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Space-Based Ka-Band Direct Radiating Phased Array Antenna Architecture for Limited Field of View

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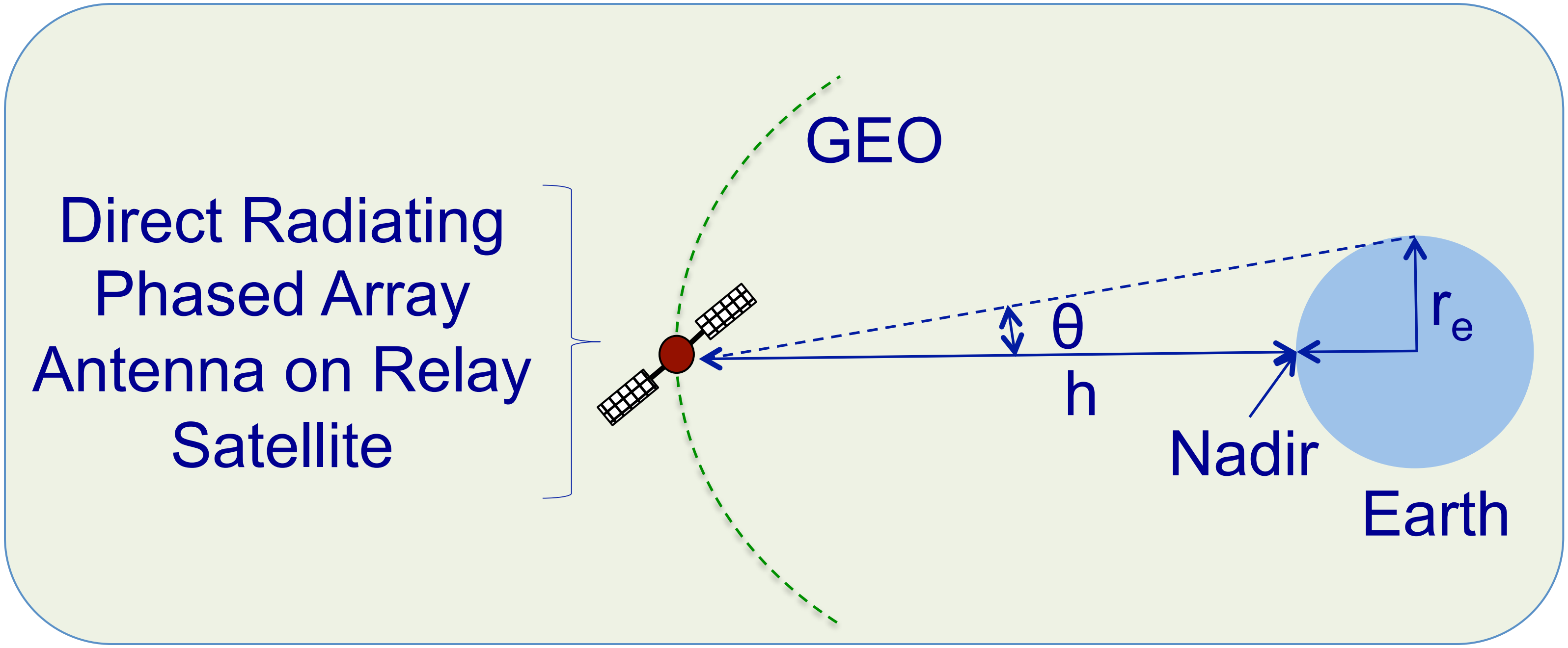
Problem Or Challenge

- ★ To investigate the feasibility of designing a direct radiating phased array antenna as a replacement for the TDRS reflector antennas without compromising performance (EIRP = 63 dBW, G/T = 26.5 dB/K, bandwidth, etc.)
- ★ Specifically, to investigate if a phased array with microstrip patch antenna elements coupled with Gallium Nitride (GaN) based amplifiers can meet the above requirements

Spaceborne Phased Array Antenna



The altitude h = 35,786 km above mean sea level & Earth's radius r_e = 6378 km

At such a distance, the Earth subtends a small conical angle of θ = ±8.7°. Consequently, the phased array onboard the relay satellite has to scan a limited field of view (LFOV)

