Computers and Electrical Engineering 000 (2017) 1–8

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

An FPGA implementation of novel smart antenna algorithm in tracking systems for smart cities☆

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ARTICLE INFO

Article history:
Received 28 December 2016
Revised 6 June 2017
Accepted 7 June 2017
Available online xxx

Keywords:
Beamforming
MUSIC
MSR-CORDIC
RLS
DOA

ABSTRACT

The area of digital signal processing (DSP) faces a great challenge in suppressing the noise and interference in the transmitting signal. A huge number of applications are in need of such control methods for good audio communication, etc., and the most widespread method for achieving this is through COordinate Rotation DIgital Computer (CORDIC) based on QRD-RLS. However, this method requires several iterations for its calculations, and therefore in order to reduce the complexity of the calculations and for faster calculation with a minimum number of iterations, a modified CORDIC based on the QRD-RLS algorithm for the purpose of beamforming is proposed in this paper and named mixed scaling rotation coordinate rotation digital computer (MSR-CORDIC). In this work, beamforming and direction of arrival (DOA) estimation will be achieved using the MSR-CORDIC and MUSIC algorithms respectively. The proposed algorithm is developed using Verilog HDL and implemented using the Xilinx field-programmable gate array (FPGA). In all cases, the proposed algorithm shows remarkable improvement compared with the conventional SCC (space code correlator) beamforming algorithm.

1. Introduction

The environment for receiving speech signals is usually noisy, i.e., the appropriate signal is corrupted by other signals and affected by a reverberating environment. Therefore, in order to obtain the appropriate received signal, separate measures must be taken to extract the message from the noisy signal [1]. In the case of a cocktail party environment, humans are able to separate out only a single conversation in a noisy environment, but reproduction of this cocktail party-environment separation process is a huge scientific challenge [2]. Furthermore, it is clear that the quality and the intelligibility of the recovered signal cannot be improved by using a single channel at a time. To overcome this limitation frequency/time information is added together with some spatial information in the single channel operation. The use of more than one channel results in so-called multichannel operation. Two main categories are available in the multichannel algorithm; beamforming and blind source separation (BSS). The information about the mixtures observed is sufficient for estimating the source signals in the BSS method. However, the beamforming algorithm focuses on the sum of the desired source and considers the remaining sources as an interference signal, as shown in Fig. 1.

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Associate Editor Dr. S. Smys.

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http://dx.doi.org/10.1016/j.compeleceng.2017.06.009
0045-7906/

