SAR Implementation Technology

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All the space you need

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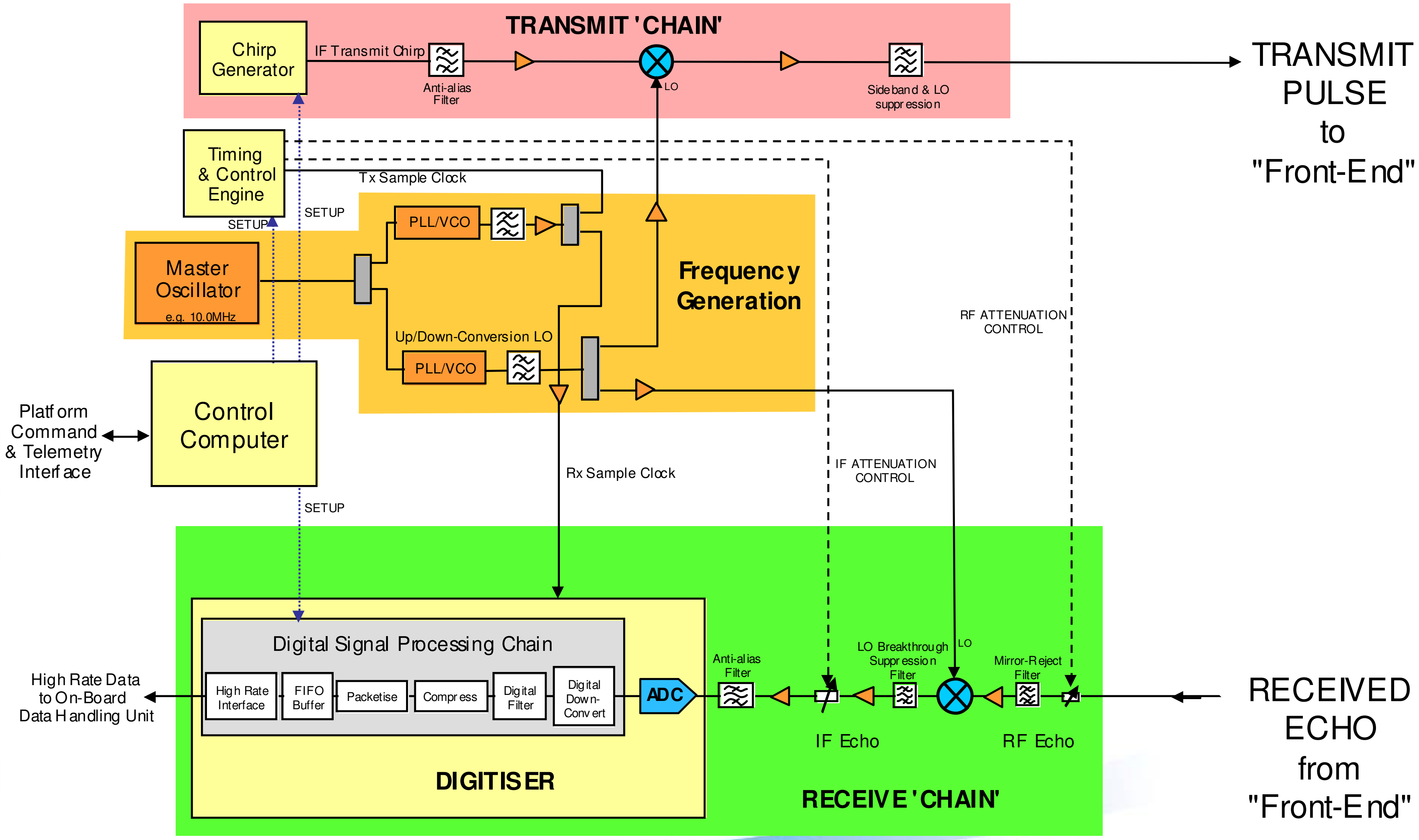
Topics

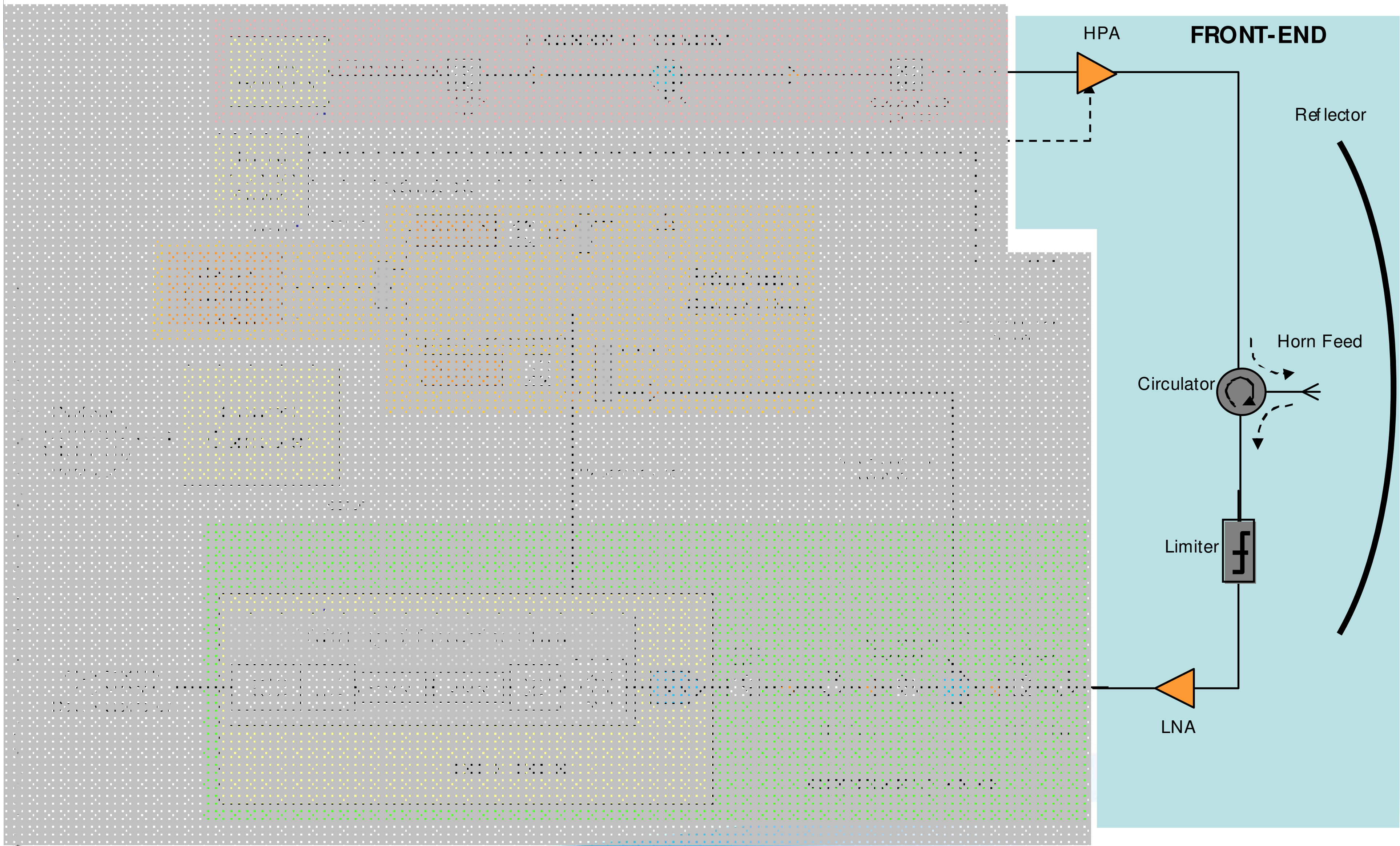
- SAR Instrument Architectures
- Radiator Technologies
- High Power Amplifier Technologies
- Timing & Control Implementation
- Transmit Waveform Generation
- RF Technologies
- Receive Digital Signal Processing

