Space Frequency Coordination Group

Report SFCG 33-2

TYPICAL TECHNICAL AND OPERATING CHARACTERISTICS FOR SPACEBORNE RADAR SOUNDER SYSTEMS USING THE 40-50 MHZ BAND

Abstract

The purpose of draft report is to present frequency band selection rationale and the typical technical and operating characteristics of a spaceborne radar sounder for operation in the 40-50 MHz band.

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1 Introduction

There is an interest in remote sensing in the vicinity of 40-50 MHz for remote measurements of the Earth's subsurface providing radar maps of subsurface scattering layers with the intent to locate water/ice/deposits using active spaceborne sensors. This document provides the preferred frequency band selection rationale, and typical technical and operating characteristics.

The technical and operating characteristics of an active sensor at 40-50 MHz are described and the sharing situation with other services allocated in this frequency range is examined. The 40-50 MHz band is currently allocated to the fixed, mobile and broadcasting services. The uses of the 40.98-41.015 MHz frequency band by space research service are on secondary basis.

2 Frequency band selection rationale

The reason for an allocation between 40 MHz and 50 MHz for a spaceborne sounding radar is based upon the following selection criteria: surface penetration, length scale of observation, region of electromagnetic scattering model, and previous work.

2.1 Surface penetration

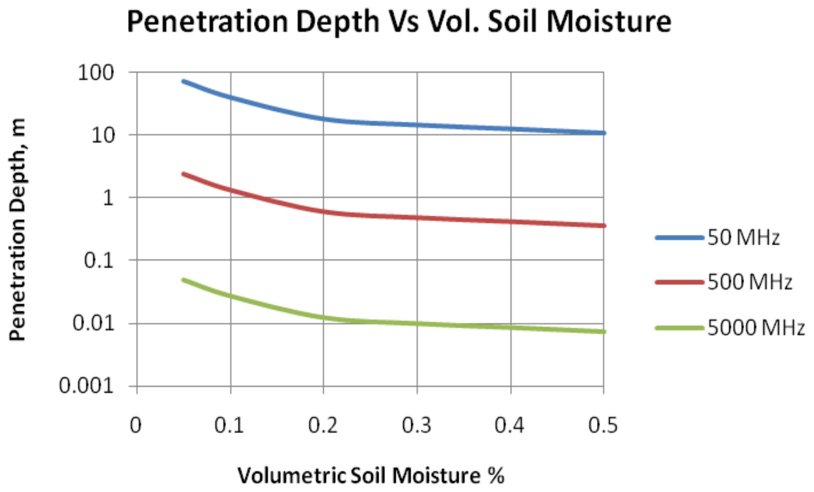
Penetration of an incident radar wave is normally many tens of wavelengths. Under the proper conditions of wavelength and composition of the scattering medium, radio waves can readily penetrate the dielectric materials comprising the Earth's surface and cover. A quantitative estimate of this depth δ_p is as follows:

$$\delta_p = \frac{\lambda_0 \sqrt{e'}}{2\pi e''} \tag{1}$$

where λ_o is the wavelength, and e' and e'' are the real and imaginary parts of the surface dielectric constant. Using this expression with the soil dielectric constants, Fig. 1 shows the surface penetration depths for 50 MHz, 500 MHz, and 5 000 MHz. From the figure, it is evident that surface penetration at 50 MHz is deeper than for 500 MHz by a factor of 20 to 30, and is thus most favourable for Earth penetration studies. The objectives would be to provide radar maps of subsurface scattering layers with the intent to locate water/ice/deposits using active spaceborne sensors.

FIGURE 1

Surface penetration depth



2.2 Length scale of observations

The addition of 50 MHz to the exiting 435 MHz and 1 250 MHz bands would extend the range of length scales at which the roughness of the surface is observed. For many geologic surfaces, backscatter is dominated by that harmonic component of the surface whose wavelength is near the projected radar wavelength and longer, whereas, other components of the surface contribute only through second order effects. Thus, radar measurements at as many frequencies as possible over as wide a range of incidence angles as possible increase the ability to accurately describe the surface.

