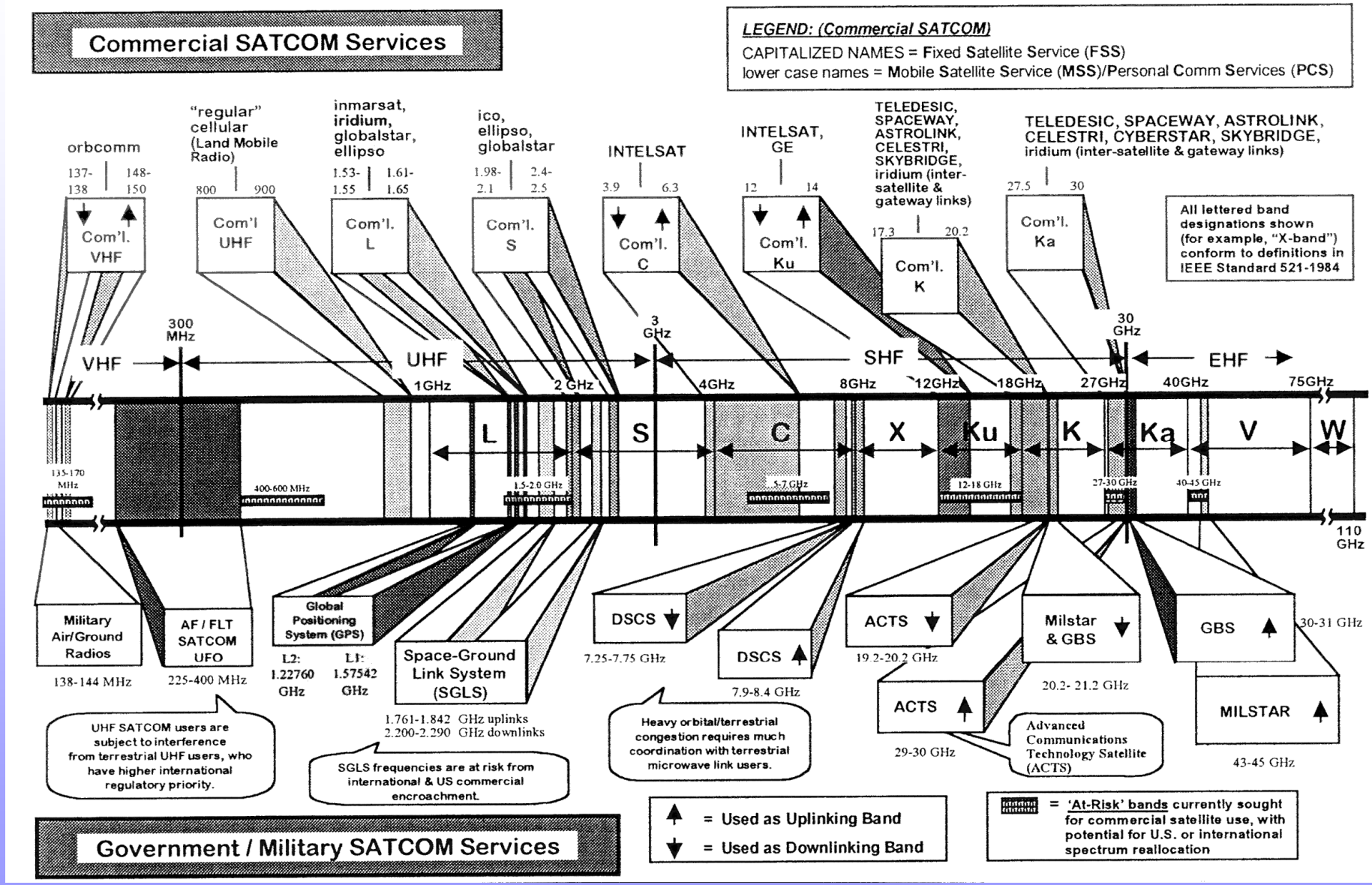
Caratterizzazione 2/2

- 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

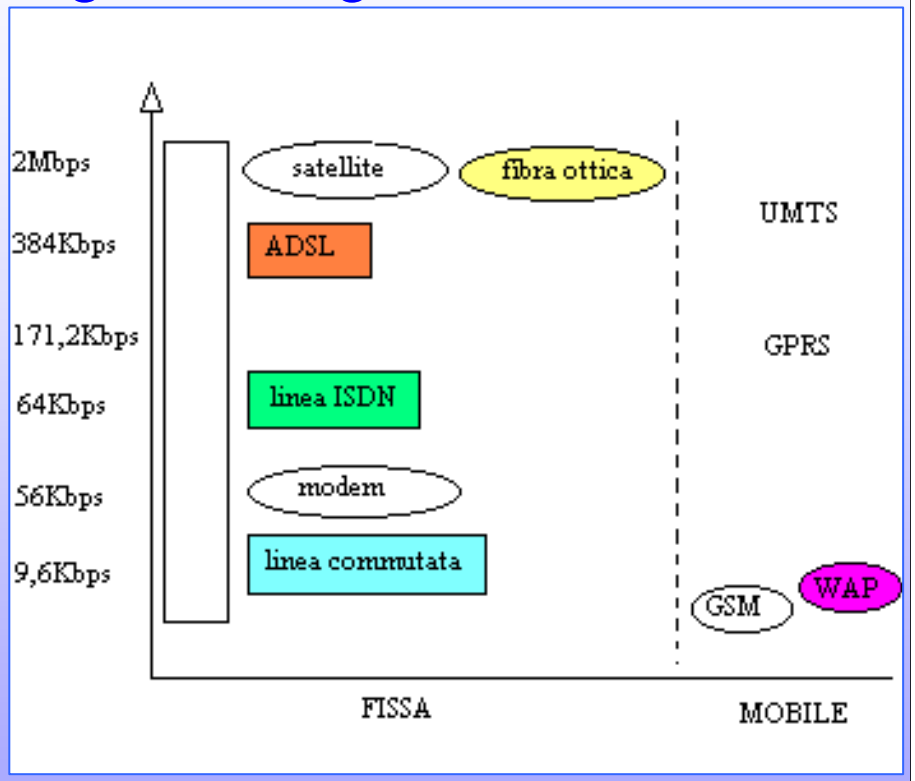
Data Rate: numero di bits di informazioni al secondo che devono essere trasferiti lungo il collegamento

