Paper TU-A1.1P.4

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Performance Comparison of Ka-Band Cross-Aperture Coupled Circularly Polarized Microstrip Patch Antenna with Single Feed

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Introduction - Motivation

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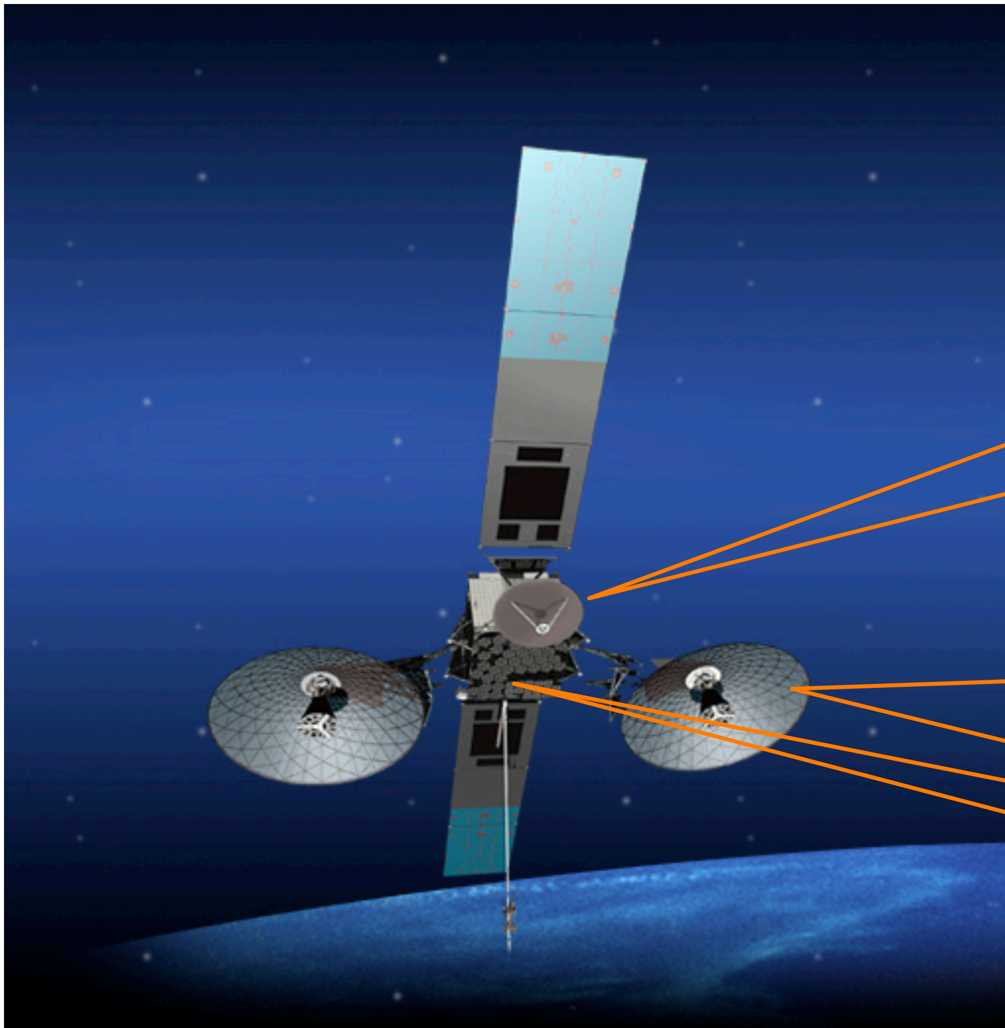
NASA's Third Generation GEO Tracking & Data Relay Satellite (TDRS)



- TDRS-K, Launched Jan 30, 2013
- TDRS-L, Launched Jan 23, 2014
  - Power: 2.2 kW
  - Weight: 3455 kg at liftoff with fuel
  - Dimensions: 21m (L) by 13.1 m (W)
  - Designed Mission Life: 11 years

Space-to-Ground Link Antenna
- White Sands Complex (WSC)
- Guam Remote Ground Terminal
- Perpendicular LP

Tri-Band Single Access Antenna
- Two (15-foot diameter & steerable)
- S-Band (2.0 to 2.3 GHz)
- Ku-Band (13.7-15.0 GHz) (300 Mbps)
- Ka-Band (22.5-27.5 GHz) (800 Mbps)

Multiple Access Antenna
- Array (32 Tx & 15 Rx elements, LCP)
- S-Band (2.0 to 2.3 GHz)

