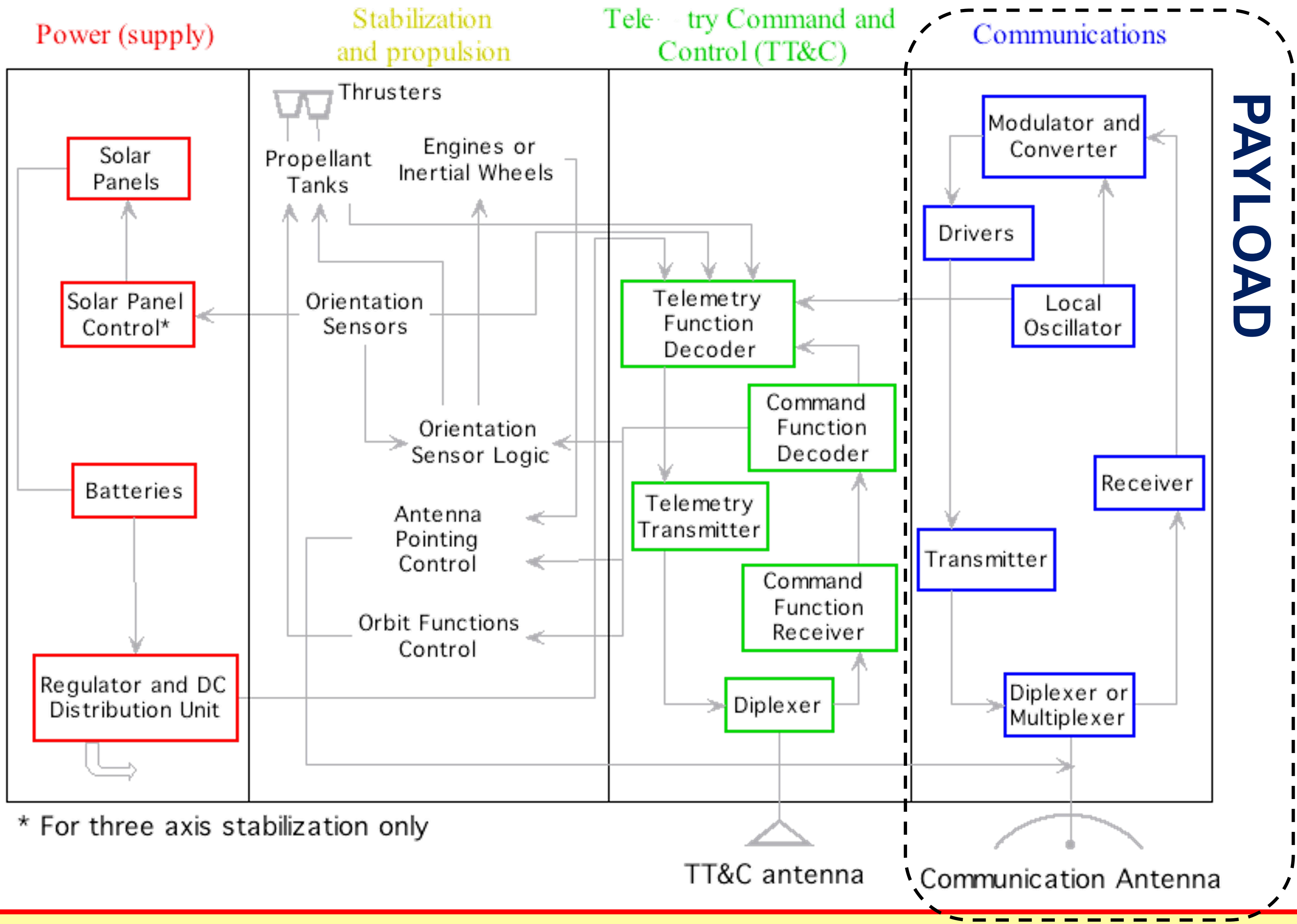
PAYLOAD

Application	
Presentation	Application
Session	
Transport	Transport
Network	Internet
Data Link	Network Interface
Physical Layer	Physical
The space segment: Architecture, technology, equipment	

Communications satellite block diagram



* For three axis stabilization only

Payload functions

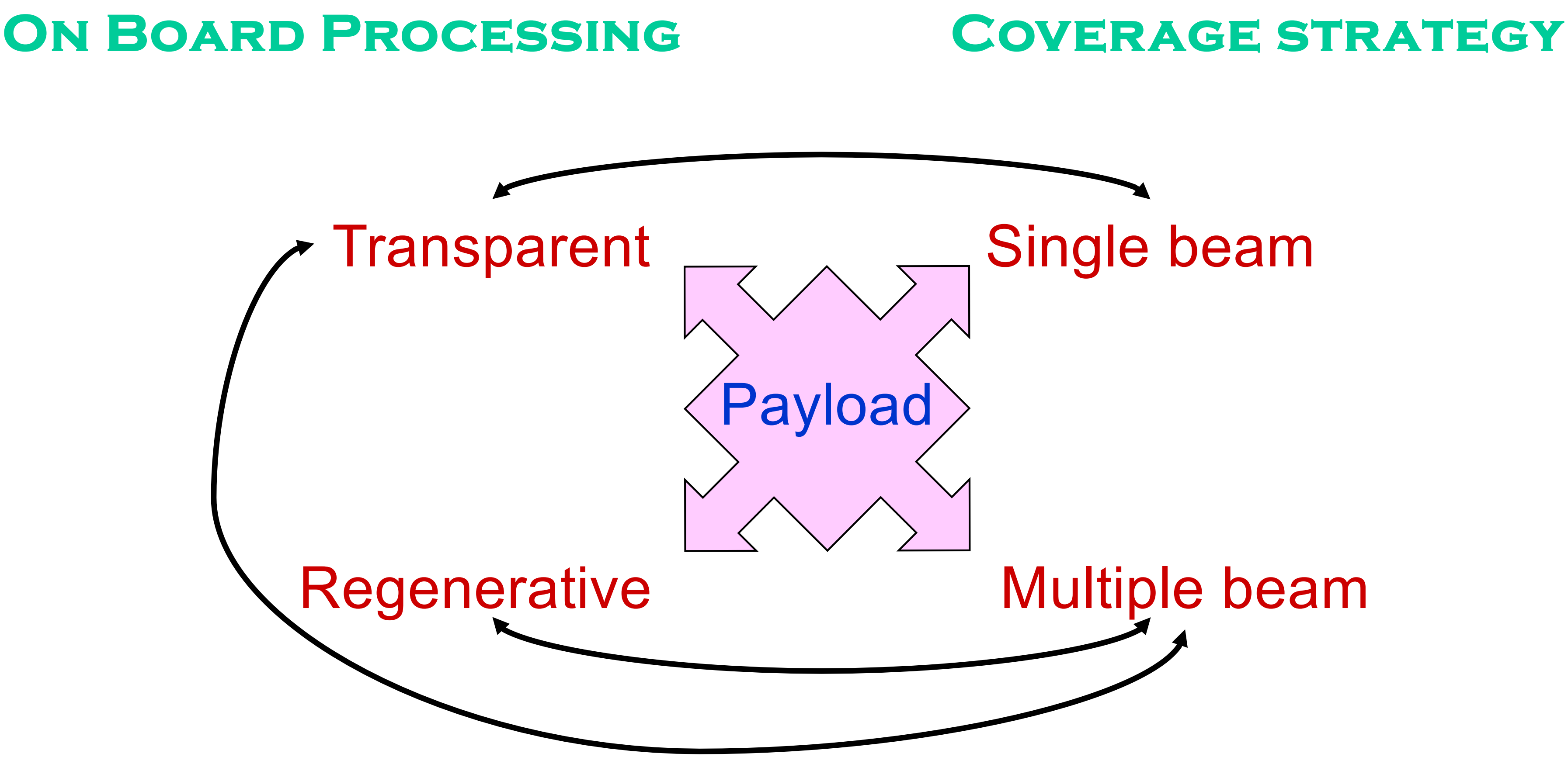
At least

- To provide radio relay for links between earth stations
- To capture the carriers transmitted by the earth stations
- To amplify the received carriers
- To change carrier frequency
- To radiate carriers back

and also ….

- To change polarization
- To regenerate signals
- To interconnect beams
- To route packets
- To switch messages

