Design VHF Antennas for Space Borne Receivers for SmallSats.

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Science and Mission Payload
Advance Technology

Abstract: Space borne microwave remote sensors at VHF/UHF frequencies are important instruments to observe reflective properties of land surfaces through thick and heavy forestation on a global scale. One of the most cost effective ways of measuring land reflectivity at VHF/UHF frequencies is to use signals transmitted by existing communication satellites (operating at VHF/UHF band) as a signal of opportunity (SoOp) signal and passive receivers integrated with airborne/space borne platforms operating in the Low Earth Orbit (LEO). One of the critical components of the passive receiver is two antennas (one to receive only direct signal and other to receive only reflected signal) which need to have ideally high (>30dB) isolation. However, because of small size of host platforms and broad beam width of dipole antennas, achieving adequate isolation between two channels is a challenging problem and need to be solved for successful implementation of space borne SoOp technology for remote sensing. In this presentation a novel enabling VHF antenna technology for Cubesat platforms is presented to receive direct as well as reflected signal with needed isolation. The novel scheme also allows enhancing the gain of individual channels by factor of 2 without use of reflecting ground plane

Introduction

VHF/UHF microwave band is very useful for measurement of soil moisture (surface soil moisture (SM) as well as root zone soil moisture (RZSM)) because of their large wavelengths capable of penetrating above ground biomass as well as subsurface layers up to depth of 50-100 cm. However, current active VHF/UHF microwave remote sensing technology requires prohibitively large size antennas with complex hardware to achieve reasonably good spatial resolution.

A promising new technology consisting of a simple passive microwave receiver on an airborne or space borne platform in conjunction with already existing transmitter (called Signal of Opportunity(SoOp) transmitter) in a bi-static radar configuration has shown a great potential to measure land/ocean surface properties and many other Earth science parameters [1,2]. Space-Airborne Bi-Static radar configuration (where GNSS satellites act as a space borne SoOp transmitters and airborne L-band as a passive receiver act as a receiver) has been proved to be useful for altimetry of the ocean surface and ocean surface wind estimator [3-5]. Recently, NASA is funding efforts to use military SatCom known as Follow-on satellites operating in VHF/UHF bands as SoOp transmitters and an airborne/space borne platform for a passive VHF/UHF receiver to measure SM as well as RZSM simultaneously through above ground biomass.

In SoOp technology, the passive receiver consists of two channels to receive separately a direct signal from the transmitter and the reflected signal from the land surface. In order to be able to perform post processing on these two signals, the two antennas (one for each channel) are required to be isolated with maximum possible isolation. Otherwise, the direct signal being much stronger than the reflected signal will always mask the weak reflected signal. However, because of close proximity of these two antennas and their broad beam widths, achieving good isolation greater than 20 dB is difficult but important for successful operation of SoOp receiver. In this presentation, we report a novel technique that can achieve isolation greater than 18 dB without use of an isolating screen or Yagi antenna concept. Use of an isolating screen between the two antennas or Yagi antenna concept will increase the volume and weight of antennas. Further isolation between the two signals can be achieved exploiting their different time of arrivals and differences in their polarizations caused by reflective characteristics of land surfaces.

Theory

Figure 1(a) shows the SoOp technology concept for Earth remote sensing and Figure 1(b) shows the antenna model mounted on a cubesat platform for EM simulation. The crossed dipoles are used to produce circular polarizations for the direct as well as reflected channels. The crossed dipoles mounted on zenith looking face of a

cubesat is polarized with RHCP and used to receive direct signal from military SatComm Follow-On satellites. The crossed dipoles mounted on the face looking towards the ground is polarized with LHCP and is used to receive the reflected signal. Flat strips fabricated using measuring tape material is used for each dipole. The measuring tape material is selected because of its easiness in packaging and deployment. The cubesat is assumed to have perfect electric conducting surface for antenna design and simulation purposes.

The CST Microwave Studio (commercial EM simulation software) is used to design and select dimensions of antennas to resonate at VHF (250 MHz) center frequency with a bandwidth of 30 MHz. This choice was dictated by the frequency band used by the Follow-On satellites for their downlinks.

Array Pattern Synthesis:

The far field pattern, $\vec{E}_t(\theta,\phi)$ of the dipoles for receive mode can be expressed as

$$\vec{E}_t(\theta,\phi) = \sum_{n=1}^{4} a_n \vec{E}_n(\theta,\phi) \qquad (1)$$

where $\vec{E}_n(.)$ is the embedded radiation pattern of nth dipole and a_n is the unknown complex weighting factor for n^{th} receive channel and will be estimated for desired/given $\vec{E}_t(\theta,\phi)$ using the least mean square algorithms.

The embedded patterns and the mutual coupling between the dipoles required for the radiation pattern synthesis are numerically estimated using the CST EM simulation software.

Results and Discussion:

The computed values of S-parameters for 4 dipoles as a function of frequency are shown in Figure 2, indicating excellent impedance matching over 30 MHz bandwidth around 250 MHz center frequency.
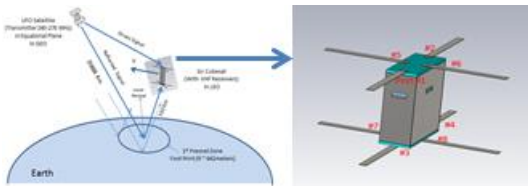

Figure 1(a) SoOp technology concept for remote sensing, (b) antenna model mounted on a cubesat.

Figure 3(a) and 3(b) shows computed radiation patterns for direct and reflected channels, respectively. From Figure 3(b) it clear that the reflected channel will receive strongly the direct signal making it difficult to extract the reflected signal free of the direct signal.

For reflected channel, the desire pattern requires high directivity in the direction of specular point on the ground and null in the direction of SoOp transmitter.
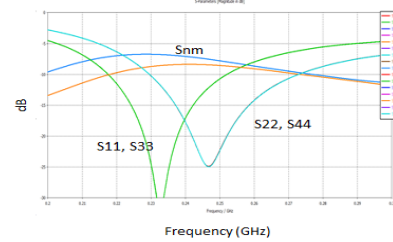

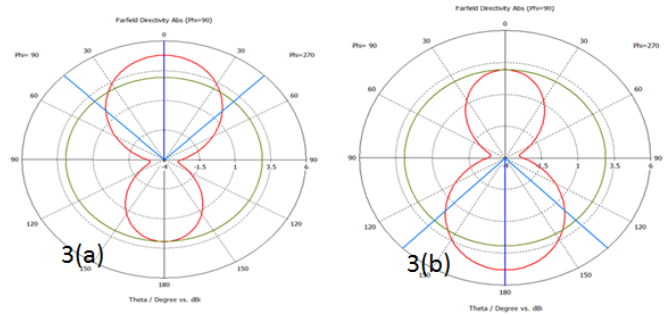Figure 2: Computed S-parameters of 4 dipole antennas

Figure 3: Computed radiation patterns for (a) direct, and (b) reflected channels

This is achieved by appropriately combining the far fields of each individual dipole antennas. Optimization procedure for achieving desire radiation pattern and associated experimental results will be presented.

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