The Wideband Ionospheric Sounder Cubesat Experiment (WISCER)

M.J. Angling[1], G. Kirkby[1], P. Harkness[2], M. McRobb[2], M. Vasile[3], and T. Sinn[3]

[1] Poynting Institute, University of Birmingham
Edgbaston, Birmingham, B15 2TT, UK.

[2] School of Engineering, University of Glasgow
University Avenue, Glasgow, G12 8QQ, UK.
e-mail: patrick.harkness@glasgow.ac.uk

[3] Advanced Space Concepts Laboratory, University of Strathclyde
Glasgow, UK.
e-mail: massimiliano.vasile@strath.ac.uk

Abstract

This paper describes a preliminary design study to assess the possibility of flying a wideband ionospheric sounder cubesat experiment (WISCER). WISCER comprises a wideband (~100 MHz) beacon on a low cost cubesat designed to measure and evaluate the ionospheric channel in anticipation of the development of operational, space-based, low frequency (i.e. around 450MHz) synthetic aperture radar (SAR) systems.

1. Introduction

There are considerable design challenges to be overcome in order to develop space based foliage penetrating (FOPEN) synthetic aperture radar (SAR) systems. One area of uncertainty is the impact of the ionosphere on the wideband radar signal, since the ionosphere is often the dominant degrading factor in these sorts of systems. The ionosphere affects, to some extent, all trans-ionospheric radio frequency (RF) communications, surveillance [1] and navigation systems [2] operating at frequencies below approximately 2 GHz. The most problematic effects are those caused by small scale structure in the ionosphere (especially the post sunset equatorial ionosphere) that can cause amplitude and phase scintillation on trans-ionospheric signals [3]. The impact of the ionospheric structures is frequency dependent, so that the greatest effects are observed at the lower frequencies. For low frequency SAR systems, the ionosphere controls the orbit choice, the selection of the transmitted waveforms and integration times, together with signal and image post-processing.

Previous studies have used both ground and space based systems to probe the ionospheric channel. Space systems have generally been limited to narrowband measurements [4]. Ground based approaches have used radar returns from calibration spheres [5], but have been limited to quite modest bandwidths (~18 MHz) at UHF and require large antennas (10s of metres) and powers (megawatts).

This paper describes some elements of an initial design study on a wideband ionospheric sounder cubesat experiment (WISCER). WISCER comprises a wideband (~100 MHz) beacon on a low cost cubesat designed to measure and evaluate the ionospheric channel in anticipation of the development of operational low frequency (i.e. around 450MHz) SAR systems.

2. Payload

The WISCER payload comprises a waveform generator, a linear power amplifier and a wideband antenna. These sub-systems are described in the following sections.

2.1 Waveform generator

For WISCER, it is proposed to use a 100% duty cycle, 131071 chip m-sequence [6]. In practice, the transmitted waveform will be constructed from a pseudo-random concatenation of two different m-sequences. This allows the overall repetition interval to be extended, reducing the spacing of the spectral lines in the waveform's spectrum.

The waveform has been simulated in Matlab to assess its properties. Figure 1 shows the waveform's impulse response as a function of delay and Doppler shift. It can be seen that the waveform provides a peak-to-sidelobe ratio in

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excess of 50 dB around 0 Hz Doppler shift. This degrades with increasing Doppler shift (in this test up to ±300 Hz), but the sidelobes remain below -40 dB.

The impact of the orbital Doppler shift and ionospheric dispersion have also been assessed. Doppler correction will be required to account for the satellite velocity, but sub-pulse correction (i.e. correction for the rate of change of Doppler during a single pulse compression sequence) will not be required. Due to the low frequency of operation and the high bandwidth, the dispersion due to the bulk ionosphere will require correction (i.e. via an equalisation technique).

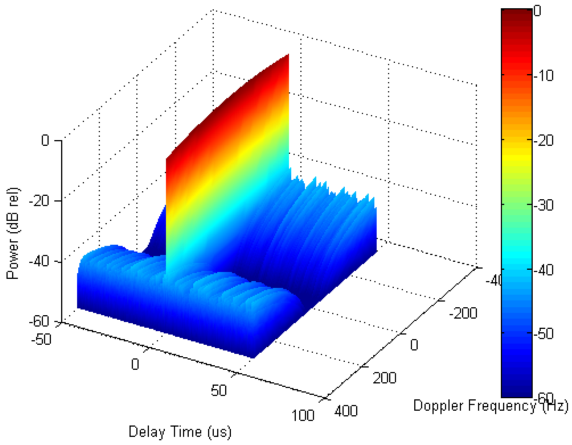

Figure 1. Impulse response as a function of Doppler shift.

2.2 Antenna

A range of candidate WISCER antennas have been modelled. These are: short helix; planar log-periodic; conical helix; wide-band, crossed (Moxon) dipole; planar log-spiral; and the Vivaldi. The wideband crossed dipole (Figure 2) and an inflatable conical helix (Figure 3) have been identified as potential candidates for WISCER. Thus the candidate antennas exploit different electrical and mechanical designs and therefore provide some mitigation of development risks. Additional, more detailed, modelling will be required before one of these antenna can be selected for prototyping.

