Performances of LMS and RLS Algorithms for the Design of Smart Antenna of Microstrip Array

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Abstract : Comparative studies on performances of least mean square (LMS) algorithm and recursive least square (RLS) algorithm for the design of adaptive smart antenna of microstrip array are presented in this paper. Microstrip array considered here is E-plane array. Beamforming using RLS algorithm provides reduced side lobe level (SLL) compared to that using LMS algorithm and directivity of radiation beam in RLS algorithm is higher than that obtained using LMS algorithm.

IndexTerms - Smart antenna, LMS Algorithm, RLS Algorithm, side lobe level.

I. Introduction

Multiple antenna system in the form of an array with smart signal processing algorithm is used in smart antenna to enhance the performance of a cellular network (Godara, 1997, Balanis, 2002). In switched beam antenna system, antenna can generate beam towards some predefined fixed directions, but not very accurately. In adaptive smart antenna, based on the direction of arrival of desired signal, using signal processing algorithm, beam can be pointed exactly towards the user and null of the radiation pattern of the array can be generated towards the undesired interferer (Sarkar et al, 2003, Ali et al, 2013, Senapati et al, 2015). Efficient spectrum utilization, high security and less power consumption in mobile communication can be achieved using smart antenna system. Commonly used signal processing algorithms for adaptive beamforming are least mean square (LMS) and its variants, recursive least square (RLS) algorithm and sample matrix inversion (SMI) algorithm (Balanis, 2002, Sarkar et al, 2003, Ali et al, 2013, Senapati et al, 2015). In most of the research papers on adaptive beamforming of smart antenna, isotropic antennas are used.

In this paper, microstrip antenna array is used for the beamforming of adaptive smart antenna. Millimeter wave frequency band of 28 GHz is used for antenna design. This 28 GHz band is recommended by international telecommunication union (ITU) for future 5G mobile communication (Rappaport et al, 2013). Microstrip antenna is low profile, thin patch antenna, fabricated on printed circuit board and is useful for high frequency applications (Lo et al, 1979, Bahl et al, 1980). Some reports on smart antenna design at lower microwave frequencies using microstrip array are available (El-Tager et al, 2009, Pavitra et al, 2013), but comparison of performances of adaptive algorithms in beamforming of smart antenna using microstrip array is not available. In this paper E-plane microstrip antenna array is used for beam formation. Adaptive signal processing algorithms, LMS and RLS are used. Performances of smart antenna of microstrip array based on beam direction (BD), null direction (ND) and SLL are reported. Millimeterwave frequency band of 28GHz is used for sector beamforming of smart antenna for cellular network. In cellular communication, to combat traffic load antennas are sectored in cell site. Commonly 3-sector cell or 120^0 sector cell is used where each antenna system coverage is120^0. Here 120^0 coverage of radiation beam is considered.

II. Adaptive Algorithms

Least mean square (LMS) algorithm is an adaptive signal processing algorithm where to reduce error in computation, weight vectors are updated by iterative process along with cost function to achieve desired performance of the system under consideration. Error e(n) between desired signal and d(n) and array output y(n) is minimized by as (Ali et al, 2013, Senapati et al, 2015)

$$e(n) = d(n) - y(n). \qquad (1)$$

Weight vectors in LMS algorithm is updated by the equation (Senapati et al, 2015)

$$w(n+1) = w(n) + \mu\, x(n)\, e^*(n) \qquad (2)$$

Where, μ is the step size parameter and complex conjugate of e(n) is e*(n).

The most inherent capacity of recursive least square (RLS) is its high convergence rate, because the error at any point of time is independent of the statistical properties of the signal. The algorithm updates the auto correlation matrix for the next instant with the aid of the auto correlation matrix calculated for the present instant. It suffers from the drawback of having high computation complexity. The RLS weight update equation is (Senapati et al, 2015)

$$\bar{w}(k) = \bar{w}(k-1) + \bar{g}(k)\,[d^*(k) - \bar{x}^H(k)\bar{w}(k-1) \tag{3}$$

III. DESIGN OF SMART ANTENNA USING MICROSTRIP ARRAY

Linear antenna array of N antenna elements with uniform inter-element spacing of ‘d’ is shown in Fig. 1. Antennas are fed by equal current having progressive phase shift of ‘α’.