SAR Instrument Architectures

SAR Payload Central Electronics ('Back-End') Architecture

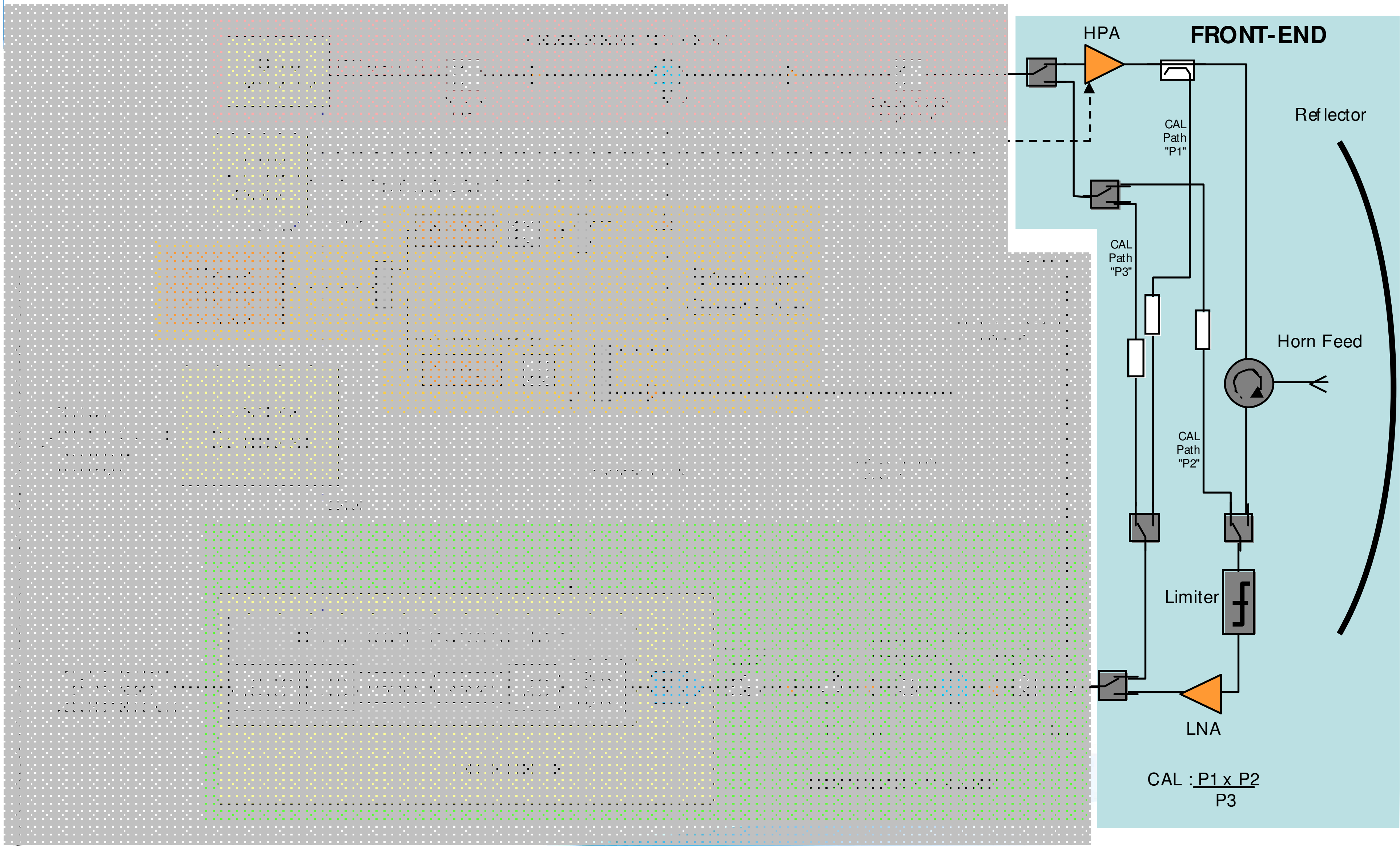


SAR Payload Architecture (with simplest 'Reflector + Horn Feed' Front-End)



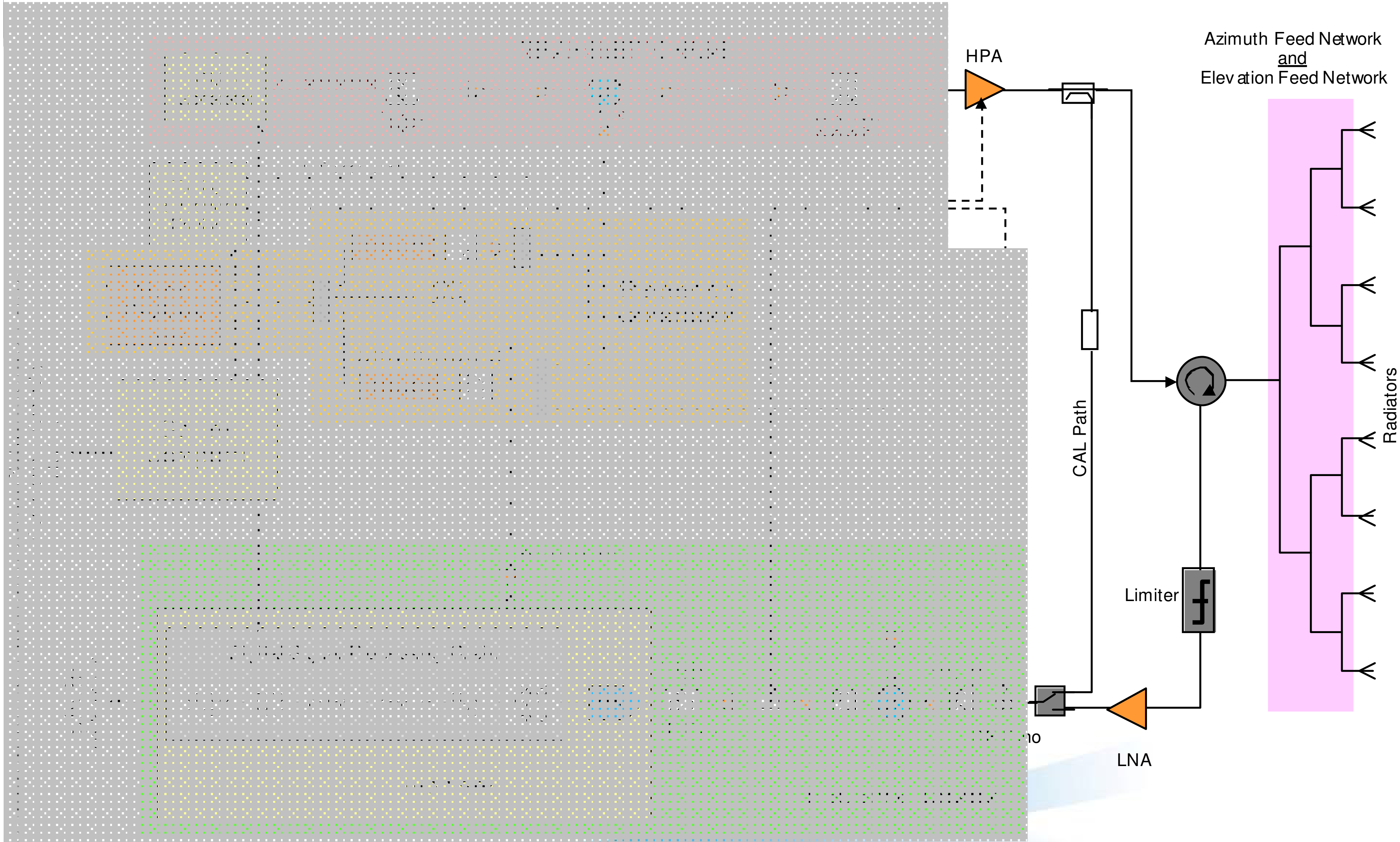
EXAMPLE REAL SYSTEM USING THIS ARCHITECTURE
SAR Lupe (Germany)

SAR Payload Architecture (with 'Reflector + Horn Feed' Front-End plus Calibration paths)



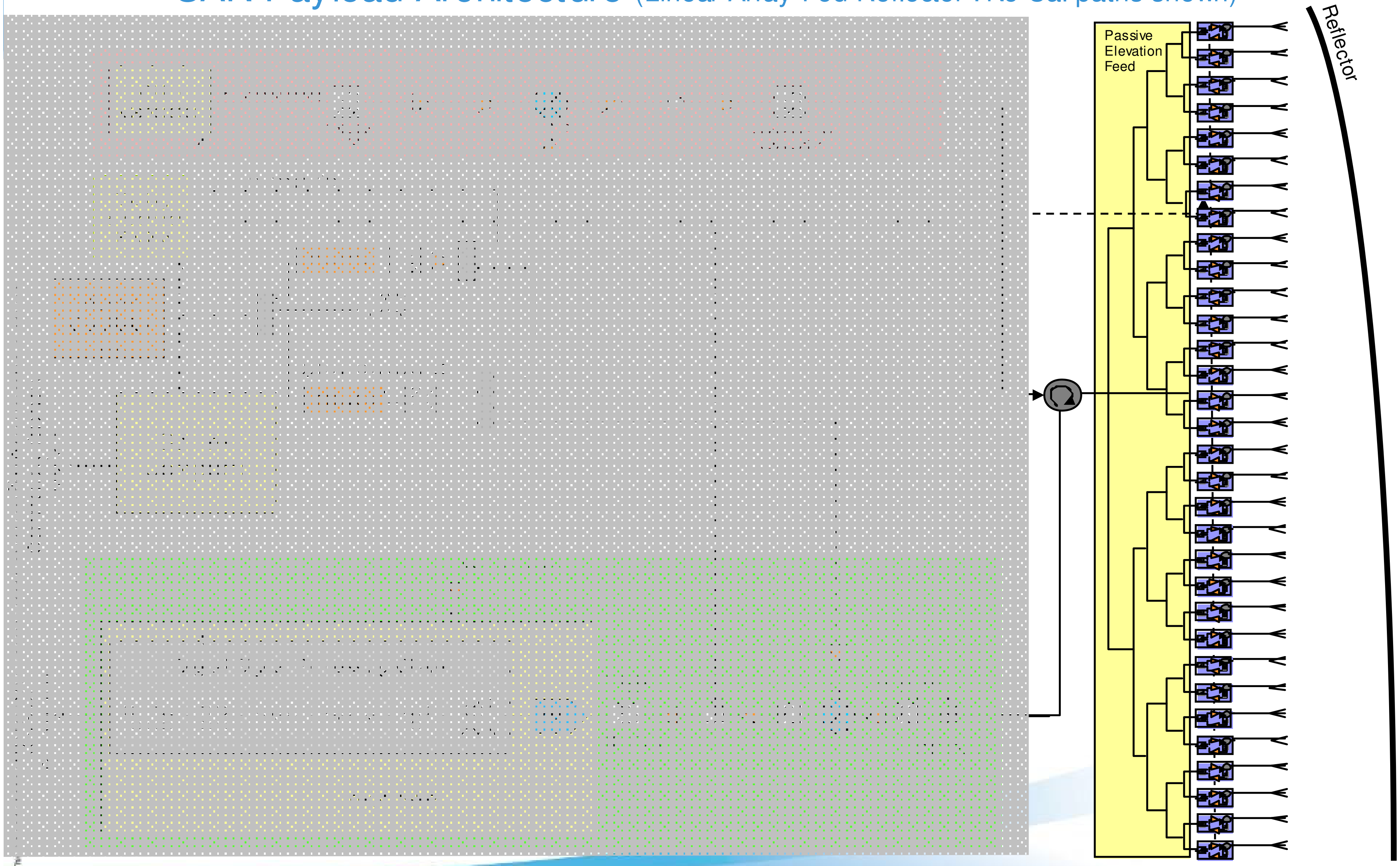
EXAMPLE REAL SYSTEM USING THIS ARCHITECTURE
SAR Lupe (Germany)

