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DESIGN AND DEVELOPMENT OF EIGHT ELEMENTS SERIES-FED TWO DIPOLE ANTENNA ARRAY FOR OUTDOOR WLAN BASE STATION APPLICATIONS

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Abstract

Antenna design is the key performance indicator in the development of wireless communication technology. In this paper, eight-element series-fed two dipole antenna array is developed for the outdoor WLAN base station applications. The proposed antenna operates at IEEE 802.11b standard 2.4GHz frequency band with the improved gain for supporting outdoor wireless local area network applications. A modified microstrip balun feeding is used for providing impedance matching. This antenna is designed on the FR4 substrate with dielectric permittivity of 4.4 and height of the substrate is 1.6 mm and loss tangent of 0.002 to achieve lower return loss. The dimension of the proposed antenna is 400×160×105mm^3. This antenna is simulated in an integral based solver simulation software called CST Microwave studio v2020 and obtained results such as VSWR of 1.26, return loss of -18.26dB with Bandwidth of 200 MHz, Directivity of 15.4dBi, gain of 14.9dB, Port isolation is -16.5dB and an efficiency is of 85%. This antenna suitable for WLAN base stations used in larger coverage areas.

Keywords:

WLAN, Series-Fed Two Dipole Antenna Array, Base Station Antenna, Patch Antenna

1. INTRODUCTION

The development of antennas for outdoor wireless local area communication is getting huge importance due to which wide range of devices can be connected efficiently at the same time to the internet. The importance of effective outdoor wireless connectivity is highly recommended in wireless mesh networks, outdoor Wi-Fi, school wireless networks, College campus wireless networks and office networks.

This outdoor wireless connectivity improves overall performance of the IOT devices. The use of 2.4GHz frequency in all WLAN communication devices requires an efficient base station antenna with high performance for operating exclusively for this operating band. The strength of wireless connectivity in outdoor network is depends on the types of connections you want to use between parts of the network, Wireless Clients, Access Points, Ad-Hoc Nodes, and more importantly of the quality of antennas used. Therefore, this paper focuses on the design of eight elements series-fed two dipole antenna array for providing 2.4GHz out door base station applications.

The design of single, two and four element series-fed two dipole antennas has already been discussed in [4]-[6] which performed well for the indoor applications. There are several antennas reported in the literature [7]-[20] in the section 2 has a problem of providing larger coverage area with the stable gain. Therefore, the objective for this research work is to cover outdoor areas while keeping the fundamental design an antenna array by using eight elements is developed and its design and operational parameters are discussed briefly in this paper.

The software used in this work is CST Microwave studio v2020. This CST microwave studio selected based on its user interface, which is very simple and has the capability of simulating complex array structures.

The organization of this paper includes the introduction as section 1 followed by the literature review in section 2 and design methodology in the section 3 followed in the development of the proposed antenna array as and the next section 4 consists of results and discussion finally conclusion and future works section as 5 which concludes the paper.

2. LITERATURE REVIEW

The literature review deals with the basics of micro patch antennas [1]-[3]. Fundamental designs of the series-fed two dipole antenna array is presented in [4]-[6]. A reconfigurable antenna with sum-pattern and difference-pattern for WLAN access points is discussed in [7].

Circularly polarized patch antenna with high isolation for MIMO WLAN applications is discussed in [8]. Design of compact high-isolation MIMO antenna with multi-objective mixed optimization algorithm is presented in [9]. Design of metamaterial antenna for 2.4GHz WiFi applications is discussed in [10]. Broadband 8-antenna array design for sub-6GHz 5G NR bands metal-frame smartphone applications is presented in [11]. Compact liquid crystal polymer based tri-band flexible antenna for WLAN/WiMAX/5G applications is discussed in [12]. Very-low-profile grounded coplanar waveguide-fed dual-band WLAN slot antenna for on-body antenna application is available in [13]. High-gain directional antenna for WLAN and WiMAX applications is discussed in [14].

