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THE ARMY'S ELECTROMAGNETIC ENVIRONMENTAL TEST FACILITY

A Presentation

by

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In 1901 the first case of radio frequency interference (RFI) was reported as a "serious transmitter interference" during the press coverage of the International Yacht Races. At that time the interference was regarded as an inconvenience; however, by 1955 the picture had changed.

The Army, guided by the experiences of World War II and the Korean conflict, published a regulation stating the Army's policy on RFI. A portion of this regulation states, "Radio interference, by degrading the performance of communications equipment, endangers the attainment of military objectives and the lives of personnel." Thus, with the passage of 50 years, RFI which was once considered a mere inconvenience is now recognized as a formidable enemy capable of creating havoc on the battlefield. The regulation mentioned above delineates the following responsibility to the Chief Signal Officer: "Developing the instrumentation and procedures necessary for the measurement of radio interference and radio interference rejection." A portion of this responsibility was further delegated to the United States Army Electronic Proving Ground at Fort Huachuca, Arizona; and in 1960, after several years of planning, work was begun on the Electromagnetic Environmental Test Facility.

This facility concerns itself primarily with the interference problems encountered by tactically deployed units. Through "worst-case" experiment design, the facility is capable of detecting the presence of interference; determining the amount of degradation this interference will cause; pinpointing the source, or sources, of interference; and recommending the means to effectively reduce this interference. The environmental nature of this facility allows these measurements to be made under the same conditions which the equipment would experience in a combat situation. These capabilities will allow the Electromagnetic Environmental Test Facility to meet its objectives stated as follows:

1. To reveal and determine the incompatibilities of existing army equipment and systems.

2. To suggest modifications to existing army equipment to reduce interference.

3. To provide a firm basis for the establishment of realistic standards for new army equipment.

4. To test army methods of frequency assignment.

5. To test newly developed army equipment prior to its acceptance by the Army.

In order to provide the listed capabilities and thus enable the accomplishment of the above objectives, the Electromagnetic Environmental Test Facility has been further divided into:

a. A field facility.

b. An RFI prediction model.

The field facility is an outdoor electromagnetic laboratory encompassing approximately 2,400 square miles of desert in southern Arizona. It represents an objective, sophisticated interference-measuring system in which actual hardware is measured for interference under realistic conditions. The RFI prediction model is a digital computer program which, when completely validated by field data and provided with proper input data, will be capable of providing varied interference information heretofore unattainable. The validation techniques will be presented in a companion paper; Research Foundation, consequently, the remainder of this paper will be primarily concerned with the field facility. It should be remembered, however, that the objectives of the Electromagnetic Environmental Test Facility will be achieved by a combination of both its components.

The dimensions of the field facility are 40 x 60 miles -- the approximate frontages and depth of an army corps. In this case there are three divisions forward and one in reserve. The reason for selecting this particular area of the United States for this facility is based upon the availability of land and the low ambient electromagnetic environment. Although the "electromagnetic vacuum," claimed by some newspaper reporters in referring to this area, would be desirable an ambient does exist and special measures have to be taken to insure consideration of this parameter. As of this

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writing, the field facility possesses the capabilities of testing the communication links of a division in the electromagnetic environment created by the communications equipment and selected forward radars of a corps. This capability is achieved by the accomplishment of the following functions:

1. Generation of an environment equivalent to that which the equipment tested would experience if it were deployed under battlefield conditions.

2. Control of the environment to facilitate rapid testing and provision of the frequency monitoring capability to assure accurate results without interfering with the electromagnetic activity outside the test area.

3. Testing of communication links in such a manner that the existence, extent, and cause of interference may be determined objectively.

4. Evaluation of test results to enable accurate analysis of a situation and provide the basis for corrective recommendations.

The function of generating an environment is achieved by the use of actual military, communications-electronic equipment deployed in accordance with a realistic tactical scenario. The first step in the achievement of this function was the determination of the type of environment to be created; and since the success of an army is determined by its action on a battlefield, a tactical situation was determined to be necessary to test the effect of RFI on military operations. The size of the unit selected was that of an army corps -- with three divisions forward and one in reserve. This type unit was selected because it contained an adequate cross-section of army, communications-electronic equipment as well as the provision for sufficient density to test facility capability and a means of model validation.

