NEW CONCEPTS OF EW ENVIRONMENTAL SIMULATION FOR OPERATOR TRAINING

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THE IMPACT OF CHANGE

To be effective in the field of EW environmental simulation we must be aware of and design in accordance with technologies that vary as a result of other technologies. For just as technological changes have varied the environment in which the EW operator finds himself, they have also altered the equipment with which he samples that environment. This continuing technological growth of radar and ECM equipment must, therefore, be accompanied by an expansion of equipment and techniques for the training of operators.

That technologies change is certainly not a new problem; it is the rate of change that has become the challenge and seems to create more problems for us than it resolves. As a result, equipment and techniques must teach operators to react effectively in tomorrow's environment, not in yesterday's - or even today's. Instructors must be able to help students learn to adapt to changing environments with new ECCM techniques rather than simply teaching them how to respond to existing environments and known sequences. The operators must be continuously trained to adapt to these changes in hardware and the language used to describe them or the panic of obsolescence will severely attenuate his learning potential and his ultimate usefulness in an environment that requires his expertise. The environment in which he operates has become extremely complex and very unforgiving of mistakes.

Effectiveness is, however, only one side of the coin - the trainer approach must also be efficient. What, for example, is the impact of the trainer on the user's already limited resources? Does he have to become proficient in other disciplines and terminologies (computer programming, etc.) to be able to operate the trainer? Does the trainer allow modular growth - that is, can he continually expand the capabilities of the trainer without obsoleting the existing equipment? Efficiency does not happen by accident; it is a result of a continual awareness of technological trends and customer requirements. Accordingly, the purpose of this paper is to consider some of the current technology in EW simulation equipment and of the changes in technologies which have facilitated their development.

TRENDS IN SEMICONDUCTOR TECHNOLOGIES

Rapid changes in technologies is certainly not a new challenge in this century. In the past 70 years, for example, the aircraft industry has made a drastic change. From small, flimsy flying machines with only slightly better than rubber-band propulsion, we have moved to planes of monstrous proportions whose landing gear dwarf the planes of the Wright Brothers. The B-52, for example, is a 1000-times heavier than the Wright Brothers' plane and the 747 is twice as heavy as the B-52. By comparison, the changes in the semiconductor industry have been just as drastic - but in the last 10 years, and in the opposite direction. Typical area reductions of 1000-to-1 have been obtained in the past 10 years.

Currently, the trend to make better instruments in less volume for less money is the result of development philosophies in most companies. Massaged by such concerns as the energy crisis and inflation, designers are building instruments so intelligent and so small that they need computers to understand their operation and electronic microscopes to work on them. Without a doubt the main factor in this increase in sophistication is the change in the semiconductor state-of-the-art (SOA). Significant examples of these changes can be found throughout the digital, analog, and RF disciplines.

As an example, consider the change in the requirement to build a 16 x 4 bit random access memory (RAM). A graphical history of the changes in the cost and area requirements for the RAM is shown in Figure 1. During the early 60's, if you had wanted to build such a RAM using discrete components, approximately 1000 components would have been required with approximate costs of $225./bit. A total area of 150 inches^2 and 3.5 to 4 watts of power would also have been required. In the mid to late 60's the advent of small scale integration devices provided the first significant change. Use of components such as the SN 7400, 7474, etc., allowed cost reductions of 80 to 1 and size reductions of 6 to 1. In the early 70's, the MSI devices provided further decreases and in the last few years the availability of LSI components such as the SN 7489 has provided us with the 16 x 4 bit

