STUDIES ON CIRCULAR ARRAY BEAMFORMING FOR SONAR

RAJENDAR BAHL

Thesis submitted to the
Indian Institute of Technology, Delhi
for the award of the degree of

DOCTOR OF PHILOSOPHY

Department of Electrical Engineering
Indian Institute of Technology
New Delhi-110016

FEBRUARY 1982

CERTIFICATE

This is to certify that the thesis entitled 'Studies on Circular Array Beamforming for Sonar' being submitted by RAJENDAR BAHL for the award of the degree of Doctor of Philosophy to the Indian Institute of Technology, Delhi, is a record of bonafide research work done by him under my supervision. The results contained therein have not been submitted to any other University or Institute for the award of any degree or diploma.

(Prof.P.V.Indiresan)

To my parents

ACKNOWLEDGEMENTS

It is with a deep sense of gratitude that I acknowledge the advice, encouragement and guidance rendered to me by my supervisor Prof.P.V.Indiresan during the course of this work. It is entirely due to his abiding interest that this work has been accomplished.

I would also like to thank Prof.B.Bhat , Head, Centre for Applied Research in Electronics for her interest and support provided to me in this endeavour.

It is a pleasure to acknowledge the fruitful association I have had with my colleagues in the Signal Processing Group at CARE. I would like to express my gratitude to Dr.Surendra Prasad for his interest and help in providing theoretical backing to some of the ideas embodied in this thesis. The very helpful companionship of Messrs A.L.Vyas and M.Balakrishnan, Dr.D.T.Shahani and L.Cdr.George Varkey, I.N. is also gratefully acknowledged.

I would also like to take this opportunity to express my appreciation to the Department of Electronics, Govt. of India for the support in the form of the many facilities provided at the Centre.

The efficient and prompt typing of this thesis by Shri H.L.Narang and the drawings made by Sh.R.P.Kapoor deserve my special thanks.

And lastly, it is with the deepest sense of gratitude that I acknowledge the care, understanding and constant encouragement I have received from my parents throughout the course of this work. To them, I dedicate this thesis.

RBahl

RAJENDAR BAHL

I.I.T.DELHI

FEBRUARY, 1982.

ABSTRACT

This thesis is concerned with studies on circular array beamforming for SONAR.

The circular array is finding increasing use in present -day sonar systems. Its usefulness can be ascribed to its symmetry which affords efficient formation of multiple beams for scanning the sonar environment. However, the circular array intrinsically suffers from a poor sidelobe ratio as compared to a linear array. The limitation of bandwidth of the array is also a matter of concern in sonar applications. We have, therefore, in this thesis adopted an integrated approach to study specific problems in circular array beamforming. The emphasis is on obtaining an insight into these problems and to propose ways of obtaining the maximum advantage from particular beamformer configurations.

The problem of beam pattern degradation due to phase error has been studied in detail. This knowledge has then been applied to the case of digital phase quantization and guidelines evolved for minimising the pattern degradations. The study of amplitude tapers has been made to analyse their pattern modification ability. The effect of some of these tapers on the bandwidth and beamwidth has been studied and compared with the special case of arc-arrays.

The phase-shift beamforming technique as applied to multiple-beam-steering has been studied. The combined effects of spatial sampling and demodulation have been analysed to reduce the frequency - dependent beam-squint. The spatial domain processing approach has also been investigated and a fresh insight into sidelobe reduction has been obtained.

A new beamforming structure - the Delta Modulation beamformer has been proposed and studied in detail. Compact hardware structures have also been put forth. The Delta Modulation beamformer has been built in hardware and its performance studied with the help of simulated signals and noise.

The various analytical results obtained have been largely verified and supported by computer simulation studies.

C O N T E N T S

Page

CHAPTER 4

AMPLITUDE MODULATION EFFECTS IN CIRCULAR ARRAYS