TRACK WAVEFORM SELECTION BASED ON TARGET AND CLUTTER CHARACTERISTICS

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Abstract:

Target detection performance is improved by selecting a waveform based on tracked target characteristics and background environment. We consider a radar system which is capable of adjusting the waveform based on target and clutter statistics. This paper presents an algorithm utilizes target's RCS, unambiguous radial velocity, unambiguous range and the clutter spread in the direction for selecting the track waveform. Time on Target and best suited waveform is dynamically selected from a set for each target which gives required SNR and best visibility in interested range and Doppler. The waveform selection logic also takes into account the clutter regions identified in the site installation of the radar. Using the track waveform selection algorithm based on target and clutter characteristics, target detection performance can be improved and the radar resources can be effectively utilized.

Keywords: Track waveform, waveform selection, clutter characteristics, Doppler visibility, medium PRF.

I. INTRODUCTION

The choice of transmitted waveform is an essential concern in radars. In case of search waveforms no information is available in advance about the target, but in case of track waveforms target characteristics are fairly determined in search and confirmation stages. Conventional approach of tracking systems considers detection and tracking systems independently, and optimizing the detection of target based on background environment and target characteristics are never liked. The presented scheme for dynamic waveform management defines a cost function that describes the cost of detecting a target in a particular location for each individual waveform in the set and selects the waveform that gives best chances of detection on a dwell by dwell basis. This scheme significantly improve detection performance in clutter presence, where radars detection performance degrades[1,2].

In this paper we consider the problem of dynamic waveform selection for tracking a single target in clutter using an active radar with a fixed set of waveforms. The aim is to select the best sequence of waveforms to track the target in different phases of its range and velocity changes with the best possible detection probability. In general, a waveform can be tailored to achieve good Doppler or good range detection, but not both simultaneously. This is a problem faced by medium PRF radars in heavily cluttered environments, such as when a radar seeking to detect a target in presence of sea or rain clutter where clutter occupies many Doppler filters[3] or in mountainous terrain where background returns are much stronger.

The problem formation of track waveform selection is described in Section II, where in case of medium PRF radar, apart from other waveform parameters unambiguous range and unambiguous Doppler's impact on the detection of tracked targets is discussed. In section III, the purposed track waveform selection algorithm based on cost function on detection is presented. The algorithm's effectiveness in selection of best suited track waveform for a example radar with its set of track waveforms is evaluated in Section IV.

II. PROBLEM OUTLINE

Radar waveforms transmitted in the desired target direction plays an important role in how efficiently the target will be detected and tracking parameters determined. The problem of optimizing the detection of target based on selecting a waveform considering the background environment and target characteristics is presented.

Considering a Medium PRF ground based radar, the waveform parameters affecting tracked target's detection, are time on target (TOT) and PRF. The dependence of TOT on tracked targets RCS, range and swerling case can be derived from the range equation. The track waveform's PRF plays an important role in detection of target based on its range and Doppler parameters. The PRF induced aliasing effect introduces unambiguous domain in both in range and velocity.

For the considered medium PRF waveform, unambiguous range of the tracked target shall be considered, as, apart from falling into blind range region of that waveform, the target's true range might fold over and fall in the region with heavy clutter presence, thus degrading the detection for the target. In urban or mountainous terrains the heavy land clutter, often, overflows into other Doppler filters, where the target has to compete with it to get detected. Also, radars apply sensitivity time control (STC) attenuation in the initial ranges, thus detection of tracked targets falling in this region after fold over will suffer [1].

Also the tracked target's unambiguous Doppler plays an important role, as the target might fall in the blind Doppler region or in the nearby filters, where the MTI processing and the presence of sea or rain clutter spreads will degrade detection performance[1]. If the folded Doppler is near zero Doppler region, if the target velocity changes from the previous measurement then it might move to zero Doppler and presence of land clutter and clutter map processing will degrade its detection probabilities.

III. TRACK WAVEFORM SELECTION

In present radar, due to the dependence of other subsystems like signal processor, exciter, radar computer etc, waveforms are not generates online, instead best suited waveform is selected from a set of predetermined waveforms. Dynamic track waveform management selects the best sequence of waveforms to track the target in different phases of its range and velocity changes with the best possible detection probability. The selection process defines a cost function, for each range and Doppler domains, that describes the cost of detecting a target in a particular location for each individual waveform from the set.

Based on the time on target required for the target with a particular designed RCS, the maximum range is divided into range sectors and for each range sector a set of waveforms is defined. Waveform set is selected such that it provides maximum range and Doppler visibility within the range sector.

The targets parameters are already accurately determined in the search and confirmation stages, thus in waveforms selection process, after selecting the corresponding waveform set based on its RCS and range, we calculate weights for each range and Doppler domains, based on its chances of detection ability.

Range weights

As discussed earlier in Section II, initial ranges of the medium PRF will have STC attenuation and clutter overflows from strong urban and mountainous terrains. Therefore, based on the unambiguous range position of the target within the PRI each waveform in the set is given a weight equivalent to relative tracked target's range cell distance from the clutter spread distance, more being positive and less being negative. Waveforms giving target's unambiguous range corresponding to less than $delta_1$ range or more than $delta_2$ range are discarded.

Where

$$delta1 = (\tau + CFAR_{window} + \alpha + \delta)*c/2, \text{ and} \quad (1)$$

$$delta_2 = UnambRng_{PRI} - (\tau + CFAR_{window} + \beta + \delta) *c/2, \quad (2)$$

α and β being the receiver on and off timing respectively, $UnambRng_{PRI}$ *is the unambiguous range of the PRI,* $CFAR_{window}$ is the window size of the CFAR considered at either side of the target range cell, τ is the pulse width used and δ is the constant taken to allow any changes in the tracked targets positions such that it doesn't fall in the blind range.