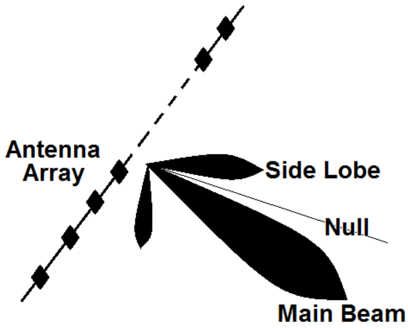

Fig. 1 Linear antenna array

Array factor for N element isotropic antennas is given by (Balanis, 2005)

$$AF' = \sum_{n=1}^{N} A_n\, e^{j(n-1)(\frac{2\pi d}{\lambda}\sin\theta + \alpha)}. \tag{4}$$

The resonant frequency of a rectangular microstrip antenna with dimensions L and W, substrate dielectric constant ε_r , substrate height ‘t’, can be determined from the formula (Bahl et al, 1980)

$$f_r = (c/_2\sqrt{\varepsilon_e})\sqrt{[(\frac{m\pi}{L})^2 + (\frac{n\pi}{W})^2]}. \tag{5}$$

Effective dielectric constant (ε_e) is defined as

$$\varepsilon_e = (1/_2)\{(\varepsilon_r + 1) + (\varepsilon_r - 1)\left(1 + \frac{12t}{W}\right)^{-1/2}\}. \tag{6}$$

In this work it is assumed that the smart antenna in the cell site is centered at 0^0 and coverage is from -60^0 to $+60^0$ where users and interferer are present. Microstrip array used here is E-plane array (depending on mutual coupling between microstrip antennas) and the array arrangement is shown in Fig.2.

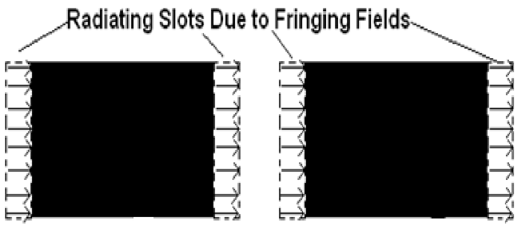

Fig. 2 E-plane microstrip array

Radiation field of microstrip antenna can be calculated by considering radiation of a microstrip antenna due to two slots (of width ‘h’) at the two edges of the patch.

For single radiating slot, radiation field at a distance ‘r’ from the origin of the source (Bahl et al, 1980)

$$E_\varphi = -j2V_0 W k_0 \left(e^{-jk_0 r}/_{4\pi r}\right) F(\theta,\varphi).,\quad E_\theta = 0. \tag{7}$$

V_0 is the voltage across the slot and $V_0 = tE_y$. Here, E_y is calculated considering a rectangular microstrip antenna as a cavity and this microstrip cavity is excited at fundamental TM_{10} mode.

Where

$$F(\theta,\emptyset) = \frac{\sin(\frac{k_0 h}{2}\sin\theta\cos\emptyset)}{\frac{k_0 h}{2}\sin\theta\cos\emptyset}\;\frac{\sin(\frac{k_0 W}{2}\cos\theta)}{\frac{k_0 W}{2}\cos\theta}\;\sin\theta. \tag{8}$$

for $\Theta=\pi/2$, $F(\varphi)$, E- plane pattern (x-y plane) is determined by considering microstrip antenna radiation due to two slots separated by a distance 'L' and can be expressed as (Bahl et al, 1980)

$$F(\emptyset) = \frac{\sin\left(\frac{k_0 h}{2}\cos\emptyset\right)}{\frac{k_0 h}{2}\cos\emptyset}\cos\left(\frac{k_0 L}{2}\cos\emptyset\right). \tag{9}$$

The final array factor for microstrip array is

$$AF = \sum_{n=1}^{N} F(\theta,\emptyset)\; e^{j(n-1)\left(\frac{2\pi d}{\lambda}\sin\theta+\alpha\right)}. \tag{10}$$

The normalized array factor is

$$AF_{norm} = \frac{AF}{AF_{max}}. \tag{11}$$

AF_{max} is the maximum value of array factor, AF.

For microstrip antenna array design, dielectric substrate RT/Duroid5870 with dielectric constant, ε_r=2.32, thickness (t) = 1.575 mm., is considered. The dimensions of rectangular microstrip patch antenna at frequency f_r=28 GHz are length of the patch (L)=3.88mm., width of the patch (W)=3mm.

The array factors for adaptive smart antenna at different desired beam directions using LMS Algorithm are shown in Fig.3, Fig.4 and in Fig.5. Inter-element spacing in all the cases d=0.5λ. In LMS algorithm step-size μ=0.002 and in RLS algorithm forgetting factor α=0.9. These values of parameters give best results presented in this paper.

