Design and development of Dipole Array Antenna for Wi-Fi Applications

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Abstract

This paper illustrates the design and development of the Series-fed Two Dipole Array antenna (STDA) for Wi-Fi applications. The proposed antenna consists of two dipole elements of different lengths, which are serially joined by the Coplanar Strip Line (CPS). The design incorporates an alternative feeding mechanism of coaxial/probe feeding technique with balun. The primary objective of this paper is to develop the high gain antenna with array configuration for Wi-Fi applications. The performance parameters of an antenna such as return loss, radiation pattern, gain and directivity are investigated for STDA array configurations. It operates at 2.4 GHz and produces a high gain of 21.6 dBi with reflector. The STDA antenna has been analyzed for different array configurations in the formation of 1×4, 1×8, 2×8 STDA array formation in order to improve the overall gain. The proposed antenna is fabricated an FR4 substrate with a dielectric constant of 4.4 and Loss tangent (tan δ) of 0.007 with the thickness of 1.6 mm. The size of an antenna is about 105 mm × 80 mm. The proposed antenna meets the requirements of an antenna which is operating at 2.4GHz with a bandwidth of 200 MHz; hence, it is found to be suitable for Wi-Fi applications.

1. Introduction

Various types of wireless communications antennas have been widely used in recent years, because high data rate services are most required [1]. Wi-Fi is commonly used indoors and outdoors to provide wireless connectivity to end users of this system such as routers and wireless repeaters. The efficiency of these devices depends on the antenna capacity that determines how the wireless network covers efficiently. The traditional STDA is used in many mobile communications base station applications due to its ability to operate with lower mutual coupling losses and to provide greater gain. The series-fed two dipoles array antenna which consists of two dipoles with different lengths and truncated ground plane which are further connected in series through a parallel strip line, which is chosen from different types of broadband antennas[2]. This kind of antenna is used in mobile communication in a wide range of applications such as base station antennas, phased array antennas, printed dipole with an integrated balun, a printed dipole pair, a double dipole antenna, a planar, almost yagi, a two layer, printed dipole and a trapezoidal dipole antenna due to their balanced gain of the wide bandwidth. In most cases the antenna size is very difficult to reduce because an antenna size often requires total control over the performance of wireless devices [3].

There are several types of antennas designed for Wi-Fi applications through different mechanisms. Parametric evaluation of the log-periodic dipole array antenna (MLPDA) microstrip is performed using the transmission line's corresponding circuit. Hence, this MLPDA antenna is ideal for wireless C band applications such as Wi-Fi and wireless applications with a 5GHz band. The thickness of the substrate is 1.6 mm, and its dielectric constant is 4.2. Gain of the antenna is 4.8 dBi [4]. For multi-3G/4 G applications, a Quasi-Antenna with a modified bow-driver has been developed. The measurements show that the antenna has a return loss of 10 dB, 80.4 percent of the bandwidth between 1.45 and 3.4 GHz, because the antenna is constructed using the FR4 substratum with a dielectric constant of 4.2. Measured gains in all the bandwidth are greater than 4 dBi [5]. A dual-band series dipole pair antenna is constructed using proximity-coupled strips and split-ring resonator controllers. The antenna provides dual-band characteristics with the 1.56–1.63 GHz and 1.68–2.87 GHz frequency bands. This antenna comes with VSWR < 2. The antenna gain ranges between 5.9 and 7.5 dBi. The antenna is designed on FR4 substrate. [6].

The linear array of mutually coupled parallel dipole antennas has been designed with desired side lobe level and return loss. The dipole antenna has an omnidirectional radiation pattern, and it achieves a return of 25dB. The antenna is built using a 1.6 mm height FR4 substrate [7]. Log Periodic Planar Dipole Array Antenna, constructed on the FR4 substrate, has a maximum gain of 7.5 dBi between 3–6 GHz range [8]. A series-fed two-dipole array antenna using nearby Parasitic Director for bandwidth and gain enhancement has been developed. This performance is compared to the traditional STDA antenna that operates in a 1.7–2.7 GHz frequency band with a gain of > 5 dBi. A VSWR < 2 is achieved in this antenna which satisfies the condition [9]. A compact ultra-wideband planar printed Quasi-Yagi antenna has been designed for water detection in the Egyptian Desert. Its bandwidth extends from 47 to 150 MHz with 45% size reduction and the gain of the antenna was around 4.5 dBi[10]. A series-fed dipole pair broadband antenna with parasitic strip-pair director has been developed. The performance is compared to the performance of the traditional SDP antenna generated on a FR4 substratum. The antenna frequency was 1.63–2.97 GHz; the antenna gain was 5.6–6.8 dBi and 58.26 per cent performance [11]. The design of a band-notched broadband series-fed two dipole array antenna has been simulated and analyzed. To get a band rejection the WLAN band was conducted in 2.4–2.484 GHz. Compact series-fed two dipole array antenna has been designed by using top-loaded components [12]. A size-reduced STDA is achieved, which covers a frequency band from 1.7 GHz to 2.7 GHz with a gain of > 5 dBi. Conventional STDA has a bandwidth of 48.7 percent from 1.68–2.76 GHz and a reasonable gain of 5.6–6.0 dBi compared to the proposed antenna parameters. [13].

