Earth Station

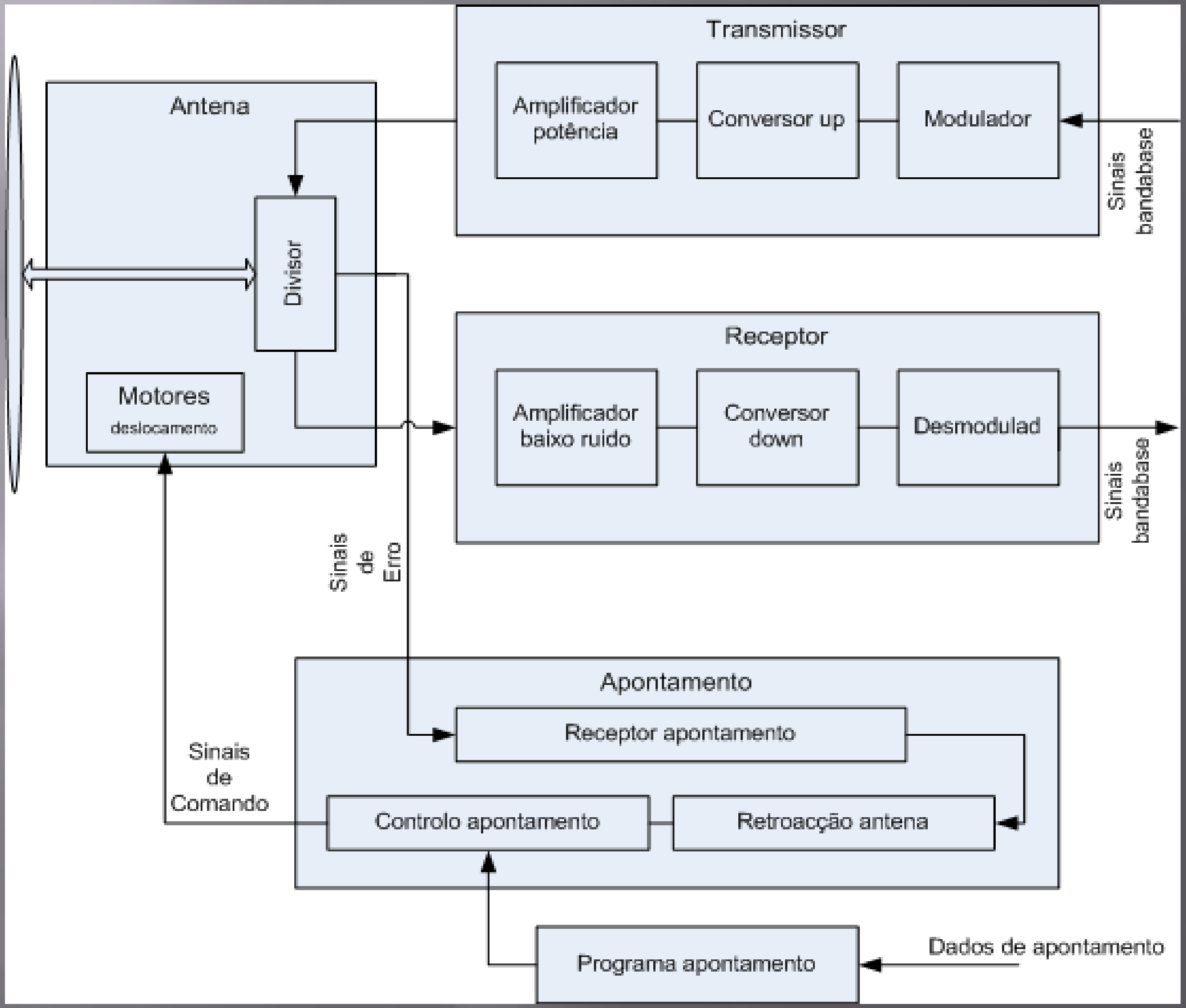
Technology

- Antennas
  - Types, TVRO-*Television receive only*, Tx_Rx,Telemetry
  - Antenna characteristics performance (G/T-, isolation contour,sidelobe transmission, gain)
  - Feed
  - Tracking

- RF equipment
  - BUC-*Block up converter)*, LNB-*Low noise block)*, Transceivers, Filters, Modem, Waveguides, coaxial cable, beacons

- Test equipment, measurement units
  - Spectrum analyser, Power meter, Power sensor , data analyser dBM, dBW, EIRP, dB

Earth Station Schematic



Antenna 1

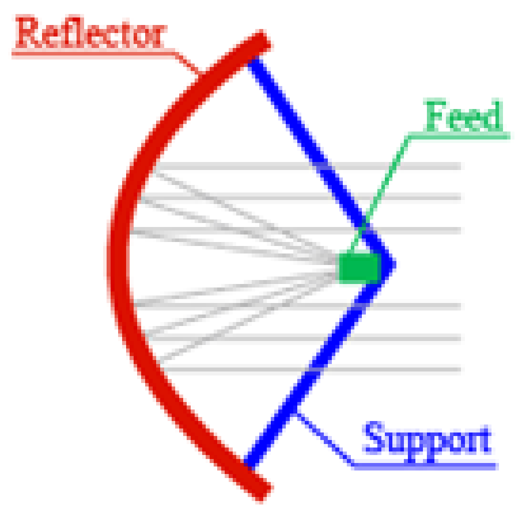
Service type

- Transmission and Reception standalone
- Transmission and Reception transportable
- Satellite News Gathering
- TeleVision Receive Only
- Telemetry

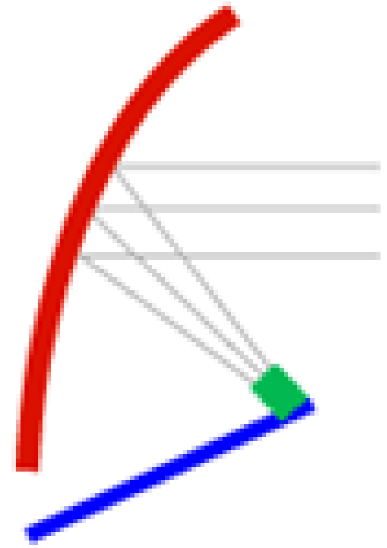
Antenna 2

- Single paraboloid reflector antenna
  - Paraboloid
  - Paraboloid with *single feed offset*
  - *Paraboloid horn reflector*
  - Parabolic with multi *feed offset*
- Dual reflector antenna
  - Cassegrain
  - Cassegrain + horn reflector
  - Cassegrain + 2 or 4 reflector
  - Offset Cassegrain
  - Gregorian
  - Offset Gregorian

Antenna 3



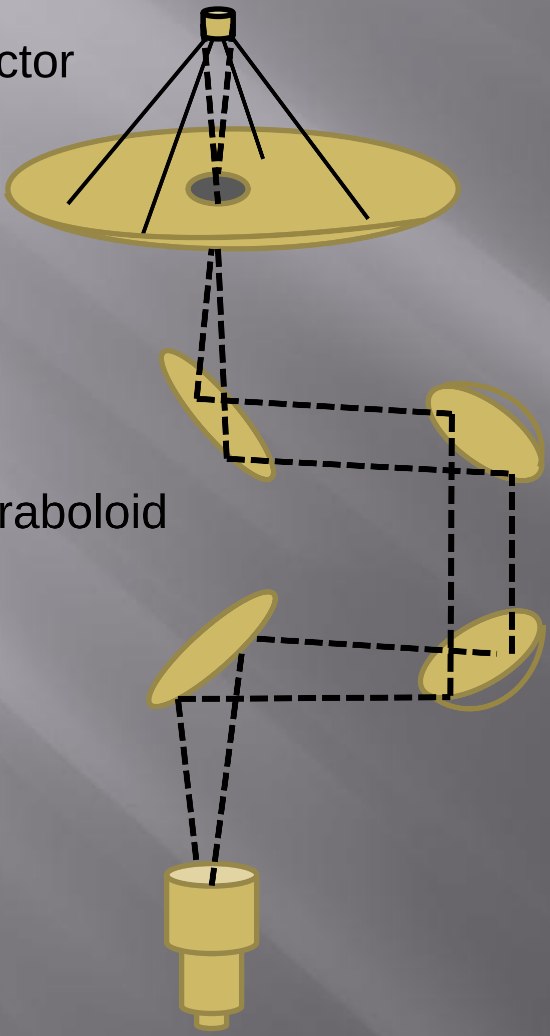
Parabolic



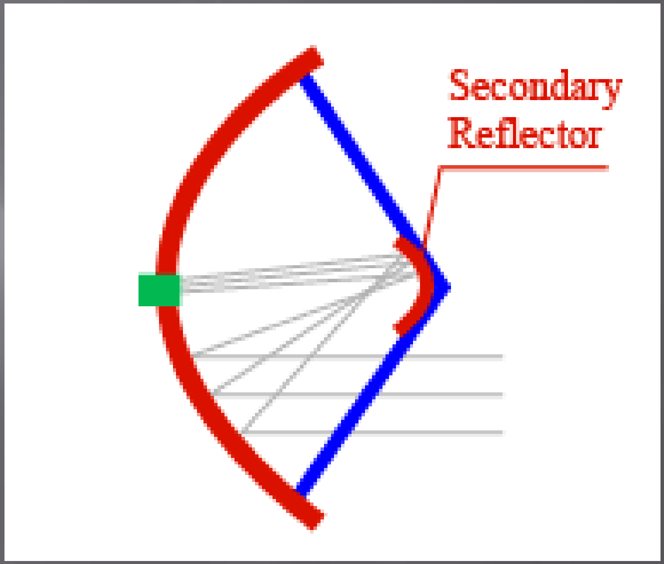
Off-center

Antenna 4

Cassegrain
Main & Subreflector
Paraboloid



Cassegrain
Subreflector-paraboloid
Focused beam



Gregorian
Subreflector - elipsoid

Antenna standard intelsat

STANDARD TYPE	FREQUENCY BAND (GHz)	G/T (dB/°K)	DIAMETER (M)	SERVICES USED FOR	INTELSAT DOCUMENT
A	6/4	35.0	15 - 20	ALL	*IESS* 207
B	6/4	31.7	10 - 13	ALL	*IESS* 207
C	14/11; 14/12	37.0	11 - 15	IDR/IBS	*IESS* 208
E1	14/11; 14/12	25.0	2.4 - 3.5	IBS	*IESS* 208
E2	14/11; 14/12	29.0	3.7 - 4.5	IDR	
E3	14/11; 14/12	34.0	6.1	IBS, IDR	
F1	6/4	22.7	4.5 - 6.0	IBS	*IESS* 207
F2	6/4	27.0	7.0- 8.0	IBS, IDR	
F3	6/4	29.0	9.0 -10	IBS, IDR,	
H2	6/4	15.1	1.5 to 1.8	DAMA	*IESS* 207
H3	6/4	18.3	2.4 to 2.7	DAMA	
H4	6/4	22.1	3.5 to 4.2	DAMA	
K2	14/11; 14/12	19.8	1.2	VSAT IBS	*IESS* 208
K3	14/11; 14/12	23.3	1.8	VSAT IBS	
G	6/4C or 14/11; 14/12	-	All sizes	LEASED SERVICES*	*IESS* 601

Antenna performance

The Satellite Operators define a set of rules for granting equipment aproval within its network.
In case of Intelsat there the IESS – Intelsat Earth Station Services, that by the SSOG – Satellite Services Operation guide, define the type of tests shall be performed to be submitted for technical aproval :

- Receive system figure of merit G / T
- Transmit Gain and EIRP stability
- Isolation Contour (ortogonal ploarization)
- Transmit and Receive antenna pattern

G / T - Figure of Merit 1

In satellite communications the recepion system work always with very wesk signals mainly due to distances and accordingly the <u>gain towadrs satellite shall be very high</u> besides the <u>performance of receivers</u> .This combination known as G / T or Figure of Merit represents the ratio - antenna gain versus noise temperature - and is in direct proportion to the ratio of power carrier and noise power density.

