A Simultaneous S/X Feed-System for a LEO-Satellite-Tracking Reflector Antenna

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***Abstract*— S-band has been used for satellite Telemetry, Tracking and Control (TT&C) applications for many years and more recently X-band has also been deployed. A theoretical design for a new dual S/X-band feed-system for a ground station with S-band transmit and receive capabilities and X-band receive capabilities is presented.**

I. Introduction

An additional ground station antenna is required to communicate with an existing Low Earth Orbit (LEO) satellite system. The application requires an antenna feed-system to suit a 6.4m prime-focus antenna that can operate simultaneously in S- and X-band.

The S-band portion of the feed-system is required to uplink Telemetry Control (TC) signals to the satellites and downlink Telemetry Monitor (TM) signals from the satellite.

The X-band portion of the feed-system is required to receive data from the satellite. The feed-system is not required to transmit in X-band.

The theoretical preliminary study of the feed-system and antenna performance is reported here.

II. S/X Feed-System

The target specifications for the complete antenna are listed in Tables 1 and 2 for S-band and X-band respectively.

Table 1: Target specifications at S-band.

Receive Band (Rx)	2.200 - 2.300 GHz
Transmit Band (Tx)	2.025 – 2.120 GHz
Power Handling	50 W minimum
G/T	19 dB/K at 5º antenna elevation
Tx-band sidelobes	29-25log θ dBi; 2º < θ ≤ 35º -10 dBi; 35º < θ ≤ 140º 5 dBi; 140º < θ ≤ 180º
Polarization	Rx: LHCP or RHCP; Tx: RHCP
Axial ratio	Rx: < 1.6 dB; Tx: < 1.6 dB
VSWR	Rx: <1.5 : 1; Tx: <1.5 : 1
Transmit gain	40 dBi
EIRP	55 dBW

Table 2: Target specifications at X-band.

Receive Band (Rx)	8.0 – 8.5 GHz
G/T	28 dB/K at 5º antenna elevation
Polarization	RHCP
Axial ratio	< 1.6 dB
VSWR	<1.5 : 1

The proposed reflector geometry is a symmetrical prime-focus paraboloid with a 6.4m diameter and a focal-length of 2.56m. The f/D ratio of the reflector (where f is the focal length and D is the diameter) is therefore 0.4. A 1m-diameter central blockage is included to simulate the blockage of the feed-system. At present, however, no feed-support legs are considered in these preliminary results.

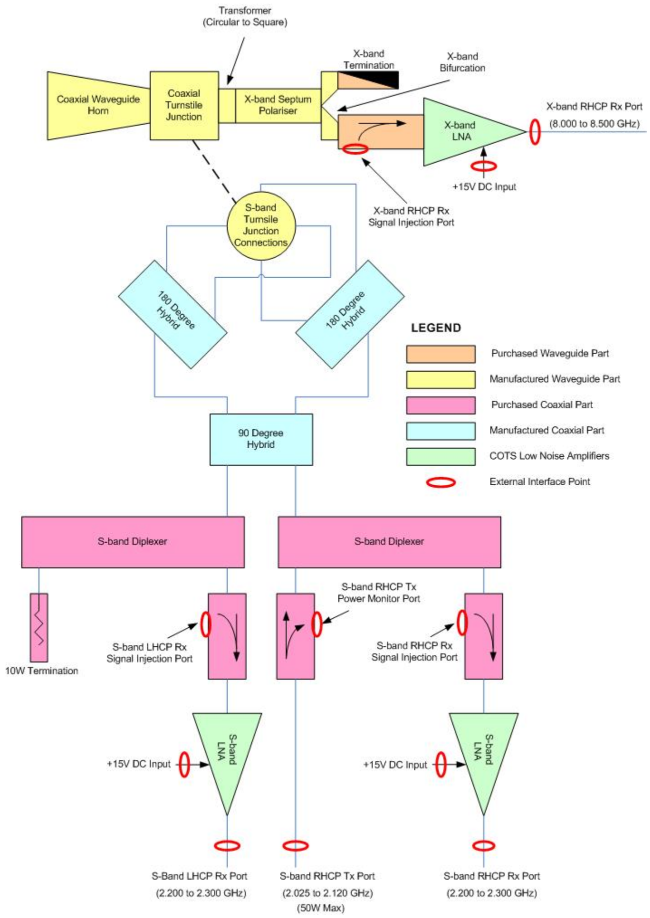
The half subtended-angle for the reflector, as seen from the focus, is $\theta_e \approx 64^o$. A simplified block diagram of the proposed S/X feed-system is shown in Fig. 1. The feed-system utilises a coaxial waveguide horn to ensure a common phase centre for both S-band and X-band. The theoretical radiation pattern (linear polarisation) of the coaxial horn is shown in Fig. 2 for 2.072 GHz, in Fig. 3 for 2.250 GHz and in Fig. 4 for 8.250 GHz while the theoretical return loss is shown in Fig. 5.

