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UTILISING THE PARTICLE SWARM OPTIMISATION TECHNIQUE, MICROSTRIP PATCH ANTENNA DESIGN OPTIMISATION

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Abstract: It is crucial to research novel distributed beamforming techniques by array antenna because wireless communication techniques are used in mobile communication, radar, and satellite systems. A single antenna cannot provide the criteria for a high directivity signal with extremely quick beam steering. The phased array antenna, which combines a number of tiny antennas and may produce a beam with great directivity and very quick electronic beam steering, provides assistance for this requirement. The weighting mechanism and array design have a significant impact on the radiation pattern of an antenna array. Because the radiation pattern depends on the weights, the choice of the weights has drawn a lot of attention. However, despite having a significant impact on the radiation pattern, the array shape has received very little consideration. There are primarily three types of beam synthesis that are carried out in practise, according to different radiation pattern requirements. These include narrow beam synthesis (Tchebyscheff, Taylor, Binomial Array), beam formation by null placement (Schelkunoff Array), and sector beam synthesis (Fourier Series, Woodward-Lawson Method). Schelkunoff Array can only position the nulls in the desired direction and has no control over side lobe level, and there is no widely accessible way for Flat-Top sector beam synthesis. High side lobe level and grating lobe difficulties plague phased array and classical narrow beam patterns. These problems with the beam pattern are producing a lot of communication interference, which limits their practical application.

I Introduction:

The fundamental sensor for all wireless devices is an antenna, which is a transducer for electromagnetic waves. The traditional designs for antennas have undergone many alterations as technology has advanced quickly. However, the fundamental ideas haven't changed all that much in terms of applicability. Thus, the antenna is employed in every device to either transmit electromagnetic waves in the desired direction or receive them with the necessary gain. Higher level parameter control is thought to be necessary nowadays due to the new generation technological uses of antennas, and research is being done in many ways for updated applications. As the need for global connection shifts more and more in favour of wireless networking and the use of higher frequency spectrum, many applications are starting to require the control of beamwidth and directivity in unwanted directions. A single element antenna system cannot meet the requirements of the newest generation of applications. A set of antennas known as an array has been shown to be the most effective option for contemporary communication networks and applications.

It is generally known that antennas play a significant role in the communication system; these unique structures are designed for effective electromagnetic wave transmission and reception. Gain and beamwidth are two parameters that define an antenna's performance depending on the application. Furthermore, the sidelobe levels and their radiation patterns in the distant fields determine the directivity control. The beamwidth is the angular measurement of the primary lobe in the direction in which this gain is attained, and the gain is specified with reference to an isotropic antenna. Thus, gain is seen as the antenna's capacity to focus the emitted radiation in a certain direction. Only in the intended direction does the gain represent the absolute rise in the levels of radiation, not in all directions. Along with the level of the mainlobe increasing throughout this process, there is also a noticeable pattern shift in the sidelobes, which must be controlled during design to minimise interference in the mainlobe's neighbouring directions.

Researchers have focused a lot of their attention on antenna arrays for a long time. Numerous text books and works of literature have included a great deal of study for the development of performance of numerous factors. The antenna handbook has been the best resource for understanding the characteristics among them. The literature research pertinent to the current approach has been projected in this part in order to arrive at the best answer for contemporary wireless communications, which place high demands on bandwidth performance and directivity. In addition to introducing basic problems with all wireless networks, Rappaport S. Theodore et al. [1] established new wireless standards and technologies that provide full. Rappaport used real-world examples to demonstrate each essential idea. J.L. Volakis and others. [2] Antenna Handbook contains all the traditional antenna types as well as several cutting-edge designs utilised in satellite communications, radar, and developing uses for smart antennas. The foundational ideas of antenna theory were first presented by C.A. Balanies et al. [3] and used to analyse, design, and measure antennas. He has also worked extensively with microstrip and smart antennas, as well as the most recent wireless communication applications. Jerry C. Whiter and others. For engineers and personnel engaged in the design and upkeep of electronic systems and devices, the Electronics Handbook is written.

