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Ultra-wideband RF helmet antenna

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ULTRA-WIDEBAND RF HELMET ANTENNA

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ABSTRACT

This paper addresses the development of an ultra - wideband, vertically polarized communications antenna integrated into the camouflage cover of a standard military-issue Kevlar helmet. The Helmet Camouflage Cover Antenna (referred to as the "helmet antenna") is one of three antennas based on the antenna COMbat Wear INtegration (COMWIN) concept developed at the Naval Postgraduate School (NPS) for the man -portable implementation of the new Joint Tactical Radio System (JTRS). The results of computer simulations and proto type measurements for the helmet antenna are presented.

INTRODUCTION

The JTRS is being developed to meet emerging needs for ultra-wideband tactical radios. The desired 2 MHz to 2000 MHz operating frequency range poses a major challenge with regards to the antenna system. The current tactical radio antennas are not capable of operating efficiently over such a wide frequency range. In addition, they also have visual signatures that expose the operator's position. Therefore, in order to implement the JTRS, new types of antennas need to be developed, especially for the man-portable implementation. This paper presents computer simulation results and prototype measurements for a conformal helmet antenna intended to operate from 500 MHz to 2000 MHz, i.e., over a 4:1 bandwidth. The antenna is constructed of conducting cloth (polyester interwoven with nickel/copper fibers) and attached as a liner to the helmet's camouflage cover. The helmet antenna is therefore visually undetectable, except for the connector in the back of the helmet. A number of conformal helmet antennas have been designed and their performance simulated using Ansoft's High Frequency Structure Simulator (HFSS) finite element software, with different trade-offs between the low frequency cut-off and the maximum VSWR "ripple" within the operational band. In addition, a prototype Mk I [1] helmet antenna has been built and measured at the NPS. Measurements of the input impedance and VSWR as functions of frequency for the Mk I prototype show performan ce exceeding the HFSS computer model predictions. The VSWR for the Mk I prototype was measured to be less than 3:1 for all frequencies between 500 and 2000 MHz, except for an isolated band around 900 MHz. The presence of an operator wearing the helmet improved the VSWR somewhat, indicating a moderate degree of coupling to the operator. The development of the RF helmet antenna at the NPS is continuing with the design and fabrication of the second prototype (Mk II).

RF HELMET ANTENNA DESIGN

The antenna consists of two radiating surfaces separated by a gap. The top and bottom radiating surfaces are of (approximately) equal surface area for the optimum electrical performance. The conducting strip in the front of the helmet provides connection between the top and the bottom half of the helmet antenna. A coaxial feed line at the back of the helmet feeds the antenna. The inner conductor of the coaxial feed is soldered to the upper half of the antenna while the outer conductor (shield) is soldered to the lower half. The size and geometry of the gap separating the top and the bottom halves control the input impedance of the antenna. The conducting cloth that makes up the radiating surfaces is made of thin polyester cloth interwoven with nickel/copper fibers. Thus the antenna is lightweight, conformal to the helmet, and can be easily integrated into the helmet. The Mk I prototype of the helmet antenna is shown in Figure 1. The canvas base (to which the conducting cloth was applied) shows as the lightest gray, the copper tape (used to vary the gap size) shows as a shiny surface in the middle of the antenna, while the rest is the conducting cloth material.

COMPUTER SIMULATIONVALIDATION

Computer simulation results were obtained using Ansoft's High Frequency Structure Simulation (HFSS) software. In order to validate computer models (including the effects of Kevlar) measurements of input impedance and VSWR were completed using the vector network analyzer HP-8510. The measured results were compared with the HFSS

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predictions. Figures 2 and 3 show the real and imaginary parts respectively of the helmet antenna input impedance obtained from simulation and measurement, and the VSWR is shown in Figure . The figures show good agreemnt between simulation results and measurements, thus validating the simulation model.

