Investigation of Beamformer for Reducing Multipath Fading

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ABSTRACT: A QR decomposition technique which decomposes a matrix into an orthogonal and a triangular matrix using Gram-Schmidt orthonormalization method has been studied. Quadratic Rotation decomposition (QRD) based recursive least squares (RLS) algorithm can be used in variety of communication applications and its low complexity implementation. In this paper we have presented an application of QRD based RLS algorithm using Coordinate Rotation by Digital Computer (CORDIC) operator for implementing an adaptive beamformer.

Key Words: Antenna Arrays,Adaptive beam forming, Fading, Beamforming, Multi input multi output systems.

INTRODUCTION

Spatially propagating signals encounter the presence of interfering signals and noise signals. If the desired signal and the interferers occupy the same temporal frequency band, then temporal filtering cannot be used to separate the signal from the interferers. However the desired and the interfering signals generally originate from different spatial locations. At the same time, some detrimental effects in randomly varying mobile communication environment like multipath fading, co-channel interference and Doppler effects need to be addressed. Adaptive beamforming is a recent method that known to offer the solution for the above mentioned problems.

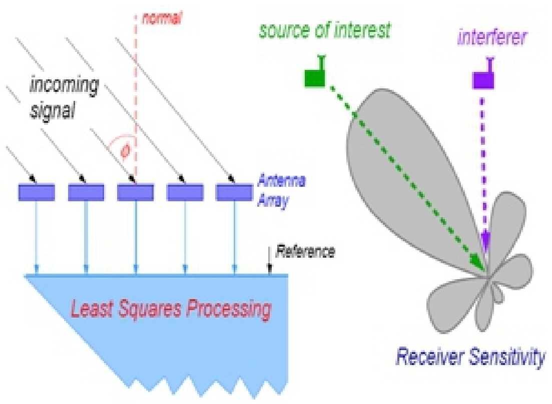

Fig 1: Concept of Adaptive Beamforming

Research on applications of adaptive antenna arrays have been an interesting subject over past 40 years [1] contributing to the invention of adaptive beamforming method. By taking advantage of the fact that users collocated in frequency domain are typically separated in spatial domain, the beamformer is used to direct the antenna beams toward the desired user while canceling signal from other users [2]. The beamformer electronically steer a phased array by weighting the amplitude and phase of signal at each array element in response to changes in the propagation environment. Capacity improvement is achieved by effective co-channel interference cancellation and multipath fading mitigation. Fig 1 shows the concept of adaptive beamforming. The beam pattern produced by a phased array antenna can be steered electronically to place the region of greatest sensitivity towards a source of interest, and nulls in the directions of interferers.

The desired incoming signal arrives at the antenna elements in order, separated n time by Δt. This time is calculable if the spacing between antenna elements, e is known. In the equation below, c represents the speed of light.

$$d = e \sin \phi \qquad (1.1)$$

$$\Delta t = \frac{d}{c} \qquad (1.2)$$

Putting (1.1) in (1.2)

$$\Delta t = \frac{e \sin \phi}{c} \qquad (1.3)$$

The adaptive filter controls the radiation pattern by applying adjustments to the signal arriving at each antenna element, according to the time delay (Δt) between pairs of elements. A reference signal is necessary in order to generate appropriate weight adjustments.

Modern communication systems require adaptive filters which converge much more quickly than Least Mean Squares (LMS) algorithm.

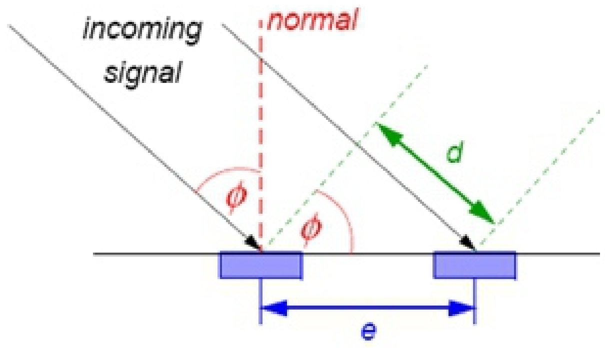

Fig2: Array of Antennas

The QR algorithm is a Recursive Least Squares (RLS) technique which meets this need and is particularly suited to Field Programmable Gated Array (FPGA) implementation. The LMS has been widely used for more than 40years. It is well known that the LMS is an approximation to the least squares (LS) solution for adaptive filtering, however its convergence and simple implementation have made it the algorithm of choice for applications such as echo control, and wire line channel equalisation. One key point regarding wire line channel equalisation is that there enough time to train the adaptive filter, and once adapted the channel is stationary and does not change. However for wireless applications including equalisation, and multi-antenna beamformers, MIMO systems etc. The time available for training the system is very small, and further the channel will change and a complete re-training of the system is required. Now, the faster the channel changes, the shorter the time available for training, and the training is required more frequently. Hence faster adaptive algorithms are required. This is the simple motivation and drive for the move real time LMS to real time LS algorithms.

