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NAVAL POSTGRADUATE SCHOOL

Monterey, California

RMS SYSTEM RELIABILITY STUDY

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Three alternate antennas have been designed, constructed and radiation patterns confirmed by test. Two are circularly polarized and the third is vertically polarized. Three additional antennas are being synthesized. Electromagnetic propagation studies were initiated in the field and results verified laboratory predictions that multipath effects contribute to wild ranges and no response. Sensitivity decrease in micro B transponders was observed due to thermal effects.

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SUMMARY

The RMS Research Group at NPS has investigated several antenna configurations for consideration as alternatives to those utilized in the existing RMS system. Two circularly polarized antennas, one omnidirectional and one high gain, and a high gain vertically polarized antenna have been designed, prototypes constructed and initially field tested with performance superior to the present RMS antennas. Two other prototype antennas are nearly ready for radiation pattern testing. The initial portions of computer simulation programs for evaluating antenna radiation patterns, as on a tank, have been completed and checked out.

The second area of investigation was concerned with the radiation link between the A and B stations. Both laboratory and field tests have shown conclusively that multipath effects contribute significantly to large range measurement errors and to distortion and reduction in magnitude of the telemetry signals. Recommendations are included in this report for follow-on studies to further characterize the multipath problem and to determine operational methods to minimize these effects.

In the course of investigating multipath effects, severe thermal degradation of equipment performance was observed. A careful alignment procedure was developed by the NPS Group which permitted acceptable field operation. Additional investigation is required to determine the cause of the "thermal hysteresis" observed in the transceiver sensitivities.

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I. INTRODUCTION

The U. S. Army Combat Developments Experimentation Command at Forts Ord and Hunter Liggett Military Reservations, California has experienced extensive operational difficulties with the Range Measurement System (RMS) developed and supplied by the Electronics Division of General Dynamics. Previous investigations had been made in the FHLMR environment with minimal results. A group in the Electrical Engineering Department of the Naval Postgraduate School (NPS Group) was engaged in Fiscal Year 1977 to carry out an investigation limited to the RMS antenna systems. Additionally the NPS Group was charged with identifying problems as encountered that affect the reliability of the RMS system. The scope of the Group activity was defined to be antennas and propagation. Known operational difficulties in RMS system operation are; wild range measurements, loss of data due to no response and excessively high field failure rates of some equipment items.

These operating problems led the NPS group to pursue a two-pronged attack. The first approach was to investigate new low profile, higher gain antennas, design and construct prototypes of those appearing feasible for elliptical (circular) polarization. It should be noted that, prior to this effort, elliptical polarization had not been investigated. During initial discussions it was inferred that a continuing relationship between CDEC and NPS would be mutually beneficial and rewarding. As a result of the discussions, the decision was made that the second approach would be a systematic engineering investigation of the RMS system. This study would start with radiation from the antennas and observe the propagation effects on signal waveforms. The logical progression was to proceed through the R-F links between the A stations and micro B units, the micro B units themselves followed by other links and equipment in the system. The study would end with an evaluation of the hardware and software computer system components at the data processing center. Problems affecting the RMS system reliability and performance would be identified as encountered and possible solutions were to be recommended.

II. ANTENNAS

The Antennas effort by the NPS RMS group resulted in the following areas of investigation.

(a) Provide a lower cost more rugged interim replacement antenna.

(b) Design and construct prototype antennas as possible replacements for the existing RMS antennas.

(c) Provide prototype circularly polarized antennas for field comparison with the existing vertically polarized system with respect to multipath effects and system performance.

The first objective was completed, after a search for a commercially available low cost antenna, by the Phelps Dodge 1065-A model. It is a low profile ruggedly constructed antenna priced in the \$20 to \$30 range depending on quantity and has an omnidirectional pattern that compares fairly well with the much higher priced RMS antennas. Its principal disadvantage is the ground plane requirement.

The second objective resulted in the design and prototype construction of six antennas. The table on the next page lists the essential information on these antennas.

The third objective resulted in construction of the two circularly polarized helical antennas. They were not extensively field tested due to:

(a) late date of completion

(b) field micro-B unit failures

(c) NPS Group's inability to obtain field usable micro-B units.

Antenna Type	Polarization	(a) Status	Performance	General
* Axial Mode Helical	Circular	D, P, L, F	1	Directional Pattern
*Normal Mode Helical	Circular	D, P, L, F	1	Omnidirectional Pattern
Dual Bi-Triangular Flat-Plate	Circular	D, P, L	2	Directional Pattern
**Bi-Triangular Flat-Plate	Vertical	D, P, L, F	1	Directional Pattern
Downward Looking Airborne	Vertical	D, P	2	For use with aircraft or tethered balloons Omnidirectional
Thin Film	Vertical	D	2	For helmet application

Code: D = designed
L = laboratory tested and pattern measured
F = field tested
P = prototype constructed

Notes:

1. Limited field testing. Performance equal to or exceeded the RMS antenna. No multipath performance data obtained.
* Reference 3 ** Reference 4

2. These antennas have not been completed and will be covered in individual Masters theses.

Computer simulation is being developed for evaluation of field patterns when the antenna is mounted on a tank or a personnel carrier. The advantages of such an approach should result in money and manpower savings. Initial results will be available in thesis form.

