Ingegneria delle Telecomunicazioni

Satellite Communications

6. Back to the Earth: Ground Station & User Terminal

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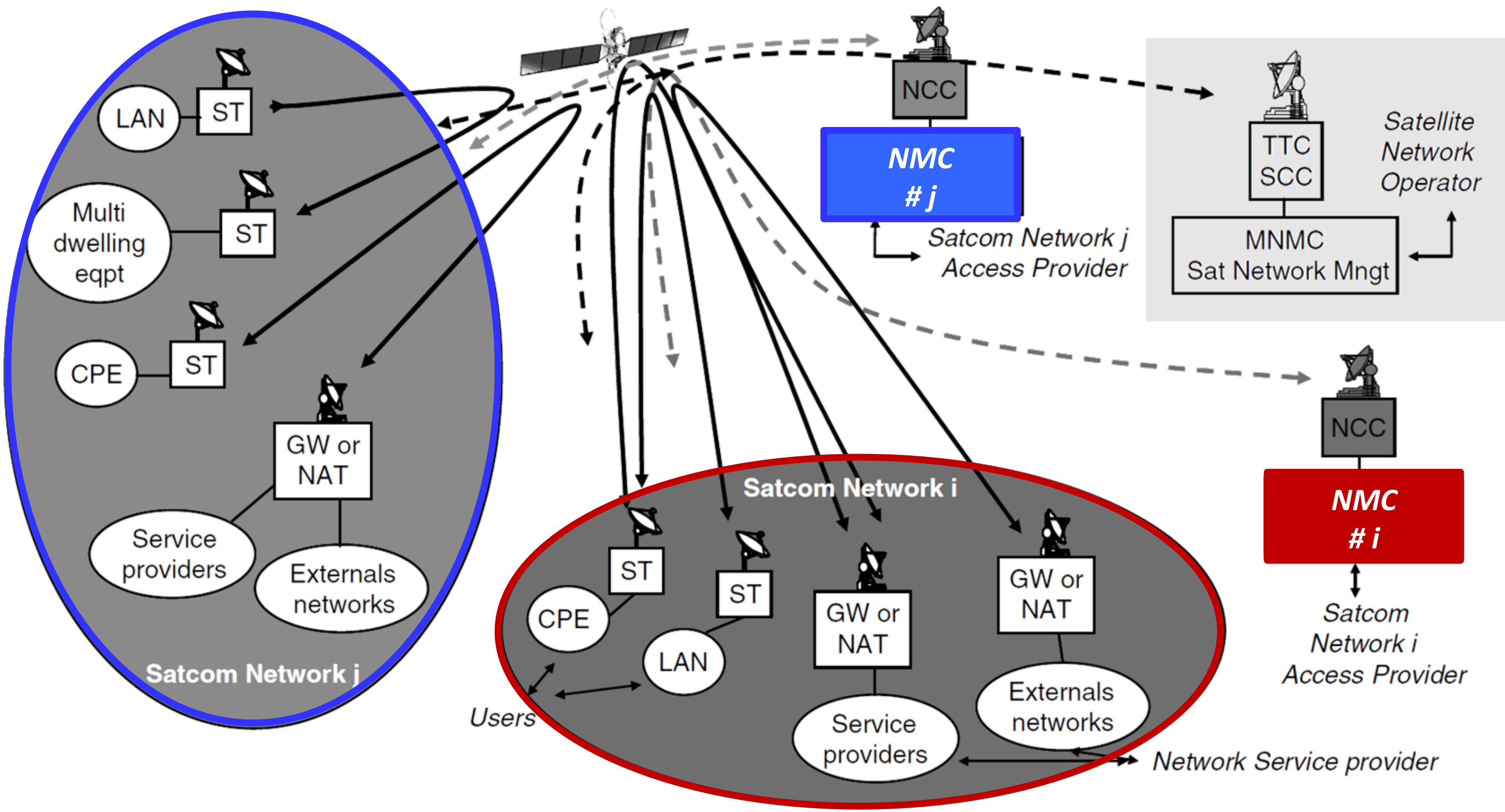
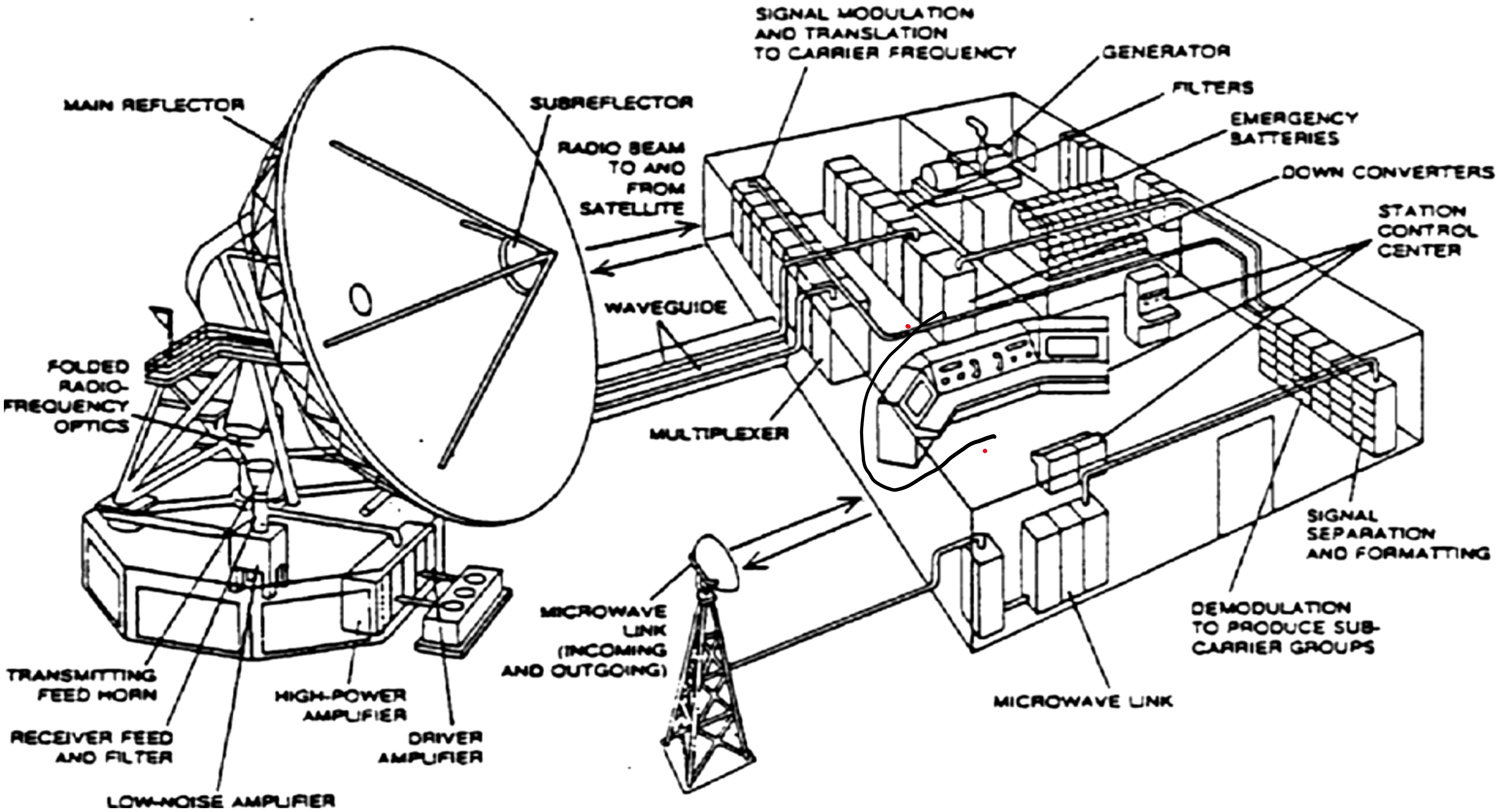
Satellite Network Components



Other Services may need different Network Architectures (broadcasting)

