Smart Broadband Astronaut Helmet Antenna for Lunar/Mars Surface Network

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1. Introduction

For terrestrial applications, development of broadband conformal helmet antenna has been successfully carried out [1, 2], and a smart helmet antenna for terrestrial applications was reported a decade ago [3]; both efforts were made by the senior author and a research team at Wang Electro-Opto Corporation (WEO).

The development of a smart astronaut helmet antenna, presented in this paper, is motivated by the need for a helmet antenna in NASA's planned Lunar/Mars exploration. As discussed in a recent news release on prime-time U.S. television, NASA now publicly envisions the Lunar Exploration to be conducted initially by 3 astronauts with a Lunar Electric Rover as a mobile base camp. Since WEO has been developing a smart platform antenna for the planned Lunar/Mars exploration [4], it is expedient and timely to develop a smart astronaut helmet antenna by cross-fertilizing its helmet antenna, platform antenna, and smart antenna technologies. This paper presents such a smart astronaut helmet antenna design for possible application in NASA's planned Lunar/Mars exploration.

2. Technical Requirements

The astronaut helmet antenna has the same stringent requirements as the platform antenna in [4], with the additional safety requirements for physical and RF radiation hazards to the wearer. In particular, volume, weight and power consumption of the smart antenna must be minimal in order to meet extremely harsh transport and operational environments. As a helmet antenna, the antenna is preferably easy to mount and remove from the astronaut's helmet, in order to be compatible with other helmet-mounted devices. Protection of the astronauts from RF radiation hazard is of primary importance, but is often ignored by most body-wearable antenna designers.

2. A Breadboard Model for Broadband Smart Astronaut Helmet Antenna

Figure 1 shows a photograph for a broadband smart astronaut helmet antenna mounted on a mockup of an astronaut helmet. As can be seen, the antenna is a switched-beam array of four element antennas, similar in array architecture to that of [3], with a broad beam switched by an embedded control system. The four element antennas, located around the periphery of the helmet, are supported with four arms with embedded stripline feedlines. Each element antenna is unidirectional in radiation pattern with circular polarization. The array operates over 1.9–2.4 GHz with circular polarization.

Three of the four element antennas are flat disks in shape, 2.5” diameter x 0.5” thick. The fourth element, located at the front of the helmet above the visor, is rectangular, 3.0” wide x 1.78” high x 0.5” thick. Each element antenna is attached to a small support arm (eventually to be made of a titanium alloy), which encloses a stripline RF feed.

The array provides hemispherical coverage with a broad beam adaptively switched over the hemisphere to enhance RF link in a network with time division duplexing (TDD), in which Tx/Rx are at the same frequency (or nearly the same). Miniaturized with embedded beamsteering system with fully autonomous operation, the array antenna has the desired small size, low weight, and low power consumption. The beam-steering control hardware and software are similar to those for the smart platform antenna described in [4], for which considerable details of the fundamental design were extensively reported in [5].

The helmet antenna is foldable for transport, easy to mount and remove, and weighs < 265 g (9.3 oz.), with minimal and acceptable physical and RF hazard to wearer. The helmet antenna is designed as a standalone system, transparent to the radio, with a low-power embedded microcontroller to provide its adaptive switching function. CMOS silicon-on-insulator (SOI) switches are used in this breadboard model based on their RF performance, radiation tolerance, low power consumption, and CMOS-compatible control.

3. Performance of the Breadboard Model

Figure 2 shows the measured SWR of the antenna, over 1.9–2.4 GHz, in a typical beam state. As can be seen, the measured SWR of this early breadboard model averages about 2:1 over the 1.9–2.4 GHz band of interest. It is expected that the SWR can be improved significantly in later advanced designs.

Figure 3 shows the measured azimuth radiation patterns ($\theta = 90°$) of the breadboard model in four beam states, across the desired 1.9–2.4 GHz frequency range. As can be seen, the set of four beam states provide nearly fully 360° coverage in the horizontal (azimuth) plane. The elevation patterns, not shown here, are broad-beamed (over 90°), and are tilted slightly upward above horizon. Thus the breadboard model provides nearly the desired hemispherical coverage.

4. Conclusions

A breadboard model for a smart astronaut helmet antenna has been developed. The antenna provides smart beamsteering function, for a TDD wireless surface network, which is at present on the drawing board. Thus, the antenna attempts to provide its "smartness" in a fully autonomous fashion, transparent to the radio system being developed.