2 Literature Survey

The data rates required are increasing rapidly for the next generation of wireless technologies. The channel models are where making the most of the huge bandwidth available in the frequency spectrum of mmWave will become a much more interesting subject. Making use of the massive frequencies available in the mmWave frequency band (30-300 GHz) is an ideal way of increasing the speed of data. A better approach to combat the massive free-space loss in route is one of the more researched mmWave applications. Researchers have recommended the idea that mmWave Multi-Input, Multiple Output (MIMO) as well as Multiple-Input Single-Output (MISO) techniques employ beam forming, lenses array antennas as well as antenna selection strategies as well as hybrid structures and techniques for power use to compensate for the high loss of path in mmWave to achieve both gain as well as directivity. In this section, we will review the particulars of different approaches that are related to the topics mentioned earlier.

Antennas, on which contemporary communication systems depend, have expanded at their quickest rate in recent decades. Researchers are drawn to develop new antenna applications and enhance existing design technologies in order to increase performance qualities. An outline of this dissertation, which discusses the synthesis of a highly contemporary phased array antenna using optimisation methods, is provided in the preceding chapter. This chapter presents a literature review of this dissertation that will provide an in-depth analysis of the current and historical sectors of interest in the domain of phased array antenna synthesis with a focus on the use of optimisation methods.

With James Clerk Maxwell's (1831–1879) seminal paper on electromagnetic field theory [1-3] and its explanation that electrical and magnetic fields could propagate as waves through space moving at the speed of light, the development of antennas and wireless communication began in 1865. Heinrich Hertz (1857–1894), a German scientist, discovered by experiment that Hertzian waves, subsequently referred to as radio waves, could be produced experimentally and were reflected by metallic surfaces in 1887[4].Half wave, end loaded, and parabolic reflector antennas are his least expensive gifts in the area of radio communication. The famous Indian scientist Sir Jagadish Chandra Bose created the first full two-way wireless communication system employing a complete transmitter and receiver system operating at 60 MHz with cylindrical horn antennas[5].

Along with his groundbreaking work on the bow-tie and bi-conical antennas, Sir Oliver Lodge introduced the monopole antenna idea first[6]. A simple apparatus for detecting and preventing ship collisions in fog was built using Christian Hulsmeyer's first experimental use of electromagnetic radiation [7]. It was the first commercial device that resembled RADAR and used radio waves to find an item. A fan and monopole antennas were used by Guglielmo Marconi (1874–1937) in a series of successful tests he later carried out on radio wave communication systems for long distance communication [8]. This discovery spurred a greater interest in global communication and radar system development. During the second world war, significant advancements in wireless communication and antenna design were seen. In order to avoid using a big antenna, an antenna array was initially developed for military uses in the 1940s. It has been shown experimentally[9] that the gain of certain directional antennas at far field may be enhanced by increasing the distance between array members, even when the array elements are not properly phased. The first mathematical model for controlling the directive features of linear arrays was proposed[10]. It uses a complicated algebraic polynomial approach to express the radiation direction in space. A significant relationship between the maximum beamwidth and its associated side lobe level of a linear symmetric broadside array's radiation pattern was discovered [11]. It was shown using examples that for a constant beamwidth, an equal valued sidedelobe is generated when all the elements are stimulated with the same phase but with a current distribution whose magnitudes are the coefficients of Tchebyscheff polynomial.

