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A New Algorithm for Phased Array Radar Search Function Improvement in Overload Situations

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***Abstract*—A new algorithm is proposed for phased array radar search function resource allocation. The proposed algorithm adaptively priorities radar search regions and in overload situations, based on available resources, radar characteristics, maximum range and search regions, optimally allocates radar resources in order to maximize probability of detection. The performance of new algorithm is evaluated by the multifunction phased array radar simulation test bed. This simulation test bed provides capability to design and evaluate the performance of different radar resource management, target tracking and beam forming algorithms. Some results are presented that show capabilities of this simulation software for multifunction radar algorithms design and performance evaluation.**

***Keywords*—Phased array radar, radar resource allocation, radar modeling, radar simulation, radar performance evaluation.**

I. INTRODUCTION

DURING phased array radar operation, a portion of time is dedicated to search function. This portion of time which is variable during an operation and is a function of more important radar tasks (such as tracking and fire control) is generally referred to as allowable search load. In Multi Function Array Radar (MFAR), search function should be done based on this allowable search load. When this allowable search load is less than required load, two options exist: either useful detection range should be decreased (spend less dwell time in each direction) or some regions, with lowest priority should be excluded from search function. Useful detection range is defined as track initiation range in which target track initiation is possible immediately after target detection. In this range target SNR is so high that after early detection, target confirmation is done and target track will initiate. This is a good decision: do not detect targets that fail confirmation conditions so that radar resources do not be wasted. When target SNR decreases, useful detection range will also decrease and here an algorithm is required to determine useful detection range and to concentrated radar resources for target detection in this range. The second solution (exclusion of some search regions) can save radar search time as well. The difficult task is selection between two solutions in overload situations. The parameter that should be optimized by this selection is probability of detection; which solution will increase overall probability of detection. In this paper a new method is proposed for optimal allocation of radar resources during search function based on adaptive prioritization of search regions. The proposed algorithm is able to allocate radar resources in order to maximize probability of detection based on available search load and adaptive prioritization of search regions. In other words it decides between decrease of useful detection range and exclusion of some search regions. Performance of the proposed algorithm is evaluated by Multi Function Array Radar Simulation Test Bed (MFARSTB) initially presented in [1]. MFARSTB is a tool for MFAR designers. In the MFARSTB, active phased array radar is considered as a pilot for different radar resource management, target tracking and beam forming algorithms development and comparison. In this simulation test bed, transmitting and receiving chain, antenna structure and signal processing algorithms are fixed. User may write his or her own radar resource management, target tracking and beam forming algorithms and after defining appropriate operational scenarios, asses results of the designed algorithms on the radar performance. This is necessary because these different data association, tracking and radar management algorithms should be designed in relation to each other and the interactions between them should be considered in the design stage.

Organization of the paper is as follows: In section II adaptive prioritization of search regions is presented. In section III radar search function optimization algorithm in overload situations is illustrated. Section IV describes the simulator architecture and capabilities, models of radar subsections and received signal modeling. In section V some simulation results are presented which show performance of the new algorithm and capabilities of MFARSTB in the development and performance evaluation of different MFAR algorithms.

II. ADAPTIVE PRIORITIZATION OF SEARCH REGIONS

In order to allocate radar resources effectively it is required to assign a relative priority factor to each search region during operation time and then allocate radar resources to these regions based on their relative priority. In this way it is possible to assign fewer resources to less important regions in order to concentrate radar resources in more important regions for better target detection. It is expected that by this method probability of detection would increase or with a less search load the same probability of detection will be attained. Implementation of this method requires prioritization of regions.

Some factors useful for prioritization are [2]:

- If a target was detected in a region, the priority of that region will increase because generally targets attack in groups not individually.

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- Lower elevation angles have higher priority because targets appear at low elevation angles at first.
- Priority of a region may be determined based on external resources of information by the user.

In [3] a method is proposed for search region priority assignment based on most threatening target path. It has reported that in classic prioritization methods regions above an obstacle that targets appear from there, have higher priority. This reference gives priority number to regions based on the intensity of the most threatening target path in them. A threatening target path is determined based on distance between radar coverage zone to supported region and probability of target detection on that path.

In [4], [5] two methods based on Fuzzy and hard logic were considered for adaptively prioritizing targets and search regions. Their results, although different more or less, show no preference for either of methods. Fuzzy logic exhibits smooth transitions but hard logic has membership functions with hard changes. Due to uncertainty in parameters of priority calculation decision tree, it seems that minor differences in priorities have no importance and priorities may be assumed fixed in some times like hard logic behavior. Hard logic has much less computation load in comparison with fuzzy logic. A comparison between results of two methods is shown in Fig. 1 from [5]. The results of [4], [5] show no overall preference between two methods in target and search region prioritization.