2.3 Region of electromagnetic scattering model

The addition of 50 MHz to the existing 435 MHz and 1 250 MHz bands would expand the region of validity of electromagnetic scattering models. The 50 MHz radar would be more sensitive to subsurface morphology because the rms height of the surface is a smaller fraction of the wavelength, resulting in a lower measured radar backscatter. The greater sensitivity of 50 MHz to subsurface morphology combined with the fact that the 50 MHz signals penetrate deeper into the soil, increases the subsurface volume in which scattering occurs, resulting in a much greater ratio of power received from the subsurface relative to that received from the surface than that a shorter wavelengths. Also, scatterers embedded in the alluvial cover will be smaller relative to 50 MHz than either 435 MHz or 1 250 MHz.

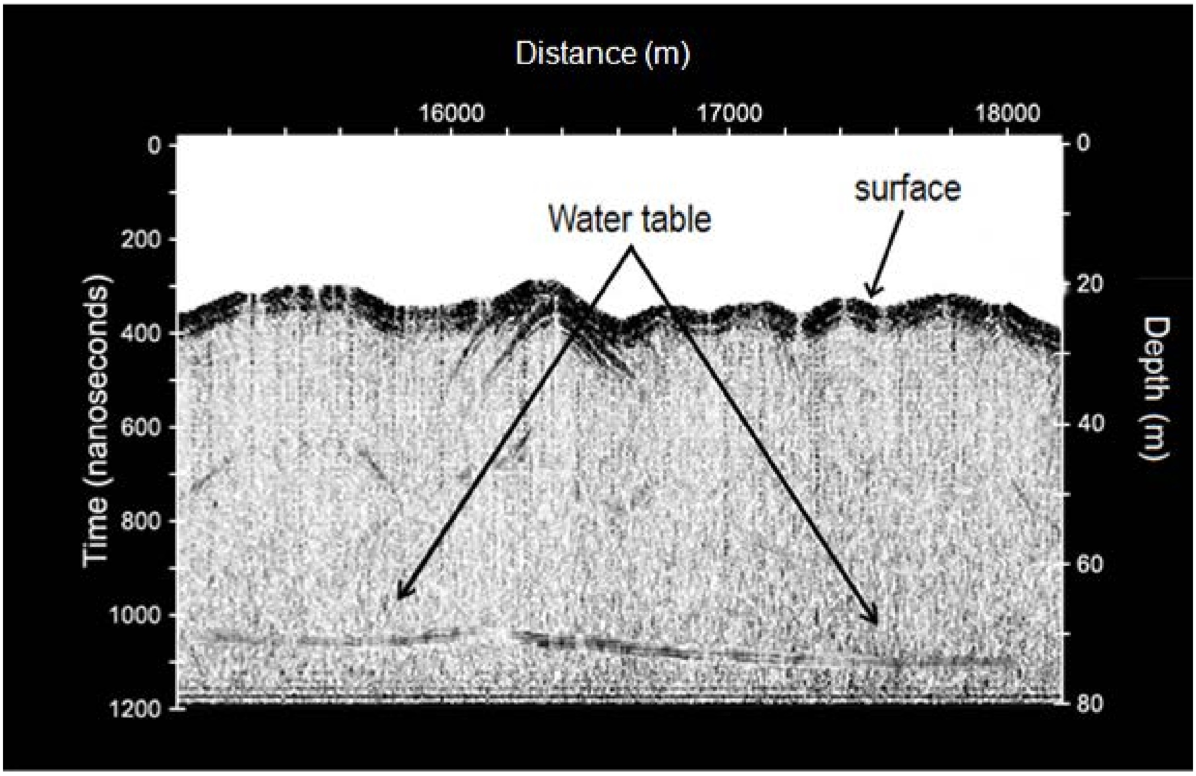
2.4 Previous work and regulatory status between 40-44 MHz band

A considerable amount of work in the form of ground-based and airborne radar systems development and data collection has already been done at 3-50 MHz. Along with this hardware development has been computational work aimed at studying the surface penetration depth versus soil moisture content at 3-50 MHz and analysis of measuring ocean returns by oceanographic radars.