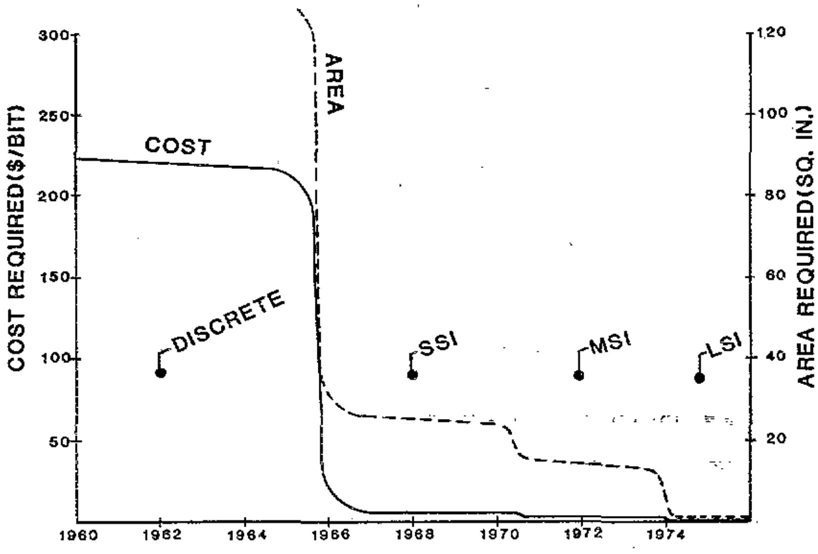

Figure 1. Cost/Area Variation-Vs-Time for 16 x 4 RAM

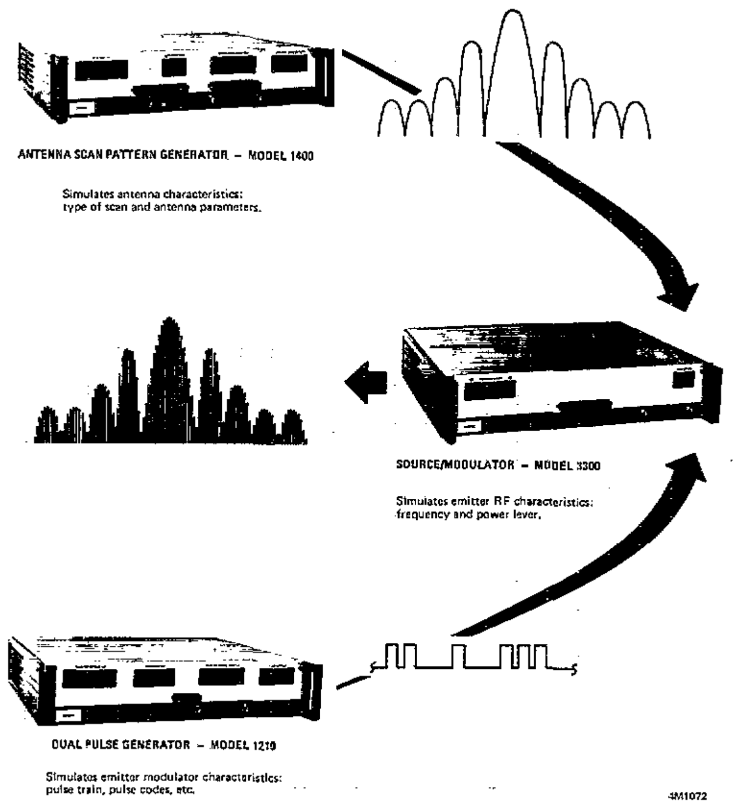

Figure 2. Programmable Emitter Model

RAM on a single chip. The total decrease in cost/bit in the past 10 years has been 1500 to 1 and the decrease in area has been 150 to 1.

The change in the next few years might not be quite so drastic, but it will be significant. IC manufacturers are currently working on many techniques to increase density with less power. The fastest growing of these is integrated-injection logic (I^2L). I^2L will offer greater densities with less power dissipation than even MOS technology at speeds comparable to bipolar. I^2L circuits will also be able to operate off of low voltage batteries. Use of this technology in conjunction with low power RF oscillators and low power analog and pulse circuitry as currently used in the ANTEKNA Model 1418 will lead to emitter models which fit in the palm of your hand. Such emitter models will also provide sufficient realism to test the signal analysis circuitry of receivers currently being developed.

In the linear IC area four quadrant analog multipliers have changed drastically in only the last five years. Area requirements have decreased by a factor of 10 during that time, but accuracy and stability have increased significantly. Analog generation of many complex, transcendental equations can now be accomplished quite accurately using only a few components and requiring mW of power.

The state of RF source technology has also changed significantly over the past decade. In this case the changes have not been a decrease in size but rather significant increases in band coverage, power out and spectral purity. The main changes during the next five years will continue to be increased frequency coverage and power output.