The measurement includes:

- Adjust receiver IF bandwith for the signal (carrier and sidelobe) with minimum of noise using 3dB bandwith receiver technique
- Use reception systems with low noise temperature or in case high dimension antennas, submerge the receiver amplifier in liquid nitrogen or helium reaching phisical temperatures of about -4 ºK (-293 ºC)

G / T - Figure of Merit 2

Noise Temperature is a useful concept in communication receivers, since it provides a way of determining how much thermal noise is generated by active and passive devices in the receiving system.At microwave frequencies all objects with physical temperature T_p greater than 0ºK generate electrical noise at the receiver frequency . The noise power is given by:

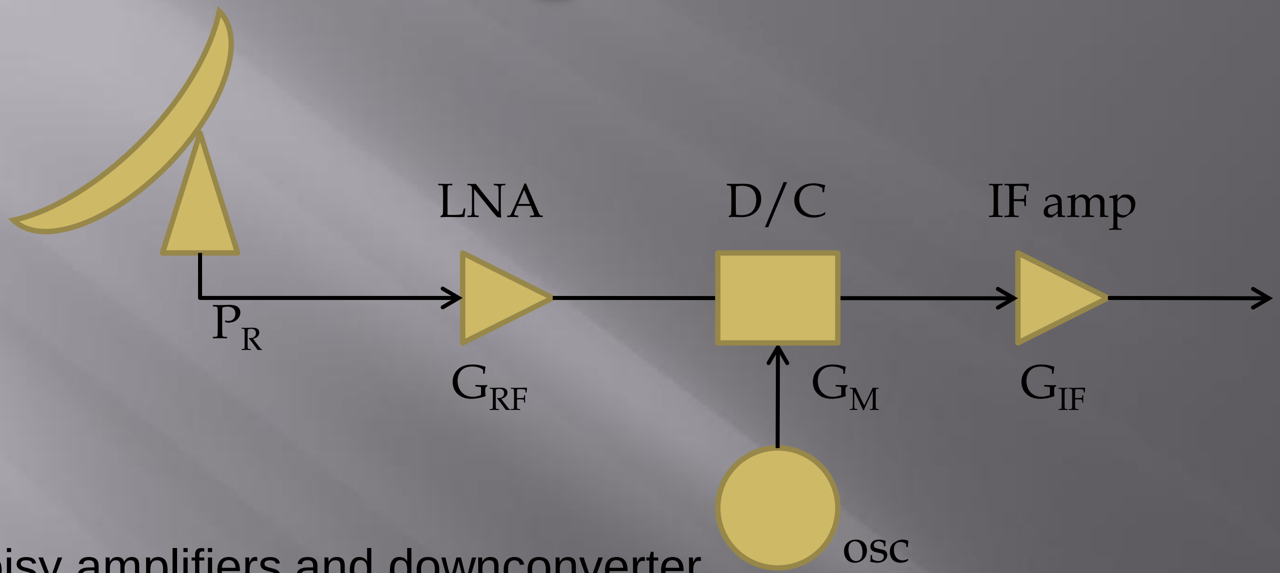
$$P_n = K\,T_n B$$

K -Boltzman's constant = 1,38x10^{-23} J/ºK = -228,6 dBW/K/Hz

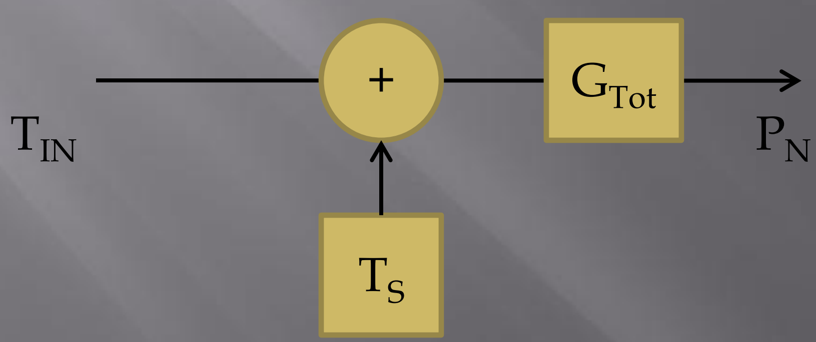
T_n - Noise temperature of source in ºK

B - bandwith of power measurement device in K

G / T - Figure of Merit 3



And if noisy amplifiers and downconverter have been replaced by noiseless units with equivalent noise generators at their input



ou

$$\boxed{P_N = K\,T_S B G_{Tot}}$$

G / T - Figure OF Merit 4

In other way the noise power has been calculated swapping the antenna by a global noise source at the receiver input and the several stages gain by G_{Tot}.

$$C / N = P_R \,.\, G_{Tot} / K.T_S.B.G_{Tot}$$

$P_R\ G_{Tot}$ represents signal plus sidelobe at the receiver output

once $P_R = P_{Tx}.G_{Tx}.G_R.[\lambda/4\Pi R]^2$ and showing C/ N

$$C / N = P_{Tx}.G_{Tx}.G_R / K.T_S.B \,.[\, \lambda / 4\Pi R]^2$$

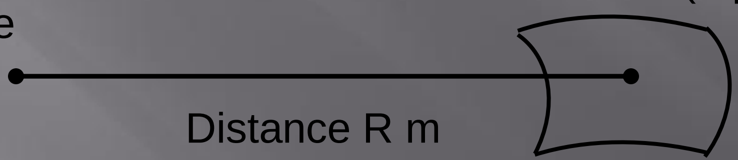
And thereafter

$$\mathbf{C / N = P_{Tx}.G_{Tx} / K.B \,.\, [\lambda/4\Pi R]^2 \,.\, G_R / T_S}$$

Figure of merit

Antenna gain

Defined as the relation between the power radiated per unit solid angle (in determined direction) and the power radiated also by a solid unit angle (by na isotropic antenna)



$F = P_T / 4\Pi R^2$ W m^{-2}

$P_R = F . A$

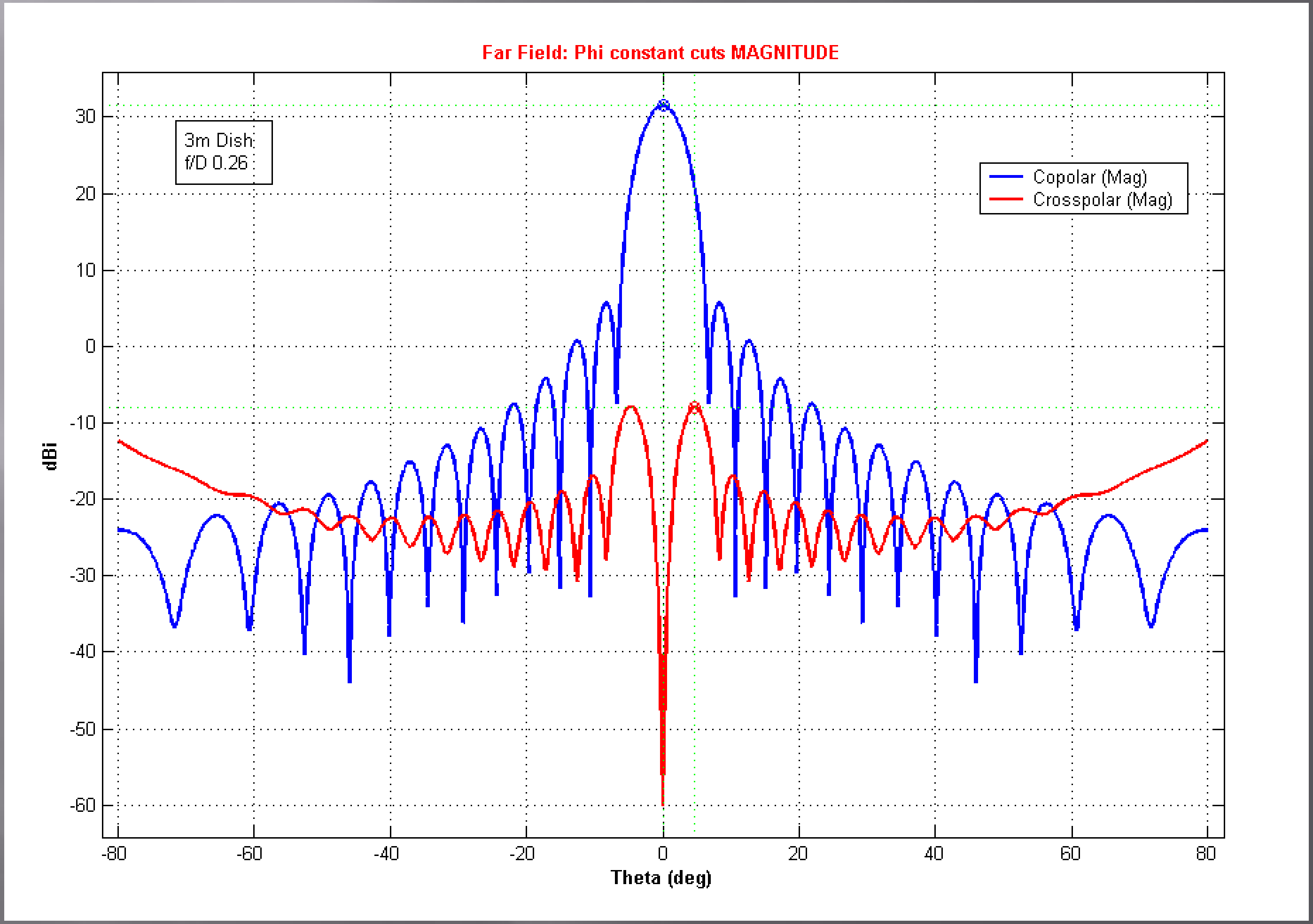
$G(\theta) = P(\theta) / [P_0 / 4\Pi]$ ou $G = 4\Pi / \lambda^2 . A\, \eta$ e $\boxed{G = 4\Pi A_e / \lambda^2}$

being $A_e = \eta A$

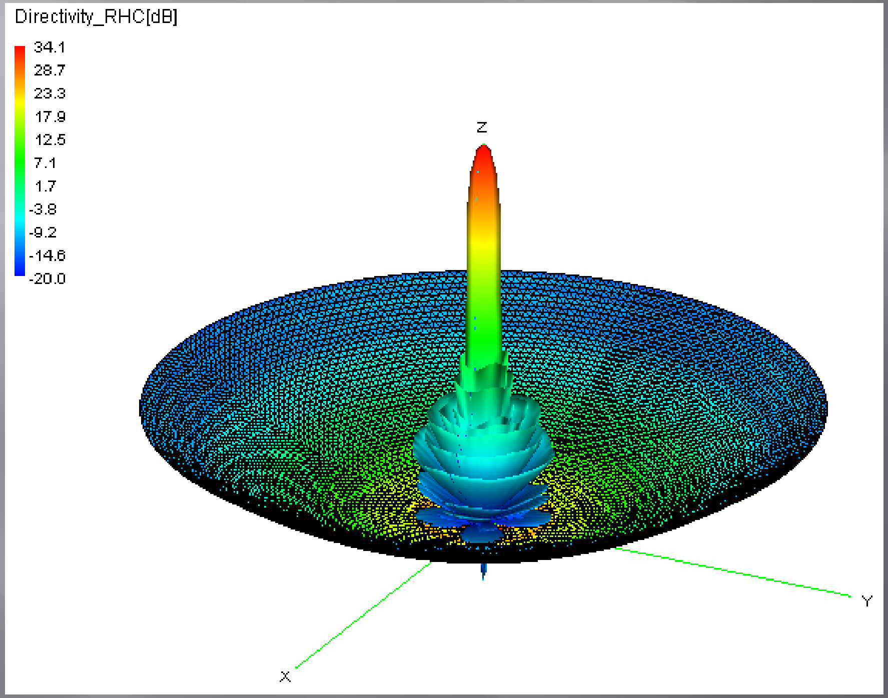
Isolation Contour

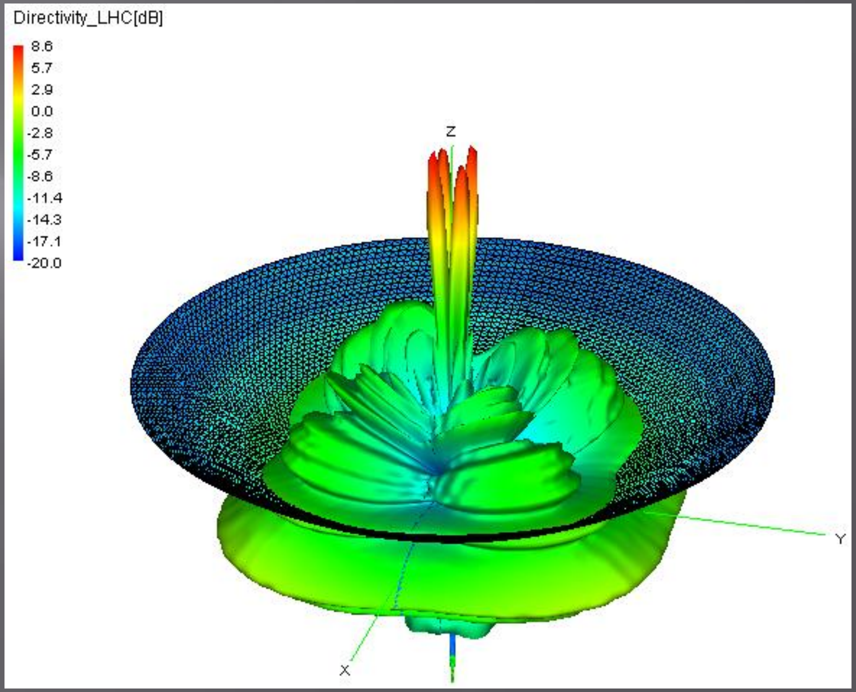
- Being quite common an antenna transmit the same frequency in orthogonal polarizations it is mandatory measure his efficiency at cross-polarization, to reduce minimal possibility of interferences.
- The purpose of the Isolation Contour Test is to measure the crosspol performance of the EUT-Earth Station under Teste at the 0.5dB and 1 dB beamwidths of the antenna.