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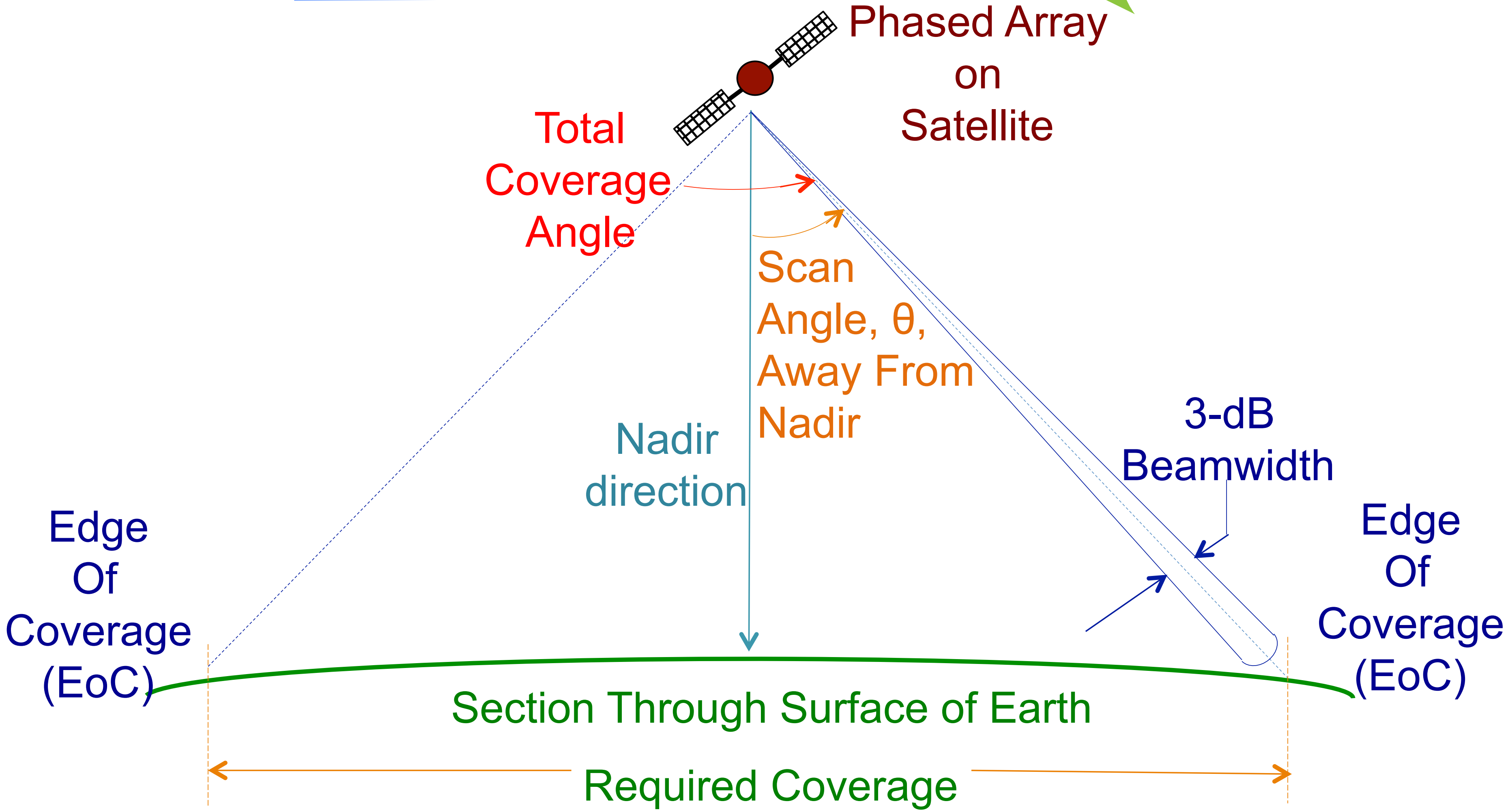
Individual Beam Scan Angle Within a Coverage