Priority of a region is strongly dependent on the importance of targets in that region. So for prioritizing a region it is required to determine priority of different targets. In this paper, parameters of table I are used for target priority calculation. Here at first target type is estimated (based on target's RCS, type, distance and direction of motion) and then target priority will be calculated. RCS Estimation is done by a α filter based on measurement of target SNR in successive pulses. Estimation equations are [6]:

$$\hat{\sigma} = 1.12\hat{\sigma}, \Delta SNR_M \geq 1dB$$

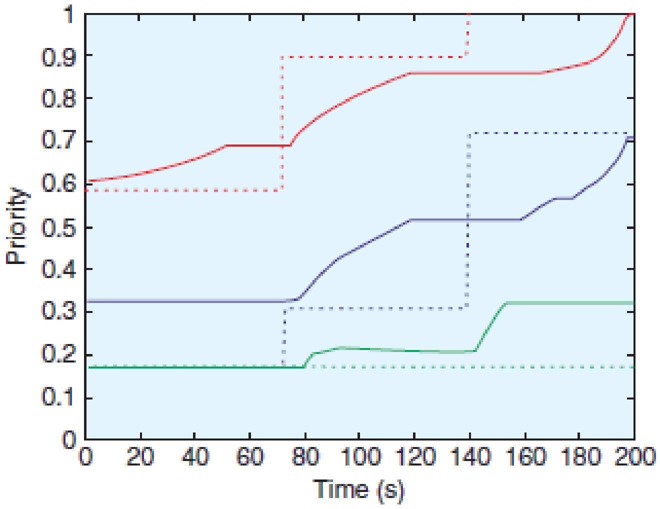

Fig. 1. Priority of three regions calculated by Fuzzy logic (continuous lines) and hard logic (dashed lines) [5].

TABLE I
TARGET PRIORITY PARAMETERS

Parameter	Priority
Interrogation Friend or Foe (IFF)	Enemy:3, Unknown:2, Friend:1
Target Type(T)	Fighter:5, Missile:4, Helicopter:3, UAV:2, charter:1
Velocity(V)	High(>300m/s):3, Medium:2, Low(<200m/s):1
Direction(D)	Inward:3, Cross:2, Outward:1
Position(P)	Near:3, Medium:2, Far:1

TABLE II
PRIORITY OF SOME TARGETS

Target characteristics	Priority value
Closing enemy fighter in medium distance	39
Closing missile in near distance	36
Closing helicopter in near distance	30
Friendly charter in medium distance in cross direction	6

$$\hat{\sigma} = \hat{\sigma}, -1dB \prec \Delta SNR_M \prec 1dB$$
$$\hat{\sigma} = 0.89\hat{\sigma}, \Delta SNR_M \leq -1dB \qquad (1)$$

In (1), ΔSNR_M is difference between expected SNR and measured SNR and $\hat{\sigma}$ is RCS of target. Based on estimated RCS and velocity of the target, target type classification is roughly done. After RCS estimation and classification of targets, based on parameters of Table I, target priority is calculated by simple rules and a threat order is assigned to each target for tracking purposes.

Target priority TP_i is calculated by:

$$TP_i = IFF \times T \times V \times D \times P \qquad (2)$$

Parameters in (2) were defined in Table I. Priority of some targets is calculated in Table II.

Priority of each region is determined by initial priority of that region, number of important targets and new targets input rate. It seems that these three parameters are sufficient to consider all factors affecting priority of a region. Priority of a region is determined through:

$$RP_i = PR0i \times NT \times TR \qquad (3)$$

In (3), $PR0i$ is initial priority determined by the user based on external information sources, $NT \geq 1$ number of important targets that are present in the region and $TR > 0$ is new target appearance rate equals to number of target detections per unit time. Number of important targets is determined by number of targets in a batch multiplied by relative importance of targets in that batch.

$$NT = \sum_{i=1}^{N} TPr_i \times NTPr_i \qquad (4)$$

In (4), NT is number of important targets, TPr_i is relative importance of a batch of targets, $NTPr_i$ number of target in a batch with the same relative importance. N is the number of batch of targets. TPr_i is equal to:

$$TPr_i = \frac{TP_i}{\max(TP_i)} \qquad (5)$$

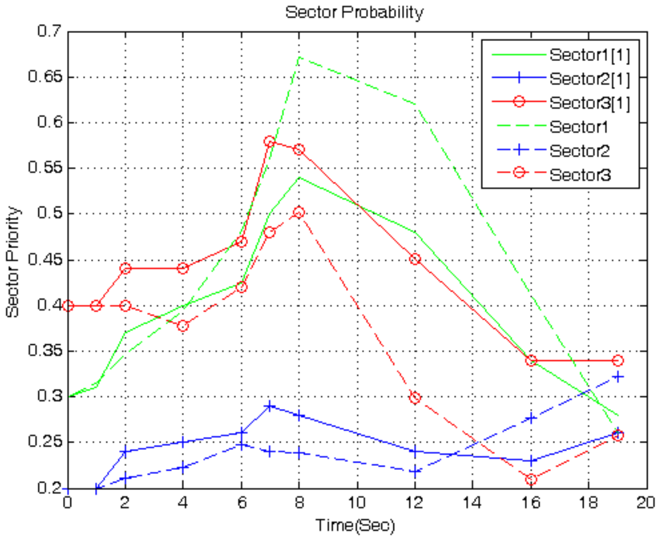

Fig. 2. Target input rate to three regions versus time.

relative priority of a region will be equal to:

$$RPr_i = \frac{RP_i}{\sum\limits_{i=1}^{n} RP_i} \tag{6}$$

In (6), RPr_i is relative priority of a region and RP_i is priority of that region determined by (3). In this paper relative priority of a region is assumed equivalent to a higher number of more important targets in that region. So if a target exists, it is with probability RPr_i in one of the n regions so that

$$\sum_{i=1}^{n} RPr_i = 1$$

Probability of detecting more important targets is defined as product of probability of more important targets existence by probability of detection provided that target exists. By prioritizing search regions, search sequence is determined and in overload situations radar task would be specified.

