Performance Analysis of Linear Antenna Array Using Multiple Optimization Techniques for WLAN

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Abstract—this paper uses multiple optimization algorithms for the synthesis of broadside and end fire linear antenna array. In this paper optimum value of current of each antenna element is determined which produces radiation pattern with minimum side lobe level. Optimization is done using MATLAB. Multiple algorithms i.e.PSO,RCGA,SGA,Taguchi's and chaos methods are used in which PSO gave better results among them cause of search in broader space along randomly generated directions to produce new generations. This improves the performance greatly to achieve the directivity and maximum reduction in side lobe level with minimum function calls and efficiently applicable for WLAN.

Keywords: Antenna array, PSO, SGA, RCGA, chaos Taguchi's cost function, fitness function, WLAN.

I. INTRODUCTION

With the advent of technology and recent developments in communication, wireless communication has reached to new level. Recent updates in wireless communication were not possible without application of smart antennas. Use of smart antennas is one of the vital characteristic that has led to third and fourth generation standard developments. However, smart antenna theory always driven by the Antenna array and so do the wireless communication. With antenna pattern synthesis there come speed and robustness to the existing system thereby improvising transmission parameters [3]. Along with this radio wave propagation is a matter of research that accounts to faster and reliable transmission, since wireless is generated from the roots of radio communication. However, there is a long way to go and research will contribute entirely for new upgrades in it. The primary objective of this paper is to study the effect of linear array antenna on wireless local area Network (WLAN) and then the optimization of a linear array antenna using multiple methods for side lobe level reduction thereby improving the communication.

II. ANTENNA ARRAY

An antenna array [5] is a set of N spatially separated antennas. In this paper, antenna with N=5 elements are considered as array of antenna. An array of antenna can have number of elements which may include several thousand elements. An antenna array is preferred over single antenna as it has ability to filtrate the intentional electromagnetic radiation in the air.

Consider a linear array of n isotropic elements of equal amplitude and separated by distance d. The total field E at a far field point P in the given direction φ is given by,

$$E = 1 + e^{j\psi} + e^{2j\psi} + e^{3j\psi} + \cdots \dots \dots \dots \dots \dots + e^{(n-1)j\psi}$$

Where, ψ = total phase difference of the fields from adjacent sources. It is given by;

$$\psi = 2\Pi \left(\frac{d}{\lambda}\right) \cos\varphi + \alpha$$

α is the phase difference between excitation current of adjacent element of antenna array. The basic setup of an arbitrary antenna array is shown in Figure 1.

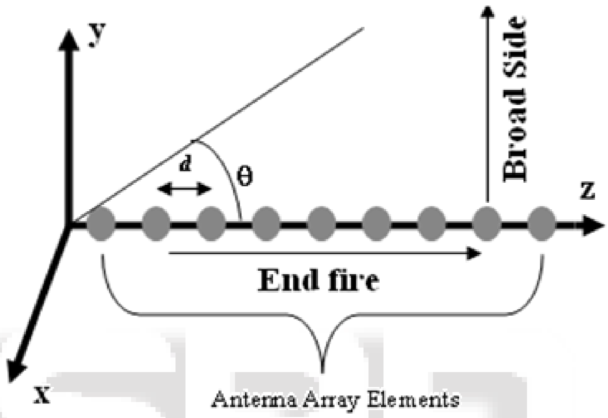

Fig. 1: uniform Antenna Array

The array factor for, N number of elements

$$AF = \sum_{n=1}^{N} E_n = \sum_{n=1}^{N} e_n{}^{jk}$$

Where $E_n = e_n{}^{jK}$ and K= (nkdcosθ + β_n) is the phase difference. β_n is the phase angle.

The antenna array can be used to:

1) It increases the overall gain of the transmission.
2) It helps to determine the direction of incoming signals
3) Maximize the Signal to Interference Plus Noise Ratio(SINR)
4) "Steer" the array so that it is most sensitive in a particular direction
5) Cancel out interference from a particular set of directions
6) Provides diversity reception

III. OPTIMIZATION TECHNIQUES

With the current development in antenna technology, optimization techniques have been as popular as a method of improving the recent standards in various parameters. In this paper we have used the particle swarm an optimization method. The increased level of side lobes can significantly degrade the system performance as well as antenna power efficiency. Though it is confirmed that Side lobe reduction is the basic way to achieve power efficiency and signal losses during transmission, yet it has to be followed with certain processes that results in side lobe reduction. Below are the processes through which the fact can be achieved.