3 Methodology

Due to its intriguing qualities, such as cheap cost, Microstrip Patch Antennas (MPA) are particularly popular for usage in various applications. On the other hand, MPA's low bandwidth, which may be as low as 1%[1], is its biggest drawback. The following sections go through the methods for frequency tweaking and broadbanding microstrip antennas:

3.1 Frequency Tuning Methods and Dual Band Microstrip Antenna Operation

Operating the same antenna across two or two distinct frequencies using band separations that are arbitrary is beneficial in numerous situations. Microstrip antennas are able to operate on multiple bands because of various approaches. Inner and outer Radii can be used to change the operating frequency for an annular circle. The relationship between two frequencies is comparatively limited, but it is not a perfect match. Another approach to achieve dual-frequency operation is stacking quadruple patches. The antenna's polarisation can be adapted to the two bands of frequency also. Karamakar and Bialkowski[4] created a right-hand circularly polarised microstrip that can cover the frequencies from 1545-1559 MHz as well as 1646-1661 millimetres using one wide band antenna.

A method is to stack circular patches that have strip of perturbation on top of each other in order to get dual band operation. The possibility exists to obtain an increase in frequency through altering the form of the antenna's fundamental shape [55. But, this involves long-term physical changes to the antenna, and is not utilized to electronically alter or control the efficiency that the antenna. In general, a microstrip-type antenna is developed to be used in the predominant method of operation. The efficiency of radiation as well as the impedance patterns get worse in the following higher-frequency mode. Patches have high Q resonance structures. In the case of operating in dual bands, the radiating elements should be placed in a way that the structure is not less planar. Coaxial probes, aperture coupling or microstrip feed lines could be all used to feed the lower patch.

There are other types of patches like pentagonal patches [7circles [8, and trapezoidal patches can be made by using the same technique. To create the case of a 1.22-m dish Kerr 10 has developed the dual frequency shepherd's crook feed. A X-band waveguide's flange joined by a linearly-polarized microstrip in the L-band band, and is lit by the hole that is drilled into the middle. Malagisi (11) has demonstrated that circular microstrip components equipped with shorting pins can be utilized in the construction of a reflector that is phase-shifting. Machine screws were used in experiments as shorting posts that can be detachable to create a post-loading technique. Right-hand circular, left-hand horizontal linear and vertical linearly polarized fields could all be produced with a single microstrip [1213]. The shorting posts can be used to allow adjustments in frequency without affecting the input impedance as observed in Kernweis as well as McIlvenna [13(13, 13). By etching small spaces within the antenna, dual-band operation is made practical [14],and [15].

A different approach is to use the use of a single device for negative resistance that is incorporated into a patch antenna that can create an antenna suitable that can be used in GPS as well as Universal Mobile Telecommunication Systems (UMTS) applications [1616. The antenna consists of two rings which are laid over one the other, and have a common location at which the negative resistance device is placed. Stubs that are part of transmission lines could also be used for tuning frequency [17and. In order to tune frequencies the two stubs linked to an antenna may be of different lengths. For the purpose of adjusting the antenna the air layer can be placed between the surface and the ground plane. If the patch is connected to the stub via the PIN's control via optical means microstrip patch antennas are altered optically within a limited frequency band [1919. The resonance frequency of an antenna is usually determined by length of the patch, while patch size has no impact. Input resistance and bandwidth are significantly influenced by the patch's width. Wider patches increase the radiation power that lowers the resistance of resonant and increases the radiation effectiveness.

4 Experiments & Results

From a linear array of isotropic components, the ramp patterns are extracted using a real coded genetic algorithm. The distance between the elements is calibrated at /2. Equation (2.2) is used to get the array factor, and equation (2.4) is used to determine the appropriate ramp pattern. Equation (2.9) evaluates the fitness function. The values of the control parameters responsible for beam shaping are shown in Table 2.2. The errors are quantitatively calculated using the equations (2.5-2.8) that were previously discussed. Results for a finite ramp width (u0) of 0.4 are obtained by altering the number of elements. The array factor is calculated using the amplitude and phase excitation of each element as determined by the algorithm, and the simulated results are presented for N=20, 40, 60, 80, 100, and 200 elements.