EFFICIENCY: A RESULT OF COORDINATED DEVELOPMENT

Obviously, to take full advantage of such significant changes, a company's development plans would have had to include components such as these in the designs. That is, to use video tape recorders to recreate such functions as antenna scan patterns and video pulse trains would not have resulted in such a significant increase in efficiency as would the use of digitally-controlled analog processing equipment. Even the use of computers to generate required scan and pulse patterns would not have resulted in such significant increases in efficiency and versatility.

In summary then, current technologies facilitate the development of EW simulation equipment in three ways:

1. Currently available digital and analog components allow the generation of complex analog scan functions and pulse sequences in a fraction of the space required only a few years ago.

2. Currently available YTO and VTO's allow simulation of RF signals with high accuracy and repeatability or frequency modulation with 5- to 20-MHz rates over the entire band.

3. Digital data sources from cassette recorders to computers are available to control the operation of these signal sources. Simulators from small to portable systems to large laboratory systems for receiver T & E or operator training can thus be controlled.

But, to provide efficient EW training equipment requires more than efficient instruments; the system itself must allow the user to operate effectively without excessive demands on his resources. Efficiency must be designed in during development programs. Consideration must be given at least to the following:

1. Simulation systems must continue to allow modular growth - newly developed equipment, for example, must be compatible with previous equipment.

2. Computer control systems must allow the operator to set up realistic threats with sufficient accuracy to be processed by new receivers with advanced signal sorting capabilities.

3. Software control systems must allow the operator to program threats in terms of standard radar parameters instead of computer languages.

4. Developments to simulate dense background environments must be altered to provide equipment to generate dense threat environments with complex threat and threat sequence simulation.

5. Systems must be capable of stimulating receivers at either RF or video to allow T & E or training on a variety of receivers instead of simply providing synthesized displays - for specific receivers. Use of computers to synthesize displays on indicators cannot test or evaluate the equipment nor adequately train operators in the understanding of anomalies and distortions inherent to his equipment.

CURRENT EW SIMULATION SYSTEMS

In 1972 a large trainer was built and shipped by ANTEKNA to the Navy to train operators in the field of electronic intelligence. The trainer consisted of six racks of computer-controlled instruments simulating 40 simultaneous emitters in the COMM through microwave bands and in a two-hour scenario provide hundreds of different emitters and attack sequences. The stimulator was designed to drive four separate receiver types and provide a simulation situation in which subsurface, surface, and airborne emitters move relative to the subject vehicle.

Simulation of emitters was based on the ANTEKNA programmable emitter model which consisted of three rack-mounted instruments as shown in Figure 2.

The basic philosophy behind the emitter model design is not to use the computer to perform functions more simply done by inexpensive function generators nor to include in the devices complicated circuits to perform math routines more simply done by the computer. Each emitter model or target can be programmed by the computer to synthesize a desired signal. Without further intervention the emitter model would continue to simulate the signal throughout the scenario. Alternately, one second later or at any time throughout the scenario, the emitter model can be set to establish an entirely different signal. As such, computers with less than 24K core and without mass storage devices can be used to program and control elaborate scenarios.

Subsequent feedback from the operators on the initial trainer have been very positive - mainly insofar as reliability and operation are concerned.

- The approach and the products were found to be very reliable. Data supplied by the customer shows the following results:

Total Number of Devices	105
Total System Operation (Hours to Date)	6726
Total System Down-Time (Hours to Date)	72
System Availability	98.9%
Total Failures (All types for two years)	56

- Mission scenario preparation can be controlled by students. The trainer conversational programming and scenario preparation sequence were so straightforward that the instructors changed the curricula to include a training task in which the student prepared his own scenario, loaded it into the computer, and checked the results. According to the instructors, this has provided an unusually high transfer of analysis skills and retention of operational tactics.

- Use of the trainer for T & E. The trainer was also used to evaluate a complex new receiver system by the customer during off hours. Thus, the overall efficiency of the site was increased appreciably by performing operator training during the day and T & E at night.

Since 1972, four other large trainers equal in size to the first trainer and many smaller trainers were installed at various sites throughout the United States and Canada. Each of these trainers indicated the same reliability as the first, and each again verified the viability of the emitter model approach to the EW environmental simulation.

