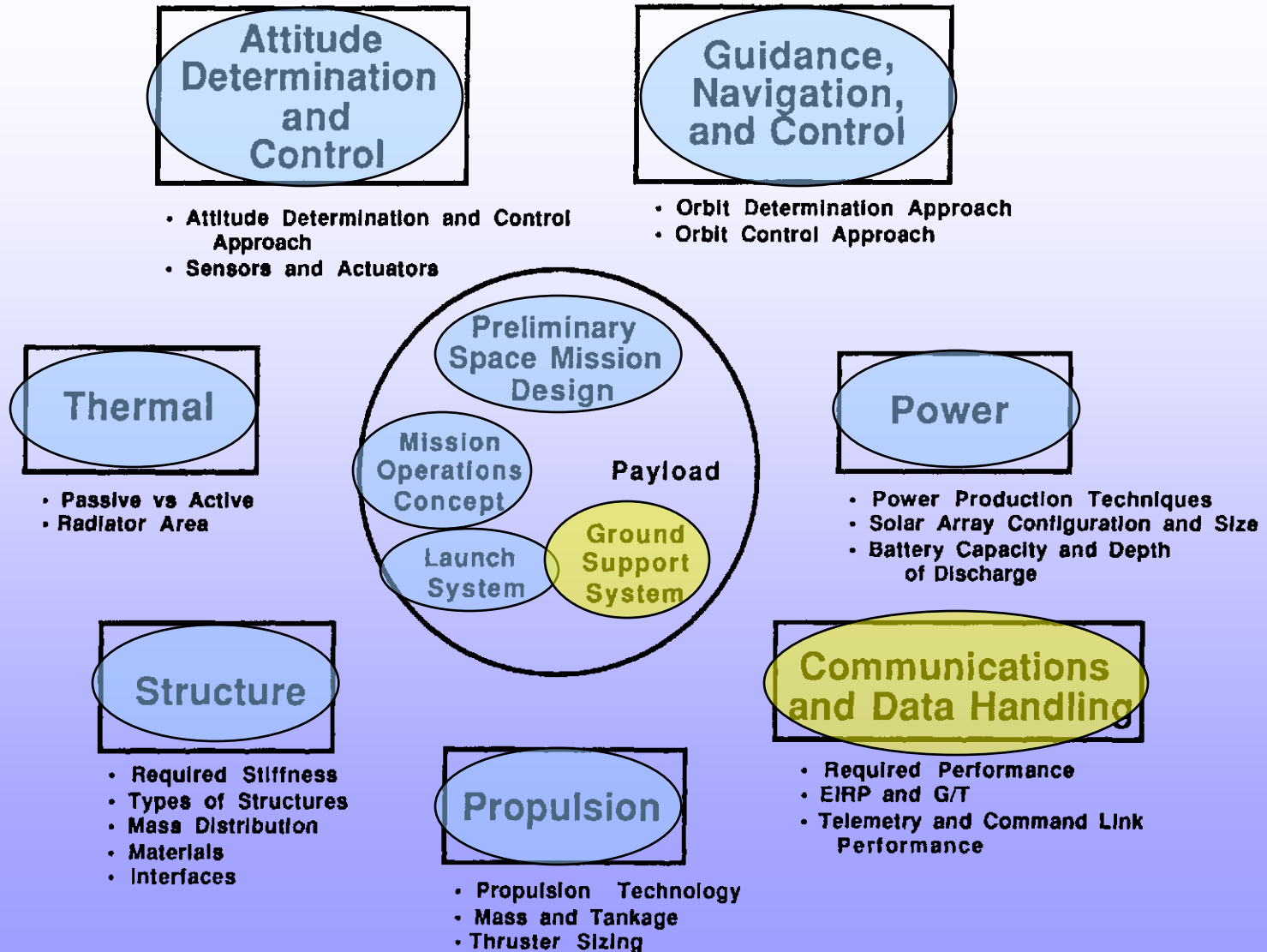
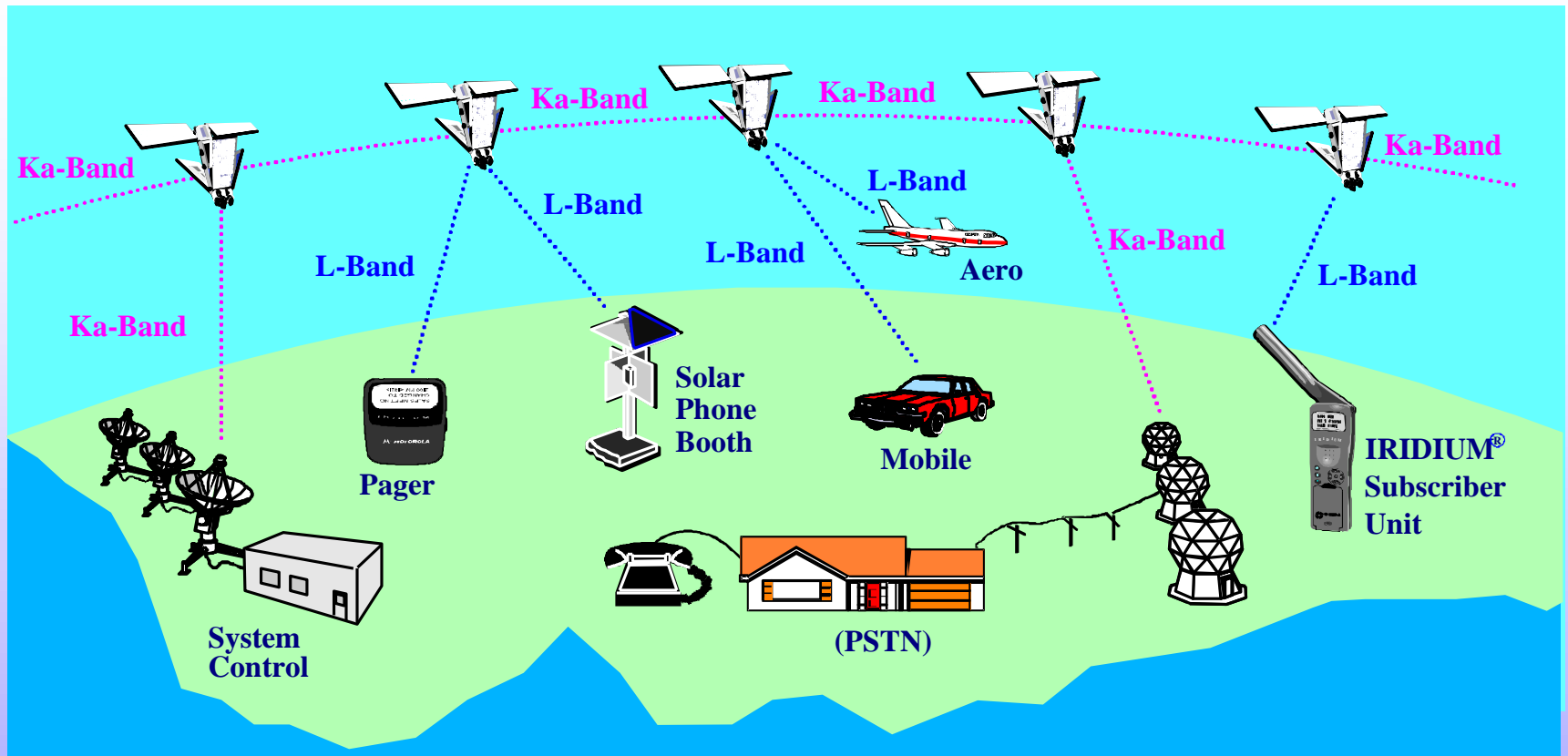

