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Modelling of ELINT Receiver, Performance and Direction Finding Capability under Multi Emitter Scenario

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Abstract: Electronic Intelligence (ELINT) is the result of observing the signals by radar systems to obtain information about their capabilities. ELINT provides timely information about threatening system such as radar that guide aircraft or missile to target. It can be installed in all kinds of airborne, sea based, and ground based assets and is used for identifying and avoiding threats. Amplitude comparison direction finding method is used in this design to determine the Angle of Arrival of the received signals by distributing eight antennas circularly. Determining the direction or Angle of Arrival of a radar signal is fundamental to electronic intelligence. It uses eight directional antennas circularly distributed, whose boresight are pointed in different directions. The boresights are typically offset from each other such that the gain patterns overlap along the 3dB edge. When the signals arrived, it is down converted to intermediate frequency using Digital Down Converter (DDC) and Fast Fourier Transform (FFT) is taken. The ratio of power amplitudes of the antennas are compared to known antenna gain patterns which is then used to calculate the Angle of Arrival. The equation of Angle of Arrival was derived by taking the ratio of signal amplitudes between each two adjacent antennas due to their associated Angle of Arrival over 360 directions. This method makes the system simple in analysis and implementation and gives good accuracy and resolution over a wide range of frequencies. This system provides the horizontal (azimuth) direction of the arrived signal as related to the reference direction automatically without steering antennas and then overcomes the mechanical problems. The proposed system in this paper operates over a wide band of frequency (0.5 to 18GHz) and covers the whole 360 degrees.

Keywords: Amplitude comparison, AOA, Direction Finding, ELINT, Multi Emitter.

I. INTRODUCTION

ELINT is used to obtain valuable information while remaining remote from the radar itself. It is most useful in hostile situations; the information could be obtained directly from the radar user or designer. The value of ELINT is that it provides timely information about threatening systems, such as radars that guide aircraft or missiles to targets. ELINT also provides information about defensive systems, which is important in maintaining a credible deterrent force to penetrate those defences. The rotating antenna direction finders suffer from delay time to obtain the AOA because they need a long time to complete one cycle (360°) rotation (the speed of rotation is low). These systems require a pencil beam antenna and high precision mechanical system to provide accurate steering angle of antenna to represent the AOA which complicates its implementation [1].

The super heterodyne DF receivers require long time to scan the frequency over the designed range of frequency. Therefore they suffer from a delay time to find the AOA through one scan of frequency, therefore they are used for small range of frequency [1]. If a frequency scanner is used with direction finder then the system requires synchronization between frequency of the desired signal and measuring the AOA which need more measurement time. The phase difference DF's cannot cover the whole angle (360°) because they cover only a section of a determined angle and require a time and mechanical system to steer the antenna array to the other directions. The direction finders using the principles of amplitude comparison are mostly simple in design and implementation. In this paper the ratio of amplitude of the signal between largest and second largest antennas are taken to find the Direction of Arrival. The proposed system in this paper will use eight directional antennas circularly distributed as shown in the figure (1).This system provides the horizontal (azimuth) direction of the arrived signal as related to the reference direction automatically without steering antennas and then overcomes the mechanical problems.

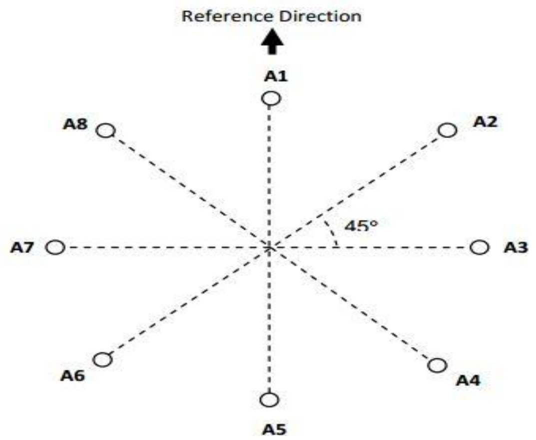

Figure 1: Distribution of Antennas [1]

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ELINT can refer to nearly any non-communications emission. Receiving radar signals is often not difficult because the available power density is quite high. The power transmitted by radar is proportional to the fourth power of the range at which it is to detect a target; whereas the power available at an ELINT receiver is proportional to the reciprocal of the square of the distance from the radar [3]. ELINT receivers may be found in a variety of locations, including ships, aircraft, balloons, and ground locations.