NEW SIMULATION TECHNIQUES AND EQUIPMENT

In late 1974 and early 1975, a study was made concerning the emitter model approach and how it compared to the current state-of-the-art as well as customer requirements since both had varied significantly since 1972. A development program was then started to:

- Develop new techniques to simulate dense threat environments using less hardware.

- Provide a portable environment.

The result of this development was the Model 1418, Model 3400, Model 7236 series and the Model 6000 PDS series.

Model 1418 Multiple Scan/Pulse Generator

The Model 1418 was designed specifically to generate dense environments containing realistic threat signals and lock-on sequences as well as background signals. The Model 1418 contains eight independently controlled, asynchronous scan pattern generators and eight independently controlled, asynchronous pulse generators. Each scan generator can be independently set to simulate scan patterns such as circular, conical, omni, unidirectional, and bidirectional. With the addition of the optional complex scan module, scans such as raster, palmer raster, palmer and spiral can be simulated. The pulse generators provide asynchronous crystal-controlled pulse trains which can be programmed in 1-Hz increments. With the addition of the optional complex pulse module, complex pulse sequences with up to 16 pulses per burst can be simulated. The outputs of each scan and pulse generator are available at the rear panel as parallel outputs or as a single multiplexed-scan and multiplexed-pulse output. Figures 3 and 4 show scope presentations of a possible setting of the eight scans and eight pulse trains as sampled from the parallel output connectors. In addition to these outputs, a four-bit binary word containing the target number of the scan/pulse on the multiplexed output is available. This data word can be coupled to additional units such as the Model 3400 and Model 7236 to set the frequency and range and bearing of the target being simulated.

Model 3400 Fast Tuning Source/Modulator

The Model 3400 incorporates a fast slewing VCO and operates in conjunction with time-multiplexed pulse and scan signals generated by the Model 1418 to simulate up to 16 signals throughout any of the standard octave or waveguide bands from 0.5 to 18 GHz. The

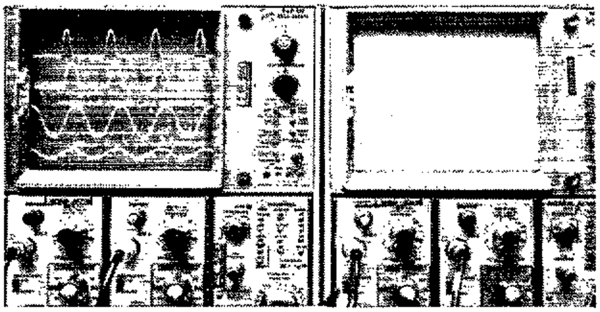

Figure 3. Typical Arrangement of the Eight Programmable Scan Patterns of Model 1418

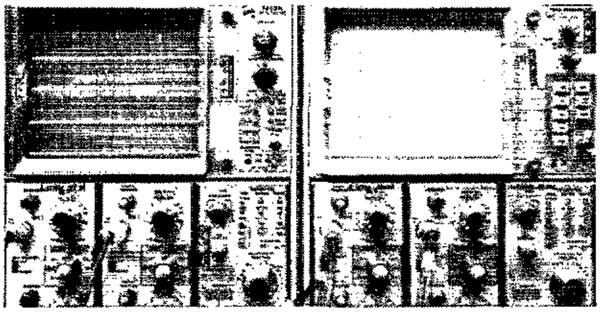

Figure 4. Typical Setup of the Eight Programmable Pulse Trains of the Model 1418

Model 3400's incorporate fundamental oscillators to provide greater output power with increased spectral purity. Special control circuitry has been included in the Model 3400 to minimize post tuning drift and enhance frequency stability.

The Model 3400 provides the capability to change RF frequency under program control in a few microseconds, making it possible to change frequencies on a pulse to pulse basis. Additionally, the Model 3400 incorporates a frequency and level (or range) random access memory (RAM) to store data words of up to 16 different RF frequencies and levels. These settings may be accessed randomly or sequentially to set the output frequency and/or level. External inputs are also provided for frequency modulation (up to 20-MHz deviation rates) and amplitude modulation.

The Model 3400 can, therefore, be used in such applications as multiple RF emitter generation, frequency agile and pulse compression radar simulation, noise jamming simulation, complex pulse radar simulation and wide band RF signal generation.