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

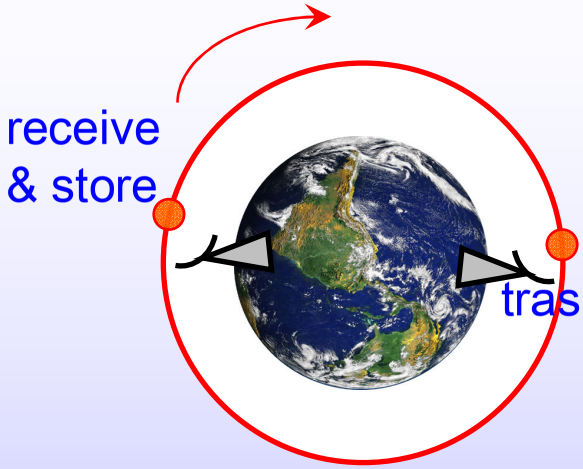


Teorema del campionamento:

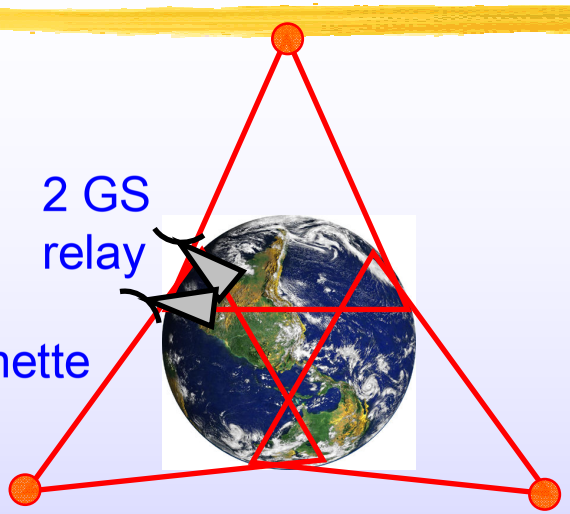
un segnale analogico con f_{max} puo' essere ricostruito completamente da campioni presi ogni $1/(2\ f_{max})$ secondi