Architecture of a Large Network Gateway (Ground) Station



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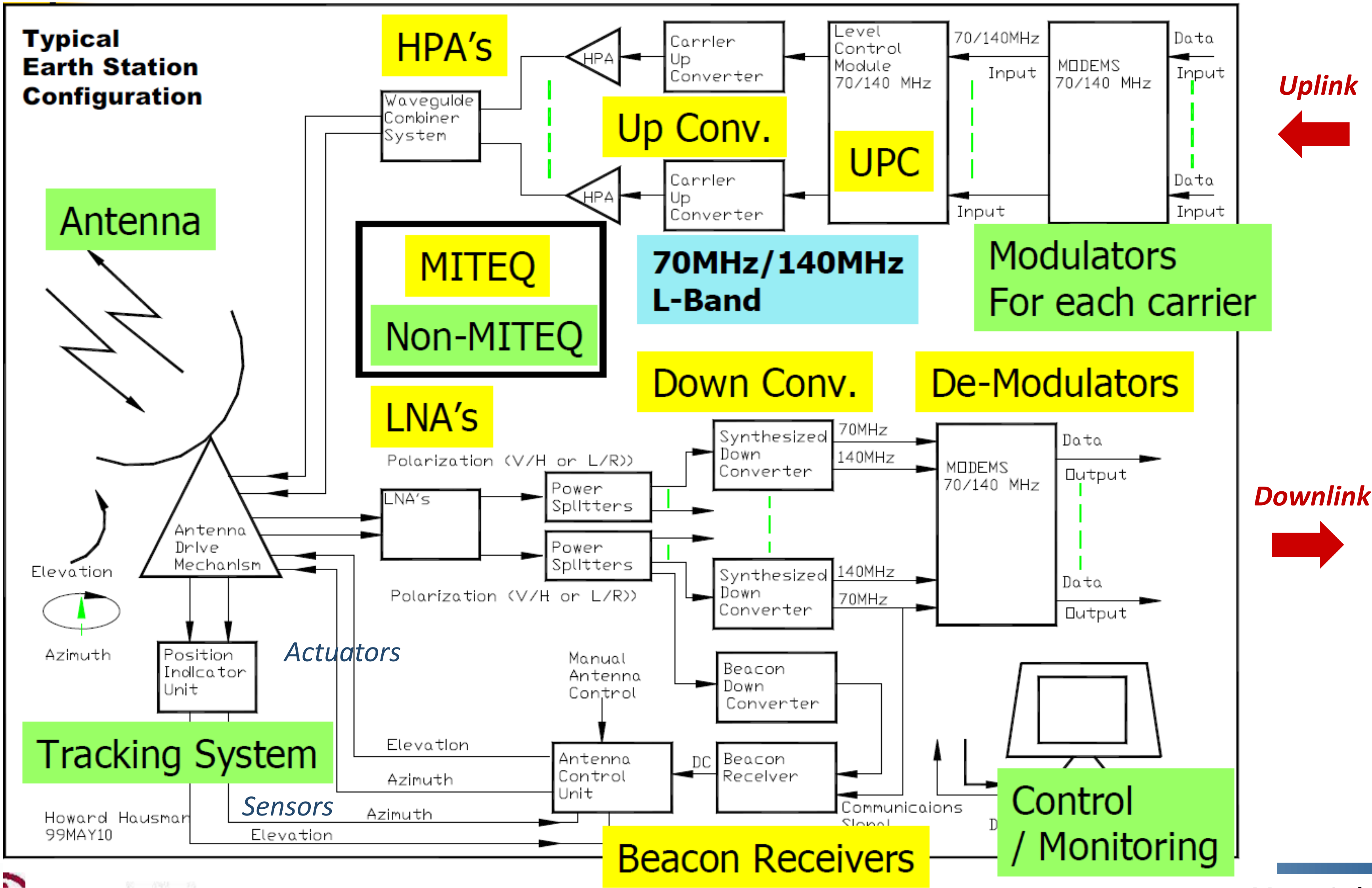
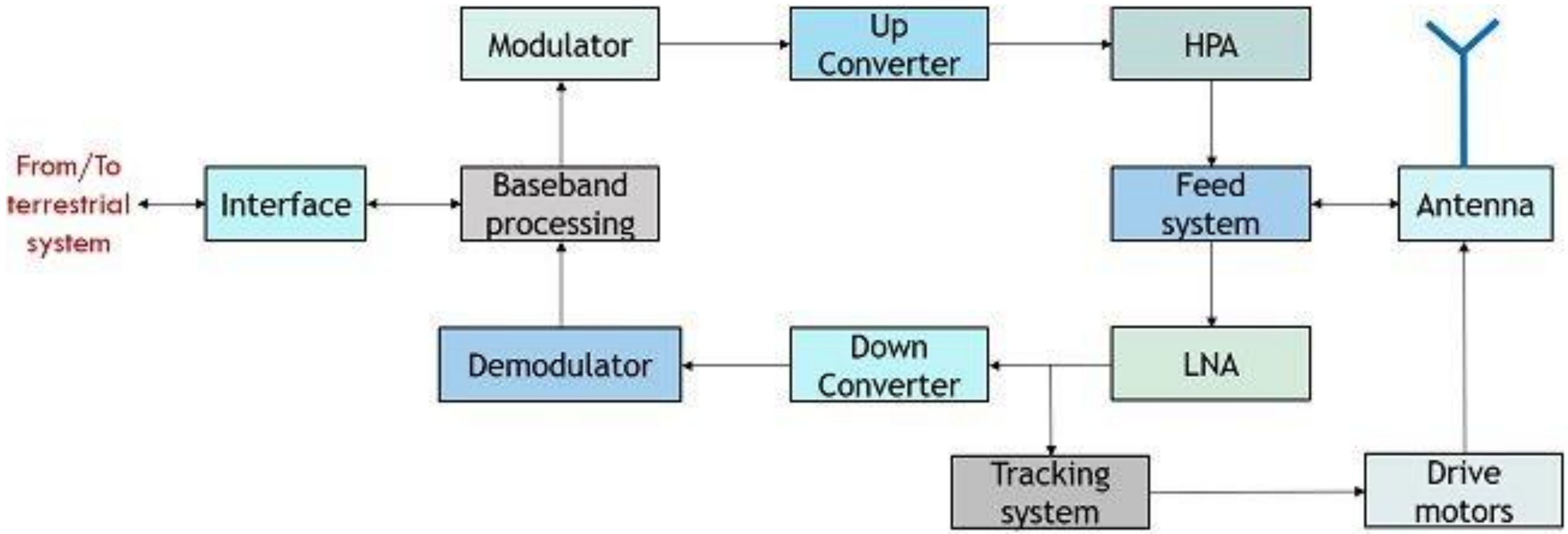
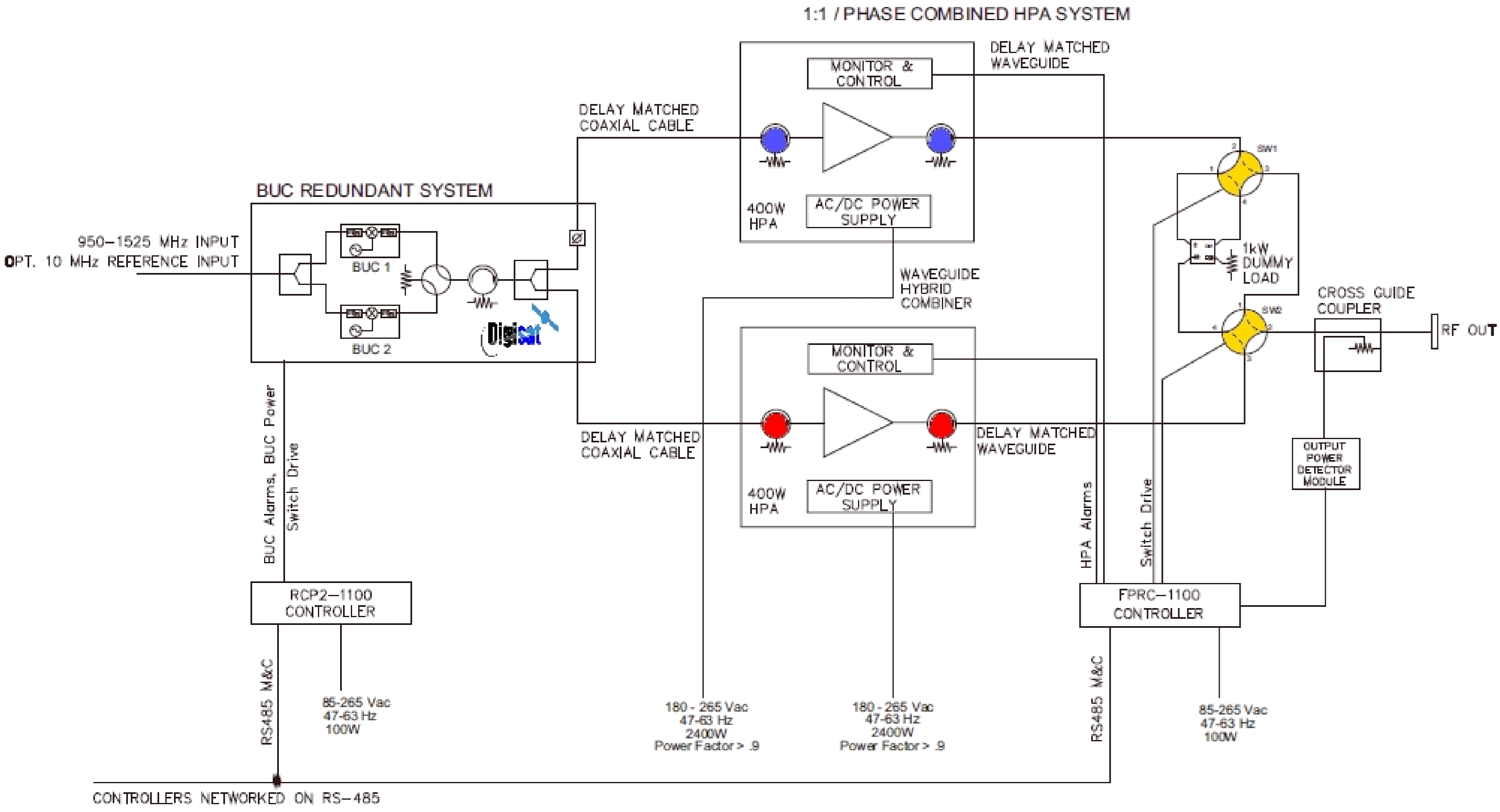
Earth Station Architecture/Functions (Narda/Miteq)



