Radar Emitter Location Simulation and Implementation on FPGA

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Abstract—This project aims at developing and implementation of algorithm emitter location for radar. There are two techniques to find out the emitter location. They are (1) Based on Direction of Arrival: in this we use three systems, each system give its own direction of arrival of the emitter signal. By using the triangulation method we can find out the location of the emitter. The drawback of this technique is dependence of the emitter location accuracy on the errors of the direction finding system. (2) Hyperbolic Position Fixing Technique: by using this technique we can measure the time of arrival (TOA) & time difference of arrival (TDOA) of the signal to find out the emitter location. As part of this project the emitter location using the hyperbolic position fixing technique will be implemented. Simulation of the algorithm will be first done in MATLAB then implemented on FPGA with VHDL. FPGA takes distance of arrivals at three or more sensors as inputs algorithm will be implemented on the time differences and outputs coordinates of the emitter. Using this technique we can implement the 2D and 3D emitter location.

Index Terms—Hyperbola, Radars, Position Location Techniques.

I. INTRODUCTION

Electronic Warfare is the practice of technical opportunism and expediency, exploiting weakness in an enemy’s use of electronics for his weapons and sensors, and cleverly taking advantage of features of enemy equipment design or his use of electronic equipment. EW is classified into three categories:

Electronic Support Measures (ESM): ESM is a passive EW System that uses enemy transmissions to support surveillance operations by monitoring the electromagnetic (EM) spectrum.

Electronic Support (ES): ES focuses on action taken for the purpose of real-time threat recognition in support of immediate decisions involving Electronic Attack (EA), Electronic Protection (EP), Weapon avoidance, targeting or other tactical employment of forces.

Electronic Attack (EA): In addition to ECM, Electronic Attack function includes the use of directed energy weapons (lasers, microwave radiation, particle beams), anti-radiation missiles and EM pulse (nuclear weapons, destruction of electronics) to destroy enemy electronic equipment.

II. POSITION LOCATION TECHNIQUES

There are three basic approaches to obtain position location they are
1. Angle of Arrival (AOA)
2. Time Of Arrival (TOA)
3. Time Difference Of Arrival (TDOA)

1. Angle of Arrival (AOA)

It is often important to determine the location of the emitter. A direction finding (DF) system is useful in locating the signal source. A DF system gives the direction of emitter. Two or more D.F. systems are necessary to obtain the location of the emitter by triangulation. Alternatively the D.F. platform can move in space, and taking D.F. measurement at different times, it is possible to locate the emitter.

2. Time of Arrival (TOA)

Time of arrival is another well-known technique used to determine the emitter location. The key point in this method is to determine the time it takes, for the signal, to travel from the source to the receiver on the forward or the reverse link. For this purpose, the base station transmits an inquiry to the emitter and measures the time in which the unit responds.

3. Time Difference of Arrival (TDOA)

In the TDOA method, the DOA is computed based on the difference of the time of arrival. The difference in the arrival time of the RF signal at each pair of antennas with respect to the baseline formed by the two antennas is measured which is proportional to the DOA. The difference of time arrival in turn depends on the span (distance between the antennas) of the base line. The TDOA approach yields high DF accuracy, but the limitations are the requirement of large base lines and high speed processing circuits to measure the time difference of the order of nanosecond very accurately. TDOA approach is useful for pulsed signals only.

III. PROPOSED METHOD

A sensor is a device which receives and responds to a signal. The sensors were placed and fixed. The RF front end is generally defined as everything between the antenna and the digital base band system. The antenna passes the modulated signals along to the RF receiver’s front end. After much conditioning in the front-end circuitry the modulation or information portion of the signal now in the form of analog base band signal is ready for A to D conversion in to
the Digital. Once in digital realm, the information can be extracted from digitized carrier waveforms and made available as video. Development and implementation of algorithm for location fixing in 2D in Virtex4 FPGA is done. Co-ordinates of emitter with sign bits, zone and bearing are observed in LSA.

