SFCG-25
12-20 October, 2005
Beijing, China

NASA

PREFERRED FREQUENCY RANGE, TECHNICAL CHARACTERISTICS, AND INTERFERENCE ASSESSMENT FOR A MICROWAVE OBSERVATORY OF SUBSURFACE AND SUBCANOPY (MOSS) FOR 1 MHZ BANDWIDTH IN THE FREQUENCY RANGE OF 100-150 MHZ

(SFCG-23 AGENDA ITEM 9.4 "Active Sensors")

Abstract

This document presents rationale for the frequency band selection, technical and operational characteristics of active spaceborne sensors in the Earth Exploration-Satellite Service (active), and interference assessment for a 1 MHz bandwidth sensor in the 100-150 MHz frequency range. The active spaceborne sensors expected to be operating in the frequency range of 100-150 MHZ is the synthetic aperture radar (SAR) such as the MOSS. The technical characteristics, mission objectives, orbital parameters, design parameters, antenna characteristics, and preliminary interference assessment are given for MOSS.

The purpose of the document is to provide rationale for the frequency band selection, technical characteristics of the active spaceborne sensor Microwave Observatory of Subsurface and Subcanopy (MOSS) that can be used to analyze the compatibility of active spaceborne sensors and other systems of 1 MHz bandwidth in the 100-150 MHZ frequency band. A preliminary interference assessment is also provided.

Introduction

SFCG-23 Agenda Item 9.3 includes, as a topic for consideration by the SWGs, under active sensors, the possible use of 137-138 MHz band or alternative band for soil penetration below vegetative canopy.

There is no WRC-07 Agenda Item which addresses the allocation for the EESS (active) in the frequency range 100-150 MHz.

However, this document calls for consideration of provision of up to 1 MHz of frequency spectrum to the Earth exploration-satellite (active) service in the frequency range 100-150 MHz.

Technical characteristics are provided herein of the active spaceborne sensor MOSS that can be used to analyze the compatibility of active spaceborne sensors and other systems in the 100-150 MHZ frequency range.

Other services which are allocated in the frequency range 100-150 MHz include Broadcasting, Aeronautical Radionvigation, Aeronautical Mobile, Space Operation (space-to-Earth), Meteorological-Satellite (space-to-Earth), Mobile-Satellite (space-to-Earth), Space Research (space-to-Earth), Fixed, Mobile except aeronautical mobile (R), and Amateur. Studies will have to be conducted to confirm that sharing is feasible with the existing allocated services.

Technical Characteristics of MOSS

Microwave Observatory of Subsurface and Subcanopy (MOSS) synthetic aperture radar (SAR) was once a proposed NASA mission for the NASA instrument incubator program. This mission address the current NASA science priority of measuring soil moisture "under a substantial vegetation canopy and reaching a useful depth within the uppermost soil layer" under the Global Water and Energy Cycle science topic.

The proposed system is a synthetic aperture radar (SAR) with 1 MHz bandwidth operating at the two low frequencies bands of the VHF frequency range 100-150 MHz and the UHF, P-band 432-433 MHz and to enable the vegetation and deep soil penetration.

Mission Objectives of MOSS

The primary objective of MOSS is to develop a system that delivers science data and products to directly address the current NASA science priority of measuring soil moisture "under a substantial vegetation canopy and reaching a useful depth within the uppermost soil layer" under the Global Water and Energy Cycle science topic.

One key revolutionary SAR technology to develop and validate is the spaceborne light-weight 30-m mesh reflector antenna, fed by a dual-frequency single-structure feed array. This technology enables the antenna subsystem weight to be significantly reduced to 285 kg for the 30m diameter antenna or antenna density of 0.4 kg/m^2, compared to the state-of-the art antenna density of 25 kg/ m^2.

Orbital Parameters of MOSS

MOSS will orbit the Earth at an altitude of 1313 km, an inclination of 101 degrees, and a sun synchronous 6am-6pm orbit with a repeat period of 7 days. This establishes a requirement of coverage of 430 km, and allows global coverage every 7 days.

Design Parameters of MOSS

MOSS transmits linear FM pulses with 1 MHz bandwidth in the frequency range 100-150 MHz. Depending upon the mode, the signal is right and left circularly polarized at both transmission and reception, the pulsewidth is 100 microsec, and PRF of 320 Hz. The relatively short LFM pulse allows the 1000 W peak power radar to have a low average power of only 32 Watts (dual channel). The 1 MHz bandwidth will enable a low resolution of 1 km, a large number of looks (45 looks), a wide swath of 430 km, global access, and frequent revisit times (7 day exact repeat). The significant parameters for the SAR for the 100-150 MHz frequency range are given in Table 1.

