PASSIVE SURVEILLANCE 3D LOCATION FIX SCENARIO SIMULATOR / SIGNAL EMULATOR

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Abstract—Location fixing of targets based on their onboard electromagnetic emissions is a very important aspect of Electronic Warfare scenario.   Multilateration based passive emitter location using geographically distributed sensors is used for achieving high accuracy emitter location.   Since the sensors are geographically distributed, there exists a requirement for simulating the scenario and testing of the algorithms developed for their performance within the lab before the actual field deployment of the system. The present paper brings out the design and realization of a 3D location Fix simulator /signal emulator for use in multilateration based Passive Surveillance Systems.

Keywords—Passive Surveillance Systems, Multilateration DTOA, ESM

I. INTRODUCTION

3D location fix Passive Surveillance Systems are based on multilateration and track emitters based on their on-board transmissions like IFF, DME, radars, and other pulsed transmissions. Multilateration systems have both civilian and military applications. Multiple (usually four or five) time synchronized sensors are installed over a couple of tens of kilometers to cover the region of interest. The sensors are interconnected with a master station using line of sight microwave links or wired links. The distance between the sensors is limited only by the interconnection link, which is the line of sight for the microwave link, which is usually used for data transfer. Each multitude of sensors and Master Station forms a cluster. Several such clusters can typically be spread across the required region for increased geographic coverage.

Simulation and Testing of a multilateration system is not a straight forward affair. The achievable accuracies in a multilateration system are dependent on a number of factors like time synchronization between sensors, distances between sensors, geometry of deployment of sensors, location of emitter with respect to the sensors etc., in addition to the other electrical factors.   Therefore, the technologies and the algorithms have to be tested and proven sufficiently under the expected field conditions in the lab, before the system can be deployed in the field. There is a requirement for a lab based multilateration simulator for this purpose. The present paper brings out the design, development and realization of a multilateration based location fix simulator for algorithm design, performance measures and a user friendly way of

inputting and displaying the results achieved in a PSS Scenario.

II. REQUIREMENTS CAPTURE

A. Multilateration system configuration :

The Passive Surveillance Systems are based on differential times of arrival at geographically distributed receivers which are electromagnetic sensors intercepting the electromagnetic emissions. The time of arrival at each receiver is used to compute the time differences of arrival between pairs of sensors. The System configuration is given in Fig. 1. Each sensor intercepts the signal in the desired frequency band, processes it, forms the Pulse Parameter Word (PPW) for each intercepted pulse, which provides the complete pulse profile of the intercepted pulse including frequency, amplitude, pulse width, intra pulse modulations etc. The formed PPWs are transmitted to a centrally located Master station on a microwave wireless link or a wired link to compute the location fix in three dimensions, azimuth, elevation and range.
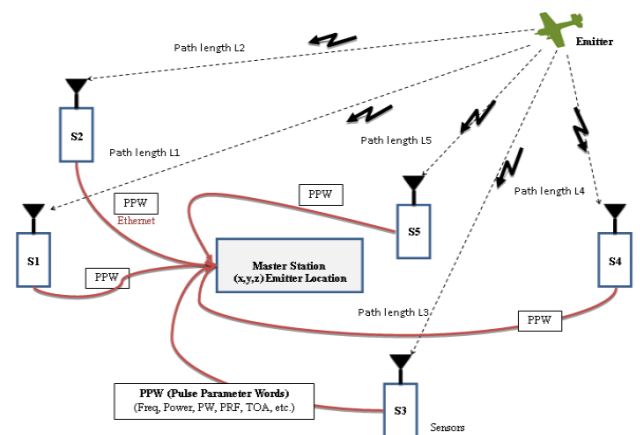

Fig 1. Multilateration radar-sensor scenario

The sensors can be manned or unmanned stations, intercepting the emitter radiation and computing the parameters of the emitted signals. The system design is such that most of the processing functionality is incorporated as part of the master station. Only the pulse parameters are extracted and sent to the master station for computations in the Slave stations.