A series-fed two dipole-array antenna has been modified to get a reduction in size. The antenna covers at 1.7–2.7 GHz frequency range, with a 5 dBi gain. The antenna had a bandwidth of 49.7 per cent. The frequency ranges from 1.68–2.79 GHz and the gain range from 5.86–6.13 dBi [14]. A wide scanning tightly coupled wideband dipole array is constructed. The architecture adopts an Integrated Balun. The size, weight, cost and even compared with normal feeding techniques are substantially reduced. By removing bulky external baluns, the bandwidth is simultaneously increased by over 30 per cent. This antenna has low <-20dB cross-polarization over most channels, in a dual-polarization configuration. Measured results for a prototype 8× 8 module antenna display good simulation agreement [15]. For improved gain and front-to-back ratio, a series-fed two-dipole array antenna was designed using bow-tie components. The frequency band, with the gain > 5 dBi, ranges from 1.7 to 2.7 GHz. This compares its efficiency to that of the STDA antenna. The antenna has a bandwidth of 48.8 per cent in the 1.69–2.78 GHz range. Its gain ranges from 5.8 to 6.3 dBi and the front-to-back ratio ranges from 14 to 17 dBi with a decrease of 10 percent in the overall antenna width [16].

A dual-band loop-loaded printed dipole array antenna which is incorporated with a balun structure has been designed. It is designed with loop-loaded printed dipole antenna array. It operates in a dual-band at 3.0 and 5.5 GHz. To achieve balanced and matched excitation to the antenna array. A new corporate balun/feed structure is employed [17]. A double-layered printed dipole antenna with parasitic strips has been developed. This antenna has 75% impendence bandwidth, VSWR < 2, operates between 2.5 and 5.5 GHz bands. Moreover, stable radiation patterns with 6.3–9.1 dBi peak gain and low cross-polarization are obtained within the bandwidth. An eight-element printed dipole antenna array is assembled and measured, showing a good performance in the array [18]. A double-printed trapezoidal patch dipole antenna for UWB applications has been designed. The proposed antenna exhibits, band-notched characteristics. The antenna covers the entire UWB band ranging from 3.1–10.6 GHz with a gain of 3.1dBi. It has a notched band for the IEEE 802.11a frequency band at 5.825 GHz, which has a gain of 5.1dBi [19].

From the above literature survey, it is observed that the antenna parameters such as bandwidth, gain, directivity are very low. Several attempts are being made to realize the antenna for Wi-Fi band applications, where the array elements are added either serial formation or parallel formation. Hence the STDA with reflector antenna has considered as the array element and analyzed in 1×4, 1×8 and 2×8 STDA array configurations. High directivity, gain, bandwidth and better Signal-to-noise ratio has been acknowledged with different array configuration. The proposed antenna operates in S-band (2–4 GHz) and is constructed on a 1.6 mm thick FR4 substratum with 4.4 dielectric constant. This antenna has a Wi-Fi functionality. The array antenna is designed and evaluated for S-band applications.

In the previous literature to enhance the bandwidth and gain, the parasitic director with STDA is used. In this attempt, to enhance the gain and bandwidth, the parabolic reflector with STDA is incorporated. The STDA with reflector antenna has considered as the array element and analyzed in 1×4, 1×8 and 2×8 STDA array configurations. High directivity, gain, bandwidth and better Signal-to-noise ratio has been acknowledged with different array configurations.

The minimum gain requirement for wifi system is about 3dBi. A higher-gain antenna, installed for instance on an access point, improves range from the access point to the client radio and from the client radios to the access point. This is different from increasing transmit power on only the access point, which would only increase range for the communications going from the access point to the client radios. The reason is that a higher-gain antenna improves range in both directions. It is identified that the higher gain of the antenna improves both transmission and reception of radio waves. Therefore, the installation of higher-gain antennas can provide significant increases in range without making changes to the client radios. In addition to using higher-gain antennas, antenna diversity can also help extend range in both directions because it minimizes multipath propagation. Diversity is an important part of 802.11n, and various vendors sell 802.11n access points and client radios that have different levels of diversity.