Problem Or Challenge

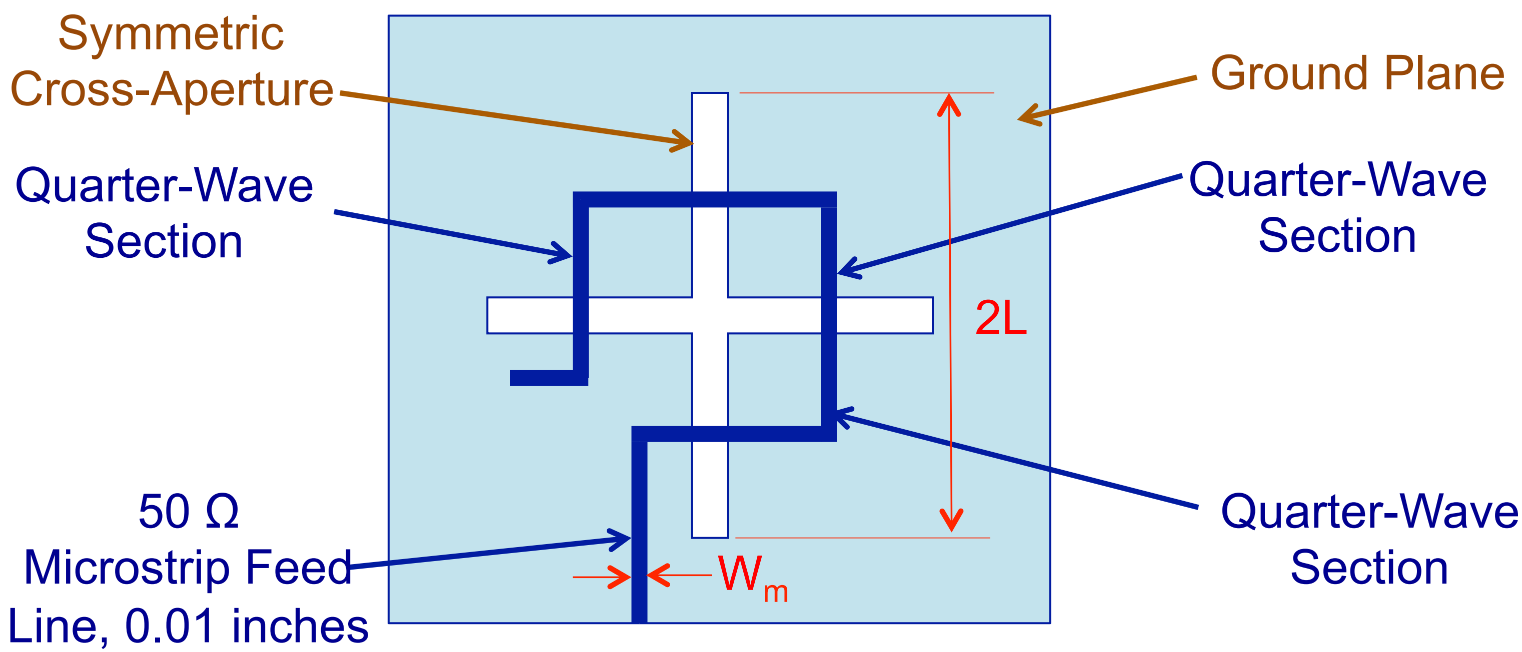
★ To investigate the feasibility of designing a direct radiating phased array antenna with performance characteristics (EIRP = 63 dBW, G/T = 26.5 dB/K, bandwidth, etc.) similar to the reflector antennas on the current generation TDRS satellite

★ Specifically to investigate, if microstrip patch antenna element based phased array antenna can meet the above requirements

A Possible Solution

- ★ **Aperture Coupled Microstrip Patch Antenna**
  - ➢ **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
    - ✧ If required the two substrates can be separated by a small air gap to enhance coupling efficiency
    - ✧ Furthermore a parasitic patch can be stacked over the driven patch to enhance the gain/bandwidth
    - ✧ The radiation can be circularly polarized (CP)