The model has demonstrated the essential features needed and desirable for application to NASA's initial exploration on the Moon. An advanced breadboard design is, of course, needed to meet the harsh transport and operational environments of the mission. In particular, the specifications for the temperature and shock will dictate the components, parts, and materials to be employed in the design and its smart function must adapt to the final surface network to be implemented in the mission.

Acknowledgement

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References

[1] J. J. H. Wang, "Broadband Omnidirectional Helmet Antennas," 2006 IEEE Antennas and Prop. Symp., Albuquerque, NM, July 2006.

[2] J. J. H. Wang, "Multioctave Broadband Body-Wearable Helmet and Vest Antennas," 2007 IEEE Antennas and Prop. Symp., Honolulu, Hawaii, June 2007.

[3] J. J. H. Wang, J. K. Tillery, K. E. Bohannan, and G. T. Thompson, "Helmet-Mounted Smart Array Antenna," 1997 IEEE Antennas and Prop. Symp., Montreal, Canada, July 1997.
[4] D. J. Triplett and J. J. H. Wang, "Miniaturized Broadband Adaptively-Steered Smart Antenna for Lunar/Mars Surface Networks," 2009 IEEE International Antennas and Prop. Symp., Charleston, SC, June 2009.
[5] J. J. H. Wang, D. J. Triplett, and C. J. Stevens, "Broadband/Multiband Conformal Circular Beam-Steering Array," IEEE Trans. Ant. Prop., Vol. 54, No. 11, pp. 3338-3346, November 2006.

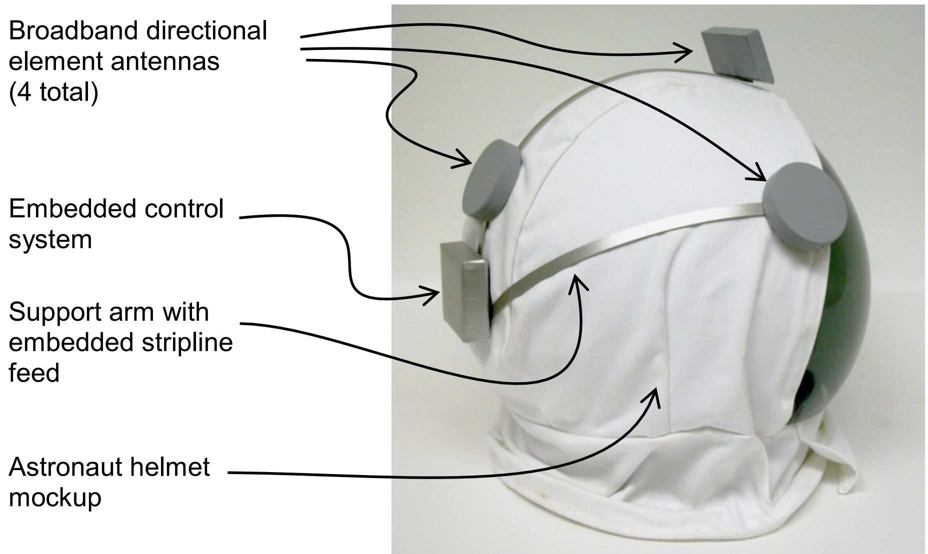

Figure 1. A broadband smart astronaut helmet antenna breadboard mounted on helmet mockup.

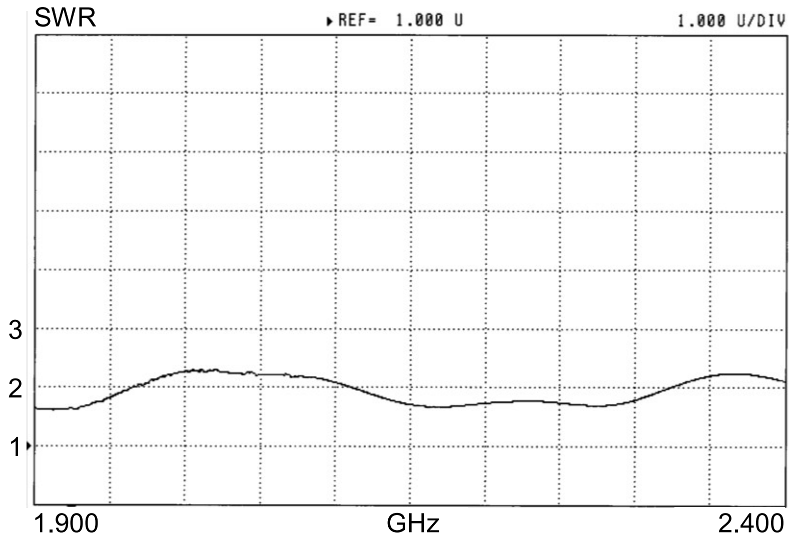

Figure 2. Measured SWR of the smart astronaut helmet antenna breadboard in a typical beam state.