Antenna Gain of MOSS

MOSS uses a spaceborne light-weight 30-m mesh reflector antenna, center-fed by a dual-frequency single-structure feed array. The feed is a dual-frequency linear array patch antenna with dimensions 4.7m x 1.2m for both frequencies. This technology enables the antenna subsystem weight to be significantly reduced to 285 kg for the 30m diameter antenna or antenna density of 0.4 kg/m^2, compared to the state-of-the-art antenna density of 25 kg/ m^2. The antenna coverage in elevation is 430km at 21 deg look angle, eliminating the need for antenna movement. The antenna beamwidth is for VHF about 9.8 deg in elevation and 6.0 deg in azimuth, with an overall gain of 27.0 dBi. Figure 1 shows the schematic of the antenna and feed system .

TABLE 1

MOSS Synthetic Aperture Radar Characteristics

RF Frequency Range	100-150 MHz
Altitude	1313 km
Peak Radiated RF power	1000 Watts
Pulse Modulation	Linear FM chirp
Pulse Bandwidth	1 MHz
Pulse Duration	100 μsec
Pulse Repetition Rate	320 pps
Compression Ratio	100
Antenna Type	Mesh reflector 30m x 11m
Antenna Gain	27.0 dBi
Antenna Orientation	17 to 36 deg incidence angle
Antenna Beamwidth	9.8 deg (El), 6.0 deg (Az)
Antenna Polarization	RCP, LCP
System Noise Temperature	400 deg K
Noise Equivalent σ_0	-44 dB

Preliminary Interference Assessment in the 100-150 MHz Frequency Range

The preliminary band-by-band interference analysis has been performed for the MOSS interference into other systems in that band. Since the MOSS spacecraft is orbiting Earth, the spacecraft is in line-of-sight to locations on the Earth for part of the time in orbit and for variable durations. The simulations used either 7-day periods, which is the orbital track repeat time for MOSS, or three month periods.

100-108 MHz Band

The 100-108 MHz frequency range is allocated to the Broadcasting service and is used primarily for FM radio and associated auxiliary services. While MOSS is unlikely to cause interference to many FM receivers, in particular those receivers near the broadcast towers, this band is probably not appropriate for MOSS operations since this service is so wide spread and global.

108-117.975 MHz Band

The 108-117.975 MHz band is allocated to the Aeronautical Radionavigation service worldwide and is used by aeronautical navigation aids and related systems, including the VHF Omnidirection Range (VOR) and Instrument Landing System (ILS). The VOR and ILS systems are used for landing operations close to airports. Due to the criticality of the aeronautical navigation systems, the MOSS system must not cause harmful interference and it is recommended to not use this band.

117.975 -137 MHz Band

The 117.975-137 MHz band is allocated to the Aeronautical Mobile service (R) and is used worldwide by aeronautical communication systems including air traffic control voice and data systems for both terminal and enroute operations and data services such as the Automated Weather Observation Systems (AWOS) and the Automatic Terminal Information Systems (ATIS). Due to the criticality of the aeronautical communications systems, the MOSS system must not cause harmful interference.

The principal use is for air-to-ground voice systems using sideband amplitude modulation radios, while future systems will employ digital modulation schemes. The aviation community has defined the minimum system noise temperature in which radios must operate as 6000K. The ground stations typically use a dipole antenna on towers with a gain of 2.2 dBi. Airplanes typically use two antennas, one mounted above the fuselage and one below, with a gain of –4 dBi. The interference analysis for several nonsensitive radios shows that the I/N is +6.2 dB to +39.3 dB into the downlink into ground stations and 0 dB to +33.1 dB into the uplink into airplane radios. Future digital systems may be even more sensitive.

Due to the criticality of the air-to-ground communications for aeronautical systems, the MOSS system must not cause harmful interference, and it is recommended that MOSS not use this band.

137-138 MHz Band

The 137-138 MHz band is allocated to the Space Operation (space-to-Earth), Meteorological-Satellite (space-to-Earth) , Mobile-Satellite (space-to-Earth), and Space Research (space-to-Earth) services. The systems operating in this band primarily transmit space-to-earth downlinks that are received by a limited number of locations.