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

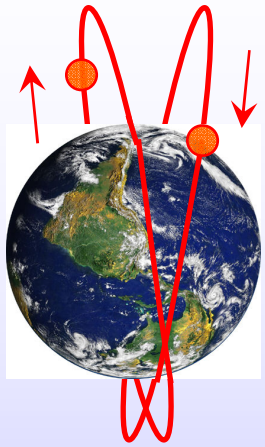
Communication Link vs Architettura



store & forward

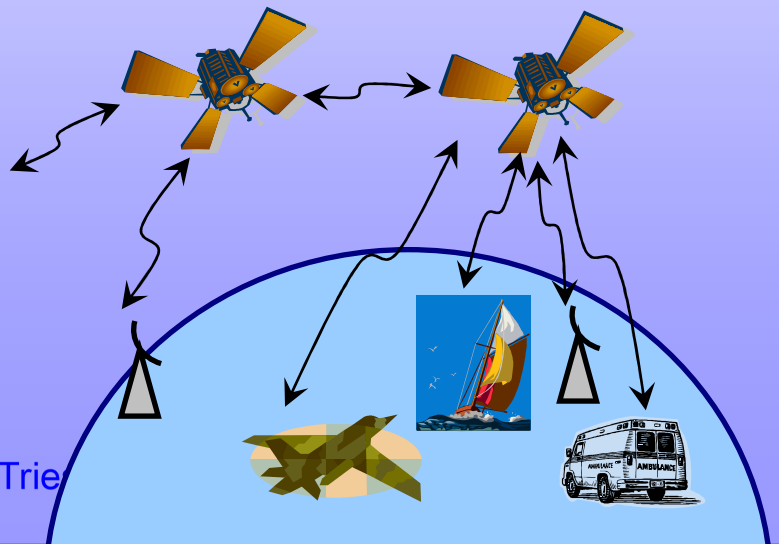


geostationary

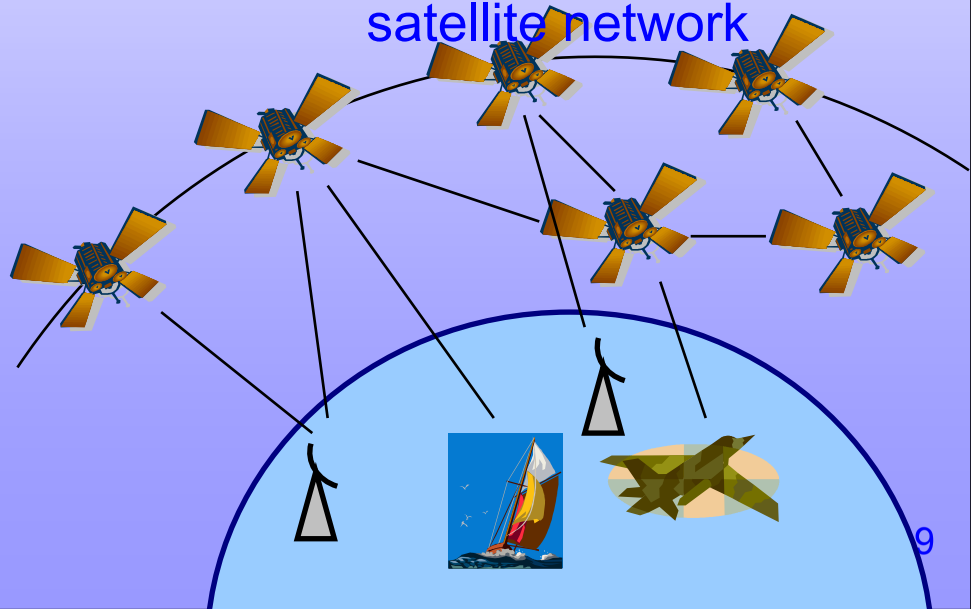


Molniya

cross-link in communication satellite system