Payload architecture classification



Payload architecture evolution

ON BOARD PROCESSING | **COVERAGE STRATEGY**

TRANSPARENT — SINGLE BEAM

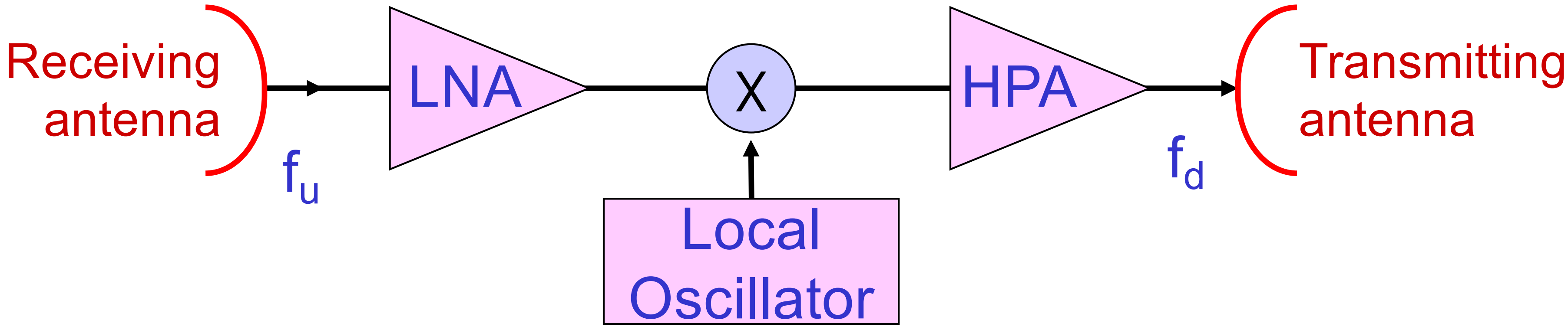
Higher frequencies
larger antennas

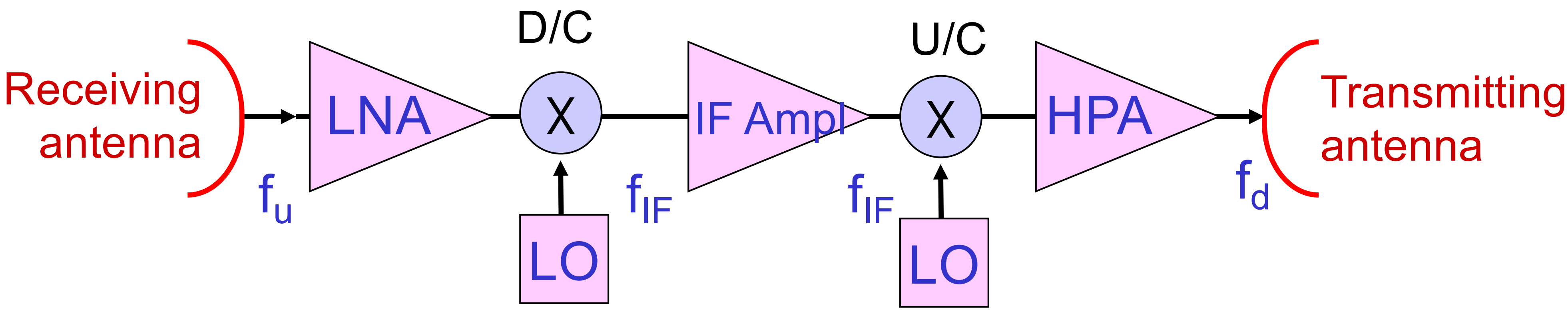
TRANSPARENT — MULTIBEAM

OBP technology

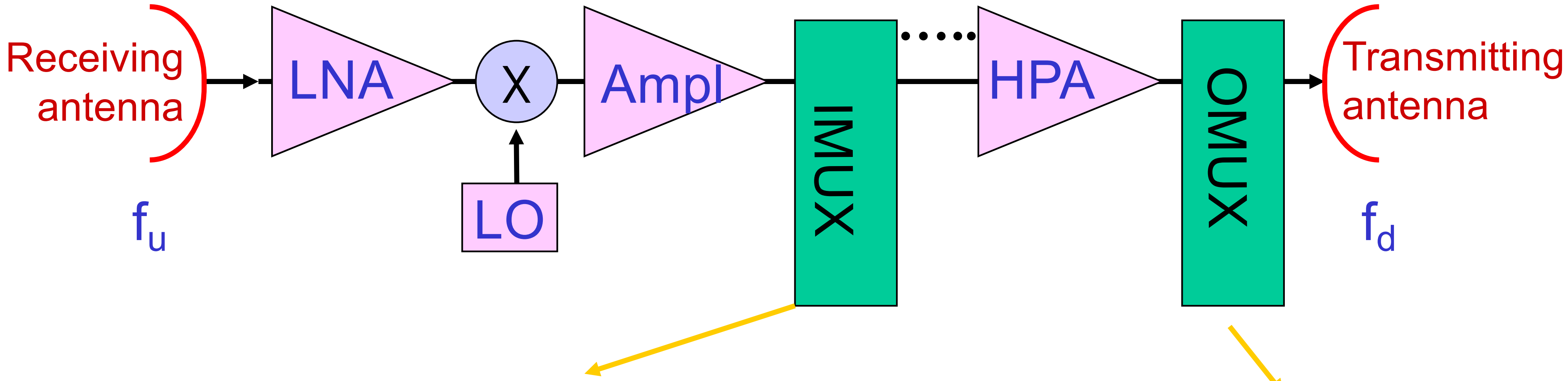
REGENERATIVE — MULTIBEAM

Repeater architecture: transparent-single beam





Repeater architecture with multiplexing stages



Divides the total bandwidth into different sub-bands

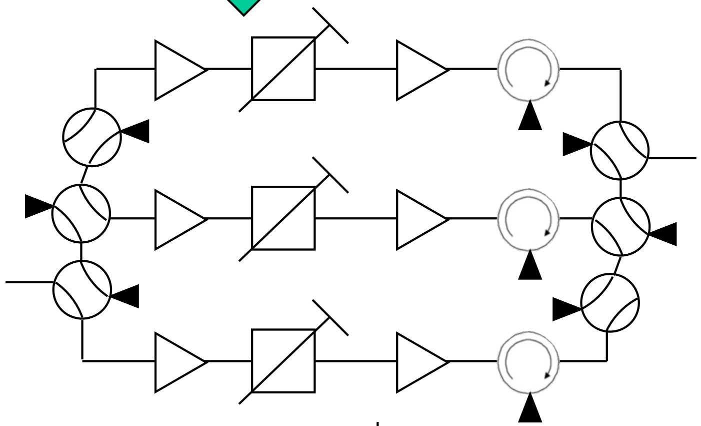
Recombines the channels after amplification

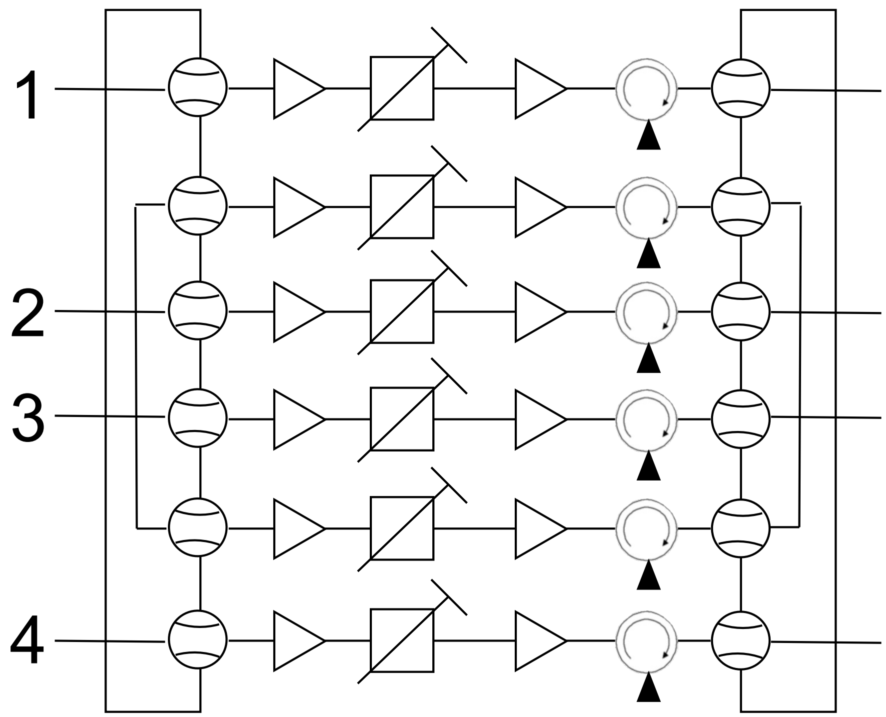
Repeater segmentation (transponder)

- Total allocated bandwidth is too large to allow a single amplifier to deliver sufficient power density
- No carrier needs such amount of bandwidth
- Segmentation alleviates intermodulation noise (each amplifier must handle a smaller number of carriers)
- The total repeater bandwidth is split into sub-bands $\Rightarrow$ **TRANSPONDER**
- Transponder bandwidth typically 40 MHz (36 MHz actually used) or 80 MHz (72 MHz actually used)

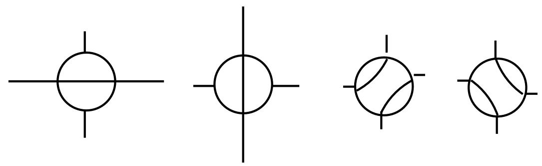
Repeater reliability

- Equipment intrinsically more reliable (and as a consequence much more expensive)
- Redundancy
  - 2/3 scheme
  - Ring





2 positions switches 

 4 positions switches

LNA characteristics

Uplink frequency (GHz)	6	14	30	47
Noise Figure (dB)	1.5	1.8	2.1	2.4
Effective input noise temperature	120K	150K	180K	210K

TWTA and SSPA characteristics

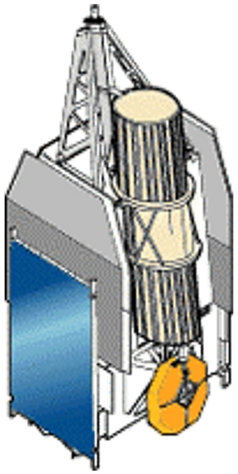
	TWTA	SSPA
Operating band	C, Ku, Ka	C, Ku
Saturated power output (W)	20-250	20-40
Gain at saturation (dB)	~55	70-90
Third order intermodulation product relative level $(C/N)_{IM}$ (dB)	10-12	14-18
AM/PM conversion coefficient	4.5	2
DC to RF efficiency (%)	50-60	30-45
Mass (kg)	1.5-2.2	0.8-1.5
Failure in 10^9 h	<150	<150

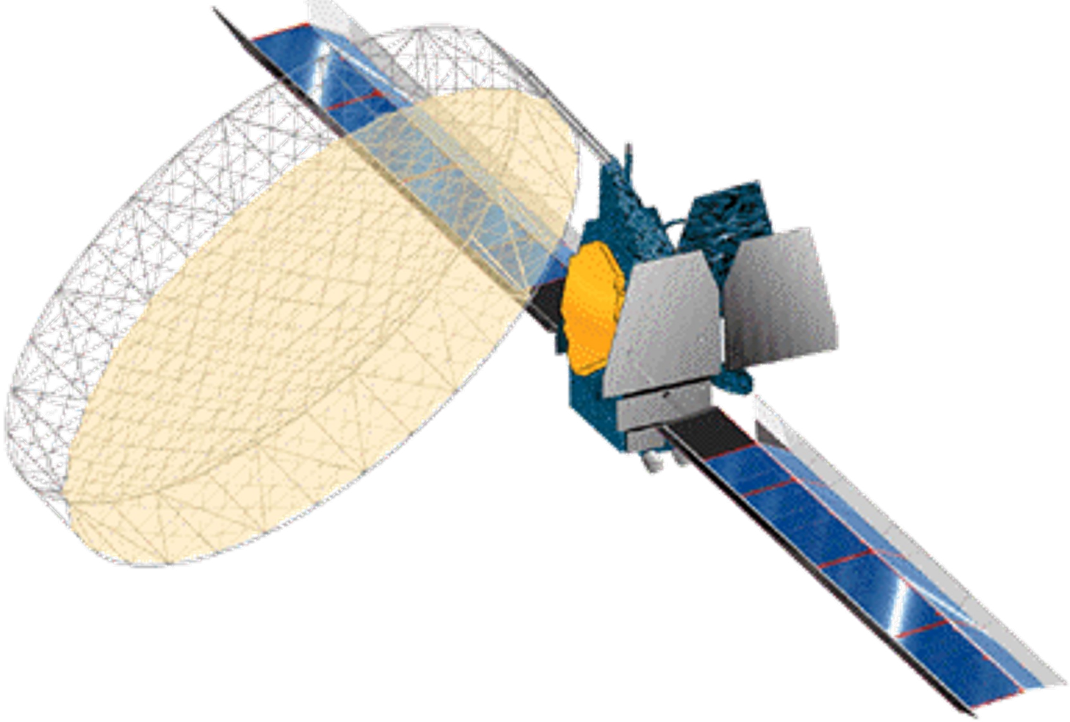
Note: these figures are just an example, every payload is characterized by its peculiar figures.