A typical corps area with frontage and depths similar to those used in the field facility has many communications-electronic emitters. This corps has approximately 15,000 C-E emitters -- 12,000 of which are communication types. If testing were to be accomplished throughout the entire area, it would be necessary to place the entire 15,000

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emitters in the field. This presented severe economical and physical problems; consequently a closer examination of the emitter population revealed that equipment was in general employed in bands parallel to the front. The first band could represent the small front line company and platoon type equipment, the second band could represent company headquarters and possibly battle group equipment, etc. Thus, if a path were selected parallel to the front line there would be little gradient in the types of communications-electronic equipment found. Furthermore, if this path were to run perpendicular to the front line, there would be a definite gradient in the type of equipment located along the path. It was determined that two test sites would suffice. The Forward Test Site (FTS) is approximately 4 miles from the front between the first and second band. The Rear Test Site (RTS) is located in the fourth band approximately 19 miles from the front. Both sites are centrally located in the center division of the corps. At the present time, the FTS represents a company while the RTS represents division main.

After the test sites had been selected, it was necessary to determine what emitters must be deployed in the facility to create a realistic environment at those sites. To accomplish this economically and yet retain realism, the following reduction rules were evolved.

1. Radio silence
2. Effect at test site
3. Net principle

The first of these rules was based on a tactical assumption that units in reserve would be observing radio silence. The second rule states that any emitter which does not contribute to the environment at either of the test sites would be eliminated. The third rule set forth the application of the netting principle which in general states -- where emitters are netted on one frequency, only one of these emitters would be in a transmit mode at any particular instant of time. Accordingly, the remaining emitters in that particular net could be eliminated. The application of these rules resulted in the final requirement for 412 communications emitters and 83 noncommunications emitters in the field facility. It should be noted here that the 412 communications-type emitters was the number used during the first 2 years of the contract. Experience during this period has shown that additional emitters are required, and these will be employed during the subsequent 3-year period.

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Although the 412 emitters represents a feasible quantity, it was necessary to group these to ease the problem of control. This grouping is based on a theory which states that an emitter can be moved 15 degrees in azimuth and 25 percent of the distance between the emitter and the test site without changing the effect of that particular emitter, at the test site, by more than a matter of several decibels. The application of this theory allowed the emitters to be grouped around vans which are referred to hereafter as Environment Generator Vans. Those sets which were close to the test site had to retain their deployment as required by the tactical scenario. The end result was the utilization of 26 EG sites consisting of the 2 test sites and 24 EG vans. EG

Up to this point, we have considered the EG's as emitters without describing their type, characteristics, etc. Due to the availability of the equipment and to retain the realism required in the facility, the actual tactical communications-electronic equipment would be used for environmental generators. Due to the automatic nature of the facility, it was necessary that certain modifications be made in the army equipment to enable performance monitoring. The monitors assure that when the performance of the equipment falls below accepted standards, the equipment is automatically placed in a standby condition and this fact recorded. Three types of monitoring are presently utilized for communications equipment: RF output, modulation, and -- in those cases where radioteletype is utilized -- frequency shift keying input. Although the modifications for the radars presently utilized in the facility are in the planning stage, indications are that the parameter utilized to determine performance in the case of these equipments will be magnetron current. The next function to be considered is that of control.

The control function of the facility is centralized at the forward test site from which control links extend to the various EG sites and to the RTS. Each EG site controls the EG's or actual transmitters located in the vicinity of that particular site. Control is achieved by the use of a punch card system in which the same deck of cards is used to control the test as well as record the test results.

The hub of this control system is the control console located at the forward test site. This console with its associated equipment

REAR TEST SITE

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starts each test, determines the mode of operation (whether it is to be manual or automatic), and constantly monitors the performance of each of the EG sites. In addition, this control point issues the commands to the various EG sites to advance one card out of a deck which has been furnished each site prior to the commencement of each test run. If the commanded card does not drop, a malfunction indication is given to the console operator who manually advances the card at the site in question.

At each of the EG sites, when the card commanded by the forward test site drops into the card reader, pre-punched commands are passed to the EG's. Should any of the EG's experience a malfunction during a specific test, this information is held in memory throughout the period of the test. Following that specific test, the information that was held is punched into a card which reflects the status of the various EG's. It should be noted here that a period of approximately 3-1/2 to 4 seconds is allowed for the environment generators to warm up before the malfunction circuit is placed into operation. This warmup period allows the generators to reach the specified values for RF output, modulation, etc. When an EG malfunctions during a test, the test run will continue; however the operator at the EG site will be advised of the malfunction and will correct it as soon as possible.