An advantage of using higher-gain antennas is that it impacts range in both directions. As a result, it may be able to get by with changing the antenna configuration on only the access point, avoiding the need to alter each client radio. The cost of upgrading the antennas, however, might be. Therefore, the cost might be prohibitive in larger networks. Be sure to take into account different antenna gain and diversity with actual propagation testing in the target operating environment to determine the lowest overall cost of deploying the network. The trouble with increasing antenna gain for purposes of extending range is that you will likely place the access points farther apart. This results in a larger 802.11 collision domain, which limits the capacity of the WLAN. Finally, in order to enhance the distance, reduce the diversity and cost, the antenna gain is improved through array configurations.

The antenna array is used to increase overall gain, provide diversity of reception, cancel interference, maneuver the array in a particular direction, gage the direction of arrival of incoming signals, and maximize the signal to interference plus noise. Most types of array antennas are constructed using several dipoles, typically half-wave dipoles. The aim of using multiple dipoles is to increase the directional gain of the antenna over the gain of one dipole [29]

The structure of the paper is as follows; Sect. 2 discusses the geometry and the method to construct the STDA antenna. Array implementation of the STDA is presented in Sect. 3, which is followed by the analysis of the simulated and measured results in Sect. 4. The result and discussion are presented in Sect. 5 and Finally, Sect. 6 concludes the paper.

2. Antenna Geometry

The proposed antenna occupies the overall size of 80 mm × 105 mm on an FR4 substrate with a dielectric constant of 4.4 and has a thickness of 1.6 mm. The design parameters like dielectric constant (ε_r), substrate height (h), loss tangent (tan δ), patch length, patch width and thickness, are mentioned in Table 1.

Table.1 Design parameters of the STDA

Abbreviate	**Value (mm)**	**Abbreviate**	**Value (mm)**
L	80	W_{SL}	1.6
W	105	W_{CPL}	20
S_1	34	Wg	12.5
S_2	34	Lg1	2.5
W_4	25.2	Lg	36
W_3	29.2	W_1, W_2	11
W_{GD}	15	W_5	27.2

The proposed antenna is shown in Fig. 1. The STDA antenna consists of two printed-strip dipoles with various lengths, which are connected via a CPS line, and a ground reflector placed below the first dipole to increase the gain at the low frequency band. An integrated balun between the MS line and the CPS line is implemented on the CPS line to feed the antenna, and the end of the MS line is shorted using a shorting pin at the feeding point. The length and width of the elements (two dipoles and ground reflector) and the spacing between these elements are optimized to maximize the bandwidth and the realized gain of the antenna. In this design, FR4 is chosen as a substrate because of low material cost and easy to fabricate, along with its ability to produce optimal performance for a variety of applications.

3. Design Procedure

3.1 Design of STDA A STDA is designed with a reduced size, which consists of two strip dipole elements (D_1 andD_2) having different length and a ground reflector. The height of the ground plane W_{GD} is 12.5 mm. The length L_2 = 70 mm and width W_2 = 11 mm for dipole1 of D_1, respectively, and for dipole2, D_2 and L_1 = 74.4mm and W_1 = 11 mm, respectively as shown in Fig. 1. The Fig. 1(a), Fig. 1(b) and Fig. 1(c) shows the front, ground plane and side view of the STDA. The STDA is devised by cutting the CPS with the width of 1.6 mm from the top till the ground as shown in Fig. 1(a). The balun is adjusted and a stub is introduced in order to match the impedance. The impedance matching is achieved simply by adjusting the position of the feed point of the integrated balun.

3.2 Design of Balun The electric field of microstrip lines is normal to the substrate and the electric field across the gap between the arms of the dipole is along its length, thus, the dipole cannot be fed directly from a microstrip line. Balun is required for feeding mechanism which is being used for balance an unbalanced transmission line. The balun is designed in such a way that it matches 50Ω input impedance to feed the designed antenna through hole. The outer conductor of the coaxial line and the λ/4 short-circuited wire form a λ/4 two-conductor shorted stub and provide infinite impedance at the feed point which is fixed at the top of the balun, thus eliminating current flow on the outer surface of the outer conductor of the coaxial line. So, an integrated balun is designed between the MS and CPS lines to match the input impedance of the antenna with the 50Ω feed line. The end of the MS line is shorted with a shorting pin at the feed point. The width of the CPS line and slot line are denoted as W_{CPL} and W_{SL}.