Table 4.1. Excitation levels of 20 elements

Element Number	Amplitude Excitations $A(x_n)$	Phase Excitations $\Phi(x_n)$
1	0.2635	-0.4463
2	0.2851	-0.7444
3	0.5934	-0.5753
4	0.3083	-1.3064
5	0.5461	-0.7950
6	0.7143	-1.6130
7	0.1818	0.0722
8	0.9829	-0.8671
9	0.7823	-1.2108
10	0.5621	0.1711
11	0.5225	0.2133
12	0.4413	0.7374
13	0.2065	0.3321
14	0.5915	1.7335
15	0.4837	0.8580
16	0.4598	0.0016
17	0.7874	-1.6310
18	0.2209	0.6120
19	0.1975	-2.0480
20	0.4407	-1.4280

Table 4.2. Excitation levels of 40 elements

Element Number	Amplitude Excitation $A(x_n)$	Phase Excitation $\Phi(x_n)$	Element Number	Amplitude Excitation $A(x_n)$	Phase Excitation $\Phi(x_n)$
1	0.1698	-2.8178	21	0.9574	0.8267
2	0.1865	0.6125	22	0.8135	1.8397
3	0.0361	-1.6651	23	0.6257	0.9807
4	0.4531	-1.3529	24	0.1301	0.9664
5	0.2250	0.9665	25	0.1891	1.2207
6	0.1827	0.6140	26	0.2250	0.6657
7	0.5250	-0.1441	27	0.4217	1.2867
8	0.5947	-0.3684	28	0.7754	2.2365
9	0.1832	0.0883	29	0.6933	2.6200
10	0.1700	-2.3014	30	0.5437	0.1218
11	0.3740	1.0163	31	0.2570	2.4812
12	0.0595	0.8860	32	0.7151	-1.0317
13	0.0979	0.0160	33	0.2483	0.7088
14	0.8299	-0.7145	34	0.4611	-1.2741
15	0.4363	0.0125	35	0.4277	2.1418
16	0.8193	-1.0822	36	0.2190	0.7803
17	0.9014	0.0685	37	0.4195	-0.6631
18	0.7261	0.3061	38	0.2684	2.1207
19	0.9462	0.2980	39	0.0565	0.2934
20	0.6769	1.0982	40	0.5459	0.0023

Table 4.3. Excitation levels of 60 elements

Element Number	Amplitude Excitations $A(x_n)$	Phase Excitations $\Phi(x_n)$	Element Number	Amplitude Excitations $A(x_n)$	Phase Excitations $\Phi(x_n)$
1	0.6610	-2.6968	31	0.2774	0.9906
2	0.2911	0.7144	32	0.1156	0.9685
3	0.7982	2.0381	33	0.0301	0.9873
4	0.1067	-0.7386	34	0.8285	-1.3434
5	0.1532	0.8258	35	0.9672	-0.9604
6	0.5005	2.4286	36	0.9857	-0.7224
7	0.2447	0.0258	37	0.7629	-2.2763
8	0.3110	0.0164	38	0.9026	-1.0567
9	0.3025	0.3984	39	0.7496	0.4524
10	0.4676	0.2118	40	0.7926	0.3472
11	0.6090	0.7227	41	0.6895	0.2457
12	0.1762	0.9095	42	0.5106	0.1197
13	0.5173	1.9791	43	0.6349	0.9074
14	0.1240	0.0000	44	0.7167	0.6246
15	0.2920	-0.9004	45	0.6387	0.8586
16	0.2006	0.0379	46	0.1326	0.9758
17	0.4883	-0.7731	47	0.6814	0.9987
18	0.6884	0.7033	48	0.5854	0.9858
19	0.1916	0.8717	49	0.4394	0.7448
20	0.0974	0.9713	50	0.1084	0.9490
21	0.2213	-0.3931	51	0.6219	1.3449
22	0.5884	-0.6561	52	0.4609	0.5129
23	0.7002	-1.3039	53	0.6016	-2.7881
24	0.6928	-1.6269	54	0.5422	1.4036
25	0.4689	0.3356	55	0.1499	-1.0601
26	0.4224	-1.1910	56	0.8484	-2.8079
27	0.6522	0.9980	57	0.3161	1.8066
28	0.6414	0.7540	58	0.6182	-2.1497
29	0.6043	0.9886	59	0.3625	2.8423
30	0.3283	0.9752	60	0.4485	2.8944