The frequency monitoring portion of the control function is achieved through the use of five environmental analysis vans. Four of these vans are located on the periphery of the facility and one mobile van is located within the facility. At the present time, these vans have a frequency monitoring and direction finding (DF) capability extending from 500 kilocycles (kc) to 1 kilomegacycles (kmc). Plans are presently under way to extend this capability to 15 kc and 10 kmc. These vans continually monitor the spectrum which is in use by the field facility to determine the presence of intermittent contributors to the ambient electromagnetic environment. This information is necessary to insure that all possible contributors have been considered in the assessment of any specific interference problem. In addition, these vans check the utilization of frequencies by the field facility to insure that assigned frequencies are properly used and to check against excessive frequency drift and/or modulation.

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The testing function is accomplished in two distinct phases. The first phase is the preparation of the test plan -- the first step of which is the establishment of realistic frequency assignment sheets. In the preparation of these sheets, standard army frequency assignment practices are utilized to insure that no interference problems are intentionally generated. The second step is to determine which communications links are to be tested. Each link consists of a transmitter located within the field facility and a receiver located at a test site.

At the FTS the receivers are located at ground level deployed around the test site which is in a depressed area to prevent any masking of the signals arriving at the test receivers. At the present time, there are two classifications of test links utilized in the field facility. The first type, a class I link, indicates that the particular link has a definite tactical connotation. The class II links are those which lack any tactical connotation and are used to provide additional data points for model validation. The number of class I links is strictly limited by the tactical scenario used as well as by the type of headquarters being represented by each specific test site. The number of class II links is limited only by the number of possible transmitter-receiver combinations. Once the desired test links have been determined, a set of cards is prepared to accomplish the "set-up run" for the test links in question. A set-up run is based on worst-case experiment design in that all transmitters in the environment are energized to determine whether or not, with the entire environment "on", the test link in question suffers any degradation. If no interference is encountered during the set-up run, no further tests are conducted with that particular test link. If interference is encountered an isolation run is planned. At the present time, isolation runs have been standardized so that only one set of cards is required -- an isolation deck consists of approximately 1,617 cards. These cards are so prepared that the first step in isolation is the cycling "on" of each emitter -- one at a time. The second step utilizes lattice square design to determine which, if any, doubles were causing interference. The third step examines the rows and columns of the lattice squares so that tables of redundancy may be applied to determine third and higher order intermodulation interference sources.

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The second phase of the testing function is the actual performance of tests as indicated by the test plan. In a simplified test involving only one environment generator site and the Field Test Site, one of the transmitters is selected as a test transmitter and the remaining transmitters are utilized to establish the environment. The test transmitter is modulated with a test signal while the other EG's are modulated in accordance with their normal tactical usage. At the FTS, a received test signal is processed through interference detection equipment, and the amount of degradation suffered is punched on the test card. This entire test period requires 30 seconds for completion. Of this 30 seconds, approximately 20 are utilized for testing time.

Presently, there are two types of interference detection equipment which are referred to as voice-interference analysis sets (VIAS) and radio teletypewriter interference analysis sets (RTTIAS).

The voice-interference analysis set is basically a modernized version of the Licklider machine and is based on the French-Steinberg theory. The test signal used for voice-interference analysis is a 950-cycle sine wave modulated by a 5-cycle-per-second triangular wave. This signal establishes the level of operation for the VIAS. The entire speech spectrum is broken down into 14 equal information carrying segments based on modified French-Steinberg theory, and the signal-to-noise ratio of each of these segments is evaluated. Following this evaluation, all of the ratios are summed, a mean value determined, and this mean value is turned into an articulation index ranging from 0 to 1 in 20 data levels. This information is then recorded on a punched, test card.

The RTTIAS is much simpler, in that it utilizes a character-by-character comparison between sent and received copy. In practice, a 100-character test message is sent, and the score is determined by the number of correct characters copied.

At the present time, measurement of degradation in noncommunications equipment must be carried out subjectively by operating personnel; and although an objective method for making such measurements is planned for the future, provision for this capability is not expected for several years.

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The final function of the facility is the evaluation of the data collected. It should be stated at this time that the actual evaluation of data is just beginning. Although the facility is now over 2 years old, the major portion of this period was spent in building the facility and developing its present capabilities. Also, the data collected in the early phases was not objective in nature and therefore is not regarded as significant for evaluation purposes.