II. SYSTEM DESIGN

Determining the direction or angle of arrival of a radar signal is fundamental to electronic intelligence. Multi lobe amplitude comparison makes use of antennas with their beam peaks (boresights) aimed in different directions (squinted). The amplitude is measured independently in each antenna, and the AOA is calculated as being between the boresight angles of the pair of antennas having the largest amplitudes. The individual channel amplitudes are measured, as are the difference to allow selection of the channel pair having the largest and next-to-largest amplitudes. The actual angle is computed based on the ratio of the amplitudes. This method will provide accurate DOA measurement with less error by associating a RF monopulse beam former within the antenna [2]. This method is normally applied for azimuth plane only. The main advantage of this method in ELINT equipment in which, high antenna gain, coupled with a high sensitivity receiver, allows DOA measurements at the antenna side lobes of the scanning emitter, thus by passing the low PRI relevant to its main lobe.

In this approach to amplitude comparison DF is to use eight antennas circularly distributed in order to provide eight angular quadrants of azimuth coverage. The concept of operation is to compare the amplitudes of the RF emitter signals as received by each antenna. The antennas usually use in ELINT equipment are planar spiral antennas.

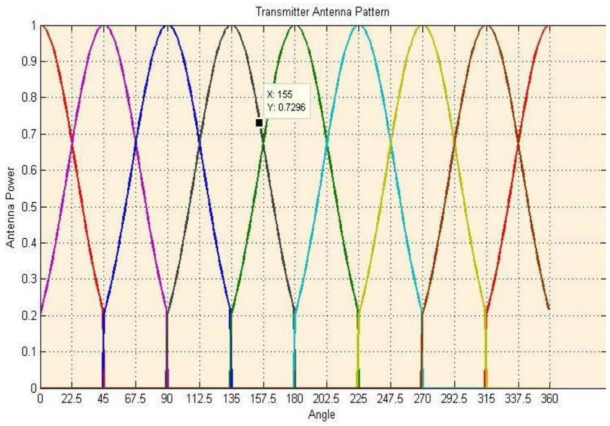

Figure 2: Transmitter Antenna Pattern

The gain patterns of spiral antenna is approximated by a Gaussian function, which is the azimuth plane can be expressed as,

$$G(\theta) = Ai^2 e^{\left[\frac{-k^2(\theta 1-\alpha)^2}{\theta b^2}\right]}$$

Where, Ai is Amplitude gain peak of the Composite Antenna or Receiver,θb is Half power beam width (-3db) of the antenna pattern (for eight antenna configuration, θb =45°, at the lower frequency end of the covered bandwidth.), k^2 is $-\ln\left(\frac{1}{2}\right) = 0.693$ and α is "Squint Angle" that is the half of the angle between the boresight direction of any to antennas ($\alpha = 22.5$ in eight antenna configuration).

A. *DDC Design*

DDC is Digital Down Converter, which works by first shifting the bandwidth of interest to baseband by multiplying the received signal by a close approximation to the original carrier. A Digital Down Converter is basically complex mixer, shifting the frequency band of interest to baseband. Consider the spectrum of the original continuous analogue signal prior to digitisation, because it is a real signal it has both positive and negative frequency components. If this signal is sampled by a single A/D converter at a rate that is greater than twice the highest frequency. The continuous analogue spectrum repeated around all of the sample frequency spectral lines.

The first stage of the DDC is to mix, or multiply, this digitised stream of samples with a digitised cosine for the phase channel and a digitised sine for the quadrature channel and so generating the sum and difference frequency components, the mixer frequency has been chosen in this example to move the signal frequency band down to baseband .This spectrum of both phase and quadrature signals can now be filtered using identical digital filters, to remove the unwanted frequency components. The phase and quadrature samples must be filtered with identical filters. The unwanted frequency components fall outside the pass bands of the filter, giving the resultant spectrum for both phase and quadrature [4]. The sample frequency is now much higher than required for the maximum frequency in our frequency band and so the sample frequency can be reduced or decimated, without any loss of information.