Multiple beam parasitic array radiator antenna for 2.4GHz WLAN applications is presented in [15]. A modified circular patch antenna is presented for 4.8GHz Wi-Fi applications with a gain of 5.78dBi is discussed in [16]. A reconfigurable antenna with radiation pattern and polarization reconfiguration capabilities operating at 2.4GHz is investigated in [17]. A compact wideband dual-polarized slot-coupled stacked patch antenna with a stable radiation pattern is obtained in the range of 2.5-6.5GHz for wideband wireless communication systems is discussed in [18]. A low radar cross section (RCS) antenna array with reconfigurable scattering patterns based on digital antenna units, The digital antenna unit has two scattering states that are controlled by PIN diodes to address the challenges of bistatic radar systems is presented in [19]. A compact antennas using the Ridge Gap Waveguide (RGW) technology working in the millimeter-wave band (60GHz), with a high-purity and broadband circular polarization (CP) are numerically and experimentally analyzed in [20].

From the literature it is found that the antenna is designed widely for the mobile communication base stations to cover different range of frequencies and single, two and four elements STDA [4]-[6] are proposed and there is a serious problem of shorter coverage using the design methodology in the previous models.

Therefore in this work the eight-element series-fed two dipole antenna array is developed for WLAN base station applications for covering wider coverage area along with the improved gain which is extremely important for the outdoor applications. In the next section the design methodology is presented.

3. ANTENNA DESIGN

This section presents the detailed design methodology of the proposed eight elements series-fed two dipole antenna array for WLAN outdoor base station applications. The perspective view of the proposed antenna array is given in Fig.1.

The overall dimension of the proposed eight-elements series-fed two dipole antenna array consists of overall length (*L*) which is 400mm and width (*W*) is 160mm dimension and the height (*H*) of 105mm.

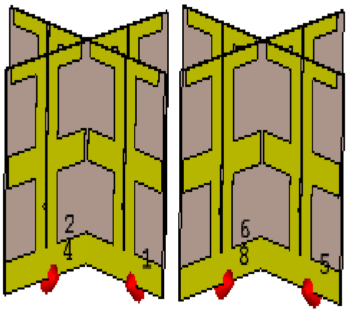
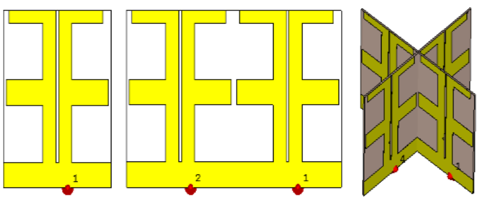


Fig.1. Proposed Antenna Array

Here is the evolution process of the proposed eight-elements series-fed two dipole antenna arrays are presented in Fig.2. In this Fig.2(a) represents the single element antenna. The Fig.2(b) represents the design with the two elements antenna array. The Fig.2(c) represents the design with the four elements antenna array. The dimension of single element diploe array antenna is length of 105mm, and the width of 80mm. The dimension of two element dipole antenna array is length of 105mm, and the width of 160mm. The dimension of four element dipole array antenna is length of 200mm and width of 160mm and the height of 105mm. The evolution of single, two, four element dipole array antennas are shown in Fig.2.



(a) (b) (c)

Fig.2. Design Evolution

The proposed eight elements series-fed two dipole antenna array is finally developed by the addition of two four elements series-fed two dipole antenna array in the linear plane. The distance between the two four elements series-fed two dipole antenna array is based on the results obtained from the parametric study conducted by the variation of the distance separation.

The proposed antenna array is developed on FR4 Substrate with permittivity of 4.3 and thickness 1.6mm. The patch is designed in copper material having electrical conductivity of $5.8e^7$ with a thickness of 0.035mm. The balun feed is modified at the joint as bending curve to provide perfect impedance matching.

In further section the results and discussion are presented. The proposed antenna operates at IEEE 802.11b standard 2.4GHz frequency band with the improved gain for supporting outdoor wireless local area network applications.

4. RESULTS AND DISCUSSION

In this section the results and discussions for the eight-element series-fed two dipole antenna array are presented. The design and simulation are done in CST microwave studio v2020 and its results such as return loss, VSWR, farfield radiation, surface current, gain and efficiency front to back ratio were discussed below.

4.1 RETURN LOSS

The minimum return loss obtained at 2.4GHz is -18.26dB for the proposed eight elements series-fed two dipole antenna array which is given in Fig.3.

