ABSTRACT
This paper is aimed to implement the detection and mono pulse tracking of Air borne Radars in missiles are used to provide hit to kill capability during terminal guidance phase. They are designed to be compact, light weight and ruggedized to work in harsh environment. The accuracy levels of such Radars are very high that the target cannot escape. Air borne Radars are supported by ground based long range Radars. Ground based long range Radars detect the enemy targets at longer range and initiate the action to launch an interceptor missile. Both the target and the interceptor missile shall be under the ground based coverage. The missile shall be guided towards the target through command guidance. When the distance between the target and missile is less (terminal phase distance), the air borne Radar is switched ON and instructed to detect the target of interest. Initial target information (Coordinates, range and velocity) is provided by the ground based Radars. Air borne Radar shall transmit RF energy, receive the reflected energy and process the received energy to find the target range, velocity and angular deviations. With detection algorithms like Doppler processing, range processing and angular processing implemented by using MAT LAB

KEY WORDS Air Borne Radar, Monopulse Tracking, FFT.

1 INTRODUCTION
Air-borne active radar system is developed to detect and track a target coming from the other direction. Detection has to be performed at the height of around 25 to 40 kms from the surface of the earth. Detection and tracking of a small RCS target of 0.02m² with relative velocity of around 3 to 5kms up to 500mpts is a difficult task to be performed by air-borne radar. The information of the target range and angle with an accuracy of ±500 meters in range and ±0.8° in angle (angle between missile axis and antenna to target line) are available to the radar through On-Board Computer (OBC). The time for detection and track is 500msec. After 500msec, the output of the seeker will give range and angle information with maximum error of 15 meters in range and 2 mrad in angle and the update time for range and angle information to be given to OBC is at every 50msec. In the ARS system, a pilot signal is also generated for testing and calibration of the system. The pilot signal has to be generated when there is no transmission and is also enable on command. The pilot circuit requires a control signal to activate it. The pilot signal injected appears at the sum and two difference channels. These signals have to be sampled only during the pilot window. The system is complex and modular. Since the system is in Ka-band, it had many design challenges in high frequency circuits. The target RCS is being extremely low, DSP system so designed has very low noise floor. Receive signal being very weak, has to be amplified to an appreciable level. This demands high gain receiver with high dynamic range. Provision is built-in for amplitude and phase matching across the chain of the system. Most of the PCBs so designed have multi-layer hence extra care has been taken to design these PCBs particularly those with mixed RF and analog circuits. DSP algorithm has been implemented to take care of every bit of improvement possible. Total system design has been subsystems, which make the system modular. Microwave & RF circuits are housed in metal housings and digital control & signal processing subsystems are residing in multiplayer printed circuit boards, which are inter connected by mother board.

2 ALGORITHMS USED
Detection Algorithm:
When the target is at longer distance, the target is detected in velocity and range. To detect the target, the echoes are separated from noise and processed accordingly.

Doppler processing:
Once the target range is known approximately, the air borne radar transmits RF pulses continuously and receives the echoes continuously during transmitter OFF time. The received echoes are processed in frequency domain to find the Doppler generated by the target and the velocity of the target is calculated accordingly.

Range Processing:
In range processing, a burst of RF pulses are transmitted and the same burst of echoes are received. Based on the timing, the range is calculated.

Angle Processing:
The antenna of the Air borne Radar is provided with monopulse comparator network which provides the signals corresponding to Sum (sum of four quadrants), Azimuth error and elevation error channels. When the antenna is properly aligned towards the target, Azimuth error and elevation error signals shall be zero. Echoes from azimuth error and Elevation error channels are processed with respect to Sum channel to find angular error between the target and antenna bore site.