Doppler weights

Due to the presence of sea or rain clutter spreads, MTI processing and to cater for target velocity estimation errors, each waveform in the set is given a weight from 0 to 1, based on the position of the target's normalised unambiguous Doppler. Doppler weight value of 0.2 to 0.8 Doppler can be considered to give good performance, with 0.5 doppler weight corresponding to the centre of the PRF considered best.

Also at the radar's installation time the heavy clutter return regions and sea starting range are mapped and stored in the radar data processor.

Based on these weights the best suited waveform is selected based on a compromise between both range and Doppler weights. All the waveforms are sorted according to the decreasing range weights, as with the increase in range the land clutter returns amplitude decreases, thus even if a target due to velocity estimation errors or manoeuvre falls near zero Doppler region its chances of detection are better. Then from this range sorted waveforms, excluding waveforms having negative weights, we are selecting the waveform having a better Doppler weight iteratively in a stepped search manner considering a step of 0.1 from both sides of PRF centre, increasing the step size with each iteration. In cases where target range is less than clutter spread range, waveforms having negative weights are also considered. For the selected waveforms target masking by already identified clutter regions are checked, if so the waveform is discarded and next best waveform is selected.

IV. PERFORMANCE EVALUATION

The track waveform selection algorithms performance is evaluated, for a medium PRF ground based radar having a maximum range of 180 km and uses a set of waveforms for different range sectors.

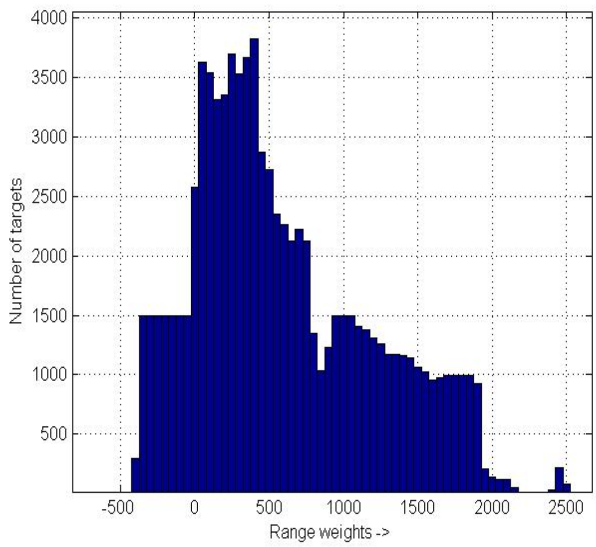

Fig.1 Histogram of range weights of waveforms selected by the algorithm

We varied the tracked target's range from 180km to 7km in a steps of 200m and velocity from -1000m/s to 1000m/s in steps of 20m/s. We also defined initial 30km as heavy land clutter region. The targets parameters were input to the track waveform selection algorithm and the best selected waveforms range and Doppler weights were recorded. As seen from the histograms of these weights, Fig.1 and Fig.2, range weights are always positive, other than instances where target range is less than clutter spread range and Doppler weights are mostly around 0.5 and rarely exceeding the 0.2 to 0.8 normalised Doppler region, such that target detection performance is not affected.

CONCLUSION

An approach to link the detection and tracking performance was made by considering a dynamic track waveform selection algorithm which takes into account the

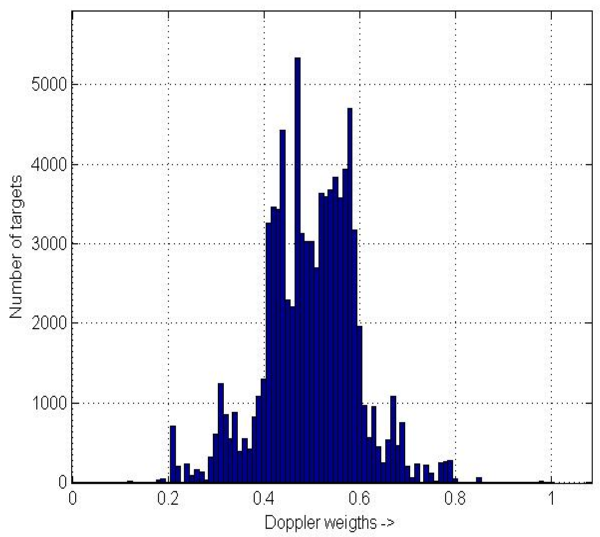

Fig.1 Histogram of Doppler weights of waveforms selected by the algorithm

background environment and target characteristics. The Algorithm defines a cost function, for each range and Doppler domains, which describes the cost of detecting a target in a particular location for each individual waveform from a predetermined set, and the best waveform is selected based on a compromise between both range and Doppler weights. Considering a example radar the performance of track waveform selection was evaluated. The algorithm will show improvement of detection performance in sea or rain clutter and heavily cluttered environments, like in mountainous or urban terrain where background returns are much stronger.

REFERENCES

[1] M. I. Skolnik, *Radar Handbook*, 3rd Edition, New York: McGraw-Hill, 2008.

[2] Richards, M., *Fundamentals of Radar Signal Processing*, McGraw- Hill, New York, 2005.

[3] Peter N.C. Nooy, Jean Claude D., Medium PRF Waveforms- an optimum solution for ground based radars, *28th European Microwave Conference*, Amsterdam, 1998.

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