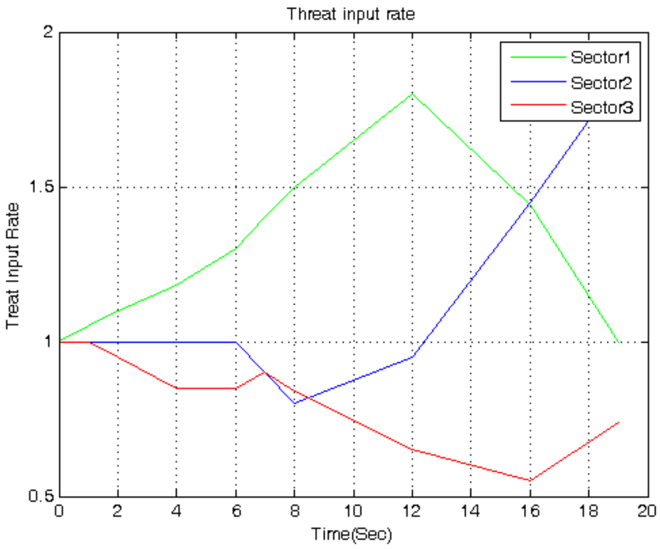

Fig. 3. Simulation results of region priorities with Fuzzy (continuous lines) and hard (dashed lines) logic.

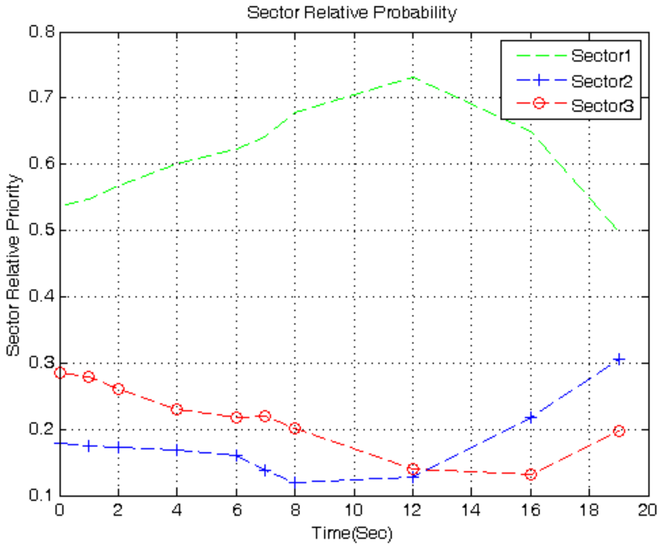

Fig. 4. Relative priority calculated for three regions.

Simulation results of region priorities with Fuzzy and hard logic, for target input rate of Fig. 2, is presented in Fig. 3. Fuzzy logic results were simulated by the use of initial conditions of [7]. As is evident, priority calculation with hard logic has acceptable results in comparison with Fuzzy logic but with much less computational load. Also hard logic results show better performance relative to results presented in Fig. 1 from [5] (sudden changes in priority are omitted as a result of the method presented in this paper). Fig. 4 shows relative priority of three regions calculated by proposed algorithm. In this calculation target input rate is the same as Fig. 2, initial priority of regions is assumed: 0.3, 0.2, 0.4 and importance of target in three regions is assumed 10, 5 and 4 respectively.

After calculating priority of regions it is possible to calculate probability of target existence in each region and use it in the improved search algorithm.

III. ADAPTIVE SEARCH ALGORITHM

By priority assignment to regions, search sequence may be determined and in overload situations better resource allocation would be done. Measure of improvement in performance is probability of detection or reduction in required search load with the same probability of detection. The problem is this: when radar resources is not enough to have a required dwell time on target (to reach to required SNR) is it better to delete some search regions or to decrease useful detection range of all regions? Which method yields more overall probability of detection?

To answer this question, assume that there is n search regions in which probability of target existence in each of them is equal to P_i (i=1:n). Probability of target detection in all regions with sufficient resources and at designed range R_1

is equal to:

$$P_D = \sum_{i=1}^{n} P_i P(R_1) \tag{7}$$

In (7), $P(R_1)$ is designed probability of detection at range R_1. When there are not enough resources, probability of detection at range R_1 reachs to:

$$P'_D = \sum_{i=1}^{n} P_i P'(R_1) \tag{8}$$

In (8), $P'(R_1)$ is decreased probability of detection due to shortage of resources. Probability of target detection after deletion of j regions of lower priority would be equal to:

$$P''_D = \sum_{i=j+1}^{n} P_i P(R_1) \tag{9}$$

Here it is assumed that deletion of j regions is sufficient to remove shortage of resources. This is useful only when $P''_D > P'_D$ or equivalently when:

$$\sum_{i=j+1}^{n} P_i P(R_1) > \sum_{i=1}^{n} P_i P'(R_1) \tag{10}$$

or:

$$P'(R_1) < \frac{\sum\limits_{i=j+1}^{n} P_i}{\sum\limits_{i=1}^{n} P_i} P(R_1) \tag{11}$$

Otherwise, performing search in all regions with reduced probability of detection would be more useful than deletion of some regions.

As an example assume that there is three regions that probability of target existence in them are 0.5, 0.3 and 0.2 respectively. If resources decrease such that probability of target detection in each region decreases to less than 0.8 of its initial value, it is better to exclude the region with probability of 0.2. Otherwise it is better to search all regions with reduced probability of detection. This result is somehow expectable.