3 SPECIFICATIONS
Specifications for the radar system are provided below:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCS of Target</td>
<td>0.3m²</td>
</tr>
<tr>
<td>Range at First Detection</td>
<td>36 Kms</td>
</tr>
<tr>
<td>Probability at First Detection</td>
<td>0.9</td>
</tr>
<tr>
<td>Probability of False Alarm better than</td>
<td>10^-6</td>
</tr>
<tr>
<td>Radar Height</td>
<td>30-40 Kms</td>
</tr>
<tr>
<td>Range Accuracy</td>
<td>15 m</td>
</tr>
<tr>
<td>Angle accuracy</td>
<td>2 mrad</td>
</tr>
</tbody>
</table>
System Inputs for Detection (Apriory Data on Target)

- Target position in range: With an error of 500 m in all three planes.
- Look angle for antenna with respect to the missile axis: Target relative to missile axis with an error 0.83.
- Relative velocity with an accuracy of ±250 m/sec in full band may be used in acquisition mode to enable detection.
- Single target scenario with no clutter.
- The target is already in the beam during acquisition mode and hence the radar requires no search.
- Target is a steady target and hence can be considered as a point target for signal processing.

Missile-borne active radar seeker system is required to detect and track a target coming from the other direction. Detection has to be performed at the height of around 25 to 40 kms from the surface of the earth. Detection and tracking of a small RCS target of 0.02 m2 with relative velocity of around 3 to 5 km/sec from 25 kms up to 500 meters is a difficult task to be performed by missile-borne radar. The information of the target range and angle with an accuracy of ± 500 meters in range and ±0.8° in angle (angle between missile axis and antenna to target line) respectively are available to the seeker through On-Board Computer (OBC) from a ground based radar. The time for target acquisition and detection is 500 msec. After 500 msec, tracking of the target starts and the output of the seeker should give range and angular error information with maximum error of 15 meters in range and 2 mrad in angle. The update time for range and angle information to be given to OBC is at every 50 msec. The detailed configuration of the airborne radar system is shown in fig 1.

**5 TARGET DETECTION PROCESS**

- The detection process in PPU consists of the following steps:
  - Sum Channel Data Acquisition in Process Window
  - I Q Imbalance Correction
  - Compensation for pulse position change using the known velocity and acceleration
  - Compensation for phase change due to acceleration
  - Coho-On-Receive Processing
  - FFT based Doppler Processing
  - Cross Spectrum estimation
  - Power Spectral Averaging
  - Correlation and Centroiding
  - 2D Peak Detection

**5.1 Compensation for pulse position change using the known velocity and acceleration**

The time of received pulse from the target for the nth pulse is given by:

\[ \tau(n) = \tau(0) - \frac{1}{c} \left[ \frac{1}{2} \left( V(0) + A(0) \cdot t \right) \right] \]

where, \( T \) is the pulse repetition time, \( PRT \)

\( V(0) \) and \( A(0) \) are the initial radial velocity and radial acceleration respectively at the time of 0th pulse. \( c \) is the velocity of light. This change in pulse position from PRT to PRT gives rise to misalignment of the pulses during integration. Thus the integration gain is reduced. The method used for compensating this is to shift the sampling window by an amount corresponding to the shift in pulse position due to velocity and acceleration. The sampling time is corrected using velocity and acceleration estimates as indicated below:

\[ \tau(n) = \tau(0) - \frac{1}{c} \left[ \frac{1}{2} \left( V^{est}(k) + A^{est}(k) \cdot t \right) \right] \]

where \( T_{base} \) is the basic clock period and the 'round' function rounds its arguments to the nearest integer. If continuous updates of velocity and accelerations are available, equation can be modified further as:

\[ \tau(n) = \tau(0) - \frac{1}{c} \left[ \frac{1}{2} \left( V^{est}(k) + A^{est}(k) \cdot t \right) \right] \]

where \( V^{est}(k) \) and \( A^{est}(k) \) are the velocity and acceleration estimates for the kth pulse. Thus the sampling window is shifted in every pulse. This is accomplished using the TSG circuit.
6 PHASE COMPENSATION DUE TO ACCELERATION

This document is generated for explaining the MATLAB code for phase compensation due to acceleration of the target. The content within the brackets with italic fonts are the corresponding variable names in MATLAB code. In this simulation we have chosen following parameters.

