MULTIBEAM SIGNAL PROCESSING FOR GROUND BASED RADAR

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Abstract:
Multiple receive beams in radar are used for improved performance in volumetric surveillance, reduced beam shape loss, improved performance in extreme clutter environments and angle estimation. The receive beams are highly overlapped making the signal processing complicated. This paper presents signal processing for multiple receive beams to find detections from the individual beams and estimation of target parameters. Implementation of multi beam detection combining and Maximum likelihood angle estimation algorithm is presented. Compared to conventional single beam radars performance improvement in target detection and better angular accuracies and resolution are achieved.

Keywords:* *Multiple receive beams, Maximum Likelihood (ML), Sidelobe blanking (SLB), Radar signal processing.

I. INTRODUCTION

Modern surveillance radars use a wide transmit beam and a cluster of multiple receive beams. A multibeam radar is widely used for advantages like the covering the same volume with fewer dwells for volumetric fence surveillance, reduced beam shape loss, improved performance in extreme clutter environments and angle estimation. With the requirement of adaptive beam forming techniques and availability of multiple beams signal processing architecture needs to be changed for handling multiple beams. Multibeam radar handles the digital video data received from the beams focused at different angles at the same time, which makes the surveillance volume by single dwell much larger than those of the conventional single-beam radars by the number of beams. Although due to the advances in processing technology handling such multibeam data is not so complicated nowadays, but combined processing of these beams for detection and target parameters estimation brings other challenges. The receive beams are highly overlapped to decrease the beam shape loss, making the signal processing complicated as issues like multi detections of same target in different beams and implementing the algorithms like side lobe blanking.

Consider a ground based radar employing a single wide transmit beam and 12 independent multiple receive beams in each look direction (3 auxiliary) through DBF (Digital Beam Forming), as shown in FIg.1. Due to multi beam cluster formation beam shape loss improvement is achieved, and larger volume is covered in the given time. The signal processor has to process the data available in the individual beams to search for target detections in the look direction and in case of a target presence, it has to to estimate target parameters like range, doppler, azimuth and elevation etc. To perform this functionality efficiently in changing environments it performs algorithms like SLB, CFAR and clutter map.

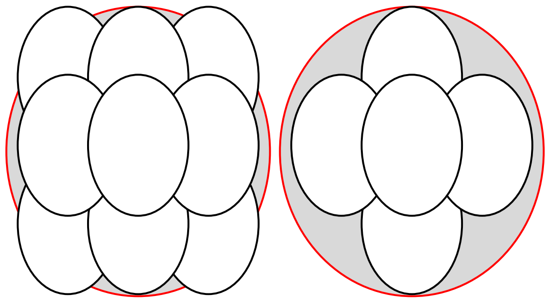

Fig.1 Radar with wide transmit and multiple receive beams for Search and Track respectively

In section II multibeam radar signal processor architecture is discussed in detail. Processing of individual beams data with various algorithms and combining to form a common detection report are presented in this section.. Algorithm for combining the individual beam's detections is presented in the Section III. In the end, Section IV discusses the Maximum likelihood algorithm used for angular parameters estimation.

II. MULTIBEAM SIGNAL PROCESSOR ARCHITECTURE

Multibeam radar signal processor architecture is presented which receives 9 highly overlapped individual beams forming a cluster of 3x3, covering the wide transmit beamwidth. Primary function of the processor is to search for target detections in search volume of look direction, which is achieved by individually processing the multiple receive beams data with various algorithms and generating individual detection reports. Individual beam is processed separately with Pulse Compression, Doppler filtering, CFAR and Clutter map processing on this data to generate detections for each individual beams, keeping a check on the false alarm rate. Then SLB algorithm is applied to individual beam detections for masking the detection coming from the side lobe of the antenna. This individual beam processing approach, due to its similarity with conventional radars processing, allows reuse of all the optimized algorithms that were used for conventional radars.

As highly overlapping beams are employed in the receive beam cluster, a single strong target will give rise to detections in multiple adjacent beams. Individual beam's detections are then combined to eliminate common detections in different beams.

