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14. ABSTRACT Future warrior-carried communications systems have at least two needs that must be met if current plans are implemented. The first is the ability to transmit or receive voice, video, and data over an extremely wide frequency range. The hand-held version of the Joint Tactical Radio (JTR) scheduled for production in 2006 is designed to meet part of this need. The second is the ability to hide the identity of the radio operator from snipers who seek to disrupt command, communications, and control functions at the squad level. Integrating the antenna into the uniform provides both ultra broadband transceiving capability and the ability to make the radio operator indistinguishable from any other soldier or marine. The Combat Wear Integration (COMWIN) Antenna System in conjunction with the hand-held JTR fulfills both needs. Published in <i>Proceedings of MILCOM Conference</i> , Anaheim, CA, October 2002.					
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TESTING AND INTEGRATION OF THE COMWIN ANTENNA SYSTEM

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ABSTRACT

Future warrior-carried communications systems have at least two needs that must be met if current plans are implemented. The first is the ability to transmit or receive voice, video, and data over an extremely wide frequency range. The hand-held version of the Joint Tactical Radio (JTR) scheduled for production in 2006 is designed to meet part of this need. The second is the ability to hide the identity of the radio operator from snipers who seek to disrupt command, communications, and control functions at the squad level. Integrating the antenna into the uniform provides both ultra broadband transceiving capability and the ability to make the radio operator indistinguishable from any other soldier or marine. The Combat Wear Integration (COMWIN) Antenna System in conjunction with the hand-held JTR fulfills both needs.

The COMWIN System consists of antennas in the form of a vest able to transceive at any frequency from 30 MHz to 500 MHz, in the form of a helmet able to transceive at any frequency from 500 MHz to 2400 MHz, in the form of flak jacket, pants, and shoes able to receive at any frequency from 2 MHz to 30 MHz, and a distribution system that routes the signal from the radio to the appropriate antenna. Each antenna is hidden by the soldier's uniform so that only a small microphone near the operator's mouth is visible. When operating individually the vest antenna has a voltage standing wave ratio (VSWR) of less than 3:1 for almost all frequencies between 31 and 475 MHz. The helmet antenna has a VSWR

of less than 3:1 for all frequencies between 440 and 2310 MHz. The whole body antenna has a VSWR of less than 2:1 for all frequencies between 5 and 30 MHz. Using a portable VSWR meter the COMWIN system has a measured VSWR of less than 3:1 for all frequencies between 5 and 1200 MHz.

The gain of the vest and helmet antennas is excellent at most of the frequencies between 30 and 2400 MHz. The maximum gain is 5 dBi. Typically, the gain of both the vest and helmet for horizontally polarized radiation is 10 dB less than that which is vertically polarized. There are lobes in the radiation patterns for the vest antenna at frequencies higher than 200 MHz. The lobes in the radiation patterns for the helmet antenna occur at frequencies higher than 700 MHz. The number of lobes and the depth of the nulls increase as the frequency increases.

Tests have been conducted with a pair of military radios to demonstrate the effectiveness of the COMWIN System as a transceiver. The vest antenna has shown an ability to transceive at twelve frequencies between 63.9 and 450 MHz at distances of up to 5 miles (the limit of line of sight in the Point Loma region) at an input power level of 3 W. Although the range is reduced by a factor of 3, the vest antenna can transceive at these frequencies even if the wearer is horizontal. The helmet antenna has successfully received video data at a frequency of 2.4 GHz at a data rate of 11 Mbps under an 802.11 protocol. The whole body antenna worn by a person in Point Loma, CA has successfully received time and voice information from station WWV in Boulder, CO at frequencies of 5, 10, 15, and 20 MHz. The signal level was within a

factor of 2 compared to that received by a 35 foot whip. Further testing is ongoing.