B. Simulator Features:

Conventional ESM systems provide only the Direction of arrival of the input signals. However multilateration systems compute the emitter location information, in Two Dimensions (2 D) or Three Dimensions (3D), depending on the system configuration.

Testing a conventional co-located ESM system is a relatively simple proposition. The requirement for the far field condition is reasonably realizable physically, which usually is taken as 20 to 30 times the diameter of the ESM system's Antenna Array. This is a few tens of meters for phase or amplitude comparison based systems and a couple of hundred meters for time difference based systems. The ESM system sensitivity permits a commercial signal generator with associated power amplifiers and transmission antennas to be placed at distances meeting the far field criterion. The other requirement of injection mode testing of ESM systems is the ability to generate signals in the required phase, amplitude or time progression as the case may be. The complete system can therefore be tested in the lab in both injection mode and radiation mode and fielded.

The testing of location fix systems, which are essentially distributed systems, however, makes it impossible to test and demonstrate for their performance in lab conditions since the physical geographic spacing of the sensors spans over a few tens of kilometers, leading to a few tens of microseconds delay in case of simultaneous illumination of the sensors, and of the order of milliseconds for scan type of emitters.

The Location Fix simulator/signal emulator has been designed and developed by DLRL to meet the requirements of algorithm development and performance validation for passive surveillance systems in lab conditions.

The following requirements have been drawn while designing the system :
- Should be cost effective
- Should be scalable with respect to the number of sensors, and the number of signals
- Ease of User configurability
- Error profile introduction
- Should be able to emulate the signal profile and provide methodology to be able to independently test the Location fix processor algorithms, without the physical requirement of hardware
- Integrated GDOP/PDOP computation for configuring the deployment of the system
- Should provide a user friendly integrated view of the radar - sensor scenario with respect to Best sensor configuration for required coverage or Best coverage with the specified sensor configuration
- Should be integratable with the actual multilateration system to meet the Master Station system BITE requirements

- Deterministic generation of controls to the RF hardware, controllable to nanosecond timing

An innovative combination of RF hardware, Commercially available software/hardware modules and intelligent calibration mechanism to offset timing mismatches has been carried out to generate the simulation environment and emulate the required signal conditions for development of algorithms, testing and validation of the developed systems.

The System has been configured around Commercial PXI hardware which provides an expandable chassis with a pick and choose option of various modules including signal generators, high performance FPGA Boards, high speed ADC boards, required number of signal generators to meet the number of signals to be physically simulated.

C. Simulator configuration :

The configuration of the simulator is based on the sensor deployment configuration, radar configuration, and the levels within the sensor at which comprehensive simulation, emulation and testing has to be done.

The deployable sensor consists of the following subsystems as given in Fig. 2:
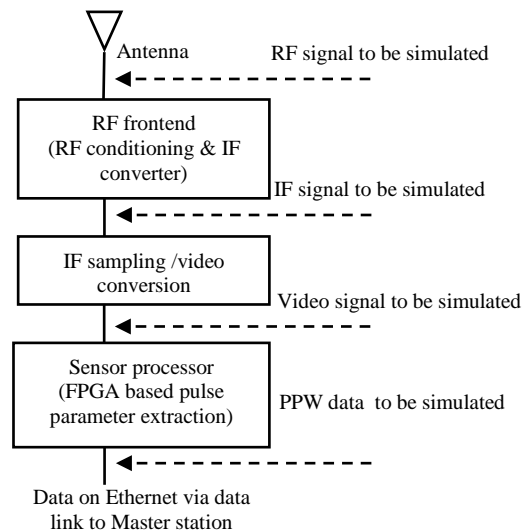
Fig 2. Sensor Configuration & Signals to be simulated / emulated within the sensor

1. Antenna – in the desired band of interest
2. RF frontend – which may consist of signal conditioning and/ or IF converter
3. The frontend output is sampled using a IF or video sampling ADC for generating the digital equivalent of the input RF signal
4. Sensor processor – which may consist of an FPGA based pulse parameter extraction and form the PPWs
5. A GPS / synchronization mechanism to ensure that all the sensors are synchronized to the required accuracy
6. Data Link for transmitted the generated PPWs