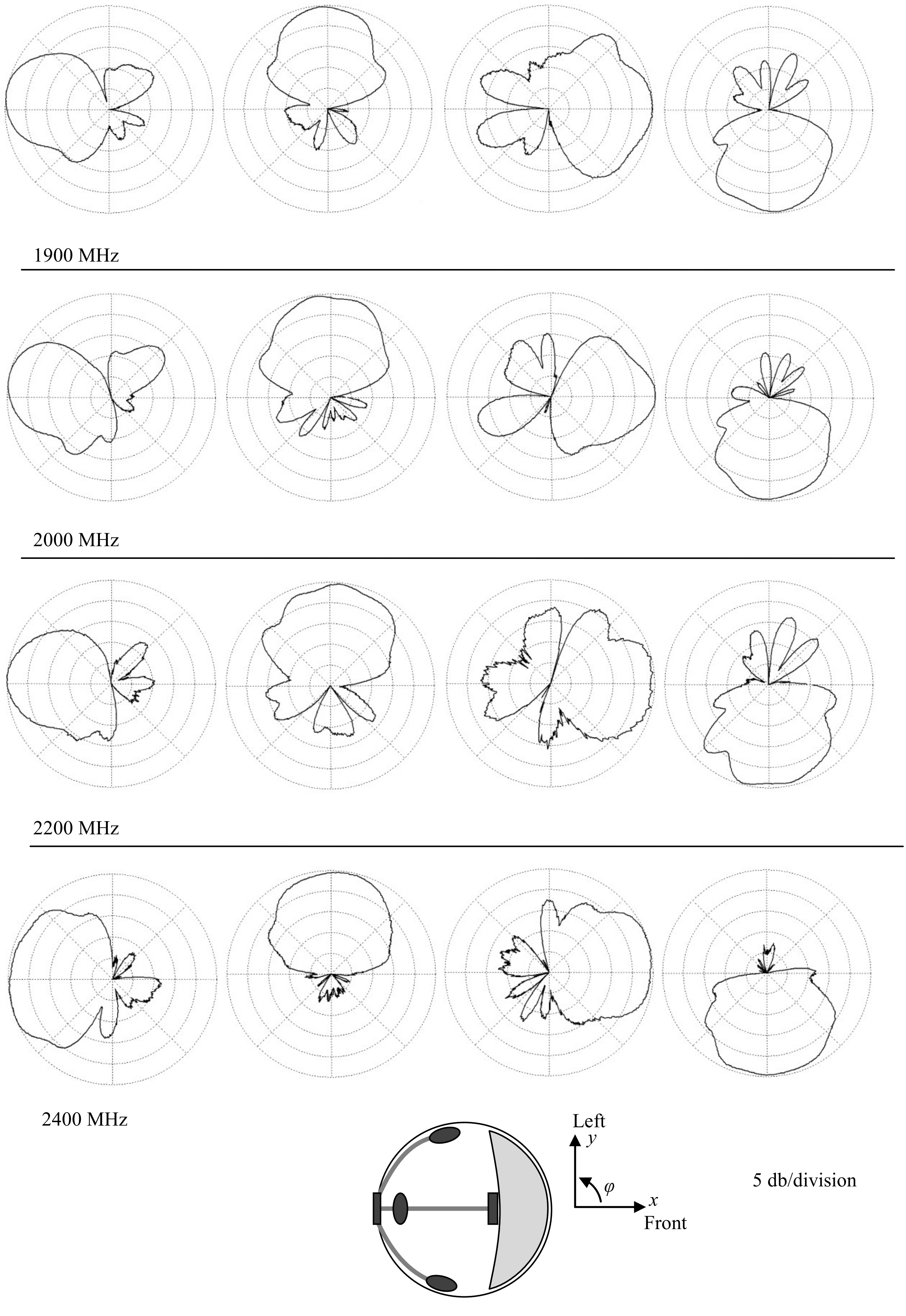

Figure 3. Measured azimuth patterns of breadboard model in four beam states over 1.9–2.4 GHz at $\theta = 90°$.