INTRODUCTION

Future warrior-carried communications systems have at least two needs that must be met if current plans are implemented. The first is the ability to transmit or receive voice, video, and data over an extremely wide frequency range. This frequency range must accommodate the established military bands and frequency-hopping systems. The second need is the ability to hide the identity of the radio operator from snipers who seek to disrupt command, communications, and control functions at all levels including the squad. The hand-held Joint Tactical Radio (JTR) scheduled for production in 2006 is designed to provide the signal to meet these needs in the 2 MHz to 2 GHz band. An ultra wideband antenna is needed for this radio for efficient transmission at all frequencies in this band. Integrating the antenna into the uniform provides a method for ultra wideband transmission and making the radio operator indistinguishable for any other soldier or marine. The Combat Wear Integration (COMWIN) Antenna System in conjunction with the hand-held JTR fulfills both needs. A paper presented by Abramo et al. at MILCOM 2000 described the effort to develop and test a component of this system, the first version of the Vest Antenna.

The COMWIN project started in May, 1999 with the association of researchers at SPAWAR Systems Center San Diego with Professors Lebaric and Adler of the Naval Postgraduate School in Monterey, CA. Lebaric originated the concept and basic design of the subsystems as well as the term COMWIN to describe one goal of the effort. He decided that no one antenna could possibly transmit efficiently over the entire 1000:1 frequency band of the JTR. He developed the original design for antennas in the form of a vest to cover the 30 to 500 MHz band, in the form of a helmet to cover the 500 to 2000 MHz band, and in the form of a shirt, pants, and shoes to cover the 2 to 30 MHz. Although extensive modifications have been made to increase efficiency, this design has remained the basis of the COMWIN system. Full descriptions of the fabrication and testing of various prototypes of the COMWIN antenna system are presented in technical reports published by SPAWAR Systems Center (Adams et al., 1999,

2000, and 2001) and on the SSC SD web site (<http://www.spawar.navy.mil/sti/publications/>).

This technology may be the subject of one or more invention disclosures assignable to the U.S. Government including Navy Case Numbers 83,531 and 83,503. Licensing inquiries may be directed to Harvey Fendelman, Patent Counsel, Space and Naval Warfare Systems Center, Code 20012, San Diego, CA 92152-5765, (619) 553-3001.

VEST ANTENNA

Experiments with prototypes during FY99 and FY00 demonstrated that the imposition of symmetry (top to bottom and right to left) would improve the matching of the antenna to the input impedance. To improve the matching of the impedance in the important 30 to 88 MHz band, "suspenders" were used to connect the front and rear sections of the vest antenna. This addition provided a longer path for signals and increased the efficiency of transmission at the lower frequencies while having little effect at the higher ones. A capacitor with value was 56 pf was inserted in series with the feed further improved the matching. Figures 1 and 2 present front and rear views of the full COMWIN antenna. In the deployed version of the system, the cables and antenna would be completely hidden by the uniform of the soldier or marine. Figure 3 presents a rear view of the vest antenna showing in more detail the feed arrangement and suspenders.

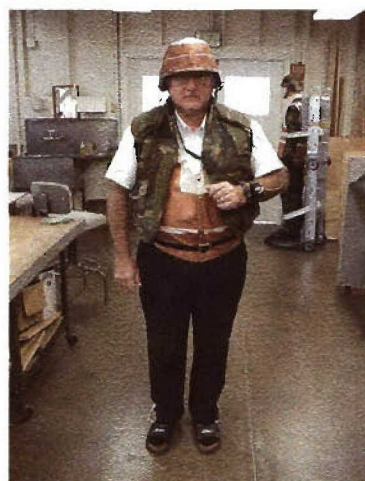


Figure 1. Photograph of the Front View of the COMWIN Antenna System. The pants have metal stripes down the sides and the shoes have metal insoles.

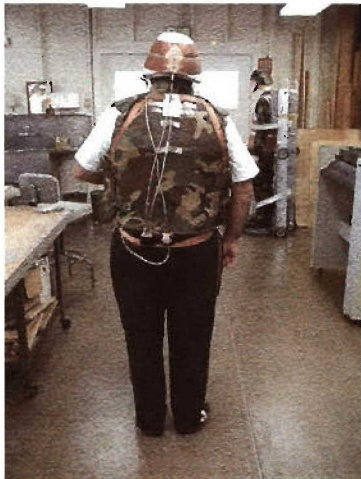


Figure 2. Photograph of the Rear View of the COMWIN Antenna System. The switch and the feeds of the whole body and helmet antennas are shown.