Diameter of Spot Size on Ground is the 3 dB Beam Width

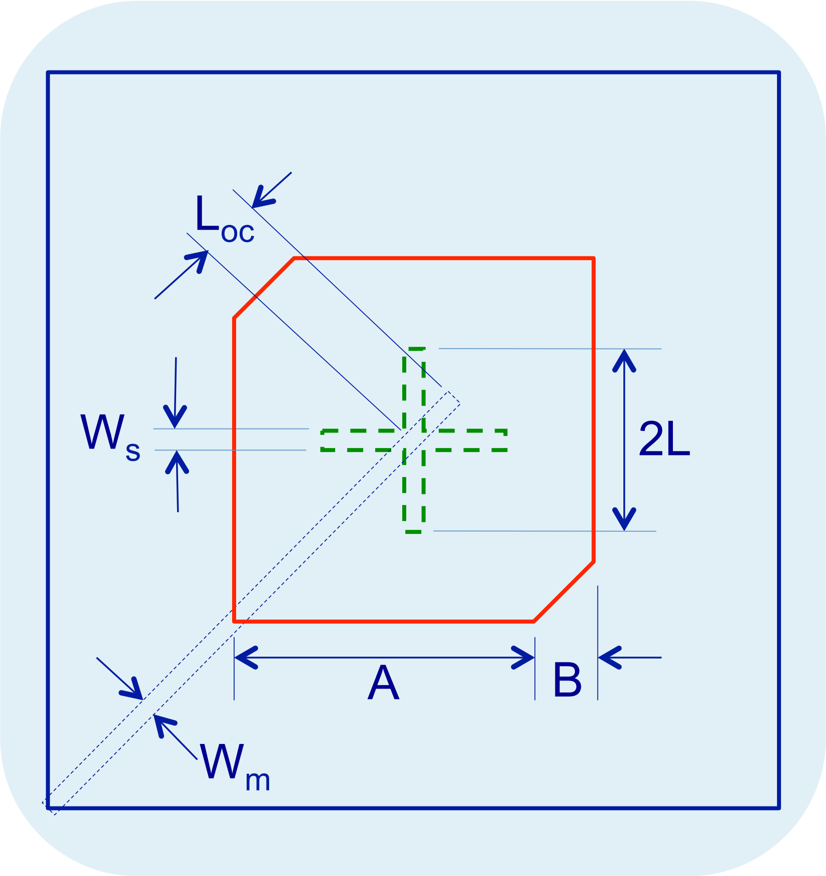
Array Design Methodology

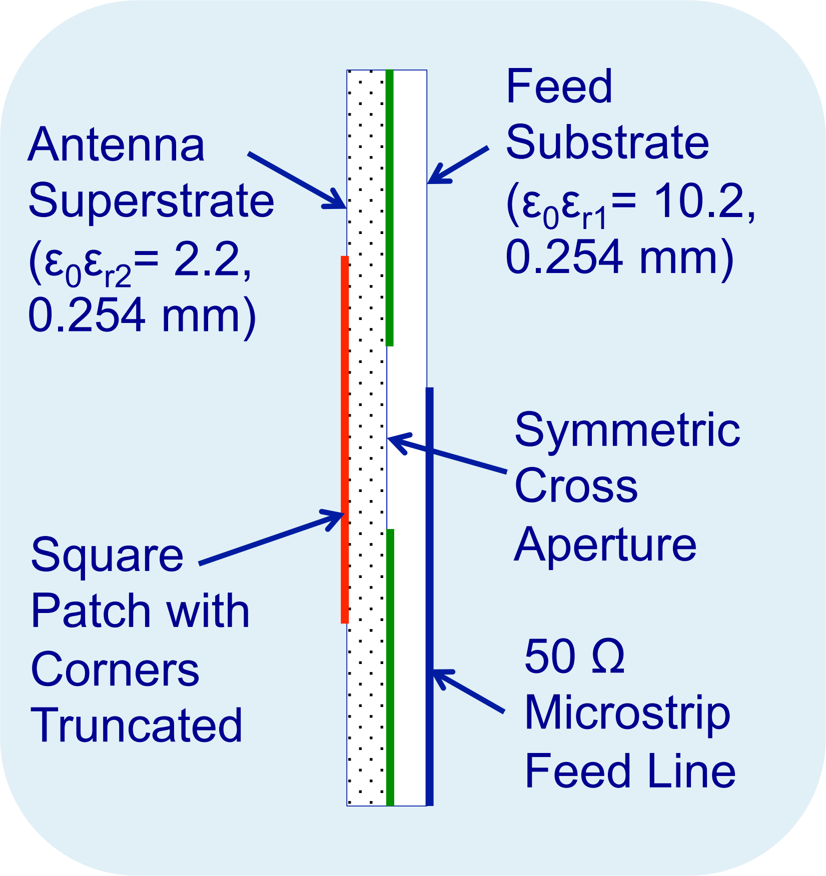
- Step 1: Antenna Element
- Step 2: Array Size
- Step 3: Element Size
  - The computations are carried out using the equations presented in the following reference:
    - A.K. Bhattacharyya, "Optimum Design Consideration for Multiple Spot Beam Array Antennas," 22nd AIAA Inter. Communications Satellite Systems Conf. & Exhibit, Paper Number AIAA 2004-3158, Monterey, CA, May 9-12, 2004.
- Step 4: Beam-Forming Network

