A Bistatic Ground Station for Concurrent Spacecraft Operations

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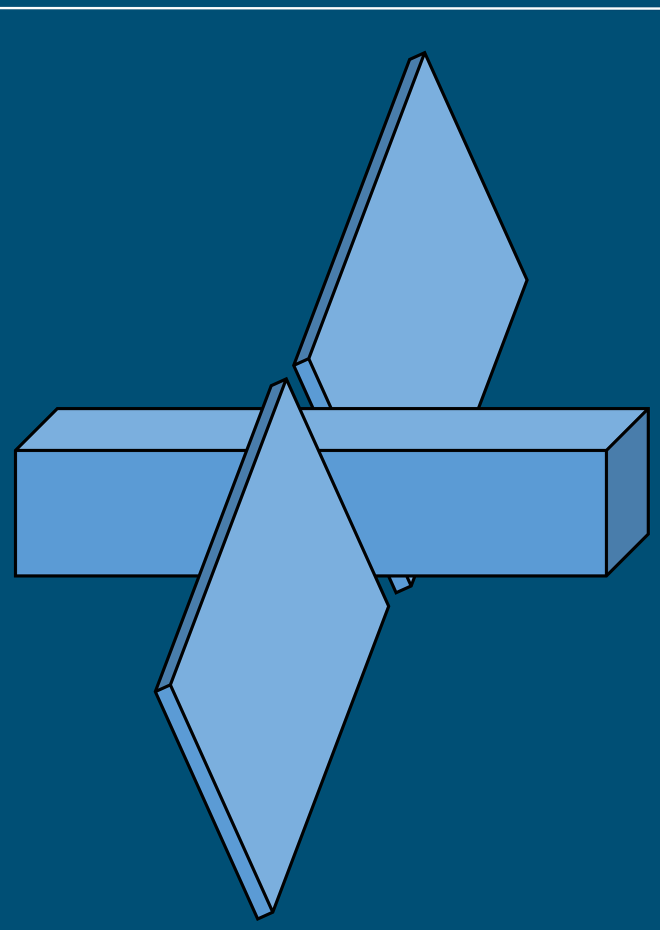
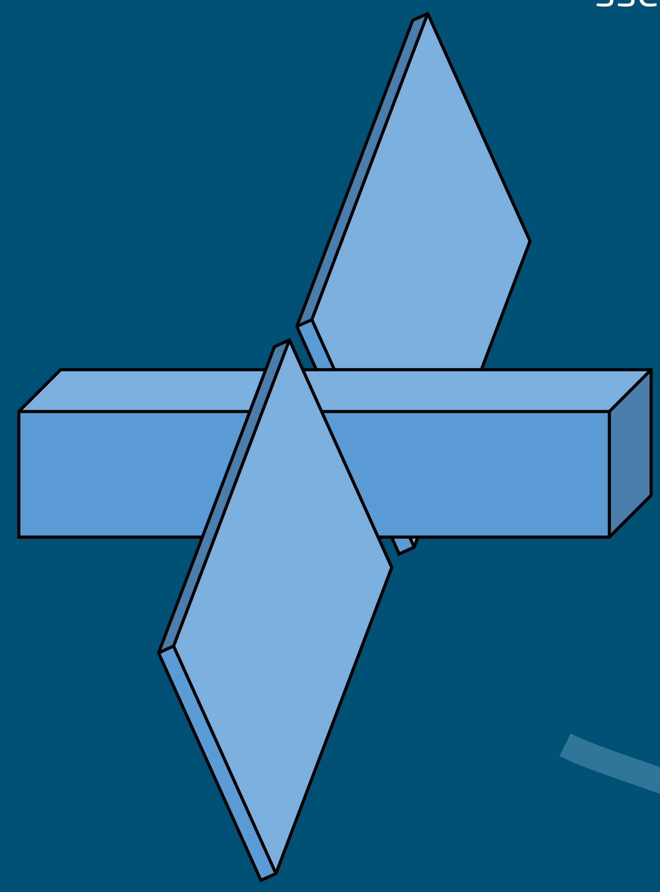


It is common for SmallSat and CubeSat operators to implement telecommunication systems using a half-duplex UHF system to reduce the cost and complexity of spacecraft hardware. This half-duplex configuration requires transmission and reception of the spacecraft signals at the same frequency, with the 402 MHz to 403 MHz band being a popular choice.

Due to practical filter limitations, it is impossible to produce an analogue filter for a ground-based receiver which can sufficiently attenuate transmissions from neighboring transmitters also operating in the same 402-403 MHz, band while still retaining a sufficiently low insertion loss to clearly receive transmissions from a spacecraft. As a result, only one such half-duplex ground station can operate in the 402-403 MHz frequency band in any local area at any one time.

We developed a bi-static station where the transmitting station is some 15 kilometers distant from the receiving station, allowing multiple concurrent spacecraft passes. Such an approach makes supporting UHF missions economic for ground station providers.



Bistatic configuration—an alternative approach

To overcome the mutual interference of ground station transmissions to other ground station antennas in a tightly packed frequency band, we have designed a bi-static antenna configuration. In a bi-static configuration the ground-based transmit antenna is located sufficiently distant to the ground-based receiver so that its transmissions do not desensitized the receiver, even when the directional antennas may point at each other.

Antenna separation

The separation between the transmit and receive antennas needs to be sufficient to attenuate the ground-based signals to below the 1 dB compression point of the receive station's low noise amplifier (LNA). An antenna separation of 15 km provides approximately 110 dB of free space path loss at 401 MHz. After taking into account the 16 dBi gain of the transmit and receive antennas and the 50 watt transmitter power, 110 dB provides sufficient attenuation to prevent desensitizing a receiver, even when its antenna points at the transmitter.

