Heliophysics radio observations enabled by the Deep Space Gateway. J. C. Kasper[1], [1]University of Michigan, 2455 Hayward St., Ann Arbor, MI 48109-2143, jckasper@umich.edu.

Introduction: The brightest emission in the heliosphere is due to nearly coherent radio waves produced by non-thermal plasmas including the solar atmosphere and corona, solar wind, planetary magnetospheres and aurora, and the termination shock and heliopause. Since the emission mechanisms are tied to local plasma properties such as the cyclotron and plasma frequencies, beam densities, and plasma beta, the spectral, temporal, and spatial evolution of this radiation encodes information related to the characteristics of the local emitting plasma, making radio observations a powerful technique for remotely characterizing energetic processes and environments. This presentation reviews the scientific potential of low frequency radio imaging from space, the SunRISE radio interferometer, which is an Explorer mission concept currently under study by NASA, and the scientific value of larger future arrays in deep space and how they would benefit from the deep space gateway (DSG).

Low frequency radio in space: For more than half a centry heliophysics missions have used single spacecraft with fixed antenna to measre the total power emitted by various non-thermal plasmas. The scientific value of these total power measurements is well documented and continues in anticipated upcoming missions such as the Parker Solar Probe (PSP) [1]. Antennas on spacecraft allow us to conduct unique radio heliophysics not possible on the Earth. The absorption and refraction of low frequency radio waves by the ionosphere limits ground-based heliospheric and astrophysical radio science: Below the ionospheric plasma frequency of 2-15 MHz, external radio waves are completely attenuated. Above the ionospheric cutoff variable refraction resulting from density fluctuations prevents high fidelity imaging.

SunRISE and imaging: Single antenna radio experients are limited to producing dynamic power spectra of radio emission as a function of time, and other data products generally related to the total emission. This is unfortunate because coherent low frequency radio emission should contain a great deal of information about energy flow and acceleration if it would be imaged. Radio emission from coronal mass ejections (CMEs) is a direct tracer of particle acceleration in the inner heliosphere and potential magnetic connections from the lower solar corona to the heliosphere. Energized electrons excite Langmuir waves, which convert into radio emission at the local plasma frequency, with the most intense acceleration thought to occur within 20 RS. The capability of ground based radio arrays to track this radio emission is limited by onospheric absorption (f > 15 MHz) to altitudes less than about 3RS. The state of the art for tracking such emission from space is defined by single antennas (Wind/WAVES, Stereo/SWAVES), in which the tracking is accomplished by assuming a frequency-to-density mapping; there has been some success in triangulating the emission between the spacecraft, but considerable uncertainties remain. The Sun Radio Imaging Space Experiment (SunRISE) mission is a NASA Explorer mssion currently under concept study. SunRISE would consist of a constellation of six small spacecraft near GEO, operating as an interferometer designed to localize and track radio emissions in the inner heliosphere. Each spacecraft would carry a receiving system for observations below 25 MHz, and SunRISE would be the first produce the first images of CMEs more than a few solar radii from the Sun.

Radio Observatories in Deep Space: There is clear value for more ambituous radio interferometer missons in deep space beyond SunRISE. Terrestrial RFI is the largest source of radio contamination for a space based radio array. While the GEO orbit reduces contamination enough to study solar radio bursts, an orbit in an Earth-moon Lagrange point or some other location near the moon would be thousands of times quieter, and would permit detection of queieter emission from objects such as Saturn, Neptune, and Uranus aurora, weak solar radio emission or even quiet Sun emission. SunRISE has six spacecraft, and the image quality (or dynamic range) scales as a the square of the number of antennas or spacecraft. An array with dozens of spacecraft would be able to make high resolution images of time varing sources. One exciting application is real time imaging of Earth's electron radiation belts.

Infrastrure Requirements: Here are several examples of how a DSG could assist the deployment and operation of a radio array.

Deployment of small satellites. The DSG could accept shipment of a series of small satellites and then inject them into the constellation, either to initially create the radio array or to replenish lost spacecraft over time.

A deep space time and navigation beacon. Many of the advances in location and signal processing on small spacecraft are made possible by the ability to determine local absolute time and location using GPS, even when the spacecraft are in orbits far beyond the nominal range of altitudes for GPS. SunRISE in GEO for example makes use of GPS timing for synchronizing data collection. The NASA Magnetospheric Multiscale (MMS) mission has demonstrated GPS receipt further from Earth, but with a larger set of electronics. The DSG could operate an atomic clock and transmit absolute time and location, acting as a supplement to GPS that would enable precision navigation and timekeeping in deep space.

High bandwidth communications and data processing. Future deep space radio arrays using higher bandwidth, time coverage, and number of antennas will produce significantly more data. The data volume scales as the square of the number of antennas for a radio interferometer, so data volumes for direct to Earth communication could quickly become prohibitive. The DSG could solve this issue by receiving data from the individual spacecraft and then either relay the data untouched to Earth, or perform data processing on a workstation at the DSG before sending down a further reduced data volume.

References:

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