Airborne radars have made measurements around 50 MHz in the desertic areas in the Arabian peninsula and Antarctica. Figure 2 shows a radargram with variations in the depth of the water table from 49 to 52 meters with data taken from an airborne VHF radar in Kuwait in 2011.

FIGURE 2

Radargram taken from airborne VHF radar in Kuwait in 2011



The frequency band 3-50 MHz was considered for the oceanographic radars along the coast (in the radiolocation service (RLS)) under WRC-07 Agenda item 1.15 and the sharing studies were documented in Report ITU-R M.2234. WRC-12 agreed to allocate RLS through a combination of secondary and primary allocations on a regional and country basis with footnotes in sub-bands between 4-44 MHz (43.35-44 MHz was the highest frequency range allocating radiolocation service with a country footnote (two countries)) with footnotes to protect the incumbent fixed and mobile services. Applications in the RLS are limited to oceanographic radars operating in accordance with Resolution 612 (Rev.WRC-12). Resolution 612 (Rev.WRC-12) also contains additional limitations to the oceanographic radars such as maximum EIRP of 25 dBW and a station identification (call sign) on the assigned frequency. In the radio regulations, there is no allocation to EESS (active) in the 3-50 MHz range. If the frequency were chosen for the spaceborne system at higher or lower frequency bands, the hardware and computational work reference would need to be repeated for the airborne radar campaigns in the desertic areas.

3 Technical characteristics of a 40-50 MHz spaceborne sounding radar

The spaceborne sounding radar will operate at 40-50 MHz and the resulting radar data will be used in the study of the Earth's subsurface with radar mapping of subsurface scattering layers with the intent to locate water/ice/deposits. The characteristics of the 40-50 MHz spaceborne sounding radar are shown in Table 1.

3.1 Mission objectives

The spaceborne active sensor will produce data with a vertical resolution of 5-7 m, and will have a surface SNR of 66 dB. It is expected to be a 9-16 month orbital mapping campaign. The mission scientific objectives are 1) to understand the global thickness, inner structure, and the thermal stability of the Earth's ice sheets of Greenland and Antarctica as an observable parameter of earth climate evolution, and 2) to understand the occurrence, distribution and dynamics of the earth fossil aquifers in desertic environments such as northern Africa and the Arabian peninsula as key elements in understanding recent paleoclimatic changes.

3.2 Orbital parameters

The spaceborne active sensor is carried on a low-Earth orbiting satellite at an altitude of 400 km, an inclination optimized for a sun synchronous orbit and an eccentricity less than 0.001.

3.3 Design parameters

The postulated system for the Earth orbiting sounding radar is an earth enhanced duplicate of the Shallow Radar Sounder (SHARAD) which was a Mars orbiting sounding radar in the SRS (active). The spaceborne sounding radar transmits an FM modulated pulse centred at 45 MHz with 10 MHz bandwidth at a pulse repetition frequency of 1200 Hz. Each pulse has a duration of 85 µsec. The peak RF power is 100 W, and the transmitted signal is circularly polarized. These design parameters are shown in Table 1.

