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Design of Adaptive Array Antenna for Wireless Communications

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ABSTRACT: - In the ad hoc networks, it consists of many sensor nodes, and each sensor node is equipped with five units. The transmission unit cares for the transmission and receiving of data through the antenna. In this paper, the microstrip patch and 1x2 array antennas are designed and fabricated. The results of simulated and measured results are compared at operating frequency 5.4GHz. The results show the enhancement in the bandwidth and low VSWR which shows the maximum radiation of power. The array antenna can be operated for the wideband with better reflection coefficient, gain, bandwidth, and VSWR and radiation pattern. This smart antenna is self-efficient to configure with multiple high directivity beam to save the power, range and use reuse of channels. Such smart antennas are used for the ad-hoc network, Wi-Fi, UWB, and high-speed LTE applications.

Key words: Array, microstrip, ad-hoc networks, wireless Sensor Networks

1. INTRODUCTION

There are two types of ad-hoc networks: Infrastructure and infrastructure-less networks. The ad-hoc network comes under an infrastructure-less multi-hop network. Nodes in the network are mobile. The wireless hosts in such networks communicate with each other without the existing fixed infrastructure and a central location. Smart antennas are used in ad-hoc networks. A mobile ad-hoc network can be connected to the other fixed infrastructure or internet. Most of the ad-hoc networks use the allocated frequencies for the industrial, scientific, and LSM band. Smart antennas usually consist of an array of antennas that work together to either focus the transmitted energy in the particular desired direction or to provide uncorrelated receptions of signal that can be combined by complex signal processing. Techniques to improve the received signal quality or both. The spacing between antenna elements is on the order of the wavelength of the carrier used for communication. If we use high frequency, the spacing between antenna elements is much smaller. To use the antennas effectively support from the higher layer protocol is necessary. The Omni-directional antenna radiates or receives energy equally in all directions. Smart antennas can receive/transmit energy in a particular direction.

For designing the microstrip smart antenna we are estimating, the width of the patch, and length of the patch, effective constant of microstrip antenna, effective length, and characteristic impedance. The effective dielectric constant is a function of the ratio of W/H of microstrip line and dielectric constant of the substrate material. The purpose of the transmission line is to get the maximum amount of energy to the other end of the line so that reflection is as small as possible. This is achieved by matching the impedance. Characteristic impedance is the impedance with no reflections in the transmission line. We are using 50ohm impedance, as we want impedance matching. The dielectric constant is the ratio between stored amounts of electrical energy in material to that stored by vacuum. The higher the loss tangent higher will be the loss and less efficiency. Where larger quality factor leads to narrow bandwidth and low efficiency. We designed a microstrip 1x2 array antenna. We used FR-4 as substrate material, copper as material to ground and patch.

There are many papers are designed and explained the array antennas at different frequencies for different applications. VANETs are very useful in road safety, global connectivity, active monitoring, and control of traffic. These do not face resource constraints, but they face regular link failures, stale routes, and an end to end delay. I-AODV routing protocol is best in the urban area VANET environment. It decreases end to end delay, media access delay, and increases throughput [5].

Simultaneous data transmission over several paths could improve the performance of ad-hoc networks, but interference still can be a problem. To avoid data rate degradation, smart antenna strategies should be applied and how efficient the application of smart antennas could be to cancel interference. There is no comparison is done between different smart antenna types exactly in a multi-path direction [6]. The use of directional antennas in ad hoc networks could increase interference due to limitations of the virtual carrier sensing network. A simple mathematical expression, which reveals the large dense network with directional antennas, can experience larger interference than in omnidirectional networks [7]. The electronically steerable parasitic array radiator (ESPAR) in small space it provides lower beamforming performance compared to phase array. They proposed RF front end connected to every antenna with tunable reactive load [8].

With the intrinsic properties of graphene, it becomes the most effective way to tune antenna matching and radiation characteristics [9]. The directional antennas are used due to their capability of spatial reuse of wireless channels. But almost all of the whole existing network simulators use omnidirectional antennas on nodes that do not provide support for a directional antenna. Here we are modeling a simple algorithm. Modeling power management in the channel to provide an asymmetrical communication behavior [10]. The directional antennas have features such as energy efficiency, security, increased coverage area, and enhanced throughput. Here directional antenna is proposed, which has the features which support the smart antenna. The suite allows loading simulation results of desired radiation patterns to simulators such as HFSS, to calculate performance-based on coverage area, packet delivery ratio, and received signal strength indicator [11]. The Connectivity is usually dependent on wi-fi routers, modems, etc. When there is no access point available, the user is left without connection. The most suitable solution to this is ad-hoc networking. It uses direct wi-fi technology and supports multi-hop directing and IP address requirements [12].