Antenna Element

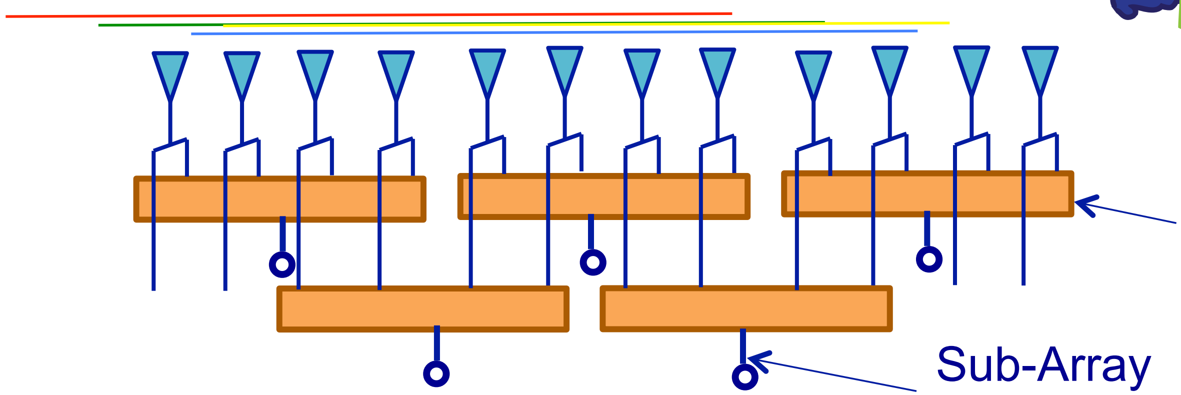
- ★ **Aperture Coupled Circularly Polarized (CP) Microstrip Patch Antenna**
  - ➢ **Key Advantages**
    - ✧ Patch antenna and the feed network reside on two separate dielectric substrates of different relative permittivity and thickness
    - ✧ Gain/bandwidth of the patch antenna and the efficiency of the feed network can be independently optimized
    - ✧ The two substrates can either be in intimate contact or can be separated by a small air gap to enhance coupling efficiency

Antenna Element & Feed Design





Beam-Forming Network



★ Overlapped Sub-Array Technique

- **Key Advantages**
  - Significant reduction in the number of control elements, such as variable gain amplifiers and phase-shifters, required to achieve the desired scan performance
  - Significant reduction in the array complexity, power consumption, overall size/mass, and cost.
  - Enhanced overall antenna reliability

Power Amplifier Modules

★ Gallium Nitride (GaN) Based Power Amplifiers (PAs)

- **Key Advantages**
  - GaN PAs have three to four times higher output power density than gallium arsenide (GaAs) based PAs
  - GaN transistors can operate at higher junction temperatures than GaAs transistors
- **Output Power**
  - Ka-Band GaN-on-SiC MMIC PAs with output power on the order of 5W are commercially available.

Conclusions

- ★ Design methodology for a direct radiating phased array Antenna for limited field of view (LFOV) has been presented
- ★ The number of array elements required for a given scan gain and scan angle has been presented
- ★ The edge of coverage directivity as a function of the element size has been presented
- ★ The optimum array elements size for the desired LFOV of ±8.7° has been presented
- ★ By integrating a GaN power amplifier with each sub-array input terminal the desired EIRP can be achieved
  - ➢ For example: It has been shown that an array of 1225 elements has a directivity > 40 dB and if each element radiates 1W, the target EIRP of 63 dBW can be achieved