HIGH FIDELITY EMITTER SCRIPTING - A SIMPLIFIED APPROACH

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ABSTRACT

High Fidelity Electronic Warfare (EW) trainers must model the relationships between emitter modes and signals, and the uniqueness of emitting platforms, to accurately support the sophistication of many modern EW receivers. Mode and signal parameter relationships must begin at the emitter scripting phase of trainer development. Typically, this effort utilizes FORTRAN or other High Order Languages, which results in hundreds, even thousands of subroutines to represent an EW library. The personnel generating this library need to have an in-depth understanding of the internal workings of the trainer and are schooled in analytical operational data, computer science, and engineering. To reduce the cost and schedule impact of previous approaches, a new technique is desired which reduces the prerequisites to only analytical skills. Additionally, the system should be easily maintained by military personnel as analytical data changes.

One obvious solution to the emitter scripting problem is to design a trainer that allows creation and editing of emitter parameters via an on-line interactive system. This system requires a set of commands and relationship expressions that allows mode and signal parameters to be realistically correlated, and the randomness of emitter characteristics to be defined. This list of commands and expressions needs to be concise to minimize implementation cost and usage complexity, yet versatile and sufficiently complete to handle the variety of correlations that may occur. The final system requirement is interpretation of these commands and development of unique sets of emitter parameters from the generic emitter data to represent each distinct emitter in a training scenario.

A simplified EW emitter scripting system is easily transportable to new trainers, provides lower cost for initial emitter scripting, and allows easy updates. This paper expounds on the usefulness and implementation techniques utilized to create EW trainers with this type of simplified emitter scripting.

Introduction

The increasing complexity of military Electronic Warfare (EW) detection and classification receivers has caused high fidelity EW trainers to become nearly as complex and sophisticated as the receivers. Trainer complexity has placed a severe burden on instructional personnel, to the point that learning how to operate and maintain the trainer can be as difficult as understanding the operation of the actual EW equipment that is being simulated.

When designing a training system, it is necessary to automate as much of the instructor's task as feasible without reducing the flexibility necessary for training requirements. Automation of trainer functions should be provided to simplify three levels of trainer operation:

1. Initial development data collection and library generation
2. Scenario creation and execution during training
3. Post delivery library updates

The initial data collection and data base generation task can be very time consuming and expensive. High fidelity EW trainers generally require the relationships between emitter modes and signals, and the uniqueness of emitting platforms to be modeled; therefore, this substantial task should be as automated as practical.

Scenario creation and execution during training should be automated to the point where instructional personnel do not need to reference extensive support documentation defining the characteristics of emitter and emitter platforms to create and execute a training scenario. Additionally, the instructor workload should not be burdened with a requirement to manually sequence emitter mode changes.

Post-delivery library updates should be straightforward so that analytical personnel can perform them without extensive knowledge or modification of the operational software or detailed data base storage structures.

To create a trainer that automates the three essential tasks previously discussed, the EW designer must first understand the simulation and/or stimulation requirements of the trainer. If the fidelity is such that emitter mode and signal relationships and unique emitting platforms are a requirement, the designer must select a data collection and library generation technique that is appropriate. Additionally, the library and implementation technique is a function of whether automated reactive mode changes during scenario execution are required. Several techniques have been employed in the past with various degrees of success. One technique that has been implemented, and has resulted in high fidelity simulation, required the use of FORTRAN subroutines to model emitter mode/signal correlations, uniqueness of emitting platforms, and reactive mode changes. This method solved the problem of instructor loading during scenario execution, but was very costly to develop and difficult to maintain by training personnel. Other methods have been tried that are less costly to implement, but these methods have usually placed the burden of achieving high fidelity on the instructional and library maintenance personnel. One technique has emerged that provides high fidelity training through automation of the various tasks of library generation, library maintenance, and scenario execution. This technique utilizes an on-line interactive system that employs a set of commands and relationship expressions to allow signal parameters to be correlated and the randomness of emitter characteristics to be defined. This technique provides a simple method of defining an emitter library that contains the information necessary for a high fidelity simulation.