It is seemed that with this method one can reach to a better search performance. The new effective search algorithm is proposed with the following steps:

1) Allowable search load is determined.
2) With this search time, beam steps, and useful detection range (R_s) with required probability of detection, dwell time at each beam step is calculated and achievable SNR and probability of detection $\bar{P}_d(R_s)$ will be calculated in whole search regions.
3) If $\bar{P}_d(R_s)$ was more than required, R_s is useful detection range and other parameters of radar such as detection threshold and waveform will be selected and step 5 is executed.
4) If $\bar{P}_d(R_s)$ was less than required, a decision would be made to delete some regions or to do search with reduced useful detection range.
5) The search will start.

The decision algorithm for deletion of some regions or reduction of useful detection range and calculation of overall probability of detection is shown in flowchart of Fig. 5.

IV. MULTI FUNCTION ARRAY RADAR SIMULATION TEST BED (MFARSTB)

Initially presented in [1], MFARSTB is a tool for Multi Function Array Radar (MFAR) designers. In the MFARSTB, active phased array radar, with specifications of Table III, is considered as a pilot for different radar resource management, target tracking and beam forming algorithms development and comparison. In this simulation test bed, transmitting and receiving chain, antenna structure and signal processing algorithms are fixed. User may write his or her own radar resource management, target tracking and beam forming algorithms and after defining appropriate operational scenarios, asses results of the designed algorithms on the radar performance. This is necessary because these different data association, tracking and radar management algorithms should be designed in relation to each other and the interactions between them should be considered in the design stage. In the following sections MFARSTB is introduced.

Previous works in this field are those presented in [8]–[11]. A thorough comparison reveals advantages of this simulation test bed to the previous works both in width and depth of modeling. For example in [8] there is limitation for number of targets and scenario which are completely removed in the present work. Also different jamming and anti jamming techniques, radar signal and data processing methods, which can easily be changed according to a specific radar design is another improvement. In the environment section, model of different clutters and multipath is included which does not exist in the previous works at all. Works presented in [9], [10] are specific radar simulators not suitable for general use. ASTRAD presented in [11] is more suited for radar primarily design phase. It provides an environment like SIMULINK of MATLAB for radar designers. None of the previous works provide a background for MFAR algorithms design and performance evaluation which is the main characteristics of MFARSTB. As mentioned earlier, in MFARSTB, the designer can use the pilot radar inherent in MFARSTB and concentrate on his or her algorithm development and evaluate the results in combination with other parts of a modern radar design and a sophisticated environment. MFARSTB makes it possible that scenarios be shared among different designers in order to compare their results.

A. *Simulator Organization*

Fig. 6 shows simulation architecture which is written in MATLAB and is running under Windows. Modern multifunction radar has many tasks to do and should therefore make a decision such as: when a dwell can be allowed whilst still meeting its other requirement. Global radar system performance depends strongly on the scheduling algorithm used in radar manager. The process of making these decisions and to determine their allocation as a function of time is done by radar manager in this simulation test bed. Radar manager section models the process of scheduling transmitting and receiving actions and pre-processing of the resulting radar measurements. This section was modeled according to [12] and consists of scheduler, search manager and track manager.

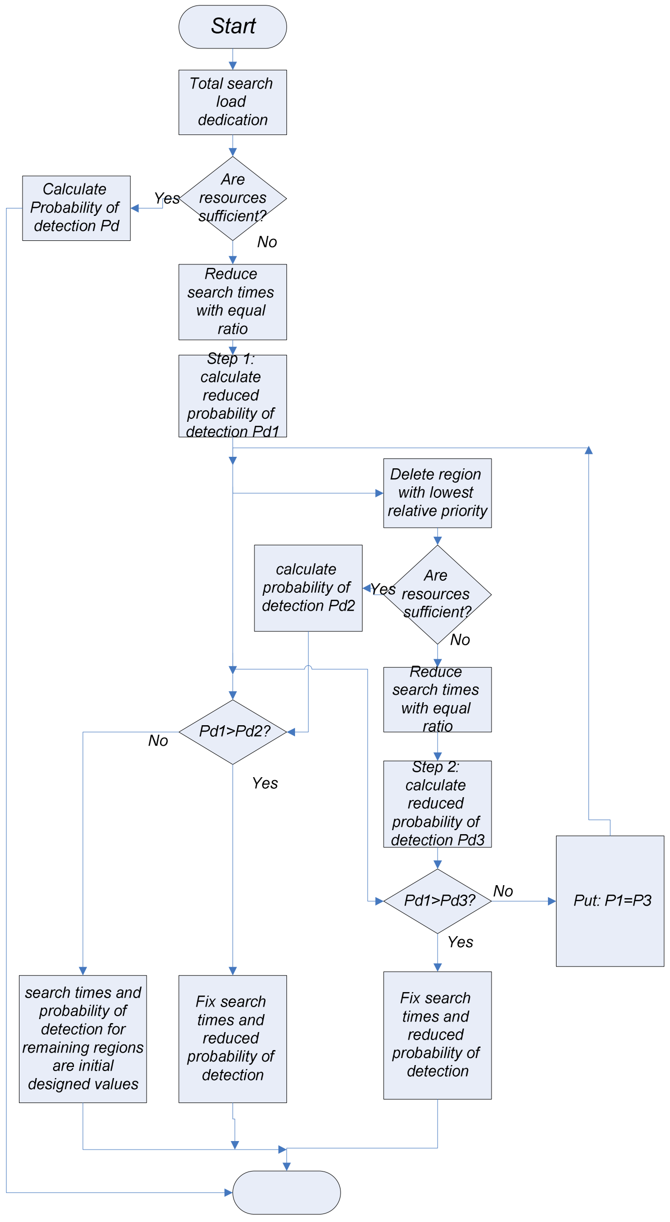

Fig. 5. The decision flowchart for deletion of some regions or reduction of useful detection range and calculation of overall probability.