Orthogonal polarization (Co-polar and cross-polar)

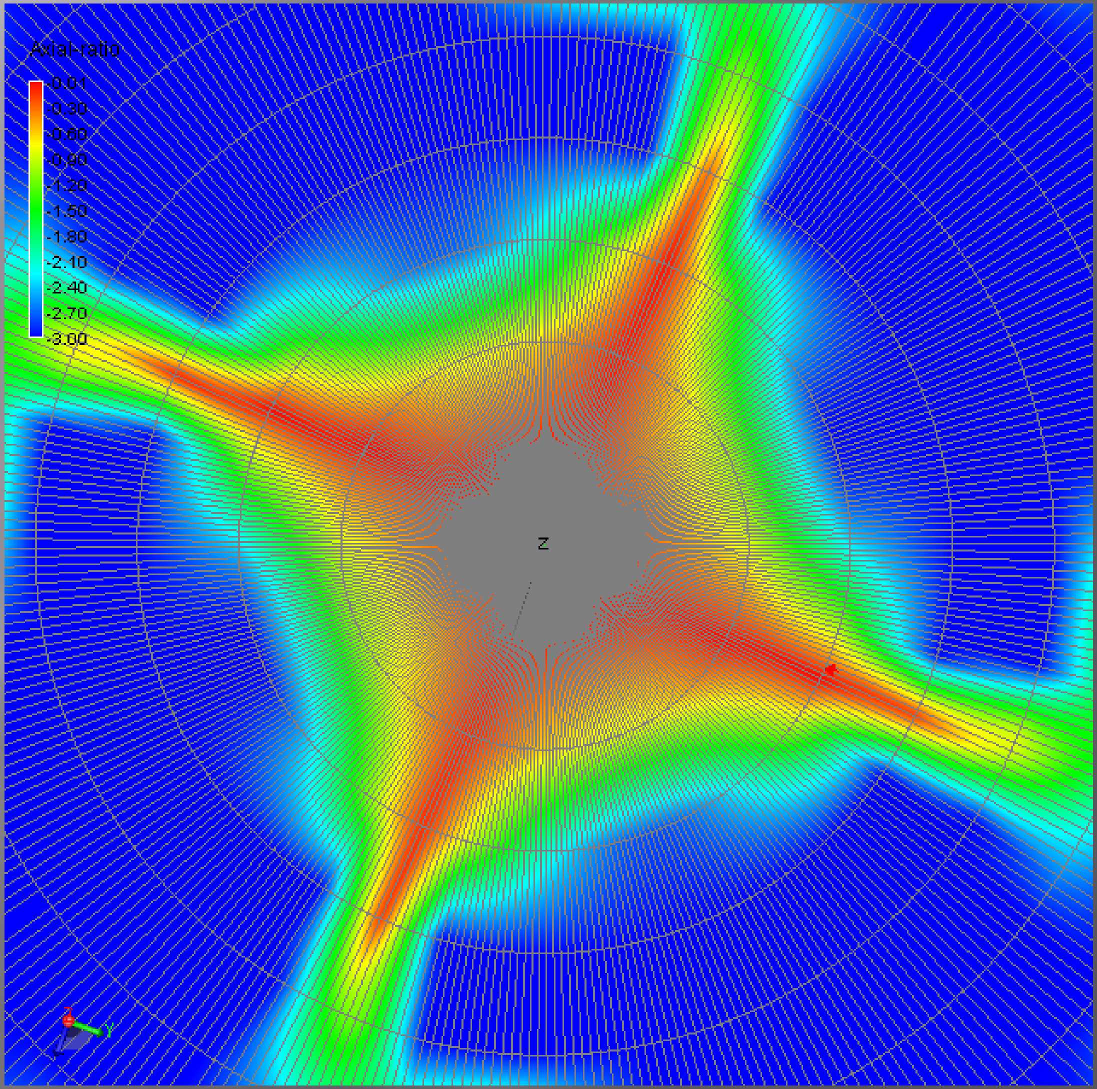


Ortogonal polarization (3D diagram)





Ortogonal polarization (3D diagram front)

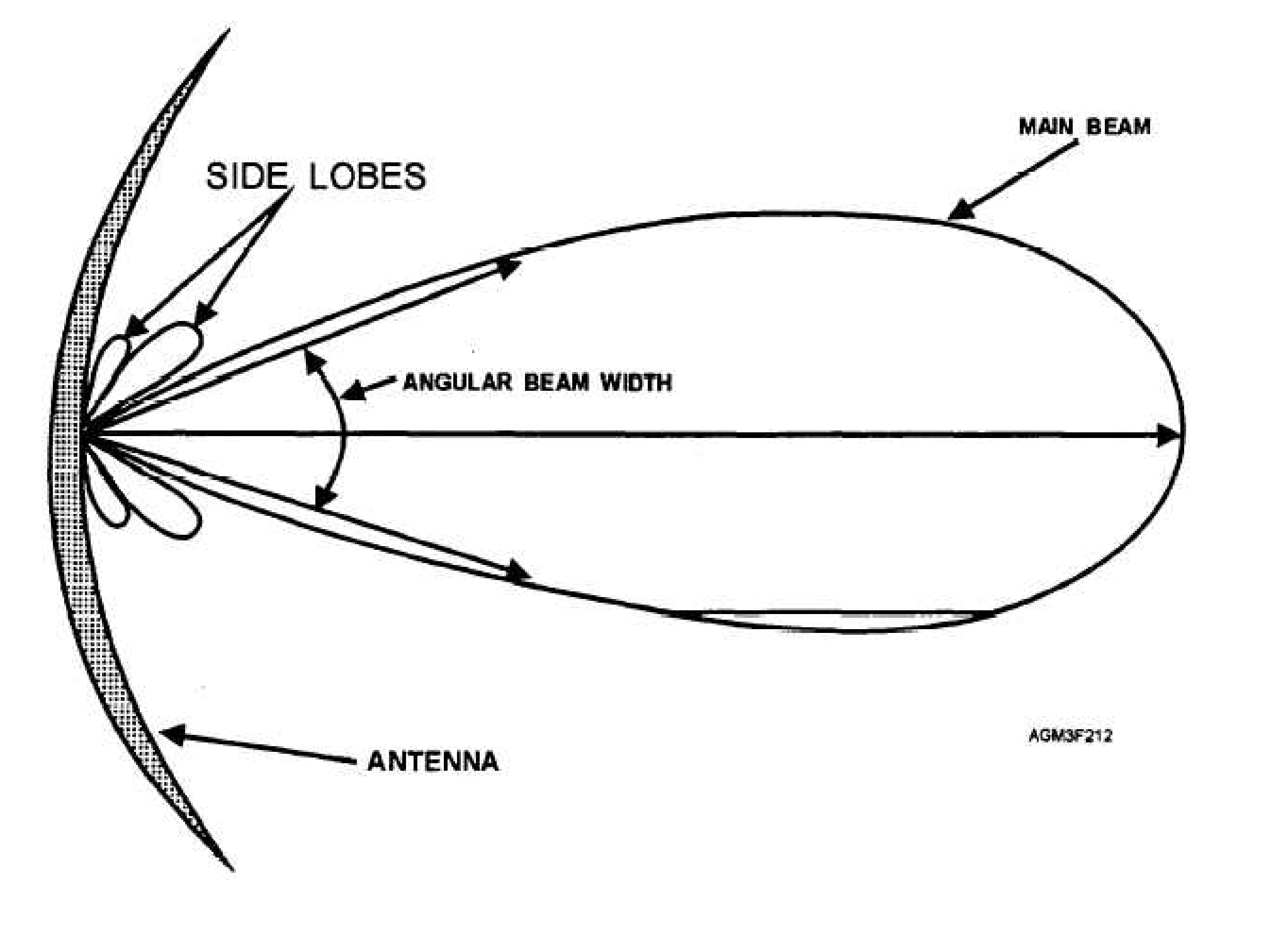


Transmission pattern (sidelobe characteristics)

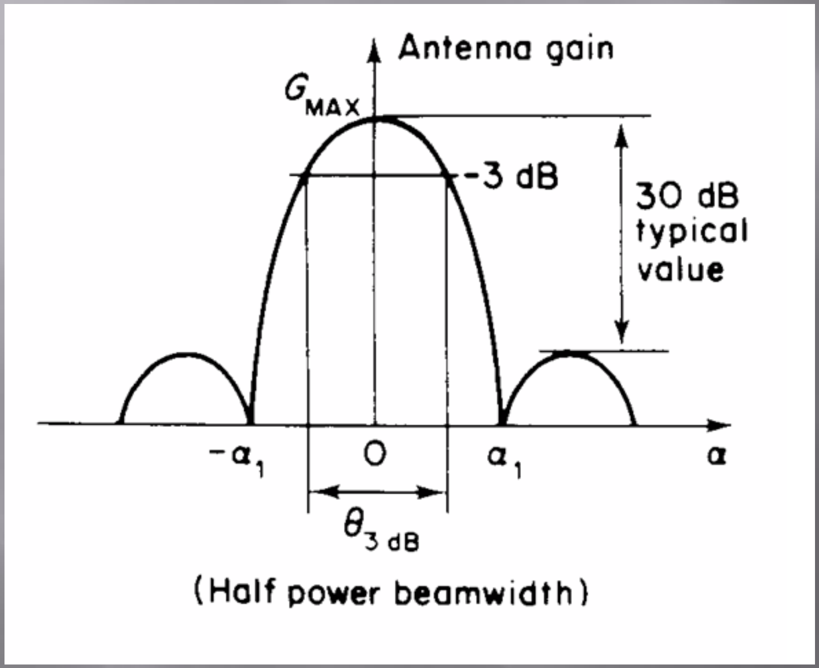
Due to the actual minimum arc spacing between 2 satellites (2º) and the potenctial interference power of sidelobes what is undesirable for the satellite itself but also to the earth stations, Intelsat and ITU imposed some restrictions on the pattern transmission.

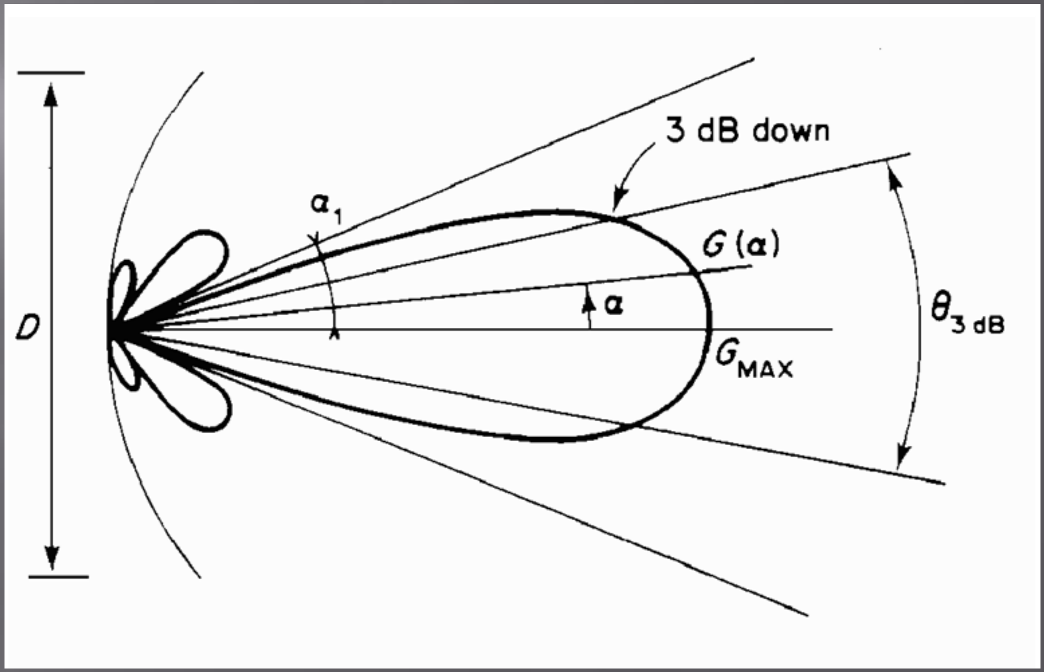
- ITU defined standards to the sidelobe performance of antenna antenas [contour G (θ) = 32-25 log (θ)]
- Also Intelsat through IESS-Intelsat Earth Station Standards verify and imposes compatibility of antenna under tests, namely, transmission gain in such way that its sidelobes and "*off axis*" emissions (included the cros-polarization) .