SAR Payload Architecture (Single HPA Planar Array Front-End)



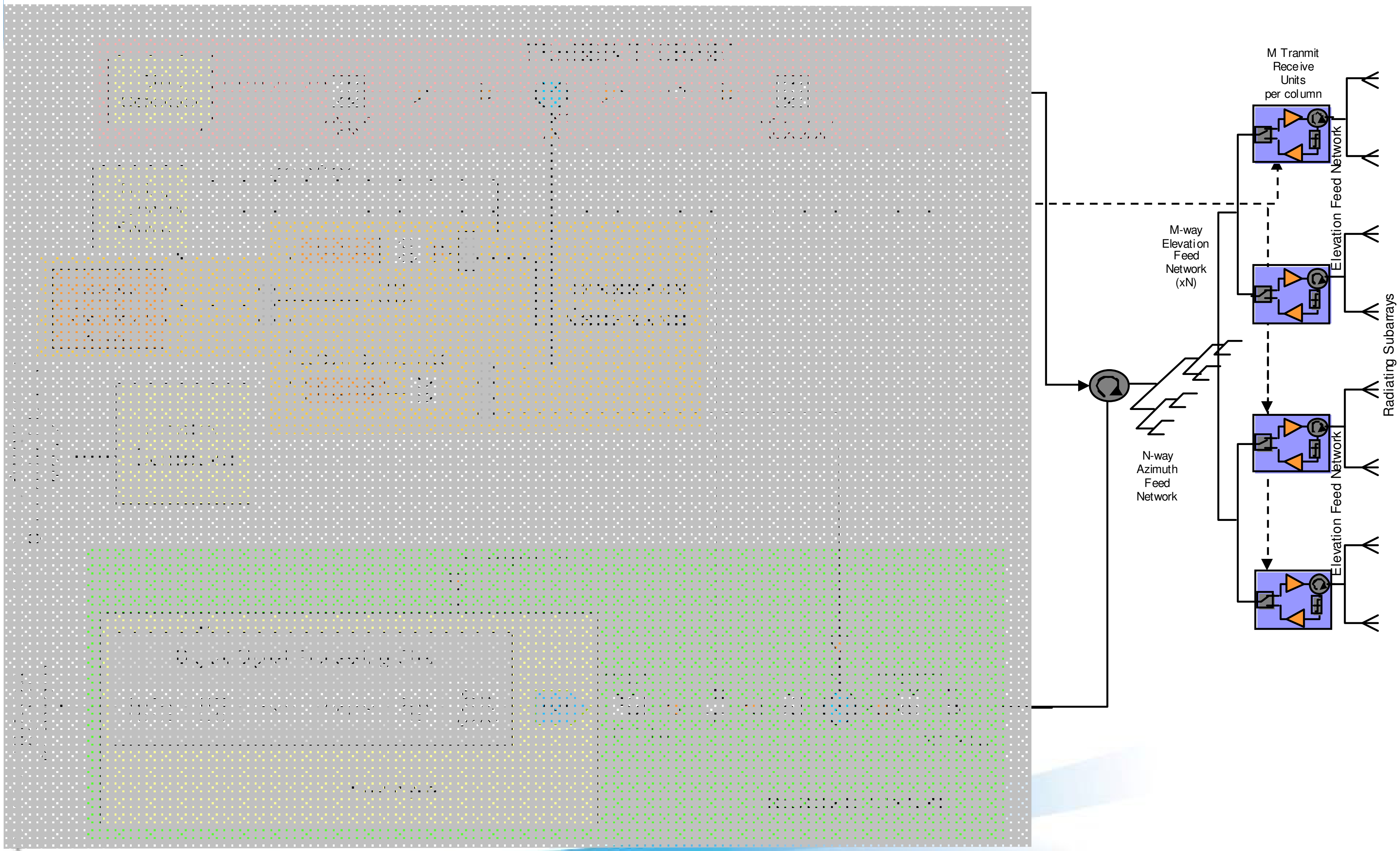
EXAMPLE REAL SYSTEM USING THIS ARCHITECTURE
ERS-1 & 2 (ESA)

SAR Payload Architecture (Linear Array-Fed Reflector : No Cal paths shown)

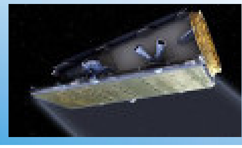


EXAMPLE REAL SYSTEM USING THIS ARCHITECTURE : None at present

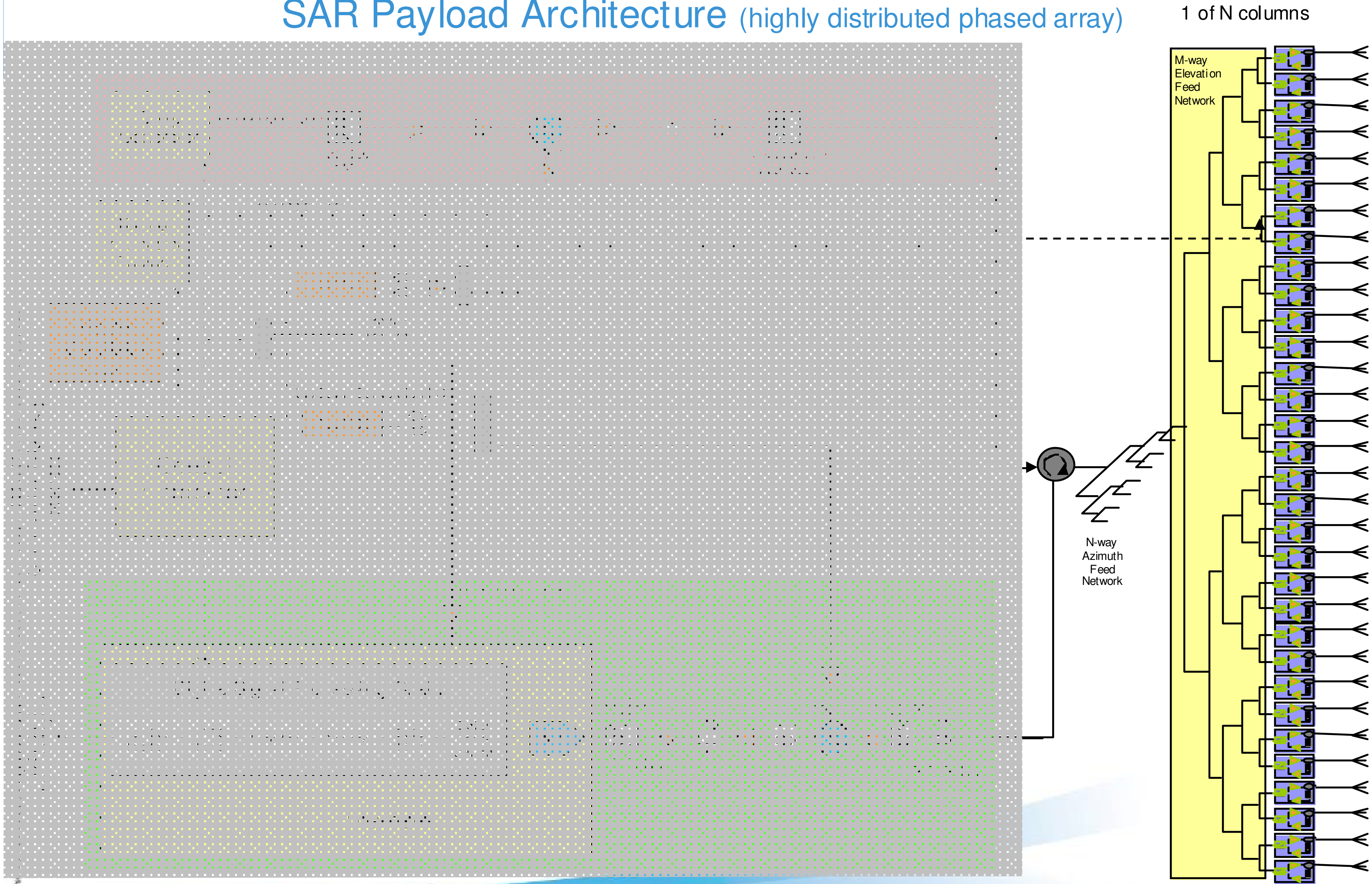
SAR Payload Architecture (Partially Distributed Front-End : No calibration paths shown)