Figure 3. Photograph of the Rear View of the Vest Antenna. The Vest was covered by the flak jacket in Figures 1 and 2.

Testing of the antenna included voltage standing wave ratio (VSWR), gain, and patterns. An Anritsu Sitemaster, Model 113B, was used to measure VSWR and impedance. The VSWR was less than 3:1 for almost all frequencies between 31 and 475 MHz. Even at a frequency as high as 500 MHz, the VSWR was less than 3.5:1. Figure 4 presents the VSWR versus frequency for the vest antenna.

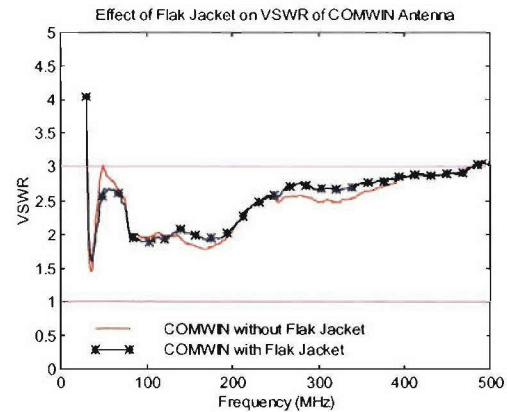


Figure 4. VSWR Versus Frequency of the Vest Antenna. The VSWR is less than 3:1 for almost all Frequencies Between 31 and 475 MHz. The figure also shows the effect of wearing a flak jacket over the COMWIN vest antenna.

Gain was measured at the SSC Antenna Range at frequencies from 30 to 400 MHz. Patterns in the azimuth and elevation directions were measured from 50 to 400 MHz. In the azimuth the maximum in the pattern was usually at boresight. The patterns were largely isotropic for frequencies less than 250 MHz. At higher frequencies nulls developed. At 400 MHz nulls 15 dB deep developed near the arms. Gain was measured by comparing the signal from the test antenna with that measured with a standard log-periodic with calibrated gain. A styrofoam model was used to provide support for the antenna.

Several experiments have been conducted using a pair of military radios (the PRC-148) to determine the effectiveness of the vest antenna. The primary criterion was intelligibility of broadcast of the time at 2 minute intervals as the wearer of the vest antenna moved. These experiments were conducted over both land and ocean. The frequencies used included 64, 142, 145, 162, 226, 258, 292, 320, 348, 432, 435 and 450 MHz. The input power varied between 0.1 and 5 W. Although the transmit antenna was usually vertical, horizontal orientation was also tested. With a power level of 3 W at 64 MHz, the COMWIN vest antenna had excellent reception even at a distance of 7.5 miles. The effect of horizontal polarization was to reduce the range by a factor of 3. There was excellent intelligibility at all frequencies and orientations at the lowest power setting at the frequencies given above out to a distance of 320 m. For

vertical polarization there was no change in volume or clarity as the wearer revolved.

HELMET ANTENNA

Figure 5 presents the VSWR versus frequency of the helmet antenna measured by a network analyzer. The VSWR was less than 3:1 at all frequencies between 440 and 2310 MHz. The boresight gain was measured for frequencies between 400 and 2400 MHz. For frequencies less than 600 MHz, the horizontal gain can be larger than the vertical. For higher frequencies the vertical polarization dominates.

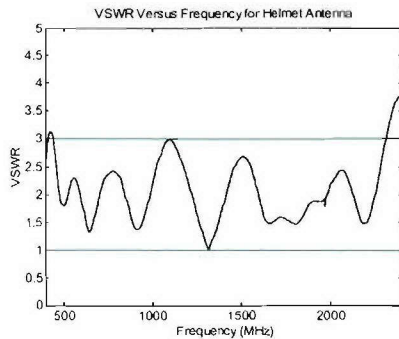


Figure 5. VSWR Versus Frequency of the Helmet Antenna

Patterns measured in an anechoic chamber indicate that there are lobes at all frequencies higher than 700 MHz. The number of lobes increases monotonically with frequency.