The LF simulator has to carry out the following functions :
1. *Scenario simulation*
2. *Signal emulation*
3. *Host controller*

Scenario simulator is used for the following :
1. Model the radars based on theoretical model or existing library data including scan rate, frequency of operation, power levels etc.
2. Model the sensors based on theoretical model or existing library of data including antenna parameters, receiver sensitivity and other electrical parameters
3. Locating the radars and distributed sensors on a map derived from a GIS platform as per user's requirements
4. Generate the signal scenario as received by the sensors based on path lengths
5. Realtime control software for associated Hardware setting and control

The block diagram for Software Interconnectivity of scenario simulator is given in Fig 3.
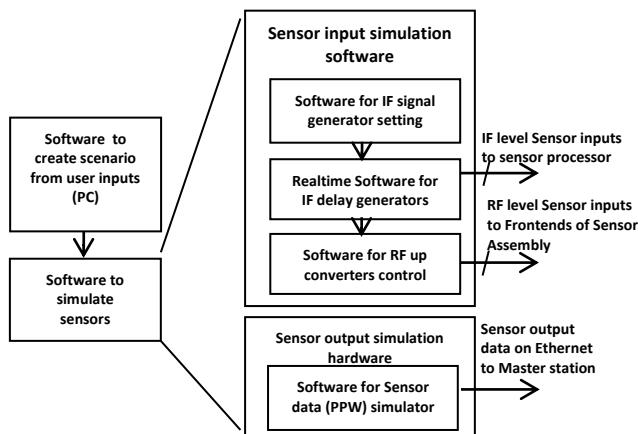
Fig 4. Hardware interconnectivity of multilateration simulator

Fig 3. Software Interconnectivity of scenario simulator

Signal emulator is the hardware configuration which emulates the signals as received by the sensors at various levels based on the control inputs received from the scenario simulator. The CW signal is generated using signal generator, externally modulated using a switch-attenuation unit, controlled & calibrated using an FPGA based controller. The hardware connectivity is given in Fig 4.

Host controller is a chassis based high end PC which used to control all the functionalities of the scenario simulator, signal emulator, configure the system, take inputs from users, generate the required controls to the subsystems based on scenario, Location Fix Algorithms development and evaluation of the algorithms under simulated / emulated signal conditions. The functionality of host controller is given in Fig 5.
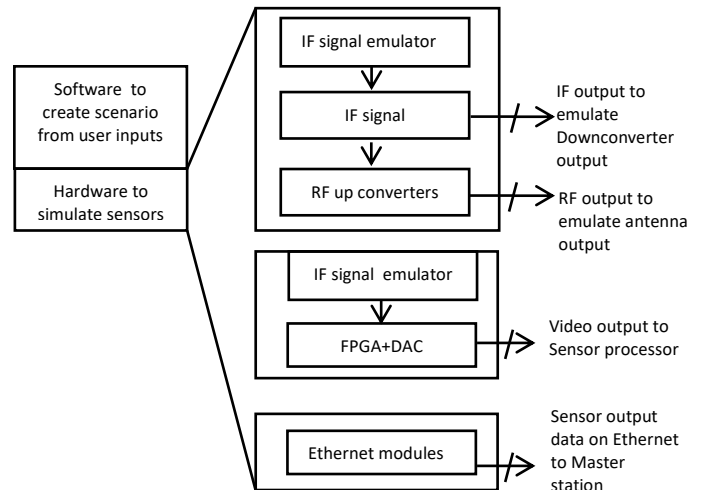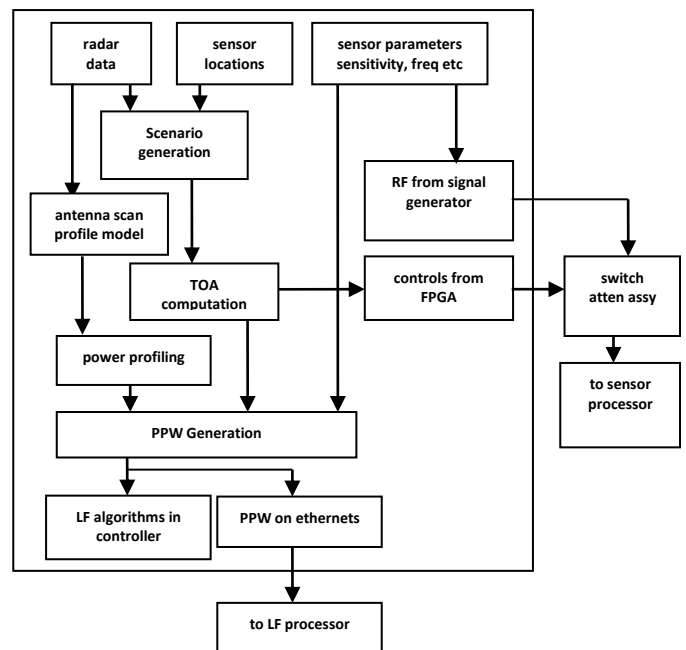
Fig 5. Functionality of Host controller for multilateration simulator