cross-link in communication satellite network



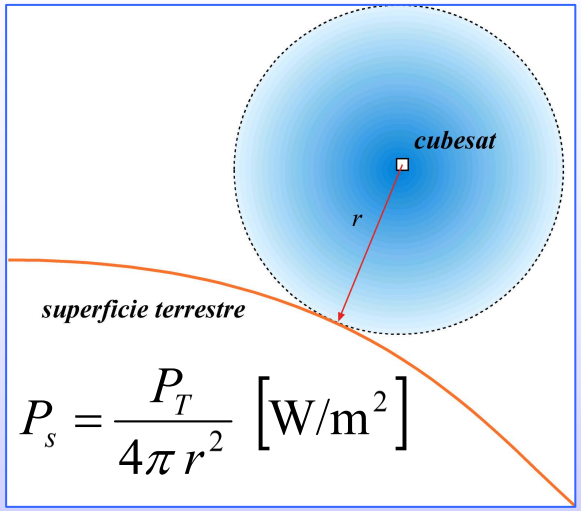
Procedura di richiesta della frequenza

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

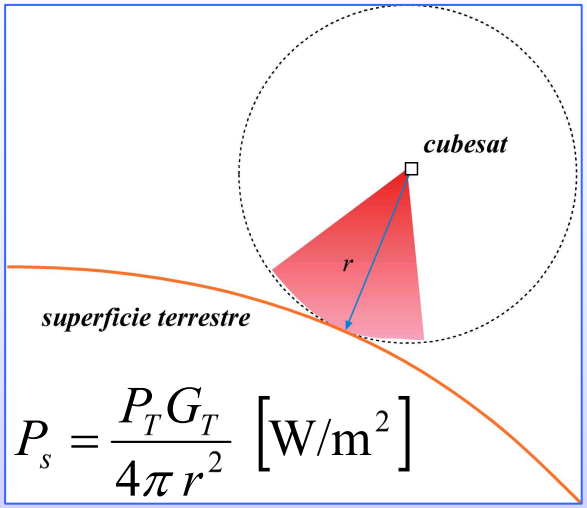
IRIDIUM

Un po' di teoria…

Trasmissione:

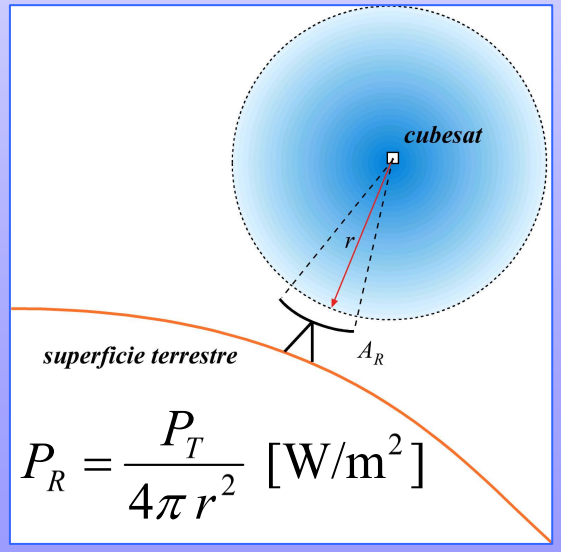


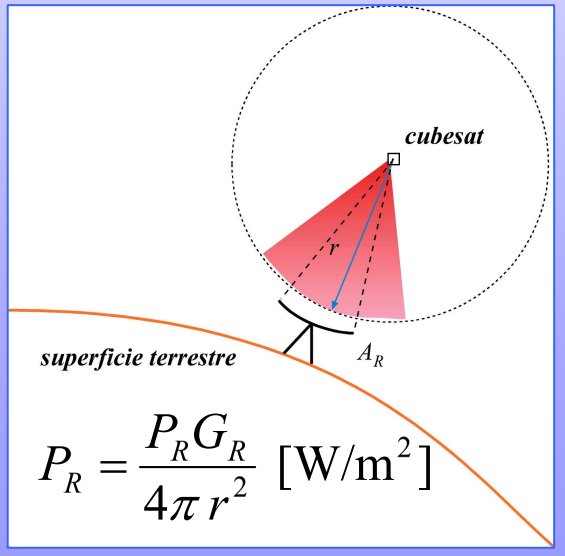
Antenna isotropa



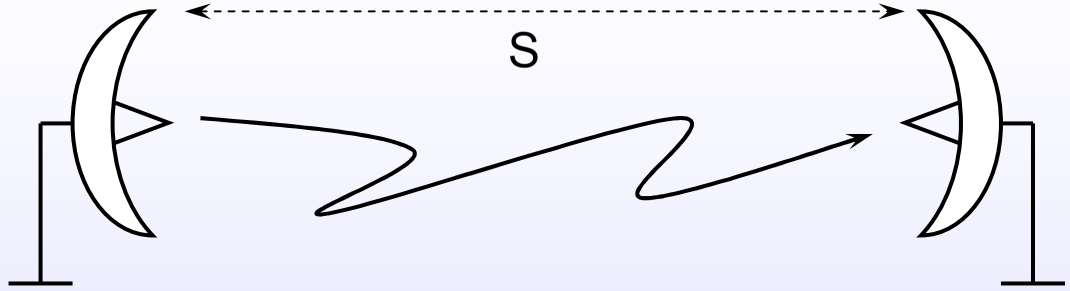
Antenna direttiva

Ricezione:





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

$$N_o = k\ T_s$$

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

figura di merito ricevitore

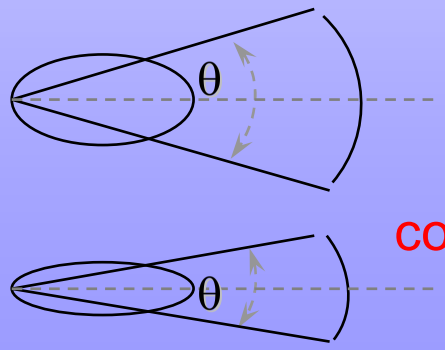
$$= (EIRP+L_s+L_a+G_r+228.6-R-T_s)\ dB$$