EXAMPLE REAL SYSTEM USING THIS ARCHITECTURE
NovaSAR (Astrium)



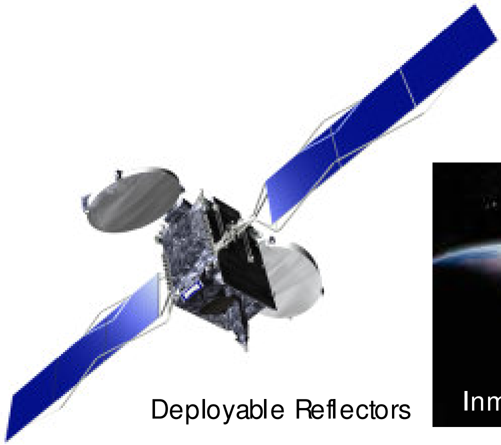
SAR Payload Architecture (highly distributed phased array)



EXAMPLE REAL SYSTEM USING THIS ARCHITECTURE : None at present

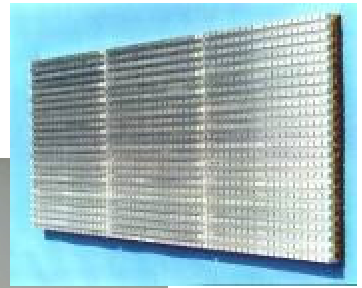
Radiator Technologies

Radiator Technologies

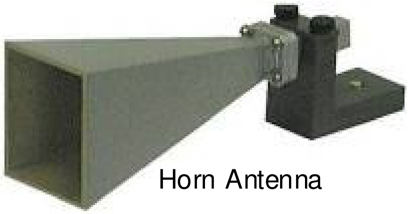


Deployable Reflectors

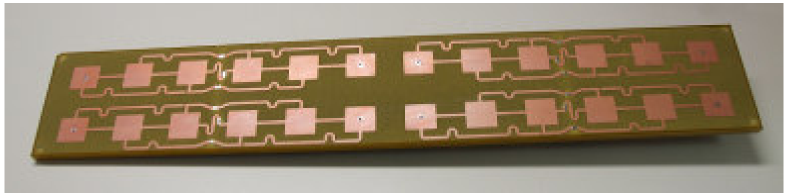
Inmarsat 4



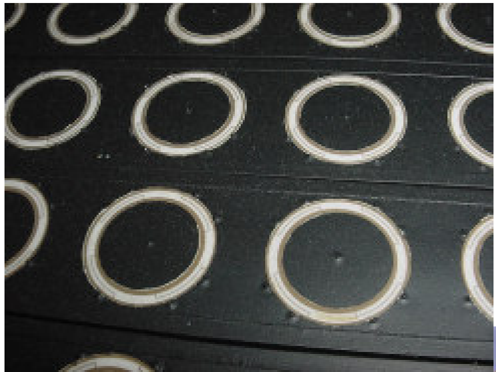
Slotted Waveguide subarrays

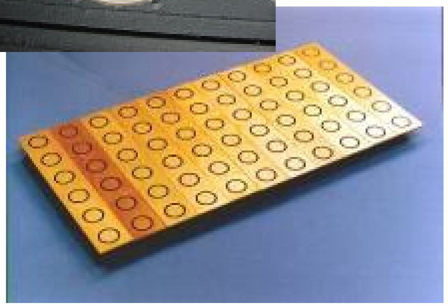


Horn Antenna



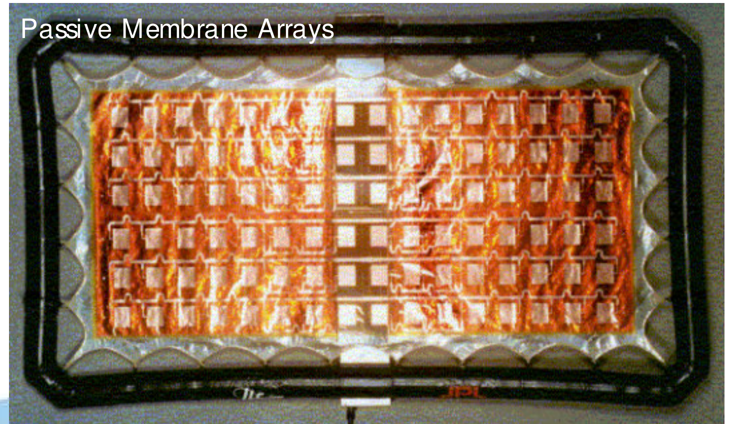
Microstrip Patch Subarrays





Annular Slot subarrays

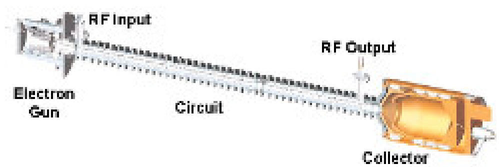
Horn Arrays



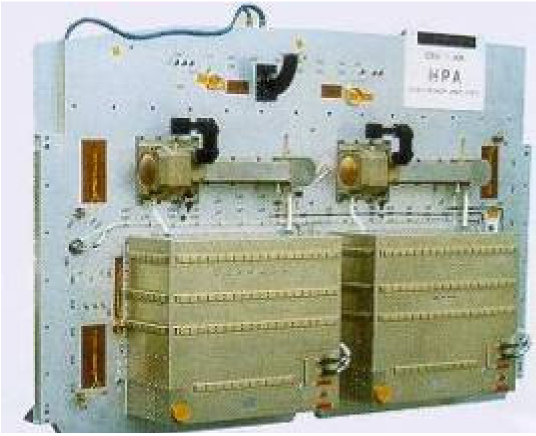
Passive Membrane Arrays

High Power Amplifier Technologies

High Power Ampifier Technologies



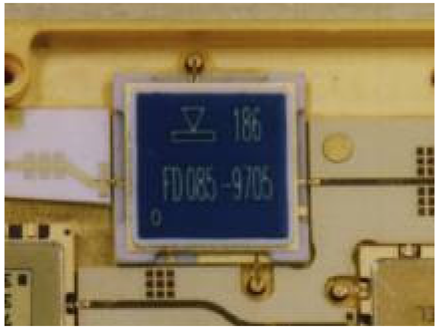
Travelling Wave Tube Amplifier (TWTA)



High Power TWTA or Klystron
100's of Watts to kW's
Very high efficiency
High cost, large PSU, high mass
Need careful control to avoid multipaction

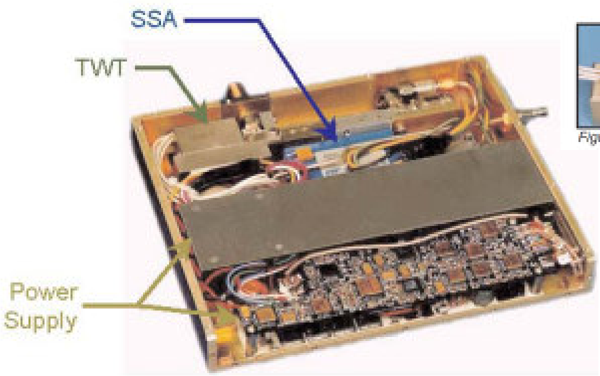
Suitable for single-HPA antennas
e.g. ERS-1 & 2, SAR Lupe