In its direct form, the RLS algorithm would require floating point precision, or very long fixed point word lengths, due to its numerical ill-conditioning. In addition to Multiply/Add standard RLS implementation also requires divide operations. Hence the consequences of overflow and underflow can cause serious problems such as Divide-by-zero errors, etc. Hence for FPGA fixed point implementation, RLS must be carefully implemented. Therefore long fixed point word length is likely to provide the dynamic range demanded by the RLS algorithm. This motivates the QR-RLS algorithm method which is the most numerically robust method of RLS implementation and aims to keep the dynamic range of values low.

IMPLEMENTATION OF ADAPTIVE BEAMFORMER

The adaptive beamformer has been implemented for four antennas and Virtex 2Pxc2vp30-7ff896 FPGA device has been used for its implementation. Code has been written in MATLAB and its VHDL code and test benches have been generated using AccelDSP tool by Xilinx. Virtex 2Pxc2vp30-7ff896 FPGA device has been specifically used to compare the performance of our implementation with implementation of the same adaptive beamformer by [1], where the System Generator design tool from Xilinx was used to implement.

For the proposed design input signal frequency has been taken as 6 GHz and has been sampled at a rate of 100 GHz. The angle of incidence for desired input signal has been kept as 0 degree and amplitude has been taken as 1V. Fig 3 and 4 show the input signal and its spectrum respectively. Whereas, for the interfering signal, frequency has been taken as 20 GHz and has been sampled at a rate of 100 GHz. The angle of incidence for the interfering signal has been kept as pi/4 degree and amplitude has been taken as 1V. Fig 3 and 4 show the interfering t signal and its spectrum respectively.

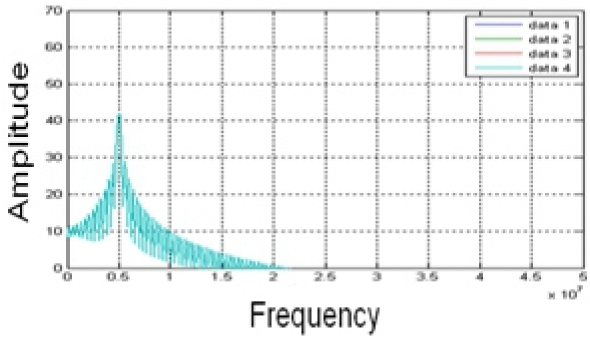

Fig 3: Spectrum of Input Signal

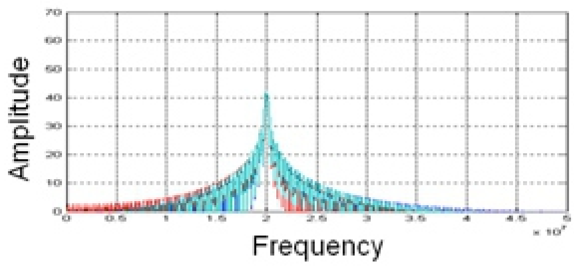

Fig 4: Spectrum of Interference Signal

Fig 4 and 5 shows the desired signal corrupted with the interfering signal.

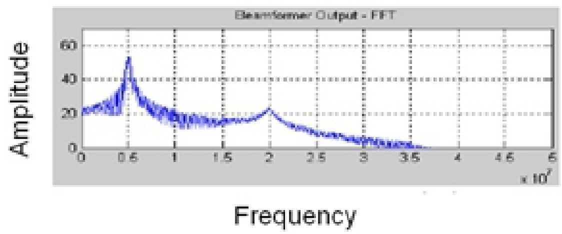

Fig 6: Broadside Array Output with Adaptive Beamforming [11]

Fig 5: Spectrum of Input Signal Corupted with Interfering Signal

Comparing Fig 5 and 4, it has been concluded that the interfering signal has resulted in an undesired peak in the spectrum, which should be removed by using adaptive beamformer.

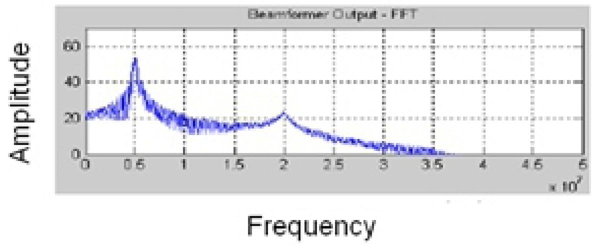

Fig 6: Broadside Array Output with Adaptive Beamforming [11]

CONCLUSION:

Modern communication systems like multi input multi output (MIMO) systems suffer frommultipath fading. Adaptive beam forming is a recent method which can be used to combat this problem. In this paper, the concept and use of adaptive beam former used in modern communication systems like beamformer has been investigated for the performance anylsis of adaptive beamformer.

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