The scripting of emitter libraries and scenarios for high fidelity EW trainers can be achieved in many ways. The following discussions describe in detail the requirements of an emitter library, various alternatives to library and scenario generation, and a preferred approach to the problem.

Trainer Simulation Requirements

Before exploring the details of various implementation techniques for EW trainer design, a discussion of the simulation requirements of high fidelity EW trainers is in order. Today, many of the EW sensor systems possess the ability to distinguish multiple threats of the same type at identical bearings. They can identify platform types by the mix of emitters received. Emitters of the same type rarely have identical frequencies and scan characteristics in actual practice; therefore, trainers must replicate these unique features for accurate reproduction. The relationships of signal characteristics between emitter modes is a recognizable attribute to EW receivers and operators. For example, the pulse repetition interval (PRI) for mode two being exactly two times that of mode one is an identifiable characteristic. Trained EW operators and operational equipment can generally distinguish these variations and unique characteristics.

The trainer system design that satisfies the aforementioned simulation requirements can be quite complex. This system needs to model many of these characteristics without making the trainer too complex to maintain or operate. Good traits of an EW trainer can be summarized by the following design criteria:

- o High Fidelity Simulation
  - target-unique signals
  - mode/signal correlation
  - platform/emitter linkage
  - automatic mode sequencing
- o Reasonable Cost
  - minimize trainer software and documentation
- o User Friendliness
  - modifiable
  - expandable
  - manageable

Comparison of Design Alternatives

At least three design alternatives with many variations have been implemented on previous trainers to satisfy the simulation requirements of a high fidelity EW trainer. These techniques vary in their capabilities, design difficulty, and user simplicity. A comparison is necessary to identify the superior method. This comparison includes the following criteria:

- o Fidelity - modeling accuracy of emitter characteristics
- o Cost/Design Complexity - initial design cost and schedule impact
- o User Complexity - manageability of emitter libraries, scenarios, and trainer execution
- o Maintainability/Expandability - complexity of adding and/or modifying emitter library data

Table 1 provides a comparison of the three techniques.

Table 1. Emitter Library Design Comparison

Design Approach	Fidelity	Cost/Design Complexity	User Complexity	Maintainability/ Expandability
Table Driven Manual Operation	High fidelity: can be achieved by user defining many variations of each emitter.	Least expensive: large data base requirements.	Difficult: many cases needed to satisfy uniqueness, user overloaded during training.	Moderate: adding new emitter requires entering several examples.
Code Driven Automatic Operation	High fidelity: any emitter uniqueness and mode and signal correlation can be modeled.	Costly and complex: software personnel needed to program each emitter signal, costly documentation effort.	Simple: generic data defined via FORTRAN code with uniqueness programmed, provides for simple trainer execution.	Difficult: adding new emitter requires writing FORTRAN code.
Table Driven Automatic Operation	High fidelity: most emitter uniqueness and mode and signal correlations can be modeled.	Moderate: design not specific to emitters, minimum documentation effort, input to trainer via data entry personnel.	Simple: generic data only with uniqueness defined provides for simple trainer execution.	Simple: adding new emitters requires interactive data entry.

The first technique (Table Driven Manual), can provide high fidelity simulation at a low cost, but this technique places the responsibility and burden of correlation, uniqueness, and coordination on the instructor. To obtain multiple emitters of the same type, but with slightly different characteristics, the instructor must first have each unique variation programmed into his library. During scenario generation, he must select unique copies to provide the desired results.

The second technique (Code Driven Automatic), provides the highest fidelity obtainable. This technique uses the language FORTRAN to define the emitter uniqueness and mode/signal correlations. FORTRAN, with its extensive mathematical and logical capabilities, can easily satisfy any peculiarities that may exist with emitters. Providing a unique FORTRAN subroutine for each signal of an emitter results in hundreds, and possibly thousands of subroutines for a typical system. This implies a costly development, since programmer personnel must be utilized. User modifications or additions of new emitters require additional FORTRAN programming.