Telecomunicazioni da/per un satellite

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 potenzialità per elevate 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

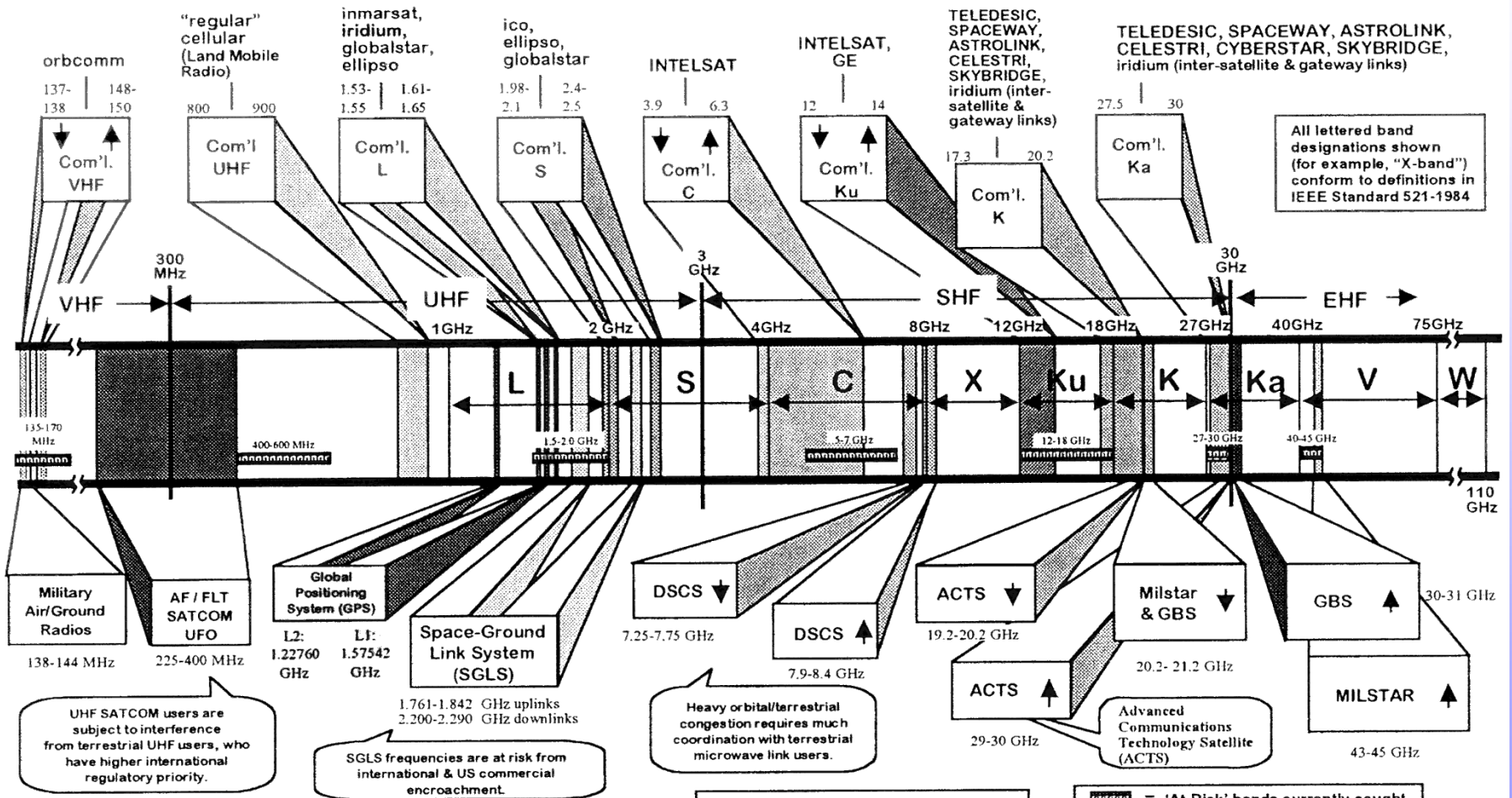
- Architecture

- Transparent
- Regenerative (on-board modulation conversion, forward error correction, storage, and information processing)