Typically, this band is used for data downlinks from orbiting satellites including video and telemetry data from NOAA Polar-orbiting Operational Environmental Satellites (POES) and Defense Meteorological Satellite Program (DMSP) satellites. In addition, this band is available for little Low Earth Orbiting satellites (LEOs) for transmitting data from the satellites to Earth.

The weather satellites and the "little LEO" spacecraft transmit only in the space-to-Earth direction. These satellites typically orbit the Earth at altitudes primarily in the 800-900 km range compared to the 1313 km orbit of MOSS. In addition, several of the sun synchronous weather satellites orbit in a day/night position, significantly removed from the likely dawn/dusk orientation of the MOSS spacecraft, and reducing the potential interference from MOSS.

An example LEO in the 137-138 MHz band would be the NOAA POES satellites transmitting toward the Earth with both a 1 W beacon using an omni antenna and a 5 W link using a helical antenna. Assuming that the NOAA POES satellite is located perpendicular to the MOSS trajectory, an interference analysis of the LEO into the MOSS shows that the MOSS noise floor is exceeded when the NOAA POES satellite is within about 20 deg of boresight (mainlobe and part of first sidelobe). Orbital simulation over a 3 month period did not reveal any events where one of the three NOAA satellites with an operational 137 MHz transmission (NOAA-14, -15, -17) was within 20 deg of the MOSS boresight. Consequently, MOSS should be able to operate in the 137-138 MHz band without harmful interference.

The 137-138 MHz band is allocated to several space services including the Meteorological-Satellite, Space Research, and Space Operation services and in several portions of this band to the Mobile-Satellite service. The interference criteria of these Earth stations is assumed to be that the interfering signal power in the reference bandwidth to be exceeded no more than 20% of the time at levels of -158.3 dBW /8.32 kHz during reception at elevation angles greater than 5 deg, and to be exceeded no more than 0.1 % of the time at levels of -151.1 dBW /8.32 kHz during reception at elevation angles greater than 5 deg. These interference criteria were established based on command and data acquisition links and direct broadcast low resolution imagery data provided by the Automatic Picture Transmission (APT) service and the Argos data collection service transmitted from the POES spacecraft. Because these services are low bandwidth amplitude modulated signals or low data transmissions, the average power of the MOSS is appropriate for assessing the potential interference. Experiments may be required to confirm the performance of an earth station receiver in the presence of short duration FM chirp pulses.

Using the average power assumption, simulations show that the short term interference criteria is only exceeded when the receive earth station is in the mainlobe of the MOSS antenna beam. Orbital simulations indicate that for an elevation mask of 5 deg, the MOSS is visible from any location on Earth less than 20% of the time, satisfying the long-term criteria. For the short term criteria, orbital simulation over a 3 month period indicates that only high-latitude stations near 85 deg may possibly experience interference exceeding the criteria when one of the three NOAA satellites with an active 137 MHz broadcast from NOAA-14, -15, -17 is visible.

In summary, for the 137-138 MHz band, MOSS emissions are unlikely to cause harmful interference to earth stations operating in the space research and meteorological-satellite services. Experiments may be required to confirm the performance of an earth station receiver in the presence of low-power sidelobe short duration FM chirp pulses.

138-144 MHz Band

The 138-144 MHz band is allocated to several services including the aeronautical mobile (OR), fixed, mobile, and radiolocation on a primary basis and the space research service on a secondary basis. Systems operating in this band include military air traffic control, security and alarms, depot, fire and medical, naval data links and buoy monitoring. In addition, the Coast Guard uses this band for search and rescue operations while NASA and other agencies use this band for land mobile operations.

For the aeronautical mobile (R) service, this band is used worldwide by aeronautical communication systems including air traffic control voice and data systems for both terminal and enroute operations and data services such as the Automated Weather Observation Systems (AWOS) and the Automatic Terminal Information Systems (ATIS). Due to the criticality of the aeronautical communications systems, the MOSS system must not cause harmful interference. The principal use is for air-to-ground voice systems using sideband amplitude modulation radios, while future systems will employ digital modulation schemes. The aviation community has defined the minimum system noise temperature in which radios must operate as 6000K. The ground stations typically use a dipole antenna on towers with a gain of 2.2 dBi. Airplanes typically use two antennas, one mounted above the fuselage and one below, with a gain of –4 dBi. The interference analysis for several nonsensitive radios shows that the I/N is +6.2 dB to +39.3 dB into the downlink into ground stations and 0 dB to +33.1 dB into the uplink into airplane radios. Future digital systems may be even more sensitive. Due to the criticality of the air-to-ground communications for aeronautical systems, the MOSS system must not cause harmful interference, and it is recommended that MOSS not use this band.