Transmission pattern 1

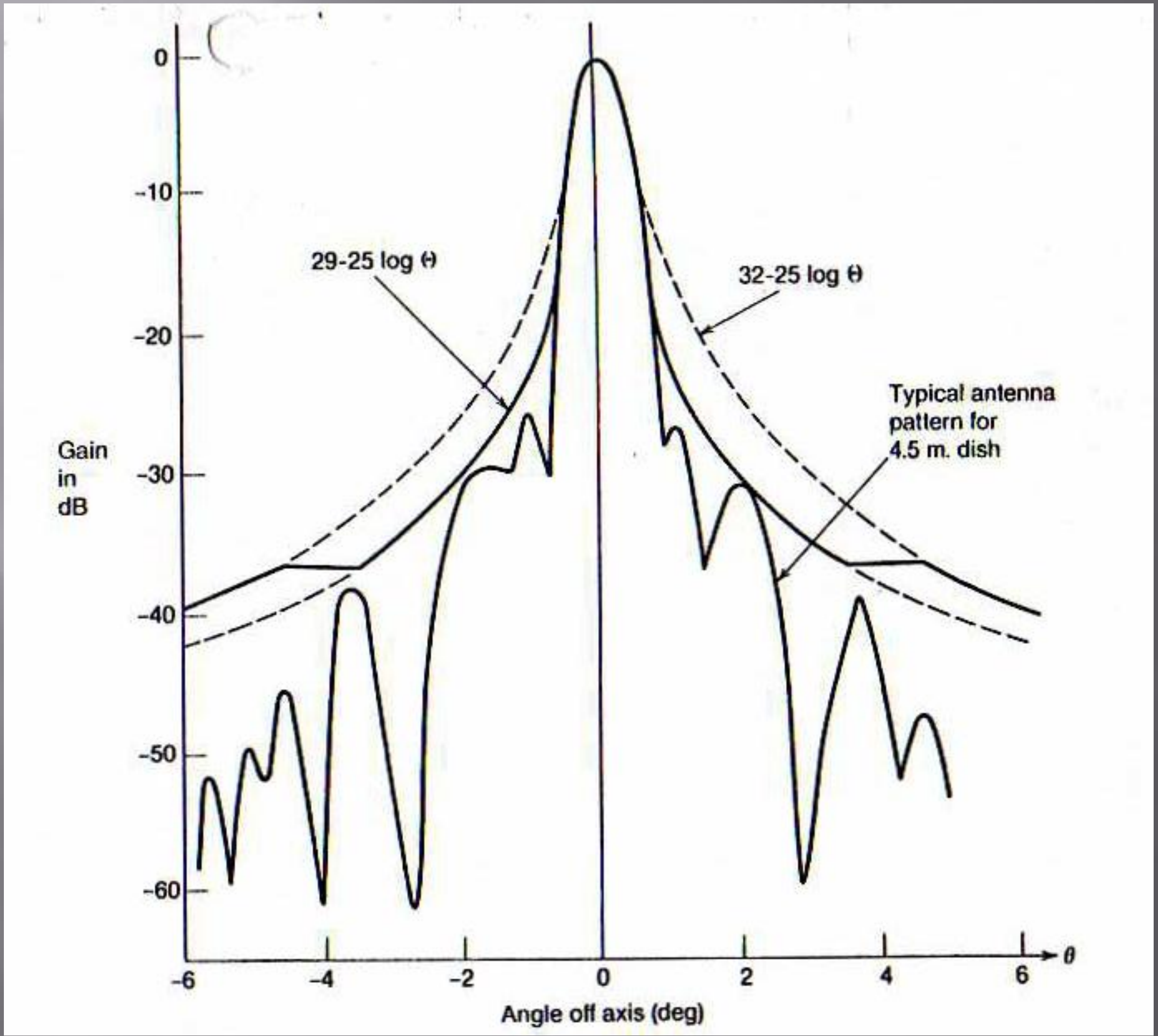


Transmision Pattern 2





Transmission pattern plus limit contour



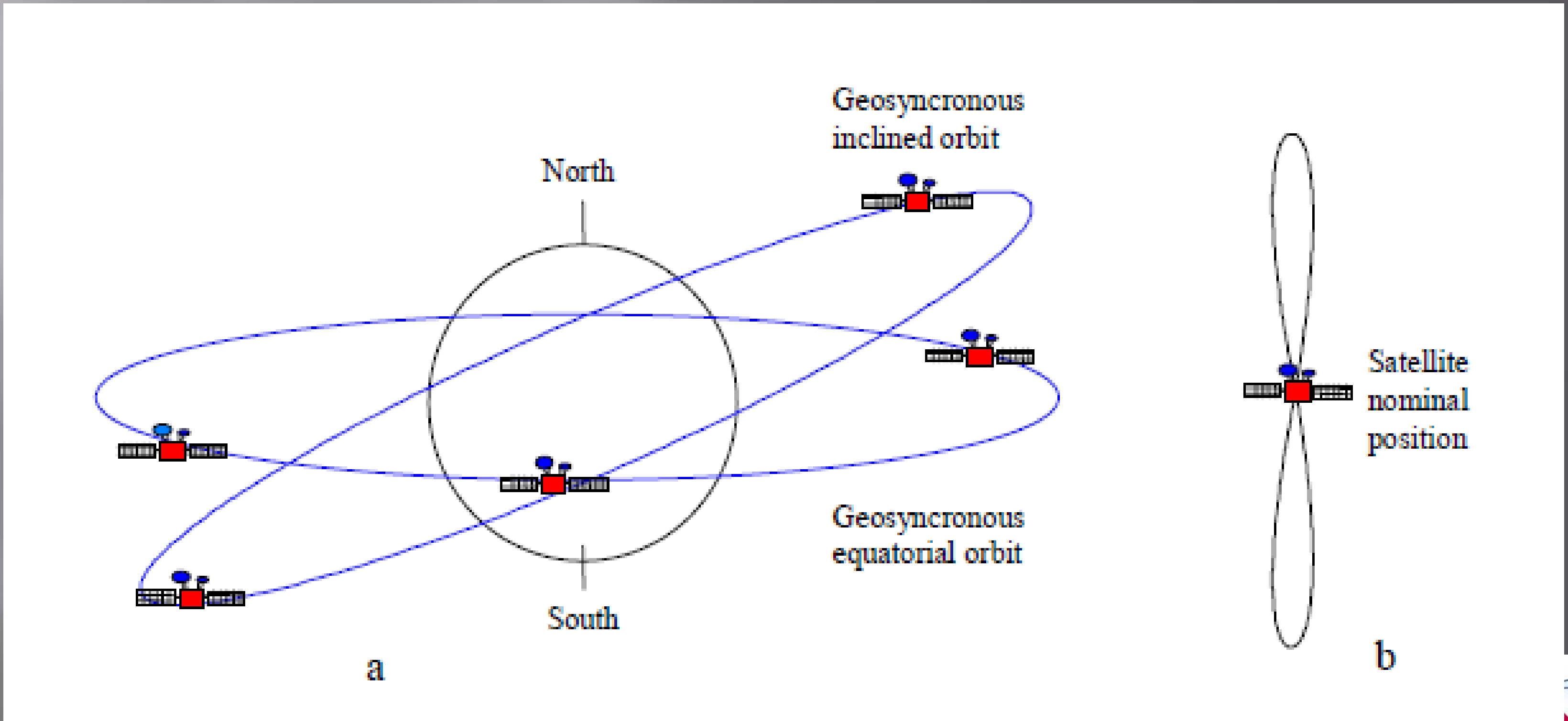
Tracking

Pointing na antenna at a geo satellite requires the knowledge of azimuth and elevation of antenna in terms of the geographic location of the station. Tracking consisits of maintaining the axis of the antenna beam in the direction of the satellite despite the movement of the satellite or the station. Pointing depends on :

- Beamwith of the antenna beam
- Aparent motion of the satellite
- Type of the station, fixed or mobile

Just as an example the 3 dB beamwith of a 25 m antenna operating at 4 GHz is typically 10' of arc, so the antenna must be pointed with na accuracy of +/- 1 ' of arc if pointing loss is to be avoided. If a satellite moves at all a very accurate program-track facility is required or auto track must be used.