The S-band signals are carried by the coaxial waveguide section and are separated from the coaxial waveguide by a turnstile junction with four rectangular waveguide ports. WR430 waveguide-to-coaxial adapters are connected to each rectangular waveguide port of the turnstile junction which allows the remaining feed-network to be completed using coaxial components. Although this approach results in a higher insertion-loss and a slight degradation in Gain to Noise-Temperature Ratio (G/T), it has the advantage of significantly reducing the size, weight and cost of the feed-system.

In order to provide a circularly-polarized four-port feed-system, the coaxial components required are two 180-degree hybrids connected to a 90-degree hybrid as shown in Fig. 1. This network provides RHCP (right-hand circular polarization) and LHCP (left-hand circular-polarization) ports that cover the entire transmit and receive frequency ranges (2.025 to 2.30 GHz). The transmit and receive signals are separated using commercially-available diplexers. Diplexers are used in lieu of standard filters so as to provide a dump-port for signals reflected from the coaxial horn; otherwise the horn mismatch will impact on the axial ratio performance. A Low Noise Amplifier (LNA) is connected to both the RHCP and LHCP receive ports to allow simultaneous reception of both signals.

The S-band transmit function works in reverse to that described above. As only a RHCP transmit port is required, the LHCP port is terminated with a coaxial load.

The X-band signals are carried by the circular waveguide section (the centre section of the coaxial structure) (Fig. 1), and pass through a circular-to-square waveguide transformer. The signal then passes through a septum polarizer which has two rectangular waveguide ports, one providing the X-band LHCP and the other RHCP. As only RHCP is required for the feed-system, the LHCP port is terminated with a waveguide load. The septum polarizer was chosen for this application because it is very compact, an advantage for feed-systems used in prime-focus applications.



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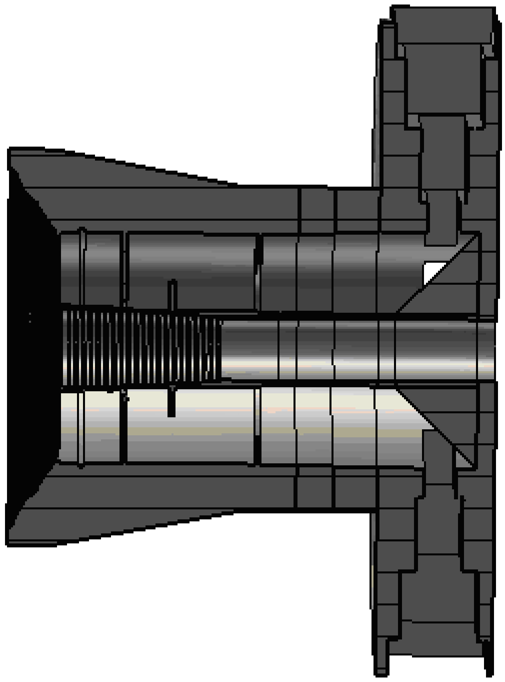

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Fig. 1: a) Simplified block-diagram of the feed-system; b) cross-section of the horn and turnstile junction