TABLE III
SIMULATED MFAR CHARACTERISTICS

MFAR parameter	Value
Detection Range	3-150km
Tracking Range	3-90km
Number of targets under TWS	100
Number of simultaneous tracked targets	12
Probability of detection	0.9
Probability of false alarm	10^{-5}
Target RCS	2m^2
Range tracking accuracy	20m
Angle tracking accuracy	12’
Antenna scanning range in Az. & El.	±45°
Antenna Tilt Angle	0-45°
Frequency Band	S
Antenna Beam width	1.5° × 1.7°
Polarization	vertical
Antenna gain	38dB
Antenna SLL	-25dB
Number of T/R Modules	5000
T/R Module peak power	5w
Signal Processing Techniques	MTI, CFAR, Pulse Compression
PRF	2-10 KHz
Target Tracking filter	$\alpha-\beta-\gamma$ and kalman filtering
Data Association Method	GNN

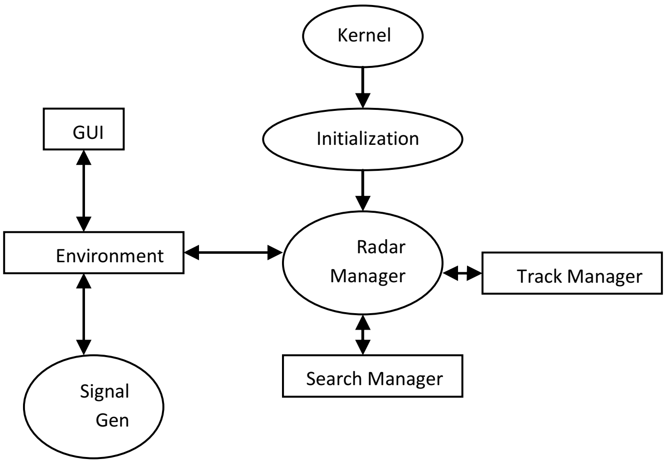

Fig. 6. Architecture of simulation.

Search manager schedules search functions in time slots specified by radar manager. Track manager schedules tracking of previously detected targets on revisit times specified by radar manager according to required tracking accuracies.

The users may set up the radar parameters and operational environment conditions through Graphical User Interface (GUI). Simulation results are presented via GUI. There are three main sections in GUI: Target definition which accept target trajectories, target RCS and its swerling type, and jammer characteristics. In terrain definition window, user sets terrain type (e.g. surface or volume clutter) and its parameters. In radar parameters section angular coverage of radar and its threshold is specified. Environment simulates the received radar signals including target return, noise, surface and volume clutter and jamming signal. After receiving an echo, target detection and position measurement would be done by Digital Signal Processor (DSP) section. DSP models the signal processing algorithms in radar such as Constant False Alarm Rate (CFAR), pulse compression and Moving Target Indication (MTI). Measured coordinates is transferred to Data Processing (DP) section which models the data association algorithms and tracking filters. In this section a new measurement is assessed if it is a new target or not. For new targets a confirmation process is requested.

B. Antenna Design

For MFARSTB it was required to design a capable antenna that provides necessary background for MFAR algorithms

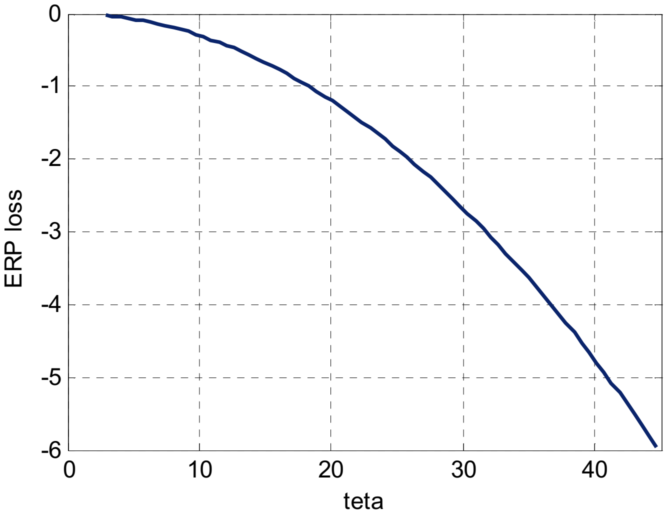

Fig. 7. Decrease of ERP (dB) with scan angle (degree) because of both element pattern and beam broadening in E-plane.