However, the antennas need to be spaced sufficiently close that the spacecraft Acquisition of Signal (AOS) and Loss of Signal (LOS) times at both stations are similar. At 15 km separation, the AOS and LOS times of spacecraft observed at both sites typically differ by less than 1 s, depending on the spacecraft orbit.

Transmit station

Invercargill, New Zealand

Multiple spacecraft support and redundancy

To increase throughput, multiple transmitters and multiple receivers can be collocated at the transmitter and receiver sites respectively. This arrangement requires only two ground station sites to provide multiple , simultaneous half-duplex communication links. Having multiple transmit and receive antennas also provides system redundancy, which increases scheduling flexibility and provides "hot standby" in the case of an unexpected failure as well as increasing the number of supported customers and resource utilisation efficiency. Furthermore, locating all the antennas at two centralised sites allows for easier maintenance and monitoring of the antennas, further improving the system reliability and reducing maintenance overheads.

Receive signal processing

At our receive site, we use a 3-pole 10 MHz bandwidth interdigital cavity filter, which was sufficient to reduce out of band signals while minimising insertion loss to preserve receiver sensitivity. The LNA connects directly to the back of the filter. We found it helpful to use a second, sharper (with additional insertion loss) filter after the LNA to ensure out of band signals remained with the dynamic range of the SDR. After the LNA and band filtering, the signal is sampled using a software defined radio (SDR). A digital signal processing, high-order band-pass filter is then be used in the receive chain to filter out transmissions from other spacecraft and noise within the band except the desired spacecraft center frequency. A typical UHF spacecraft operating bandwidth is around 12 kHz with further 20 kHz required for doppler shift compensation.

Internet connectivity

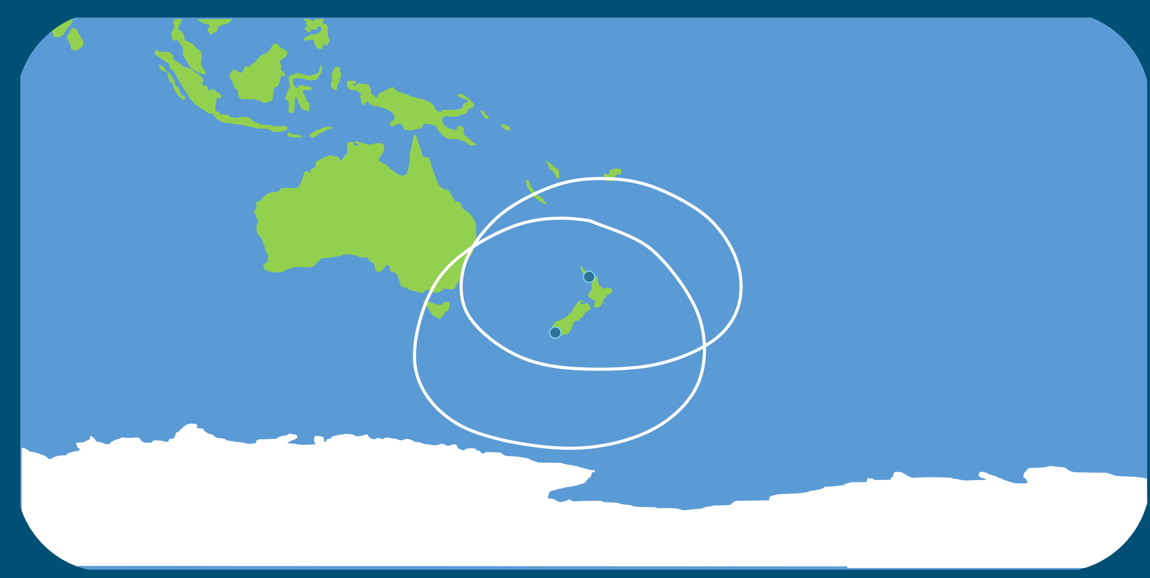
The transmit and receive stations are linked via the internet, which allows the transmitter and receiver to operate simultaneously as if they were located at the same site. The internet connectivity provides increased system flexibility, as adding new antennas, or even new ground station sites to the network only requires a reliable internet connection and appropriate networking configuration. The internet connectivity also makes it possible to implement remote on-air monitoring and control of the antennas.

Antenna location

The transmit station is not affected by background RF noise so it is located in an accessible location close to Invercargill city. However, the receive antenna requires a low noise environment, so it is located at the Awarua Satellite Ground Station, which is an excellent low-noise environment for receiving at UHF.

Omni-directional transmit antenna

SpaceOps NZ intends to install an omni-directional transmitting antenna, which will provide the capability to simultaneously transmit to multiple spacecraft from the one transmit antenna by simply linearly superimposing the transmit signals. This superimposition can be easily achieved in software. This multiple-spacecraft-per-aperture concept reduces capital expenditure required to support concurrent missions and simplified operations.



Virtual ground stations

In a bi-static configuration, two antennas are controlled from a central server. It is a simple extension of the topology to add additional bi-static antennas spaced further apart virtually increasing the field of view. SpaceOps NZ is planning a second UHF bi-static array 1250 km away (at Wakworth at the other end of New Zealand), which would provide additional LEO satellite coverage increasing the effective pass time of a polar LEO spacecraft by approximately 40%, up to about 12 minutes depending on the pass.

Receive station

Awarua Satellite Ground Station, New Zealand

Further Information

For further information please contact:
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