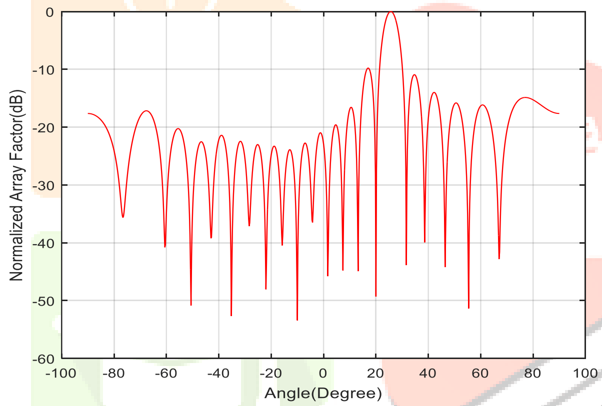

Fig.3 Simulated array factor using LMS algorithm for N=20, BD=25^0, ND=20^0

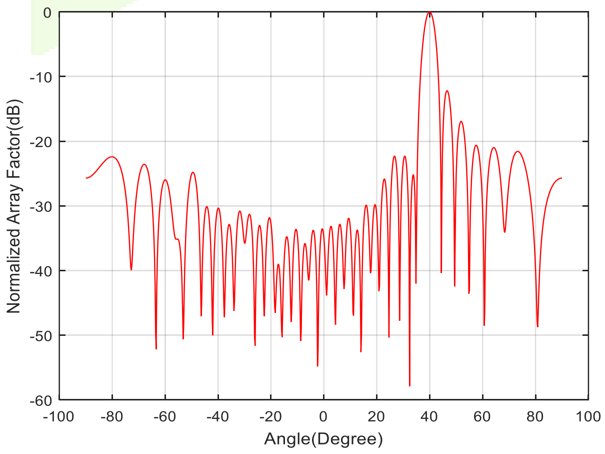

Fig.4 Simulated array factor using LMS algorithm for N=35, BD=40^0, ND=35^0

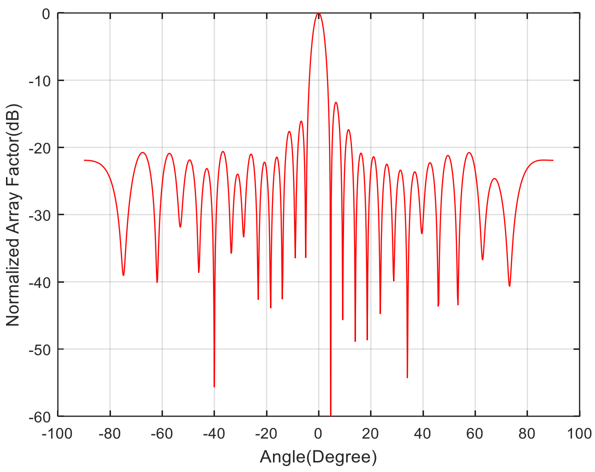

Fig.5 Simulated array factor using LMS algorithm for N=25, BD=0^0, ND=-5^0

The simulated results for the beamforming of adaptive smart antenna at different desired beam using RLS Algorithm for E-Plane Array are shown in Fig.6, Fig.7 and in Fig.8.