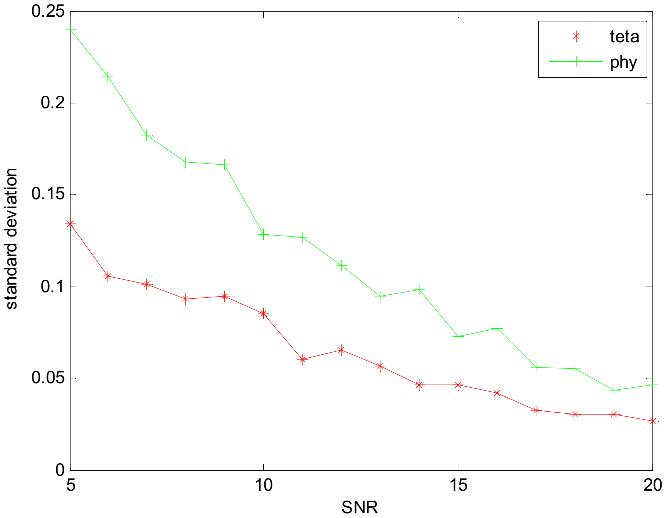

Fig. 8. Standard deviation of target direction estimation (degree) as a function of SNR (dB).

development. In this section, main results of phased array antenna designed for MFARSTB is presented. Important array parameters designed for this simulation test bed were mentioned in Table III.

1) Array Structure

By use of a rectangular aperture with 80 × 64 elements an asymmetrical pattern in H and E planes was produced. The maximum distance between radiators of a scanning antenna array is determined by maximum angle of deviation of the pattern. For electronic steering, 0.58 λ distances between elements is adequate to avoid grating lobes. So dimension of the aperture will be $4.64m \times 3.71m$.There are many weighting window types with different properties. In Taylor tapering there is a better tradeoff between decrease in the side lobe level and broadening the main beam. Amplitude weighting, at T/R module level is assumed although it leads to more complication of the module.

As mentioned, asymmetrical array structure was chosen, hence half power beam width of pattern in elevation and azimuth are different and are 1.7 and 1.5 degrees respectively. Since angle resolution in azimuth is more important than elevation, the bigger size of array aperture is mounted in azimuth direction to have narrower beam width in this plane. By 45 degree steering in azimuth the beam width will reach to 2 degree, and by 45 degree steering in elevation, the elevation beam width will be 2.34 degree. In the transmission mode the aperture of antenna array should operate with uniform amplitude illumination. In this way maximum possible power of T/R modules will be derived with maximum efficiency. By applying Taylor tapering and broadening the pattern, there will be 1.98 dB decreases in total gain. Micro strip patch is used as antenna element with 80 degree half power beam width. Total loss due to beam steering and loss of element pattern effect is depicted in Fig. 7. Here the decrease of radiated power is about 6dB at maximum scanning angle. A 6 bits phase shifter has been selected for this antenna.

2) Angle Measurment

In the MFARSTB, mono pulse Likelihood function is used for direction estimation of target. Taylor & Bayliss tapering are applied for side lobe reduction of sum and difference patterns. Bayliss tapering is applied at output of 160 sub arrays each with 4×8 elements. This tapering will increase side lobe level of difference relative to sum pattern about 16dB. Usually target detection and acquisition is performed by sum pattern and after that, target tracking in a short range gate is done by difference pattern. So higher side lobe level in the difference pattern would not cause false alarm due to clutter or other unwanted targets [13]. Fig. 8 depicts standard deviation of target direction estimation as a function of SNR.

3) Side Lobe Canceller (SLC)

Widrow-Hoff Least Mean Square algorithm described by [13] was implemented in the simulation test bed for SLC. The benefit of using the SLC can be measured by jammer cancellation ratio (CR). CR is defined as the ratio of the output noise power with and without the auxiliary array. For instance the CR value obtained in this simulation test bed with one auxiliary antenna is about 30 dB for a jammer at 15° azimuth angle. The gain of auxiliary antenna with respect to the side lobe of the radar antenna in the jammer direction is an important parameter called gain margin. In the steady-state of an adaptive SLC, a large value of the gain margin would be desirable but in the transient state a low value of gain margin is preferable. A compromise value of gain margin is about 10dB used in this design.

C. Radar Processor

1) Signal Processing

DSP section of MFARSTB includes pulse compression, CFAR, and MTI processing. Target detection is done in signal processing section and stream of detected targets will be sent to data processing section.

2) Tracking Algorithms

Target tracking in MFARSTB includes data association algorithms and tracking filters. Global Nearest Neighbor (GNN) is implemented as default data association algorithms. The $\alpha-\beta-\gamma$ and Kalman filters are implemented as tracking filters. Both fixed and adaptive update rates are modeled based on [14]. However each user may implement his or her tracking algorithms easily. In each dwell, measurements related to the revisited target is specified by data association algorithms and passed to tracking filter for target position smoothing and prediction.

3) Resource Management

Resource management in MFARSTB is done based on Butler algorithm [12]. Radar tasks are scheduled primarily by their defined priority and after that by earliness or lateness of their execution time.

D. Signal Simulation

Received signal in MFARSTB includes target echo, multi path, clutter, noise and jamming, which are modeled and simulated as illustrated in the following subsections.

1) Target Signal Modeling and Simulation

Target Trajectory

In the MFARSTB, every scenario may include arbitrarily number of targets each one with its own three dimensional paths, RCS characteristics and jamming type. Once a scenario was defined, it can be saved and reloaded for next simulations. Target trajectory can also be imported from real measurement.

Target RCS

Target RCS is defined by its mean value and swerling type [15].

Echo Signal Simulation

Echo signal power is calculated by (12):

$$P_r = \frac{P_T G_T G_R \lambda^2 \sigma}{(4\pi)^3 (R)^4 L_T L_R} \tag{12}$$

In (12), P_T: radiated power, G_T& G_R: transmit and receive antenna gain, λ: wave length, σ: radar cross section, and L_T&L_R are transmit and receive path losses. Target Doppler is calculated by radial velocity between target and radar and is considered in target echo.