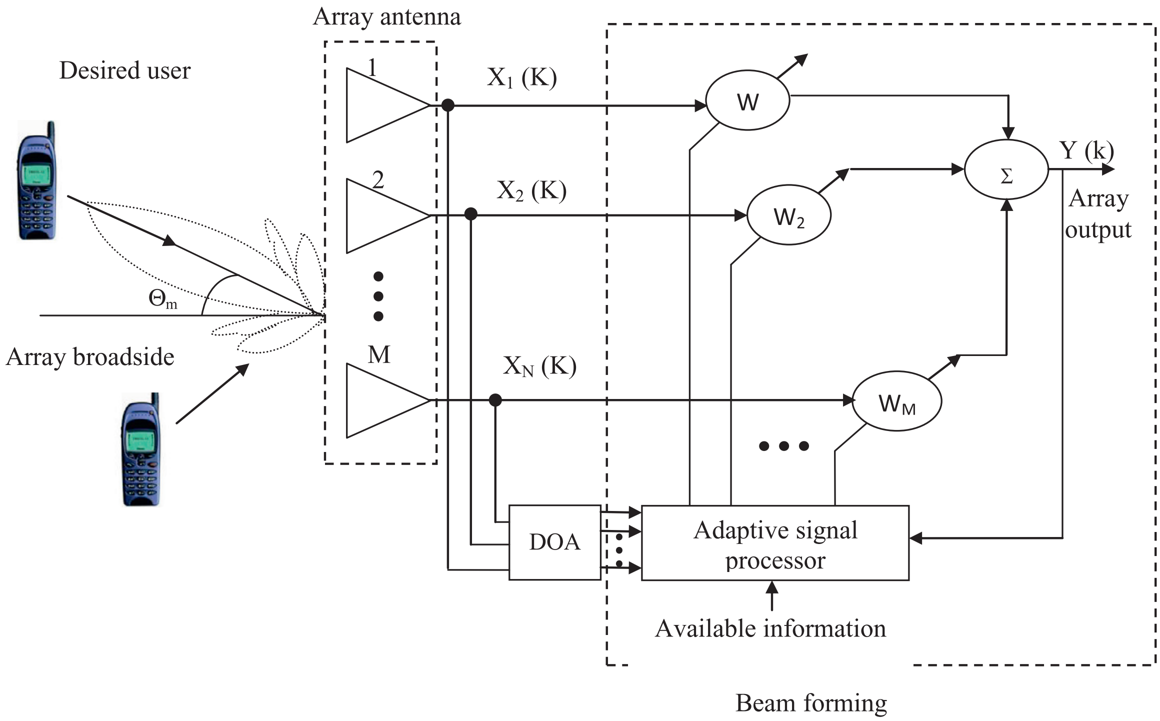

Fig. 1. Smart antenna system.

1.1. Overview of identified problem

The combination of a digital signal processor (DSP) with a conventional antenna is called a smart antenna [3]. Effective reception and transmission of a radio signal is the main function of a smart antenna, with the additional features of beam formation and DOA (direction of arrival) estimation. The direction of arrival (DOA) can be estimated using various algorithms such as Capon [4], Bartlett, maximum entropy and linear prediction.

Similarly, the beam forming can be performed by various methods, for example least mean square (LMS) methods [5,6]. The performance of the algorithm is evaluated in [7]. To overcome the drawback of the convergence rate, the LMS algorithm is replaced by a recursive least-squares (RLS) algorithm [8]. In [9], various algorithms such as LMS, RLS, SMI (sample matrix inversion) are evaluated for beam formation in smart antenna. In our previous work, we have implemented eigenvector decomposition (EVD) for beam DOA. In both methods, the QR decomposition is performed using the CORDIC (coordination rotation digital computer) algorithm. In this work, the recursive least-squares (RLS) algorithm is used for beam formation, but the QR decomposition is performed by mixed scaling rotation coordinate rotation by digital computer (MSR-CORDIC). For the simple and efficient evaluation of the proposed system, we estimate the direction of arrival (DOA) using the MUSIC algorithm [10].

The organization of the paper is as follows. In Section 2, an introduction to the CORDIC algorithm is given, The proposed method is then discussed in Section 3, followed by the evaluation and conclusion in Sections 4 and 5.

2. Preamble to CORDIC algorithm

2.1. CORDIC algorithm

CORDIC is an algorithm used for the calculation of two-dimensional vector rotation operations in hyperbolic, circular or linear coordinate systems. It is used in several applications, such as discrete transformations like the discrete cosine transform (DCT), fast Fourier transformation (FFT) [11], Hartley transformation [12], chirp Z transform [13], solving the singular value and Eigenvalue problem, digital filters [14], Kalman filters [15] and Toeplitz and linear system solvers [16]. Two types of operations take place in CORDIC, namely the vectoring mode and the rotating mode. In rotation mode, a vector (a, b) is rotated by an angle ϕ, resulting in a new vector (a^*,b^*) as shown in Fig. 2.

For every micro-rotation *'j'*, some fixed angles with the value arctan (2^{-j}) are added to or subtracted from the angle remainder $\phi_{j,}$ with the result that the angle remainder approaches zero. Similarly, in vectoring mode, the angle with the a-axis α and the length L are computed. To obtain this rotation of the vector towards the a-axis, the b component remains