D. Signal Emulation:

Depending on the scenario and the system parameters, the pulsed signals at various levels have to be emulated and generated by hardware. This is done in four stages :

1. Generation of RF or IF signal
2. Modulation of RF signal based on Radar parameters with respect to scan rate and pulse parameters
3. Introduction of appropriate delays in each channel depending on scenario
4. Introduction of error profile on each pulse

The delay calculation between the generated pulses is based on the distance between the sensors locations and the emitter locations in 3 dimensions. Based on the location of the emitter each sensor receives the signal at a different instant of time and the sensor that first receives the signal may be different. Since it is not possible to advance a signal, the sensor that first receives the signal is identified and the controls to the other channels delayed with respect to this channel.
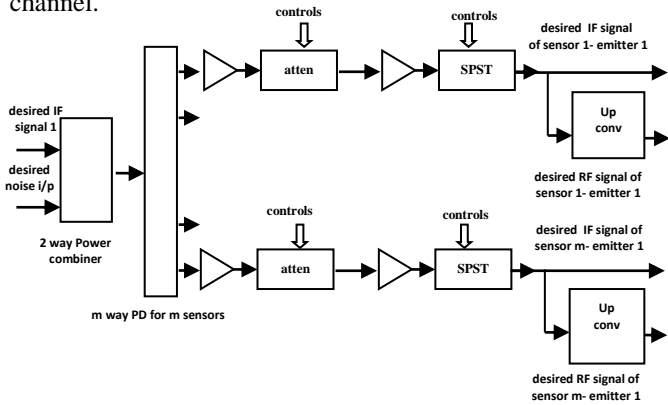

Fig 6. IF/RF emulator configuration for one emitter

The IF RF emulator configuration for one emitter and 'm' sensors is given in Fig 6. The desired IF signal frequency is generated as a CW signal from a signal generator. Required noise is also power combined and fed to an m-way power divider, m being the number of sensors required to be emulated. Each switch is individually programmable for on-off which is used to generate the PW – PRI combination based on the radar to be emulated. The signal in each path is individually controlled with respect to the other paths for emulating the differential delays. The switching control to each SPST switch is generated as per the scenario with appropriate calculated delay. The required delays are generated by an FPGA with 1ns resolution.
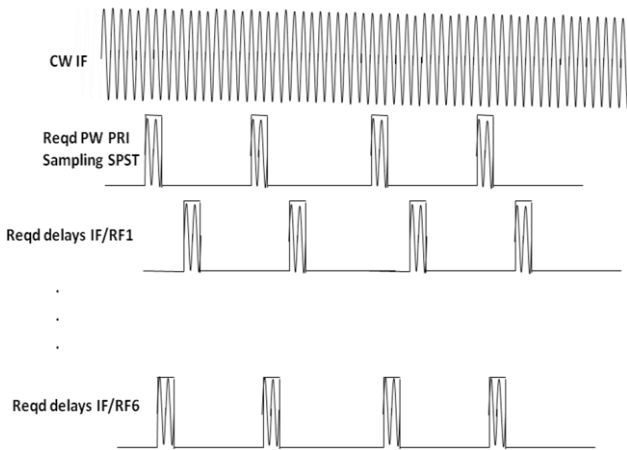