Model 1418 and 3400 Multiplex Interface

The Model 1418 and 3400 can be operated together to stimulate a single or multiple signal environment. The multiple signal environments can consist of either of the following arrangements:

- Up to eight signals, each with independently selectable scan pattern, PRF, PW, RF Frequency, range and bearing (when used with Model 7236).
- Up to 16 signals, each with independently selectable PW, RF Frequency, range and bearing (when used with Model 7236). In this case signal pairs (not necessarily adjacent in frequency) will have common scans and PRF's.

The units normally operate on a multiplexed frequency basis. Obviously, such an approach offers some disadvantages as well as advantages. The disadvantage is the resultant pulse drop-out. Circuitry has been included in the Model 1418 and 3400, however, to decrease this drop-out to typically less than 1% on a statistical basis.

Some of the important advantages offered by this approach are:

- Dense environments (16 signals) with minimal hardware (2 units), and minimal interface cabling.
- Higher power outputs as compared to 16 sources combined onto one RF line.
- Increased high power compatibility.

If the multiplexed RF output is coupled to a standard TWTA, multiple emitters can be obtained with full saturated power on each signal without intermod products.

Figures 6 through 9 show scope photographs of the RF spectrum for the Model 1418 and 3400 Mini-System as shown in Figure 5. With the addition of the Model 7236 the MPX RF output can be divided onto four RF lines and modulated to stimulate a quadrant D/F receiver system such as the ALR 45, ALR 46, DPEWS, etc.

The increased efficiency provided by the multiplexed approach can be demonstrated by a comparison such as shown in Figure 10. The system on the right simulates 16 simultaneous RF signals; the mini-system on the left simulates 16 multiplexed RF signals. The significant point to be made is not that the new equipment replaces the earlier devices but rather that it complements the earlier equipment. The new equipments were designed in accordance with ANTEKNA's modularity concept and are compatible with the standard data bus. Thus, the new products can also be added to existing systems to double, triple, etc., the emitter capability of the system with minimal impact on system size.