=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

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



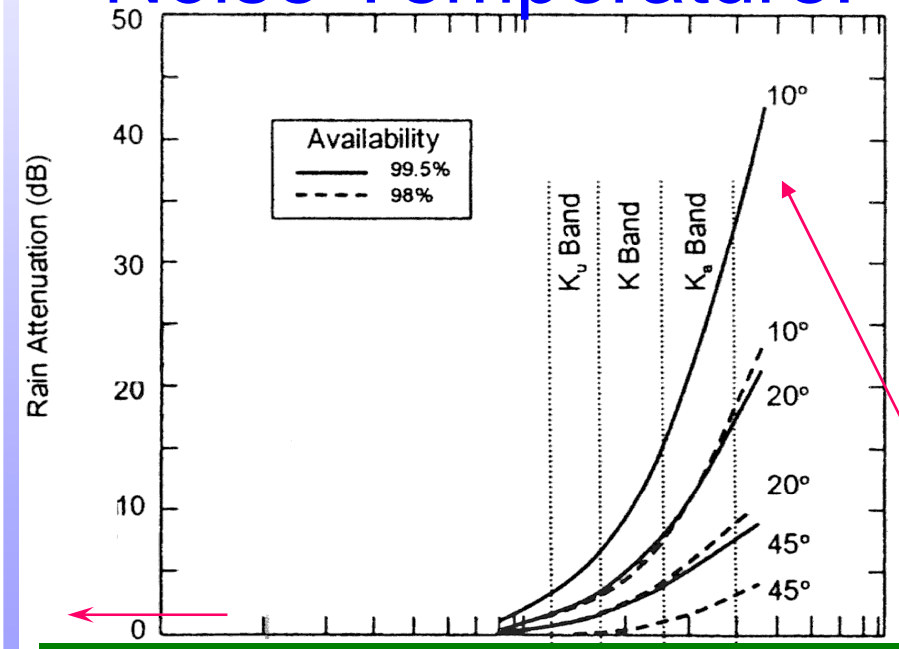
coverage area →

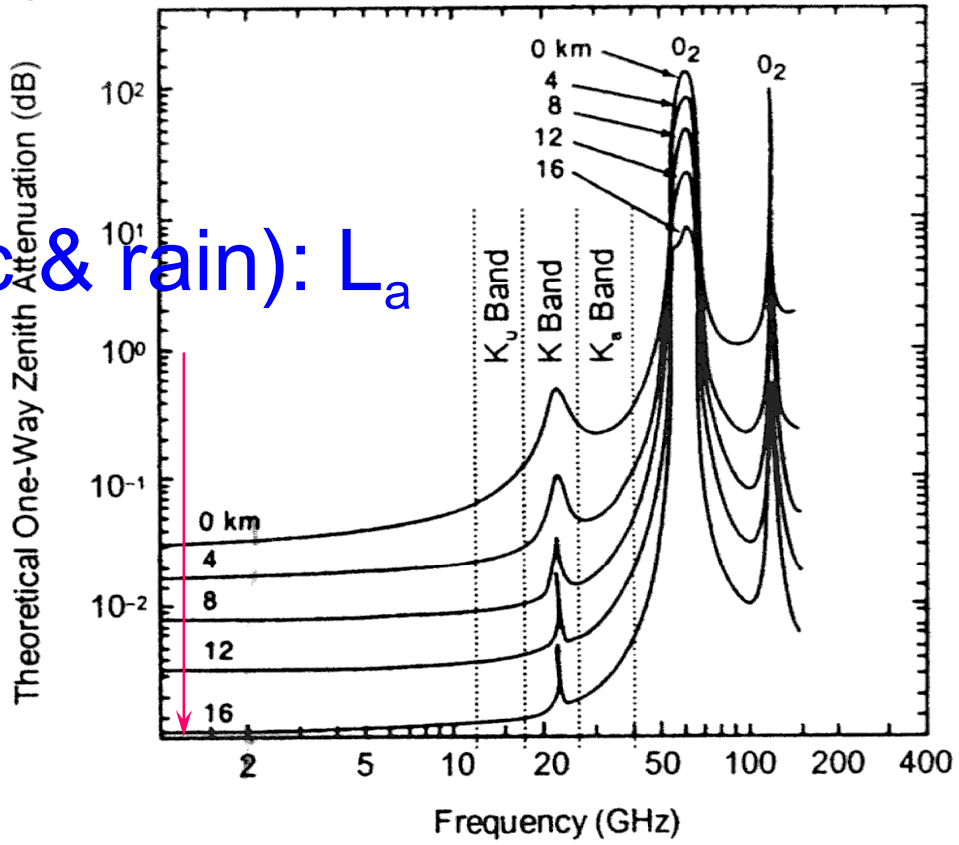
figure of merit →

		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

Perdite

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





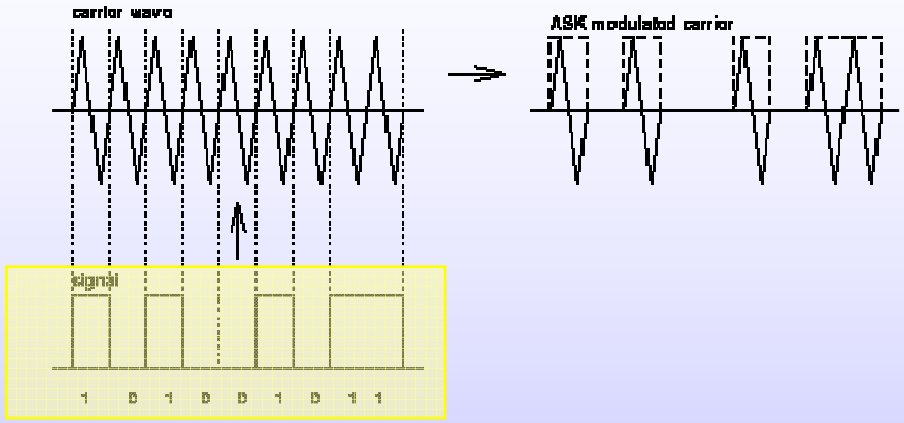