TABLE 1

50 MHz spaceborne sounding radar characteristics

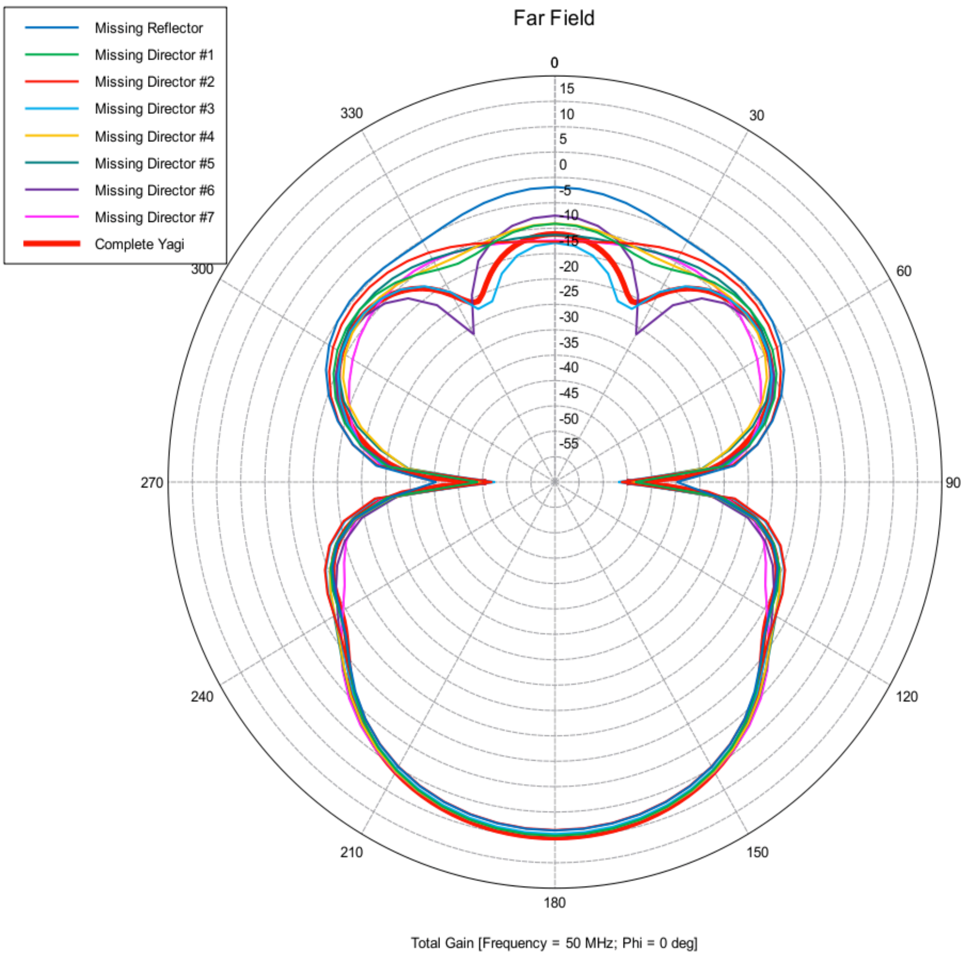
Parameter	Value
Orbital altitude	400 km
Orbital inclination	97º
RF centre frequency	45 MHz
Peak RF output power	100 Watts
Polarization	Circular (LHC on transmit, RHC on receive)
Pulse modulation	Linear FM chirp
Pulse bandwidth (-20 dB)	6-10 MHz
Pulse width	85 µsec
Pulse repetition rate	1220 Hz
Parameter	**Value**
Compression ratio	510-850
Antenna type	Cross Yagi (9 elements)
Antenna peak gain	10 dBi
Antenna orientation	nadir
Antenna beamwidth	40 deg (El), 40 deg (Az)

3.4 Antenna gain pattern

The spaceborne sounding radar antenna is a 9 element cross Yagi antenna, with antenna gain of 10 dBi, and beamwidth of 40° in range and azimuth as shown in Figure 3.

FIGURE 3

9-Element Yagi antenna pattern



3.5 Operational limitations

The sounding radar is to be operated only in either uninhabited or sparsely populated areas of the ice sheets of Greenland and Antarctica and deserts of northern Africa and the Arabian peninsula. The radar is to be operated at night-time only from 3 a.m. to 6 a.m. locally when the ionospheric perturbations to the radar signal is at a minimum and man-made RFI is expected to be lightest.

4 PFD and spectral PFD levels at Earth's surface

For the parameters of the sounding radar in Table 1, the power flux-density (pfd) level is calculated to be −93.3 dB (W/m^2) at 45 MHz, corresponding to spectral pfd levels of −163.3 dB (W/m^2-Hz) at 45 MHz assuming 10 MHz bandwidth.

5 Conclusions

There is an interest in remote sensing in the vicinity of 40-50 MHz for remote measurements of the Earth's subsurface providing radar maps of subsurface scattering layers with the intent to locate water/ice/deposits using active spaceborne sensors. This document provides the preferred frequency band selection rationale, and typical technical and operating characteristics for a possible instrument.

Characteristics of a spaceborne radar sounder that would operate in the frequency range 40-50 MHz have been developed.