In this attempt, initially, the antenna design begins by designing a conventional STDA antenna with the help of literature. The STDA is optimized to operate at 2.4GHz. The antenna was printed on an FR4 substrate with a dielectric constant of 4.4 and a thickness of 1.6mm (loss tangent = 0.007). It consists of two strip dipole elements (D_1 andD_2) which is having different lengths and a ground reflector. The minimum distance between the dipoles and ground plane is maintained in order to reduce the return loss.

The length of the short and long dipoles are selected in such a way that to control the upper and lower operating frequencies. The radiation mechanism of this antenna depends on the dipole length and width, distance between two dipole pairs and ground plane and balun dimensions. Figure 2(a) shows the current distribution of the proposed antenna, which starts from the feeding point through the balun from the bottom to top surface of the dipole antenna. The current flow indicated by the red region shows how current is effectively distributed over the effective aperture of the proposed antenna. The current is concentrated on the first dipole at 2.4 GHz, which is the operating frequency of the antenna, as shown in Fig. 2(a).

The photograph of fabricated STDA is shown in Fig. 2. Figure 2(b) shows the front view of the fabricated antenna and Fig. 2(c) shows the back view of the fabricated antennas. The overall size of the antenna is about to 80 mm × 105 mm = 8400 mm^2.

The proposed antenna is designed using commercial EM software CST Microwave Studio. And the proposed antenna is developed at Nucleus Satellite Communication Madras Pvt Ltd, Chennai, India. Finally, it is measured using vector network analyzer at Saranathan College of Engineering, Trichy, Tamil Nadu, Chennai

4. Formation Of Array

4.1 Single STDA without Reflector Many techniques are used to increase the gain of the antenna such as super state, multilayer stack and array of elements. An antenna array is a combination of several single-element antennas forming a single STDA in order to achieve an improved performance in comparison to an elementary antenna. The performance may increase the overall gain. However, the use of different types of antenna in an array is also possible. Monopoles, dipoles, slot-in waveguides and microstrip are the types of elements that are generally used in arrays. There are many advantages of an antenna array that includes increasing gain and achieving desired radiation pattern. The gain is equal to the product of antenna radiation efficiency and directivity.

4.2 Array of 1× 4 STDA without Reflector Fig. 3 shows the array of 1×4 STDA. The spacing between the two elements is 5 mm which is obtained using the formula W/2 [20]. It has four dipole antennas and four ports as S_{11}, S_{22}, S_{33}, and S_{44}. S_{11} is the input port voltage reflection with coefficient, S_{22} is the output port voltage reflection with coefficient, S_{21} is the forward voltage gain, and S_{12} is the reverse voltage gain. The scattered parameters describe the input-output relationships between the ports.

4.3 Array of 1× 8 STDA without Reflector Fig. 4 shows the array of 1×8 STDA. The spacing between the two elements is 5 mm. This configuration has 8 antennas and 8 ports as S_{11}, S_{22}, S_{33}, S_{44}, S_{55}, S_{66}, S_{77}, and S_{88}.

4.4 Array of 2× 8 STDA without Reflector Fig. 5 shows the array of 2×8 elements. The spacing between the two elements is 5 mm. This configuration has 16 antennas and 16 ports as S_{11}, S_{22}, S_{33}, S_{44}, S_{55}, S_{66}, S_{77}, S_{88}, S_{99}, S_{1010}, S_{1111}, S_{1212}, S_{1313}, S_{1414}, S_{1515}, and S_{1616}

4.5 STDA with Reflector The parabolic reflector converts an incoming electromagnetic wave that moves along the axis into a converging spherical wave toward the target. The STDA uses a parabola reflector, a curved surface with a parabolic cross-sectional form to guide the radio waves. The most common type is a reflector in the shape of a dish and is generally referred to as a dish antenna or parabolic dish. A parabolic reflector's biggest benefit is that it has high Directivity. It functions similarly to a reflector of a searchlight or flashlight to direct the radio waves in a narrow beam or receive radio waves from one direction only. The Parabolic reflector have some of the highest gains, which means they can generate the narrowest beam widths, of any form of antenna. The schematic view of a reflecting parabolic Reflector is shown in Fig. 6.

Parabolic antennas are used as high-gain antennas for point-to-point communications, in applications such as microwave relay connections that carry telephone and television signals between neighboring cities, wireless WAN / LAN connections for data communications, satellite communications and spacecraft communication. They are used in radio telescopes too.

The Aluminum (Al) material is utilized for reflector. In Fig. 7, Fig. 8, Fig. 9 and Fig. 10, the material (Al) is same, however, the diameter is diameter. Typically, the reflector converts an incoming electromagnetic wave that moves along the axis into a converging spherical wave toward the target. The STDA uses a parabola reflector, a curved surface with a parabolic cross-sectional form to guide the radio waves. In array configuration, the number of elements increases so the size of the reflector becomes larger. Hence, the radiated signals are directed to one direction to achieve more gain in different array configurations. The simulated results are obtained using commercial EM software CST Microwave Studio.