Utilizzo delle frequenze

Commercial SATCOM Services

LEGEND: (Commercial SATCOM)
 CAPITALIZED NAMES = Fixed Satellite Service (FSS)
 lower case names = Mobile Satellite Service (MSS)/Personal Comm Services (PCS)



Government / Military SATCOM Services

▲ = Used as Uplinking Band
 ▼ = Used as Downlinking Band

[Hatched Box] = 'At-Risk' bands currently sought for commercial satellite use, with potential for U.S. or international spectrum reallocation

Processo di Disegno del Sistema

- Identifica i requisiti
 - Specifica: tipo dati, utenti, locazione utente, quantità di dati, Ground Station, tempi di accesso, ritardi di trasmissione, disponibilità...
- Verifica il possibile utilizzo di altri sistemi
 - Identifica: collegamenti e posizionamento GS e “processing” già in uso
 - Considera l’uso di satelliti/GS “relay”
- Determina il data rate
 - $n_{\text{campioni}} \cdot n_{\text{bit/campione}}$
- 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

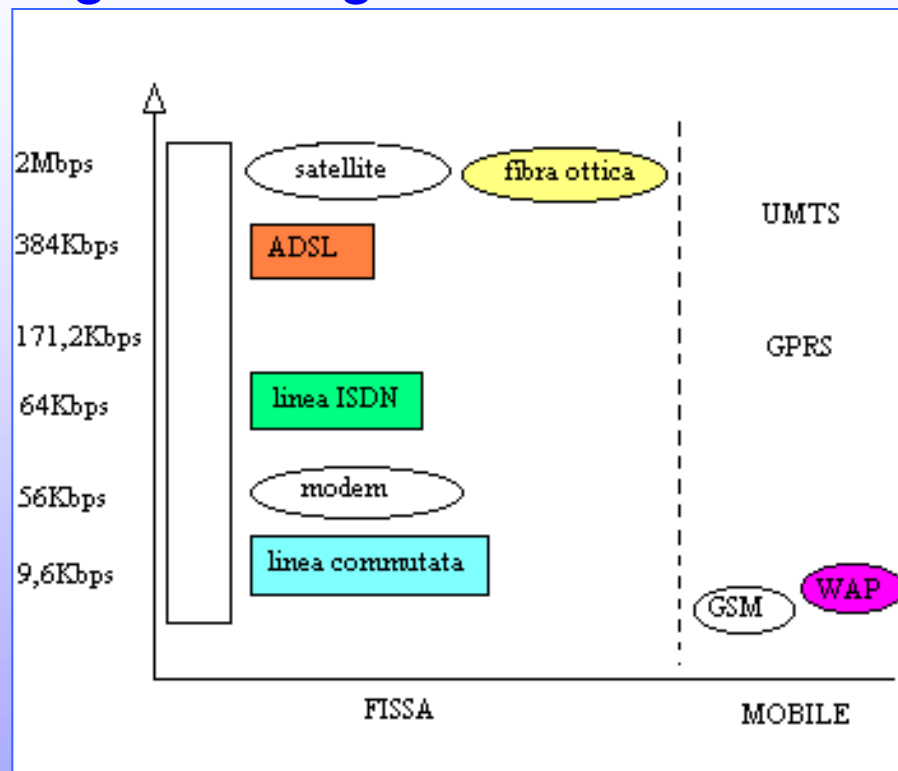
Sistemi digitali: segnali analogici campionati e quantizzati !

circuito vocale telefonico:

$$n_{\text{campioni}} = 8000 \text{ campioni/s}$$

$$n_{\text{bit/campione}} = 8 \text{ bit/campione}$$

$$\Rightarrow \text{data rate} = 64 \text{ kbps}$$



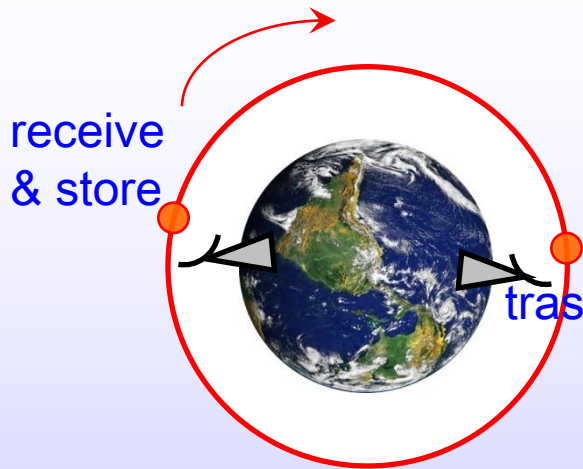
Teorema del campionamento:

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

Esempio: musica di alta qualita' $f_{\text{max}} = 20 \text{ kHz}$,

CD player lavorano con un sample di 44.1 kHz

Communication Link vs Architettura



store & forward

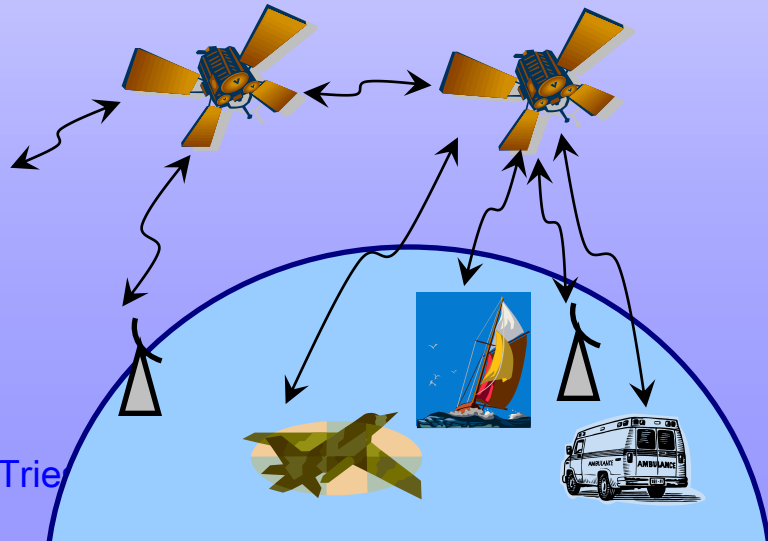


geostationary

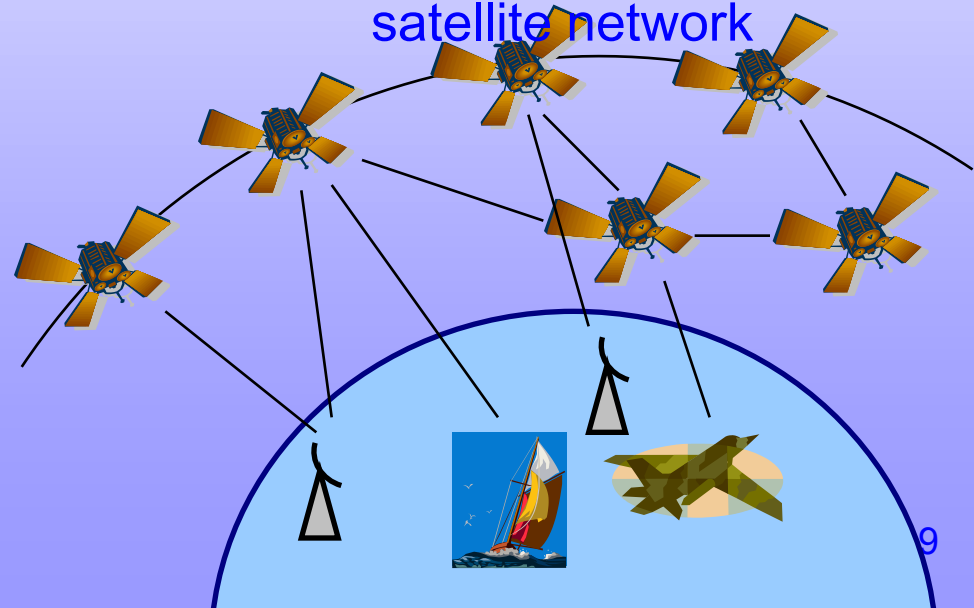


Molniya

cross-link in communication satellite system



cross-link in communication satellite network



Procedura di richiesta della frequenza

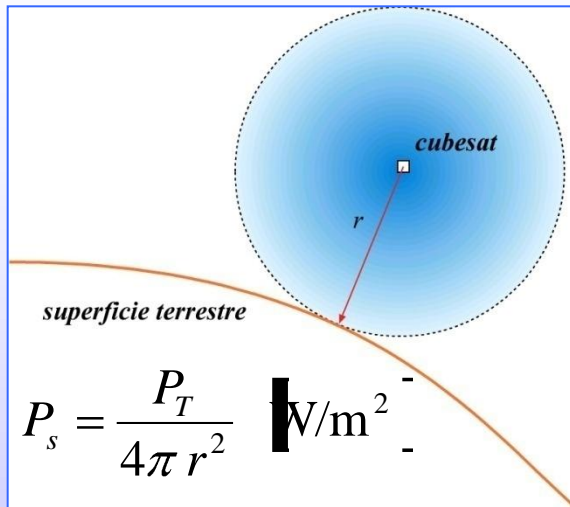
- Richiesta nazionale: FCC (usa) 1990
- Italia: richiesta internazionale ITU 1992
- ITU: World Administrative Radio Conferences (WARC) 1992
- ITU: pubblica le regole 1995

IRIDIUM

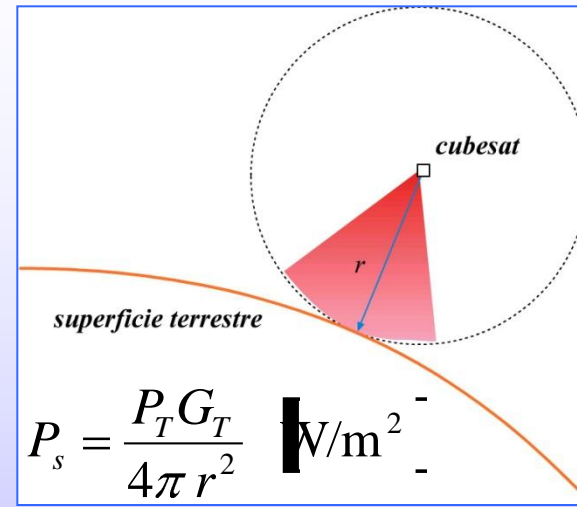


Un po' di teoria...

