An Approach for Rotating Multi Function Radar Waveforms Management

S. Elayaperumal[1], J. Senthil Rengarajan[1], LGM Prakasam[1]

(1. Electronics & Radar Development Establishment, DRDO, C.V. Raman Nagar, Bangalore-560093)
s.elayaperumal@gmail.com

Abstract:

In Rotating Long Range Multi Function Radars, time and beam management has to be optimized to utilize the radar resources efficiently for different radar functions like search, confirmation, track initiation and active tracking. In this paper a new approach for search function is evolved by splitting the entire range into Short Range, Medium Range and Long Range. For each of the Range areas different dwell time, different Doppler filters and different PRFs are selected by considering various factors like, the clutter environment, duty cycle limitation, signal processing losses and the required search frame time. This approach reduces the shorter range clutter leak confirmations time and increases search update rate for longer ranges compared to the scan to scan PRFs change approach.

Keywords: *Rotating phased array, search, confirmation, LPRF, MPRF and Waveforms etc.*

I. Introduction

In the short and medium range surveillance radars LPRF waveforms are used to perform the search function. As the radar range increases the PRF decreases for the LPRF waveforms. If complete LPRF approach is selected for search function then, due to low duty cycle limitations dwell time required will be more and it is vulnerable to the weather clutters due to the very less ambiguous velocity. In the rotating radars single beam dwell time is limited by the rotation rate of the antenna and azimuth beam width. MPRF waveforms have better performance in the weather clutter environments. If complete MPRF approach is selected for search function, to cover the entire range & velocity coverage of the radar multiple PRFs has to be used in each beam position. One option is to have M out of N criteria binary integration in search and resolve the ambiguity in search itself. But this leads to the increased dwell time for each azimuth position. This can't be allowed all the time because in rotating phased array radars this leads to more azimuth deflection from antenna bore sight, which causes reduction in the two way gain, eventually system losses will increase. Another option is to change the PRF scan to scan but in each scan the complete radar range and velocity coverage can't be ensured. In this approach due to clutter leak at short range many false confirmations may be generated. In this approach search detection range is ambiguous in nature because of that even though the clutter leak detection is from near range the confirmation dwell time will be for the radar maximum range. Therefore, radar resources are wasted unnecessarily for these clutter leak detections which leads to increased search frame time. In this paper an approach for management of search waveforms in the 300 Km maximum detection range radar is presented. Section II discusses how the waveforms are managed to cover the entire radar range. Section III discusses how the PRFs are selected for the waveforms. Section IV discusses the implementation results of this approach.

II. Waveforms Management

The approach is to divide the entire radar range coverage into short range, medium range and long range and manage the dwell time for the required range only. This approach is applicable in case of the lower elevation fences in the volumetric surveillance radars where the detection range requirement is more. The short range waveforms cover up to 50 Km. The medium range waveforms cover up to 200 Km and the long range waveforms covers from 200 Km to 300 Km. The ratio of the dwell times for long and short range will be high. In each range area Medium PRF waveforms are used. Here it is assumed that the ground clutter is dominant up to a range of 50 Km where the short range waveform is used for the search function with the dwell time required up to 50Km. For theses waveforms alone separate FIR filters with high ground clutter attenuation (80 dB) are employed. If the ground clutter attenuation requirement is more means the loss occurs due to Doppler filtering also will be more. For short range waveforms this loss will not affect the dwell time requirement because at short ranges the dwell time is not limited by the range rather by the minimum dwell time requirement of the radar and the number of pulses required for meeting the clutter suppression. After this high clutter attenuation Doppler filtering also if some strong clutter leaks and leads to detections then also the confirmation time is less because it is also having the same dwell time as that of the search waveforms. For medium and long range waveforms the PRFs are chosen such that it covers the required range in one or two range fold over after masking the detections up to the ambiguous range of 50Km. By doing so the clutter leak confirmations are avoided because most of the clutter leak will happen in the shorter ranges. After 50 Km even the zero Doppler filter detections are enabled for medium and short range waveforms because the clutter returns will be very less in these areas unless if a strong clutter source is present. The Doppler filters used for the medium and long range waveforms are different to cater different clutter attenuation required at different ranges. Normally at the long ranges the clutter attenuation requirement will be less, therefore for the waveforms which covers these areas are designed with the less ground clutter attenuation Doppler filters. These Doppler filter losses will be less due to this the dwell time requirement for covering the long range detections can be slightly less compared to what is originally required. Another important advantage with this approach is that different update can be maintained for search at each range area level. For example, at shorter ranges update rate can be more, at medium range area the update rate can be moderate and at along ranges the update rate can be still lesser. Mainly it depends on the radar actual mission requirements. The Fig1 shows the pictorial representation of radar coverage division in to short range, medium range and long range.