The received signals are of high data rates making it difficult to process the signals to extract information of interest. Filtering is implemented in stages to obtain efficient response. A DDC allows the frequency band of interest to be moved down the spectrum so the sample rate can be reduced, filter requirements and further processing on the signal of interest become more easily realizable. DDC's typically decimate to a lower sampling rate by using several stages of decimation filters. Before decimation, filtering is performed using linear phase filters to limit the bandwidth to our signal of interest. The decimated signal, with a lower data rate, is easier to process on a low speed DSP processor.

The output of DDC is I and Q data that is nothing but real and imaginary part of the signal. These real and imaginary signals (I and Q) will convert to a complex signal by a "Real-Imag to complex" block in Simulink. Buffer block is used next to this to buffer input sequence to a frame size. The Buffer block always performs frame-based processing. The block redistributes the data in each

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column of the input to produce an output with a different frame size. Buffering a signal to a larger frame size yields an output with a *slower* frame rate than the input. In this block we can mention the required buffer size. In this model the buffer size is 2048**.**

B. *FAST FOURIER TRANSFORM – FFT*

FFT is a faster version of Discrete Fourier Transform. The FFT utilizes some clever algorithms to do the same thing as the DFT, but in much less time. FFT takes a signal in the time domain and transforms that signal into its discrete frequency domain representations. FFT is used in this design to operate the system in multi emitter scenario. That is if more than one radar is present at a time, this receiver is capable of processing that signals simultaneously and find the Angle of Arrival. The output of FFT data is an array of complex values, are again converted into real and imaginary parts using "Complex to Real-Imag" block in Simulink. The I and Q of the signal is solved to using the equation shown in the following subsystem in Simulink.

C. *ANGLE OF ARRIVAL*

The measurement of the emitter AoA is accomplished by considering two antennas that receive the strongest signal amplitudes have to be considered and the ratio of these two power levels after the logarithmic amplifiers have to be evaluated. The ratio R (in dB) of the two power levels after the logarithmic amplifiers is simply the difference between the two outputs.

$$\text{Rdb} = A_{1db} - A_{2db} + 48\left(\frac{\alpha\theta}{{\theta_b}^2}\right)$$

The ratio of Rdb between two strongest signals is proportional to the emitter AoA. Therefore the emitter's Angle of Arrival is given by,

$$\theta = \text{Rdb}\left(\frac{{\theta_b}^2}{48\alpha}\right)$$

III.SYSTEM CHARACTERSTICS

There are certain factors should be considered when the receiver is operating in real time scenarios. They are the operating Frequency, Range and threshold value detection.

A. *FREQUENCY COVERAGE*

Frequency coverage of the antenna syst0em and receiver front-end must include all of the frequencies used by the transmitters of interest [5]. In many cases, the frequencies in use are not known, and thus wide frequency coverage is the rule for intercept systems. In this system the airborne radar use 2-18GHz**,** the ground radar receiver system will be in 0.5-18 and 0.5-40 GHz configurations.

B. *DYNAMIC RANGE*

The idea of dynamic range is simple to convey: it is the ratio of the largest signal amplitude that the receiver can process to the smallest signal amplitude that the receiver can instantaneously process [5]. A precision phase measurement within the pulse requires a larger signal than simply stating that a pulse has crossed a threshold. Likewise, the largest signal that can be tolerated also depends on the measurement being made. Making a precise ERP measurement when the radar's main beam is pointed toward the intercept receiver requires that saturation be minimized; whereas a frequency measurement can be made after a limiter and saturation is of little importance if only one signal is present. This receiver system is designed to operate within 1000 Kilometres range.

C. *THRESHOLD DETECTION*

Threshold detection plays a central role in automated ELINT receivers, since it is necessary to first make a decision that a signal is present before any parameter Characteristics of ELINT Interception Systems measurements can be made.