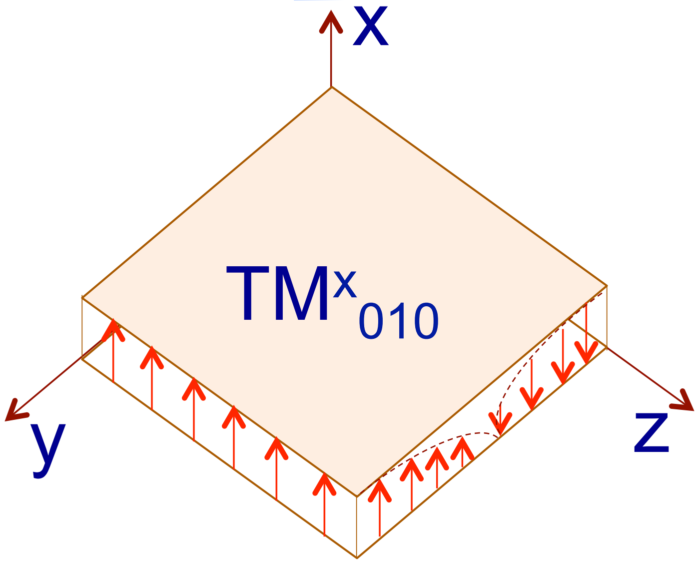
Limitations of Prior Art Antenna Configurations

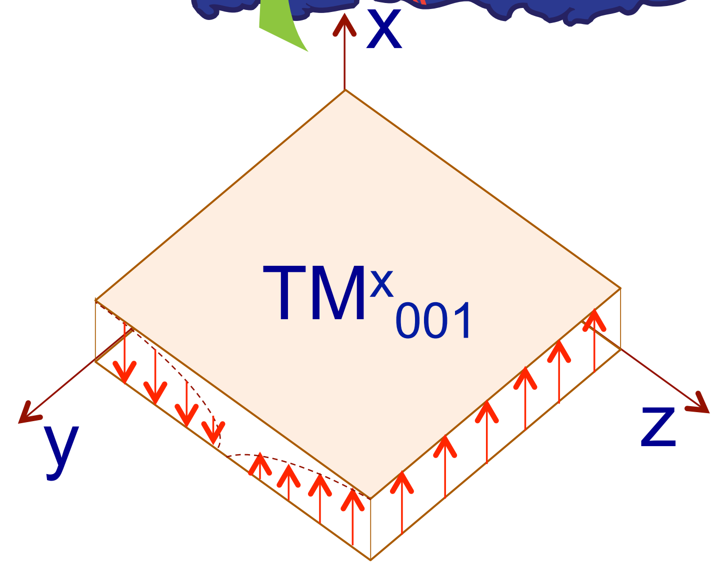


At Ka-band frequencies, the cross-aperture resonant length 2L becomes very small, for example at 27.0 GHz, 2L = 0.0251 inches, which is approximately equal to 2 x W_m. Consequently, it is a challenge to scale the design to higher frequencies

New Configuration

Field Configurations for Square Patch





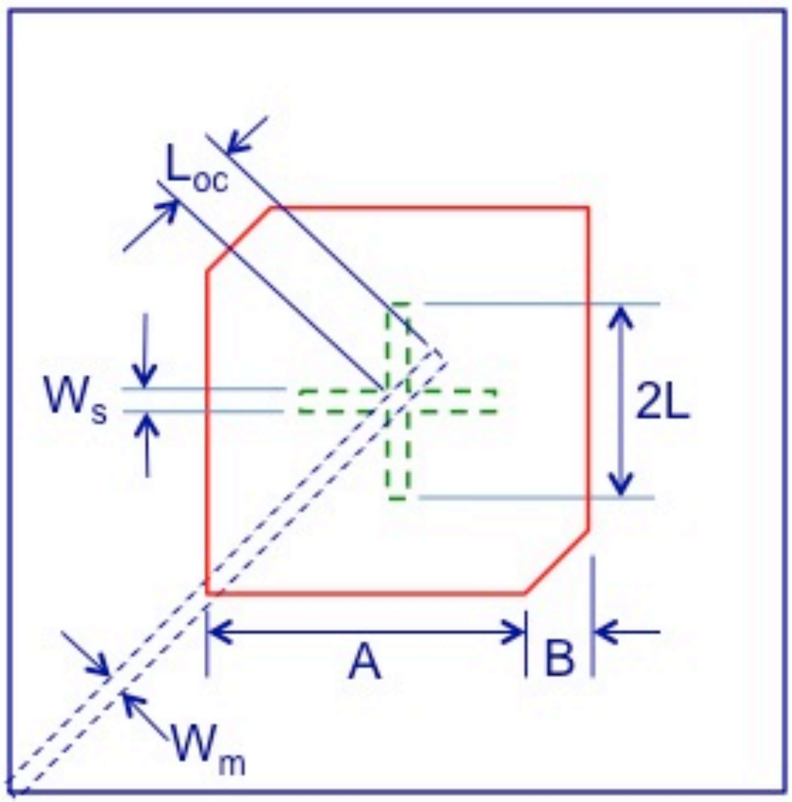
TM^x_{010} mode produces an electric far-field E_y linearly polarized (LP) in the y direction