It should be noted that four additional theses will be the direct result of the NPS RMS group effort.

III. PROPAGATION AND EQUIPMENT

The NPS Group section on propagation decided with agreement by CDEC to attempt to determine the multipath effect in the radiation link between A stations and micro-B units on the performance of the RMS system and reliability of range values and data acquisition. To accomplish this investigation a high performance oscilliscope was obtained. To aid in interpretation of results in a potentially noisy environment in the field it was decided to experiment in the laboratory with adjustable "hard wired" propagation paths. Reference 5 details the procedure. The laboratory experiments demonstrated conclusively that wild ranges and no responses occurred when the interfering signal strength and phasing were correct. This occurence not only affected the leading edge of the range pulse but also modified the address and telemetry pulses. The micro-B units and the A station furnished by the calibration facility at Fort Hunter Liggett Military Reservation (FHLMR) performed to specifications for extended periods of time in the cool NPS micro wave laboratory.

Upon successful completion of the laboratory experiments, field testing was initiated at FHLMR. Difficulties were immediately encountered in the field. After several fruitless trips to FHLMR (each time with micro-B units from the CDEC alignment facility and including one unit from General Dynamics) the group decided to investigate the performance of the micro-B units at elevated temperatures in the micro wave laboratory at NPS. The results are presented in Reference 5. Each micro-B unit tested experienced severe sensitivity degradation at temperatures much lower than specification temperatures. Furthermore, the sensitivities did not return to normal when the units were returned to room temperature. A very careful alignment to an A station frequency was devised by the NPS Group. This alignment procedure enabled some field testing to be accomplished at FHLMR.

The results of this phase of the effort are:

1. Instrumentation and techniques were developed to observe and document multipath effects on signals in the field.

2. A large percentage of field micro-B unit failures is due to thermally caused sensitivity decreases. (100% of the micro-B units tested at modestly elevated temperatures experienced thermal degradation.)

3. The leading edge of the range pulse which is used for range measurement can be severely degraded by multipath effects leading to wild ranges.

4. Telemetry bits and address bits were shown to be degraded by multipath effects.

5. An alignment procedure which resulted in improved micro-B performance was developed by the Group.

IV. CONCLUSIONS

The NPS Electrical Engineering Group arrived at the following conclusions.

1. The antennas designed, constructed and tested have been successful. Standing wave ratios when connected to a 50-ohm line have been 1.5:1 or less.

2. The vertically polarized antenna system now in use is suspect in the FHLMR and Camp Roberts terrain. The circularly polarized antennas designed at NPS show prospects of improving the RMS system performance. Note: They are not recommended for quantity purchase and installation at the present time. Much additional comparison testing and evaluation is required.

3. Multipath or Rayleigh fading propagation effects contribute significantly to the ranging and telemetry problems encountered by the RMS system.

4. The thermal sensitivity degradation of the micro-B units is a significant factor in the unreliability of the RMS system in the field.

5. A large percentage of the existing broomstick antennas that had been physically damaged can be economically repaired as demonstrated by the NPS technician, V. Mc Cullough.

6. The problems itemized in 3 and 4 above may be masking other significant problems in the remainder of the RMS system.

7. The NPS alignment of the micro-B units is not a cure for the thermal degradation of sensitivity. The problem is still there although temporarily hidden.

V. RECOMMENDATIONS

1. Field radiation studies by the NPS Research Group should be continued at Fort Hunter Liggett. An intensive study should be made in an area that has proven troublesome when experiments were instrumented. These studies in propagation should include explicitly the following:

(a) With the existing vertically polarized radiation R-F link determine a sufficient number of locations that exhibit multipath effects and/or screening effects and accurately mark these sites.

(b) At the determined locations measure field strengths from the A station.

(c) Determine at the A station site the field strengths from each of the field locations.

(d) Still using vertical polarization at both locations (i.e. A and the several B locations) take a series of interrogations and responses to each of the field locations.

(e) Use the prototype circularly polarized antennas at both A and B unit sites for a series of similar interrogations and responses. The range data and telemetry information obtained will be used for comparison purposes. Continue this testing with vertical and circularly polarized antennas in various combinations.

2. The cause of the degradation of the sensitivity of the micro-B unit due to elevated temperatures must be determined if the reliability of the RMS system is to be improved. It is suggested that this investigation be made before additional hardware effectiveness is evaluated.

3. Based on the NPS Group's experience with the RMS system, it is strongly recommended that an integrated total system investigation and analysis be made.

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