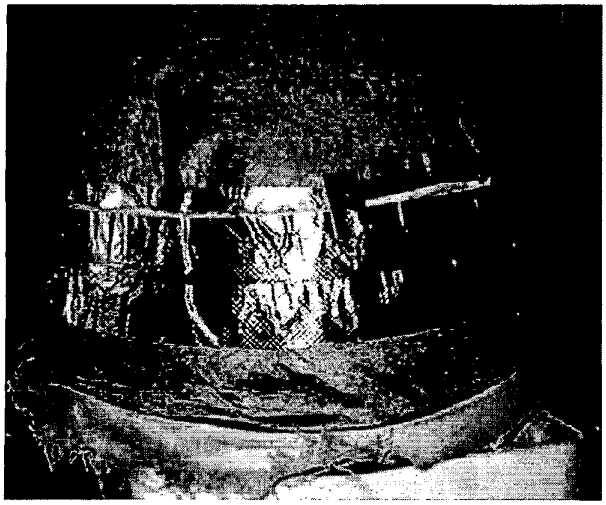

Figure 1: Helmet Antenna Prototype

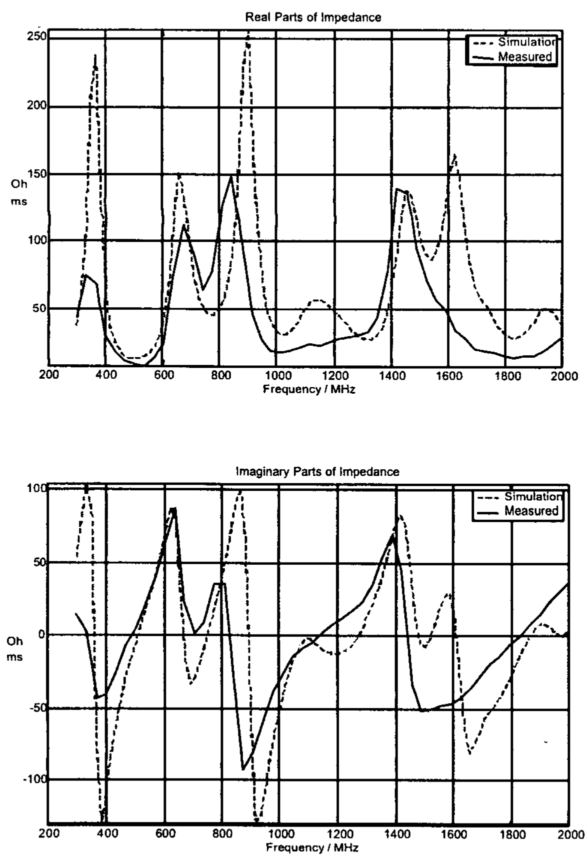

Figure 2: Input Impedance - Simulation and Measured

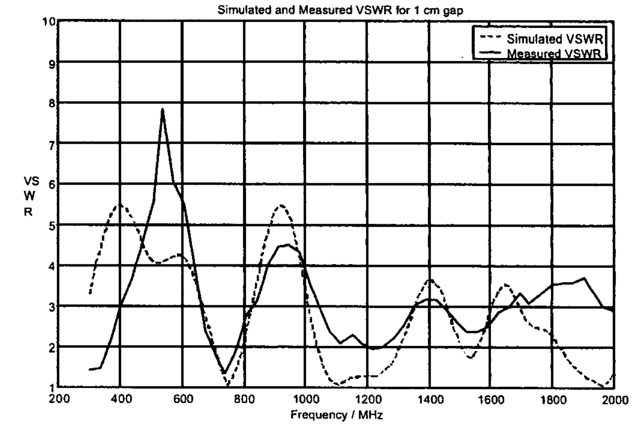

Figure 3: VSWR- Simulation and Measured

PROTOTYPE MEASUREMENTS

In order to determine the optimum gap width (resulting in the lowest VSWR over the widest frequency range) the Mk I prototype was constructed such that adding or removing sections of copper tape could change the gap width. Measurements of input impedance were made for three gap widths: 0.25 cm, 0.5 cm and 1 cm. The VSWR for these gap widths are plotted in Figure 4, showing that for the simple parallel gap, the optimum gap width is about 0.5 cm.

