EXPLORATION OF THE LUNAR PLASMA ENVIRONMENT USING LONG WAVE RADIO T. Marshall Eubanks[1], Charles F. Radley[1], W. Paul Blase[1], [1]Space Initiatives Inc , Palm Bay, Florida 32907 USA; tme@space-initiatives.com;

The Plasma Environment at the Lunar Poles: At the lunar polar regions astronauts will be entering a novel and relatively poorly explored plasma and radio frequency (RF) environment, quite different from the direct sunlight and solar wind encountered in Apollo EVAs. We are developing a unified "LunaCell" system with very small SDR modules for deployment onto the lunar surface, with low frequency radio capabilities both to enable communications beyond the line-of-sight, and as a tool for exploring the lunar RF environment [1].

Table 1 briefly describes the complicated and time-variable plasma environment near the lunar surface. The Moon is in the complicated plasma dynamics of the Earth's magnetotail roughly 25% of the time, and the remainder of the time will be in the supersonic solar wind [2]. In the lunar wake the e^- density is substantially decreased, and the plasma can become non-neutral as the thermal velocities of the solar wind electrons are higher than the bulk wind velocity, while the thermal ion velocities are substantially lower. Charge-stratified plasmas are thus likely to form in shadowed lunar craters [3], and possibly also in the lunar wake, in both cases on a scale that does not allow for laboratory simulation on Earth. These non-neutral electron clouds could produce significant charging of astronauts and their equipment in shadowed regions[4] and must be better characterized to understand this safety hazard.

The low frequency radio range can be conveniently separated into a regime between 30 and 100 MHz, where radio waves will not be affected by the near-Moon plasma and should be able substantially penetrate the regolith, allowing for direct communication "through-the-rocks," a medium-wave regime around 1 MHz where a long distance day-time ground-way propagation using the layer of photo-emitted electrons (e^-) caused by the solar UV flux should be possible, and a very long-wave band below 30 kHz where night-time reflections off the lunar wake should be possible; this very long-wave band could possibly be used for both low-bit-rate night-time communications and to monitor the entire wake environment.

Long Range Lunar Radio: The very low frequency lunar environment is relatively unexplored. Photo-emitted electrons at the lunar surface may allow for long range ground-wave communications over the lunar day-time surface at $\sim$1 MHz [6]. LunaCell RF propagation tests at 1 MHz between widely separated stations could thus both investigate the bulk dielectric properties along the ground-wave raypaths, and test this form of long range communications.

Region	e^- Density # cm^{-3}	Plasma Frequency
Solar Wind	$\sim$7	$\sim$ 24 kHz
UV-Disassociated e^-	$\sim$600	$\sim$ 2 MHz
Earth Magnetotail	$\sim$0.3	$\sim$1 kHz
Shadowed Craters	$\sim$0.01	?
Lunar Wake	$\sim$0.01	$\sim$30 Hz

Table 1: Typical Plasma Regions Near the Moon (conditions are subject to large variations). The shadowed craters (and possibly the wake) may contain non-neutral plasmas with a zero plasma frequency. References: [3, 5, 6, 7].

At very low frequencies, roughly at or below the solar wind plasma frequency of $\sim$24 kHz, night-time communications should be possible using reflections off of the lunar wake, which of course would also provide a novel means of monitoring conditions in the wake. Even very low bit rate communications would find use on the Moon, both as a means of distributing alerts and for emergency communications

Charge-separation will fill shadowed craters with non-neutral electron clouds, which may support a variety of electrostatic and cyclotron waves and a very complicated plasma environment [8]. It will be difficult to directly sample this environment (satellites cannot fly inside most of the shadowed lunar craters), but LunaCells could be used to establish a lunar ionospheric radar at frequencies between 30 Hz and 30 KHz across or inside a shadowed lunar crater, mapping crater wave phenomena from the surface in real time.

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