Fig 7. Principle of gating of CW signal for pulse generation

The programmable attenuator is used to generate the modulation of the pulse amplitude based on radar scan pattern and side lobe ratios. The attenuator in conjunction with the generated RF signal power is used to emulate the path loss as seen by the sensor.

The basic output is the emulated IF output of the down converted IF signals in the RF chains of each sensor. Optionally, an up-converter in each chain may be used to generate the desired RF input to emulate the signals as received at the output of the antenna. Alternately, the emulator can be designed for emulating RF level signals also.

If multiple-emitter signal conditions have to be simulated, the number of chains has to be increased.

Fig 7 gives the principle of gating a continuous CW signal to generate the required pulse signals for each of the sensors.

The differential delays of the microwave components has been taken into consideration while designing the system. They have to be calibrated to ensure the required performance is achieved.
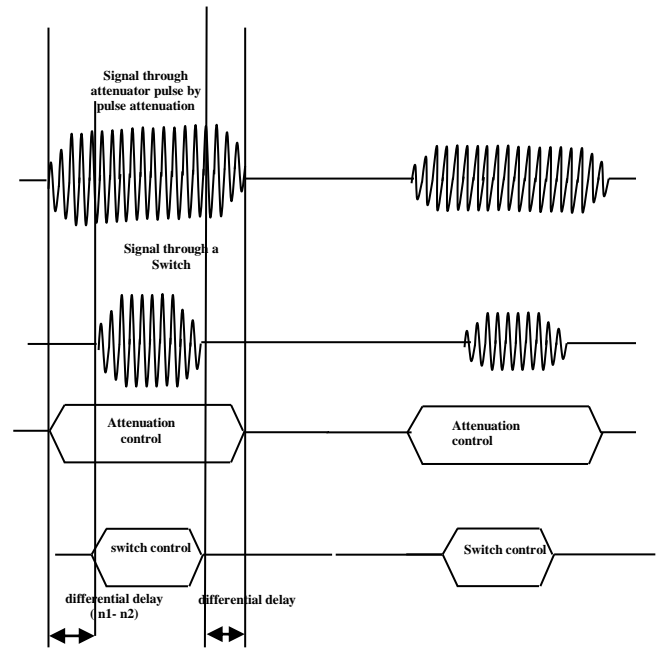

Fig 8. Calibration for differential delays

The programmable digital attenuators have a higher switching time compared to switches, by a few tens of nanoseconds. The calibration procedure involves physical measurement of the differential delays between the attenuator and the switch switching times and program the controls generated from the FPGA in such a way that the attenuator is switched into the required position before the switch is switched on. Fig 8 illustrates the differential delays to be introduced into the switching times. The advantage of using

an FPGA based control generation is the determinism and nanosecond resolution delays which are possible to be generated. Similar approach is taken for calibrating the differential delays in other paths also. The same feature is also used to introduce the required errors in 'time of arrival', on a pulse by pulse basis.

III. Conclusions

Multilateration based emitter location systems, due to their geographically distributed nature, require exhaustive scenario simulation and signal emulation studies so that the delays experienced by each pulse as received by the sensors can be properly modeled. The multilateration based 3D Location Fix simulator/ signal emulator has been designed and developed by DLRL indigenously for development of Passive Surveillance Systems. Using this it is possible to accurately simulate the scenario and generate the inputs and outputs of subsystems of the sensors like RF, IF, video and Data domain signals to facilitate development and validation of algorithms and testing of modules before the system is actually fielded.

Acknowledgments

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