For the fixed and mobile services, most of the systems deployed in this band are for voice services using traditional FM or AM transmissions. These systems likely employ low-gain antenna systems with receiver sensitivities lower than the aeronautical mobile systems (air-to-ground). Consequently, there is potential for interference to these systems. As for MOSS operations, no single fixed or mobile radio would likely cause interference to MOSS, but the ubiquitous nature of the systems could lead to interference. Additional information concerning the number and operations of these systems is needed to make a definitive assessment.

144-148 MHz Band

The 144-146 MHz band is allocated to the amateur and amateur satellite services while the 146-148 MHz band is allocated to the fixed and mobile services in Regions 1 and 3 and the amateur service in Regions 2 and 3. Amateur systems operating in this band include experimental, Morse code, and single-sideband communications. In addition, amateur terrestrial and satellite packet radio networks operate in this band.

For the amateur services in this band, both terrestrial and satellite systems operate with system characteristics ranging from low-power, low-gain radios to systems using medium gain antennas for satellite communications. Similar to the amateur systems in the 430-440 MHz band, there is a potential for degrading the performance of amateur systems, but the percentage of time is likely to be low. In addition, MOSS operations are unlikely to be significantly affected by amateur operations. Additional analysis is needed to make a definitive assessment.

For the fixed and mobile services, most of the systems deployed in this band are for voice services using traditional FM or AM transmissions. These systems likely employ low-gain antenna systems with receiver sensitivities lower than the aeronautical mobile systems (air-to-ground). Consequently, there is potential for interference to these systems. As for MOSS operations, no single fixed or mobile radio would likely cause interference to MOSS, but the ubiquitous nature of the systems could lead to interference. Additional information concerning the number and operations of these systems is needed to make a definitive assessment.

148-150 MHz Band

The 148-149.9 MHz band is allocated to the fixed, mobile, and mobile-satellite services while the 149.9-150.05 MHz band is allocated to the mobile-satellite and radionavigation-satellite services. This band is used by "little LEO" systems for uplinks as well as by other satellite systems, such as NOAA POES, for data uplinks. As with the 138-144 MHz band, many agencies use this band for land mobile communications. Organizations also use this band for scientific data collection including wildlife telemetry. Consequently, the MOSS system will not operate in accordance with the service allocations.

For the fixed and mobile services, most of the systems deployed in this band are for voice services using traditional FM or AM transmissions. These systems likely employ low-gain antenna systems with receiver sensitivities lower than the aeronautical mobile systems (air-to-ground). Consequently, there is potential for interference to these systems. As for MOSS operations, no single fixed or mobile radio would likely cause interference to MOSS, but the ubiquitous nature of the systems could lead to interference. Additional information concerning the number and operations of these systems is needed to make a definitive assessment.

For the mobile-satellite service, since the operations in this band use uplinks into nadir pointing antennas, the possibility for interference from MOSS is low except, possibly, when the orbiting satellite is in the mainbeam of the MOSS spacecraft. As results in the 137-138 MHz band indicate that this event is unlikely, so interference in unlikely. Additional analysis is needed to make a definitive assessment.

For the radionavigation-satellite service, additional information and analysis is required to make a definitive assessment concerning the potential for interference to these types of systems in this band.

Service Classification of MOSS system

The MOSS systems proposes to use two frequencies for active remote sensing:

- 1 MHz bandwidth signal centered in the 100-150 MHz frequency range; and
- 1 MHz bandwidth signal centered in the 432-438 MHz band.

For spectrum regulatory purposes, the service classification of the MOSS systems may be as follows:

- Each set of transmitters and receivers operating in a different band of frequencies (100-150 MHz and 432-438 MHz) is considered as one space station and the 100-150 MHz and 432-438 MHz subsystems may each be classified as operating in one service, but they do not need to be the same service;

- Based on the characteristics of the MOSS system, the two stations (100-150 MHz and 432-438 MHz) may be considered in one of the following services:

    - Earth exploration-satellite service;

    - Meteorological-satellite service; or

    - Space research service.

