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

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Outline

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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)
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)
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 $2 \times W_m$. Consequently, it is a challenge to scale the design to higher frequencies.
New Configuration
Field Configurations for Square Patch

$\text{TM}^{x}_{010}$ mode produces an electric far-field $E_y$ linearly polarized (LP) in the $y$ direction

$\text{TM}^{x}_{001}$ 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 $\pm90^\circ$

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 $= 50\Omega$.

★ **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