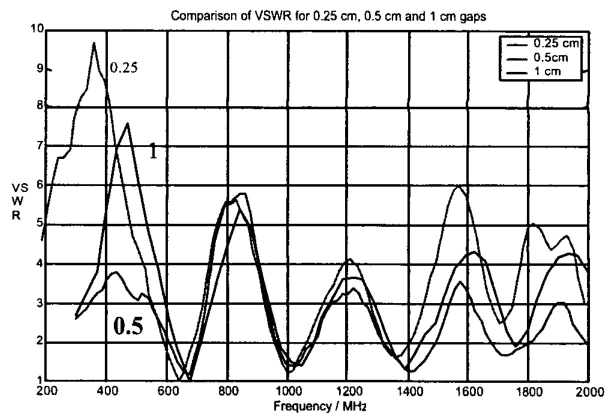

Figure 4: VSWR for GapSizes of 0.25, 0.5, and 1 cm

Having established that 0.5 cm is the gap width that gives the best antenna performance, three sets of measurements were completed in order to determine the effects of the Kevlar helmet and the presence of an operator on the antenna performance. The measurements were made for:

?? the antenna without the helmet,
?? the antenna on the helmet, and
?? the helmet-mounted antenna on a person.

Effects of the Kevlar Helmet on the VSWR

The VSWR for the helmet-mounted antenna and for the antenna without the helmet are shown in Figure 5. The graphs show that the Kevlar helmet improves the VSWR and lowers the low cut-off frequency of the antenna by about 100 MHz.

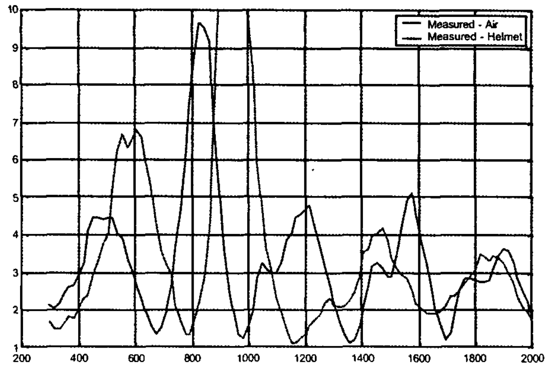

Figure 5: Effect of the Kevlar Helmet on VSWR

Effect of a Person on the VSWR

The VSWR of the antenna when a person wears the helmet and the VSWR without the person are shown in Figure 6. The presence of the operator improves the antenna VSWR over the entire frequency range.

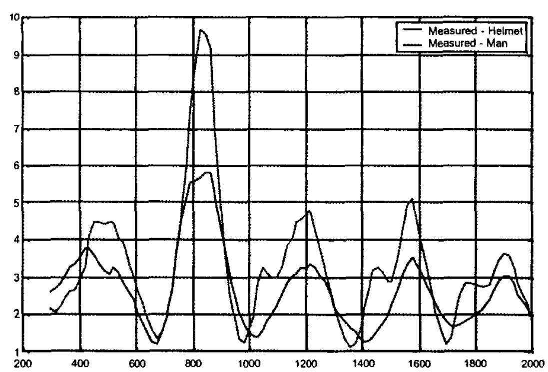

Figure 6: Effect of a Person on the VSWR

Radiation Patterns

The azimuth and elevation radiation patterns at 500 MHz and 2000 MHz respectively are shown in Figure 7 to Figure 10. The azimuth radiation patterns show that the antenna pattern changes with frequency, becoming more omni-directional as the frequency increases. The elevation radiation patterns show that most of the radiation is concentrated in the sector 0? to 60? from the horizon, which is also the target sector of operation. Note that the elevation patterns are shown for ? = 0 (fore-aft) and ? = 90 (left-right) relative to the operator orientation while the azimuth patterns are shown in the horizontal plane.