elevation angle

		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 1/3

Amplitude Shift Keying

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

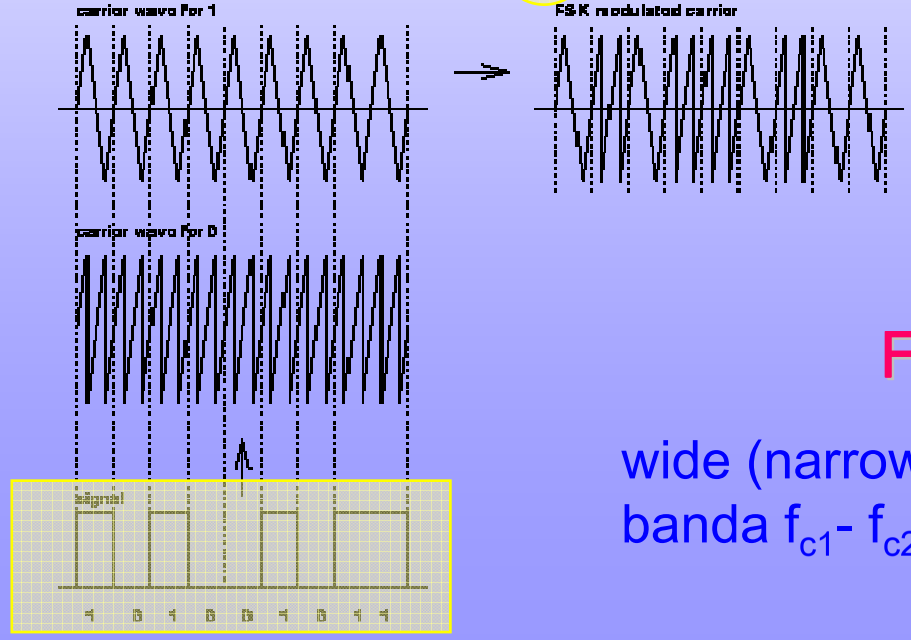


ASK

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

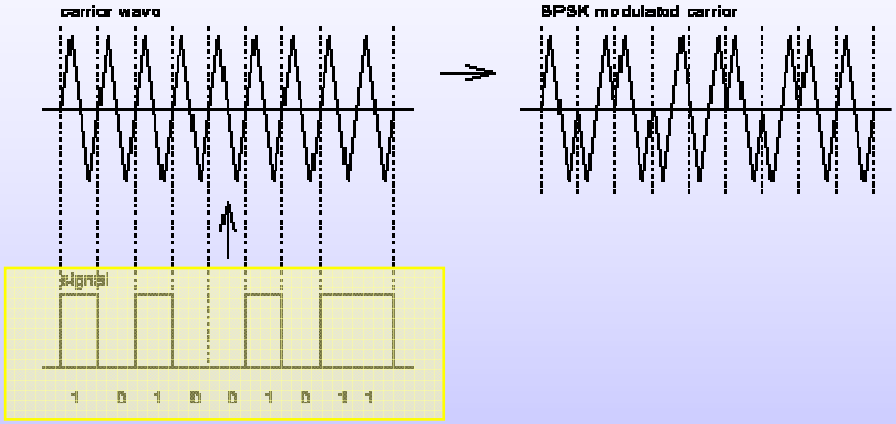
wide (narrow) band:
banda f_{c1}- f_{c2} >> banda $f_1(t)$ - $f_2(t)$