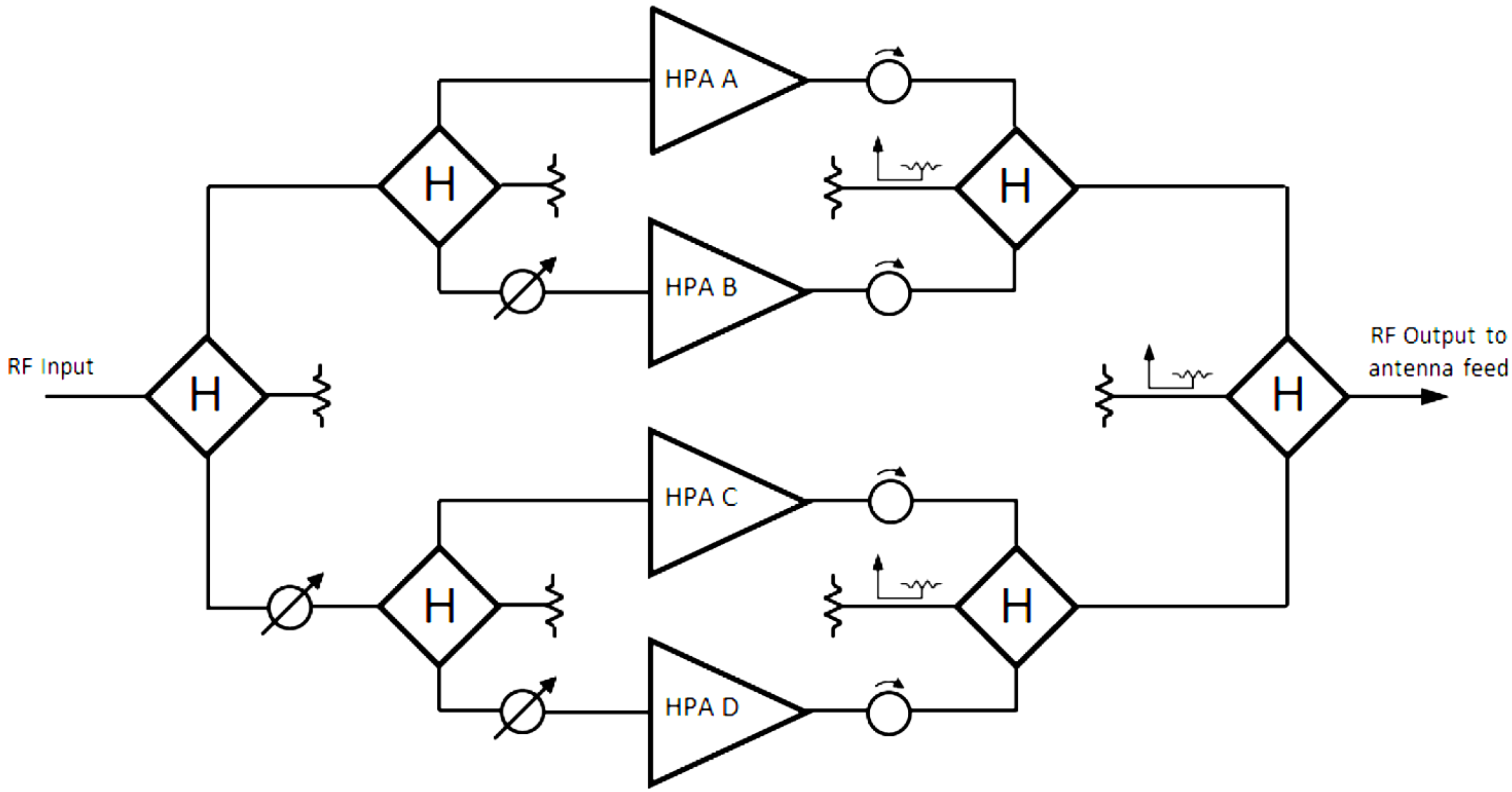
Main Functions



1:1 Redundant HPAs



"Soft" Redundancy

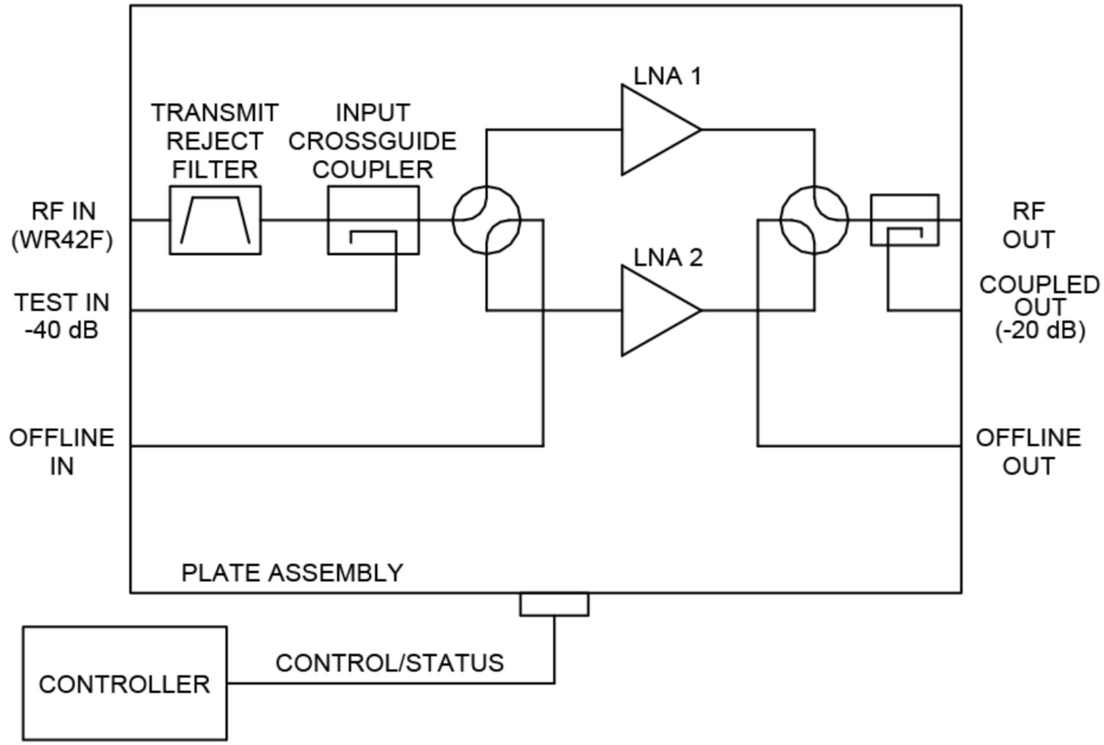


- All amplifiers are active, and are phase-coherently combined
- If one fails, the other provide slightly increased power
- No switches