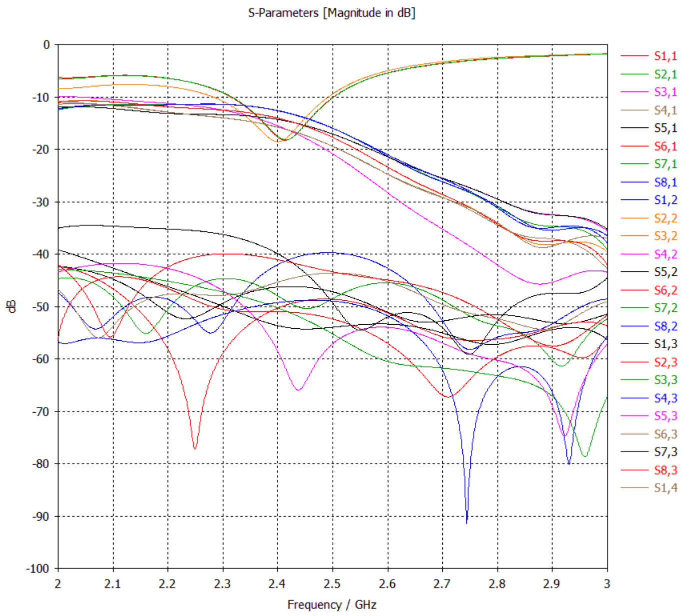


Fig.3. Return loss

At 2.4GHz resonant frequency the proposed antenna obtained a bandwidth of 200 MHz in -10dB impedance range. The mutual coupling between the elements are found to be 35dB isolation this shows that the proposed eight elements series-fed two dipole antenna array will not get affected by the mutual coupling between the four input ports and the antenna performance will be stable.

4.2 VSWR

The minimum Voltage Standing Wave Ratio (VSWR) obtained at 2.4GHz is 1.26 for the proposed eight elements series-fed two dipole antenna array which is given in Fig.4.

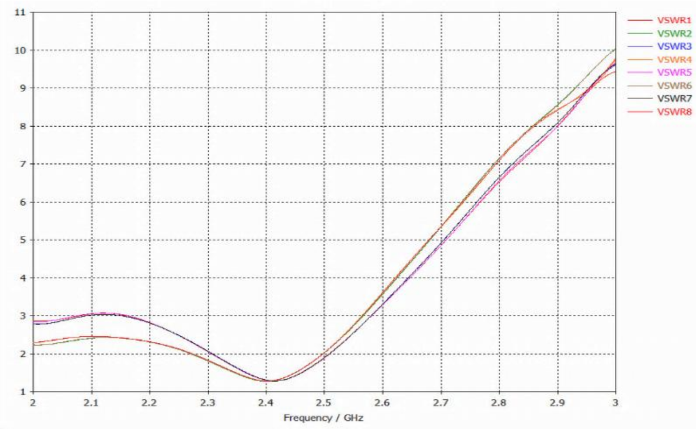


Fig.4. VSWR

The proposed antenna achieved a VSWR of 1.26 which is close to the anticipated value of 1 to meet the required specifications.

4.3 SURFACE CURRENT DISTRIBUTION

The surface current distribution is a useful tool for the analysis of design. The surface current distribution plot for the proposed series-fed two dipole antenna is given in Fig.5 obtained from the simulation shows the current distribution in which the current flow starts from the feeding point through the balun designed from the bottom to the top surface of the STDA.

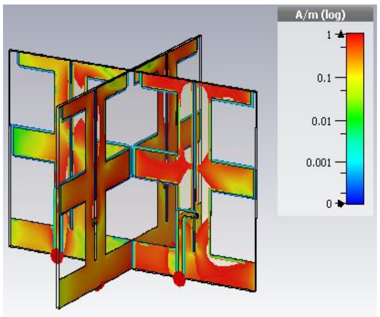


Fig.5. Surface Current Distribution

The red region indicates the maximum surface current waves generated at the frequency 2.4GHz. From the above showed surface current distribution, the proposed eight elements series-fed two dipole antenna array achieved maximum performance at the required resonant frequency 2.4GHz.

4.4 FARFIELD ANALYSIS

The radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. The 3D far field radiation is given for the proposed eight elements series-fed two dipole antenna array in Fig.6.

