A Method for Evaluating Antennas For a Low Earth Orbit Mission

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I. The Problem Addressed

Antennas for amateur satellites have traditionally been fabricated to fit into launch constraints and to deploy and operate properly in orbit. Mission profile has been considered in some antenna designs, such as that for the AMSAT Phase III satellites. Amateur satellite users are mostly experimenters who are willing to invest time and money to make up for non-optimum orbiting antennas with sophisticated ground station equipment. The service proposed for prototyping with the Packet Technology Satellite Experiment (PTSE) or "HouSat" is expected to require more from the satellite and less from each of a larger number of ground based users.

One way to get more from the satellite is to use some sort of optimized antenna. The goal of this paper is to provide a rationale for evaluating possible antennas for this service in terms of their radiation patterns. Selection of such an antenna system involves these considerations: electrical perfomance, launch constraints (envelope), and user-relative performance. This discussion primarily addresses user-relative performance desires. No particular antenna is recommended but several possibilities are discussed as a starting point for prototyping.

The ideal antenna would provide equal radiation coverage of all points on the earth that are within view (that is, within the satellite footprint), would not waste power in directions where there are not users and would provide some level of gain so as to partly make up for power limitations in the transmitting equipment or sensitivity limitations in the receiving equipment. These considerations apply to uplink as well as downlink antenna pattern models.

II. Model of the ideal radiator for this situation

We begin with the assumption that all points on the earth are of equal importance in terms of being covered by RF from the satellite. Put another way, it is desired to equally illuminate all visible points on the ground below. It is assumed that the ground track and averaged "footprint" of the satellite are distributed about the earth so as to make the equal coverage property possible and desirable in terms of the user population.

The ideal antenna model presented here requires spacecraft stabilization in two axes such that one satellite facet can be kept pointing at earth at all times. The effect of this type of stabilization on spacecraft powering has been discussed previously [1]. The effect on thermal performance is not considered in this study but should be addressed separately.

The radiation pattern considered is symmetric about the vertical axis which connects the center of the earth and the satellite. Rotation about the axis (changing the azimuth parameter) does not influence signal strength. For a fixed altitude, slant range to a point on the earth is a function of a single parameter, the angle between the segment joining the satellite with that point on the earth and the axis of symmetry.

Actual antenna and stabilization schemes will give patterns which are not symmetric about this axis. This does not necessarily mean that they are unacceptable as long as the variation is not so great that it causes signal levels to drop below desired margins or to fluctuate rapidly in time with azimuth changes due to satellite rotation or orbital motion. Such fluctuations could result in disruption of digital communications.

III. Ideal radiation pattern as a function of the angle to the nadir axis only

For a satellite in circular orbit, the parameters of interest are the altitude of the satellite and the radius of the earth.

Re = radius of the earth, 6378.145 Km
Rs = distance, center of earth to satellite,
Re + 800 = 7178.145
S = slant range, a dependent variable
a = angle from slant segment to vertical axis at satellite, a dependent variable
b = angle between user and satellite position at earth center

From trigonometry we have

$S^2 = Re^2 + Rs^2 - 2\ ReRs \cos(b)$

$a = \arcsin[(Re/S)\sin(b)]$

and will always be < 90 degrees.

Special cases are S minimum where

$S = Rs - Re$

$a = b = 0$ and

S maximum where

$S^2 = Rs^2 - Re^2 2$

$b = \arccos(Re/Rs)$

$a = 90 - b$.