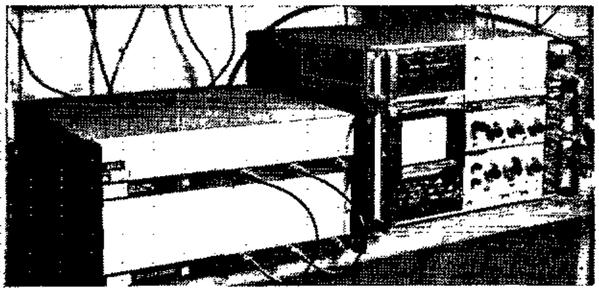

Figure 5. Model 1418/3400 Mini-System Test Setup

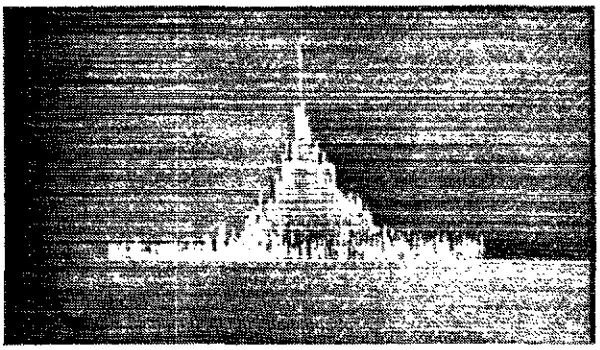

Figure 6. Single Signal Spectrum Display of a Model 1418/3400 Mini-System

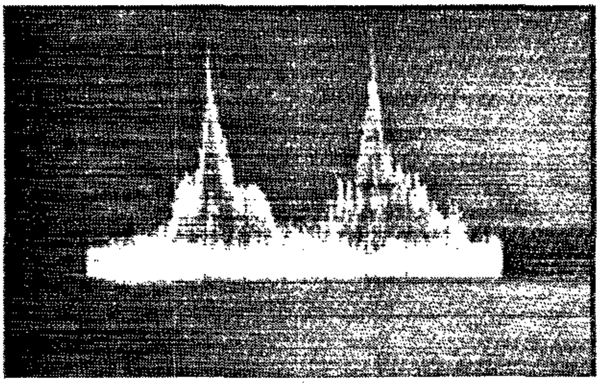

Figure 7. Two Signal Spectrum Display of a Model 1418/3400 Mini-System

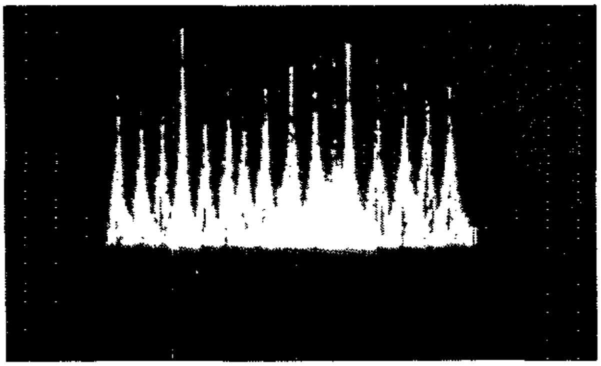

Figure 8. Eight Signal Spectrum Display of a Model 1418/3400 Mini-System

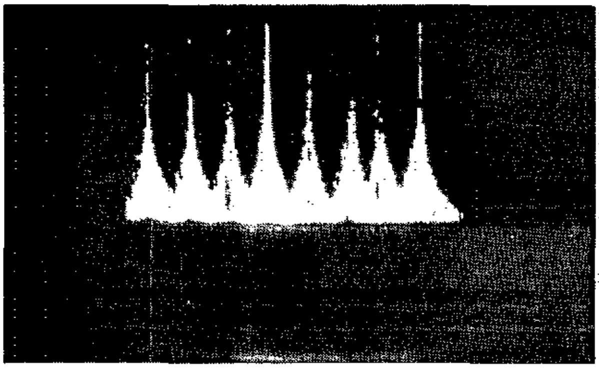

Figure 9. Sixteen Signal Spectrum Display of a Model 1418/3400 Mini-System

Alternately, new requirements could start with a few signals using the Model 1210/1400/3300 emitter model (with front-panel control) and expand to include dense signal capability at a later date by adding 1418/3400 mini-systems. Basically, of course, this growth is the heart of the modularity concept.

THE PORTABLE ENVIRONMENT

Model 6000 Portable Dynamic Simulator

The PDS 6000 is a single-man transportable "suitcase" simulation device which economically provides multiple radar and communications emitters with complete dynamics of motion and fully automatic control. Using a digital cassette unit to provide the required control dynamics, the PDS is designed to effect efficient in-vehicle training for EW, communications and radar operators in a variety of applications. Both the Model 1418 and the 3400 have a repackaged, portable version which can be inserted into the 6000 case and controlled by the Model 6280 Digital Cassette Unit. Additional modules can also be added to provide D/F modulation (quadrant or resolving antenna receivers), manual and remote control, complex pulse/guidance simulation and special purpose units.

A single case, for example, weighing less than 50 pounds can be coupled directly into the WLR-1, WLR-6, etc., to provide 16 emitters moving relative to the actual vehicle. The addition of a second module will provide simulation of simultaneous, multiband threat sequences containing ship search and track sequences phased with missile guidance and homing signals.

CURRENT DEVELOPMENT PLANS

The EW environment is by no means stagnant; neither should be the techniques of its simulation. Development programs must continue to provide innovative techniques and equipment to prepare the operators for tomorrow's environments. New synthetic simulators which can operate in conjunction with computer-aided