The fading reduction effect of the selection diversity antenna compared to the 2x2 smart antenna was 0.65-4.25dB higher in LOS and 1.15-1.75dB better in NLOS channel environments. Because the beam width of our 2x2 smart antenna system is very wide [13]. The objective is to reveal the best conditions for combining smart antennas and multi-path transmission in wireless ad-hoc networks. Data transmission capacity and rate can be increased by multipath transmission. It minimizes mutual interferences; this approach is used for the communication opportunities in 5G [13]. The designed and fabricated antennas are useful for the energy efficient wireless sensor networks [14-16].

In this paper, a patch antenna is designed and simulated and plotted the curve of reflection coefficient and VSWR at two frequencies 2.45 GHz and 5.4 GHz. The paper is organized as the introduction and literature survey is described in section 1, Section 2 describe design methodology of single and array antennas, section 3 explained the results and analysis of the designed geometry, simulation parameters and fabricated and its measured results at two frequency and its comparisons are mentioned. Section 4 concludes the paper.

2. DESIGN METHODOLOGIES OF ARRAY ANTENNA

The design methodology and simulation of an array antenna using the Ansoft-HFSS which stands for the high-frequency structural simulator is shown in the next section.

2.1 Simulation Parameters

The simulation parameters of design antennas and designed values are shown in Table 1 and Table 2 respectively. To design the patch, array, and feeding line using the equation (1) to (11).

Table 1: Simulation Parameters

S. No	Parameters	Values
1.	Resonant frequency (f ₀)	5.4 GHz
2.	Substrate height(h)	1.6 mm
3.	Relative dielectric constant (ε _r)	4.4
4.	Loss tangent (δ)	0.02

$$W = \frac{\lambda_0}{2} \left[\left(\frac{\epsilon_r + 1}{2} \right)^{-0.5} \right] \tag{1}$$

$$L = \frac{\lambda_0}{2\sqrt{\epsilon_{eff}}} - 2\Delta L \tag{2}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\left(1 + \frac{12h}{W} \right)^{-0.5} \right] \tag{3}$$

$$\Delta L = 0.412h \left[\frac{\epsilon_{eff} + 0.3 \left(\frac{W}{h} + 0.264 \right)}{\epsilon_{eff} - 0.258 \left(\frac{W}{h} + 0.813 \right)} \right] \tag{4}$$

$$\frac{cl}{W} \geq 0.3 \tag{5}$$

$$D = \frac{c}{f_{low}} - 2(L + 2\Delta L - E) \tag{6}$$

$$E = F = \frac{\lambda}{60} \tag{7}$$

$$A = \frac{Zo}{60} \sqrt{\frac{\epsilon_r + 1}{2}} + \left[\frac{\epsilon_r - 1}{\epsilon_r + 1} \left(0.23 + \frac{0.11}{\epsilon_r} \right) \right] \tag{8}$$

$$\frac{Wc}{h} = \frac{(8e^A)}{(e^{2A}-2)} \tag{9}$$

$$\lambda g = \frac{c}{fo\sqrt{\epsilon_{eff}}} \tag{10}$$

$$Lc = \frac{\lambda g}{4} \tag{11}$$

Table 2. Calculation dimensions result of the antenna

S.No	Component	Dimension(mm)
------	-----------	---------------

1.	Length (L)	12.67
2	Wide (W)	16.9
4	Extended length (ΔL)	5.064
5	Length (Lc)	7.07
6	Width (Wc)	3.06
7	Width of the slot (D)	2.39
8	Width of the Arms slot (E=F)	0.93
9	Length of a ground plane	13.61
10	Wide of a ground plane	26.5
12	Wavelength(λ_g)	0.0283

3. Results analysis of Simulation and Fabricated patch and array

The patch and array antennas are designed using a suitable material (FR4) which retains its high mechanical value and electrical insulating qualities in both dry and humid conditions for the ad hoc networks. The single patch and 1x2 array antennas are designed and shown in Fig 1 and Fig 3 respectively.

The fabricated single and array antennas geometry are shown in Fig.1 and Fig. 2 respectively. . The single patch is simulated at two frequencies 2.45 GHz and 5.4 GHz and its Reflection coefficient and VSWR are plotted and shown in Fig.5 to Fig 8. The 1x2 array antenna is simulated at 5.4 GHz and its reflection coefficient and VSWR are plotted and shown in Fig 9 and Fig 10. The measured results reflection coefficient and VSWR of fabricated geometry of single patch and 1x2 array are plotted and it's shown in Fig 11 to Fig 14.