To test the effectiveness of the helmet antenna for receiving images a network using 802.11 protocol was used. A camera viewing the image of the second hand of a clock sent the image to a microstrip antenna which transmitted the signal at a frequency of 2400 MHz. A second microstrip antenna attached to a laptop computer received the signal and displayed the image on the screen. If the link margin became bad enough the motion of the clock became intermittent (5 second increments rather than 1 second). The link margin using just the microstrips began to fail at a distance of 30 m. At a range of 60 m, the image froze. When the output of the helmet antenna was inserted into the port of the laptop, the image of the clock immediately resumed normal motion. This motion continued up to a range of 160 m.

WHOLE BODY ANTENNA

The whole body antenna uses metal soles on the inside of the shoes to couple the signal to the ground. The ground acts as part of the antenna to make the effective length a significant fraction of a wavelength even at a frequency as low as 2 MHz. The full circuit consists of a feed on the back of the flak jacket with two arms that go down the sides of the person and connect to the inserts of the soles. Figure 6 presents the VSWR versus frequency of the whole body antenna when the wearer is located on a ground plane and on a sidewalk. The VSWR of less than 2:1 is probably due to the loss caused by the ground and wearer.

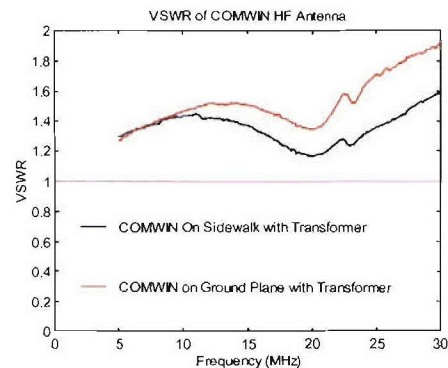


Figure 6. The VSWR of the Whole Body Antenna Versus Frequency from 5 to 30 MHz.

The ability to receive signals was tested by using a receiver in the HF band. Station WWV out of Boulder, CO that broadcasts a beeping signal every second and the standard time every minute a frequencies 5, 10, 15, and 20 MHz was received quite well at the three highest frequencies. The voice signal was somewhat scratchy at 5 MHz. The signal strength was a factor of 2 less than that measured by a 35 foot whip.

INTEGRATION

The JTR is expected to have one port for input to an antenna. There must be a distribution system so that the signal can be routed to the appropriate antenna for efficient transmission. An RF SP3T powered by three 9 volt batteries was used for this purpose. A rotary dial switch on the wrist of the wearer of the COMWIN antenna opened the appropriate port. The measurements obtained when each of the three ports was opened showed

that there was no frequency between 5 and 1200 MHz at which the COMWIN antenna failed to have a VSWR of less than 3:1. For all frequencies between 1200 MHz and 2400 MHz, the VSWR for the helmet antenna should apply. Work is continuing on using components such as diplexers that do not involve operator input.

CONCLUSIONS

A prototype warrior-carried antenna that provides efficient transmission at all frequencies between 2 and 2400 MHz has been developed and tested at SPAWAR Systems Center. The system consists of a vest, helmet, and whole body antenna connected to a distribution system controlled by a rotary dial switch on the wrist of the wearer. All of the subsystems have been tested with radios and the intelligibility of voice or video images has been compared with standard antennas. Further testing is continuing.

REFERENCES

Abramo, Robert, Richard Adams, Frank Canez, Howard Pace, and C. Peter Haglind, "Fabrication and Testing of the COMWIN Vest Antenna," MILCOM 2000, October 24, 2000.

The technical reports below can be downloaded in pdf format from the web site
<http://www.spawar.navy.mil/sti/publications/>

Adams, R.C., C. P. Haglind, H. N. Pace, J. Lebaric, R. Adler, T. M. Gainor, and A.T. Tan, "Fiscal Year 1999 Wideband Antenna Feasibility Study", November 1999, Technical Report 1808 SPAWAR Systems.

Adams, R.C., R. S. Abramo, J. L. Parra, and J. F. Moore, "COMWIN Antenna System Fiscal Year 2000 Report," September 2000, Technical Report 1836 SPAWAR Systems Center.

Adams, R.C., R. S. Abramo, D. W. Von Mueller, "COMWIN Antenna Project: Fiscal Year 2001 Final Report," August 2001, Technical Report 1866 SPAWAR Systems Center.