The evaluation function is divided into two specific areas:

a. The tactical significance of the interference information gained.

b. The analysis of equipment deficiencies predicated on their interference potential.

The determination of the tactical significance of the interference data is a two-fold task. First, it is necessary to determine the probability that the set of circumstances which caused the interference would actually occur in any specific tactical situation. Before this part of the evaluation can be completed, additional information on the relative duty cycles of military equipment will be necessary. To this end, the contract recently let by the U.S. Army Radio Frequency Engineering Office for an "Environmental Data Collection and Processing Facility" will be of great value. The second step is to establish the allowable degradation for each tactical link tested. This involves a determination of the type of traffic which would normally be passed on this specific link, the type and level of interference which is experienced, and finally, the amount of interference that can be tolerated before the link becomes unusable. At the present time, no specific criteria has been established for allowable degradation. Until this information is made available, the data from the field facility cannot be evaluated in this specific area.

Present evaluation of the interference potential of specific pieces of communications-electronic gear shows promise of yielding significant data in the near future. Basically this evaluation is predicted on the compilation of interference data for each type of communications-electronic equipment used in the facility. Before the end of 1962, sufficient data will be available to provide a basis for establishing the trend in equipment-caused interference. When this trend

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indicates that certain equipments are constant offenders, they will be removed to the laboratory for examination and through investigation of interference reduction specifications will be completed. From the results of these laboratory tests, changes will be made to the equipment reflecting proposed modifications or changes to specifications; and the equipment again returned to the field test facility. Where it is apparent that the changes or modifications have resulted in a significant decrease of interference, these changes will be forwarded through appropriate military channels to be considered for incorporation in existent military specifications or for modification work orders.

Since the requirement for realistic military specifications for the reduction of RFI is a common meeting ground for military and industry, let us give a closer examination to the part which the Electromagnetic Environmental Test Facility can play in the achievement of this goal. What are "realistic" reference military specifications? Certainly if a specification requires complete shielding, any designer can design a "completely shielded" piece of electronic equipment; however, if an additional specification requires that the piece of equipment be man-portable, this complete shielding may become a problem. Thus to be realistic, the specification must stay within the limitations imposed by the state-of-the-art. The second part of this definition of "realistic" is based on the intended military usage of the equipment and upon the environment in which this equipment will operate. The first interference regulations included a statement that spurious emissions, including audio and radio-harmonics, would be suppressed to the "lowest practical level." There was, and still continues to be, some question as to the significance of "lowest practical level." As a result, the military specifications are generally more specific. By way of example: In the case of the military specifications for local oscillator radiations, Military Specification MIL-I-11748B (SigC) specifies a maximum of 400 $\mu\mu$w. But what does this regulation actually mean? What interference have we actually prevented by limiting, in this case, local oscillator radiations to 400 $\mu\mu$w? In early investigation in the Electromagnetic Environmental Test Facility (EMETF), it was discovered that the local oscillator radiation from a Radio Set AN/VRC-10 (a vehicular mounted FM receiver/transmitter) did actually result in degradation of a communications link. A laboratory investigation

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of the equipment involved indicated that the local oscillator radiation, rather than being limited to 400 $\mu\mu$w varied between 800 and 14,000 $\mu\mu$w. Here, then, is the problem. Of three AN/VRC-10 radio sets examined for the amount of local oscillator radiation, none met the military specifications. Indeed, most of them were beyond this specification by a factor of ten. Further questions arise -- can industry maintain the 400 $\mu\mu$w requirement? Is it necessary to retain this specification? Can the specification be relaxed, and what factors must be considered to determine what the true value should be? All these questions, can, in time, be answered by the EMETF so that the specifications will not only be in accord with the capabilities of industry but will also insure that all interference-limiting design specifications are actually required for the specific piece of equipment; for the specific use to which this equipment is to be placed; and reveal a cognizance of the environment in which the equipment must operate.

What is our final hope? May we hope for an interference-free communications system? Or perhaps, be more realistic and plan an electromagnetic environment in which interfering sources are present, but do not exceed the allowable degradation. Measurement facilities such as the EMETF will aid in the establishment of allowable degradation, and further specify design requirements which must be met in order to insure that this allowable degradation is not exceeded. This much the military can accomplish. The only question remaining is whether or not industry, through its scientific potential, can provide the technical advances to meet these requirements.

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