Once combined detections are generated, target parameters need to be estimated for the detections. Parameters like range and doppler is estimated from individual beam return which has given maximum SNR for the corresponding detection. Angular parameters are estimated from output of all the receive beams for that detection using maximum likelihood algorithm.

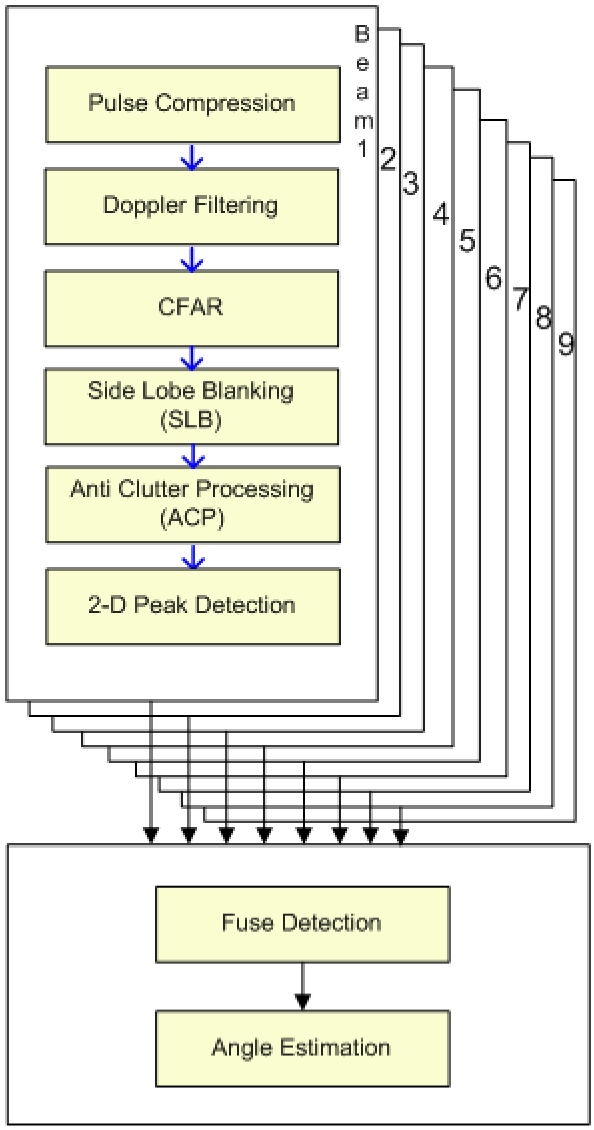

Fig.2 Signal processing architecture of Multibeam signal processor

III. Fuse Detection Algorithm

Multiple beam cluster contains highly overlapping beams, presence of single strong target will give rise to detections in multiple adjacent beams. To eliminate this, correlation processing is used to combine detections from the same target in different beams to form a common detection. One correlation window in range and doppler domain is made based on the measurement resolution of the radar in the corresponding domain. First logical OR operation is done on the detections from the individual beam for each range doppler cells. Then, for each detection in the logical OR output, Range and doppler association is done based on the correlation window size. From the detections which are correlated maximum SNR beam range and doppler cell is considered as the detection cell and range and doppler is estimated using weighted average of 3 cells in the respective domain of that beam. Once detection is found in range and doppler domain for that cell, all 9 beams outputs are used to estimate the azimuth and elevation.

IV. Angle Estimation Algorithm

The total azimuth and elevation coverage of the all the receive beams are split into number of grid points. For each detection in the fused detection output for each grid point in the beam space, SIR is estimated using Maximum likelihood algorithm which is explained by [2]. The following new approach is introduced to detect multiple targets in the beam space for a single detection in the range and doppler cell. On the SIR output, 2-D peak detection is done with a threshold which is computed adaptively from the maximum value of the SIR over the entire beam space. By this 2-D Peak detection approach in the Beam space multiple targets in the same range and doppler cell separated in only either azimuth or elevation or both can be resolved. For each detection in the beam space, grid azimuth and elevation is estimated using the weighted average of 3 cells in the respective domain.