Modulazione 2/3

Phase Shift Keying

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

0 → 0
$\pi/2$
π
$3\pi/2$
← π



PSK

BPSK

QPSK

MPSK

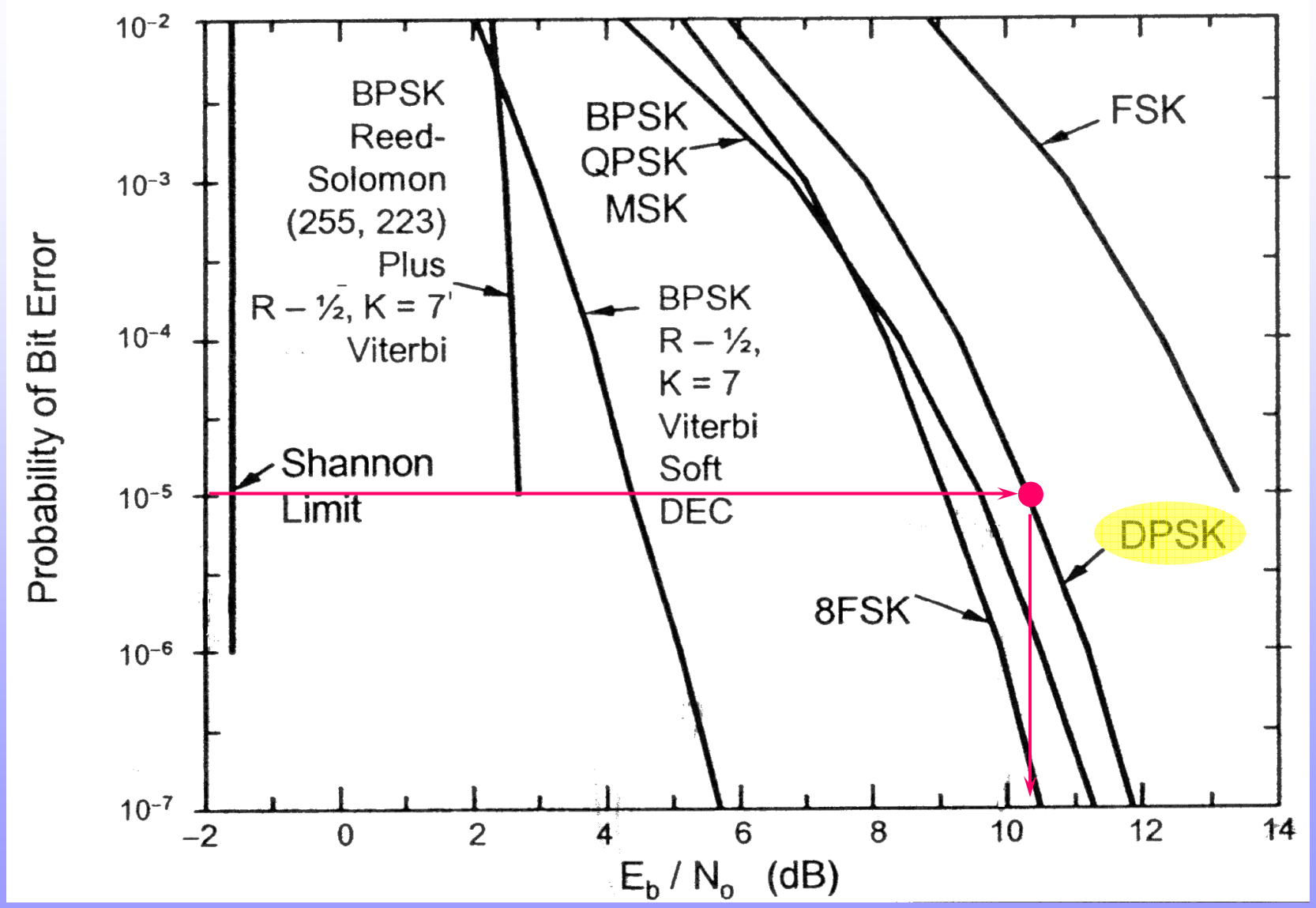
M fasi:
$2\pi m/M$
m=0,1,... M-1

Signaling rate: numero di volte in cui cambia il parametro del segnale (A, f, f). Misura: baud

AFK, FSK, PSK: bit rate = signaling rate

QPSK, MPSK: bit rate > signaling rate

Modulazione 3/3



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
  - η=0.55

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

  $\Rightarrow$ Margine = $(E_b/N_o) - (E_b/N_o)_{required}$ – perdite
- Uplink analysis …

Esercizio

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 Receiver!!!