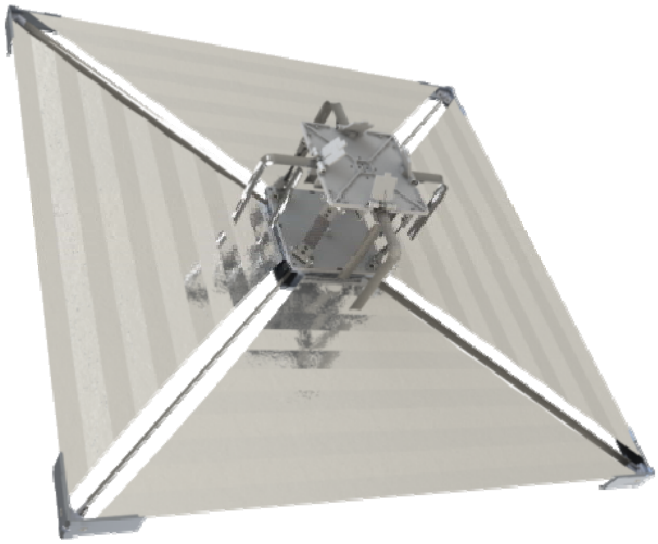

Figure 2. Final assembly of the cross-moxon antenna system comprising integrated groundplane and crossed dipole elements in deployed configuration.

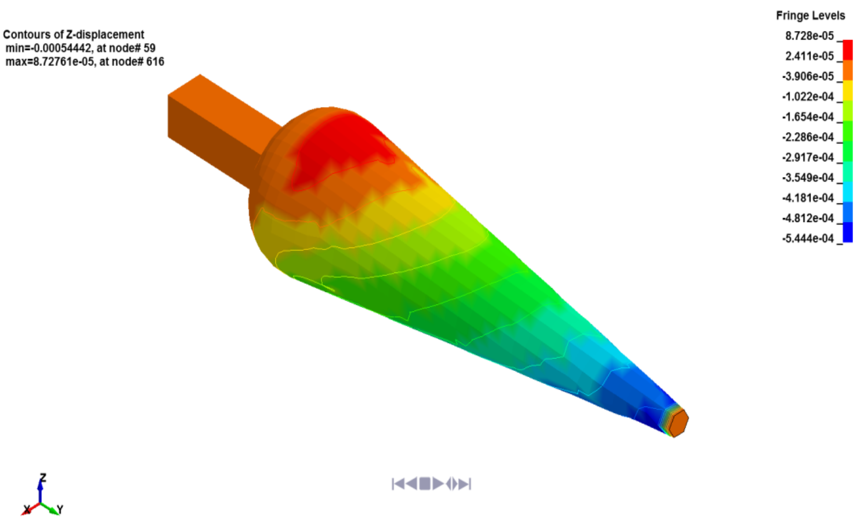

Figure 3. Simulation of deformation of inflatable conical antenna.

2.3 Link budget

A preliminary link budget has been developed (Table 1). Note that the signal to noise ratio is negative as this is quoted before pulse compression. The waveform will provide up to 51 dB of processing gain.

Table 1. System parameters and summary link budget.

System Parameters	
Satellite Altitude (km)	850
Earth Radius (km)	6380
Operating Frequency (MHz)	500
Channel Bandwidth (MHz)	100
Tx Power (W)	0.5
Tx Antenna Gain (dBi)	5
Tx Feed Losses(dB)	1.5
Rx Noise Temperature (K)	290
Rx Antenna Gain (dBi)	10
Rx Feed Losses (dB)	1

Link budget		
Elevation (degrees)	Satellite Range (km)	Signal to noise ratio (dB)
90	850	-4.5
69	913	-5.2
51	1079	-6.6
38	1310	-8.3
28	1577	-9.9
21	1864	-11.4

3. Satellite Platform

An initial assessment of the satellite subsystems has been undertaken and is described in [7]. The results (i.e. initial mass, volume, power budgets) are consistent with the 3U cubesat platform developed by Clyde Space for UKube1 [8, 9].

The requirement for a class A (i.e. linear) amplifier for WISCER means that a considerable amount of electrical power will be required to operate the sounder. Basic energy modelling has been undertaken based on the preliminary WISCER power budget. It is assumed that the sounder will be switched on for three consecutive orbits twice a day (to service two receiver sites). This is the worst case scenario in terms of power consumption and will not generally be required. The telemetry system will be used once per day. The modelling shows that steady state operation can be achieved with an input power from the solar cells of 10 W over 60% of the orbit. Furthermore, if a 30 WHr battery is used, the depth of discharge does not exceed 20%.

Some level of thermal control will be required during the operation of the sounder. A large amount of waste heat will be generated and it is likely that it will not be possible to remove this quickly enough from the satellite to achieve thermal equilibrium. Consequently some form of thermal storage will be required.

4. Conclusions

One area of uncertainty in the development of space based foliage penetrating (FOPEN) synthetic aperture radar (SAR) systems is the impact of the ionosphere on the wideband radar signal. A preliminary design study to assess the possibility of flying a wideband ionospheric sounder cubesat experiment (WISCER) has been undertaken. WISCER comprises a wideband (~100 MHz) beacon operating at a centre frequency of ~475 MHz. It is a challenge to fly such a payload on a cubesat, but the study has shown that it is feasible.

5. Acknowledgements

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