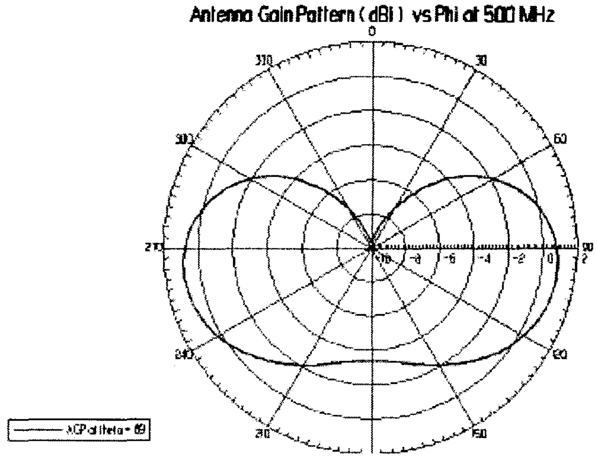

Figure 7: Azimuth Radiation Pattern at 500 MHz

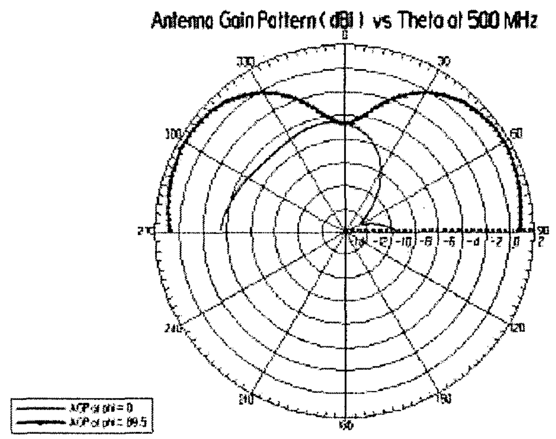

Figure 8: Elevation Radiation Pattern at 500 MHz

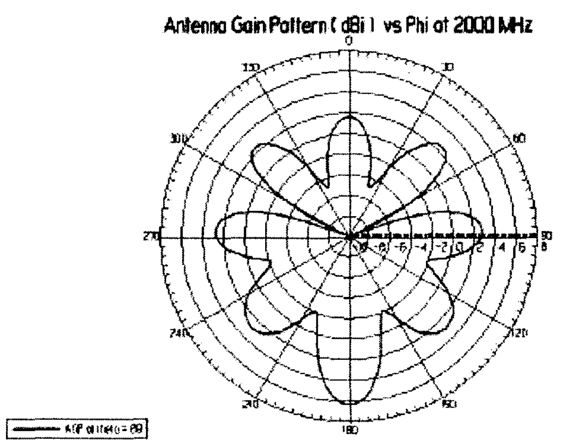

Figure 9 Azimuth Radiation Pattern at 2000 MHz

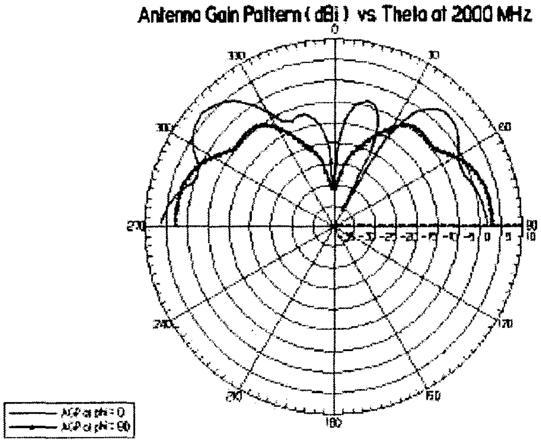

Figure 10: Elevation Radiation Pattern at 2000 MHz

WORK IN PROGRESS

As mentioned earlier, the antenna input impedance can be changed by modifying the size and geometry of the gap region. The authors are continuing with the research and developing of the new, improved prototype (Mk II) of the conformal helmet antenna with a wider bandwidth and a lower VSWR.

ADVANTAGES OF THE HELMET ANTENNA

Compared to the conventional antennas, the helmet antenna described in this paper has a number of advantages:

?? Efficient operation from 500 MHz to 2000 MHz frequency range without an antenna tuner (ultra-wide instantaneous bandwidth)
?? Nearly omnidirectional radiation
?? No visual signature (radio operator indistinguishable from any other soldier)
?? No set-up required for the antenna
?? No damage to the antenna from foliage or obstacles in an urban environment
?? All-weather antenna operation
?? Light weight
?? Inexpensive to manufacture
?? Zero maintenance

These are a unique combination that conventional man-portable antennas can not provide.

CONCLUSION

The authors have designed and built a wideband helmet antenna that operates from 500 MHz to 2000 MHz, a bandwidth ratio of 4:1. The helmet antenna is superior to the conventional antenna in terms of performance, cost, implementation and maintenance.

ACKNOWLEDGEMENTS

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