Mass and power consumption

- Mass: up to 6 t (first satellite 40 kg)
- Power: up to 12 kW (first satellite 50 W)

Large antennas (Thuraya)





Multibeam satellite payload

- The coverage is achieved by multibeam antennas
- The connectivity between any pair of beams must be ensured (reduced connectivity patterns can be allowed)
- Also hopping beams can be used

Fixed Interconnection strategy

- The interconnection pattern is decided during the design phase on the basis of traffic forecast
- The satellite contains as many active receivers as there are uplink beams
- The input demultiplexers (IMUX) divide the frequency band into different channels
- The repeater contains as many output multiplexers (OMUX) as transmitting beams

Reconfigurable Interconnection strategy

- The interconnection between pair of beams can change using switches controlled by
  - Telecommand
  - Pre-recorded sequence
- Switch matrix required

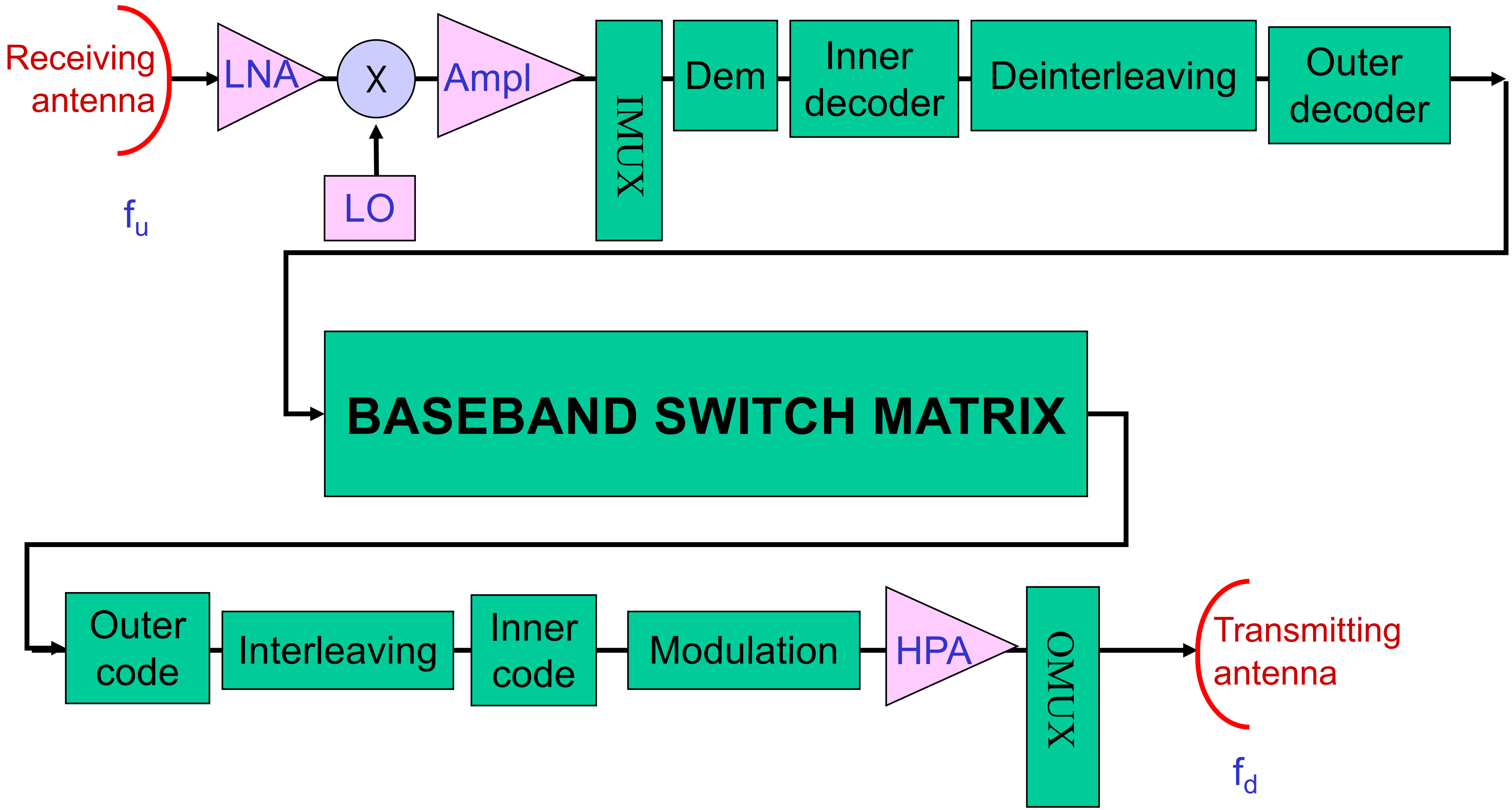
On board switching

- Very fast reconfiguration may be required (in the order of few hundreds of nanoseconds).
- Active switching elements (PIN diodes)
- Optical switching
- Switching matrix

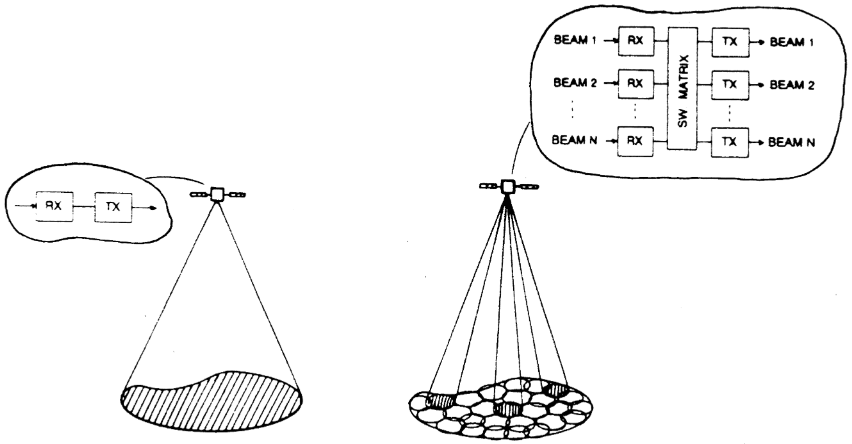
On board processing capability

- The payload must implement totally or partially the transmission chain
- Complexity and weight increase due to the presence of more hardware

