

Efficient Resource Allocation for Air-to-Air Multiple Target Detection and Tracking with AESA Radar

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Abstract

The Active Electronically Scanned Array (AESA) Radar provides a very useful feature called beam agility. This allows faster track initiations on detected targets and high priority tracking of multiple targets at different azimuth angles. In this paper an efficient method of allocating the beam time in Air-to-Air mode is proposed.

Keywords: ISAR, AESA, Radar, imaging, multiple, targets, parallel

I INTRODUCTION

In Active Electronically Scanned Array (AESA) Radar beam can be switched from one azimuth position to another distant azimuth position in a matter of microseconds [1]. After we get detections from Radar, we have to verify them for presence of targets by another beam dwell at the same locations. After they pass the verification test, track is initiated on the targets. After successful track initiation the targets are tracked in Track While Scan (TWS) mode. Frame time is the total time allocated for completing one round of search and track operations for the scan volume. It is decided by the minimum track update rate required in TWS. Maneuvering targets as well as operator selected targets are promoted to high priority tracking (HPT). In HPT the target parameters have to be updated faster than the TWS rate irrespective of the scan time by looking at the target more frequently. During each frame some new targets will enter and some tracks will be lost. Along with the new targets, there will be additional false alarms and clutter leaks which has to be verified. This increases the verification load. Also the clutter leaks pass the verification and increase the track initiation load.

In this paper we have shown a realistic approach for allocating the Radar resources (power-time) efficiently among the multiple tasks of search, verification, track initiation and HPT. Waveforms and dwell time will be different for different tasks. In the next section we will describe the required steps sequentially for time budgeting.

Here it is assumed that a medium PRF waveform is used for the Air-to-Air multiple detection and Tracking (MTDT) mode.

II RESOURCE ALLOCATION STEPS

Basically the Radar beam dwell time is the single most critical resource that has to be shared by all the search and track functions [4]. Here we propose a number of steps required for efficient allocation of beam time.

i. Frame Time Assumption

The first thing is to fix an approximate frame time and divide it between search and track operations in some ratio based on priority. For example the approximate frame time can be taken as 7s as this is sufficient for TWS track update for non-maneuvering targets. Also in 7s the maximum penetration between looks for a target moving radially at a relative speed of 1000 m/s will be 7 Km. Now if the instrumented range is 100 Km, this is less than 10% of the max range. Now if we divide the frame time equally among search and track operations, then the time allocated for search will be 3.5s.

ii. Search Time Estimation

During search the beam illuminates a specific azimuth span with slightly overlapping beam positions. The time spent at a particular beam position is called one dwell. Each dwell will have N bursts with different PRFs depending on the binary integration scheme. The burst time is calculated based on the maximum range, azimuth and elevation coverage required and pulse integration scheme used. For elevation coverage it may be required to scan multiple bars in elevation within a frame time. Figure-1 shows a two-bar search pattern with overlapping beam positions.

In AESA Radar, the beam width increases with look angle shift from bore sight which is specified by the

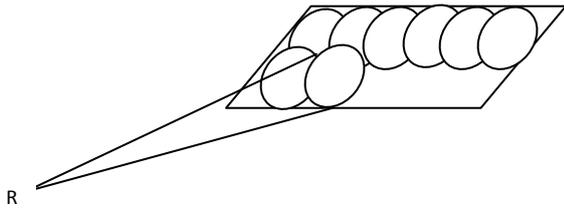


Fig. 1. Two-bar search pattern

beam broadening factor. Also the antenna gain is reduced with offset from bore sight indicated by scan loss as a function of offset angle theta. These things should be taken into account in calculations of search time.

The dwell times required for different beam positions to get the same required SNR is different due to the above mentioned factors of beam broadening and scan loss [3][5]. The signal-to-noise ratio obtained for a target of particular RCS from each dwell time should be able to meet the Pd and Pfa requirements.

iii. Track Time Estimation

The verification time consists of the time required for verification of detections obtained in search to get a second detection. The track initiation time consists of the time required to initiate steady tracks on the verified detections. Generally this requires multiple dwells at a certain interval for example 200ms. The false alarms and clutter leaks arising out of the search operation have to be verified. After verification the false alarms can be eliminated but the clutter leaks remain to go through the track initiation process along with the new targets. The number of false alarms is decided by the Pfa taken in search operation and the number of clutter leaks is decided by the clutter distribution assumed.

Now for estimating the track time requirements, a Monte-Carlo simulation is performed. Uniform distribution of targets is assumed within the rectangular grid enclosing the search volume as shown in Figure-2.

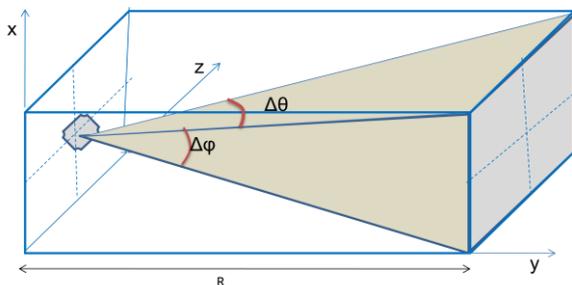


Fig. 2. Track Volume

Different types of targets with different maneuvering rates (3g to 9g) can be considered for HPT. They will need different update rates depending on the accuracy desired.

Assuming the Singer target dynamic model, an expression for the required sampling interval (T) relating the track prediction error variance (σ_p^2) is given by [2].

$$T = 0.4P_d \left(\frac{\sigma_{0\sqrt{\tau_m}}}{\sigma_m/R} \right)^{0.4} \frac{v_0^{2.4}}{1+0.5v_0^2}$$

Where

$$v_0 = \sigma_p / \sigma_0$$

σ_0 = observation standard deviation

σ_m, τ_m = target maneuver standard deviation (m/s^2), time constant(s)

R = target range (m)

Using this formula, we can calculate the approximate update rates required for targets with different maneuvering rates. The frame time can be varied from 6 s to 8 s to find the suitable one such that the total of track time when added to search time doesn't exceed the frame time.