The third technique (Table Driven Automatic), utilizes a set of commands and relationship expressions to provide emitter randomness and mode/signal correlations. This design is capable of providing high fidelity when the set of commands and relationship expressions are sufficiently comprehensive to handle most of the anomalies that may occur. Interactive terminals at the trainer's control consoles are used for emitter definition and modification. This precludes the necessity of user comprehension of the software architecture, and allows the user to concentrate on the emitter source data. Furthermore, emitter characteristics can be easily reviewed by the instructor via the trainer's control consoles.

All three design alternatives are workable solutions to high fidelity trainer design. The Table Driven Automatic approach has evolved from the other two approaches, and has proven to be the most desirable solution. The experiences gained from the other two approaches have been applied to create this new technique which provides high fidelity with user simplicity.

Cost Comparisons of the Three Techniques

Data collection, reduction, entry, and validation requires a significant effort for each of the three techniques. A typical trainer can have at least 100 emitters with each having an average of three modes and two signals per mode. This average case results in 600 signals requiring definition and entry into the trainer data base. The data base must also be validated for proper execution. Experience has shown that the first technique (Table Driven Manual) and the third technique (Table Driven Automatic) requires approximately 24 man-hours per emitter. This results in 1.2 man-years for the typical trainer. The Table Driven Manual approach varies depending on the number of unique versions chosen to represent an emitter. The Table Driven Automatic approach requires a non-recurring additional six man-months of design and programming efforts to establish the operational data base scripting system. The second technique (Code Driven Automatic) has proven to be very expensive compared to the two previous techniques. Approximately 80 man-hours per emitter is required since unique FORTRAN source code must be generated and tested for each emitter signal. This results in four man-years for the typical trainer.

The two table driven approaches are substantially less than one half of the cost of the Code Driven Technique. The Table Driven Automatic approach has a higher initial development cost than the Table Driven Manual technique, but it provides a vast number of unique emitter signals, and future modifications are easier to implement. Therefore this technique is a desirable cost effective solution.

Table Driven Automatic Approach

The Table Driven Automatic approach to emitter library scripting can best be understood when its connection to the entire trainer design is comprehended. Figure 1 illustrates the various functions associated with an EW trainer design. The design as illustrated is composed of two major sections, an off-line development portion and an on-line training mode. The salient feature of this design is a simple user interface, which is made possible by a high level of software automation. The instructor's interface to the trainer never needs to go beyond the trainer's control consoles. Almost all data to be entered into the trainer to build or modify its emitter and platform data bases can be performed without significant translation or reduction from the format available in the original source documents.

The Trainer System Design of Figure 1 illustrates four steps that are necessary for an instructor to define emitter libraries, generate scenarios, and execute a real-time training mission. The user input requirements and the associated automation software for each of the four steps is discussed in turn.

STEP 1 - Target Characteristic Inventory (TCI) Generation

This step of trainer definition provides the capability of defining target physical characteristics and resources. Physical characteristics include dynamic maneuvering parameters. Target resources define the weapon and emitter types allowable for each target. Dynamic parameters are used by the real-time training software to accurately model target motion. The allowable emitter assignments provide the instructor with a reference for platform and emitter resources available during scenario generation or on-line training.