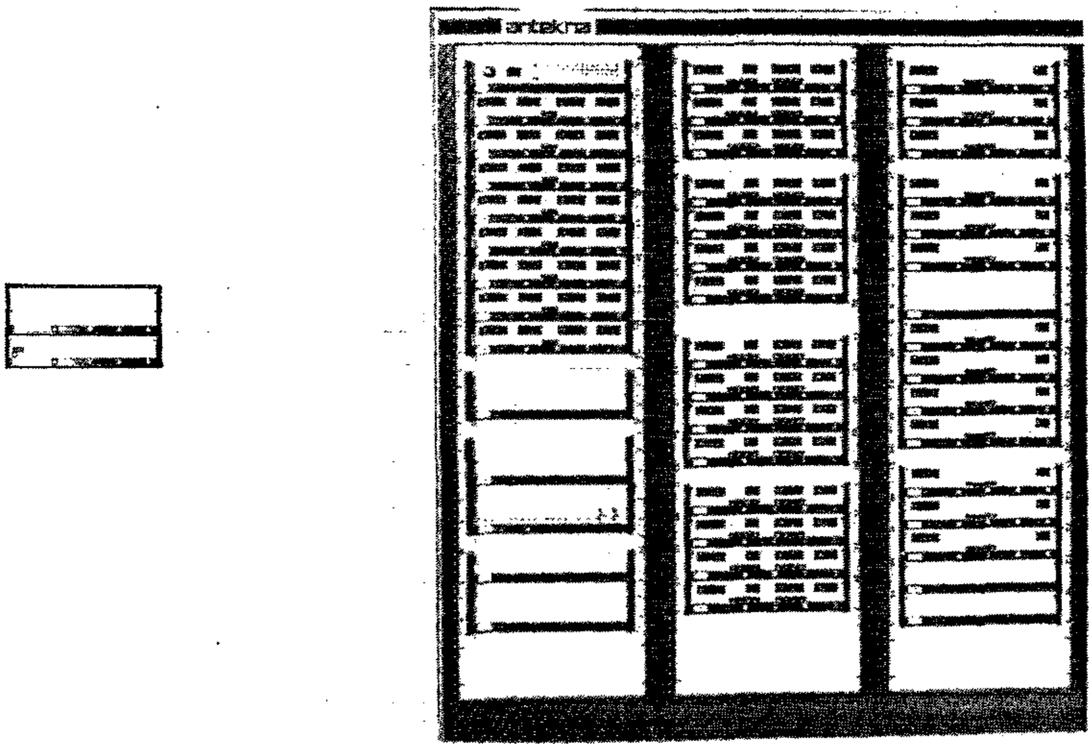

Figure 10. Sixteen Target System Size Comparison

instruction (CAI) concepts are required to effectively train the new operators in techniques of signal recognition. The ANTEKNA Model 4200, soon to start production, was developed to provide a signal requisition training capability in a CAI training environment. A picture of the Model 4200 is provided in Figure 11.

Other areas being considered for development consideration include:

- More efficient techniques of COMM signal simulation.

- Expanded coverage to include millimeter bands.

- Hand-held, walk around environment simulators containing microprocessors for pre-flight testing of the operation of complex receivers incorporating sophisticated signal sorting capabilities.

- Use of microprocessors in the portable units to provide interactive operator training on jammer and ECM equipments.

ANTEKNA is dedicated to providing efficient techniques and equipment to effectively train EW operators and evaluate their equipment. We welcome and appreciate your comments and suggestions.

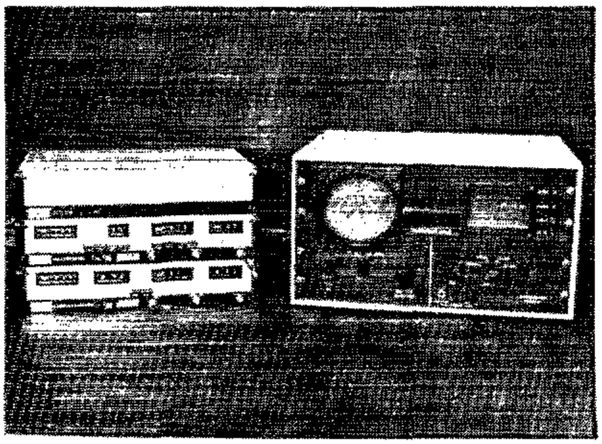

Figure 11. Synthetic Signal Recognition/ Acquisition Trainer

ABOUT THE AUTHOR

MR. WILLIAM H. McMILLAN is the Director of Engineering at ANTEKNA, INC., where his primary activities include direction of all research and development programs as well as project and product developments. He holds a B.S.E.E. degree from University of California at Berkeley. Formerly, he worked for Applied Technology, Division of ITEK, with design responsibility for video processing of portions of various active and passive systems. Prior to his graduation from the University of California, he spent 6 years as an EW operator on B-52's in the Strategic Air Command. During that time, he was involved in the B-52H test program at the Boeing plant and at Edwards Air Force Base, and was awarded the Air Force Commendation Medal for special work in establishing EW training programs and working with the EW student operators. Mr. McMillan has also written numerous trade journal articles on the RF environmental and simulation equipment.