Given the possible service classifications, the 432-438 MHz frequency band allocated to the EESS (active) is appropriate for MOSS, while no appropriate allocation currently exists near the proposed 100-150 MHz frequency range:

- 100-150 MHz: only the 137-138 MHz band in the 100-150 MHz range is allocated on a primary basis to the space research service;
- 432-438 MHz: an allocation to the EESS (active) exists for the 432-438 MHz band

Summary

This document herein presents technical and operational characteristics of an active spaceborne sensor in the Earth exploration-satellite service (active) for a 1 MHz bandwidth use in the 100-150 MHz frequency range. The primary objective of MOSS is to develop a system that delivers science data and products to directly address the current NASA science priority of measuring soil moisture "under a substantial vegetation canopy and reaching a useful depth within the uppermost soil layer" under the Global Water and Energy Cycle science topic. The preliminary interference studies on whether sharing is feasible with the existing allocated services is summarized in Table 2.

Table 2. MOSS System Preliminary Interference Assessment for 100-150 MHz Frequency Range

Frequency Band	Primary Allocations	Types of Systems	Non-interference Assessment to Primary Services	MOSS Operations in Presence of Other Systems
100-108 MHz	Broadcasting		-	-
108-117.955 MHz	Aeronautical Radionavigation	Navigational aides	Interference possible, but analysis needed	Interference unlikely
117.975-137 MHz	Aeronautical Mobile (R)	Air-to-ground radios	Interference possible	Interference unlikely
137-138 MHz	Space Operation Meteorological-Satellite Mobile-Satellite Space Research	Low rate data space-to-Earth downlinks for weather or other data services	Interference protection criteria satisfied (except very limited locations)	Interference unlikely
138-150.05 MHz	Aeronautical Mobile (OR)		Interference possible	Interference unlikely
	Fixed	Point-to-point	Interference possible, but additional information needed	Interference unlikely, but additional information needed
	Mobile	Land mobile	Interference possible, but additional information needed	Interference unlikely, but additional information needed
	Radionavigation-satellite		-	-
	Amateur	Terrestrial and satellite	Interference possible, but additional analyses needed	Interference unlikely, but additional analyses needed
	Mobile-Satellite	LEO	Interference possible, but additional information needed	Interference unlikely, but additional information needed

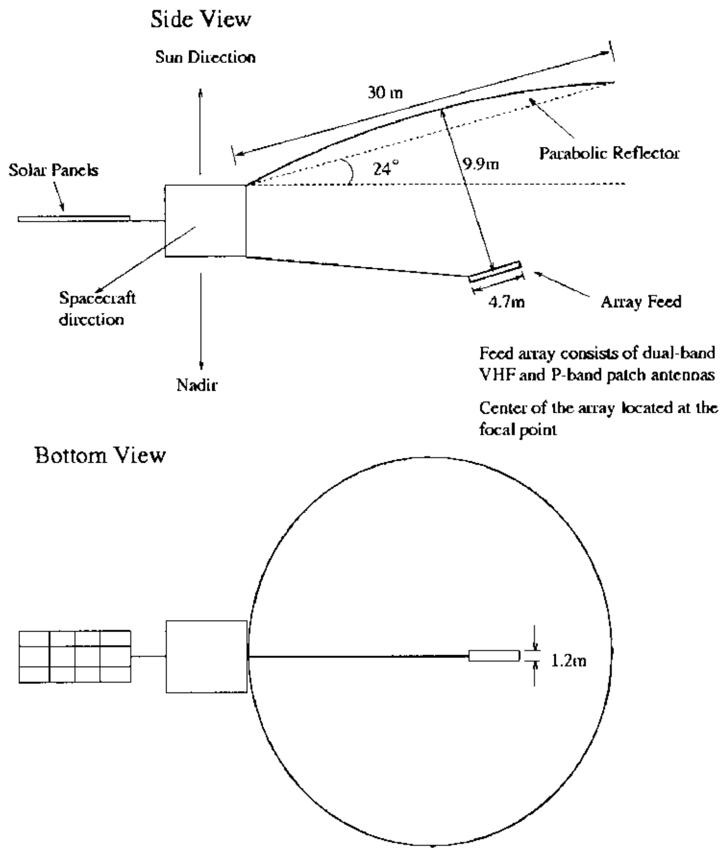

Figure 1. Schematic Of Reflector And Feed Antenna System And Their Relative Flight Geometry