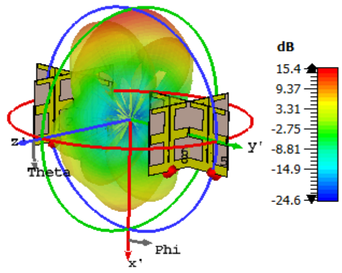


Fig.6. Farfield at 2.4GHz

The maximum directivity obtained ad 15.4dB. The maximum efficiency obtained at 2.4GHz is 85% and the total efficiency from 2 to 3GHz frequency range is 80% for the proposed antenna. The 2D farfield plot is given in Fig.7.

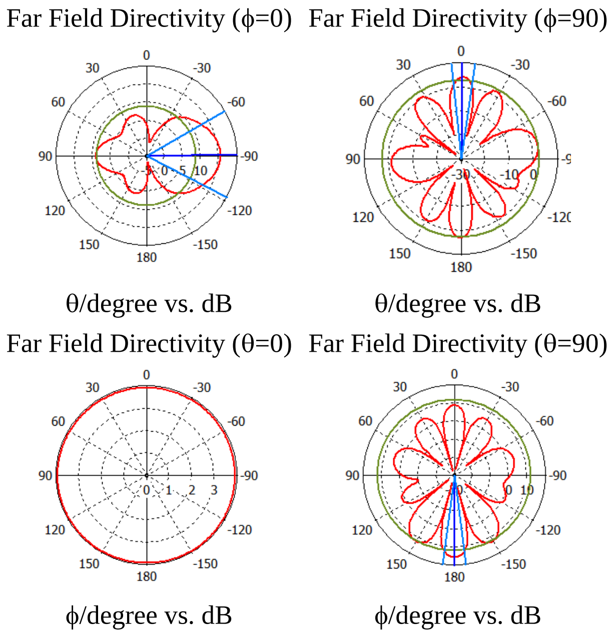


Fig.7. 2D Farfield Plot

It shows the radiation characteristics of the proposed antenna with ϕ=0 displays highly directional capability and θ=0 is displaying circular polarization therefore the proposed eight-element series-fed two dipole antenna array is very much useful for the outdoor WLAN base station applications.

4.5 GAIN AND EFFICIENCY

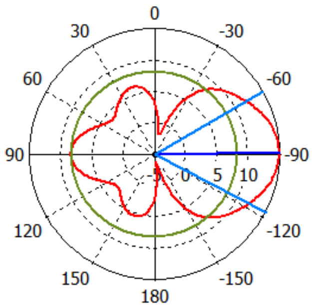
The proposed antenna achieves 15.4dB of gain and 85 % efficiency at 2.4GHz resonant frequency. The 2D polar plot displaying gain at the broad direction is shown in Fig.8. Also, the front to back ratio is the ratio of power gain between the front and rear of a directional antenna which is 6.25 for the proposed antenna. The overall result are tabulated in Table.1.

Table.1. Overall Results

Parameter	Value
Frequency	2.4 GHz
Return Loss	-18.2 dB
VSWR	1.26

Gain	14.9 dB
Efficiency	85 %
Directivity	15.4 dBi
Bandwidth	200 MHz
Front-to-back ratio	6.25

Farfield Gain Abs (ϕ=0)



θ/degree vs. dB

Fig.8. Gain of the antenna (ϕ=0)

While comparing this eight-elements series-fed two dipole antenna array with the existing single element antenna system [4]-[6] the gain is improved from 6.73dB ,11.9dB to 14.9dB and the directivity also increased from 6.72dBi, 12.5dBi to 15.4dBi without affecting the 200MHz bandwidth and the mutual coupling between the ports is reduced below -35dB. These results confirms that this proposed eight-element series-fed two dipole antenna arrays can be suitable to cover wider outdoor WLAN applications in ISM band frequency.

5. CONCLUSION AND FUTURE WORK

The proposed eight-element series-fed two dipole antenna arrays is developed and simulated using CST Microwave studio v 2020 and obtained results such as return loss of -18.26dB, VSWR of 1.26, gain of 14.9dB and bandwidth of 200MHz are following the IEEE 802.11b guidelines for operating WLAN applications in ISM band frequency.

Future work in this work will be focusing on developing an array of multiple elements series-fed two dipole antennas and design of feeding networks for the improvement of its performance and applications based on focusing the parameters such as beamforming and the feeding network development. This eight-elements series-fed two dipole antenna arrays proposed in this paper can be suitable for the WLAN base station applications for large coverage areas with high capacity data rate transmission such as educational institutions and office buildings indoor stadiums etc.

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