Sampling frequency ($f_s$): 50 KHz.
Wavelength of carrier ($\lambda$): 0.008 meter
Total time for simulation ($T$): 20.048 msec
Doppler frequency ($\nu_d$): 5.0 KHz
Acceleration of target (acc): 200 m/sec$^2$

This code first simulates a complex carrier ($\text{carrier}$) of Doppler frequency and then a linearly frequency modulated carrier ($\text{mod\_carrier}$) is generated by adding a fraction of the phase into the corresponding phase of carrier. This fraction of the phase is added because of the increment in the velocity (which is due to acceleration) of the target in one sample period ($1/f_s$). This modulated carrier is equivalent to the received signal in the seeker because of a linearly accelerating target. The task in this simulation is to calculate the phase change in every sample with the help of the acceleration estimate (acc_est) available and compensate for that phase change. If there is no acceleration, the signal appears to have a constant Doppler and the FFT based Doppler processing can compensate the phase changes and coherently integrate the pulses. As there is a variation in the velocity, acceleration comes in to existence and phase of the carrier will change due to this acceleration. Hence, the only compensation required is for the phases change due to acceleration component. It is achieved by calculating the apriori Doppler frequency and change in apriori Doppler frequency at every sample because of apriori acceleration information. Thus in this way the frequency is calculated at every sample point and based on that a compensating complex signal is generated. This generated compensating signal is then multiplied with the received signal. Thus, each of the I and Q signals are compensated for the known acceleration and such compensated samples are used for further processing. Following are the observations of the simulation.

- Because of the 200 m/sec$^2$ acceleration the Doppler frequency is spread from 5 KHz to 7 KHz in 20.048 msec time interval.
- The spread in the compensated signal is directly proportional to the error in the apriori acceleration.
- The frequency at which the peak appears in the compensated signal is nothing but the frequency error in the Doppler frequency i.e. it is directly proportional to the error in the apriori velocity (in other words we can say that down conversion of the signal is also taking place with the help of this algorithm).

7 FAST FOURIER TRANSFORM:

A fast Fourier transform (FFT) is an efficient algorithm to compute the discrete Fourier transform (DFT) and its inverse. There are many distinct FFT algorithms involving a wide range of mathematics, from simple complex-number arithmetic to group theory and number theory; this article gives an overview of the available techniques and some of their general properties, while the specific algorithms are described in subsidiary articles linked below. A DFT decomposes a sequence of values into components of different frequencies. This operation is useful in many fields (see discrete Fourier transform for properties and applications of the transform) but computing it directly from the definition is often too slow to be practical. An FFT is a way to compute the same result more quickly: computing a DFT of $N$ points in the obvious way, using the definition, takes $O(N^2)$ arithmetical operations, while an FFT can compute the same result in only $O(N \log N)$ operations. The difference in speed can be substantial, especially for long data sets where $N$ may be in the thousands or millions—in practice, the computation time can be reduced by several orders of magnitude in such cases, and the improvement is roughly proportional to $N/\log(N)$. This huge improvement made many DFT-based algorithms practical; FFTs are of great importance to a wide variety of applications, from digital signal processing and solving partial differential equations to algorithms for quick multiplication of large integers. The most well known FFT algorithms depend upon the factorization of $N$, but (contrary to popular misconception) there are FFTs with $O(N \log N)$ complexity for all $N$, even for prime $N$. Many FFT algorithms only depend on the fact that $e^{-2\pi i/N}$ is an $N$th primitive root of unity, and thus can be applied to analogous transforms over any finite field, such as number-theoretic transforms.[2]

8 DOPPLER PROCESSING APPROACH

- High PRF is used to have maximum average power.
- Designation from OBC i.e., apriori range, velocity, acceleration are used to reduce the bandwidth of the doppler signal to the minimum possible.
- Compensation is done based on digital down conversion.
- FFT based doppler processing to detect the target.
- Eclipsing cycle is at every 225m.