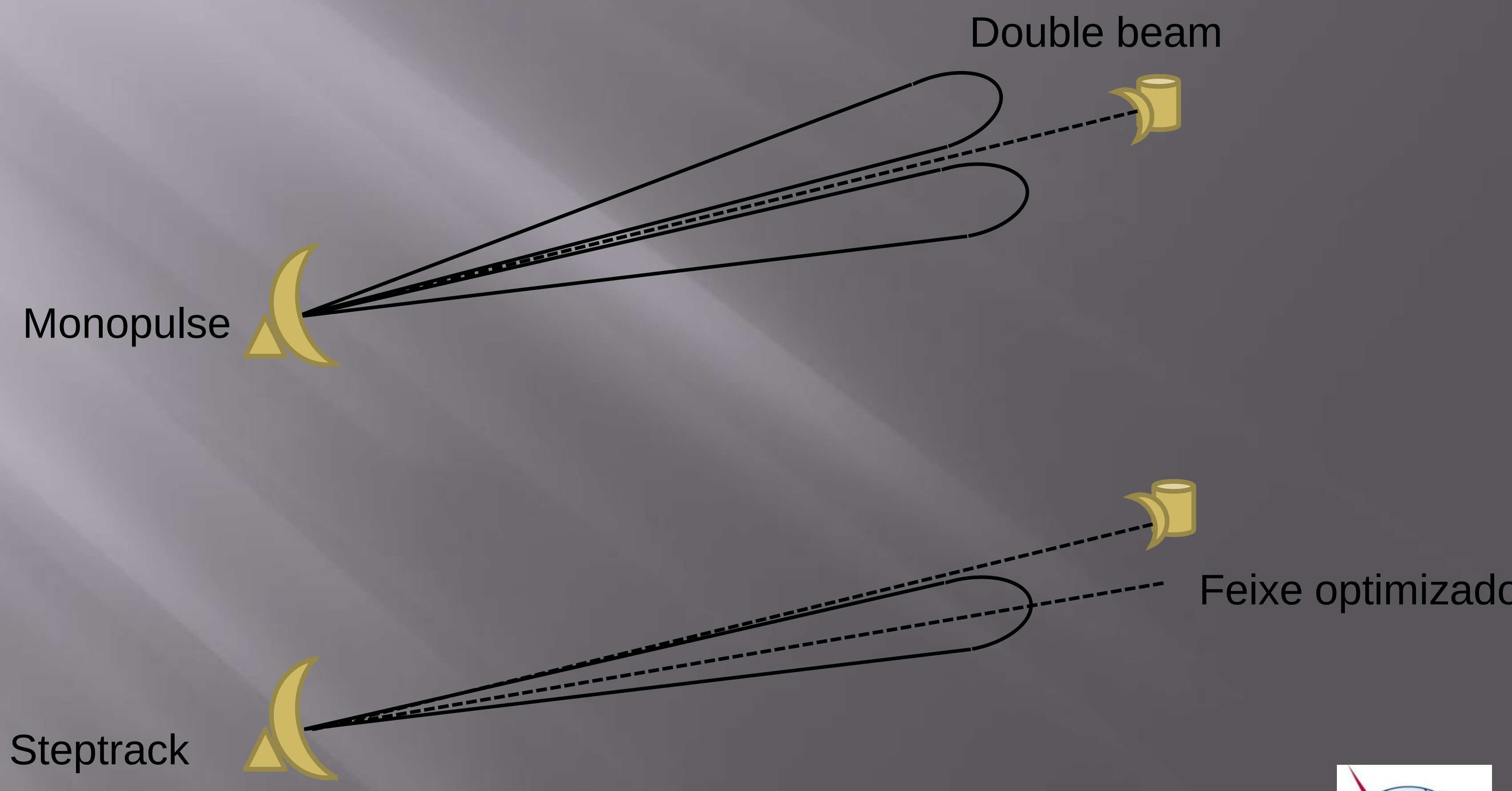
Geostationary and inclined orbits



Tracking main systems

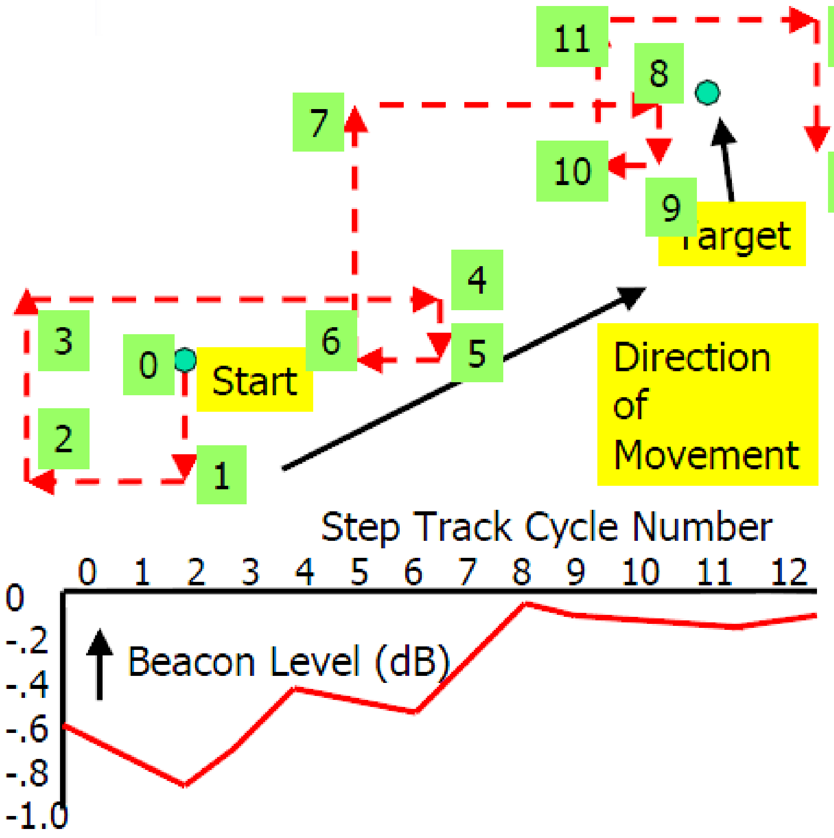
- There are 2 main tracking process
  - Monopulse
  - Step tracking
- Monopulse (or multi horn tracking) the antenna generates diferent patterns with nulls on the axis, in azimuth and elevation planes.Separate tracking receivers (or time shared) are used to detect error outputs from the Az/El channels and thus to drui«ive the antenna servos.
- Step tracking (or hill climbing) the antenna beam is moved about in a predetermined fashion and the signal amplitude noted.Maximum signal indicates the best beam position .The beam must continually be moved to check that is in the right position. This is also known as step track .In a hill climbing system the antenna is pointed away from the nominal position of the satellite by a fraction of a degree in several directions.From a knowledge of the main beam shape the true direction of the satellite is estimated and the antenna is then pointed in that direction.

Tracking systems



Beacon receiver (Antenna step tracking)

Antenna Step Tracking



- Used for Low Relative Motion
- Beacon Receiver Monitors Signal Strength
- Moves Antenna in Small Az/El Increments
- Compares Signal Strength with Previous Values to Determine Direction & Size of Next Step
- Once Signal Strength is "Peaked" Waits for Next Scheduled Step Track Cycle -

RF Equipment

- Under this designation we gather the elements of guided wave where we include the LNA-Low Noise Amplifier, the HPA – High Power Amplifier and the translators from RF (4GHz and 6 GHz) to VHF (70 MHz ou 140 MHz) namely:
  - BUC - Block up converter
  - LNB(C) - Low noise block (converter)
  - Transceiver, somemtimes installed outdoor ODU (*outdoor unit*) sometimes indoor IDU (*Indoor unit*)
  - Combiners, Dividers, circulators, switch and power divider
  - Modem
  - Wave guide, coaxial etc
  - Beacon receiver

RF equipment - HPA

Large earth stations frequently use large numbers of high power amplifiers (HPA) with output power levels up to 8,5 KW.The configuration employed depends on the number of carriers to be transmitted and whether these are FDM or TDM signals.The most common configuration employ one HPA for each transponder to be used. At 6 GHz HPA having bandwith of 40 or 80 MHz are used in large earth stations, using either air cooled TWT (Travel wave tuve) amplifiers or water cooled Klystrons.TWTA have wider operating bandwiths tham Klystrons and can cover the full 500 MHz bandwith at 6GHz allowing the TWT to be tuned to any transponder band

- Small and medium earth stations instead of using TWT, are very common SSPA – Solid State Poerw Amplifier that do not need very high voltages as those (10-50 KV)
- When several HPA are used with one antenna a combining network is needed to sum their outputs into a single transmit waveguide.
- HPA act as interface between antenna (meaning RF free space propagation) and the transceiver (IF) is nothing more than a step to treatment of baseband signals that aggregate through modems the communications channel.

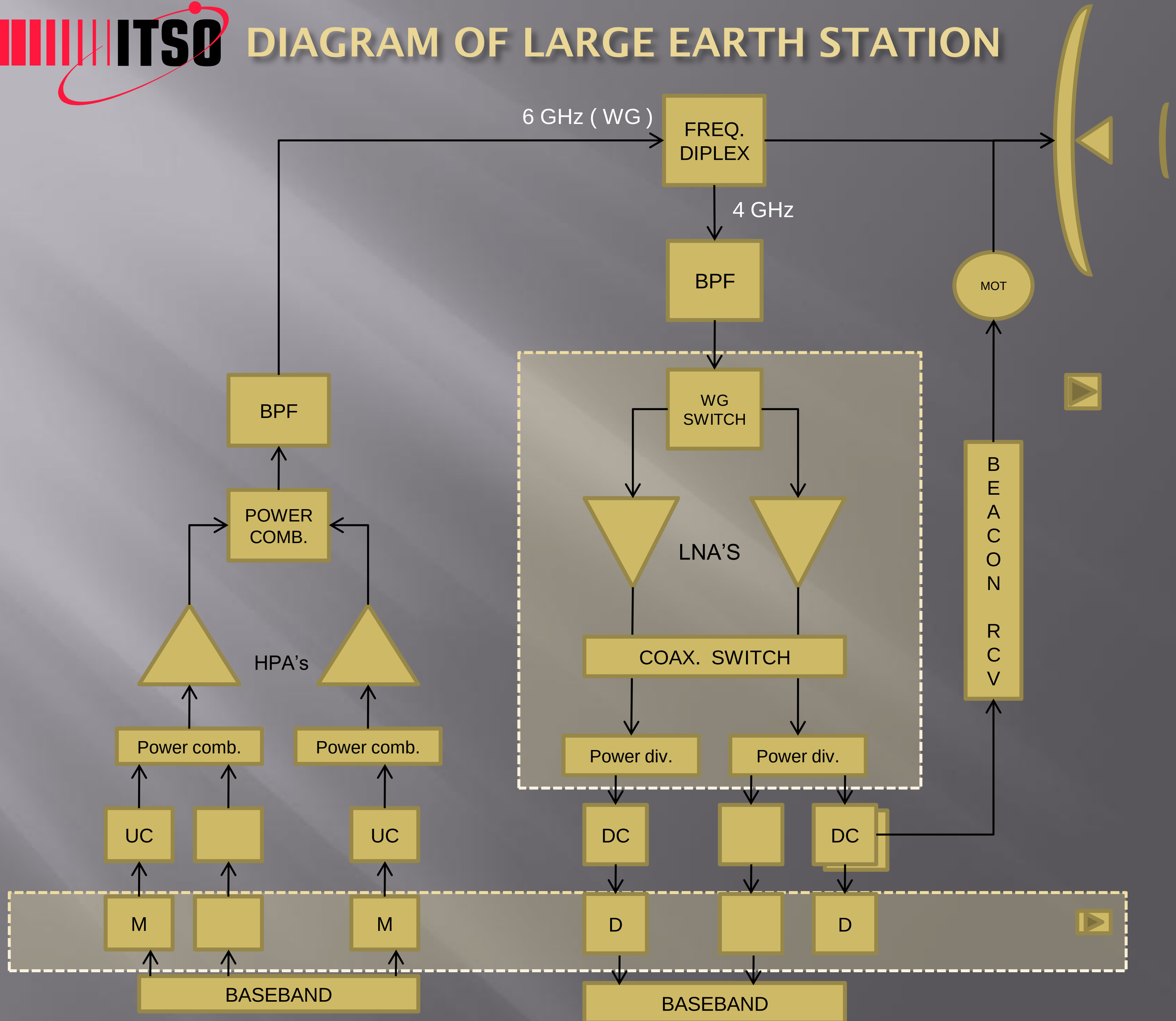
RF equipment - LNA

Large earth stations need very low noise amplifiers. Cryogenically cooled parametric amplifiers are wided used with liquid helium cooling at 4ºK above absolute zero to achieve noise temperatures of 20 to 40 K at 4 GHz. Medium and small earth stations use GaAsFET amplifiers with no cooling or electrothermal cooling. These achieve noise temperatures in the range 50 to 120 K at 4 GHz and 120 to 300 at 11GHz.

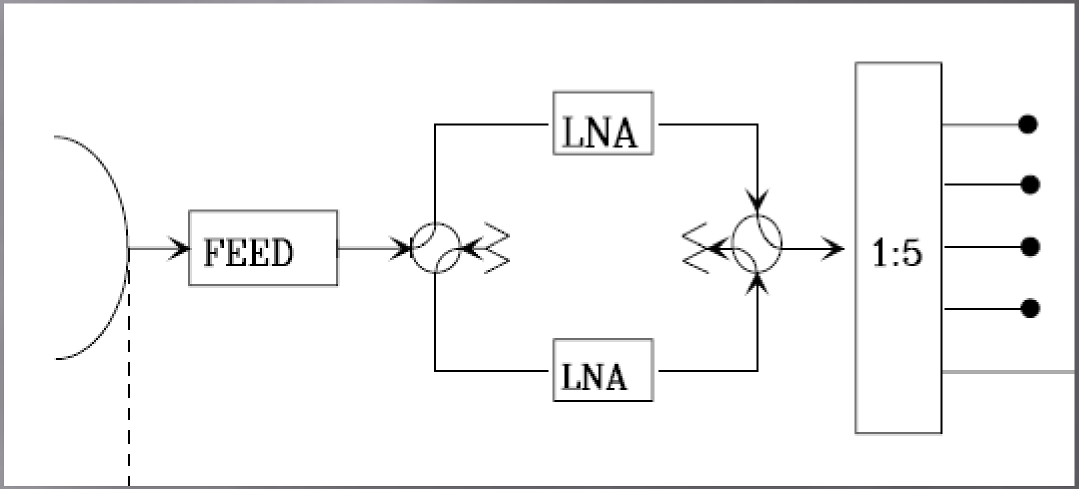
The FET amplifier is much simpler than the cooled parametric amplifier and is particularly attractive for unattended and TVRO stations especially where costs are an important factor.

- LNA's used in earth stations usually cover the 500 MHz fixed service band at 4GHz and 750 MHz at 11 GHz. In large stations a one-for-one redundancy arrangement such as indicated next slide is widely used. Failure of one LNA indicated by a loss in the pilot signal at receiver output results in immediate switchover to the second LNA.The spare (unused) LNA is often kept on test with a pilot signal or noise source input so that its state if readiness can be monitored continuously.