4.6 Single STDA with Reflector Fig. 7 Shows the Single STDA with reflector.

$$A = \pi \frac{d^2}{4} \quad \text{--} \quad (1)$$

Where A is the aperture area of the antenna, d is the diameter of the parabolic reflector using the formula above, the diameter was determined. The single STDA with parabolic reflector with a diameter of 90mm is designed, simulated and fabricated. The spacing between reflector and the antenna is 5 mm. The experimental results reveal that the antenna parameters such as return loss, antenna gain, and bandwidth are better than STDA without reflector. In terms of Antenna gain with reflector it is 11.2dBi and without reflector it is 6.74. There is an improvement of 41.3% of gain if we implement STDA with reflector.

4.7 Array of 1× 4 STDA with Reflector

Figure 8 depicts the structure of 1 × 4 STDA inside a parabolic reflector element which is designed using Aluminum material. The reflector is designed with a diameter of 200 mm, All the 4 elements of STDA is enclosed within the parabolic reflector area such that electromagnetic signals from STDA are reflected back which results in uni directional radiation pattern. In terms of antenna gain with reflector it is 14.8dBi and without reflector it is 11.9. There is an improvement of 19.5% gain for 1 × 4 STDA with reflector. The simulated STDA design with 1 × 4 reflectors is shown in Fig. 9 which reveals that the antenna parameters are improved if the antenna elements are increased. It is noticed that there is about 24.3% of gain improvement in 1 × 4 STDA in compared with single STDA

4.8 Array of 1× 8 STDA with Reflector

Figure 9 shows the array of 1 × 8 STDA with reflector elements. The spacing between reflector and the antenna is 5 mm. A 400 mm diameter parabolic aluminium reflector with 8 elements STDA is designed and simulated. The result shows that the gain of the antenna is 14.2dBi without reflector and 18dBi with reflector. There is 21% of gain improvement is noticed while incorporating the reflector.

4.9 Array of 2× 8 Elements with Reflector

Fig. 10 shows the array of 2 × 8 STDA with reflector elements with a 500 mm diameter parabolic reflector. To enhance the gain and bandwidth further, the STDA is arranged in 2 rows with 8 elements. This entire STDA contribute a total of 16 elements placed within the diameter of parabolic reflector. The simulated results of antenna gain without reflector is 15dBi and with reflector 21.6dBi with a percentage increase of 30%.

5. Result And Discussion

5.1 Return Loss (with and without reflector) Fig. 11. shows plot of the simulated return loss (S_{11}) of the single SDTA, 1×4, 1×8, 2×8 SDTA without reflector antennas and resonating at 2.4 GHz. Figure 12. shows plot of the simulated return loss (S_{11}) of the single SDTA, 1×4, 1×8, 2×8 SDTA with Reflector antennas and resonating at 2.4 GHz. The above plots show better performance when compared to SDTA without reflector antenna. Figure 13(a) depicts a plot of the simulated and measured return loss (S_{11}) of the single STDA without reflector antenna. The proposed antenna resonates at 2.4GHz frequency.

The return loss for single STDA with and without reflector are simulated from the CST Microwave Studio software and measured using Vector Network Analyzer (VNA) and the experimental setup as shown in Fig. 14

5.2 Radiation Pattern (Without Reflector)

Fig.15 (a, b, c, d) displays the 3D radiation pattern of the single STDA, 1×4, 1×8, 2×8 without reflector. It displays the simulated gain values for STDA without a reflector. The proposed antenna has a gain of 6.74dBi for single STDA, 11.9 dBi for 1× 4 STDA, 14.2 dBi for 1× 8 STDA and 15 dBi for 2× 8 STDA respectively.

5.3 Radiation Pattern (with Reflector) Fig. 16 (a, b, c, d) displays the 3D radiation pattern of the single STDA, 1×4, 1×8, 2×8 with reflector STDA. It displays the simulated gain values for STDA with a reflector. The proposed antenna has a gain of 11.5dBi for single STDA, 14.8 dBi for 1× 4 STDA, 18 dBi for 1× 8 STDA and 21.6 dBi for 2× 8 STDA respectively

5.4 Gain (with and without reflector) The proposed antenna operating at 2.4GHz and Omni-directional radiation pattern is observed. Therefore, the signals are transmitted and received in all directions without loss, which reveals that the radiation pattern obtained from the proposed antenna is the sum of all the patterns generated by each array element. This leads to enhance the gain and directivity in the presented STDA antenna.

