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Precision Direction Finding of Radars from an Airborne Platform

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Abstract: ***Electronic warfare is the military use of electronics to prevent or reduce an enemy's effective use and to protect friendly use of electronic radiation equipment. In precision direction finding of radars from an airborne platform, the method used is very simple and efficient. By finding the rate of change of phase difference, the direction of the ground based radar can be found from the aircraft. The aircraft consists of antennas on its wings and it receives the signals which are transmitted by the ground based radar. First, the path difference between the antennas and ground based radar is found. From the path difference values, the phase difference is found for each time intervals. Rate of change of phase difference is obtained by finding the difference between two successive phase difference values with respect to a particular interval of time.***

Keywords: Path Difference, Phase Difference, Antenna

1. Introduction

Precision direction finding of radars from an airborne platform deals with finding the direction of a ground-based radar by an aircraft .The aircraft consists of antennas on both sides of the wings and it receives the signals which are transmitted by the radar. The method used here is finding out the phase difference between the antennas present on the wings of the aircraft and the ground-based radar.

By finding the rate of change of phase difference, the direction of the ground based radar from the aircraft can be found. This method has its applications in Electronic warfare (EW).

2. Theory

Path difference is the difference between the lengths of two paths. When two waves have the same frequency, and travel at the same velocity, and travel the same distance they will keep the same phase difference. Phase difference is the difference expressed in angle or time between two waves having the same frequency and referenced to the same point in time. Using the path difference, the phase difference can be found.

Radar is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecrafts, guided missiles, motor vehicles, weather formations, and terrain. Radar consists of a transmitter which produces electromagnetic waves in radio or microwave domain which is received by the antennas present on the aircraft and it reflects the signal back.

By finding the path difference first and then finding the rate of change of phase difference the radar direction can be determined from the aircraft. The following method can be used to find the rate of change of phase difference.

Let us consider two antennas present on the wings of the aircraft separated by a distance d as in fig(1) and ground-based radar radiates signals which is received by it and reflects the signals back. The aircraft move from point A to point B and distance between the aircraft and ground be known. As the aircraft moves from A to B, the phase difference between two consecutive signal changes with respect to time.

Fig(1) shows the aircraft travelling along the path A to B. The base line and the ground-based transmitter is separated by some distance. Transmitter is represented by Tx. Two antennas are present on both the wings of the aircraft which reflects the signal sent by the ground-based radar. The velocity of aircraft and frequency is used for calculating the rate of change of phase difference.

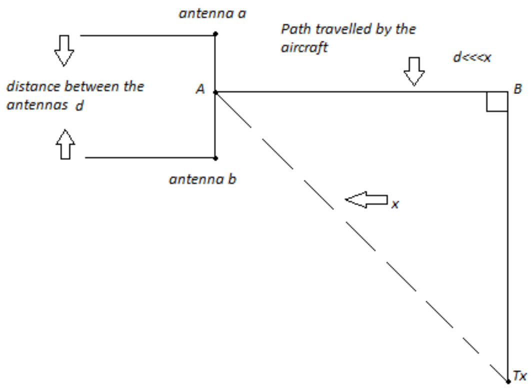


Figure 1:

In the fig (1) value of the path travelled by the aircraft is known and the perpendicular distance between the path travelled by aircraft and transmitter is known, using these values the distance *X* is found using pythagoras theorem.

In fig (2) the path *XE* which is the distance between the *antenna a* to the transmitter is greater than the distance *YF* which is the distance between *antenna b* to the transmitter by *XZ*, this distance *XZ* is called the path difference. Let us consider the triangle *XYZ* to find the angle θ and 90-θ.

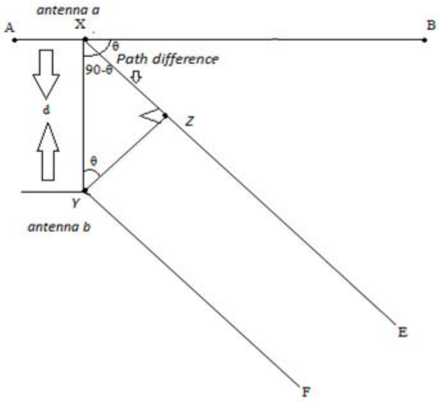


Figure 2:

In the triangle XYZ, by alternate angles are equal rule, the angle in the point *Y* can be considered as θ and sinθ , cos (90-θ) can be found by using the following formulas:

$$\sin\theta = \text{opposite/hypotenuse} \quad (1)$$
$$\cos\theta = \text{base/hypotenuse} \quad (2)$$
$$\cos(90-\theta) = \sin\theta \quad (3)$$

By using the formula cos(90-θ) in the triangle *XYZ*, the base value *XZ* can be found as we know the value of cos(90-θ) which is equal to sinθ and hypotenuse value is also known which is d. The wavelength is calculated using the formula

$$\text{wavelength}(\lambda) = \text{velocity of light(c) / frequency(f)} \quad (4)$$

The wavelength of the signal is known and the path difference is written in multiples of wavelength and its residue .For the given wavelength, the phase difference is 360 degrees. Using this information the phase difference for the given residue is found by using the formulas

$$\text{path difference} = \text{multiples of } \lambda \times \text{residue} \quad (5)$$
$$\text{phase difference} = (\text{residue} / \text{wavelength}) \times 360 \quad (6)$$