8.1 PARAMETERS USED IN DOPPLER EFFECT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse width</td>
<td>0.5μs</td>
</tr>
<tr>
<td>Pulse repetition time</td>
<td>1.5μs</td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>6MHz</td>
</tr>
<tr>
<td>Velocity of the target</td>
<td>5000 m/sec</td>
</tr>
<tr>
<td>Acceleration of the target</td>
<td>200 m/sec$^2$</td>
</tr>
<tr>
<td>Simulation time</td>
<td>13.66m sec</td>
</tr>
<tr>
<td>Radar Cross Section</td>
<td>0.3 m$^2$</td>
</tr>
<tr>
<td>Wave length</td>
<td>0.008 m</td>
</tr>
<tr>
<td>Error in the apriori range</td>
<td>±500 m</td>
</tr>
<tr>
<td>Error in the apriori velocity</td>
<td>±60 m/sec</td>
</tr>
<tr>
<td>Error in the apriori acceleration</td>
<td>±5 m/sec$^2$</td>
</tr>
</tbody>
</table>
Transmitter peak power | 500 watt  
Gain of the antenna | 37dB  
Losses | 10.5dB

9 ANGULAR PROCESSING
- Angle processing is done to find bore sight errors for azimuth and elevation channels.
- Monopulse angular error is directly proportional to the complex ratio of signal voltages derived from the antenna (d/s)

Approach
- Angular processing starts if doppler is detected in doppler processing channel.
- Measured doppler frequency and doppler measurement errors are used place of Doppler designation and designation error.
- Signal BW is reduced from 30kHz to 100Hz.
- IQ based d/s calculation with averaging is used.

9.1 PARAMETERS USED IN ANGULAR PROCESSING
- Pulse width | 0.5µs  
- Off time of the pulse | 1µs  
- Pulse repetition time | 1.5µs  
- Bandwidth | 100Hz  
- Sampling frequency (fs) | 250Hz  
- Velocity of the target | 5000 m/sec  
- Acceleration of the target | 200 m/sec²  
- No of samples | 250  
- Velocity of EM wave | 3x10⁸ m/sec  
- Simulation time | 500 m

10 RANGE PROCESSING
- Low PRF is used to take care of designation error (+/-500mts)
- Receiver keep receiving the echoes and the down converted data in put into a buffer for signal processing.
- Returned echo data is stored in a two dimensional array.
- FFT is calculated on the two dimensional data.
- Correction algorithm is performed to calculate the range.
- Range is unambiguous.

10.1 PARAMETERS OF RANGE PROCESSING
- Pulse width | 1µs  
- Pulse repetition time | 10µs  
- Sampling frequency | 20MHz  
- Velocity of the target | 5000 m/sec  
- Acceleration of the target | 200 m/sec²  
- Simulation time | 24m sec  
- Radar Cross Section | 0.3 m²  
- Wave length | 0.008 m  
- Error in the a priori range | ±500 m  
- Error in the a priori velocity | ±60 m/sec  
- Error in the a priori acceleration | ±5 m/sec²  
- Transmitter peak power | 500 watt  
- Gain of the antenna | 37dB  
- Losses | 10.5dB

11 FFT BASED DOPPLER PROCESSING
The I and Q samples of transversal filter output is sorted into separate range bins, and are stored in different memory locations as shown in the Fig. Each range bins, thus contains 200 I and Q video data and this is used to represent the received data in the form of a complex number I+jQ. The data collected over a number of ‘N’ pulses are arranged in a 2D array as shown in Fig 2.
13 CONCLUSION

It is conclude that Target detection and tracking for moving target in air borne radar by using monopulse. The tracking errors are measured with the help of OBC and update the results. With Doppler algorithm we calculated frequency of the moving target, in range processing calculated the range error and finally angular errors are calculated accordingly. These algorithms are implemented in air borne radar for the target detection and tracking with the help of PPU algorithms.

REFERENCES

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