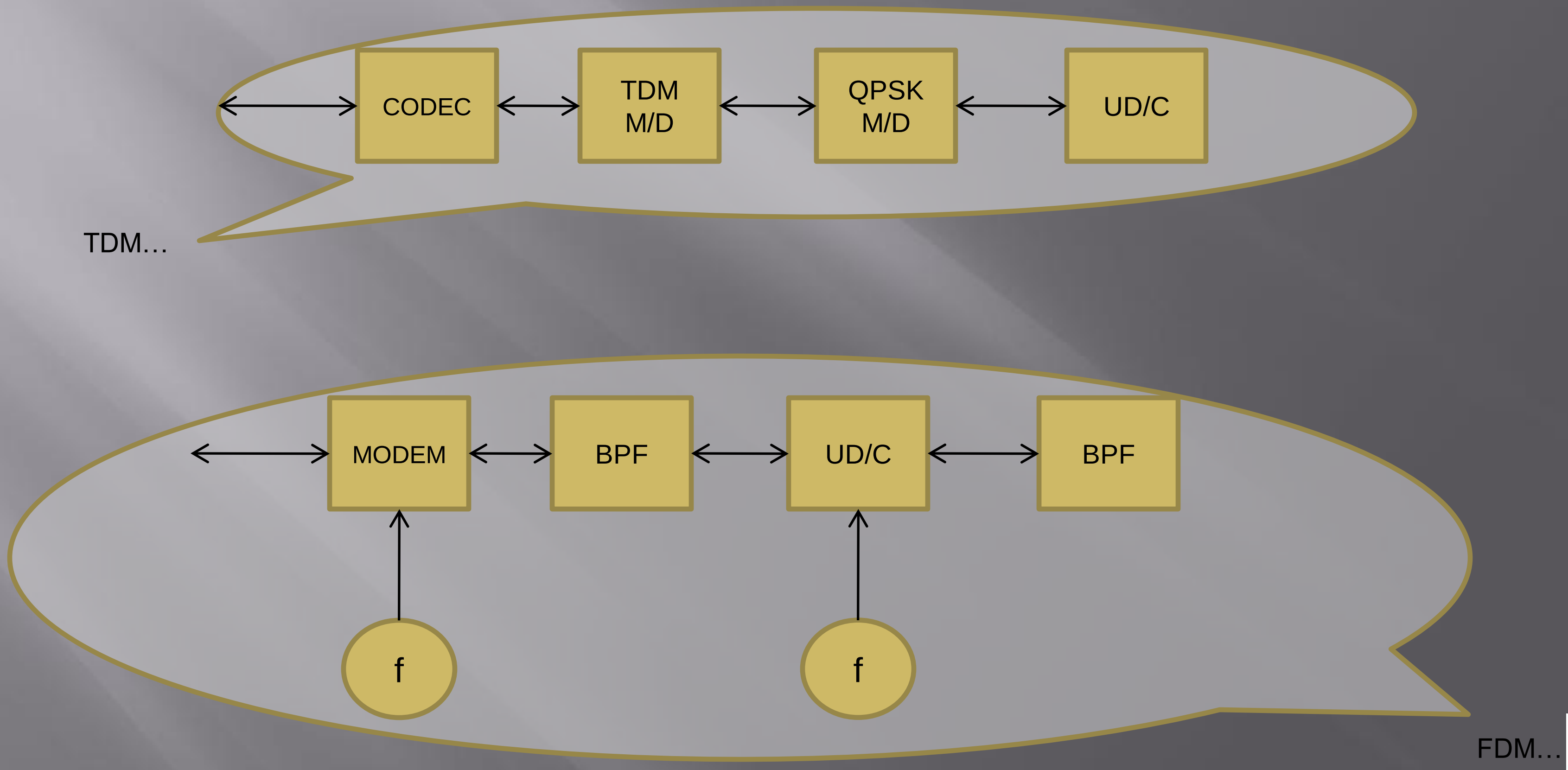
DIAGRAM OF LARGE EARTH STATION



Redundndt LNA's



FDM & TDM



Miscelaneous RF 1

The connection of transceiver to antenna shall be made to introduce low attenuation.For frequencies up to 2 GHz it used coaxial cable beause is cheap and has good characteristics and for frequencies above 2 GHz (or bellow but with large IFL) it is used the waveguide (circular or rectangular) where the attenuation per meter is very low.

For long distances (> 20 m) the waveguide are pressurized and the flanges shall be carefully choosen and in accordance with the IEC-International Electronics Commission standards.

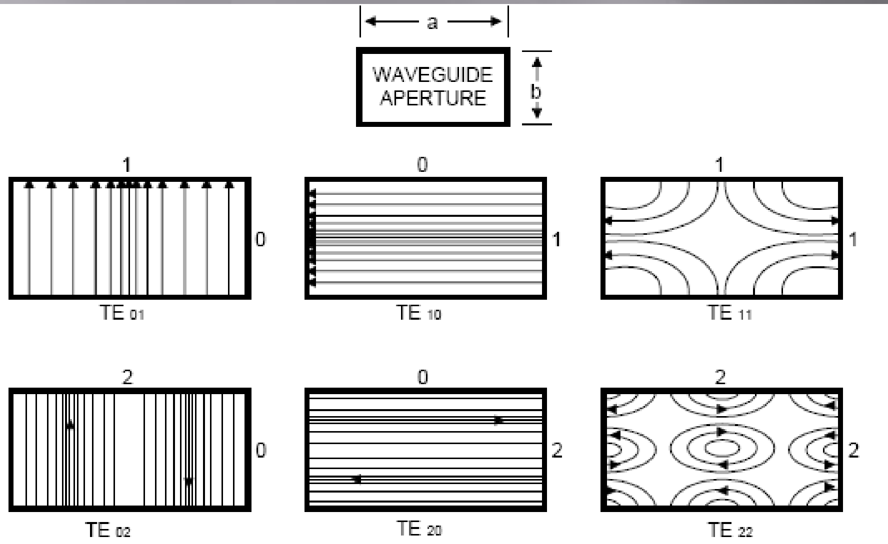
Miscelaneous RF 2

While a coaxial cable is a wideband transmission line, the waveguide can transmit only from a determined low frequency called "cutoff" frequency,which is the lowest frequency that can be transmitted, and depends on the waveguide sectional form and dimensions. At the higher frequency, other limits that have to be reached for the signal to be propagated along the waveguide.Transmission is made by modes (TE_{mn} and TH_{mn}) being dominant TE_{11} for the circular wave guide and the TE_{10} e TE_{11} for the rectangular waveguide

There are also *diplexer, polarizer, circulator e isolator* being namely fot the last two :

- *Circulator* it is a device with internal ferrite with 3 ports with function not reciprocous e.g. the signal makes always the way – 1,2,3 – and never – 1,3,2 – notwithstanding having circulators 1,2,3 (CW) ou 3,2,1 (CCW). *Isolator* It is a special circulador with one port in short circuit e.g ,the signal always flow 1,2 ou 2,1.

Miscelaneous RF
Waveguide transmission modes



TRANSVERSE ELECTRIC MODES

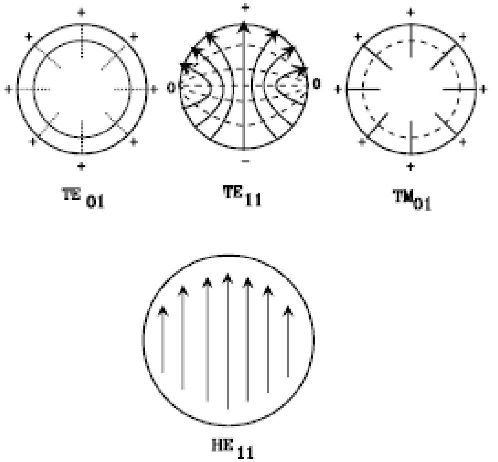


Figure A.7 Circular Waveguide Modes

Miscelaneous RF Diplexer

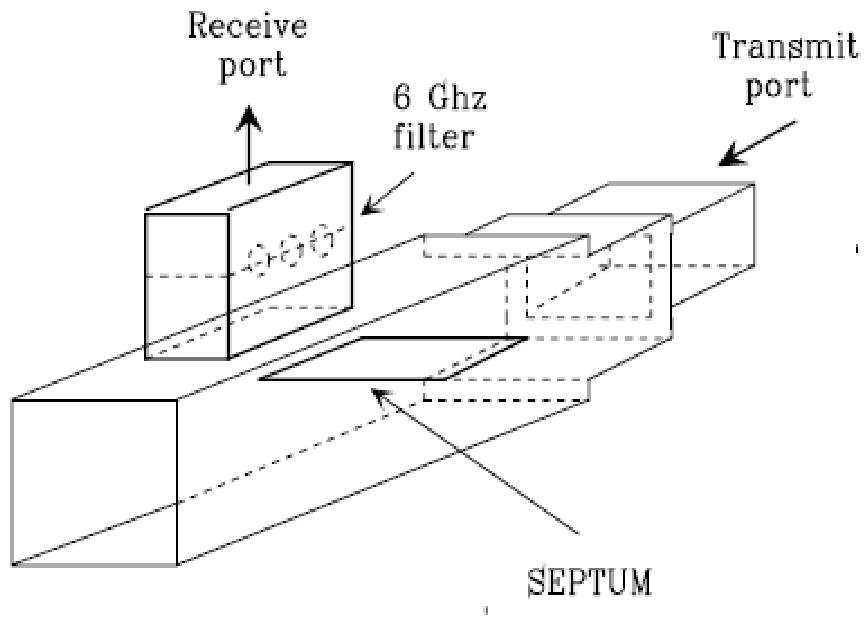
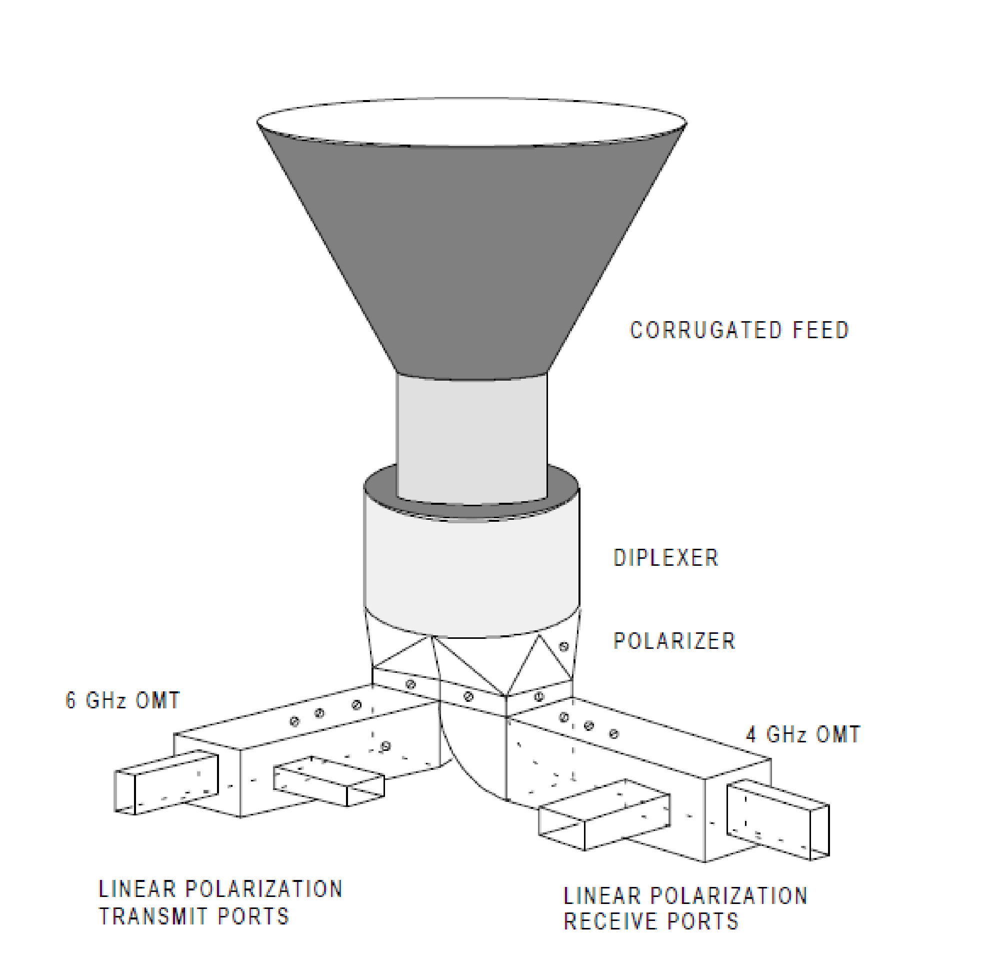