Redundant LNAs

- **Single Polarization**

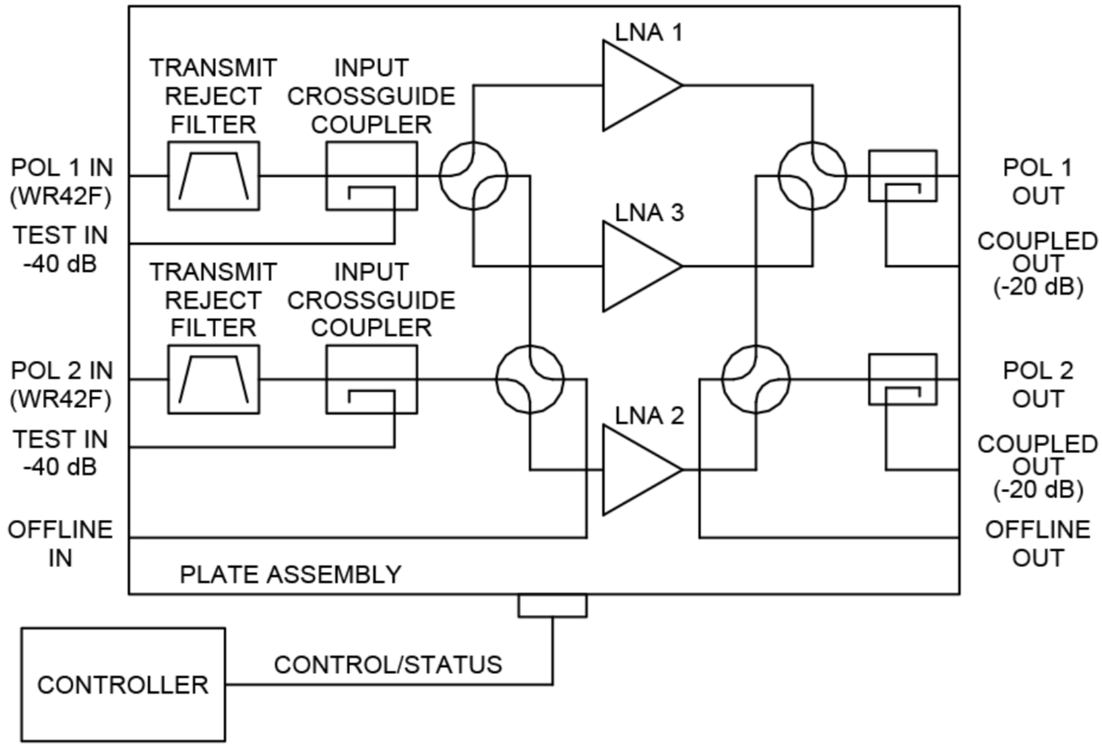
1:1 System



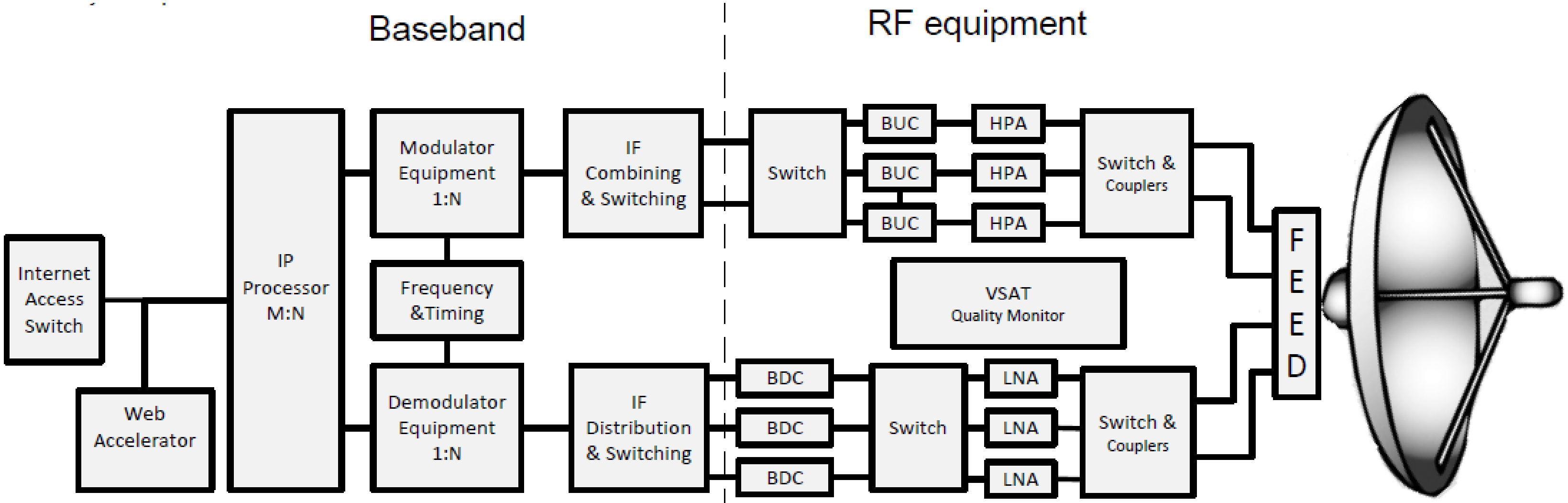
Redundant LNAs

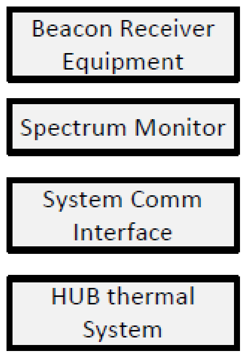
- **Double Polarization**

1:2 System



Gateway Feeder Link

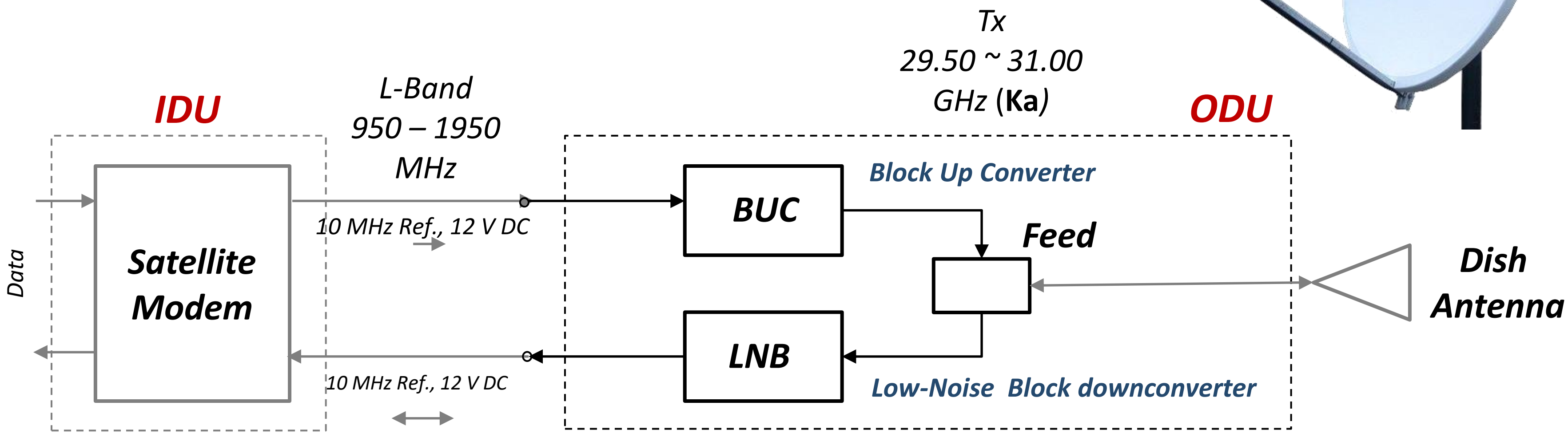


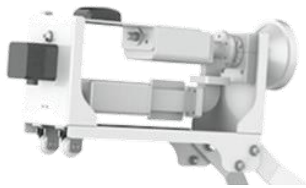


- There may be more than one RF chain

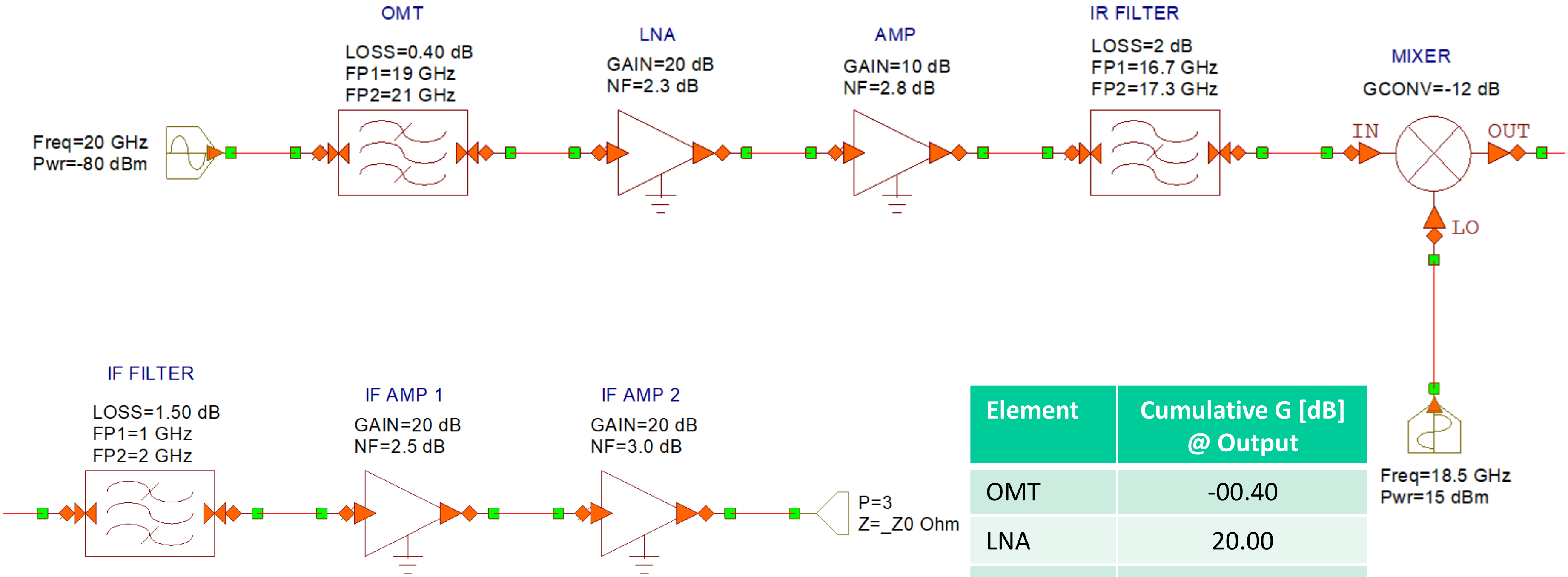
Typical VSAT Domestic User-Teminal Architecture

- User Terminal or User Equipment (UE), much simpler than Gateway Station

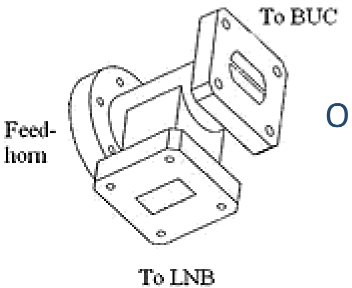




RX Power Budget/Gain

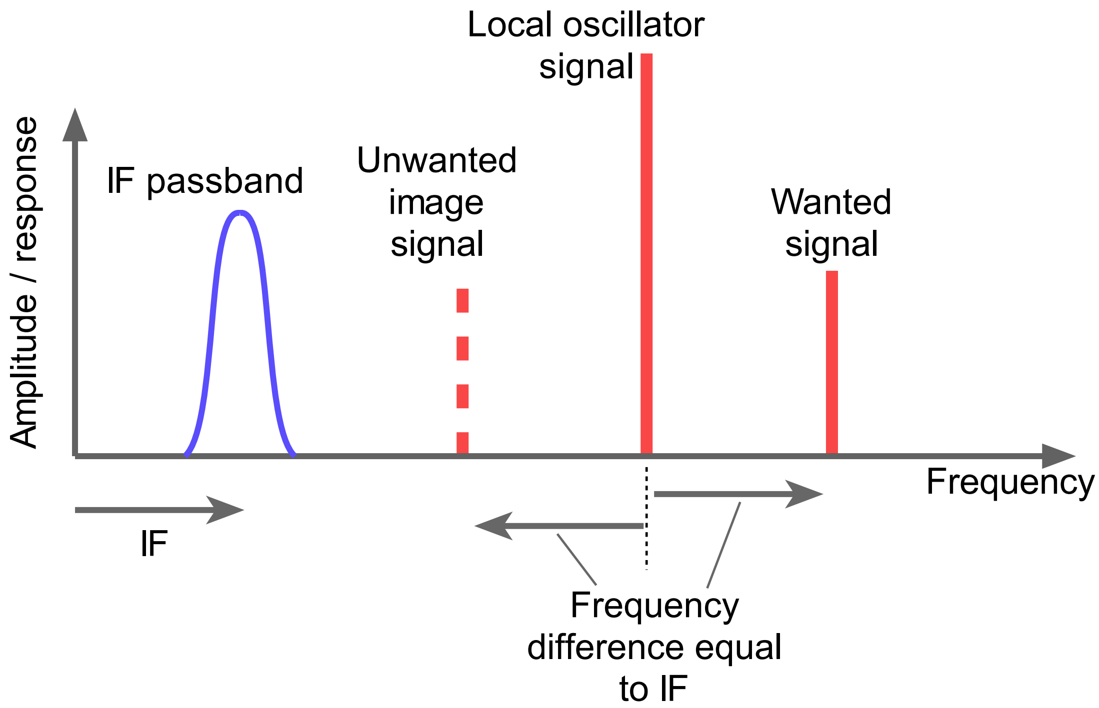


Element	Cumulative G [dB] @ Output
OMT	-00.40
LNA	20.00
AMP	10.00
IR Filter	-02.00
Mixer	-12.00
IF Filter	-01.50
IF Amp 1	20.00
IF Amp 2	20.00
Total (G)	54.10



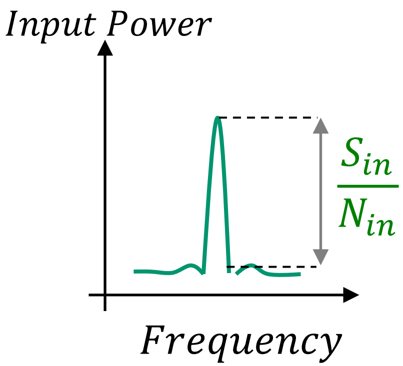
OrthoMode Transducer (OMT, Duplexer)

Image Reject

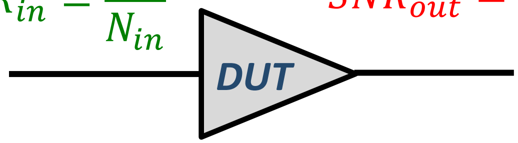


Noise Figure F

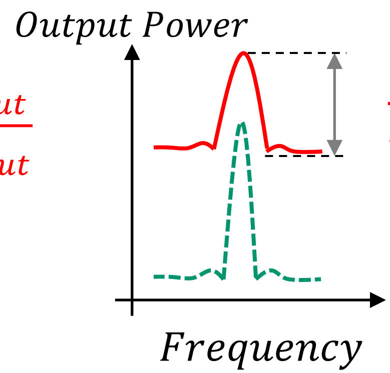
Represents the degradation of the Signal-to-noise ratio (SNR) caused by the diverse electronic components in a radio frequency (RF) signal processing chain



$$SNR_{in} = \frac{S_{in}}{N_{in}}$$



$$SNR_{out} = \frac{S_{out}}{N_{out}}$$



$$\frac{S_{out}}{N_{out}} < \frac{S_{in}}{N_{in}}$$

$$G(Gain) = \frac{S_{out}}{S_{in}}$$

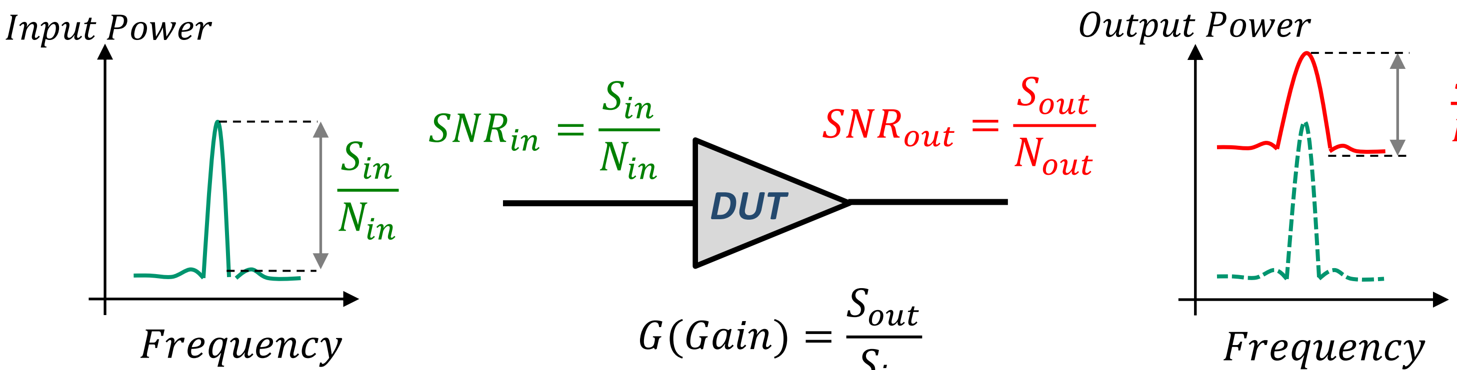
$$N_{out}\ (Output\ Noise) = G * N_{in} + N_{DUT} = G * F * N_{in}$$

$$\frac{SNR_{in}}{SNR_{out}} = \frac{S_{in}/N_{in}}{GS_{in}/GFN_{in}} = F\ ,\ F_{[dB]} = SNR_{in[dB]} - SNR_{out[dB]}$$

$$\frac{S_{out}}{N_{out}} = \frac{G \cdot S_{in}}{G \cdot N_{in} + N_{DUT}} = \frac{S_{in}}{N_{in}} \frac{1}{1 + \frac{N_{DUT}}{GN_{in}}} \Rightarrow F = 1 + \frac{N_{DUT}}{GN_{in}}\ , \qquad N_{DUT} = GN_{in}(F-1)$$