The photograph of the proposed STDA antenna with anechoic chamber is depicted in Fig. 18 and the radiation pattern of single STDA without reflector and with reflector is obtained.

5.5 Result and Analysis of the STDA in Arrays It is clear that the proposed antenna shows an improved performance in terms of return loss, gain over the existing antennas in a Wi-Fi band. The comparison of gain and return loss between the proposed STDA antenna and array antennas is clearly analyzed. It is observed that there is a great variation in the antenna parameters between the single STDA antenna and the formed array antennas. The performance of an antenna is significantly improved while there is an increase in the number of array elements, even at the cost of increase in size and complexity. The gain increases linearly when the radiating elements in the antenna are increased. The proposed antenna provides the efficient output by radiating each element

5.6 Gain, Return loss comparison for different array configuration The gain of the single STDA 1×4 array, 1×8 array and 2×8 array STDA for Wi-Fi application are analyzed and compared. It is clear that the proposed antenna shows an improved performance in terms of return loss, gain over the existing antennas in a Wi-Fi band. The comparison between the proposed STDA antenna and array antennas are listed in Table 3. From the Table, it is noticed that there is significant variation in the antenna parameters between the STDA antenna and the differently formed array antennas with and without reflectors. The performance of the antenna always improves with an increase in the number of array elements, though it leads to increase in size and complexity. VSWR is less than 2 for all the antennas

Antennas with different configurations such as single STDA, 1×4 STDA, 1×8 STDA and 2×8 STDA with and without reflectors are designed and simulated. This study is conducted to analyze the impact of increasing the number of elements and placing the STDA within the diameter of parabolic reflector. Figure 19 shows the Gain (dBi) vs Frequency (GHz) of single STDA, 1×4 STDA, 1×8 STDA and 2×8 STDA array with, without Reflector. It can be seen that as number of elements is increased from 1 to 2^n, where n = 2, 3, 4 the gain is increased from 6.74(dBi), 11.9(dBi), 14.2(dBi) and 15(dBi) for STDA without reflector respectively

Further study with reflector reveals that the gain parameter is 11.5(dBi), 14.8(dBi), 18 (dBi), 21.6(dBi) with reflector, respectively. The impact of gain for single STDA, 1×4, 1×8 and 2×8 STDA with and without reflector array configurations with respect to the number of elements is illustrated in Fig. 19. It is noticed that the gain is enhanced linearly while increasing the number of array elements

The gain of an antenna is measured and compared. The antenna gain is a parameter for the maximum effectiveness in which the antenna can radiate. Different configurations, namely, single STDA, 1×4, 1×8 and 2×8 STDA with and without reflectors are designed and measured to improve the overall gain. The impact of return loss for single STDA, 1×4, 1×8 and 2×8 STDA with and without reflector array configurations with respect to the number of elements is illustrated in Fig. 20, it is noticed that the gain is enhanced linearly while increasing the number of array elements.

Table 2
Return loss and gain comparison of the proposed antenna with and without reflector

S.No	**Types (STDA)**	**Return Loss (dB) without Reflector**	**Return Loss (dB) with Reflector**	**Gain (dBi) without Reflector**	**Gain (dBi) with Reflector**	**Gain improvement in percentage (%)**	**Return loss improvement in percentage (%)**
1	Single	-19	-36	6.74	11.5	41.3	47.2
2	1 × 4	-15	-30	11.9	14.8	19.5	50
3	1 × 8	-15	-27	14.2	18	21	44
4	2 × 8	-15	-27	15.0	21.6	30	44

Table 3
Resonant frequency, return loss, size, bandwidth and maximum gain of the proposed dipole antenna with reported antennas

Ref.	**Resonant Frequency (GHz)**	**Return Loss (dB)**	**Size (mm^2)**	**Band width (MHz)**	**Maximum Gain (dBi)**
[2]	1.4,1.5	-15	18.6×18.6	91	9
[3]	3.3, 3.8, 5	-10	204 × 175	190	5.4
[4]	5.2, 6.2, 7.4	-23	35 ×25	2511	4.8
[5]	1.5, 3.4	-10	80 × 65	-	4
[6]	1.5, 1.8, 2.8	-12	90 ×135	-	5.9–7.5
[7]	-	-25	6×2	-	-
[8]	6.36	-35	16.9×4.1	151	-
[9]	1.58, 3	-15	90 × 115	1470	6.5
[10]	0.050, 0.100, 0.150	-10	72 × 70	150	6.5
[11]	1.69, 2.3, 2.8	-18	90 × 135	-	5.6
[12]	1.8, 2.45	-30	90 × 115	113	5.8
[13]	1.8, 2.35, 2.6	-15	90 × 115	200	6
[14]	1.8, 2.35, 2.6	-25	90 × 115	110	5.86
[15]	0.69–4.37	-	12 × 18	680	5
[16]	1.8, 2.35, 2.6	-30	72× 115	300	5.8
[17]	3, 5.5	-29	66× 36	150	6
[18]	2.5, 5.5	-29	48× 32.2	180	9
[19]	3,5.5,8	-15	48× 46	-	5.9
[20]	5.8	-18	35× 35	186	10
[21]	1.8, 2.6, 5.8	-10	120 × 120	1100	7
[22]	1.88, 2.34, 2.7,3.08,3.6	-22	111 × 77	300	5.54
[23]	1.71, 2.69	-23	210 × 170	1130	10.1
[24]	2.45,5.2,5.8	-7.5	100 × 100	470	4.7 and 3