Multipath Signal Simulation

Multipath signal is formed when target echo reach to radar from indirect paths. Amplitude and phase of multipath signal is different from target echo and combination of these two would cause angle tracking error in track phase and variation in detection range in search phase. Surface reflected signal's phase is affected by two factors relative to direct path: different path length and phase change through reflection. Amplitude of reflected signal is also a function of grazing angle (ψ), polarization and type of surface. To simulate multipath signal, radar equation should be written for each of the four different paths between radar and target and then received signal power and its phase in the path with once and twice reflection is calculated [16].

Glint Simulation

Variation in the amplitude and phase of combined received signal from different scattering points of a target causes angle measurement error. Standard deviation of this error is calculated from (13) [17]:

$$\sigma_g = \frac{L}{3R} \tag{13}$$

In (13), L is apparent length of target and R is range of target. This error is added to angle measurement error.

2) Clutter Signal Simulation

Generally clutter signal is modeled by three parameters: clutter power, clutter signal amplitude distribution and clutter spectrum bandwidth. Surface is divided into rings around radar whose widths is equal to radar range resolution (Radar antenna has a different gain in each direction). Clutter power in each range cell is determined by [16]:

$$P_c = \sum_i \frac{P_T G_i^2 \lambda^2 \sigma_i}{(4\pi)^3 L_T L_R R_i^4} \tag{14}$$

$$\sigma_i = Area_i \times \sigma_0(\psi) \tag{15}$$

$$Area_i = \frac{c\tau}{2} R_i BW_{az} \cos(\psi) \tag{16}$$

In (14-16), G_i is antenna gain in the clutter ring direction, $Area_i$ is ring surface and σ is radar cross section of clutter in the ring. $\sigma_0(\psi)$ is intensity of radar cross section(m^2/m^3), c is speed of light(m/s), τ is radar pulse width (sec), ψ is grazing angle, R_i is ring distance to radar and BW_{az} is antenna beam width in azimuth. For each grazing angle and specific frequency and polarization $\sigma_0(\psi)$ is calculated from figures like figures in [15]. For land at low grazing angles ($< 4°$deg) Weibull distribution is assumed for clutter. For higher grazing angle log-normal distribution is more appropriate [15]. Phase distribution is assumed uniform between $-\pi/2 \leq \varphi \leq \pi/2$. Clutter signal is generated in the same way for rain volume clutter [16].

3) Jamming Signal Simulation

Each defined target may have onboard jamming systems. By appropriate definition of path, different jamming scenarios, including self protection jamming (SPJ), stand of jamming (SOJ) and escort jamming may be defined.Simulated jamming techniques include: Spot noise, Barrage noise, CW, Swept CW and range gate pull off (RGPO). For each jamming type its parameters (including power, antenna gain, frequency, bandwidth and sweep rate) is specified by the user and according to jammer position with respect to radar, jamming signal power received by radar is calculated by one way propagation equation at radar position. Detailed description of signal simulation in MFARSTB is beyond the scope of this paper and was summarized in [18].

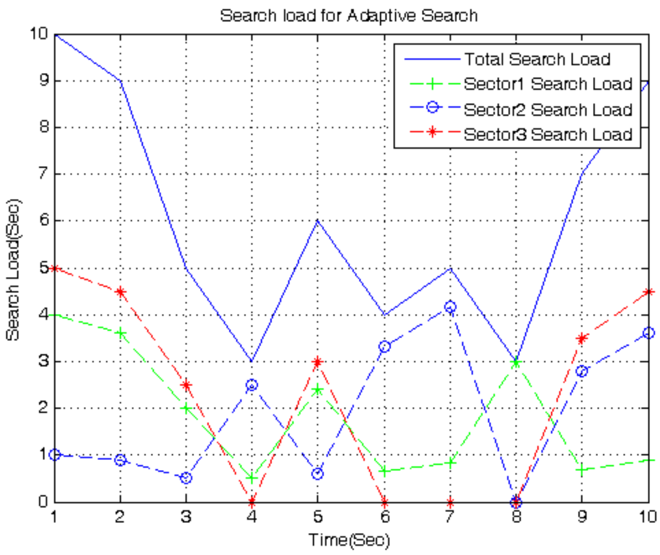

Fig. 9. XY plot for tracked targets.

V. Simulation Results

In order to show capabilities of the MFARSTB, two scenarios were defined and their results are presented in sections A&B as follows. Measures defined for performance evaluation and comparison of different algorithms in MFARSTB include radar coverage diagram, tracking errors, search and track load and target RCS estimation and priority calculation history. Also each user might define required performance measure.

A. *Effect of Target RCS on Radar Detection Range*

In this scenario two targets with $RCS = 2m^2$ and two other ones with $RCS = 0.1m^2$, approach the radar with constant velocity of $500m/sec$. Simulation results in Fig. 9 show that target with higher RCS were detected at about 150km while lower RCS targets were detected at about 70 km as was approximately expected from radar equation. In this Scenario simulation ran for about 175s and about 2.5% of time was dedicated to tracking of these targets (track load).