Trasmissione:

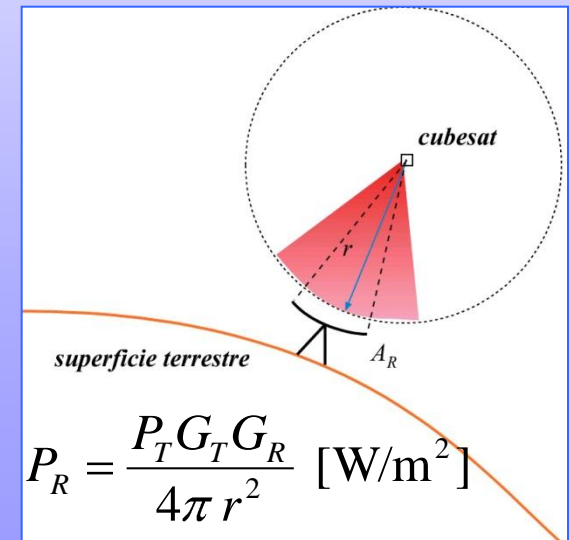
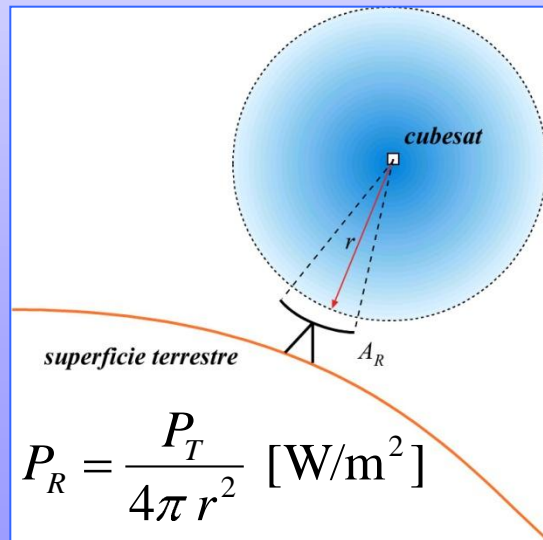


Antenna isotropa

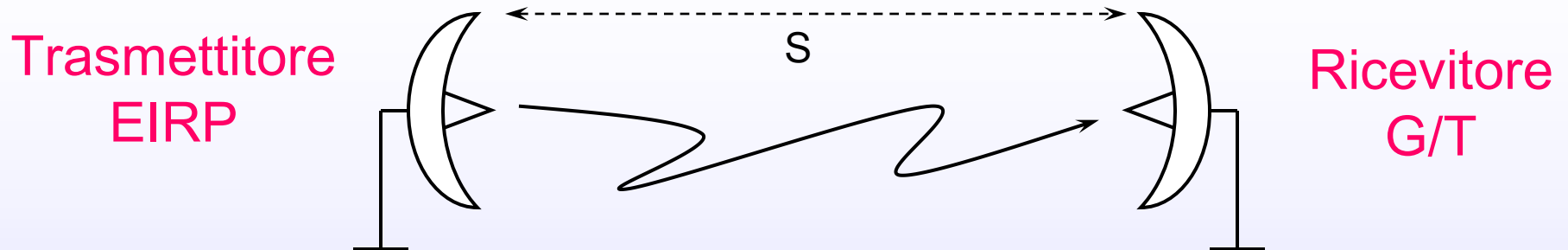


Antenna direttiva

Ricezione:



Analisi del collegamento



➤ Energy per bit (E_b), Noise density (N_o):

$$E_b = P L_l G_t L_s L_a G_r / R = \text{EIRP} L_s L_a G_r / R$$

$$N_o = k T_s$$

figura di merito trasmettitore

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

figura di merito ricevitore

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

➤ Trasmittitore: P =potenza, L_l =line loss, G_t =guadagno $= 10 \text{ Log}()$

➤ 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

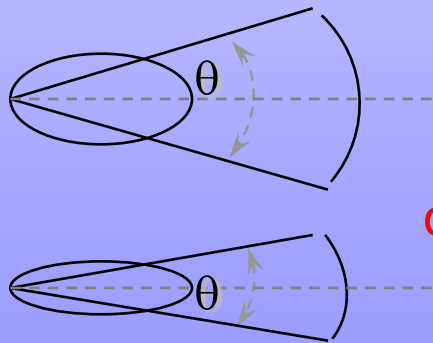
➤ $G \cong \pi^2 D^2 \eta / \lambda^2 \Rightarrow G \cong \eta (21\pi 10^9 / c\theta)^2$

➤ Half power width alla frequenza f (GHz): θ

➤ $\theta = 21 / fD$ (gradi) $\Leftrightarrow D = 21 / f\theta$ [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



coverage area →

figure of merit →

		antenna 1	antenna 2
f	(GHz)	0.500	
λ	(m)	0.600	
η		0.58	
L_f		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

