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Gradient Based Adaptive Beamforming

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Abstract - *various non-blind gradient based adaptive algorithms have been applied toobtain main beam in the direction of desired user while suppressing interfering signals at the same time by minimizing the error. Adaptive algorithms use error signal, obtained by comparing the array output with reference signal, to optimize the weight of beamformer iteratively so that minimum MSE can be attained. Different adaptive algorithms like LMS, variable step size LMS, normalized LMS, variable step size NLMS, sign LMS, hybrid LMS and leaky LMS etc. have been studied, analyzed on antenna array and compared in terms of SLL suppression, null depth, signal tracking and mean square error. The fidelity parameters are mean square error and optimum weight vectors. It is found that the hybrid LMS gives the best performance in terms of fidelity parameter as compare to other algorithms. Effects of different antenna parameters like element variation and spacing between antenna array elements have also been analyzed.*

Key Words: **LMS,NLMS,MSE,BEAMFORMER,ANTENNA ARRAY.**

1.INTRODUCTION

Least mean square is simplest gradient based adaptive beam-forming algorithm that comprises repetitive process to make successive correction in the negative gradient direction which finally results in minimum mean square error. LMS algorithm modifies the excitation weights along the direction of the estimated gradient based on the steepest descent method. LMS is sensitive to the scaling of its input vector $x(k)$ .This results in very difficult selection of learning rate i.e. step size□□to assure stability of algorithm. Least mean square is modified to NLMS which solves this problem by normalizing the input power [22-24]. Array weight coefficient updating equation of NLMS In conventional LMS low step size leads to extremely large convergence time and large step size leads to degradation in error performance.Thus optimum value of step size is necessary to maintain equivalence. This problem prompted variable step size LMS. In variable step size LMS algorithm step size is varied according to square of the prediction error [25-27]. Large prediction error results in increased step size which provides faster tracking while small prediction error leads to decrease in step size that yields smaller misadjustment

1.1 Results and Disscussion

In this section, firstly LMS is re-implemented for the desired user at -15° and interfering user at1° and 3°. Fig. 3.3 (a) and 3.3 (b) shows the paper results [12] whereas Fig. 3.3 (c) and 3.3 (d) shows the re-implemented pattern and excitation weights. This algorithm can successfully direct the main beam to the desired by suppressing the interfering users but it suffers from the problem of slow convergence due to fixed step size [12]. Thus, various modified variants are applied to improve the performance of antenna array which is shown below.

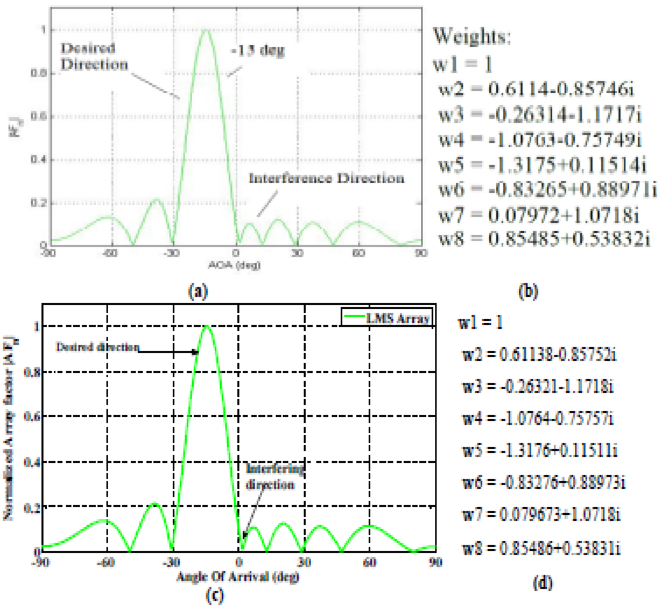

Fig. 3.3. Re-implemented LMS plot [Manikar *et al.* vol. 2, 2013) *IJERT*] (a) Paper Normalized Array factor (b) Paper weights (c) Re-implemented Normalized Array factor (d) Re-implemented weights

All of the above algorithms, described in Section 3.2, are applied on 8 element antenna array by using step size parameter μ =0.024 and SNR=20 dB. Additional parameters employed by variable step size LMS, variable step size NLMS, leaky LMS are 0.97, 2.8 10 4, 0.001and 0.001respectively. Four examples have been studied for different SOI and SNOI. All signals are assumed to be uncorrelated with each other and antenna elements are taken as without mutual coupling. All algorithms are compared in terms of Normalized Array factor pattern, SLL, null depth, computational complexity and MSE. These algorithms are run for 100 iterations. The optimal weights and errors obtained using these algorithms in MATLAB for all four examples, are given in Tables 3.1-3.5. Normalized array pattern, signal tracking ,MSE simulation in MATLAB and far field pattern in CST Mircowave Studio using these weights are shown in Figs. 3.4-3.11.