Figure A.9 Diplexer

Frequency re-use feed



Miscelaneous RF
Circle polarizer

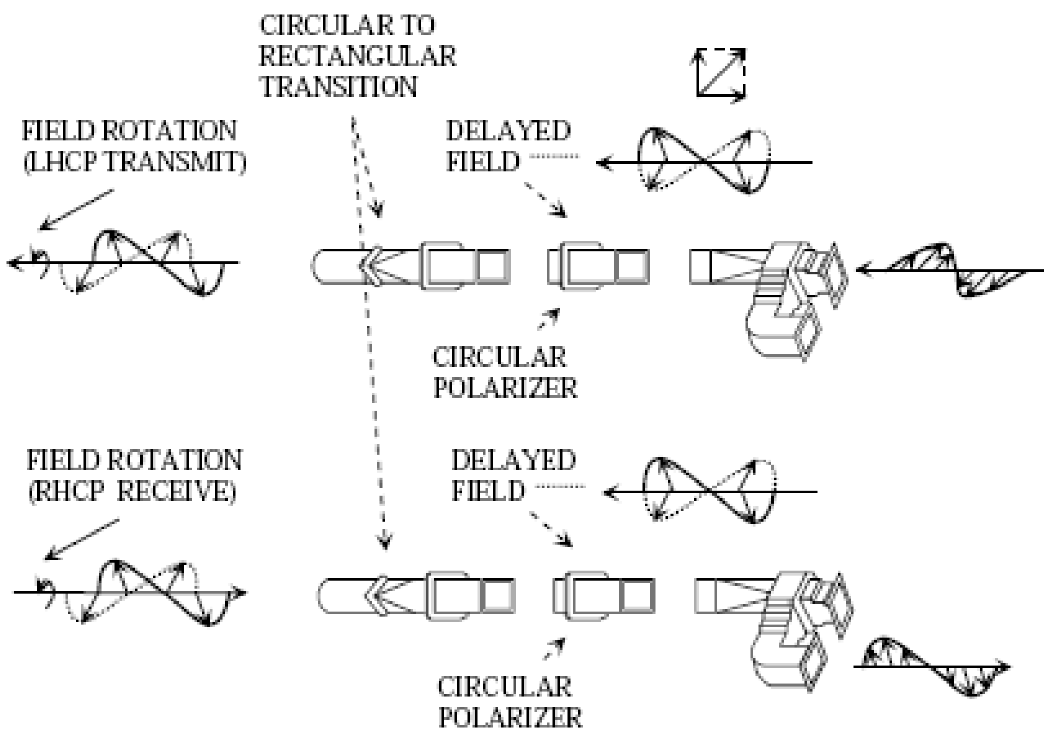


Figure A.11 Circular Polarizer

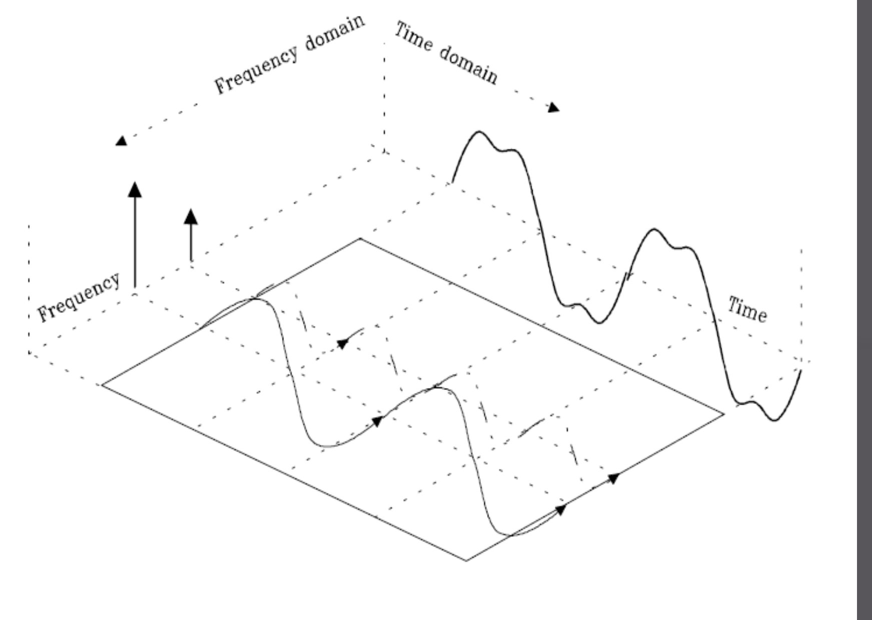
Test equipment Measurement Units

- Spectrum Analyser
- Power meter & Power sensor
- Data analyser (*ber test*)
- Volt-ohmmeter
- …..
- dB, dBm, dBW
- EIRP
- C_0+N_0/C_0
- ………….

Spectrum Analyser 1

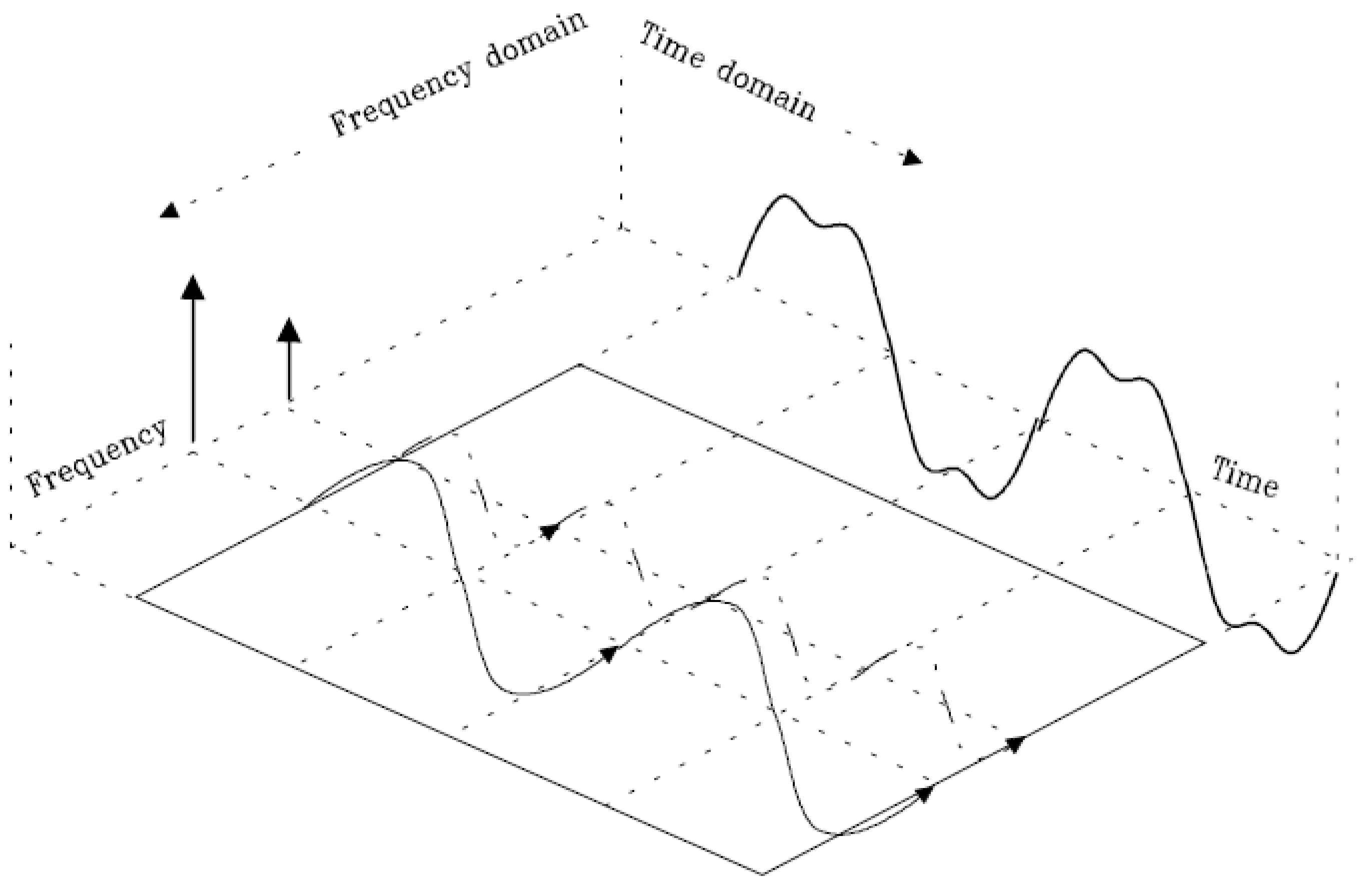
The standard method for observing electric signals is to use an oscilloscope. The horizontal axis of a CRT oscilloscope increases by a unit of time; oscilloscopes are sometimes referred to as time-domain instruments. Observation in time domain is useful to obtain signal timings and phases.

But the performance of certain elements such as amplifiers, oscillators, mixers, modulators, filters, and others require the analysis of other characteristics (frequency response, harmonic distortion, intrinsic noise, etc.), and meaningful information is not attained until their frequency responses are obtained. Instruments that display levels of an electric signal as a function of the respective frequencies are called frequency domain instruments. Typical instruments are the spectrum analyzer and the selective level meter. …/…



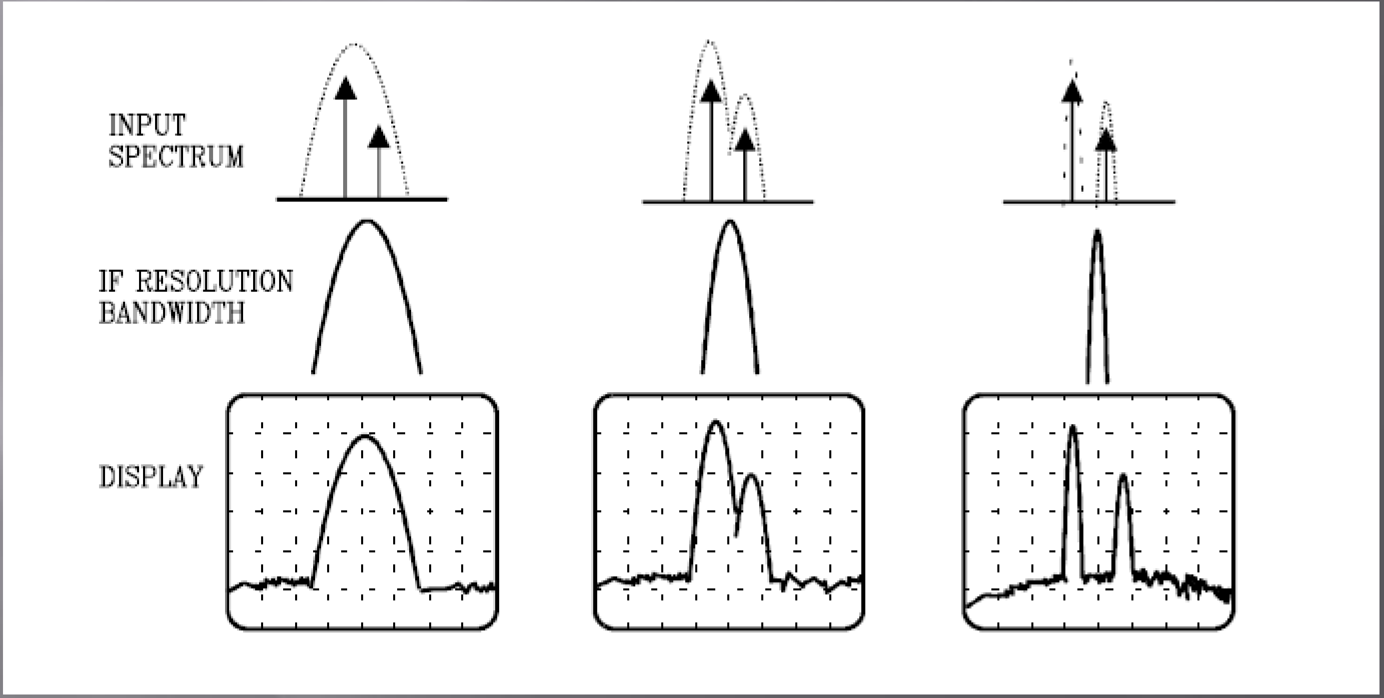
Frequency and Time Domains

Spectrum Analyser 2



Frequency and Time Domains

Spectrum Analyser 3 (Resolution as a function of IF filter)



Spectrum Analyser 4

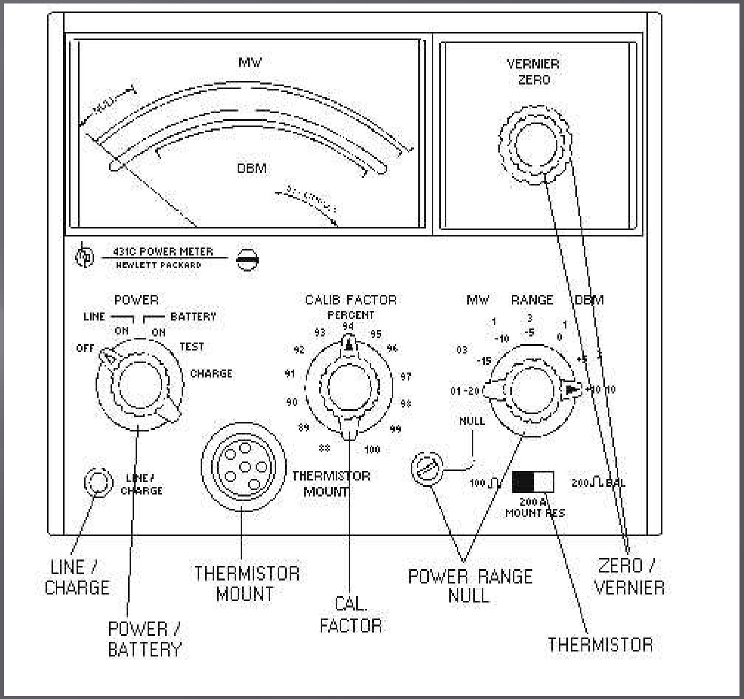
…/…

Being basically one receiver with scanning capacity, they integer one filter of variabel tunning (mixer) to convert the input signal into several IF’s, so many as the components within the original signal, showing them according to resolution band filters used, and in way to become possible visualize them.