STEP 2 - Generic Signal Library (GSL) Generation

The Generic Signal Library (GSL) process is the key element of the automated emitter scripting approach and is where the majority of the automation is provided. The GSL is the differentiating function that causes the Table Driven Automatic approach to excel over the other two alternate approaches discussed previously. Generic Signal Library generation provides the user interface for defining, reviewing, and updating emitter characteristics. The term generic is used since these characteristics are not specific for any one scenario and can

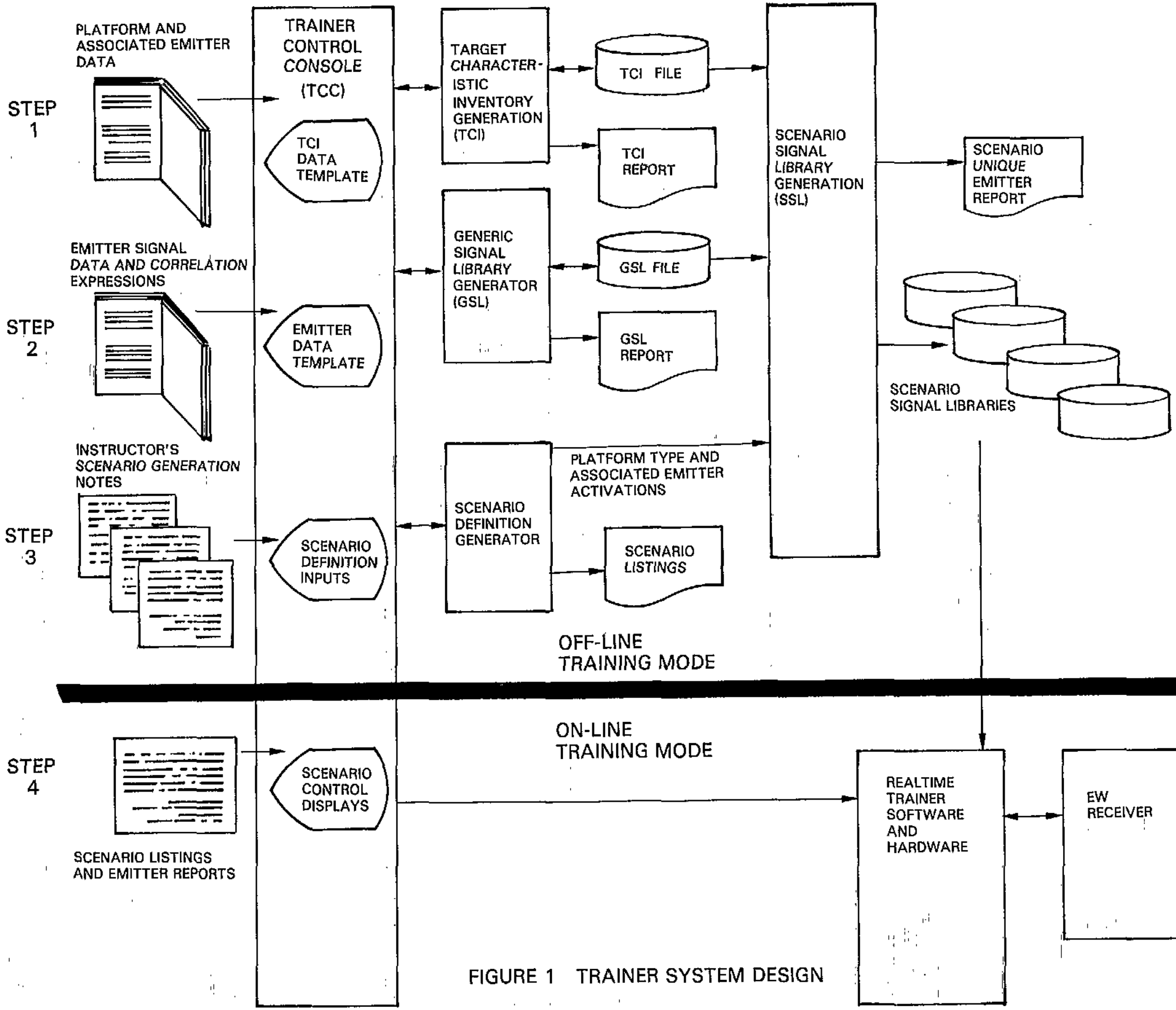

FIGURE 1 TRAINER SYSTEM DESIGN

include a range of values for sampling. These characteristics define emitters over their range of operating conditions. Correlations between signals are defined through a simple set of relationship expressions. The user enters generic data as specified by the trainer control console display templates. The GSL automation software translates the data from the user's input format to the specific trainer data base requirements. As an additional user convenience, error checking is performed to validate data ranges and expression syntax. The generic data base generated is interpreted at scenario generation time to create a unique version for each occurrence of an emitter signal in the training exercise.