OBP payload conceptual block diagram

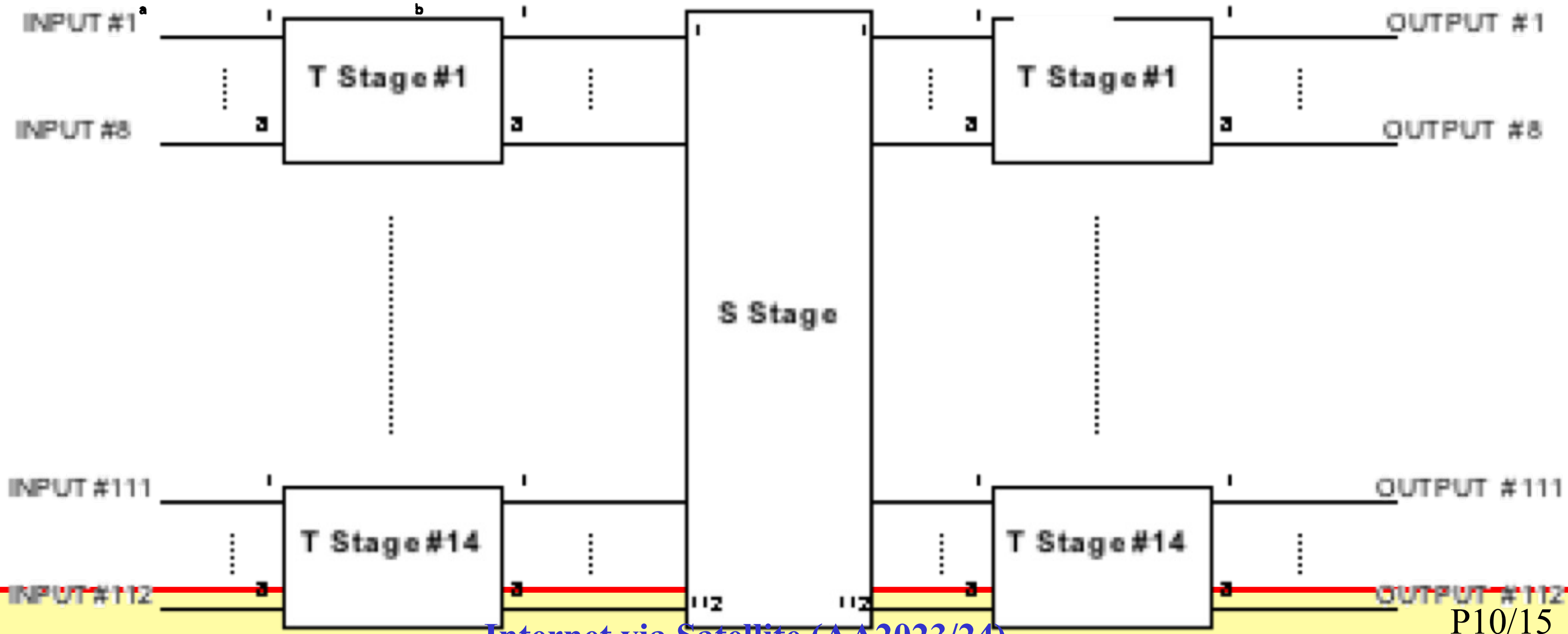


One-way and Two-way Satellite Topologies: Transparent vs. Regenerative Repeaters

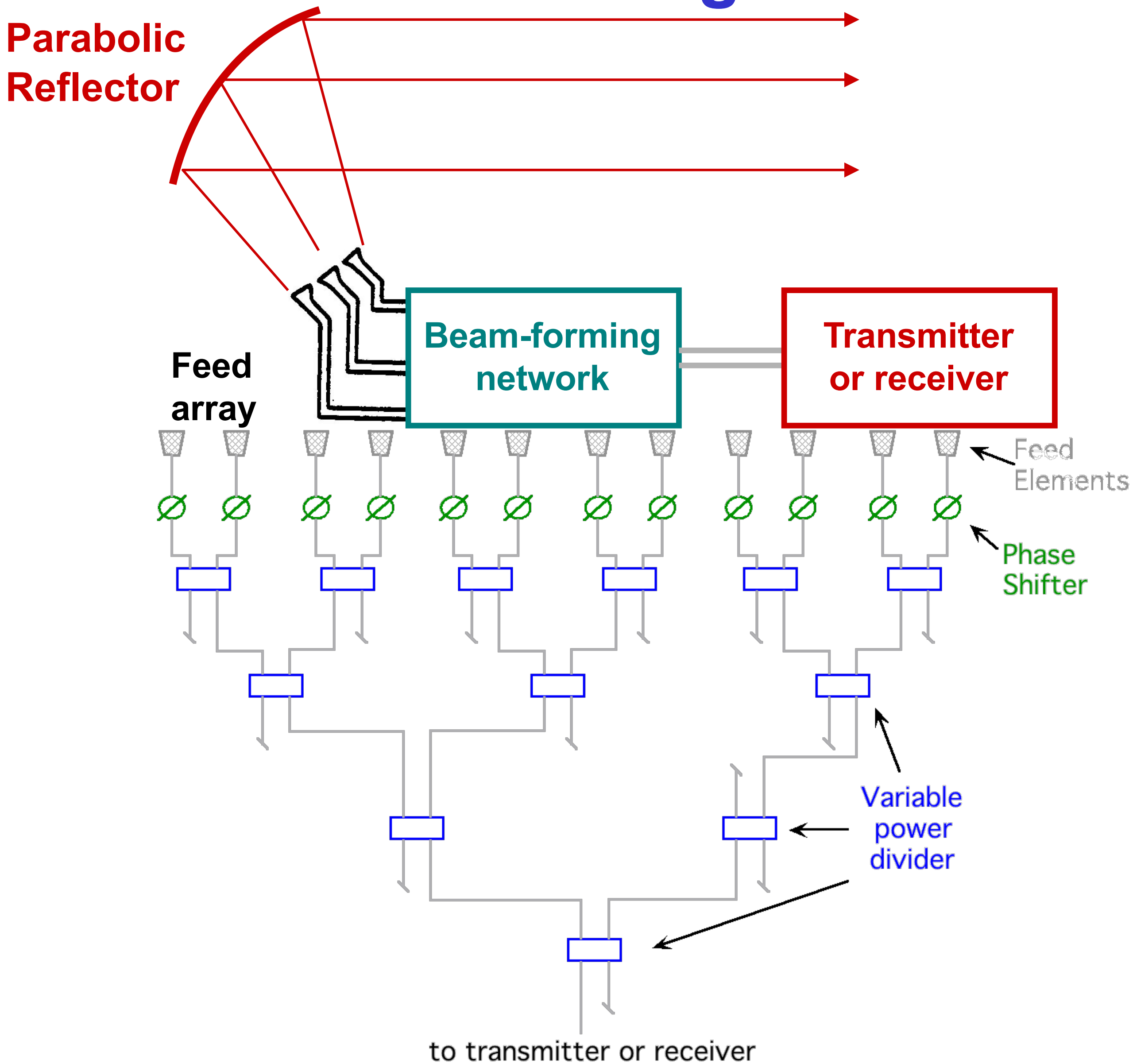


a. Global coverage antenna and transparent transponder
b. Multibeam: one receiver and one transmitter per beam, connected to a switching matrix (baseband or RF depending on OBP)

Switch matrix

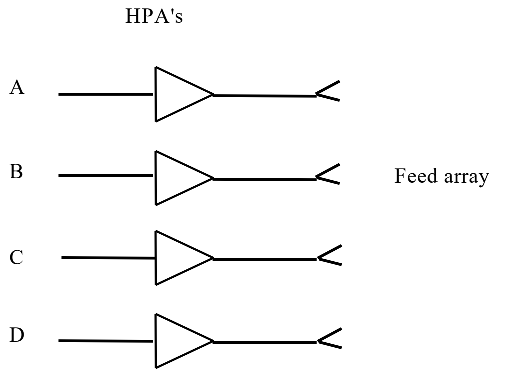


Beam forming network



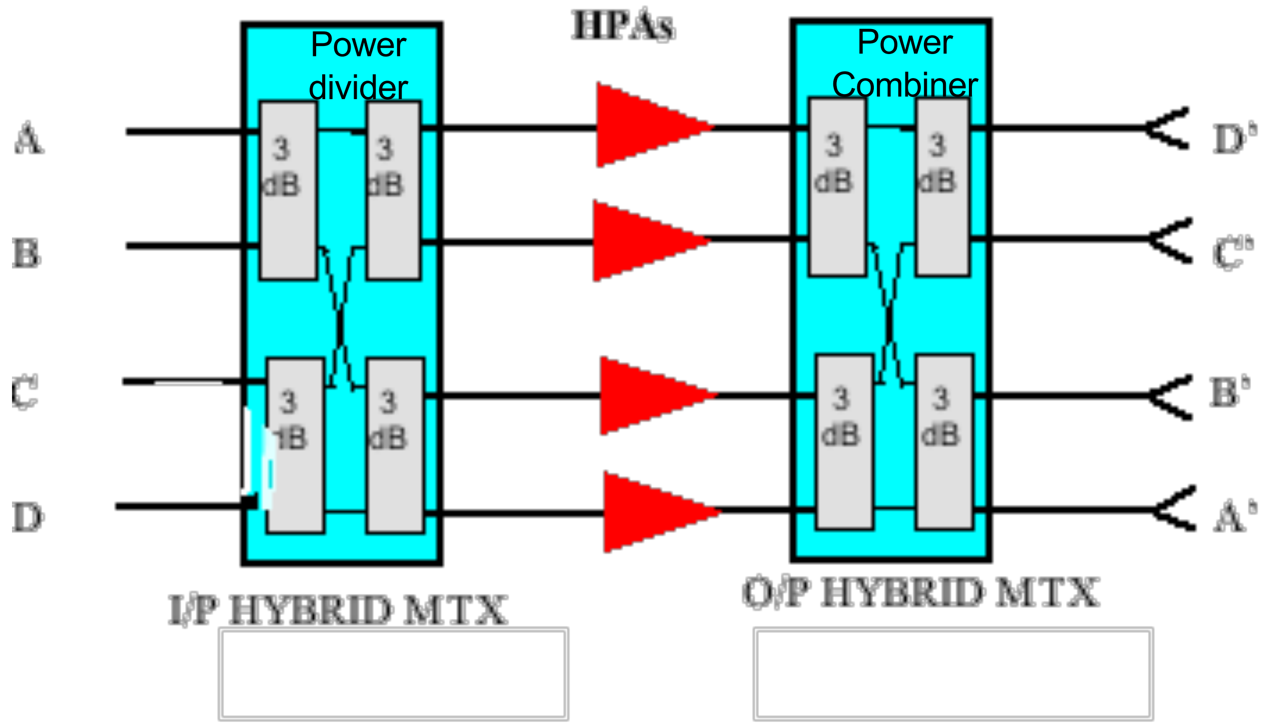
Multiport amplifier

Conventional Multibeam Transmit Front-End



N_m input
$M_n \geq N_m$ HPA
N_m output

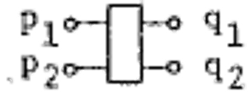
4 x 4 MPA configuration



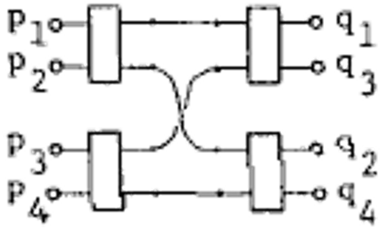
- Varying the load on any beam with total load constant, the HPAs keep the working point
- In case of failure of any HPA the system keeps on working

The Multiport Concept

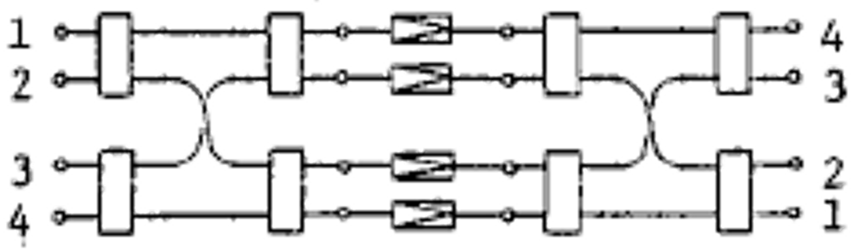
$$\begin{pmatrix} q_1 \\ q_2 \end{pmatrix} = T_1 \begin{pmatrix} p_1 \\ p_2 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & j \\ j & 1 \end{pmatrix} \begin{pmatrix} p_1 \\ p_2 \end{pmatrix}$$



$$\begin{pmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{pmatrix} = T_2 \begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} T_1 & jT_1 \\ jT_1 & T_1 \end{pmatrix} \begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 1 & j & j & -1 \\ j & 1 & -1 & j \\ j & -1 & 1 & j \\ -1 & j & j & 1 \end{pmatrix} \begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{pmatrix}$$