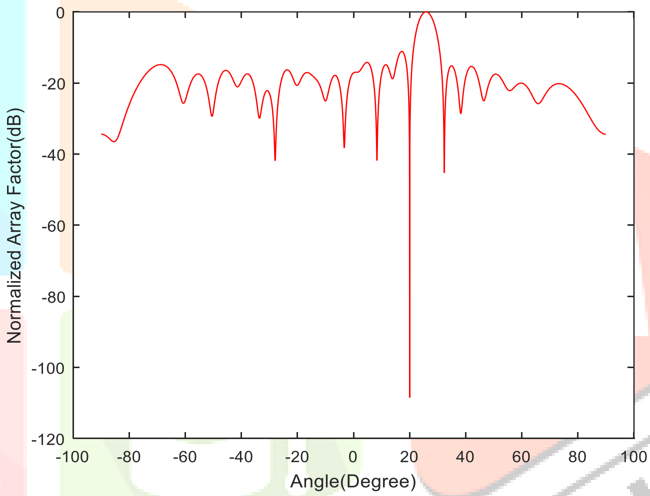

Fig.6 Simulated array factor using RLS algorithm for N=20, BD=25^0, ND=20^0

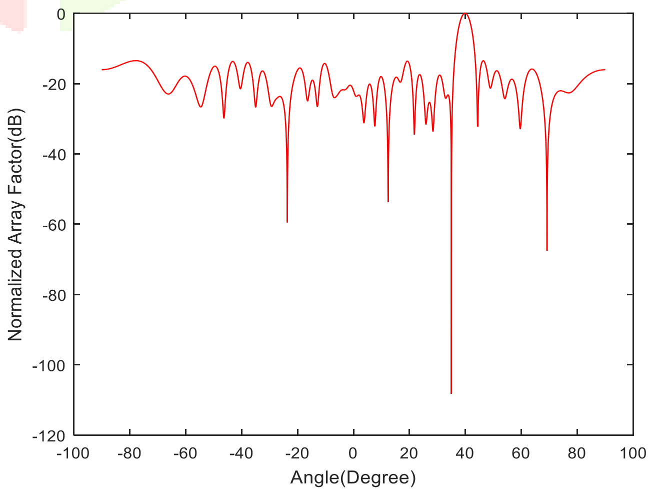

Fig.7 Simulated array factor using RLS algorithm for N=35, BD=40^0, ND=35^0

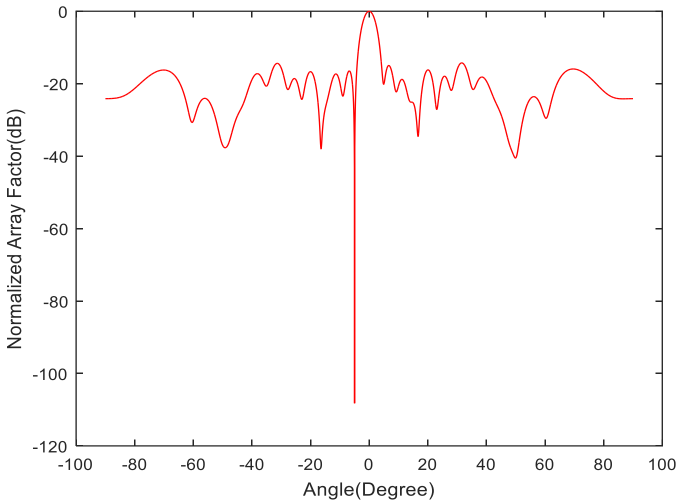

Fig.8 Simulated array factor using RLS algorithm for N=25, BD=0^0, ND= -5^0

The comparison of performances of LMS and RLS algorithms for adaptive beamforming of smart antenna is tabulated in Table-1. The smart antenna system in cellular network is assumed to have coverage angle from -60^0 to $+60^0$ having broadside direction of the array at 0^0. Therefore, results tabulated hare are valid only for this coverage angle.

Table 1 Performances of algorithms in adaptive sector beamforming [in LMS algorithm μ=0.002 and in RLS algorithm α=0.9]

Parameters	Algorithm	Obtained Beam Direction	Obtained Null Direction	SLL_{max}	HPBW
N=20 BD=25^0 ND=20^0	LMS	35.6^0	20^0	-9.8dB	5.8^0
	RLS	25.1^0	20^0	-11.4dB	4.2^0
N=35 BD=40^0 ND=35^0	LMS	40.4^0	34.8^0	-12.5dB	4.4^0
	RLS	39.8^0	35^0	-14.2dB	4.2^0
N=25 BD=0^0 ND= -5^0	LMS	0.4^0	-5^0	-14.1dB	4.4^0
	RLS	0.6^0	-5^0	-14.8dB	4.2^0

Half power beamwidth (HPBW) in all the cases are less for RLS algorithm than that for LMS algorithm, that is, directivity obtained using RLS algorithm is more than LMS algorithm.

IV. CONCLUSION

Performance comparison of LMS and RLS algorithms for beamforming of adaptive smart antenna using microstrip array is compared in this report. Results presented in figures are the best results obtained after a large number of simulations for each case. In view of lower side lobe level and higher directivity of radiation beam, the performance of RLS algorithm is better than LMS algorithm. Number of iterations, in both the algorithms is 100. Side lobe level reduction of about 2 dB is achieved using RLS algorithm compared to LMS algorithm. Mutual coupling between the microstrip antennas are not considered in this work which may be one of the future works on this topic.

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