A detailed discussion is necessary to clarify the innovative techniques used by the GSL for emitter definition. Templates as illustrated by Figures 2, 3, and 4 represent a few typical emitter parameters required for a generic signal library. Figure 2 represents general emitter information and mode characteristics. The mode characteristics provide for automatic mode changes during training as a function of emitter and ownship geometry and trainee jamming selections. Figures 3 and 4 are representative of the templates required for each signal of an emitter. The parameters listed in the leftmost columns represent the emitter characteristics that are important to the training device being simulated. The second column represents relationship expressions that are responsible for generating the unique signal characteristics and the correlation between signals of an emitter. Table 2 provides a complete list and explanation of the relationship expressions that can be utilized for column two. This list of expressions has proven to be sufficient for modeling emitter signal relationships.

Table 2. Relationship Expressions

Expression Type	Expression Format	Expression Description
Value	Floating point number	Single constant number
Relationship	S (s#, p#)	Same as parameter p of signal s
Uniform	U (x, y)	Uniform random distribution between x and y
Normal	N (x, y)	Normal distribution between x and y
Reciprocal	R (s#, p#)	Reciprocal of parameter p of signal s
Integer	I	Provides integer portion of function
Remainder	M	Provides fractional portion of function
Multiplication	*	Multiply
Division	/	Divide
Addition	+	Add
Subtraction	-	Subtract
Pick	P (x1, x2, ...xn)	Randomly selects one value from x1 to xn. X1 to xn can be any expression above.
Correlation	C (p#, x1, x2, ...xn)	Uses the same "PICK" as selected by parameter p and provides discrete value from x1 to xn list. X1 to xn can be any expression above.

These expressions can be cascaded in any combination and order and are interpreted from left to right. A few examples of these expressions will provide additional insight of their importance. The "PICK" expression, for example, allows discrete or randomly distributed values to be selected. An emitter that has been observed to operate at several different pulse repetition frequency (PRF) ranges for a given signal could utilize this expression. The PRF field of figure 3 would be defined as follows:

P(U(.125, .160), U(.300, .350)).

Evaluation of this expression by the Scenario Signal Library task would yield a randomly selected frequency range, (assume .300, .350). Then a uniformly distributed random value within that frequency range would be selected for a particular occurrence of an emitter in the training mission (assume .310). The "SAME" expression allows equating a parameter with that of a previously defined parameter and signal for the same emitter. For example, suppose the PRF of signal two was exactly twice the value of signal one. Then the PRF field (see figure 4) for signal two would be defined as:

S(1,3)*2.

EMITTER MODE DEFINITION			
*EMITTER NUMBER	001		1-300
*NATO NAME	HIGH FI		
*MODE NAME	SEARCH		
*MODE NUMBER	1		1-16 (MODES)
*APPL SIGNAL NUM	1,2		1-16
*MODE ACTIVATION TIME	6	MIN	0-999
*MAX EFF RNG	60	NM	0-999
*MIN EFF RNG	40	NM	0-999
*JAM MODE SWITCH	3		1-16 (MODES)
*NEXT MODE SEQUENCE	2		1-16 (MODES)

Figure 2. Emitter Mode Definition Template

EMITTER SIGNAL DEFINITION				
*EMITTER NUMBER		001		1-300
*SIGNAL NUMBER		1		1-16
*(1) EFFECT RAD PWR		1000	KW	0-99999999
*(2) TRANSMIT FREQ	U(.99, 1.1)	1.0	GHZ	0-99.999
*(3) PUL REP FREQ (PRF)	P(U(.125, .160),U(.300, .350))	.310	KHZ	0-99.999
* SCAN TYPE		CIR		OMNI/CIR/STD/ SEC
↓	↓	↓	↓	↓
*(4) SCAN RATE	U(.2,.6)	.4	HZ	0-99.99