Noise Figure F

Represents the degradation of the Signal-to-noise ratio (SNR) caused by components in a radio frequency (RF) signal chain



$$\frac{S_{in}}{N_{in}}$$

$$SNR_{in} = \frac{S_{in}}{N_{in}}$$

$$SNR_{out} = \frac{S_{out}}{N_{out}}$$

$$\frac{S_{out}}{N_{out}} < \frac{S_{in}}{N_{in}}$$

$$G(Gain) = \frac{S_{out}}{S_{in}}$$

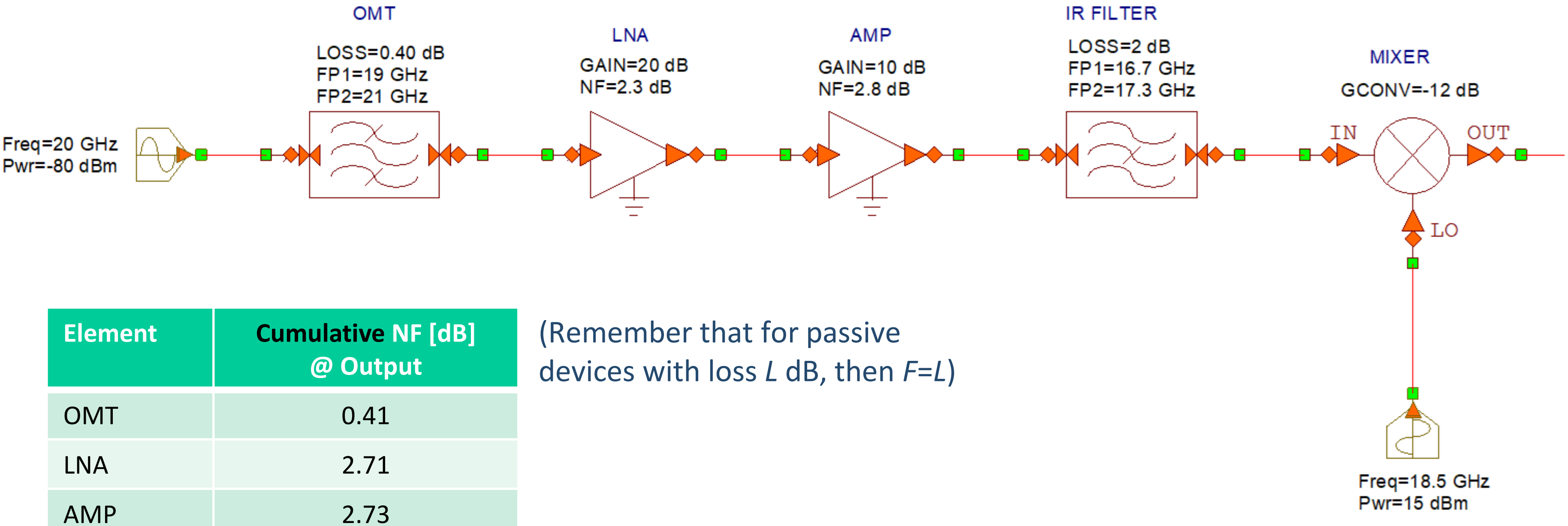
$$N_{out}\ (Output\ Noise) = G * N_{in} + N_{DUT} = G * F * N_{in}$$

$$\frac{SNR_{in}}{SNR_{out}} = \frac{S_{in}/N_{in}}{GS_{in}/GFN_{in}} = F\ ,\ \ F_{[dB]} = SNR_{in[dB]} - SNR_{out[dB]}$$

If several devices are cascaded, the total noise factor (F_T) can be calculated as :

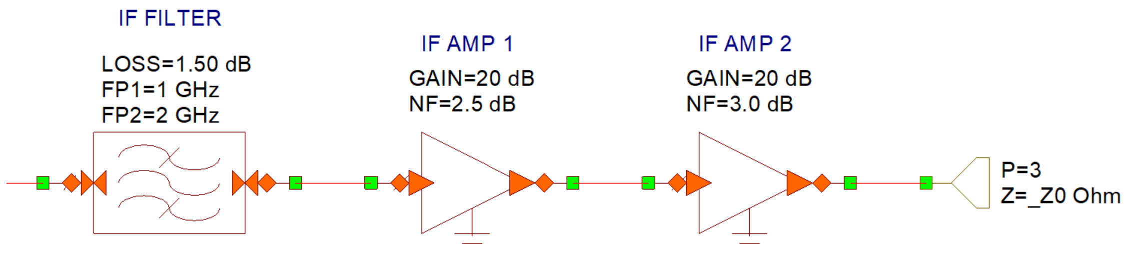
$$F_T = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 * G_2} + \frac{F_n - 1}{G_1 * G_2 * G_{n-1}}$$

RX Noise Computation



Element	Cumulative NF [dB] @ Output
OMT	0.41
LNA	2.71
AMP	2.73
IR Filter	2.74
Mixer	2.80
IF Filter	2.82
IF Amp 1	2.87
IF Amp 2	2.88
Total (NF)	2.88

(Remember that for passive devices with loss *L* dB, then *F=L*)



Noise Figure & Noise Temperature

$$N_{DUT} = G k_B T_{DUT} = G N_{in} (F - 1)$$

(Remember that internal noise N_{in} is *always* referred to the device input…)

Evaluating noise through the noise temperature(s) gives

$$N_{in} = k_B T_{ref} \quad \Rightarrow \quad T_{DUT} = T_{ref} (F - 1)$$

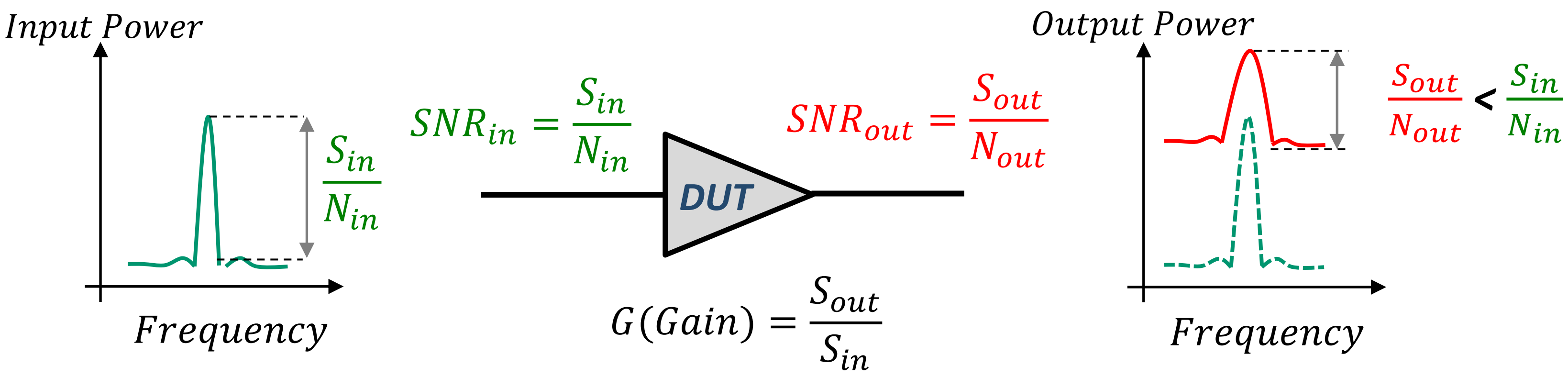
And the relation between the Noise Figure *F* and the Equivalent Noise Temperature T_{DUT} is

$$F = 1 + \frac{T_{DUT}}{T_{ref}}$$

Usually, T_{ref}=290 k

Noise Figure & Noise Temperature

Represents the degradation of the Signal-to-noise ratio (SNR) caused by components in a radio frequency (RF) signal chain



$$N_{out}\ (Output\ Noise) = G * N_{in} + N_{DUT} = G * F * N_{in}$$

$$\frac{SNR_{in}}{SNR_{out}} = \frac{S_{in}/N_{in}}{GS_{in}/GFN_{in}} = F\ ,\ \ F_{[dB]} = SNR_{in[dB]} - SNR_{out[dB]}$$

For cascaded devices, the total equivalent noise temperature (T_T) can be calculated as :

$$T_T = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 * G_2} + \frac{T_n}{G_1 * G_2 * G_{n-1}}$$

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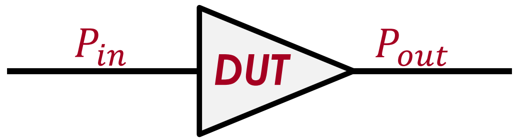
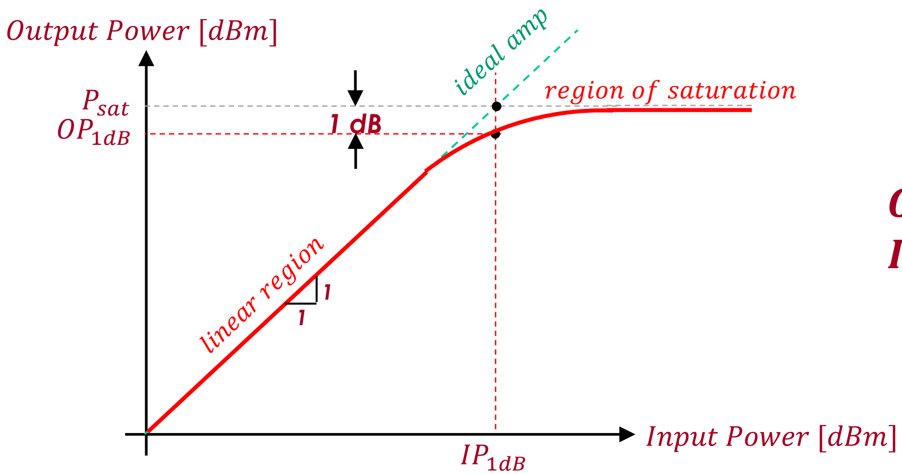
LNA – 1-dB Compression Point

An amplifier keeps a constant gain for low-level input signals. At higher input levels, it goes into *saturation* and its gain decreases. The *1 dB compression point* indicates the power level that causes the gain to drop by 1 dB from its small-signal value.