-Not discussed

Ref.	Resonant Frequency (GHz)	Return Loss (dB)	Size (mm^2)	Band width (MHz)	Maximum Gain (dBi)
[25]	4, 6, 8.5	-10	40 × 40	7000	7.7
[26]	4.2,6.2,9.6	-10	30 × 28	8000	2.5-7
[27]	3.61,5.52,9.45	-18	27 × 27	7900	4.77
[28]	4,7,9	-10	26 × 26	8700	7
Proposed antenna	**2.4**	**-36**	80 × 105	**200**	**11.5**
-Not discussed					

The impact of return loss and gain with and without reflector is reported in Table 2. Form this it is clearly environed that the return loss and gain is enhanced significantly by incorporating reflector which is highly sufficient for real time applications. There is around 28 % of return loss and 46 % of gain is improved due to the incorporation of reflector

The proposed antenna's functional parameters such as resonant frequency, return loss, bandwidth, gain and size of proposed antenna are compared with the reported antenna which is listed in Table 3. From the table, it is observed that if the gain is high either the return loss is high or size is larger. And, the gain is reduced if the reported antenna return loss is better. From the literature survey, it is clearly noticed that there must be a trade-off between gain and return loss or size. However, in this attempt, the proposed antenna is offered better gain of about 11dBi with the return loss of -36dB.

6. Conclusion

The design of compact STDA antenna for Wi-Fi application is presented. The proposed antenna consists of two dipole elements with different lengths and a ground plane that are serially connected through a parallel strip line. STDA antenna with rectangular shaped top loading is employed for the two dipole elements. Coplanar strip lines are adopted to improve the impedance matching of the antenna and to increase the gain. The proposed antenna resonates at 2.4 GHz with 200MHz bandwidth which is also fabricated and tested; array analysis was made for comparative study. The 2×8 STDA array with reflector is exhibited maximum gain of 21.6 dBi. Therefore the array antennas with these STDA configurations can be deployed for Wi-Fi application within the S band.

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Figures

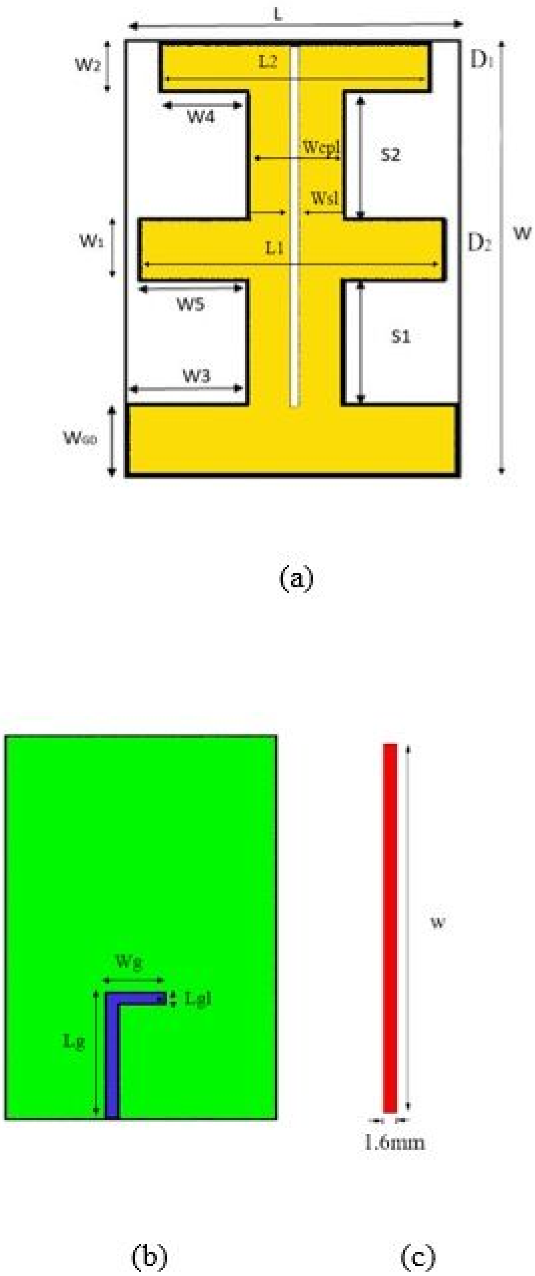


Figure 1

Schematic representation of STDA (a) Front view, (b) Ground plane and (c) Side view