1) Amplitude Only Control
2) Phase Only Control
3) Position Only Control
4) Complex Weights (Includes amplitude and phase control).

The purpose of optimization is to try to achieve the best result By adjusting input parameters; the process of optimization seeks for a better output so that the performance of a system, such asquality, monetary cost, and efficiency, can be improved. Optimization can be applied to a variety of areas and has received great attention recently. Thanks to the rapid development of computer technology, many optimization techniques such as genetic algorithm (GA), particle swarm optimization (PSO), taguchi's Method(TM), Chaos Optimization (CO) and gradient-based techniques have been implemented by computer codes. Currently in the field of electromagnetic (EM), many microwave circuits and antenna designs rely on optimization techniques []. Traditional methods, such as the trial-and-error approach, require many experiments to obtain an optimum or a satisfactory result. Therefore, an optimization technique is necessary for EM applications. In, this work following optimization methods are used which are explained in detail in this section.

1) Simple Genetic Algorithm(SGA)
2) Real-coded Genetic Algorithm(RCGA)
3) Particle Swarm Optimization(PSO)
4) Taguchi's method(TM)
5) Chaos Optimization(CO)

IV. SYSTEM DESCRIPTION

The MATLAB based simulation code has been generated for the development for the beam pattern from given antenna array pattern and has facilitated with the PSO based optimization. Following fitness function is used for all methods

$$\text{Fitness} = F1 = 20*\log_{10} (F / \max (F))$$

$$F = \text{abs} (E)$$

Where E is normalized field strength.

V. SIMULATION RESULT

S. No.	Parameter	Value
1	Frequency of operation	2.4 GHz
2	Spacing between elements d	5 cm
3	Phase between two elements	0 Radian
4	Type of antenna array	Broadside
5	No. of element	5
6	Optimization methods used	PSO ,SGA, RCGA,CHAOS, TAGUCHI'S
7	Output parameter	side lobe level, Directivity and Beam width

Table.1: The following parameters are used for the system development in MATLAB.

NO OF ELEMENTS	PREVIOUS RESEARCH WORK RESULTS (SLL IN dB)	RESULTS OBTAINED FOR PROPOSED ANTENNA ARRAY	
		SLL IN dB	DIRECTIVITY
5	-31.7	-34.38	10.93
8	-31.6601	-31.2005	11.34
16	-28.0118	-25.2933	11.67
20	-27.3382	-30.34	11.86
24	-29.1137	-27.34	11.31

Table.2: Combined Results of all the methods for Broadsided and end fire for number of elements N=5, 8,16,20,24

	SIMPLE GENETIC ALGORITHM(SGA)					
TYPE OF ARRAY	S.NO	NO.OF ELEMENTS(N)	SIDE LOBE LEVEL(dB)	DIRECTIVITY(dB)	HP BW (Deg)	CONVERGENCE TIME
BROAD SIDED	1	5	-31.04	10.67	34.12	12.347 SECONDS
	2	8	-31.2	10.79	33.26	
	3	16	-28.42	10.94	32.09	
	4	20	-31.69	10.85	32.295	
	5	24	-19.8991	11.11	30.92	
END-FIRE	1	5	-30.22	9.89	31.52	
	2	8	-24.5335	10.92	31.52	
	3	16	-24.8473	10.8589	32.09	
	4	20	-25.3131	10.8949	32.05	
	5	24	-21.897	11.0074	31.52	

Table.3: Performance Analysis of Linear antenna array for WLAN application

	REAL CODED GENETIC ALGORITHM(RCGA)					
TYPE OF ARRAY	S.NO	NO.OF ELEMENTS(N)	SIDE LOBE LEVEL(dB)	DIRECTIVITY (dB)	HPBW(Deg)	CONVERGENCE TIME
BROAD SIDED	1	5	-31.7	10.87	33.27	10.61236 SECONDS
	2	8	-31.6601	10.93	32.67	
	3	16	-28.0118	11.03	32.04	
	4	20	-27.3382	10.64	33.75	
	5	24	-29.1137	11.56	31.27	