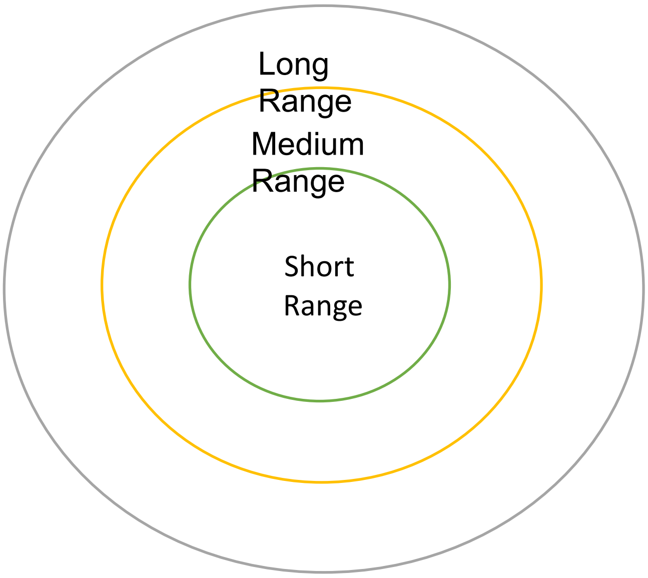

Fig.1 Rotating multi function radar coverage division

III. PRF SELECTION FOR DIFFERENT RANGE AREAS

For short range search medium PRF waveforms are employed. The choice of the PRF is also constrained by the dwell time in case of short range search. Because for Short Range search the dwell time required may be in the order of 1 to 2 ms (this also is limited by other factors as mentioned in the section II). For example, to cover 50 Km range if the dwell time requirement is 1 ms and LPRF waveform is selected then the PRI requirement is only 400 us approximately. This leads to only 2 to 3 pulses in a dwell. With this number of pulses, the clutter cancellation can't be done effectively using the Doppler filters because at near range strong clutter return occurs. Basically we need more FIR taps for the high ground clutter attenuation which indirectly increases the number of pulses requirement. Practically at least 6 to 10 minimum pulses are required to have the effective clutter attenuation. This leads to the PRIs in the range of 100 to 200 us or PRFs in the region of 5 KHz to 10 KHz. The ambiguous velocities of these waveforms are from 220 to 450 m/s at 3.3GHz. Therefore, the velocity covered by each Doppler filter will be in the order of 22 to 45 m/s for a 10 tap FIR filter bank. In this example the zero Doppler filter coverage is up to 22 m/sec which covers the ground clutter velocity which normally occurs up to 3to 6 m/s and the weather clutter (clouds) velocity up to 10 to 15 m/s. Therefore, the clutter leak is mostly avoided because the leakage will be extending to the same Doppler filter. The detection of low velocity targets may not be a problem because clutter map can be maintained for the zero Doppler filters. In the DBF based radars effect of the clutter saturation is less than the RF beam forming radars. Even if saturation occurs STC can be applied at short range waveforms alone. In the normal MPRF radars if we apply STC long range fold over targets will get desensitized. For long range waveforms if LPRF is selected its ambiguous velocity is in the order of 20 m/s at 3.3 GHz. If strong clouds are there it will spread into the many filters of the PRF. Here PRIs are chosen such that target falls after the one fold over and the zero Doppler detections are also enabled after 50 Km. Up to 50 Km all the detections are masked where most clutter leak detections are expected. For medium range waveforms the PRIs are chosen such that the target returns fall after one or two fold over. But the dwell time accounted for the medium range waveforms are only for the medium range only. For the medium range waveforms also the detections are masked up to 50 Km and zero Doppler filter detections are enabled in after 50 Km. For long range waveforms, in the folding over place the expected clutter returns are less compared to the near range clutter. Therefore, separated FIR filters are designed and used specifically for this range are alone.

IV. IMPLEMENTATION RESULTS

The above concept is implemented and field tested in rotating multifunction radar. In MPRF Compared to the scan to scan PRF changing approach this approach gives the faster search update time because the complete range from 50 Km onwards is updated in every scan (means each search frame). TWS tracking is tested with this approach which is not possible in the all ranges in case of scan to scan PRF changing approach. It was clearly observed that the clutter leak has been reduced drastically at shorter ranges. Target pick time is faster once if it is dropped due to the better search update rate. Compared to the original design with the scan to scan PRF changing approach, this new approach required approximately 7 to 8 % increase in the search frame time. But the main benefit is observed in the search update rate at longer range. Due to this all tracks need not be in full track mode at longer range, because TWS is employed. For Full tracks dwell time is computed dynamically based on the target range, therefore dwell time is high for longer range targets. With this approach the full track load is reduced drastically which is a compensation for the increased search frame time of 7 to 8%.

CONCLUSION

An approach for search waveforms management is provided in this paper. Performance of this approach is verified in DBF based multi function radar. With this approach search update rate is improved for long range surveillance. Different search update rate can be maintained for different range areas.

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[2]. Principles of modern radar volume-I, volume-II and volume-III, SciTech publications

Elayaperumal S. received B.E. degree in Electronics and communication engineering from Govt. College of Engineering, Salem in 2005. Since 2008, he is working as scientist in signal processing group in Electronics and Radar Development Establisment (LRDE), Bangalore.

Senthil Rengarajan J. received MTech Degree in communication engineering from IIT, delhi in 2006. He is leading a team for DBF based active array radar in Electronics and Radar Development Establisment (LRDE), Bangalore

L.G.M Prakasam: Born in 1961 at Tirunelveli (Dt), Tamilnadu, Graduated in E & C from Thaiagarajar College Of Engineering, Madurai in 1983, M.Tech in ICs & Systems from IIT Madras in 1986, M B A in Finance Management in 1996 from Annamalai university. Worked as Aero Engineer in HAL for two years, Lecturer for one year and working as Scientist in LRDE, Bangalore from Dec 1987 onwards. Currently Heading a group at LRDE for the design and development of an Active aperture phased array Radar with Digital Beam forming Technology.