ERS-1 TWTA
1.5kW
Dual redundant



Gallium Arsenide (GaAs)
<15 Watts
Well established
<30% efficient

Suitable for highly distributed antennas
e.g. ASAR, TerraSAR X



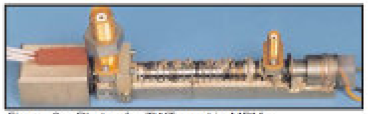
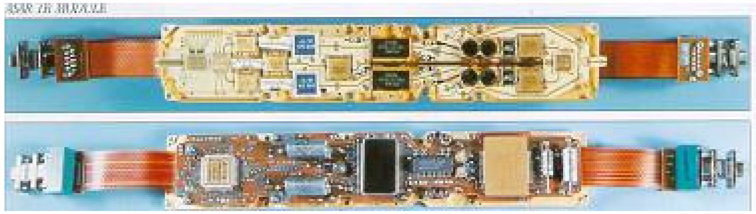
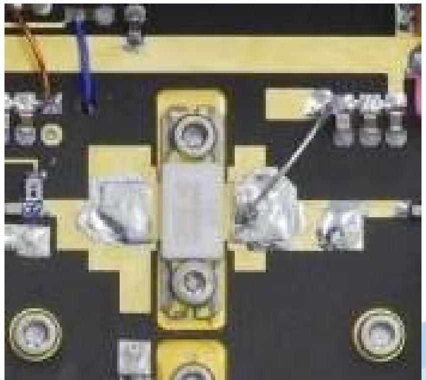


Figure 6 – Photo of a TWT used in MPMs


ASAR T/R Module using 10 Watt GaAs devices

Microwave Power Module (MPM)
Mini TWTA + Solid-State pre-amplifier
Typically ~100 Watts peak

Suitable for partially distributed antennas.
but costly to qualify for space use.
Better suited to airborne use



Gallium Nitride (GaN)
10's-100's of Watts
New technology just coming online
High efficiency (30-50%)

Suitable for partially distributed antennas
e.g. NovaSAR

Timing & Control Implementation

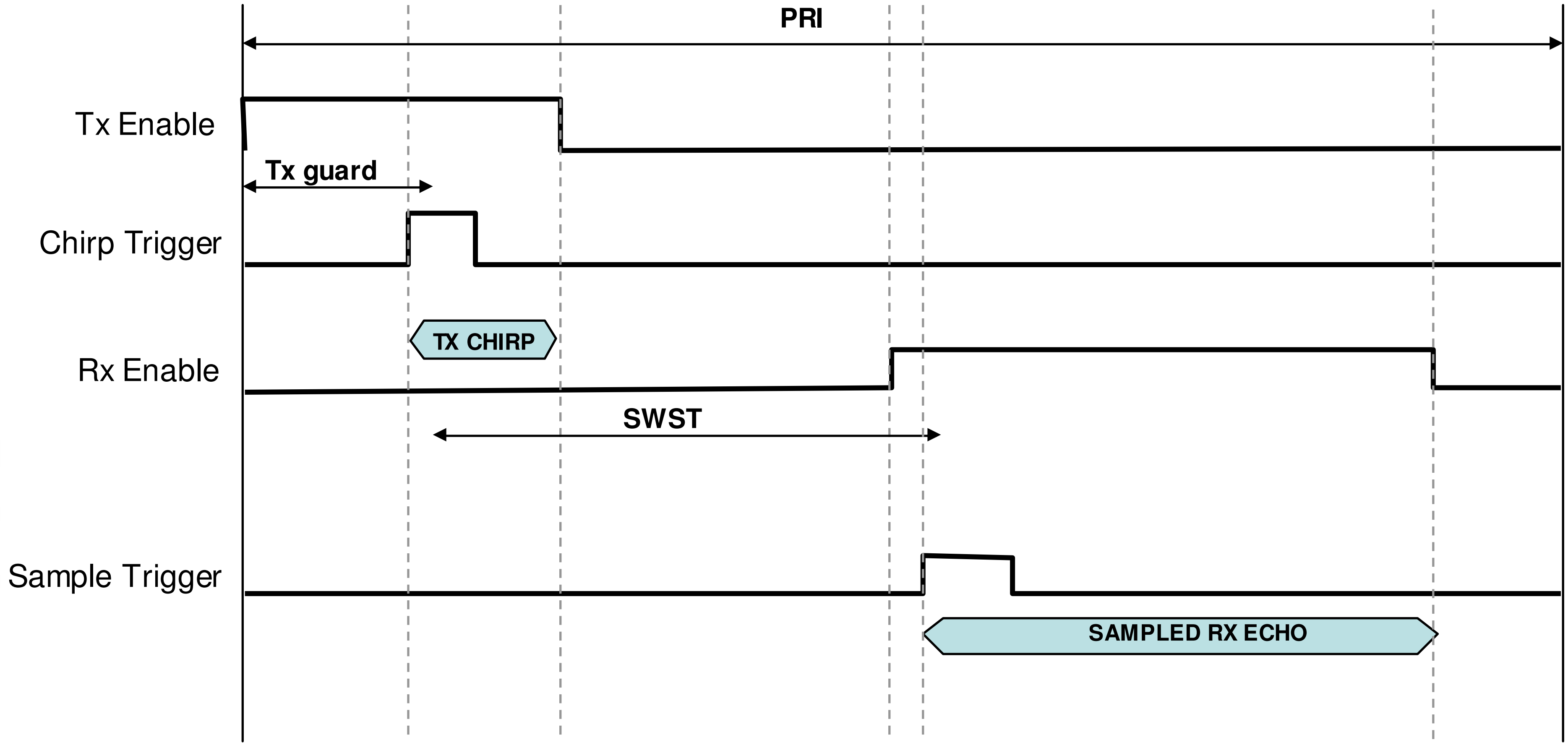
Timing & Control Implementation

- At the heart of every radar is a timing 'engine' that controls what happens and when it happens
- Radar 'Timelines' define the activity of each control signal during every different type of 'pulse repetition interval' (PRI)

  - PRI Types
    - Imaging
      - Stripmap
      - ScanSAR - includes Tx only and Rx only PRI types for use during subswath changeover
    - Calibration - Including phase centre stepping, and different CAL paths (e.g. P1,P2,P3)
    - Noise - Both 'external' (including LNA and antenna) and internal (excluding LNA and antenna)

- Modes can get complicated very quickly, and so a 'general purpose' approach to the timing engine design is attractive so that it can cope with many different timeline requirements and allows 'late changes' including post-launch

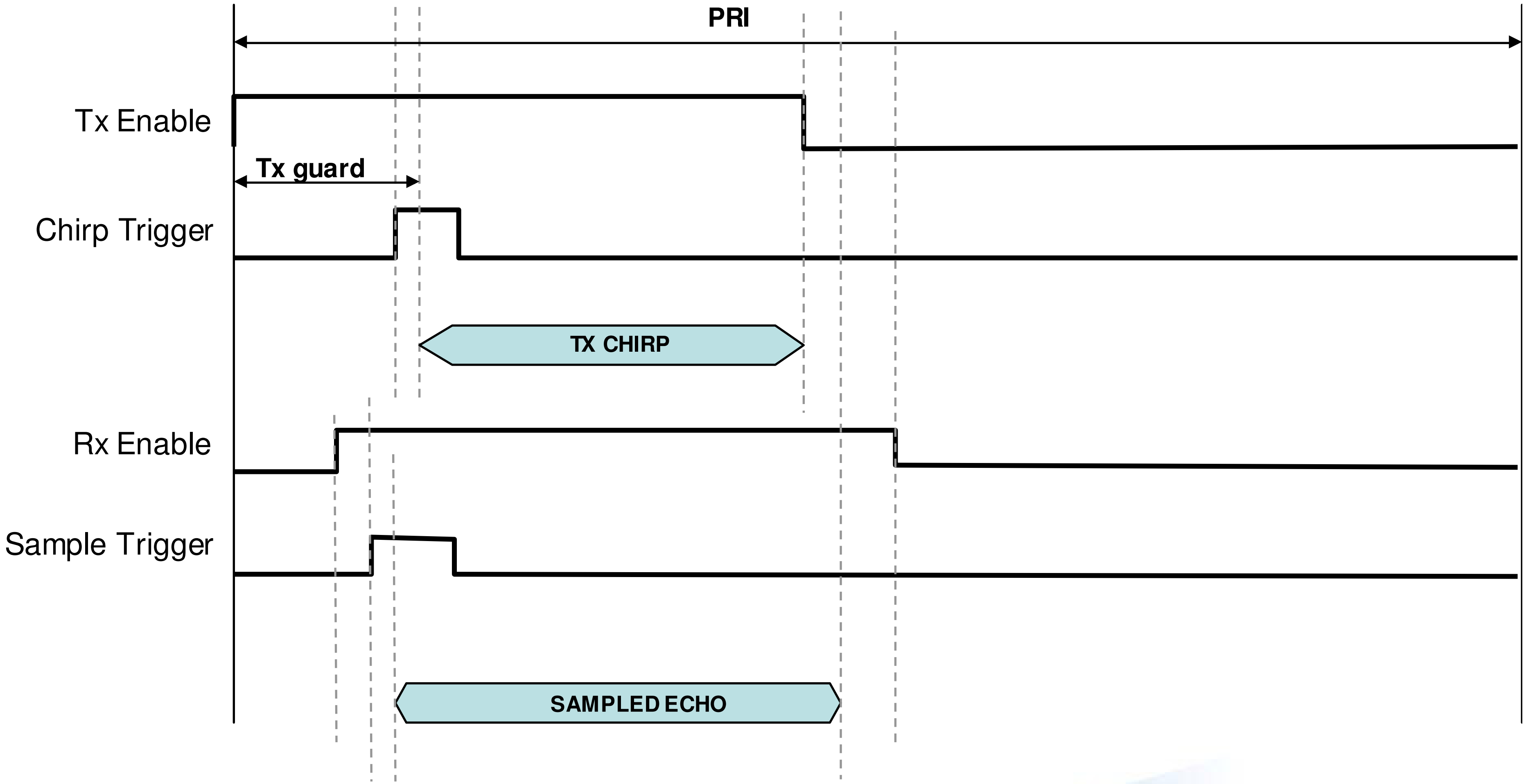
Typical Imaging PRI



NOTE 1 : In a typical airborne case, the echo sampled in a PRI is the echo of the pulse transmitted in that PRI
However in the spaceborne case, there are typically 10-20 pulses 'in-flight' simultaneously (a number known as the 'rank'),
so the echo sampled is the echo of a pulse transmitted 10-20 PRI's earlier