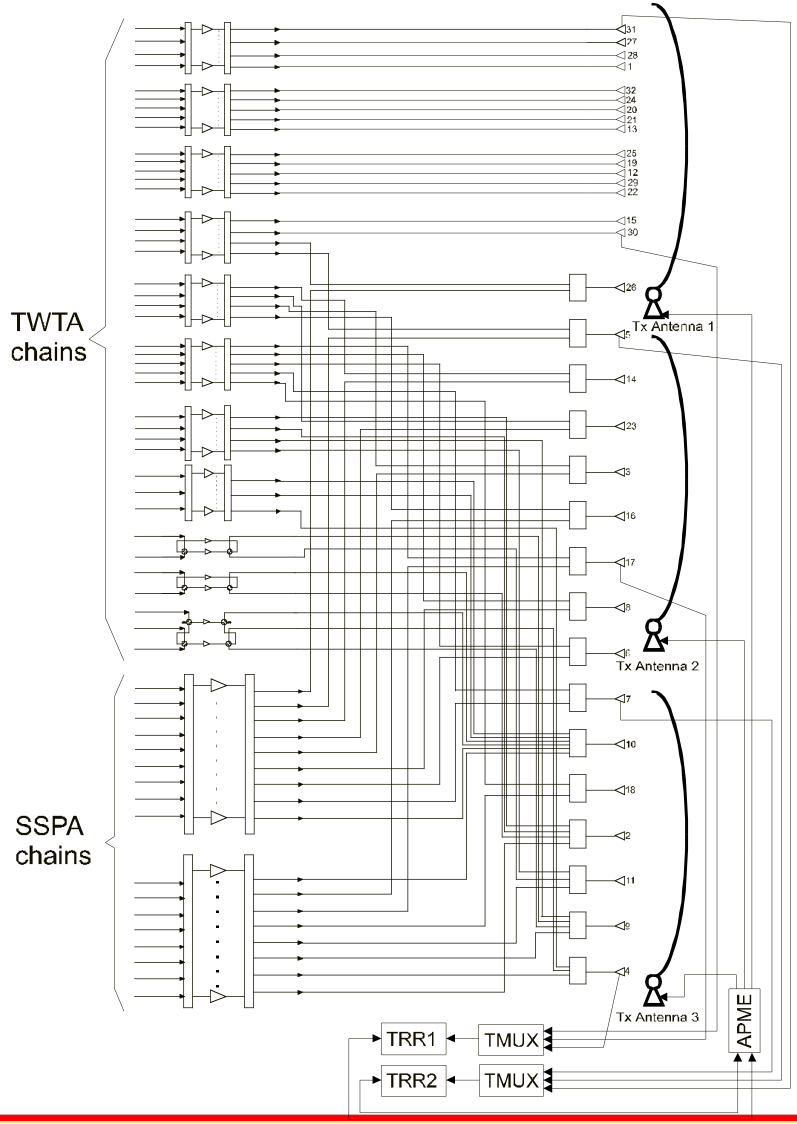


$$\begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{pmatrix} = aT_2T_2 \begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{pmatrix} = -a \begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{pmatrix}$$