SCOPE
Development and implementation of algorithm for location fixing in 2D in Virtex4 FPGA.

IV. POSITION FIXING METHOD
Hyperbola is a set of points in which the distance in difference is always constant. Using this property hyperbolic position Fixing Technique is implemented. The hyperbola is the set of points at a constant range-difference from two foci. Each sensor gives a hyperbola on which emitter lies. Intersection estimates location of all hyperbolas. Obviously, the position would actually be determined via algorithms that will convert the TD’s to a more common coordinate system.

For a single base line (AB):
Assuming one of the sensors as base station. Calculate the distance between the base station & other sensor’s.

From ΔABE by hyperbola property i.e. difference in distance is constant

\[ Z = d_a - d_b \]

By using Cosine Law

\[ d_a^2 = d_b^2 + d_{ab}^2 - 2d_b d_{ab} \cos \theta \]

Substitute \( d_b \) in cosine law, by solving

\[ d_a = \frac{1}{2} \left( z - \frac{d_{ab}^2 \cos(\phi - \theta)}{z - d_{ab} \cos(\phi - \theta)} \right) \]

Where
- \( d_a \) -distance between A & E
- \( d_{ab} \) - distance between A & B
- \( \phi \) -inclination angle with base AB
- \( \theta \) - angle made by emitter (E)
- Z- Distance difference from AE&BE i.e. AE-BE
Similarly, the same procedure is repeated for other two hyperbolas in order to locate i.e. for AC and AD base lines.

**ALGORITHM FLOW:**

![Algorithm Flow Diagram]

**Fig 3. Algorithm Flow**

Here Z1, Z2, Z3 are the difference distances. Zone is divided into 6 parts i.e. 30°, 90°, 150°, 210°, 270°, each sector is of 60°. Once the zone exists the counter starts its count from that particular zone. Counter is of 9-bit. The resolved radius is occurred from the three radius i.e. $D_a, D_b, D_c$ The multiplier accepts inputs on buses A and B and generates the product of these two values. Sin and Cos LUTs are generated and multiplied to get X and Y co-ordinates.

**I. TEST SET UP**

The test setup consists of the following method as below shown as

**Fig 4. Test Set Up Using Virtex4**

**Implementation on FPGA**

Along with the VHDL code that is written for the algorithm, a user constrained file (.ucf) is to be written based on the pin connections of FPGA to various other blocks on the board and their locations. Then the program is synthesized, mapped, placed and routed and then a programming file is generated (bit file). This bit file is then dumped on to the FPGA using the JTAG cable.

The synthesis procedure starts with floor planning, i.e., selecting the input output pins, it can be done by executing user constraints > Floor planning area /IO/Logic-post-synthesis.

- Simulation is done in MATLAB implemented in FPGA.
- Implementation on FPGA taking difference as input and output as coordinates of the emitter location.

**V. APPLICATIONS**

The various types of applications involved is

- Position Location system.
- Electronic Warfare.
- Emergency services.
- Commercial Aircraft tracking.

**VI. TEST RESULTS**

USING VHDL
Fig 5. Output Using VHDL Comparing Mat lab and VHDL

Fig 6. Output with Comparison of Mat Lab.

Table 1. Comparison of Values Obtained

<table>
<thead>
<tr>
<th></th>
<th>MATLAB</th>
<th>VHDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-ordinate</td>
<td>(30,30)</td>
<td>(29.318,29.318)</td>
</tr>
<tr>
<td>Radius</td>
<td>42.42</td>
<td>41.81</td>
</tr>
<tr>
<td>Angle</td>
<td>45</td>
<td>46</td>
</tr>
</tbody>
</table>

VII. CONCLUSION AND FUTURE WORK

The location of the radar emitter is done in MatLab, VHDL and compared. It can be implemented in 3D using hyperboloïds instead of hyperbolas.

REFERENCES