According to the band of RF we wish to check there are specific types of Analyser, e.g. - DC up to 8 GHz, 10 Hz up to 6,2 GHz or 9Hz up to 20 GHz.

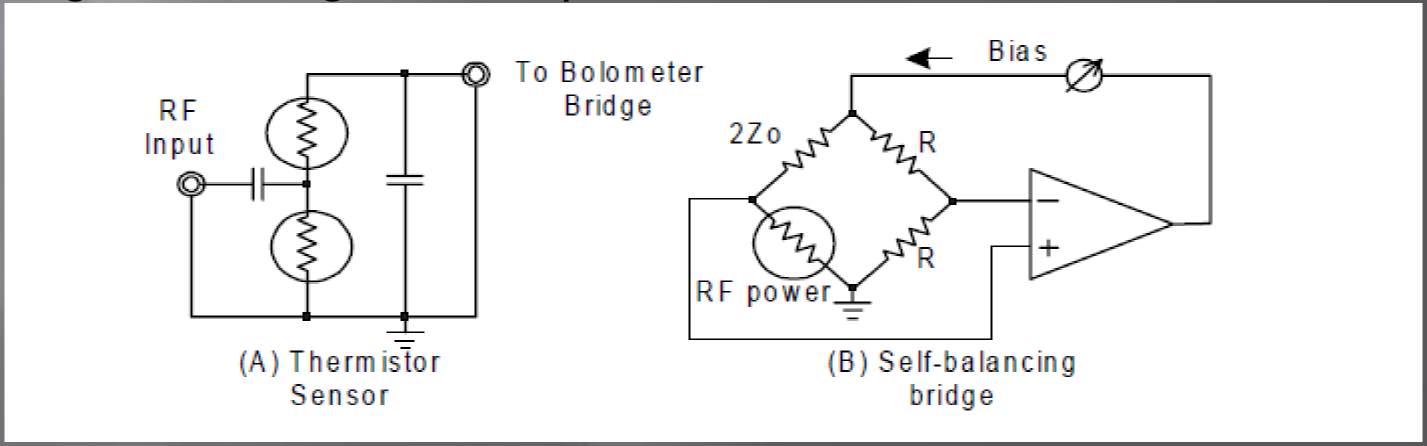
Power meter

A common technique for measuring power at high frequencies is to employ a sensing element that converts the RF power to a Measurable DC or low-frequency signal. The sensing element is often designed to form a termination that is matched to the characteristic impedance of the input transmission line. Various types of sensing elements are used. …..



Power sensor

Thermistor sensors provide a change of resistance. The typical power range is 1mW to 10mW; the maximum frequency is greater than 100GHz. Figure 8.1A shows a typical power sensor employing thermistors. The thermistors form the termination for the RF input. DC or audio power from the self-balancing bridge in Figure 8.1B raises the temperature of the thermistors until they each have a resistance of 2Z0. The RF impedance then becomes equal to Z0. Because the bridge keeps the thermistor resistance constant, any heat added by the RF power causes a corresponding reduction in bias power. The RF level is determined by measuring this change in bias power.



Data analyser

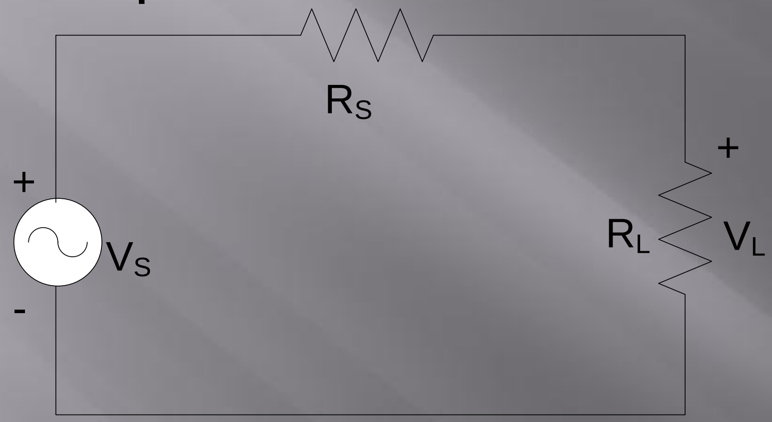
1. In digital communication, bit errors can be generated as a result of noise, jitter, or level variations. If such distortions occur, the transmitted information is received in a deformed condition, which means deterioration of the transmission quality.
2. Transmission quality is measured in terms of the degree of variation of bits (error rate). To measure the error rate accurately, a sequence of bits simulating the real data is transmitted at a rate equal to the transmission rate.
3. This pattern, called Pseudo-Random Bit Sequence (PRBS), is then compared with the one generated at the receiver, and the ratio of detected mismatched bits to the total number of bits is calculated as the bit error rate.
4. The pseudo-random bit sequence must adhere to ITU-T Recommendations O.151 and O.152 to ensure compatibility between equipment. The length of test patterns is selected according to the transmission rate of the system being tested. Table 8.1 shows the recommended ITU-T test pattern for different transmission rates.

Measurement units - dB

- The decibel (dB) is a subunit of the bel (B) and represents the ratio between two powers such as:
  - dB = 10 log $_{10}$ (P_o / P_i) where
  - Log $_{10}$ is the logaritm in the base 10
  - P_o is the output power in a amplifier
  - P_i is the input power in the previous amplifier
- The result will be an amount representing the power gain of the amplifier.The dB can not be used by itself to represent a magnitude unless a reference quantity is specified. Tha abbreviation for decibel is dB and it i often modified to suggest the reference value. For example
  - dBm is used to express power related to 1 milliwat
  - dBi is used to express the gain of na antenna relative to isotropic antenna

Measurement units - dBW

Lets see a practical case



We can say

$P_L = P_S .\ R_L / R_T$

where

$R_T = R_L + R_S$

$V_L = V_S .\ R_L / (R_L + R_S)$

$P_L = P_S . R_L / (R_L + R_S)$

$10 \log_{10} (P_L / P_S) = 10 \log_{10} (R_L / R_T)$

$10 \log_{10} (P_L) - 10 \log_{10} (P_S) = 10 \log_{10} (R_L / R_T)$

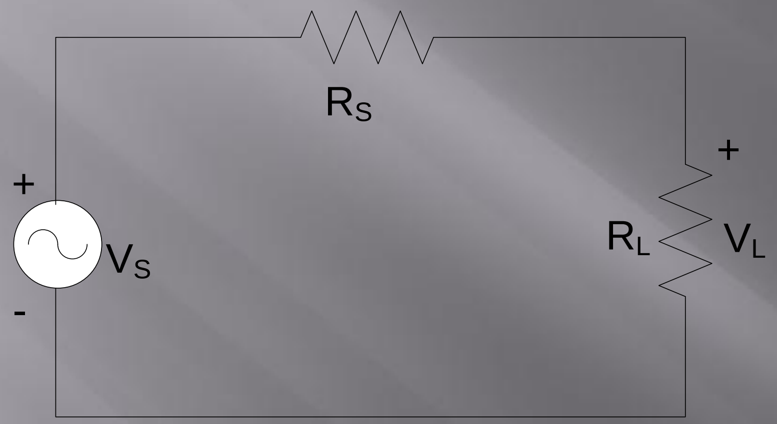
Or dividing all members by 1 Watt

$10 \log_{10} (P_L/1W) - 10 \log_{10} (P_S/1W) = 10 \log_{10} (R_L / R_T)$

$P_L (dBW) - P_S (dBW) = 10 \log_{10} (R_L / R_T)$

Measurement units - dBm

If we express power in milliwatt



We can say

$P_L = P_S . R_L / R_T$

where

$R_T = R_L + R_S$

$V_L = V_S . R_L / (R_L + R_S)$

$P_L = P_S . R_L / (R_L + R_S)$

$10 \log_{10} (P_L / P_S) = 10 \log_{10} (R_L / R_T)$

$10 \log_{10} (P_L) – 10 \log_{10} (P_S) =10 \log_{10} (R_L / R_T)$

Or dividin all members by 1 mw

$10 \log_{10} (P_L/1mW) – 10 \log_{10} (P_S/1mW) =10 \log_{10} (R_L / R_T)$

$P_L (dBm) – P_S (dBm) =10 \log_{10} (R_L / R_T)$

Units of measurement dBr, dBm_0, dBm_{0p}

Or

Designation	Reference	Conversion
dBm	1 mW	dBm = dBW + 30
dbW	1 W	dBW = dBm - 30

We can express one ratio referred to a determined point and in such case will be dBr.

For instance if we consider in a monitoring point the nominal level of one carrier as 10 dBm and in another we measure + 8,7 dBm, we can say that in the measurement point we have -1,3 dBr.

Same way we define dBm_0 and dBm_{0p} as the power referred to a transmission point of level zero, or to a point of level zero noise power respectively

Measurement units (general concept)

- The decibel concept is extended to allow the ratio of any two similar quantities to be expressed in decibel units For example two temperatures T_1 and T_2 may be expressed as $10\log_{10}(T_1 / T_2)$ and if the temperature T_2 is referred to 1ºK , the temperature Kelvin expressed in decibels would be given as dBk. For instance T_1 = 290 ºK can be expressed by $10 \log_{10} (290 / 1)$ dBk or 24,64 dBk

  Another example that occurs widely in practice is bandwith referred to 1 Hertz. Thus a bandwith of 36 MHz , is equivalent to $10 \log_{10} 36000000$ = 75,56 dBHz
- Decibel units can be added directly even if diferent units are used.If a power of 34 dBW is transmitted through a circuit that has a loss of 20 dB, the received power P_R = 34 dBW – 20 dB = 14 dBW
- Some times diferent types of ratio are related. A good example is the ratio G/T in a receiving system .Expressed in decibels $G/T_{dB/K}$ = G dBi – T dBK
- Or the ratio E_B/N_0 called Energy per bit / Noise Spectral density ratio
  - $Eb / N_{0\,dB} = C / N_{0\,dB/Hz} - 10 \log_{10} (\text{data rate})_{dB/Hz}$, where

    $Eb_{dBW/Hz}$ – Energy per bit referred to data rate

    $N_{0dB/Hz}$ – Noise spectral density

    C_{dbW} – Carrier power

Beacon receiver

- The satellite beacon signal is very weak +/- 1,5 x 10 - 15 (fW) ou seja - 118 dBm - uually not modulated whose finality is to allow the up link power control as well as telemetry and ranging.The signal is shifted and amplified in several converter units to set beacon centralized at 70 MHz IF at the beacon receiver, that selects one of pilots (each satellite has got more than one) and delivers a DC signal to the antenna control unit.
- This is responsable by decisions of optimal antenna tracking to the satellite, bearing the azimuth and elevation commands more adequated. So:
  - Beacon signals are buried between the data trasnponders
  - Beacon can be as much as 50 dB bellow the composite carriers
  - Beacon receiver must locate the beacon and measure its power level
  - Beacon signals change from CW to spread spectrum telemetry data carriers

ITSO

Nothing can stop automation

ITU

End 2nd day

Apprehension ??