A satellite tracking system at 78GHz using the over-moded TE21 ground-station antenna pattern

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***Abstract*—Low power cube-satellites are becoming increasingly popular for earth observations and fast data relay. Their low earth orbit means the available time to download data is only about 10 minutes per fly-by. High frequency (71 to 76 and 81 to 86GHz) radio links have the wide bandwidth required for fast data-transfer and very large antenna gain for a modest diameter (meaning low power can be used) but tracking the fast-moving satellite with a high-gain beam is a problem, requiring a pointing accuracy similar to radio telescopes, but with tracking speed up to 3 degrees a second. This paper outlines a method of automatic servo-tracking of the ground-station antenna to the fast-moving CubeSat (once signal has been acquired) using just the over-moded ground-station linear-polarization TE21 mode to obtain Azimuth/Elevation tracking information from the circular-polarized data signal.**

Keywords—CubeSat, circular-polarization, E-band, monopulse-tracking, TE21, wideband satcom

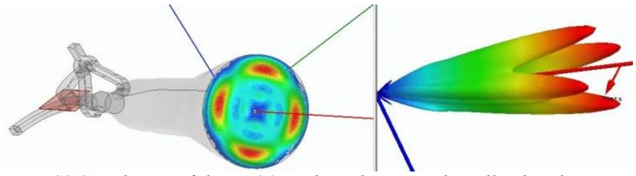
I. Introduction

Using the over-moded TE21 or TM01 mode of a waveguide-fed antenna to obtain tracking information has been discussed before for low frequencies (around 10GHz) but as far as we are aware, has not been tried at significantly higher frequencies where very high gain antennas with modest diameters are possible as well as very wide signal bandwidth (5GHz). We present a system which couples the fundamental mode TE11 circular-polarization data channel (using a septum polarizer), but also uses a linear-polarization TE21 mode (with 4 off-axis lobes and a deep central null) to additionally sample the circular-polarized TE11 signal when the antenna is slightly off-axis for tracking. This type of system is referred to as “amplitude and phase mono-pulse” from historical use in radar, but in this instance, we are guiding the ground station antenna to a circular-polarized signal being transmitted by the satellite. Traditional dual-waveguide-mode coupling systems are very complex, requiring ultra-precision small component fabrication. This is not possible at higher frequencies so it was necessary to construct a significantly simpler TE21 mode coupler but preserving performance. We also investigated the use of easier-to-manufacture smooth-wall spline horns and corrugated feed horns to support the TE21 mode for use with these systems as well as the main TE11 circular mode.

The beauty of the system, using a circular polarized input beam is that the four TE21 linear-polarized lobes have unique phase characteristics that can be separated: opposite lobes are 180-degree shifted in phase, and (due to the propagating nature of the circular polarization wave) the orthogonal axis is automatically in phase-quadrature. This is a characteristic of intercepting the circular-polarized TE11 main beam with the linear polarized TE21-lobes and we believe this beneficial property has not been fully exploited. If our simulations are correct and the waveguide-lengths are correctly calibrated, we require only ONE additional down-converting mixer for the TE21 tracking mode. AZ/EL steering data can all be unscrambled from the phase/amplitude comparison with the TE11 mixer down-converting the fundamental circular-polarization mode (the mixers share a common local oscillator and the relative waveguide paths are matched). The final phase comparison is done at intermediate frequencies, leading to a relatively simple set-up for the amplitude/phase comparison and AZ/EL steering. Many papers show that the TE21 method provides a linear-enough error signal, to allow servo-tracking of the beam. We also investigated TM01 tracking possibilities which would also work in this way, and have similarly been used before but the TM01 mode converter is harder to implement, and the beam pattern is an annulus rather than 4 beams, so the gain is lower.

We will explain the TE21/TE11 converter and simulations using a variety of horn antennas, with beam patterns and phase plots, and hopefully full measurements.

This design is scalable to higher frequencies as it is fabricated using split block sections and avoids small parts or tight tolerances. Useable frequency bandwidth is about 4%.



HFSS Simulation of the TE21 mode with a smooth-wall spline horn

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