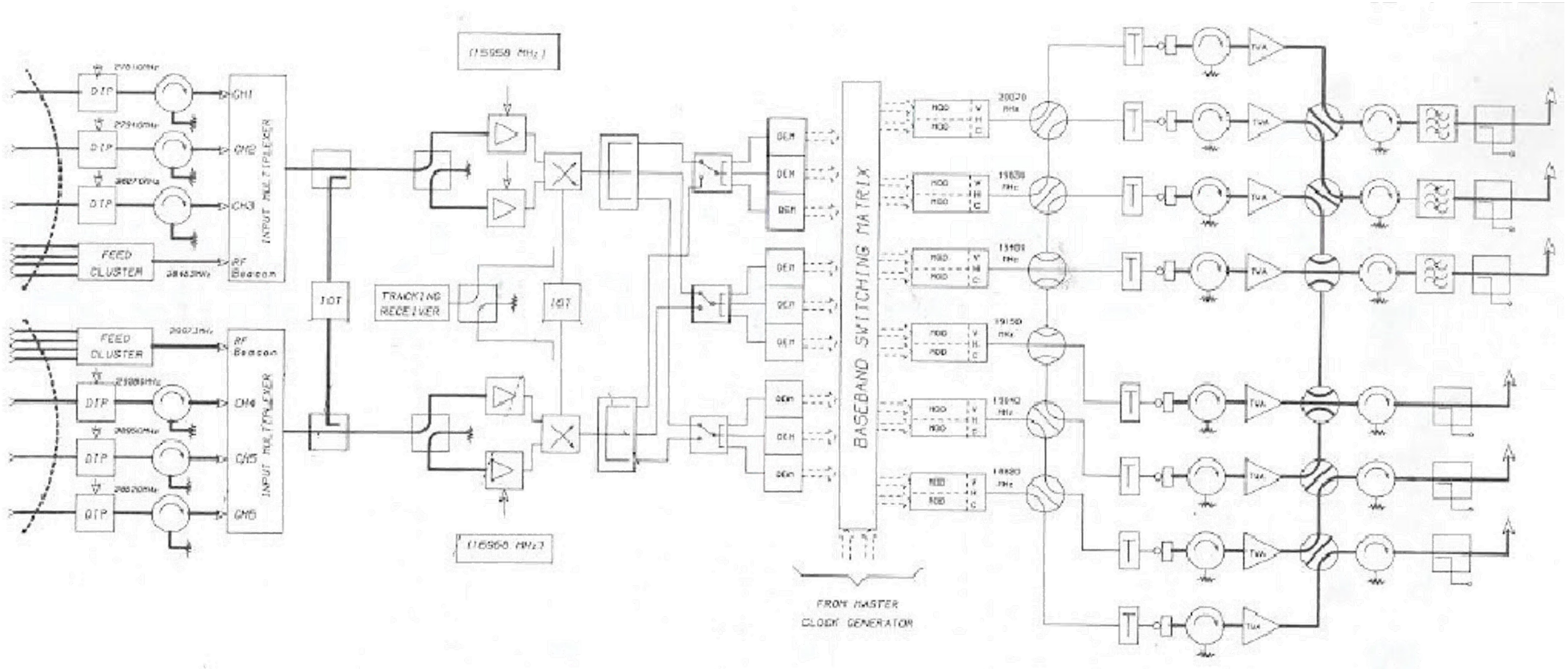


Transmit front-end configuration

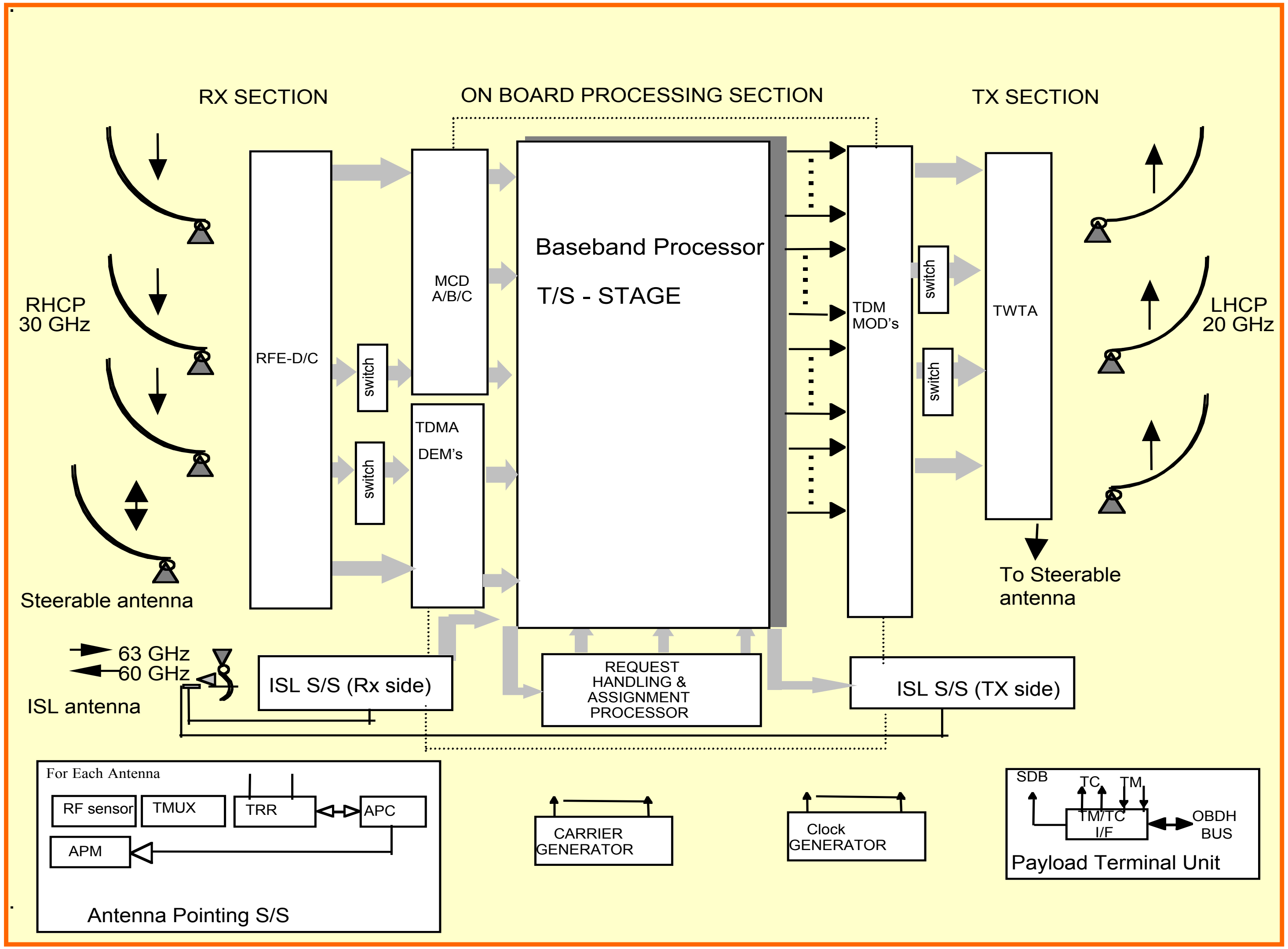
Transmitting section



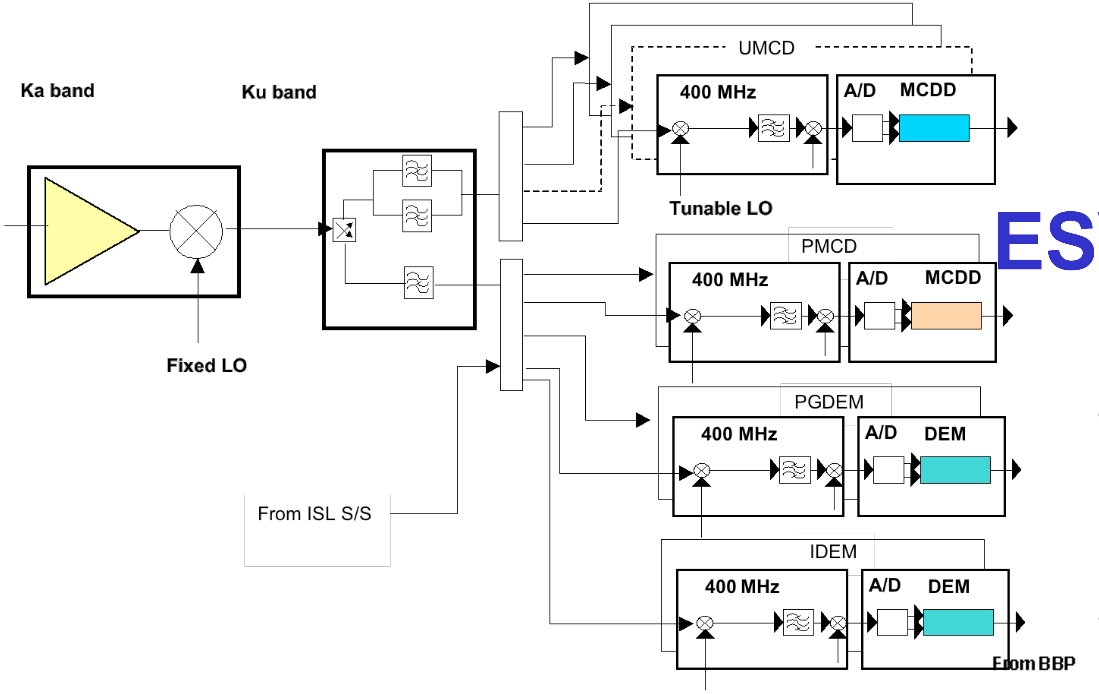
ITALSAT Multibeam Payload



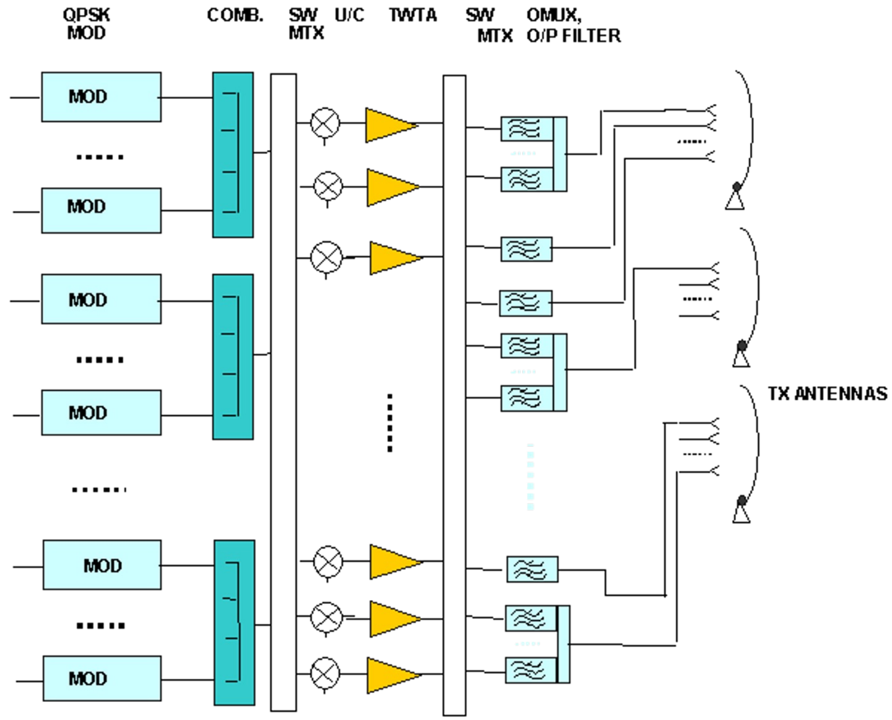
Euroskyway


RX SECTION
ON BOARD PROCESSING SECTION
TX SECTION
RHCP
30 GHz
RFE-D/C
switch
switch
MCD
A/B/C
TDMA
DEM's
Baseband Processor
T/S - STAGE
TDM
MOD's
switch
switch
TWTA
LHCP
20 GHz
Steerable antenna
To Steerable
antenna
63 GHz
60 GHz
ISL antenna
ISL S/S (Rx side)
REQUEST
HANDLING &
ASSIGNMENT
PROCESSOR
ISL S/S (TX side)
For Each Antenna
RF sensor
TMUX
TRR
APC
APM
Antenna Pointing S/S
CARRIER
GENERATOR
Clock
GENERATOR
SDB
TC
TM
TM/TC
I/F
OBDH
BUS
Payload Terminal Unit