Now the phase difference is found at the first time interval. To calculate the phase difference at the next time interval ,a new distance has to be considered as the aircraft moves forward and the distance between the path A to B is reduced as shown in fig(3) . The distance is calculated using the formula

$$\text{distance} = \text{velocity} \times \text{time} \quad (7)$$

The velocity of the aircraft is known and the time interval is known. Now the distance is calculated for the second time interval and this new distance is subtracted from the original distance by which the aircraft is travelling. The distance at second time interval is given by:

$$\text{distance at second time interval} = \text{old distance} - \text{new distance} \quad (8)$$

The distance at the second time interval will be less than the distance at first time interval. Now again the hypotenuse of the triangle and angles of the triangle for new distance is calculated. Path difference and phase difference is found by using the above method. For the next time intervals also the new distance has to be found and then the path difference and phase difference should be found.

By using the above method, the path difference and phase difference at different time intervals is found.fig(3) represents the position of the aircraft at the second time interval given by X'Y'. The aircraft is moved forward along the path AB. The new distance that the aircraft is going to travel is less than the original distance. For this new distance the above calculations are done.

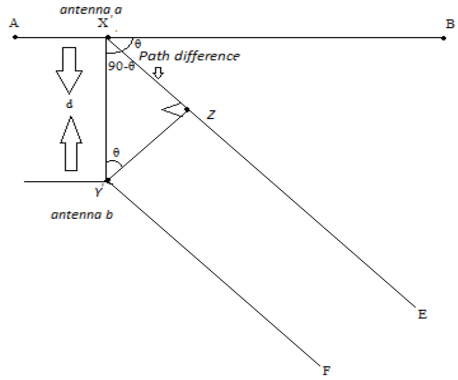


Figure 3:

Rate of change of phase difference: For each time interval, the rate of change of phase difference is obtained by finding the difference between two successive phase difference values with respect to a particular time interval.

$$\text{rate of change of phase difference} = (x2-x1)/\Delta t \quad (9)$$

Here, x1 is the first value of phase difference and x2 is the successive value of phase difference. Δt is the time interval with respect to which the phase difference is considered to be changing.

Fig (4) also represents the path difference *xy* and the distance between the two antennas present on the wings of the aircraft and the transmitter.

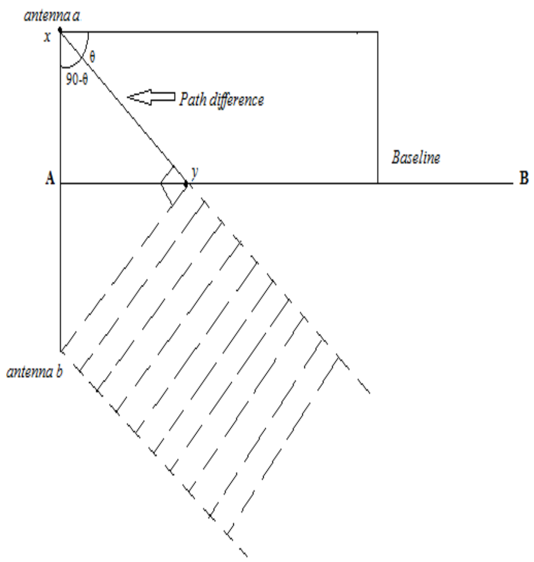
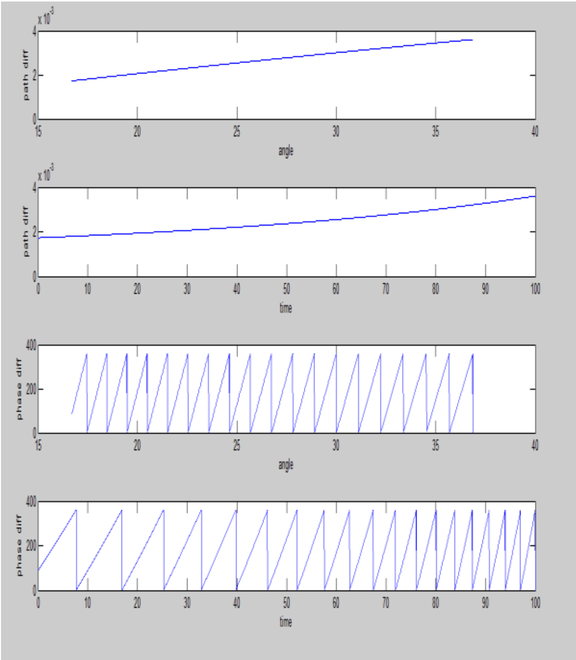


Figure 4:

3. Implementation

The above method can be implemented using a matlab code. A matlab code can be written to find the angles, path difference and phase difference and its graph can be plotted. The theoretically calculated values can be verified with the values obtained from the graph. The graph of angle with respect to time can also be plotted. The plot of rate of change of phase difference with respect to a particular interval of time can also be plotted.

The graph of path difference and phase difference with respect to time and angle obtained is as follows



4. Conclusion

The above method of precision direction finding of radars from an airborne platform is very simple and efficient way to detect the ground-based radars. This method is easy to compute and consumes less time for its implementation. Thus, the above method can be used in Electronic Warfare(EW) .

References

I was guided by Venketeswarlu, director(Engineering) of Pinaka Aerospace private limited for doing this project.