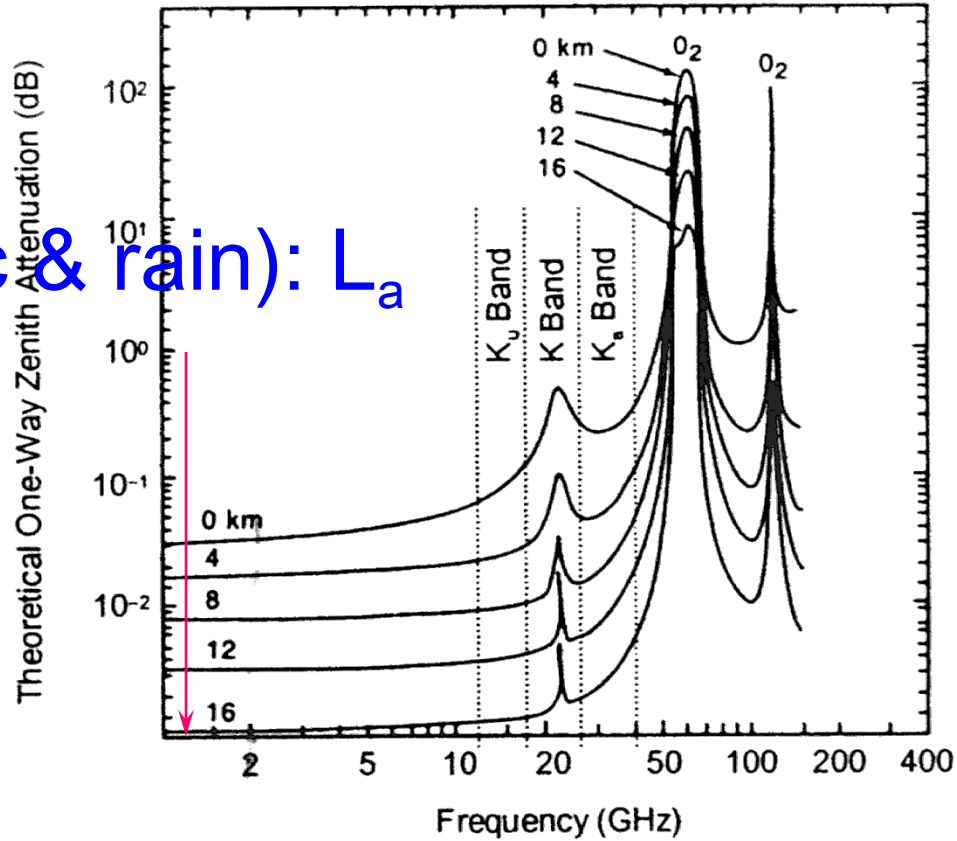
Perdite

➤ Space loss: L_s

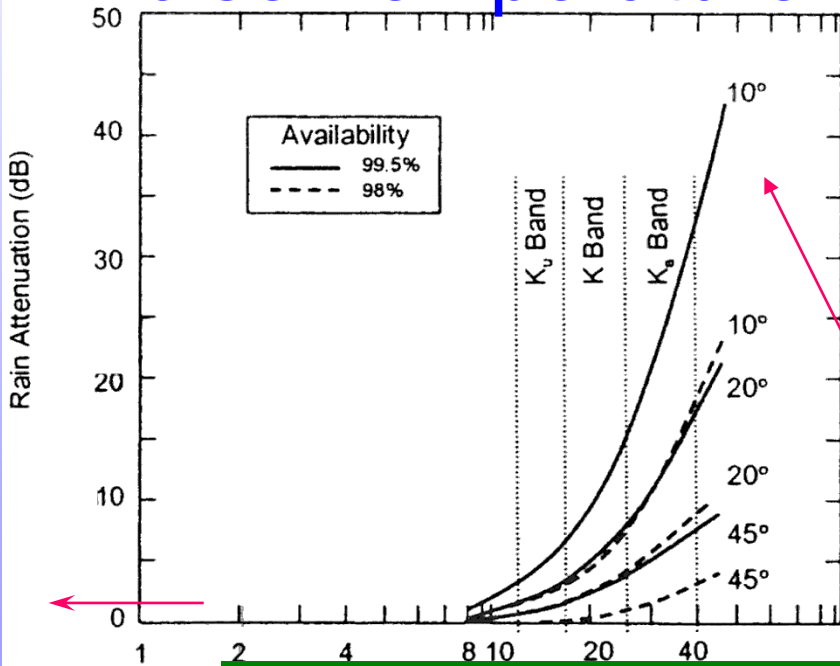
➤ $L_s = (\lambda/4\pi s)^2$ s=path length

➤ Path loss (atmospheric & rain): L_a

➤ Noise Temperature: T_s



elevation angle

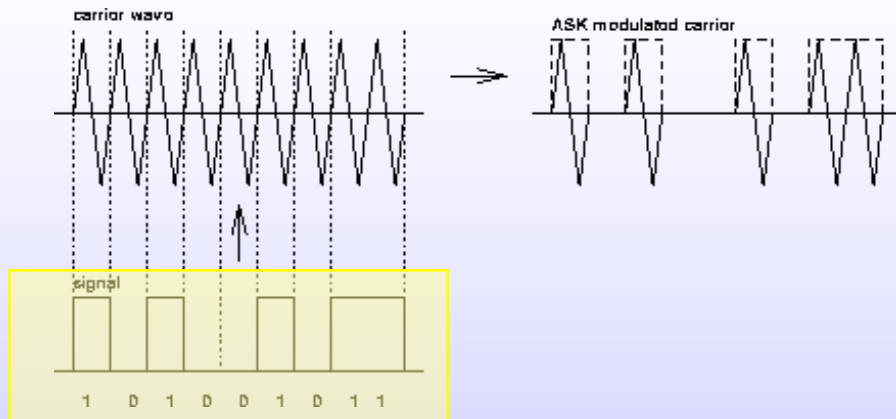


	Downlink	Crosslink	Uplink
Frequenza (GHz)	0.2 - 20	60	0.2-40
System Noise Temperature (K)	221	682	614
System Noise Temperature (dB-K)	23.4	28.3	27.9

