

# Optical Orthogonal Codes and Multi-Target Costas and Sonar Arrays

Oscar Moreno\*and Solomon Golomb

March 22, 2002

## Abstract

In this paper we explore the interconnection between Costas and Sonar arrays for multiple targets and optical orthogonal codes. Also we obtain a family of multiple target double periodical arrays (more than one array) whose auto and cross correlation is one and a family with autocorrelation 2 and crosscorrelation 1. Furthermore we give a method to obtain optical orthogonal codes from multiple target arrays.

## 1 Introduction

One of the results of our present paper is an answer to a question of [1], and we in fact prove how the concept of one dimensional modular rulers, or they also called OOC's with correlation  $\lambda$  is the same as two dimensional double-periodic arrays with correlation  $\lambda$ . Using this we obtain the signal patterns for multiple targets. Now using the previous mentioned result and a new construction of OOC's with  $\lambda = 1$ , we obtain a construction for multiple target arrays with auto and cross correlation one. This is the first family for multiple target arrays with  $\lambda = 1$ , and the arrays are of the extended sonar type. Furthermore given our equivalence theorem mentioned above (between two dimensional arrays and OOC's), and the fact that the new construction is optimal in the Johnson bound, we therefore obtain an optimal family of extended sonars with the property of double periodicity. We also apply our result to the constructions of OOC's given in [2] and obtain new construction of signal patterns for

multiple targets with auto-correlation 2 and cross-correlation 1. This is the first family with such correlation properties. Notice that the family might have more than 1 dot per row as well as per column and they are more general than the class of extended sonars. Note that the results just mentioned are quite surprising to us. One of the reasons is that it was proven that there does not exist Costas arrays with  $n > 4$  with cross-correlation 1. Note that the quadratic sonars have auto-correlation 1 and cross-correlation 2, but we researched for many years trying to find arrays with auto-correlation 2 and cross-correlation 1, without success. For many practical reasons this kind of arrays should be useful. Maybe some researchers will be motivated to implement these arrays.

## References

- [1] S. W. GOLOMB AND H. TAYLOR, Two-Dimensional Synchronization Patterns for Minimum Ambiguity, *IEEE IT Trans.* **IT-28**, No. 4 (July 1982) 600–604.
- [2] Guu-Chang Yang and Thomas E. Fuja. "Optical Orthogonal Codes with unequal auto and cross-correlation constraints". *IEEE IT Transactions*, Vol 41, No1, Jan 1995, pp 96-106

\*Work partially supported by Office of Naval Research Grant No. N00014-97-1-0973, DoD DEPSCoR Grant No. N00014-96-1-1192, NSF CISE Grant No. EIA-0080926