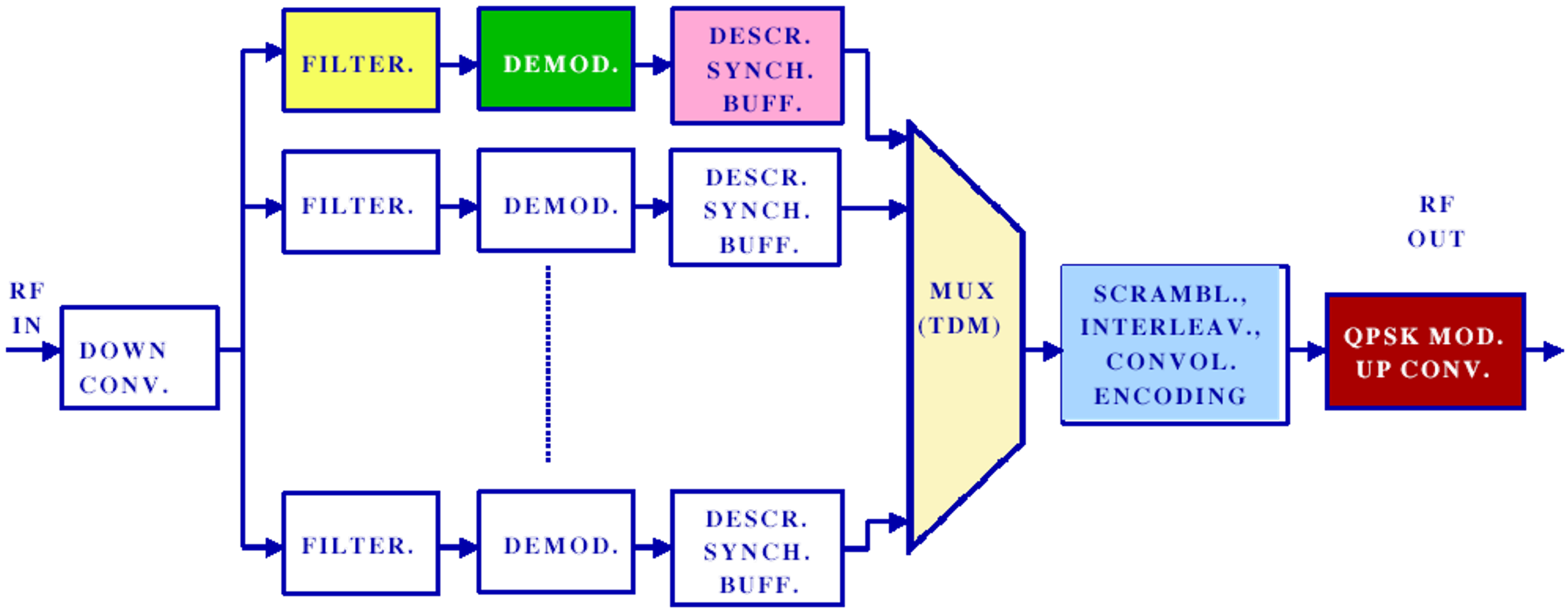
ESW Receiving Section



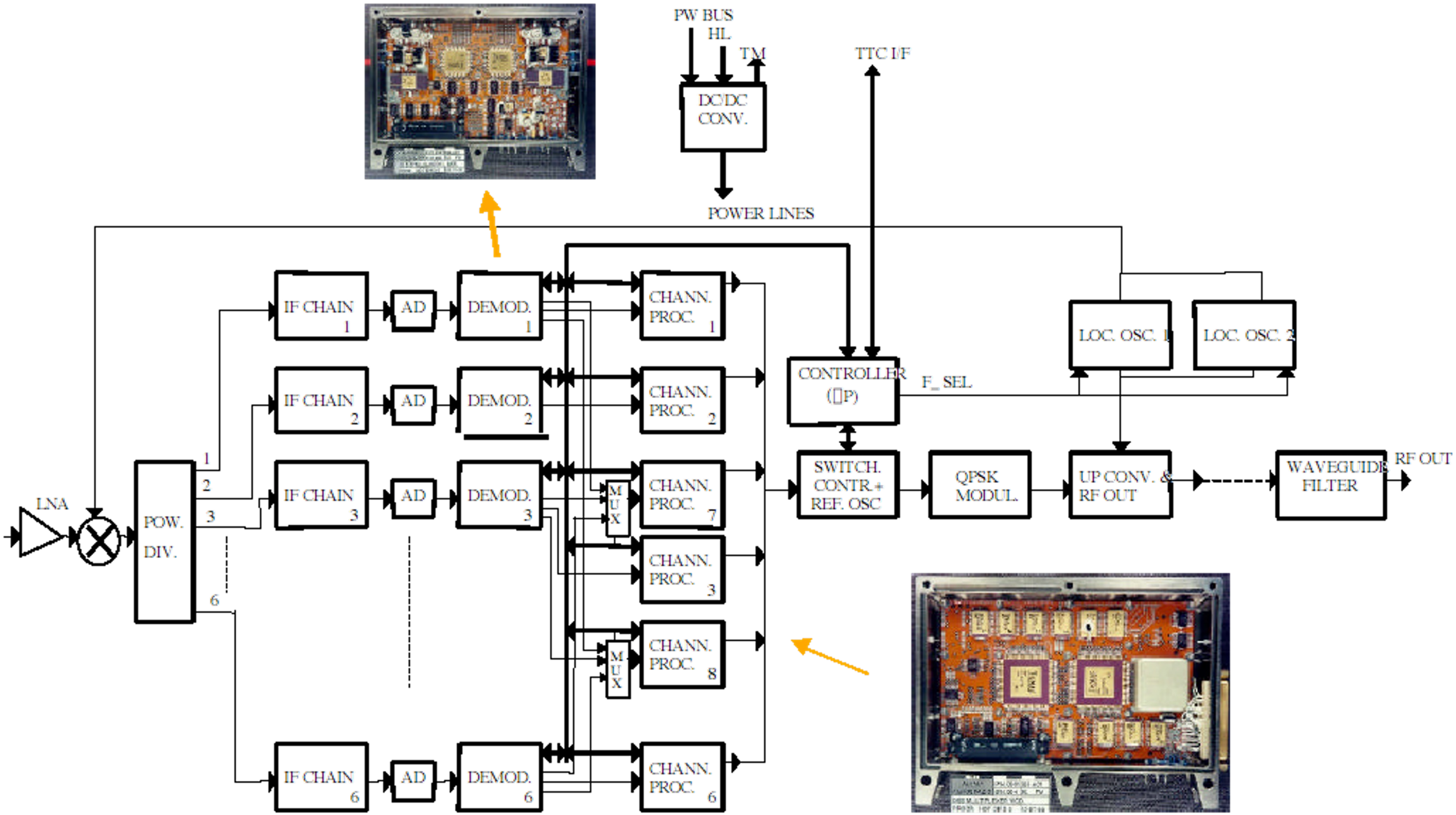
ESW Transmitting Section



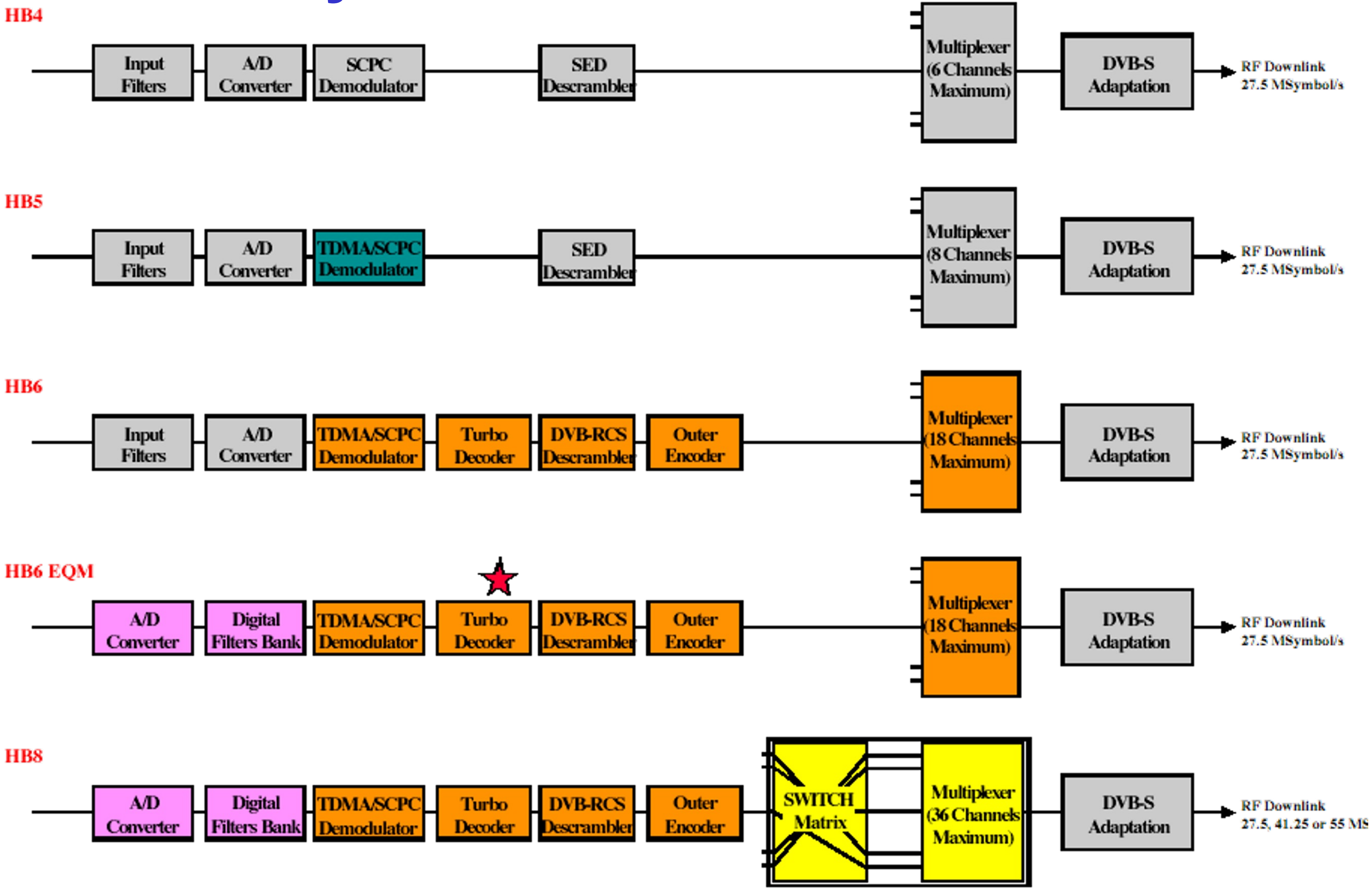
SkyPlex Functional Block Diagram



Skyplex Hardware Block Diagram



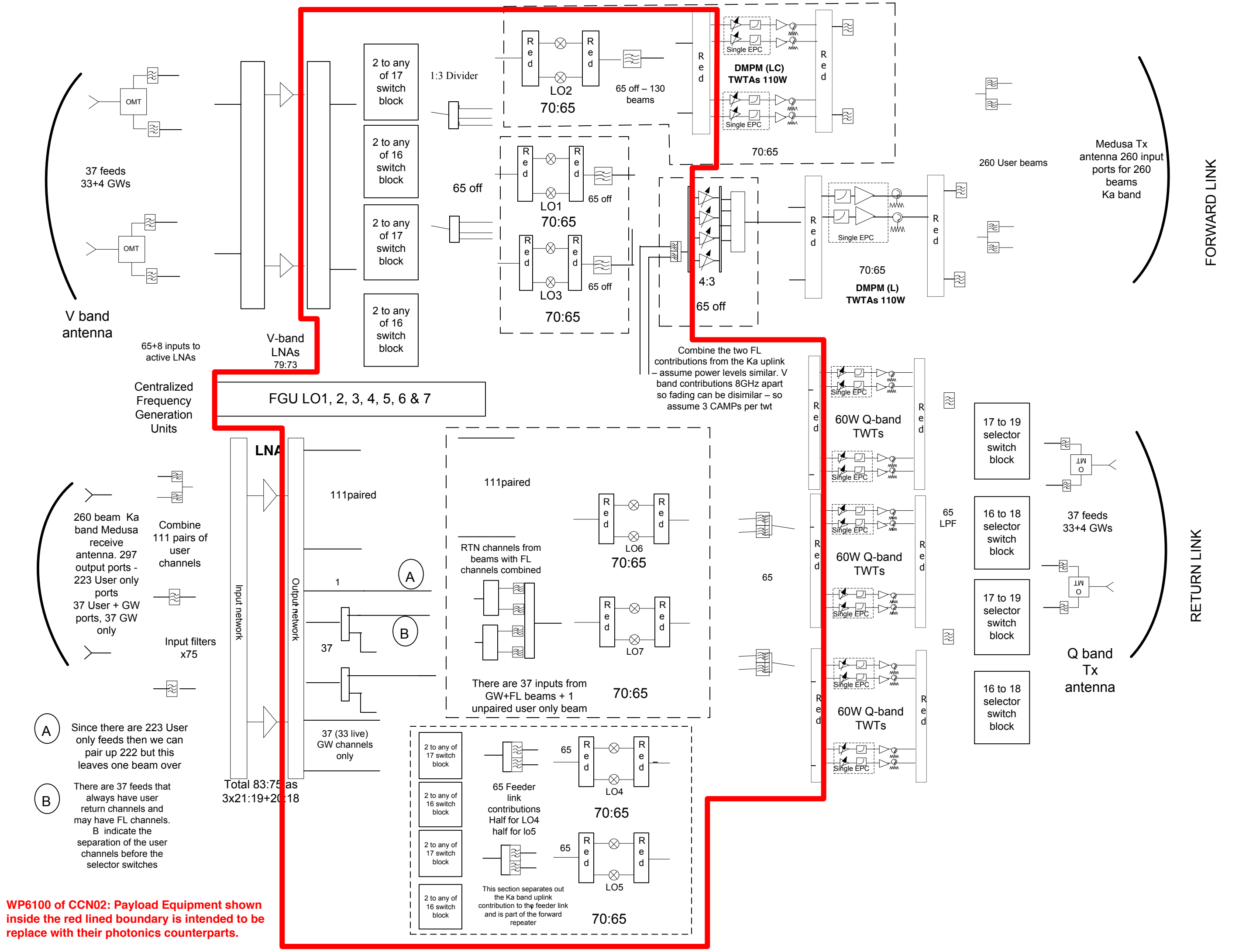
SkyPlex Processor Evolution

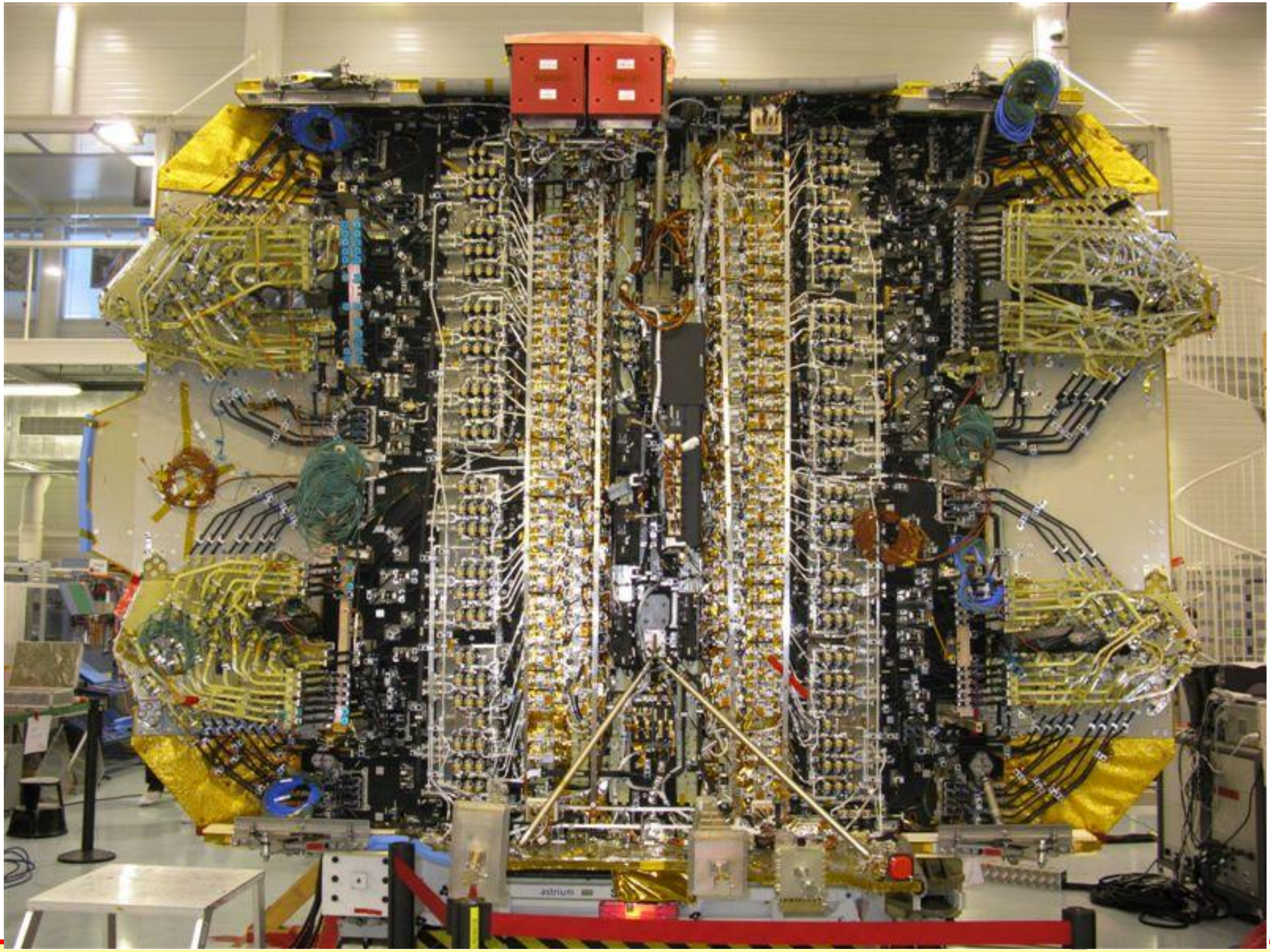


KA SAT Payload

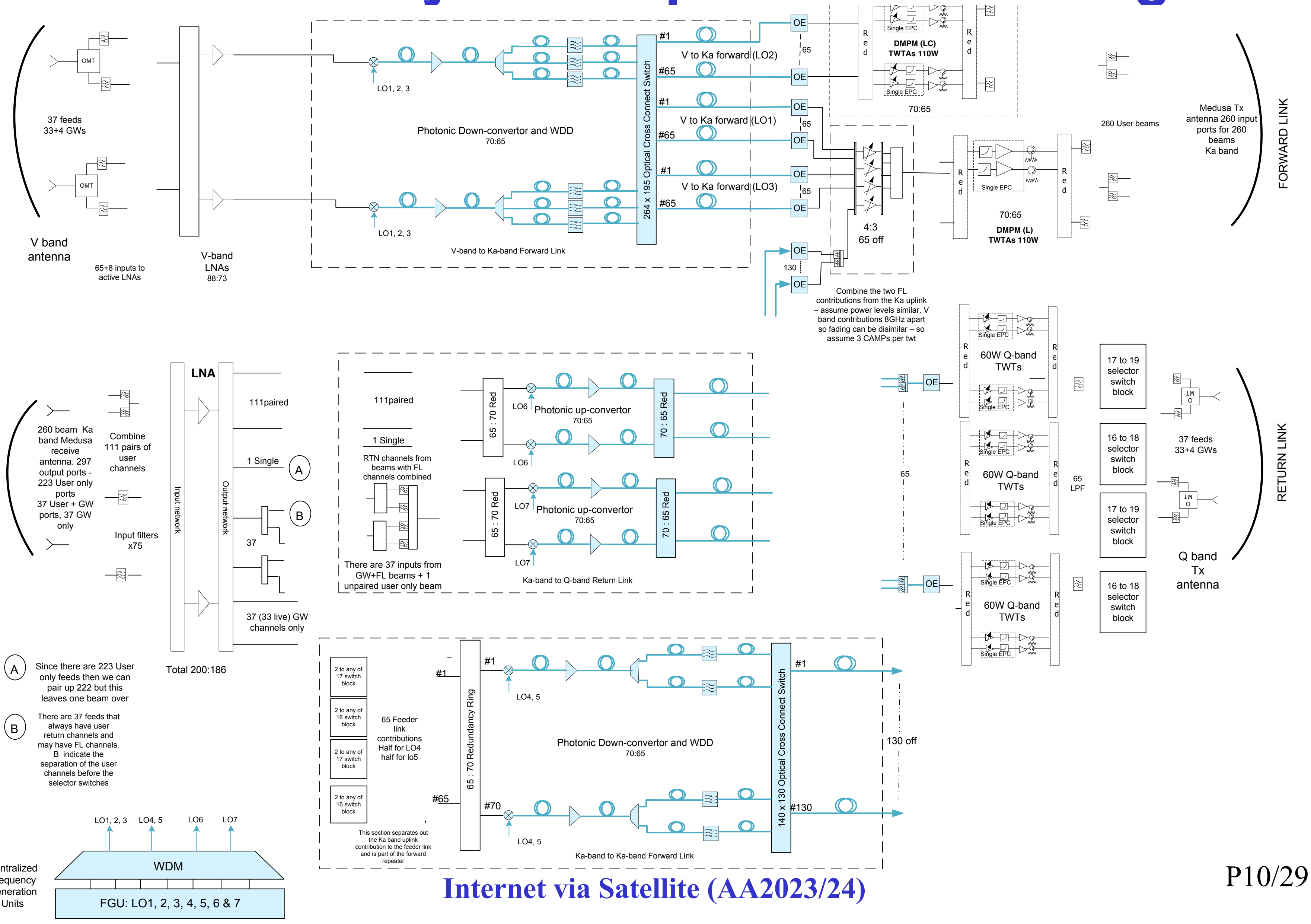
- Satellite main budgets
  - Power
    - Spacecraft Power <14kW
    - Payload DC power 11kW
    - Solar Array Power up to 16kW
  - Mass
    - Payload mass ~1000 kg
    - Spacecraft dry mass ~3170 kg
    - Satellite launch mass 5.7t -6.1t
- Orbital Manoeuvre life time 16 years
- Satellite platform: EUROSTAR E3000 (Astrium)
- Launch ILS Proton
- Launch date: December 26th, 2010

Conventional Payload Top level Block Diagram




astrium

Photonic Payload Top level Block Diagram



Payload architecture evolutions since Ka-Sat

- Several conversions in one mixer using Wavelength Division Multiplexing (WDM)
  - ➢ substantial reduction of required number of converters
- Optical routing/switching/filtering of the Down Converter output signal