Modulazione 1/4

Amplitude Shift Keying

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

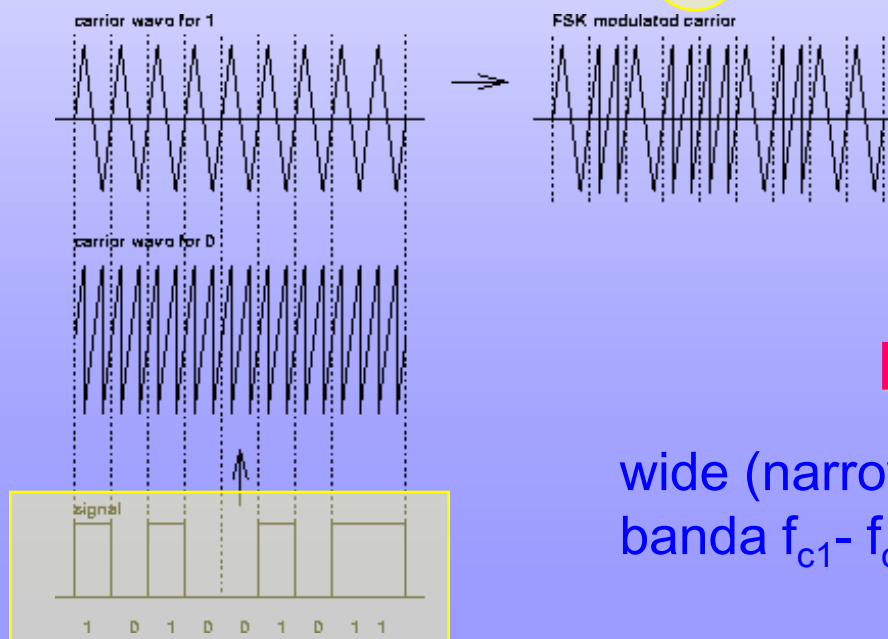


ASK

larghezza di banda
inalterata

Frequency Shift Keying

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

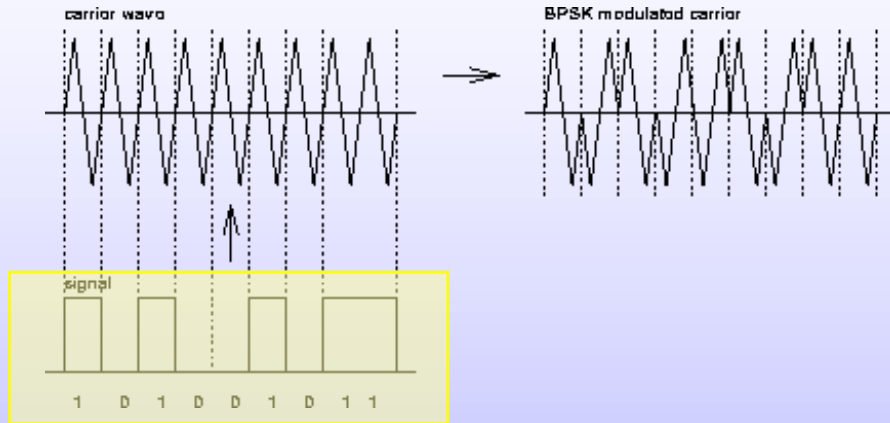


FSK

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

Modulazione 2/4

Phase Shift Keying



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

0
 $\pi/2$
 π
 $3\pi/2$

PSK

BPSK

QPSK

MPSK

M fasi:

$2\pi m/M$

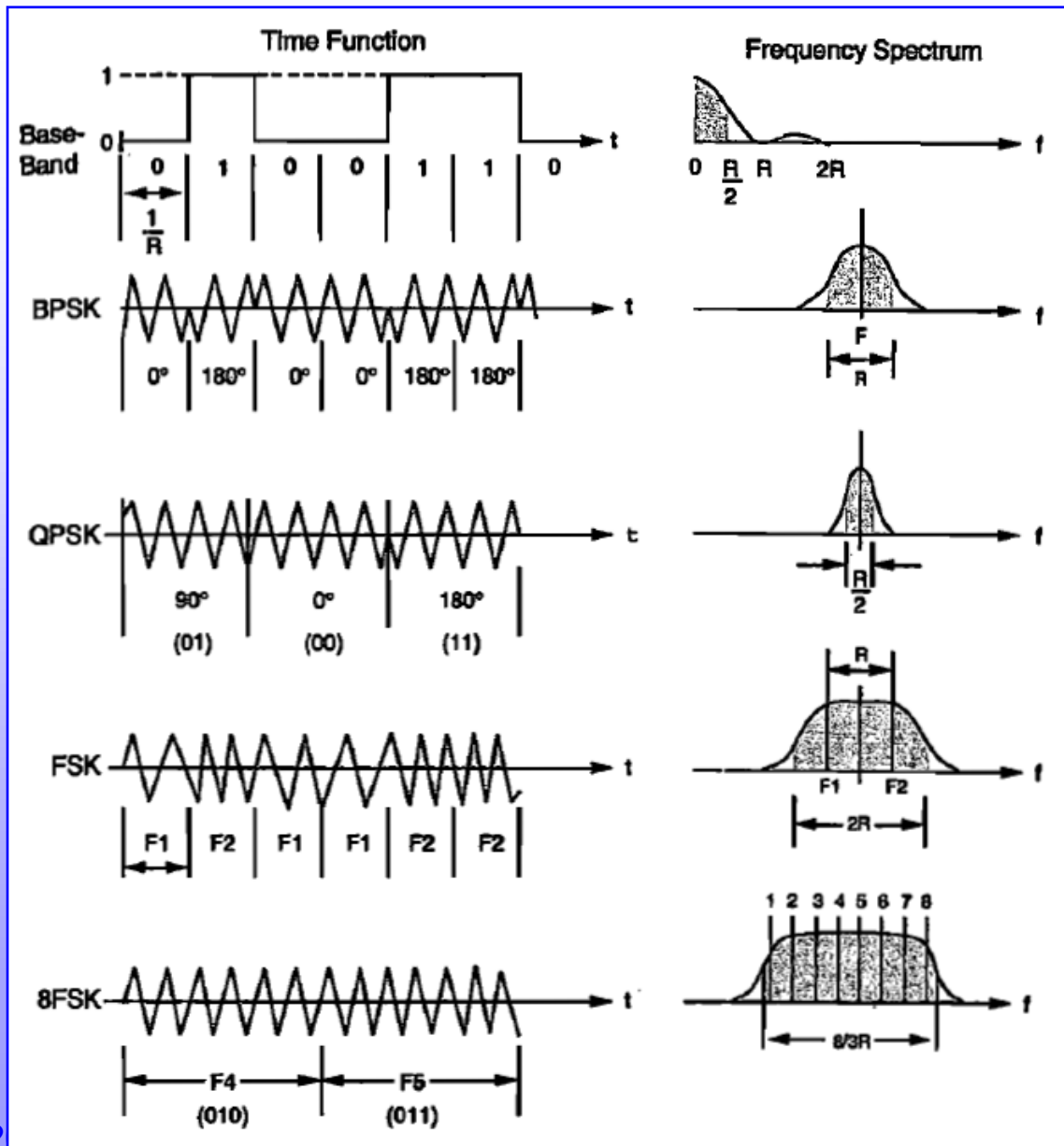
$m=0,1,\dots M-1$

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

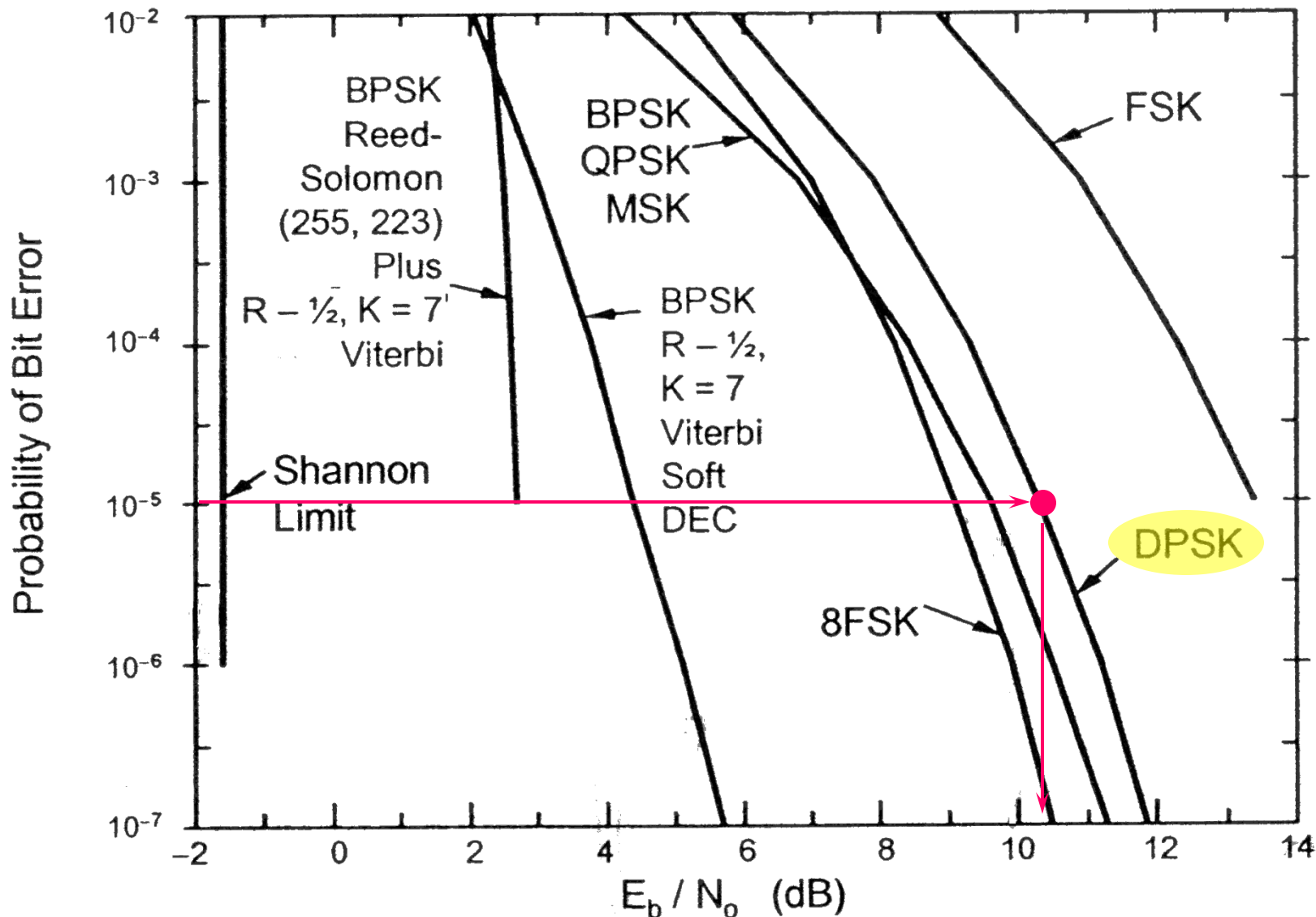
AFK, FSK, PSK: bit rate = signaling rate

QPSK, MPSK: bit rate > signaling rate

Modulazione 3/4



Modulazione 4/4



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, $e_t=70^\circ$
- $L_s=-\dots$ dB ($h=1000$ km), $L_a=-0.5$ dB
- Receiver: $G_r=39.1$ dB, $e_r=0.2^\circ$, $T_s=135$ K
- $\eta=0.55$

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

$$\Rightarrow \text{Margine} = (E_b/N_o) - (E_b/N_o)_{\text{required}} - \text{perdite}$$

➤ 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
Pointing error	0.04 deg
Noise Temperature	135 K
Increase Noise due to rain	174.55 K

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

Planning di una Missione Spaziale

Fase A

Fase B

Fase C

Fase D

- studio di fattibilita'

- simulazioni

- disegno finale

- costruzione

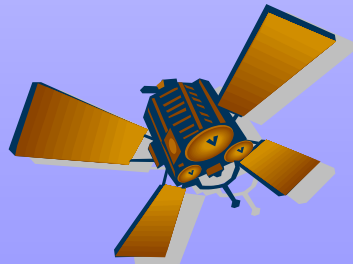
-aspetti ingegneristici

-aspetti scientifici

- test

- costi

⇒ specifiche tecniche
e scientifiche a
istituti/industrie



- Modello Strutturale

- Modello Elettrico (EMC)

-



QM

FM