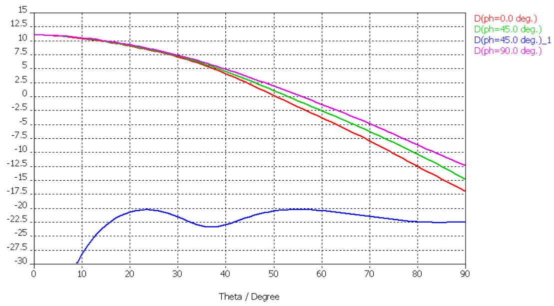


Fig. 2: Radiation pattern (linear polarization) of the feed system at 2.072 GHz.

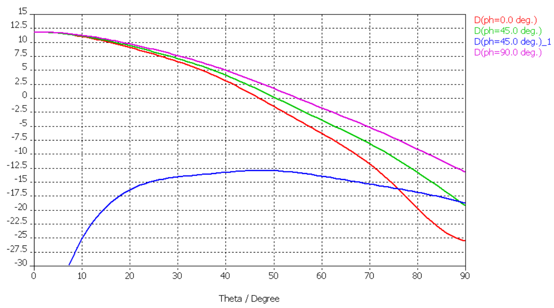


Fig. 3: Radiation pattern (linear polarization) of the feed system at 2.250 GHz.

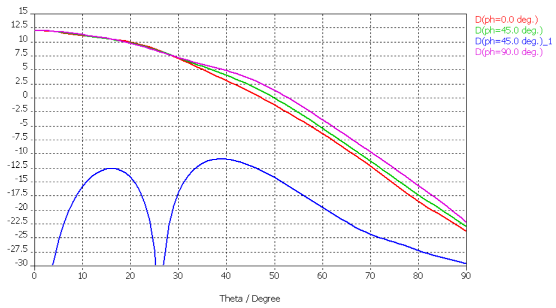
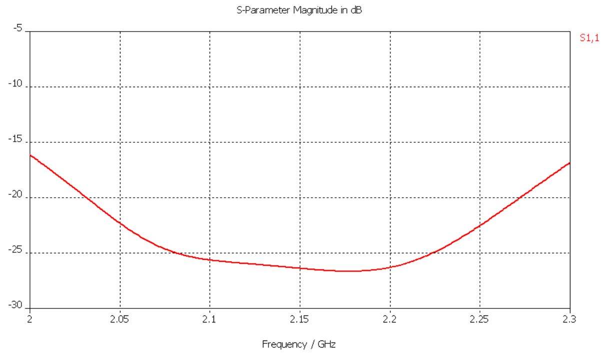


Fig. 4: Radiation pattern (linear polarization) of the feed system at 8.250 GHz.



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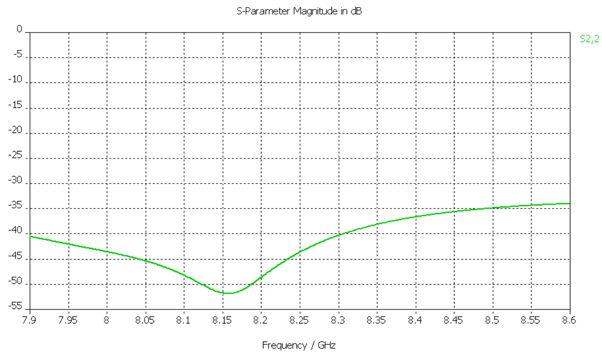

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Fig. 5: a) Theoretical return loss of the horn and turnstile junction at S-band and theoretical return loss of the horn at X-band.