The beam dwell time required for each HPT update depends on the SNR required[6][7]. The SNR required in turn depends on the desired measurement accuracy in high priority tracking. The SNR is calculated from the desired accuracy and the beamwidth of the Radar from the following equation.

$$\delta\theta = \frac{\Delta\theta}{K_a \sqrt{2 * SNR}}$$

Where K_a = Monopulse slope constant.

For high priority track there will be a single burst dwell on each of the targets at regular intervals mentioned above.

The track time budgeting is done by averaging estimated times of a large number of Monte-Carlo iterations.

III SIMULATION RESULTS

We have taken the following simulation parameters for search and track time estimation.

Max Range: 80 Km

Azimuth coverage: ± 60 deg

- Elevation coverage: 2-bar
- PRF: 10 KHz
- Antenna beam width: 3°
- Target RCS: 2 sqm
- Beam broadening factor: $\cos(\theta)$
- Scan Loss: $1/\cos(\theta)$
- Beam overlap 20%
- Cumulative Pd : 0.8
- Cumulative Pfa: $1e-6$

The dwell time required for each azimuth-elevation position in search can be obtained by the Radar Range Equation. The search time calculated by adding the dwell times of all beam positions evaluates to 3.35s.

Poisson distribution is assumed for number of new targets entering the search volume with $\lambda = 0.25$ per sec (2 targets in one frame time). In addition to new targets, 11 false alarms and 2 clutter leaks are assumed per frame. The time budgeting is done by averaging estimated times of 10,000 Monte-Carlo iterations (frames).

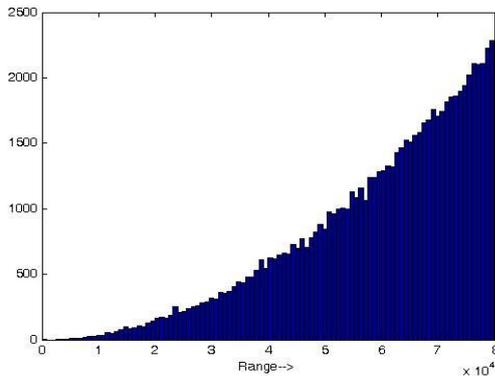


Fig. 3. Range distribution of targets inside search volume

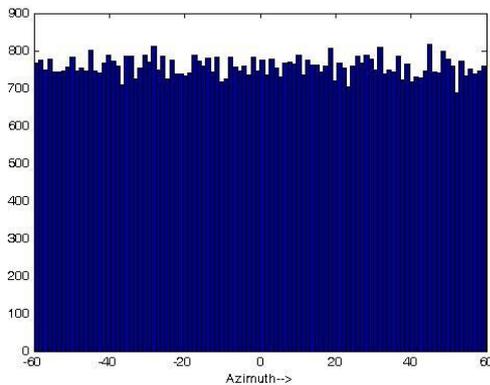


Fig. 4. Azimuth distribution of targets inside search volume

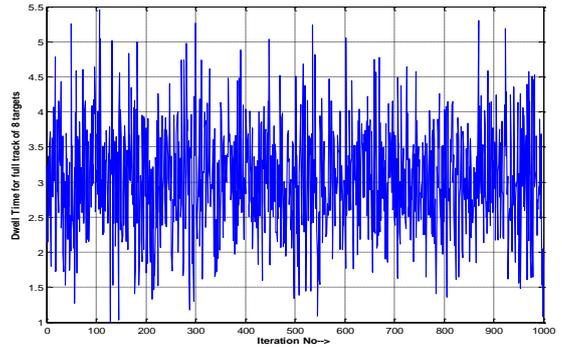


Fig. 5. HPT dwell time across iterations

Accumulated targets across iterations are taken for getting the range and azimuth distributions. The distributions for range and azimuth of the targets accumulated across iterations are shown in Figure-3 and Figure-4. We can see that maximum numbers of targets are at the max range due to look angle geometry. The targets are found to be uniformly distributed in azimuth and elevation.

The number of high priority tracks in a frame is assumed to be 6. They are randomly chosen in each iteration from the 4 target types with maneuvering rates of 3g, 5g, 7g and 9g. The required SNR for getting an angular accuracy of 5 mrad in HPT comes out to be 14 dB. All the 6 targets will require different dwell time for getting the same SNR depending on their location. The total full track time will also depend on the no. of updates required for each target.

Here the frame time is varied from 6s to 8s. The time budgeting is again done by averaging estimated times of 10,000 Monte-Carlo iterations (frames). Figure-5 shows the fluctuation in the required dwell time for HPT targets across 1000 Monte-Carlo iterations. It is observed that for frame time of 7s, the mean HPT dwell time comes to around 2.9 sec and this doesn't violate the frame time assumption.

In steady state of operation, there will be verification and track initiation of new targets as well as high priority track update of existing targets, the estimated time for each function within a frame is given below:

Task	Time Required per frame
Verification	158 ms
Track Initiation	234 ms
Full Track	2.9 s
Total Track Time	3.3 s

For the case above, the actual frame time will be 6.65 sec for the case of two-bar search with max range of 80 Km and azimuth span of $\pm 60^\circ$.

IV CONCLUSION

In this paper we have proposed an efficient method for allocating the Radar beam dwell time among different tasks at hand like search, verification, track initiation and high priority tracking.

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