NOTE 2 : A Noise PRI is similar, but has no transmit chirp trigger, and no transmit chirp. In the spaceborne case it is necessary to have at least ***rank*** PRI's without any transmit before performing a Noise PRI so that all echoes have returned. (Actually need even more due to returns from ambiguous swaths at higher slant ranges than the swath)

Typical Calibration PRI



Timing & Control Implementation

Example implementation scheme :

- Create 'PRI Definition tables' defining (for each PRI type)
  a 'pattern' of the output signals at start of PRI and at each subsequent transition time within the PRI

Example PRI definition

End of PRI Marker	Time	Pattern
0	0	0000101101110010010101000
0	1259	0000001100101000010100 0
0	8620	1000000100101000010100 0
0	15318	0000001100100000010100 0

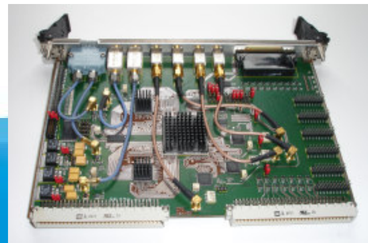
Each bit in the pattern defines one control signal e.g. Tx Enable

- Can then define 'sequences of PRIs', and define 'programs' of sequences, to facilitate the overall radar timeline for a mode. For example...

  CAL/NOISE sequence performs PRIs for P1 Cal, P2 Cal, P3 Cal, Ext Noise, Int Noise
  IMAGING sequence performs PRIs for Imaging (maybe for Tx H and Tx V as needed)

  Program performs 1 CAL/NOISE for each phase centre, then 10000 IMAGING, and repeats

- All this functionality is well suited to implementation on an FPGA or an ASIC

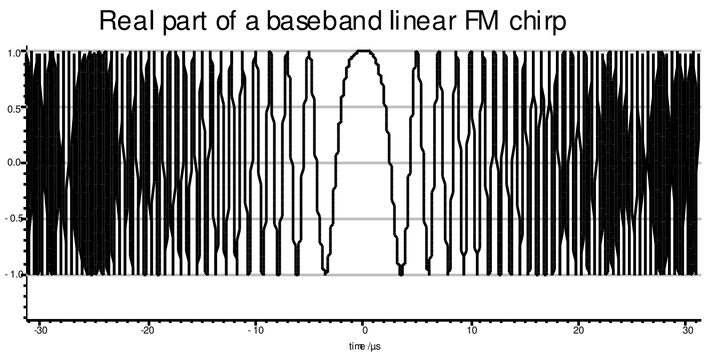


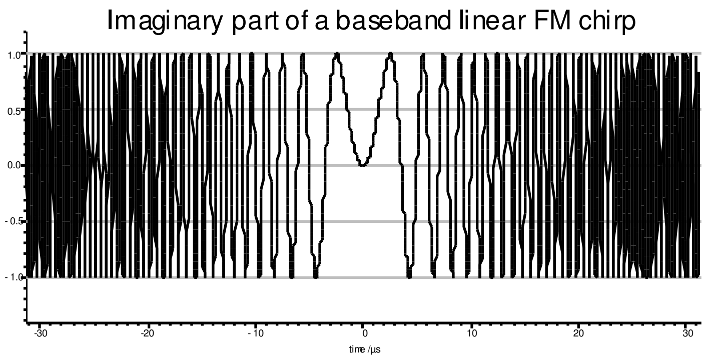
Astrium Chirp & Timing Generator Module

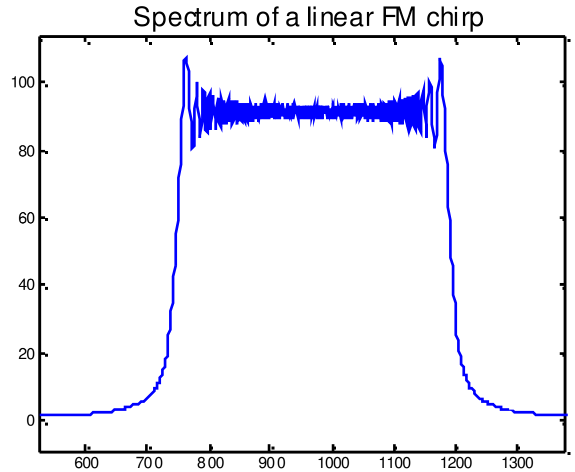
Transmit Waveform Generation

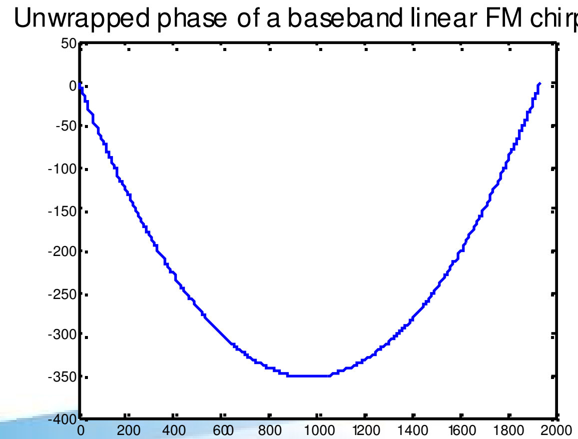
Transmit Waveform Generation

- By far the most common waveform used is the linear FM chirp
- A linear sweep from the lowest to the highest frequency (or vice versa) over the pulse duration
- Close to equal power spectral density across the bandwidth used
- Phase is a quadratic



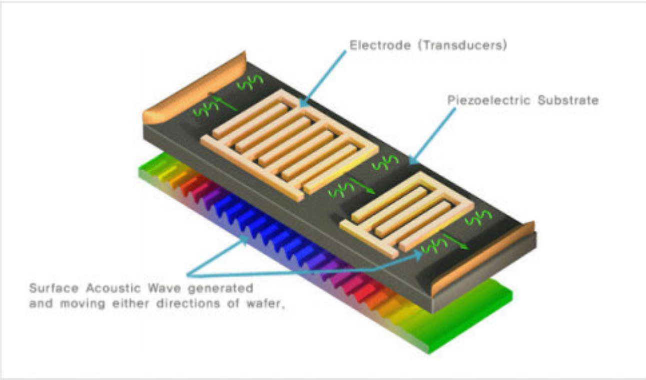




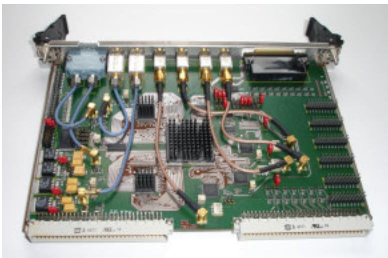


Transmit Waveform Generation Technologies

Surface Acoustic Wave (SAW) Filter

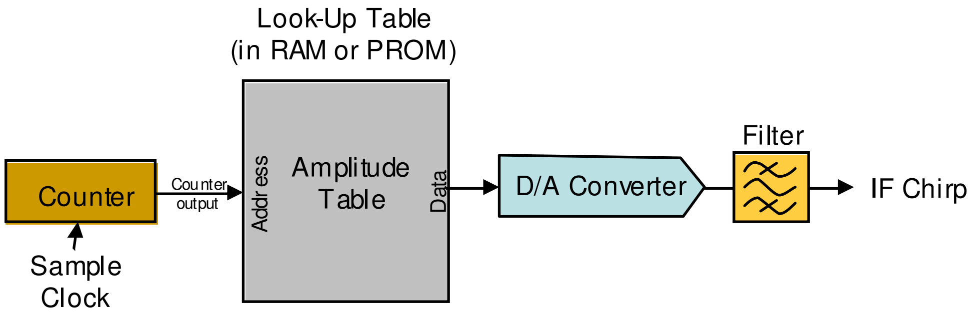


The original way in which linear FM chirps were generated
Stimulate with an impulse, and a chirp is generated
Inflexible, so not widely used today

