Ka-band Transponder for CubeSats and Nanosats

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Advances in many CubeSat technologies, particularly attitude control, have lead to the prospect of using high gain directional antennas. Most CubeSats currently use omni-directional antennas and communicate in VHF and UHF bands at tens of kilobits per second, or S-band at up to two megabits per second (Mbps). These data rates are suitable for low speed, point-to-point data and voice applications. However, broadband communications networks and optical or radar instruments require data rates of tens of Mbps. For the Antarctic Broadband program, a Ka-band transponder with steerable antennas has been developed for high data rates in a size suitable for a large CubeSat.

High data rates require high gain, directional antennas, the gain being proportional to antenna aperture area and inversely proportional to wavelength squared. A directional antenna at Ka-band, around 20 GHz, will have one tenth of the diameter of an S-band antenna with identical gain. It is therefore possible to carry Ka-band horn antennas less than 5 cm in diameter with over 20 dBi gain.

The CubeSat community is largely unfamiliar with Ka-band technology. Challenges with this band include the efficiency and linearity of Ka-band devices and atmospheric effects, especially rain and scintillation at low elevation angles. Recent adoption of Ka-band on large communication satellites has driven improvements and miniaturisation of devices and technical advances in subcomponents such as linearisers and regenerative transponders. Atmospheric effects can be partially overcome by selection of network configuration options, such as variable bit rate and path or satellite redundancy.

The Antarctic Broadband Demonstration Mission intends to place a 200x200x200mm form factor Generic Nanosatellite Bus from the University of Toronto Space Flight Laboratory (SFL) into LEO and demonstrate point-to-point communications using Ka-band. The two antenna sets must simultaneously point at separate ground targets while passing overhead. Support of the waveguide rotation as well as integrating the satellite into a nanosatellite deployer was a non-trivial design problem. The SFL XPOD deployer allows antennas to extend beyond the limits of the 200x200mm form factor which may be an option unavailable to CubeSats using the standard PPOD. The small antennas are also an advantage on the ground, reducing the cost and complexity of the tracking systems allowing ground terminals to be more easily added to cars, aircraft, ships and even Unmanned Aerial Vehicles (UAVs).

The major limitation of VHF, UHF and even S-band to achieving high data rates is the available bandwidth at these frequencies. At Ka-band the ITU has allocated spectrum for fixed and mobile satellite service downlinks between 17.3 and 21.2 GHz and uplinks between 24.75 and 31.0 GHz. While Antarctic Broadband uses 16 MHz for the Demonstrator mission forward link, future missions are intended to make use of significantly more bandwidth, with further increases in the data rate.

The prototype Ka-band transponder prototype measures 125x173x41mm, and weighs 1.7 kg. In bent-pipe mode it has over 100 dB of gain in both forward and reverse directions. The bandwidth is 16 MHz in the forward link and 500 kHz in the reverse link. In the preferred orbit it will achieve 15.84 Mbps maximum data rate and consume a maximum of 10 W at 10% DC to RF efficiency.