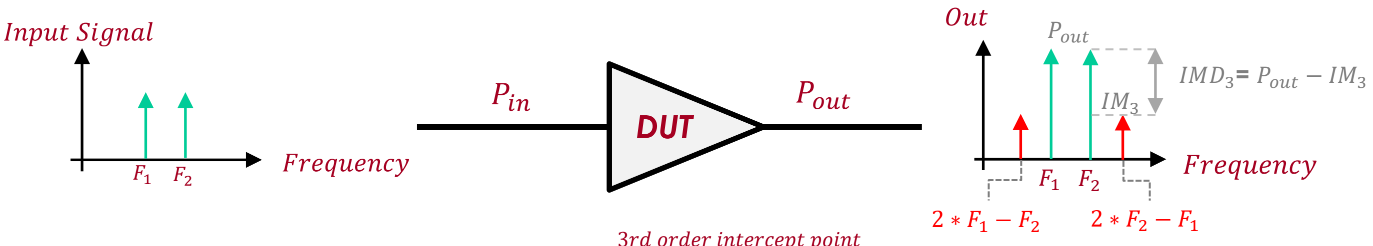
$$OP_{1dB} = IP_{1dB} + (G)_{dB} - 1 \quad \ldots [\text{dBm}]$$
$$IP_{1dB} = OP_{1dB} - (G)_{dB} + 1 \quad \ldots [\text{dBm}]$$

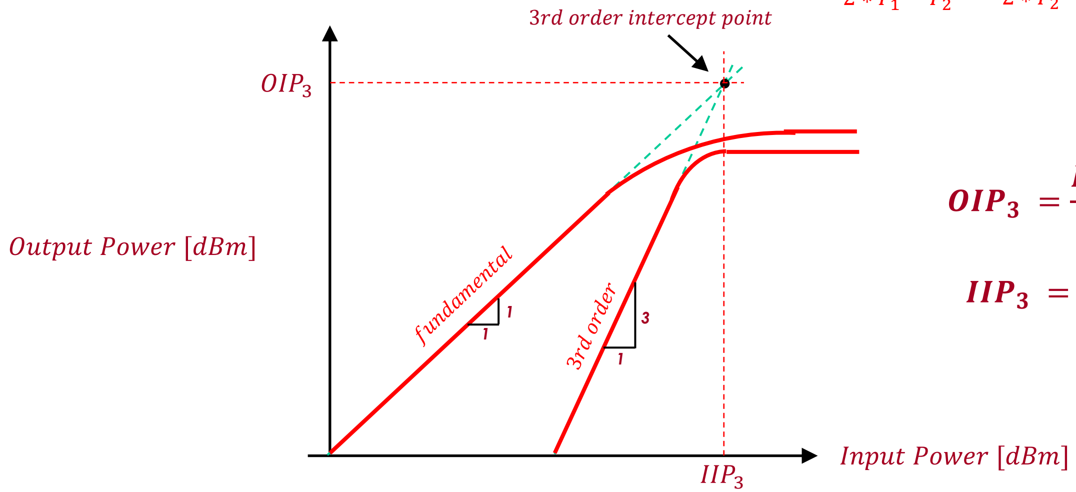
If several devices are cascaded, the P_{1dB} can be calculated as :

$$\frac{1}{IP_{total}} = \frac{1}{IP_1} + \frac{G_1}{IP_2} + \frac{G_1 * G_2}{IP_3} + \ \ldots [\text{dBm}]$$

LNA – 3rd-Order Intercept

The *3rd-Order Intercept Point* (IP3) relates nonlinear products caused by the third-order nonlinear term to the linearly amplified useful signal





$$OIP_3 = \frac{IMD_3}{2} + P_{out} \ldots \text{[dBm]}$$

$$IIP_3 = OIP_3 - G \ldots \text{[dBm]}$$

If several devices are cascaded, the IP3 can be calculated as :

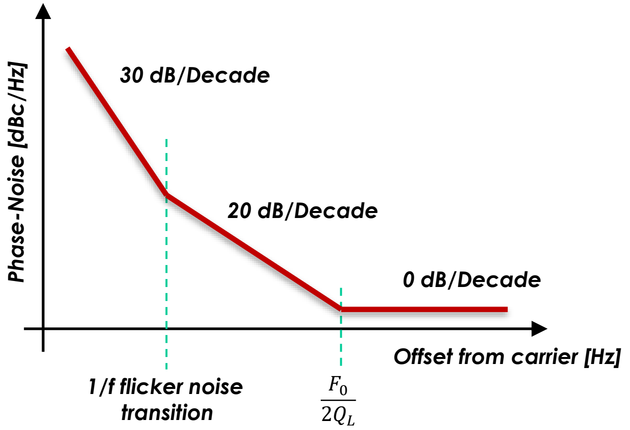
$$\frac{1}{IP3_{total}} = \frac{1}{IP3_1} + \frac{1}{IP3_2} + \frac{1}{IP3_3} + \ldots \text{[dBm]}$$

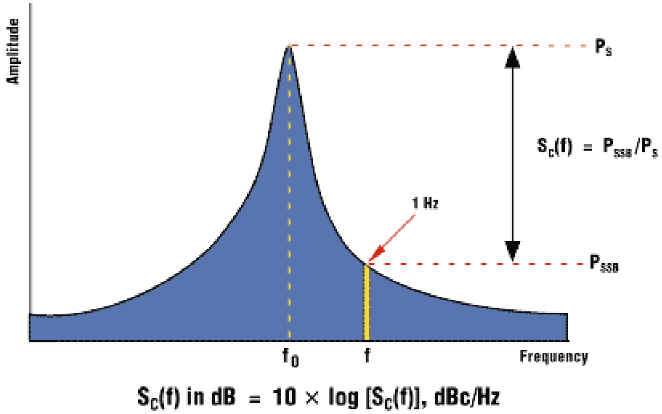
LO Phase Noise

- **Oscillator with phase noise:**

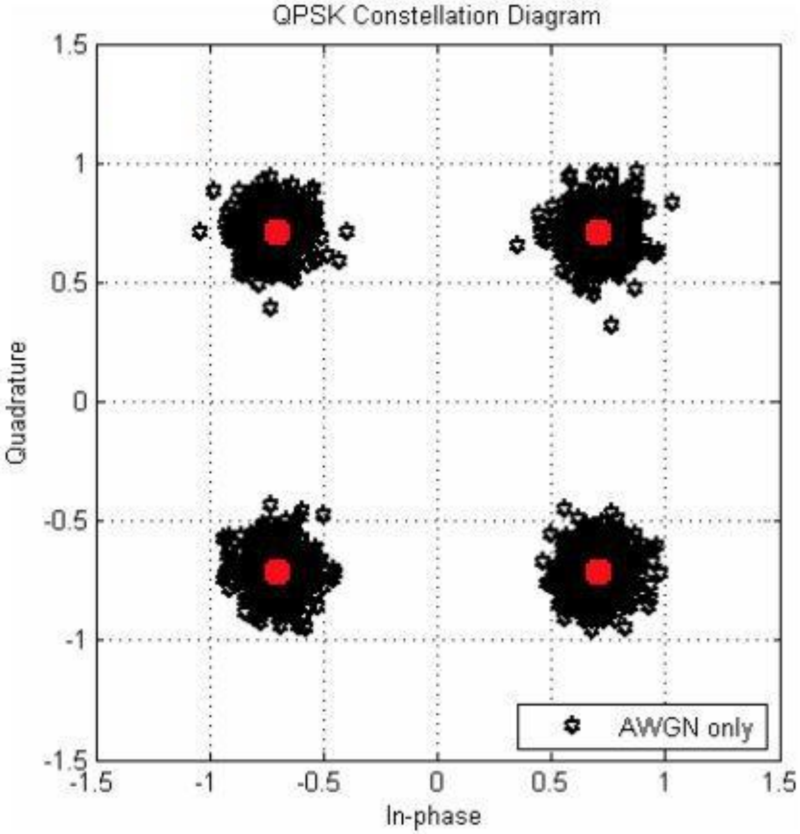
$$c(t) = \sqrt{2C}\cos(2\pi f_{LO}t + \theta(t)) \quad \Rightarrow \quad c_{BB}(t) = \sqrt{2C}\cdot e^{j\theta(t)}$$

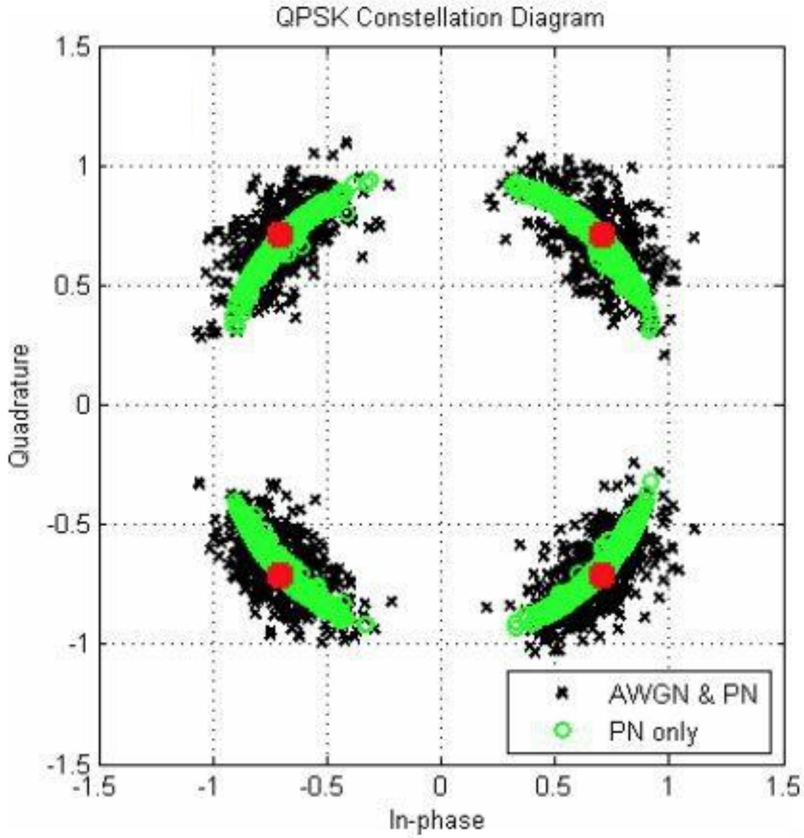
  - rapid, short-term, random fluctuations in the phase of the LO signal, caused by time domain instabilities





Effect of Phase Noise on Data Constellations





LO Phase Noise

- **Oscillator with phase noise:**

$$c(t) = \sqrt{2C}\cos(2\pi f_{LO}t + \theta(t)) \quad \Rightarrow \quad c_{BB}(t) = \sqrt{2C} \cdot e^{j\theta(t)}$$