This approach eliminates the need to dynamically compute a noise – and- interference covariance matrix, and shifts much of the maximum likelihood processing to pre-computations that can occur while a signal processor is offline during initialization [2]. For simulation two targets are introduced in the same range, doppler, elevation only in azimuth differed by 2.4 degree from each other. After the fuse detection algorithm the Maximum likelihood algorithm is applied over the beam space (9 beams cluster) and the SIR output plot is shown in the figure3.b and 3.c. In the figure, clearly two distinct peaks are visible in the respective target positions. When the target is in beam center, the ML SIR output is shown in figure3.a. The above proposed method is currently used in the DBF based fully active array radar and results are found satisfactory. The Maximum likelihood output for an opportunity target for a particular track dwell is shown in the figure 3.d.The number of grid points are chosen based on the accuracy requirements and processing time of the radar system. These grid points for search can be coarse and for track it can be kept finer for better accuracy which needs more computation.

Conclusion

An approach for ground based radar multibeam signal processing is provided in this paper. Performance of the Maximum likelihood method based angle estimation is verified in DBF based active array radar. If all the sub arrays outputs are available for the detection range and Doppler cell super resolution algorithm can be applied to resolve multiple Targets.

Figure 3.a

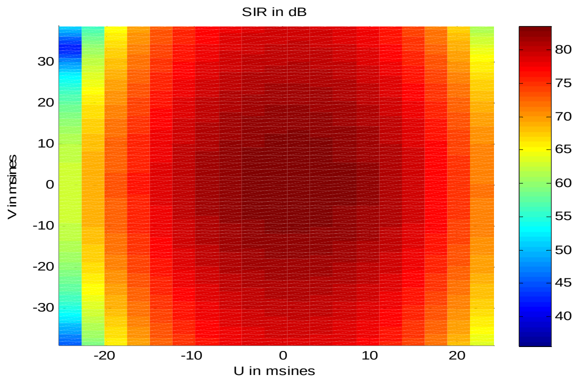

Figure 3.b

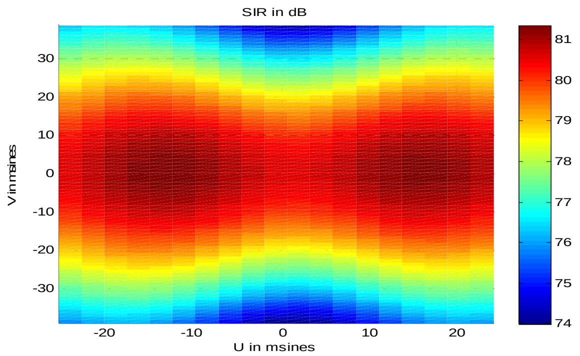

Figure 3.c

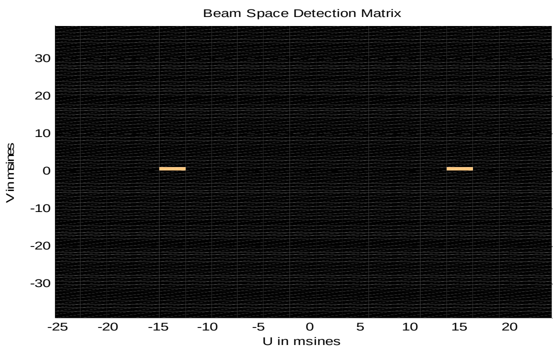

Figure 3.d

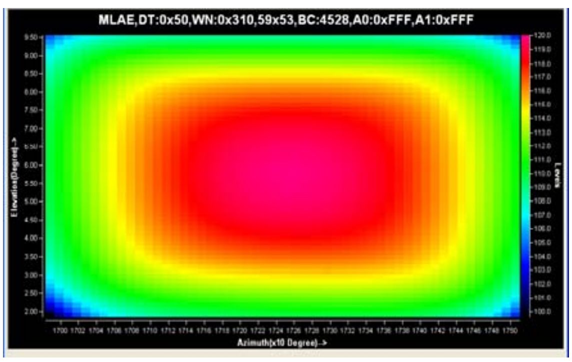

Fig.3 Angle Estimation results

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