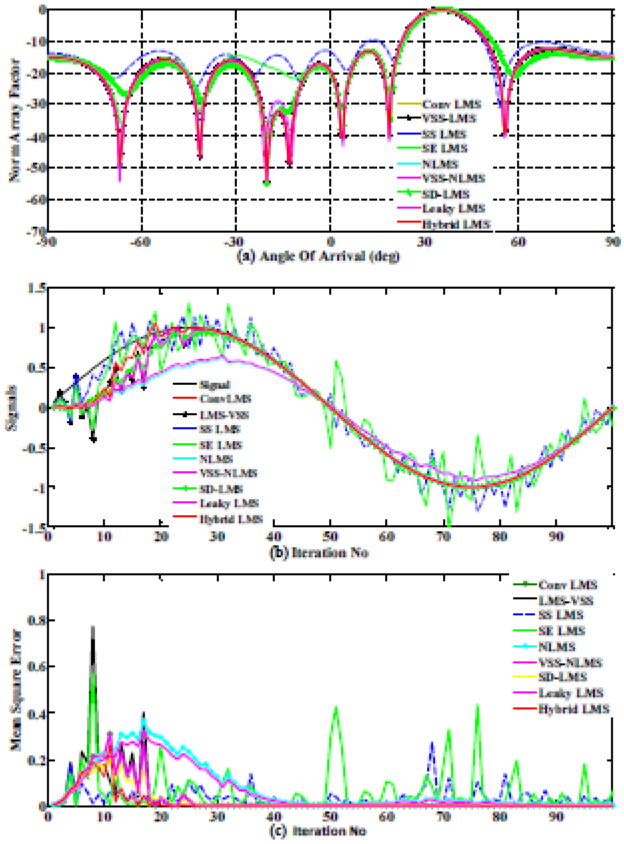

Fig. 3.4. Matlab Simulation Results of Gradient Based Algorithms having Desired Angle at 35° and Interfering Angle at -20°, (a) Normalized Array dB Pattern, (b) Desired Signal Tracking , (c) Mean Square Error

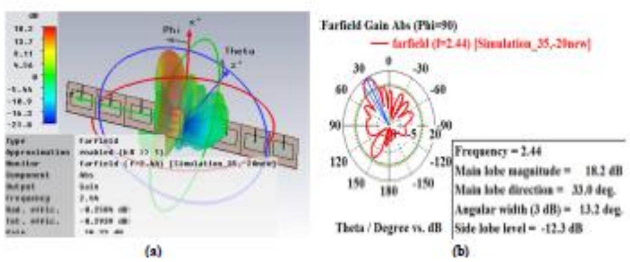

Fig. 3.5. CST Simulation Results of 8 Element Arrays using Hybrid LMS with Desired Angle at 35° AndInterfering Angle at -20° (a) 3D Far-Field Radiation Pattern, (b) Polar Far-Field Radiation Pattern.

LMS expresses slow convergence with good stability for higher step size and fast convergence with less stability for smaller step size due to its fixed value. Thus variable step size is used for good convergence and stability. Figs. 3.4-3.11 for all examples clearly shows that the LMS algorithm and its various variants place nulls in the direction of interfering signals and maximum in the direction of the desired signal. Analysis of mean square error represents that the VSS-LMS, NLMS, VSS-NLMS, hybrid LMS, leaky LMS can efficiently convergence in less iteration as compare to conventional LMS while LMS has better capability of directing mean beam toward desired direction and placing nulls toward interferers. Quantitative comparison of SLL, null depth, computational complexity in terms of adder and multipliers is shown in the Table 3.5.

1.2 Conclusion

overview of various adaptive beam-forming algorithms such as LMS, VSS-LMS, NLMS, hybrid LMS etc. has been given and their performance has been investigated and compared through antenna array design and optimization. Analysis and comparison of beamforming algorithm for the complex weight calculation for various cases is done using MATLAB and these results have been also examined using CST Microwave Studio. NLMS, VSS-NLMS, leaky LMS shows faster convergence as compare to LMS while main beam directing capability of LMS is better than others. Even though SLL suppression and interferers nullifying capability of SD-LMS, SS-LMS, SE-LMS is less than conventional LMS but it reduces computation complexity at a substantial rate. Hybrid LMS shows the best among all the variants of gradient based algorithm.

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