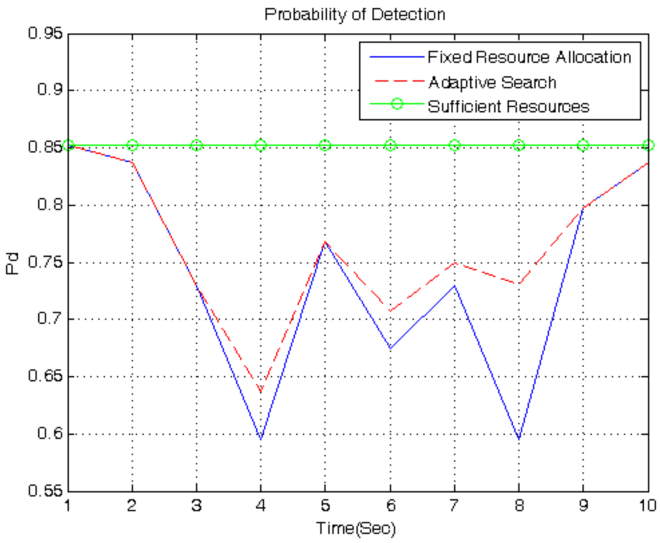

Fig. 10. Total search load and search time dedicated to each region with fixed resource allocation method.

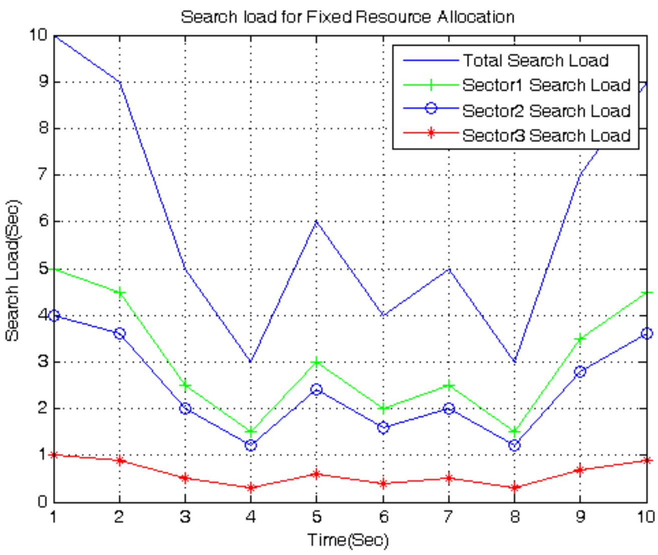

Fig. 11. Total search load and search time dedicated to each region with new proposed algorithm.

B. *Radar Search Performance in Overload Situation*

A scenario with three search regions having relative priority of Fig. 4 was simulated. Fig. 10 & 11 show total search load and search load dedicated to each region with the method of fixed resource allocation and with new proposed algorithm. In these simulations it is assumed that search load required by each of three regions in order to search the region with required probability of detection is respectively 5, 4 and 1 second. So with a total search load of 10 seconds resources are enough for search function. In fixed resource allocation method in the case of shortage in resources, search load is

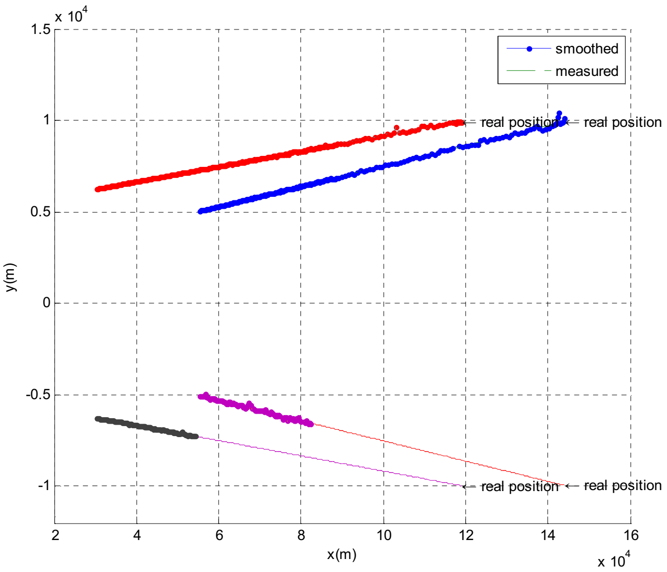

Fig. 12. Probability of detection versus time.

divided between all regions with the ratio of 5, 4 and 1 (Fig. 10). But with proposed algorithm search load is divided to maximize probability of detection and sometimes one or two regions may be excluded from search function. Achieved probability of detection in three situation of sufficient resources, shortage of resources and fixed allocation and shortage of resources and allocation by new proposed algorithm is shown in Fig. 12 which clearly shows improvement gain of new algorithm.

VI. CONCLUSIONS

In this paper a new method was proposed to determine priority of targets and search regions based on hard logic and the results were compared with results of fuzzy logic method in other references. Also a new algorithm was proposed for resource allocation of phased array radar in search function in the overload situations. This new algorithms in the case of shortage in resources decides whether to reduce useful detection range or exclude some regions from search function by adaptively prioritization of them during operation time. Performance evaluation of proposed algorithm was done by MFARSTB which is a simulation testbed for Multifunction Phased Array Radar design and performance evaluation. This simulation test bed provides capability to design and to evaluate the performance of different radar resource management; target tracking and beam forming algorithms in real scenario simulations.Simulation results show an increase in the overall probability of detection by application of new algorithm of search function.

Future works include application of MFARSTB in the design and performance evaluation of other algorithms for better phased array radar operation.

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