END-FIRE	1	5	-30.59	10.11	34.78	
	2	8	-31.49	10.85	32.09	
	3	16	-32.78	10.8	32.09	
	4	20	-31.43	10.8956	32.09	
	5	24	-31.7073	10.85	32.09	

Table.4: Performance Analysis of Linear antenna array for WLAN application

	PARTICLE SWARM OPTIMIZATION(PSO)					
TYPE OF ARRAY	S. NO	NO.OF ELEMENTS(N)	SIDE LOBE LEVEL(dB)	DIRECTIVITY (dB)	HPBW(Deg)	CONVERGENCE TIME
BROAD SIDED	1	5	-34.38	10.93	28.24	5.425 SECONDS
	2	8	-31.2005	11.34	29.42	
	3	16	-25.2933	11.67	29.42	
	4	20	-30.34	11.86	28.68	
	5	24	-27.34	11.31	28.68	
END-FIRE	1	5	-30.59	10.73	29.56	
	2	8	-21.6	10.57	33.8	
	3	16	-26.257	10.3	35.52	
	4	20	-24.35	10.1773	37.71	
	5	24	-26.9949	10.54	34.37	

Table.5: Performance Analysis of Linear antenna array for WLAN application

	CHAOS OPTIMIZATION					
TYPE OF ARRAY	S. NO	NO.OF ELEMENTS(N)	SIDE LOBE LEVEL(dB)	DIRECTIVITY (dB)	HPBW(Deg)	CONVERGENCE TIME
BROAD SIDED	1	5	-33.5165	10.31	35.51	4.388403 SECONDS(MOST TIME EFFICIENT METHOD)
	2	8	-30.474	10.407	34.93	
	3	16	-29.3421	10.5156	34.33	
	4	20	-26.9362	10.52	34.29	
	5	24	-24.0421	10.46	34.33	
END-FIRE	1	5	-31.4498	10.42	34.37	
	2	8	-29.1939	10.35	35.53	
	3	16	-30.3601	10.34	35.53	
	4	20	-24.1173	10.34	35.53	
	5	24	-29.9434	10.38	35.53	

Table.6: Performance Analysis of Linear antenna array for WLAN application

	TAGUCHI'S OPRIMIZATION METHOD (TM)					
TYPE OF ARRAY	S. NO	NO.OF ELEMENTS(N)	SIDE LOBE LEVEL(dB)	DIRECTIVITY (dB)	HPBW(Deg)	CONVERGENCE TIME
BROAD SIDED	1	5	-33.38	10.88	29.76	8.04904 SECONDS
	2	8	-25.07	10.39	34.91	
	3	16	-29.744	10.47	34.33	
	4	20	-29.2268	10.4907	34.33	
	5	24	-25.2556	10.55	34.33	
END-FIRE	1	5	-29.7287	10.479	34.37	
	2	8	-24.4329	10.53	34.37	
	3	16	-28.6717	10.53	34.37	
	4	20	-30.5283	10.1063	36.67	
	5	24	-28.7557	10.46	34.37	

	SAME RESPONSEFOR SPECIFIC METHOD		IMPORTANT OBSERVATIONS
	OPTIMIZED RESULT (BEST RESULT)		MOST EFFICENT OBSERVATION

Table.7: Performance Analysis of Linear antenna array for WLAN application

VI. CONCLUSION

In this paper the antenna array synthesis it has been found that PSO Algorithm can handle the optimization problem better. But there is a drawback of this algorithm that its value gets change with the change in the number of iteration or generations. So some algorithm combined i.e. orthogonal arrays with PSO rather than classical PSO can also be used. As a compromise in directivity is observed the work can be extended to improve the directivity also while reducing side lobe level, same simulation can be done for non-uniform arrays as compared to this.Enhancement in directivity and maximum reduction in side lobe level is observed in the work can be extended to improve the greater directivity also while reducing side lobe level, same experiment can be done for array with large number of elements as compared to this.

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