ABSTRACT

The emergence of CubeSats/SmallSats began a miniaturization revolution in the satellite industry nearly twenty years ago. Only a handful of people could have predicted their capabilities at that time, and today, these Small Satellites are changing the world in a completely different way. They have established themselves as a viable science platform. The mass of the SmallSat family usually is less than 500 kg. Mini, Micro, Nano, Pico and Femtosatellites form the SmallSat family. CubeSats are a special subset of the SmallSat family which falls under nano and picosatellite mass category. They are small satellites with a useful volume of 10 cm × 10 cm × 10 cm and a mass of approximately 1 kg, often made of commercially available off-the-shelf components. Small satellites can reduce the mass and cost of any space mission significantly and allow fast and frequent access to space in an affordable manner. Small satellites can play very important role in science missions, Earth observation, Tele-communications, weather forecasting, navigation, technology demonstrations, and education.

Antennas are among the most important sub-systems of any satellite. They are the eyes and ears of the satellite. The types of antennas used for CubeSats missions depend on the application, mission objective, frequency of operation, etc. Broadly CubeSat antennas can be classified as Low gain antennas (LGA, gain < 8dBi), Medium gain antennas (MGA, gain < 25dBi), and high gain antennas (HGA, gain > 25dbi). Medium to high gain antennas are used for data transfer whereas low gain omni-directional antennas are used for Telemetry, Tracking, and Command (TT&C) applications. Moreover, CubeSat allows various onboard scientific instruments, such as spectrometer, and these instruments sometimes need integrated antenna system to function. Given the space constraints posed by the small satellite platform, designing high performing antennas is a challenge.

This research explores various kinds of innovative antennas for small satellites, starting from X band to THz applications. In small satellites, components are very closely packed because of space constraints, and hence EMI could be a significant problem. In the first work, a compact, high gain substrate integrated waveguide (SIW) based antenna is proposed which is suitable for integration with various other circuit components. This antenna, by virtue of design, reduces mutual coupling among various closely packed components. Array of this element is also demonstrated for high gain applications.

One deployable Fabry-Perot Cavity antenna is proposed which is suitable for X-band data transfer. This work introduces the concept of spatially separated superstrate area excitation in FPC antennas. This concept is validated and applied to increase the gain and the axial ratio bandwidth of a conventional narrowband circularly polarized source patch antenna. The antenna's design leverages independent control of polarization at different frequencies, resulting in a large overall bandwidth. The fabricated prototype antenna provides right hand circular polarization. The antenna is simple, lightweight, easily integrable with CubeSat body, and useful for X-Band data downlink. Integration of this antenna with the metallic body of a 1U CubeSat also demonstrated. A deployment method is proposed for this antenna that results in a very small stowage volume.

CubeSats and other small satellites have natural grounds and they can be utilized for antenna designs. One such possibility is explored by designing a surface wave antenna. The development of a high-gain, wideband, end-fire, mm-wave surface wave launcher is proposed. The design primarily consists of three parts, viz: a Grounded Co-Planar Waveguide (GCPW) feed, a phase equalization section, and a dielectric wedge wave transformer with extended ground which is basically CubeSat chassis. The wave excited by GCPW feed is first converted into a plane wave over a wide aperture by phase-equalization section. The dielectric wedge section efficiently transmits the generated surface wave into the extended ground over a very wide frequency range, which propagates along and finally radiates from the ground edge. This launcher can be mounted on any large metallic ground directly. Towards the end, antenna for CubeSat based THz spectroscopy application is explored. A Fabry-Perot Cavity (FPC) antenna is proposed for Tera-Hertz (THz) CubeSat spectroscopy instruments. The proposed antenna is a three layer metallic structure consisting of a matching layer, a cavity layer, and a Partially Reflecting Surface (PRS) layer. The antenna is linearly polarized, provides wide BW, and high gain.