  – rapid, short-term, random fluctuations in the phase of the LO signal, caused by time domain instabilities

Offset from the carrier	Analogue DRO (Low-Cost)	Digital DRO	PLL Internal Ref. (Quartz)	PLL External Ref. (10 MHz USO)
100 Hz	Not specified	Not specified	-70 dBc/Hz	-65 dBc/Hz
1 KHz	-55 dBc/Hz	-65 dBc/Hz	-75 dBc/Hz	-75 dBc/Hz
10 KHz	-70 dBc/Hz	-80 dBc/Hz	-80 dBc/Hz	-85 dBc/Hz
100 KHz	-85 dBc/Hz	-100 dBc/Hz	-85 dBc/Hz	-95 dBc/Hz
1 MHz	-95 dBc/Hz	-100 dBc/Hz	-95 dBc/Hz	-105 dBc/Hz

Anatomy of a Ka-Band VSAT (Professional) Terminal

The transceiver consists of the following sub-systems:

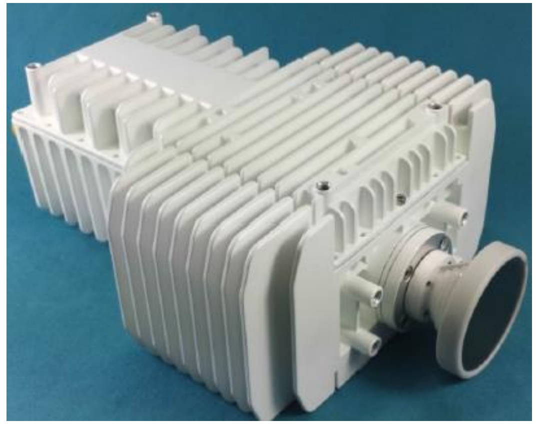
Waveguide feed

- Septum polarizer (POL) with OMT
- Diplexers (DPX)

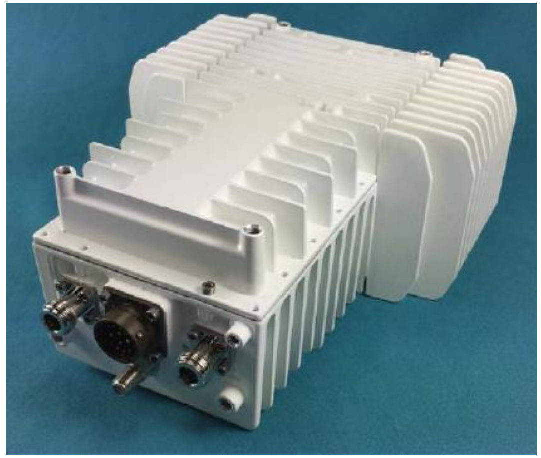
Low Noise Block-down-converter (LNB)

5W Block Up-Converter (BUC)

Monitor and Control facility (M&C)



Courtesy: Skyware



Key features:

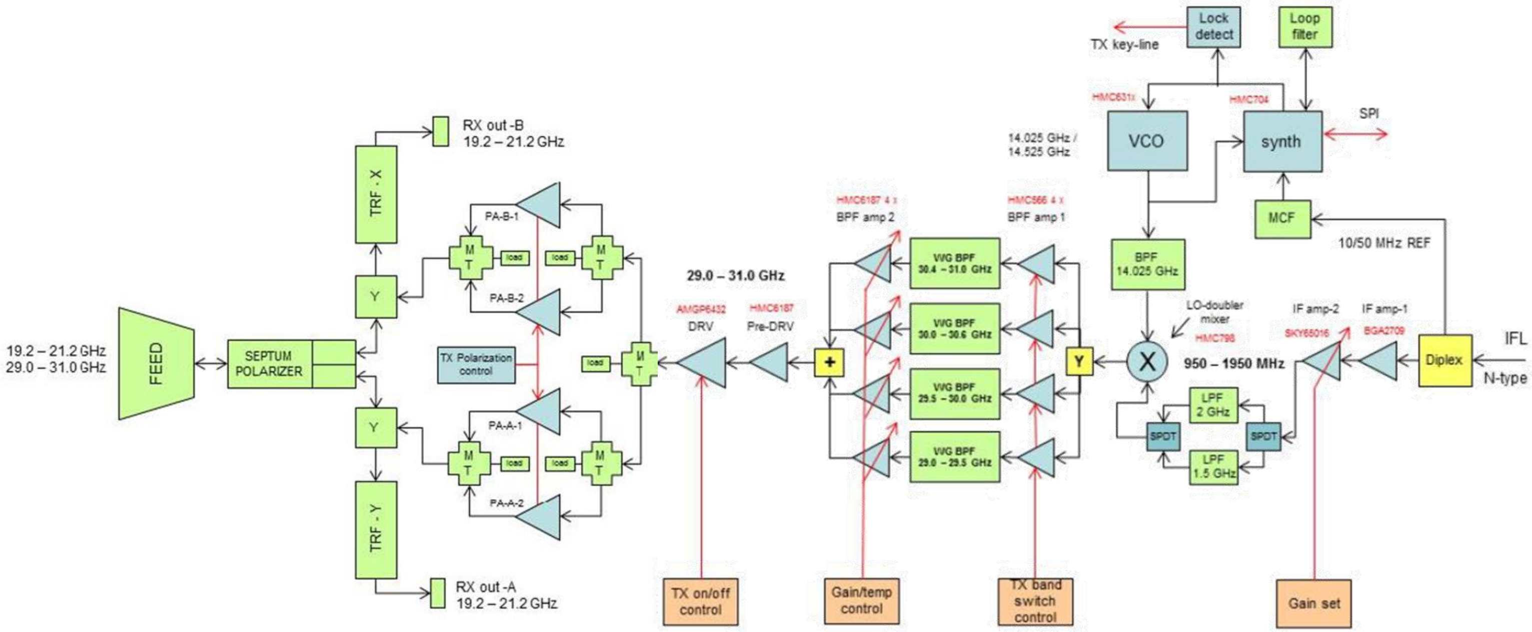
Integrated Waveguide Feed (POL+OMT+DPX)

Operation on arbitrary polarizations:

- LHCP or RHCP electronically switchable
- X- or Co-polar electronically switchable

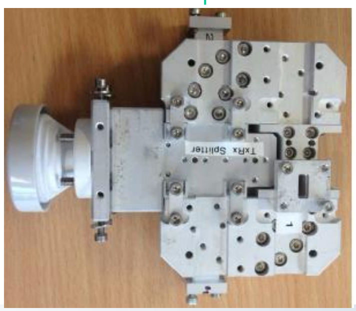
Wideband operation with electronically switchable frequency sub-bands

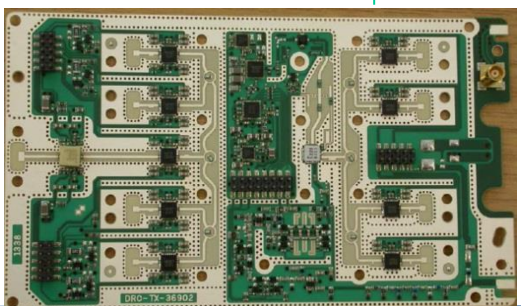
Anatomy of a Ka-Band VSAT (Professional) Terminal - TX