Preliminary results for the 6.4m diameter antenna show that the expected gains (excluding feed chain losses) are:

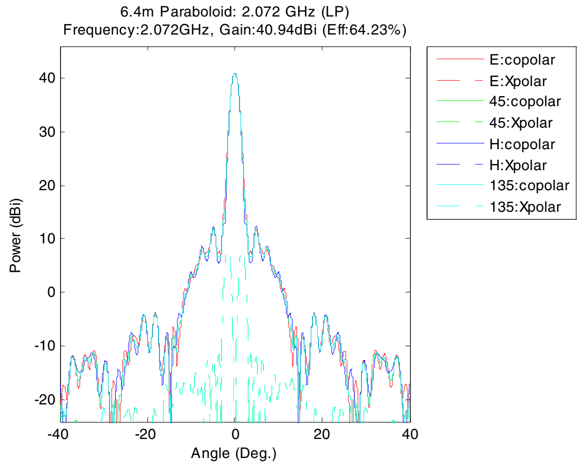
- S-band Tx: Mid-band (2.072 GHz): Gain ≈ 40.9 dBi (Aperture efficiency ≈ 64%)
- S-band Rx: Mid-band (2.250 GHz): Gain ≈ 41.2 dBi (Aperture efficiency ≈ 57%)
- X-band Rx: Mid-band (8.250 GHz): Gain ≈ 51.9 dBi (Aperture efficiency ≈ 50%)

The theoretical radiation pattern of the 6.4m-diameter antenna is shown in Fig. 6.

Preliminary results on the antenna temperature calculation show that an antenna temperature (not system temperature) of about 56 K is expected for a 5 degree antenna-elevation at mid-band (2.25 GHz) of the S-band Rx and about 73 K at mid-band (8.25 GHz) of the X-band Rx.

Once all the losses are included, a G/T of approximately 19.2 dB/K is predicted at 2.25 GHz for a 5º antenna elevation while a G/T of 30.3 dB/K is predicted at 8.25 GHz.

The S-band transmit band losses including the diplexer and coaxial network were estimated to be 0.80 dB, giving a predicted mid-band gain of 40 dBi.



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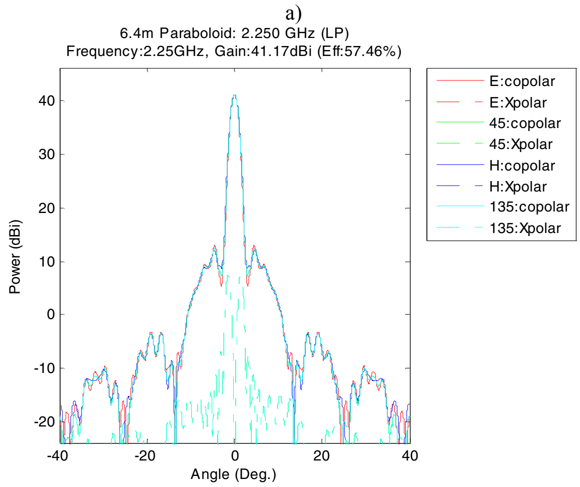

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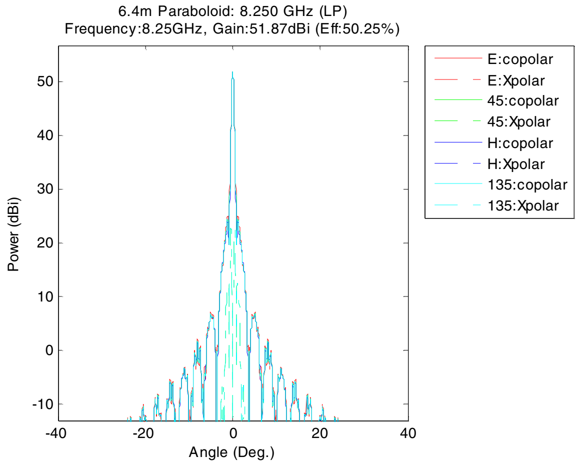

c)

Fig. 6: Theoretical radiation pattern: a) 2.072 GHz, b) 2.25 GHz and c) 8.25 GHz.

III. CONCLUSIONS

A compact low cost simultaneous S/X-band feed design has been designed for a prime focus 6.4m reflector system. The feed design is capable of transmitting and receiving in TT&C S-bad frequencies and receiving at X-band. The overall antenna performance is highly efficient with a G/T of 19.2 dB/K and 30.3 dB/K at 5 degrees elevation for S- and X-bands respectively.