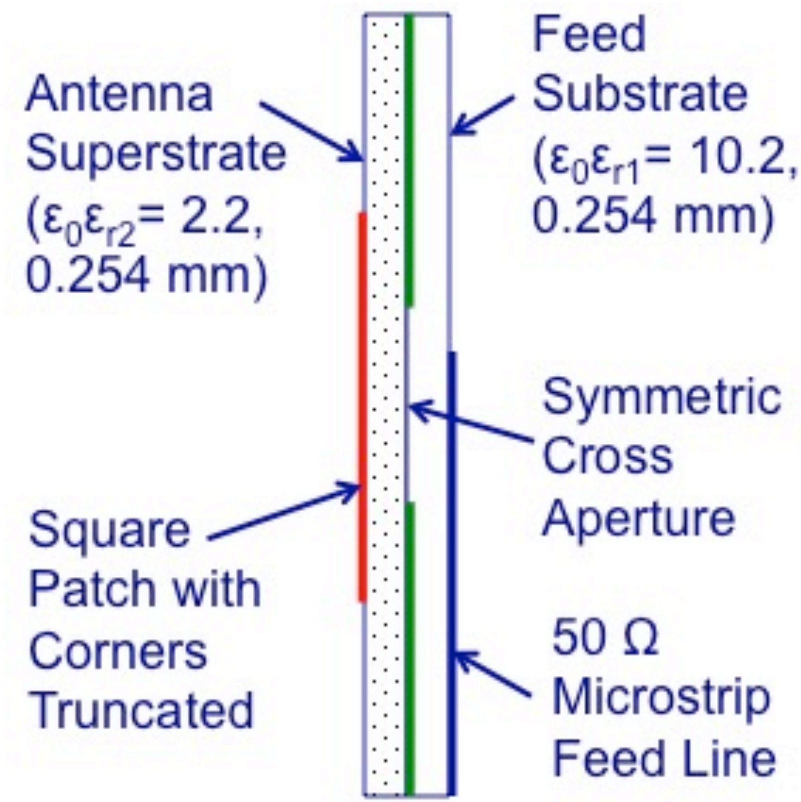
TM^x_{001} mode produces an electric field far-field E_z LP in the z direction

To achieve circular polarization (CP) the magnitude of the axial ratio must be unity while the phase must be ±90°

A practical way to achieve CP is to trim the ends of two opposite corners of a square patch

New Configuration (Continued)





Design Methodology

★ **Step 1:** Corners of a square patch are truncated for circular polarization The dimensions are designed based on the equations from: T.A. Milligan, *Modern Antenna Design*, 2nd Ed

★ **Step 2:** The design is validated by fabricating a set of patch antennas and measuring the return loss and resonant frequency

★ **Step 3:** A symmetric cross-aperture is selected for exciting the patch. The aperture slot width is set equal to 0.01 inches from ease of fabrication

★ **Step 4:** The symmetric cross-aperture length (2L) is empirically determined to be equal to 0.22 $\lambda_{g(slot)}$, where $\lambda_{g(slot)}$ is the guide wavelength in an equivalent slotline of width equal to 0.01 inches

★ **Step 5:** The Z_0 of the microstrip feed line of width W_m is set = 50Ω

★ **Step 6:** The length of the microstrip line L_{oc} beyond the junction of the cross-aperture is empirically determined to be 0.11 $\lambda_{g(microstrip)}$, where $\lambda_{g(microstrip)}$ is the guide wavelength

Conclusions

- ★ The design methodology for a CP square patch with corners truncated and coupled to a 50Ω microstrip feed line through a symmetric cross-aperture in the ground plane is presented
- ★ The analytical model for the square patch design is validated through experiments over a wide range of frequencies
- ★ An empirical model for the design of the symmetric cross-aperture is presented and validated through experiments over a wide range of frequencies
- ★ Typical measured return loss and axial ratio are presented
- ★ Future efforts include:
  - ➢ Measurement of antenna gain, radiation patterns, and front-to-back ratio
  - ➢ Performance improvement by including a stacked parasitic patch
  - ➢ Design to a planar array at Ka-band