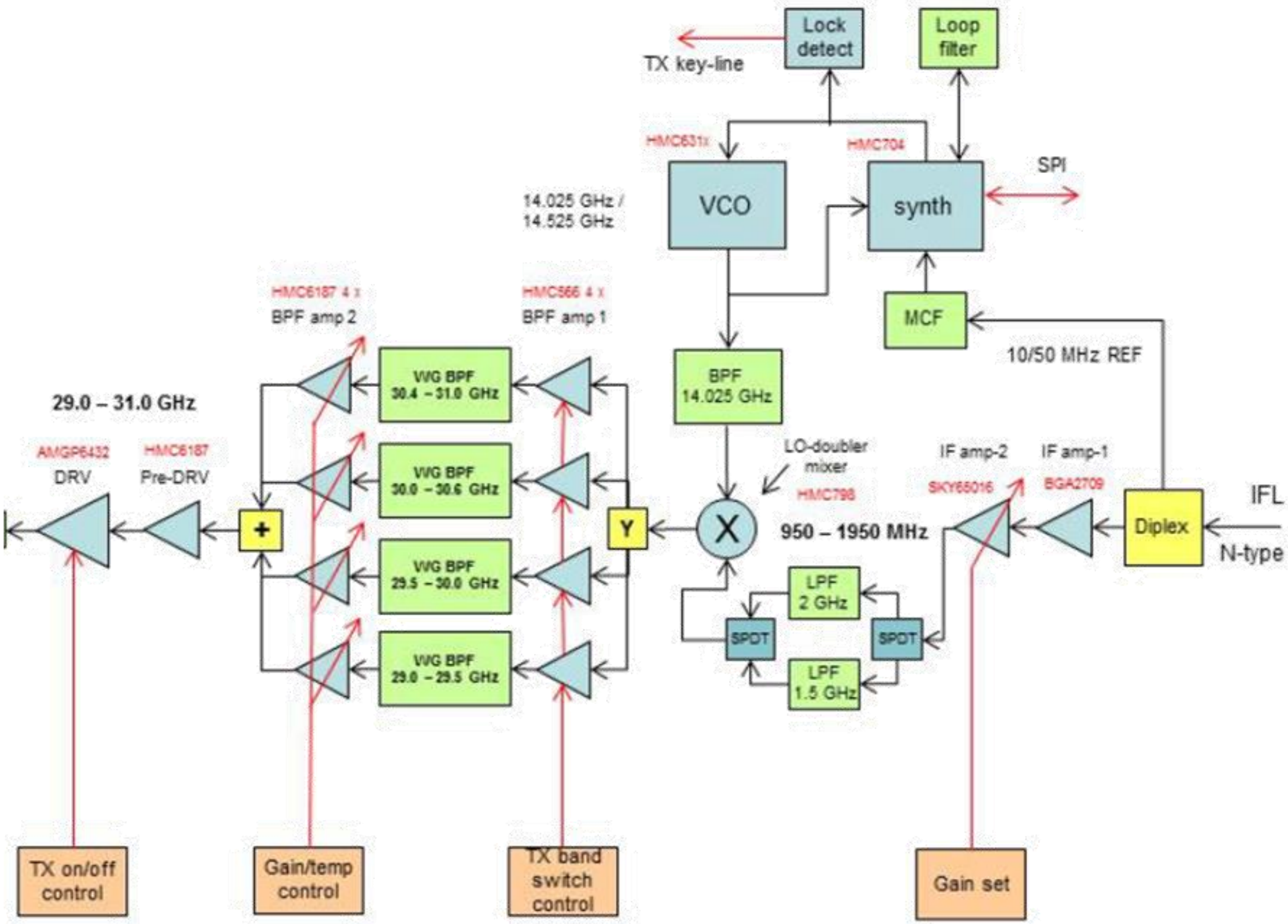
Waveguide Feed

Transmitter

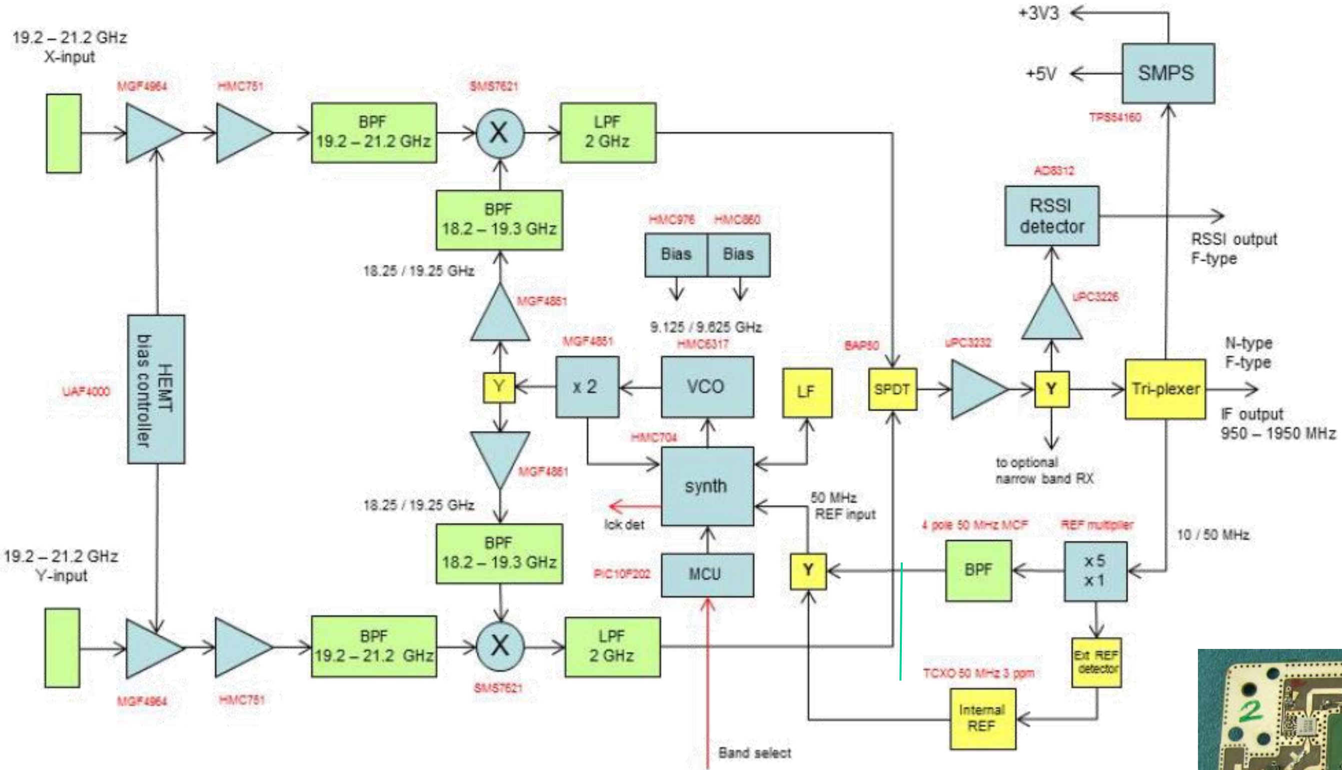




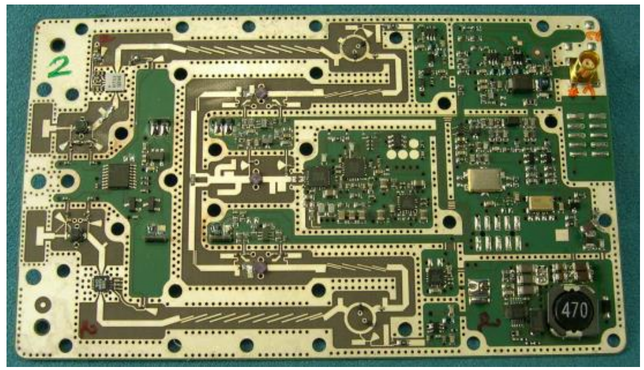
Anatomy of a Ka-Band VSAT (Professional) Terminal - TX



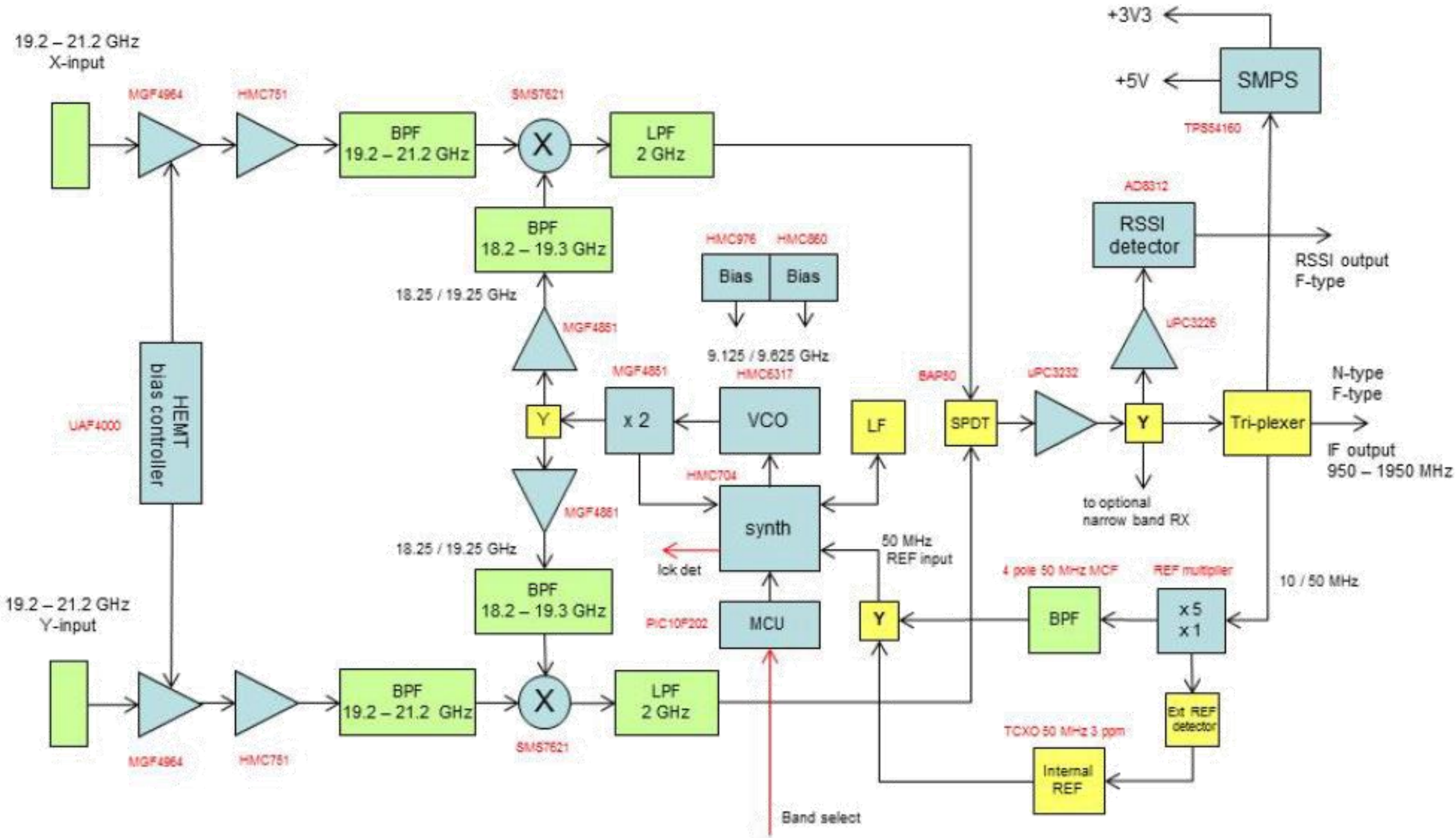
Anatomy of a Ka-Band VSAT (Professional) Terminal - RX



Receiver



Anatomy of a Ka-Band VSAT (Professional) Terminal - RX



Typical Requirements of a Universal Ka-Band (5W) Transceiver

	Parameter	Value	Comments
Receiver Subsystem	Receive (Downlink) range	19.2 – 21.2 GHz	Commercial & military
	IF output range	950 – 1950 MHz	
	LO frequency	18.25/19.25 GHz	Switchable via M&C
	LO frequency tolerance	0.7 ppm / 3 ppm	In/Ext Auto-detect
	LO phase noise	0.9 deg	1KHz – 1 MHz
	Noise figure	1.3 dB	
	Conversion gain	60 dB	
	Power Consumption	3.6 W	150 mA @ 24 V DC over RX IF supply
	Parameter	**Value**	**Comments**
Transmitter Subsystem	Transmit (Uplink) range	29.0 – 31.0 GHz	Commercial & military
	IF input range	950 – 1950 MHz	
	LO frequency	28.05/29.05 GHz	Switchable via M&C
	LO phase noise	1.3 deg	100 Hz – 100 KHz
	Conversion gain	58 dB	
	RF output spurious	EN 301459 and FCC 47	With 53 dBi antenna
	Power Consumption	62.4 W	1.3 A @ 48 V DC over TX IF supply @ RF full, CW
	Parameter	**Value**	**Comments**
Feed	Frequency range	19.2 – 31.0 GHz	
	Polarisation	RHCP/LHCP & co-/x-polar	Switchable via M&C
	XPD	26 dB	

Overall Specifications

Parameter	Value	Comments
Transceiver Output Power	5W	
G/T @ 20.2 GHz	17.0 dB/K	30 deg elevation angle
EIRP @ 30 GHz	50.5 dBW	P1dB
Polarization	RHCP/LHCP & co-/x-polar	Switchable via M&C
Tx Band Switching	Yes	
Temperature (operational)	-25 to +55 degC	
Temperature (storage)	-40 to +80 degC	
Terminal weight	19.2 Kg	Without transport case

Courtesy: Skyware

$$\boldsymbol{EIRP = P_0 - Lt + Gt} \;\ldots [\mathbf{dBW}]$$

$$\text{EIRP} = 7 - 0.2 + 43.7 = 50.5 \text{ dBW}$$

$$\boldsymbol{\frac{G}{T} = Gr - Lr - 10\log(T_{sys})} \;\ldots [\mathbf{dB/K}]$$

$$\text{G/T} = 40.2 - 0.4 - 22.8 = 17.0 \text{ dB/K}$$