- Photo-detector to convert the signal back to RF
- LO (Local Oscillator) signals distribution by optical fiber
  - ➢ mass reduction compared to co-axial cable
  - ➢ improved EMC as a by-product.

Comparison of Conventional vs Photonic Payload

Parameter	Unit	Conventional payload	Photonic payload	% Change	Photonic Payload comment
Mass budget	kg	2850	2054	-20.4%	20.4% less mass
Power budget	kW	25.1	22.9	-8.7%	8.7% less power consumption
Thermal dissipation budget	kW	14.8	12.5	-15.5%	No noticeable change
EIRP/MHz (Ka band)	dBW	33.9	33.9	0%	No noticeable change
EIRP/MHz (Q band)	dBW	31	31	0%	No noticeable change
G/T performance (V band FWD)	dB/K	25.3	25.3	<-0.5%	No noticeable change
G/T performance (Ka band FWD)	dB/K	24.4	24.4	<-0.5%	No noticeable change
G/T performance (Ka band RTN)	dB/K	23.4	23.4	<-0.5%	No noticeable change

Comparison of Conventional vs Photonic Payload per Equipment Type

Equipment type	Conventional payload	Photonic payload	% Change
Filters	485	415	-14.4%
LNAs	77	79	+2.6%
MPMs	487	487	0%
Converters	147	70	-52.4%
Waveguide & Coax	611	353	-42.2%
Switches & Miscellaneous	271	149	-45.5%