UNIVERSITI TEKNOLOGI MARA

IMPROVEMENT OF ERROR PARAMETERS IN MARITIME FMCW RADAR USING MIMO

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PhD

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

The existing standard maritime radar is serving the need of large vessel tracking. However, it is inadequate for small vessel which has a small radar cross section (RCS) and below the radar line-of-sight. There is a vessel mounted radar in addition to the standard system, which is able to cater for small vessels tracking but limited to single radar coverage. In the event of weak echoes from targets and radar failure, vessels are unavailable to be tracked due to single-input single-output (SISO) application of the radar. Thus, a system with multiple tracking node is required and this study proposed an alternative approach by implementing a frequency modulated continuous waveform (FMCW) utilising multiple-input multiple-output (MIMO), in detecting vessels. A MIMO FMCW radar processing schemes utilising a diversity of frequency was designed. Multiple frequency was applied for orthogonality between MIMO signals and interval band was introduced, to avoid interference and overlapping between neighbouring sub-bands. A new scheme to combine MIMO received signals was proposed which is termed as spectrum averaging (SA). The SA performs by averaging all FFT magnitudes received from multiple FFT blocks and produces a single frequency spectrum for target estimation, on range or velocity. The design scheme was simulated numerically using Matlab programming, over scenarios of MIMO and SA implementation, interval band application, MIMO nodes expansion and computational complexity. A Monte Carlo simulation was applied to produce a statistical behaviour of the simulated system based on random sampling, on a Swerling 1 target. Simulation results proved the improvement brought by the proposed schemes in terms of error parameter compared to conventional SISO and multi-static configuration. MIMO receiving signals were observed in time and frequency domains. However, an FMCW MIMO complexity increases with incremental number of nodes. Finally, the proposed MIMO testbed was developed and validated experimentally in controlled environment. Observations were also done on the receiving signals and range error parameters in scenarios of MIMO and SA deployment, interval band implementation, MIMO nodes expansion and distributed system. Distance2Go modules were utilised for the proof of concept. Implementation of MIMO with SA and interval band demonstrated improvement in range error parameters. The proposed schemes were found to enhance beat signals energy and increased accuracy in target estimation. Introduction of more MIMO nodes produces improvement of error and an implementation of a distributed system provides the target localisation through the cross-section between multiple nodes coverage. By having one of the attributes, error parameters can be improved, and combination of more than one of the attributes may yield a better performance. Overall, this study produces an effective and possible option through implementation of FMCW MIMO with SA using multiple frequency, in maritime radar. Through realisation of the testbed, a new set of experimental data were acquired and validated with regards to static ground and maritime target.

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