The only difference is that for radar receivers detecting target echoes, the receiver post-detection bandwidth and pre-detection bandwidths are matched to the transmitted signal and to each other. In an ELINT receiver, particularly the wideband types that most often use automatic detection, the ratio of the RF bandwidth to the video bandwidth can be quite large, which affects the statistics of the output noise.

IV.RESULT

An incoming signal is simulated by specifying the values of amplitude, frequency and direction of the signal. The amplitude received at each of the four antennas is calculated and amplitude comparison technique is employed to determine the approximate angle of arrival of the received signal.

The error in the angle of arrival is ranging from 0.1 to 0.5 degrees only. The antennas with the maximum value of signal amplitudes are compared with other two antennas with respect to their FFT points.

The FFT outputs of four antennas with incoming signals are at 10 and 150 degrees respectively. So it will have power in Antennas 1, 2, 4 and 5.

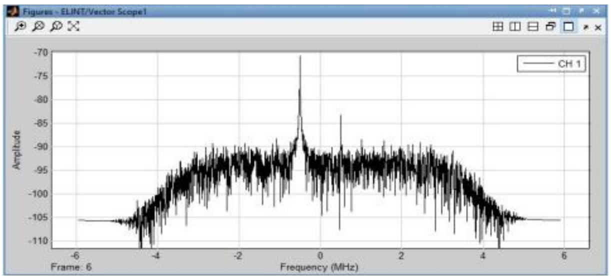

Figure 3: FFT Output of Antenna 1

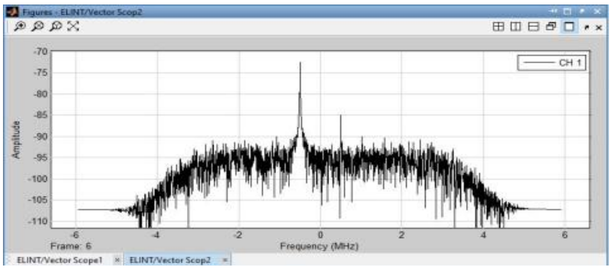

Figure 4: FFT Output of Antenna 2

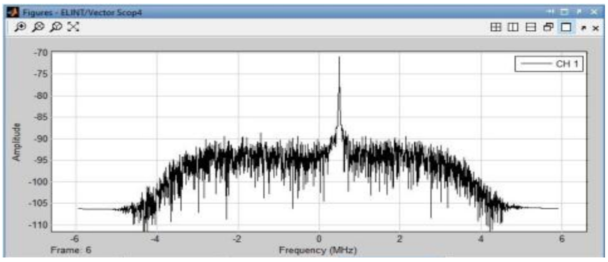

Figure 5: FFT output of Antenna 4

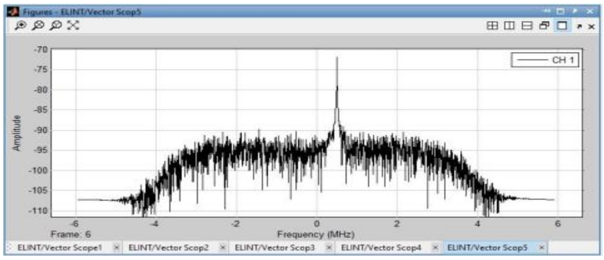

Figure 6: FFT output of Antenna 5

V. CONCLUSION

The purpose of this paper is to simulate the ELINT receiver model and thus by understanding the direction finding capability of the algorithm under various operating conditions. This model is simulated under varying operating range and noise. This algorithm is accurate and efficient than any another method and it will give final angle of arrival with minimal angular error. In this method amplitude is measured independently in each antenna, and the AOA is calculated as being between the boresight angles of the pair of antennas having the largest amplitudes. The individual channel amplitudes are measured, as are the difference to allow selection of the channel pair having the largest and next-to-largest amplitudes. The actual angle is computed based on the ratio of the amplitudes. The error in final angle of arrival is very less even under various operating conditions.

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