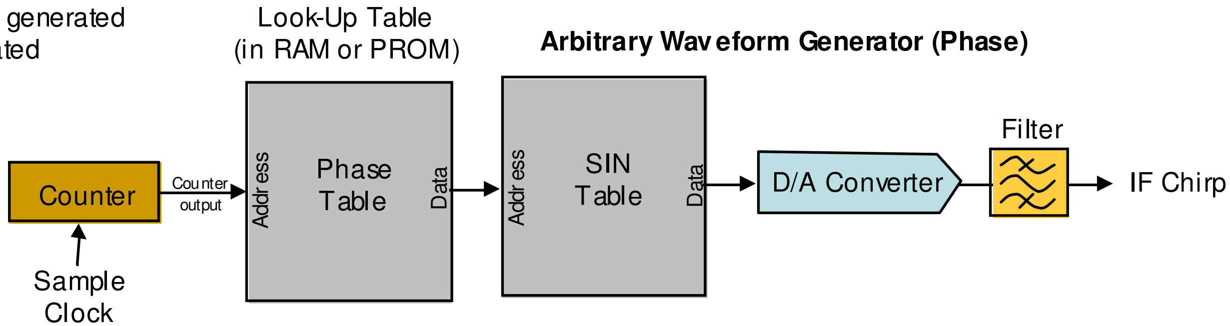


Astrium Chirp & Timing Generator Module

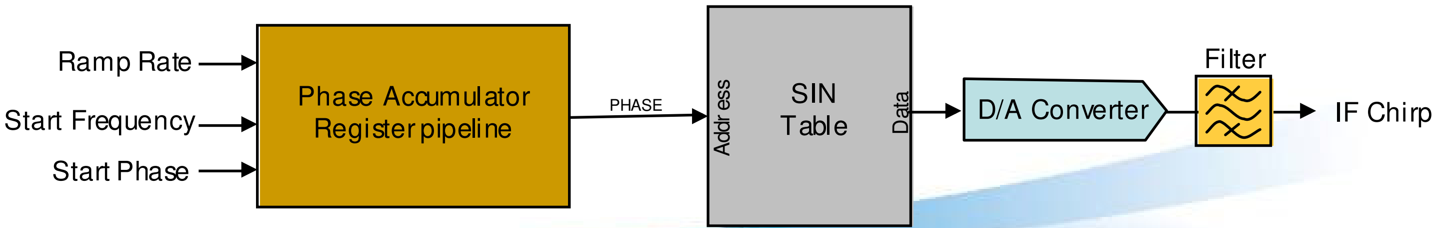
Arbitrary Waveform Generator (Amplitude)



Arbitrary Waveform Generator (Phase)



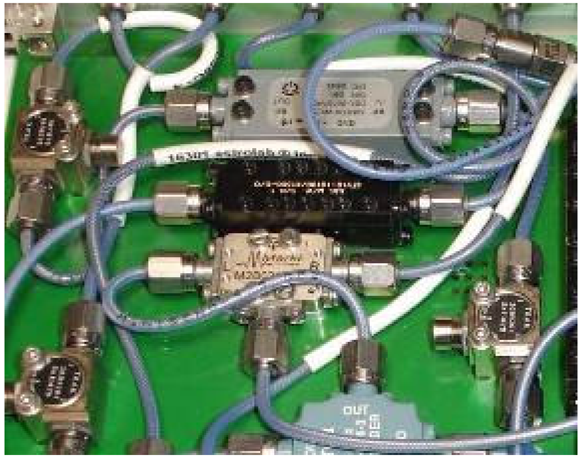
Pipeline Chirp Generator



RF Technologies

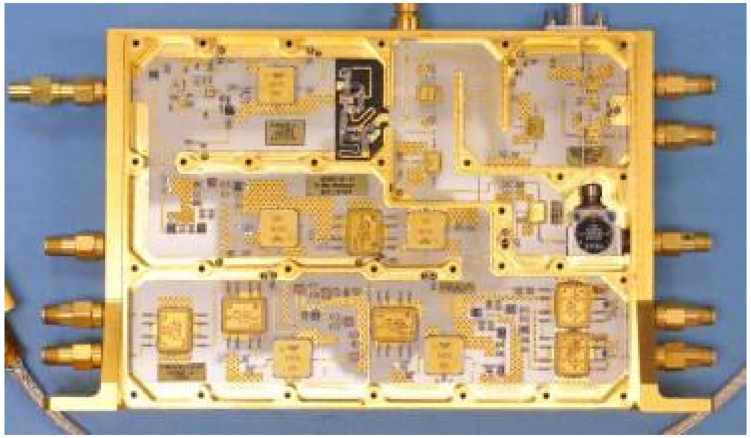
RF Technologies

Ovenised Resonant Oscillator (Astrium SpHARO)

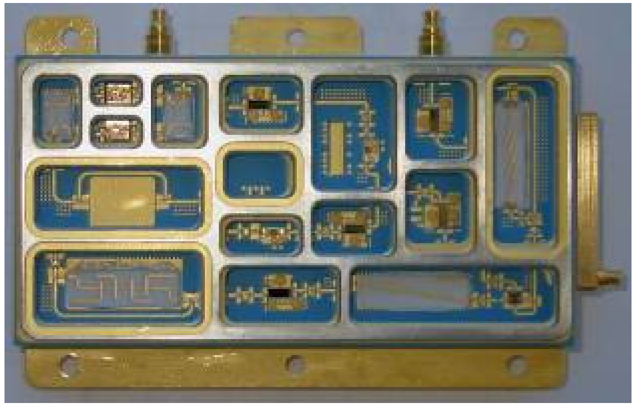


Individually packaged connectorised RF modules

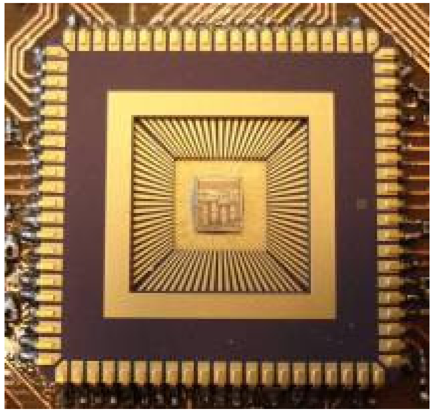
Minimum integration
Maximum access for test & troubleshooting
Low NRE cost, high recurring cost
High mass and volume



Microstrip Technology
Hermetically packaged parts on an Alumina or Duroid substrate with a metal (usually Aluminium) backing
Medium level of integration
Limited access to selected points in system
Medium NRE cost, medium recurring cost



LTCC Technology
Very high level of integration
Bare die mounted to ceramic substrate and then hermetically sealed
Highly limited access to test points
High NRE cost
Low recurring cost



Multi-Funtion RF Chips
Shown is a fractional N PLL including 8 on chip VCOs
'Ultimate' level of integration
Very High NRE cost
low recurring cost
Minimum size/mass/volume

All the space you need

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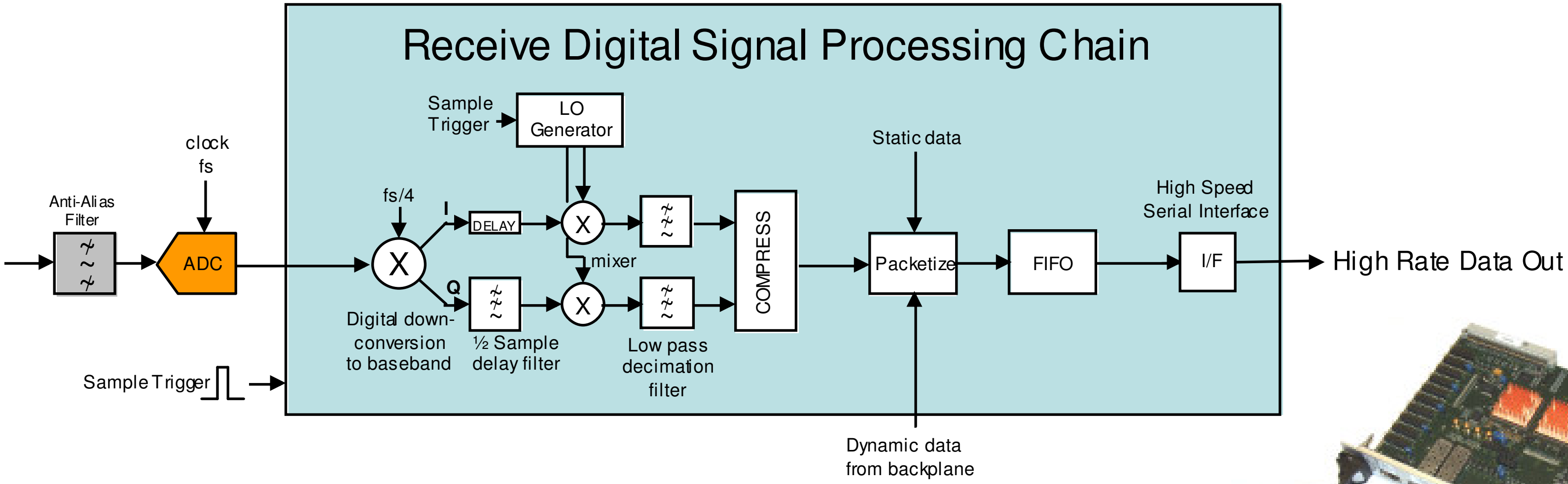
Receive Digital Signal Processing