The magnitude of the S11 parameter for operating frequency 2.45GHz is shown in Fig. 5. It is noticed that the antenna return loss is -15.74dB. The operating frequency between 2.42GHz to 2.48GHz. The bandwidth of the antenna is 60MHz. or 2.44%. The reflection coefficient of a single patch at 5.4GHz is shown in Fig.7. It is observed that the return loss is -49.09dB and the bandwidth of the antenna is 200MHz or 3.7%. The comparison between patch antenna at 2.45GHz and array antenna at 5.4GHz, the bandwidth of the adaptive array antenna greater by 1.26%. The S11 and VSWR parameters of different designed and fabricated antennas are listed in Table 3. The data shows that the array antenna's performance is better than others. The simulated and fabricated results of array antennas of S11 are similar which is shown in Fig 9 and Fig 11 respectively. The simulation and fabricated of VSWR of arrays antenna are similar which is shown in Fig. 12 and Fig 14 respectively.

The simulation results of conventional antennas at a different frequency which is applicable for the different application of wireless communication. The array antenna the same simulated at the same frequency and it was found that the performance is better than the conventional antenna. The simulated and measured results are found similar; therefore the fabricated antenna can be used for the particular application of frequency of wireless communication. This designed antenna can be operated smartly in the field of wireless communication. The results show in the above figures the simulated and measured results are similar with the proper impedance matching; thus the gain and directivity are up to the mark. The conventional and array designed antennas are compact concerning the cited paper and more efficiently. Such types of designed antennas can be operated for the ad-hoc network, Wi-Fi, UWB, and high-speed LTE applications.

Fig 1: Conventional microstrip patch antenna at 5.4GHz

Fig 2: Fabricated microstrip patch antenna at 5.4GHz

Fig 3: Microstrip array 1X2 at 5.4GHz

Fig 4: Fabricated microstrip array 1X2 antenna at 5.4GHz

Fig 5: S-parameter plot of Patch antenna at 2.45GHz

Fig 6: VSWR plot of patch antenna at 2.45GHz

Fig 7:S-parameter of microstrip patch antenna at 5.4GHz

Fig 8 :VSWR of microstrip patch antenna at 5.4GHz

Fig 9:S-parameter of array antenna at 5.4GHz

Fig 10:VSWR of microstrip array antenna at 5.4GHz

Fig 11: S-parameters of patch antenna at 5.4GHz

Fig 12: VSWR plot of patch antenna at 5.4GHz

Fig 13: Measured S-parameters of 1x2 array antenna at 5.4GHz

Fig 14: Measured VSWR plot of 1x2 array antenna at 5.4GHz

Table 3: Comparison of simulation and fabricated array antennas

Parameters	Simulation of Single Patch 2.45Ghz	Simulation of Single Patch at 5.45GHz	Fabricated single patch antenna at 5.45GHz	Fabricated 1X2 Array antenna at 5.45GHz
Reflection Coefficient	15.74	49.09	39.72	31.05
VSWR	1.22	1.007	1	1.058

4. CONCLUSION

The adaptation of smart antenna techniques in future wireless system is expected to have a significant impact on the efficient use of the spectrum and realization of transparent operation across multi technology wireless networks. The simulation and fabricated results are acceptable at the desired frequency. Improved bandwidth has been obtained with low permittivity. Bandwidth of the antenna is improved to 3.70%. Therefore, it is achieved simulation of microstrip and 1x2 adaptive array antenna at the resonance frequency. The increase in surface wave is correlated by the increase in the return loss S11 and enhancement of the practical antenna bandwidth.it can be operated for ultra wide band, Ad-hoc and high-speed LTE mobile Communication applications.

Authors Declaration

We undersigned declare that manuscript “DESIGN OF ADAPTIVE ARRAY ANTENNA FOR WIRELESS COMMUNICATIONS” is original, has not been fully or partially published before and is not currently being consider for publication elsewhere.

We confirm that manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that corresponding author is the contact for the editorial process.

Yours faithfully

Pramod Kumar

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Figures

Figure 1

Conventional microstrip patch antenna at 5.4GHz

Figure 2

Fabricated microstrip patch antenna at 5.4GHz

Figure 3

Microstrip array 1X2 at 5.4GHz

Figure 4

Fabricated microstrip array 1X2 antenna at 5.4GHz

Figure 5

S-parameter plot of Patch antenna at 2.45GHz

Figure 6

VSWR plot of patch antenna at 2.45GHz

Figure 7

S-parameter of microstrip patch antenna at 5.4GHz

Figure 8

VSWR of microstrip patch antenna at 5.4GHz

Figure 9

S-parameter of array antenna at 5.4GHz

Figure 10

VSWR of microstrip array antenna at 5.4GHz

Trc1 **S11** dB Mag 5 dB / Ref -10 dB Cal int

1

Figure 11

S-parameters of patch antenna at 5.4GHz

Trc1 S11 SWR 1 U / Ref2 U Cal int

1

Figure 12

VSWR plot of patch antenna at 5.4GHz

Figure 13

Measured S-parameters of 1x2 array antenna at 5.4GHz

Figure 14

Measured VSWR plot of 1x2 array antenna at 5.4GHz