Figure 3. Signal 1 Definition Template

EMITTER SIGNAL DEFINITION				
*EMITTER NUMBER		001		1-300
*SIGNAL NUMBER		2		1-16
*(1) EFFECT RAD PWR	S(1,1)	1000	KW	0-99999999
*(2) TRANSMIT FREQ	U(1.2,1.3)	1.25	GHZ	0-99.999
*(3) PUL REP FREQ (PRF)	S(1,3)*2	.620	KHZ	0-99.999
* SCAN TYPE		SECTOR		OMNI/CIR/STD/ SEC
↓	↓	↓	↓	↓
*(4) SCAN RATE	S(1,4)*2	.8	HZ	0.99.99

Figure 4. Signal 2 Definition Template

Evaluation of this expression by the Scenario Signal Library task would result in a PRF value for signal two that is twice the value randomly selected from the "PICK" described earlier for signal one.

These examples illustrate how randomness can be easily programmed and signal parameter relationships can be easily maintained. The expressions are thorough enough to handle almost any relationship that may exist, yet simple enough to be memorized in a short period of time. The user needs only to possess experience with analytical operational data and these expressions to perform emitter definition and modification. The trainer software provides the data reduction and interpretation necessary to translate from the user input formats to internal formats and create a high fidelity emitter simulation.

STEP 3 - Scenario Generation

After target and emitter libraries are defined correctly, the instructor can build scenarios to control the activation of targets and emitters at the desired time sequences. The scenario entry is performed via the trainer control consoles, and the input results in a list of target types and emitter activation commands associated with each target type. The Target Characteristic Inventory file built by step 1 is used to translate the emitter activation commands into a specific selection from the Generic Signal Library file built in step 2. This list of GSL emitter types is used by the Scenario Signal Library (SSL) Generator, to create a unique copy for each occurrence of an emitter type activated by the training scenario. The SSL task accesses the GSL data file, executes the signal relationship expressions, and performs random selections of parameters to create discrete emitter characteristics.

STEP 4 - Real-Time Training

Step 4, the final step of instructor interface to the trainer, is utilization of the off-line libraries to provide the high fidelity EW training. The training mode is initiated by the instructor's selection of the scenario of interest. The corresponding Scenario Signal Library files containing unique emitter data for this scenario, are accessed throughout the training exercise. The SSL files provide a unique set of signal data for each new occurrence of an emitter in the exercise. Emitters that turn off for a time period then back on, return with identical characteristics. Automatic mode changes for an emitter, when specified by the scenario, occur as a function of the following:

1. Mode activation time
2. Range from acquiring target
3. Student-selected jamming

These features can minimize the role play emitter activity burden placed on the instructors. High fidelity training is presented to the student by providing emitter reaction to his ownship maneuvering or jamming as selected. Flexibility is provided to the user for deselection of the automatic mode changes in favor of scenario time-activated mode changes or manual mode changes during training.

The automation provided during real-time training is created by general purpose software that interprets and reacts to the data provided by the Scenario Signal Libraries. This automation, in conjunction with the automation provided by the off-line library generation tasks, creates a high fidelity training exercise without instructional overload.

Summary

Designing a high fidelity EW trainer that does not overburden instructional personnel proves to be an extensive task. The large quantity of emitters, with their wide range of operating characteristics and non-uniformity, is a major contributor to this difficulty. A Table Driven Automatic approach has provided an innovative solution to EW trainer design. This high fidelity technique has proven to reduce the burden on instructional personnel, while also providing for a lower initial development cost. Transportability to new trainers, reduced documentation cost, and simplified post delivery library updates are inherent qualities.

About the Author

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