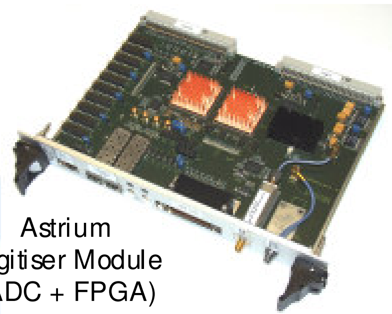
Receive Digital Signal Processing

- Most radars use an Analogue to Digital Converter (ADC) to 'capture' the echo signal
- Latest ADC devices are capable of up to 3GHz sampling rate, with up to 12 bit resolution
  - Enables sampling of wide bandwidths
  - Enables sampled signal to be on a carrier
    - Simplifies frequency plan (including through use of Nyquist 2 or 3 regions)
    - Avoids need for vector demodulators which have inherent I/Q balance difficulties

- After sampling, it is necessary to perform a number of digital signal processing steps :
  - Downconvert to baseband (I/Q)
  - Filter and resample to optimise data rate for used bandwidth
  - Apply compression algorithm



- Digital Signal Processing best implemented in an FPGA or ASIC



Astrium Digitiser Module (ADC + FPGA)

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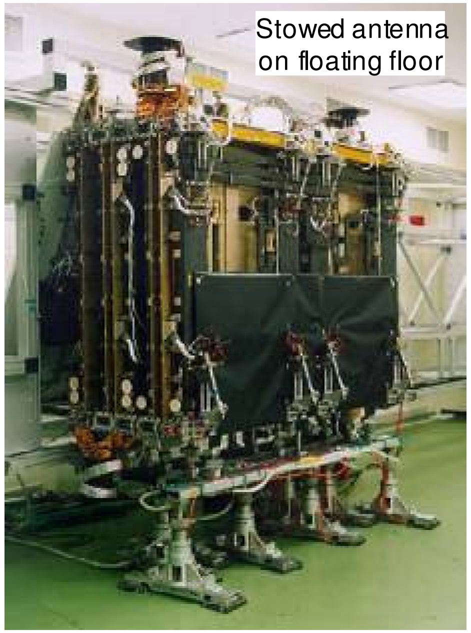
Some Real System Examples

ERS-1

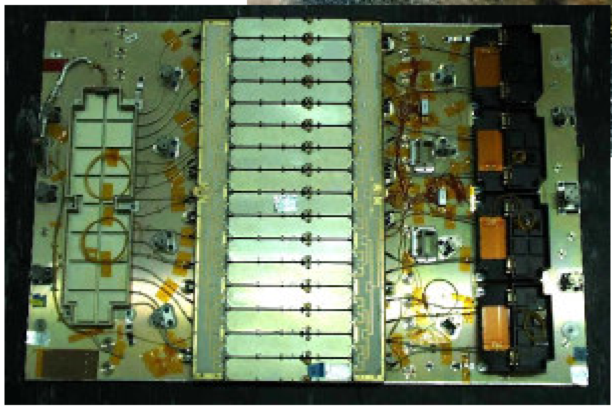

HPA
HPA Subsystem (+ Z Panel)
RF, SAR-P, Scatt Electronics
Subsystems (– Y Panel)

ASAR on ENVISAT

Deployed Antenna (radiating face)



Stowed antenna on floating floor

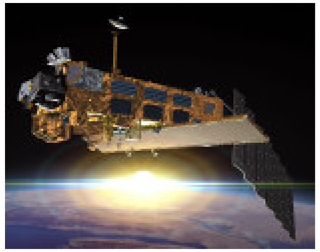


One of the 20 antenna tiles (structural model)

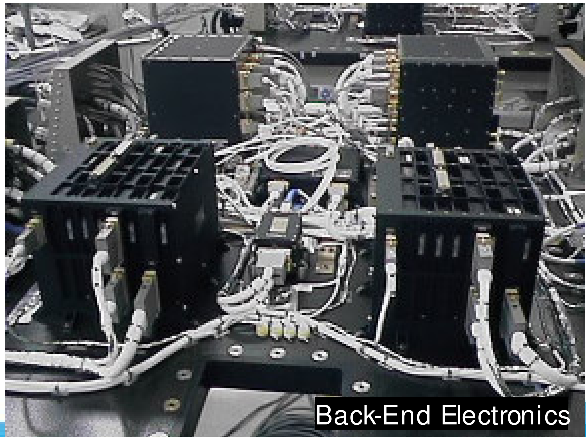
Floating-floor deployment testing

On the Spacecraft

One of the 320 T/R Modules



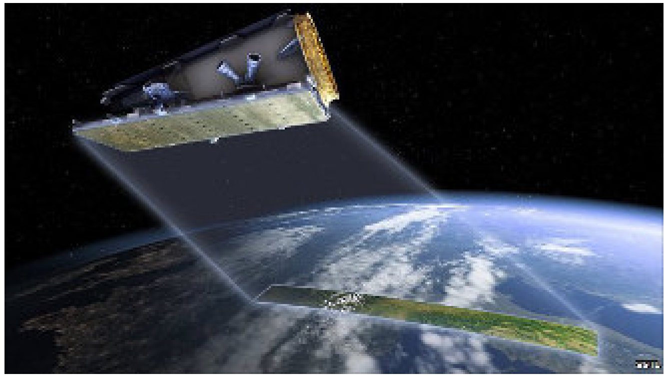
In-orbit (artists impression)

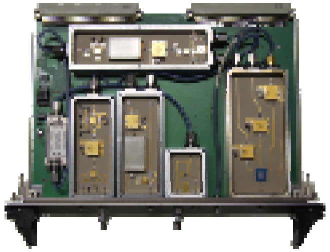


Back-End Electronics

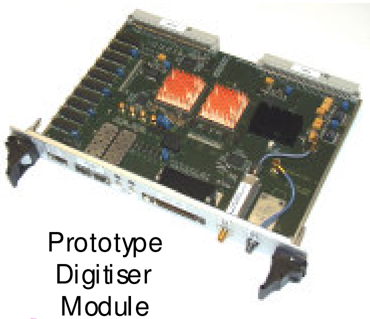
Mechanical Support Frame

NovaSAR-S

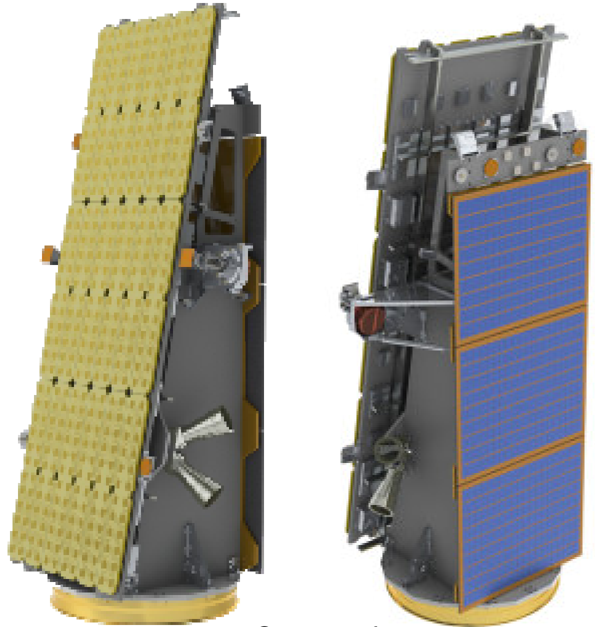




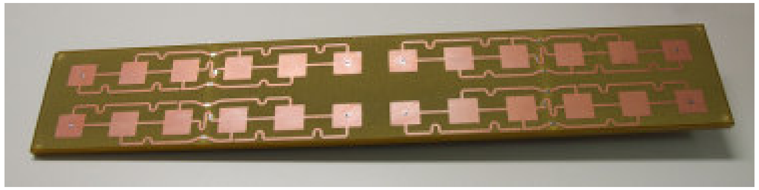
Prototype RF Module



Prototype Digitiser Module

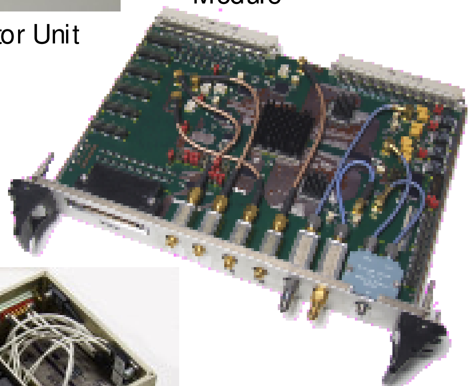


Spacecraft



Radiator Unit

GaN Transmit Unit



Prototype Chirp & Timing Generator Module

Power Conditioning Unit

Demonstrator (front)

Demonstrator (rear)