LOW FREQUENCY RADIO ASTRONOMY FROM THE MOON

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Abstract. The radio sky at frequencies of several MHz and below is essentially unexplored with high angular resolution due to refraction and opacity in the Earth's ionosphere. An interferometer array in space providing arcminute resolution images would allow a wide range of problems in solar, planetary, galactic, and extragalactic astronomy to be attacked. These include the evolution of solar and planetary radio bursts, interplanetary and interstellar scintillation, the distribution of low energy cosmic rays and diffuse ionized hydrogen in our galaxy, the determination of spectral turnover frequencies and magnetic field strengths in galactic and extragalactic radio sources, searches for "fossil" radio galaxies which are no longer detectable by high frequency surveys, and searches for new sources of coherent radio emission. In addition, it is likely that unexpected objects and emission processes will be discovered by such an instrument, as has often happened when high resolution observations first become possible in a new spectral region. The Moon can provide shielding from terrestrial interference (and from the Sun half of the time) and consequently the lunar farside surface offers an ideal site of a low frequency radio array.

1. Introduction

In the context of radio astronomical observations from space, the low frequency region of the radio spectrum can be defined as extending from the local interplanetary plasma frequency (a few tens of kHz) at the low end to frequencies at which high resolution observations can be made regularly from the ground (a few tens of MHz) at the high end. This window spans three orders of magnitude in frequency, and represents the last major region of the electromagnetic spectrum which is still largely unexplored. An interferometer array in space using very small, simple, and inexpensive array elements could produce the first all-sky images at low frequencies in which the angular resolution is limited only by interplanetary and interstellar scattering.

2. Science

This frequency range is particularly well suited for the detection of "fossil" radio sources because in typical magnetic fields the synchrotron lifetimes of electrons are comparable to the age of the universe. Coherent emission processes from objects outside our solar system are likely to produce extremely high brightness temperatures at frequencies of a few MHz and lower. Additional science goals include determining the origin of cosmic rays, mapping the distribution of diffuse HII in the galaxy, and following the evolution of solar radio bursts. A less specific but equally important goal is exploration. Such a large observational parameter space will be opened for the first time by a low frequency imaging array in space that the discovery of completely unexpected sources or physical processes is likely. This has frequently been the case whenever high resolution observations first

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became possible in a new part of the spectrum. Detailed discussions of the science possible at low radio frequencies can be found in Kassim and Weiler (1990).

3. Array Location

The individual elements of a low frequency array will have little if any directivity, so interfering signals from the earth are a potentially serious problem. The two most obvious solutions are to place the array very far from the earth or on the back side of the moon. In both cases the problem of getting data down to the ground for processing is made more complicated, but the lunar option has at least three advantages: 1) terrestrial interference is eliminated, not just attenuated, 2) only half of the celestial sphere must be imaged at a given time, and 3) the array geometry does not need to be continuously monitored or controlled. Of course the sun is also blocked half of the time. This is a concern because solar observations are one of the main science goals, and also because it implies a significant battery requirement. However, it does benefit observations of galactic and extragalactic sources, which will be much weaker than the sun.

Several sites on the lunar farside, including the craters Tsiolkovsky and Saha, have been proposed as locations for radio telescopes. Only large craters are useful for a low frequency array because baselines up to at least 100 km will be needed to obtain the highest useful angular resolution. All sources will be resolved on much longer baselines due to interstellar and interplanetary scattering. Linfield (1996) has pointed out that good phase coherence can be obtained on baselines up to at least 100 km at frequencies of a few MHz and up to at least 30 km at 1 MHz.

4. Array Deployment and Operation

The cost and complexity of deployment is an important issue for any lunar-based instrument. In the case of a low frequency radio interferometer the individual array elements can be very small in mass and volume, and as a result it may be possible to deploy the elements via "semi-hard" landings. This would still require a retro motor to decelerate each element to less than a few hundred m/s prior to lunar impact, but this is a simpler and less expensive requirement than a controlled soft landing. A two-part array element could be used in which the more massive part penetrates a few meters into the lunar regolith (providing very good thermal insulation for electronics and batteries) and the less massive wider part containing solar cells and a low-gain telemetry antenna stays at the surface. The low frequency receiving antennas could be simple wires ejected onto the lunar surface, which is a good electrical insulator at low frequencies.

The lack of significant directivity in individual low frequency antennas makes it necessary to cross-correlate data for phase centers covering the entire visible sky so that sidelobes from all strong sources can be removed. This means many cross-correlations with different delays and delay rates for each baseline. The task is not difficult if done with large ground-based computers, but it is unlikely that a lunar-based correlator would be practical. Consequently a data relay satellite or a series of data relay stations across the lunar surface will be needed to get the raw data (at a rate of several Mb/s) to earth.

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