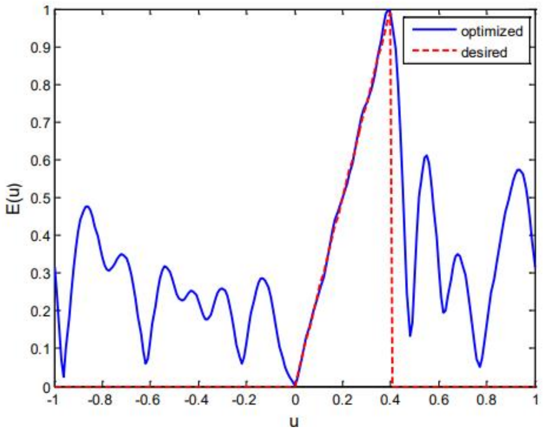

Fig. 4.1 Radiation pattern of 20 elements

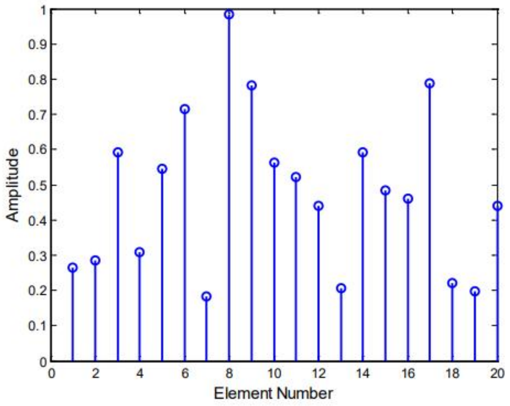

Fig. 4.2 Amplitude Distribution of 20 elements

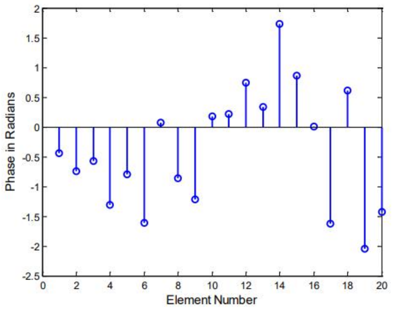

Fig.4.3 Phase distribution of 20 elements

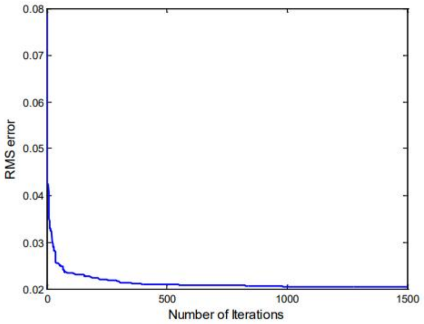

Fig.4.4 Convergence plot of 20 elements

5 CONCLUSION

To thin an array is to selectively switch off certain elements from a regularly spaced or periodic array in order to get the correct amplitude density throughout the aperture. While an element linked to a matched or dummy load is in the "off" state, an element connected to the feed network is in the "on" state. It is far easier to thin an array to create low side lobes than it is to solve the more widespread issue of uneven element spacing. The positioning of the components may be done in an endless number of ways with nonuniform spacing. There are 2Q different ways to thin, where Q is the number of array items. The alternatives for the arrangement of the components are much less if the array is symmetric. Another way to think about thinning is as discrete amplitude taper, where each element's amplitude is represented by one bit (0 or 1). The optimal thinned aperture is found by analysing a large number of potential outcomes while thinning a huge array for low side lobes.

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