Figure 2

(a) Surface current of the proposed antenna (b) The proposed fabricated STDA Front view and (c) Back view

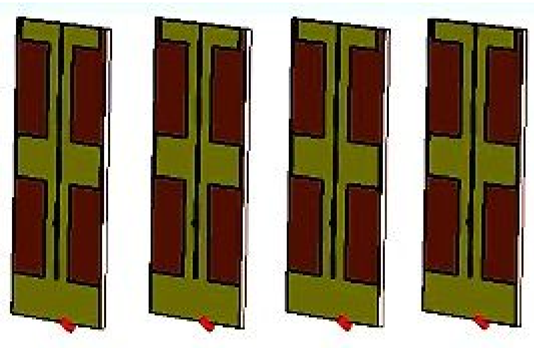


Figure 3

1 × 4 STDA without Reflector

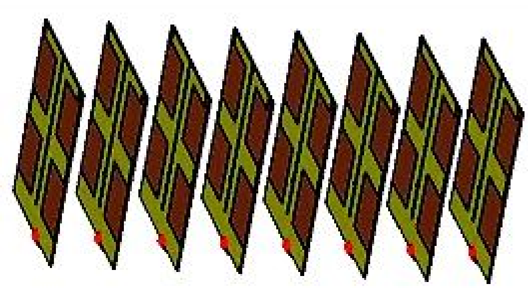


Figure 4

1 × 8 STDA without Reflector

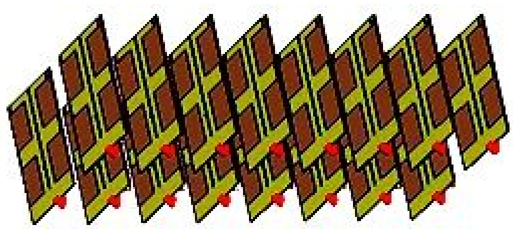


Figure 5

2 × 8 STDA Without Reflector

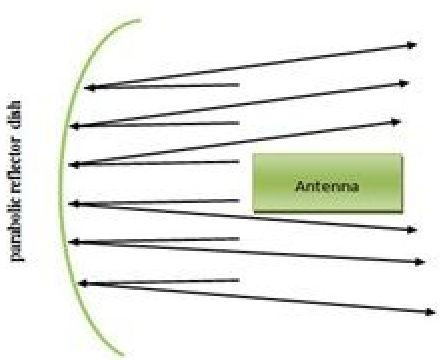


Figure 6

Parabolic Reflector

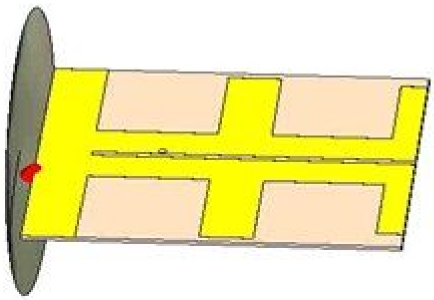


Figure 7

Single STDA with reflector

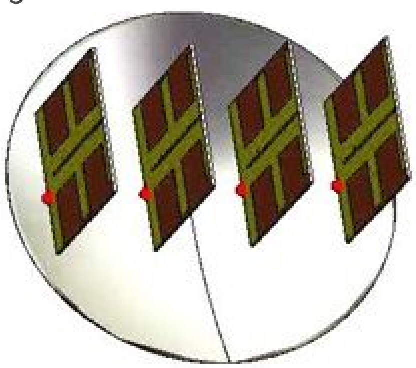


Figure 8

1 × 4 STDA with reflector

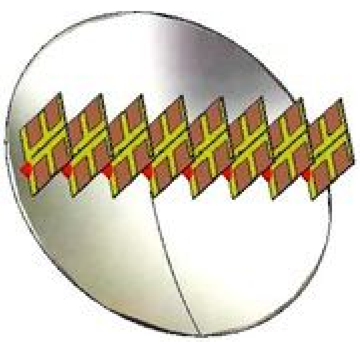


Figure 9

1 × 8 STDA with reflector

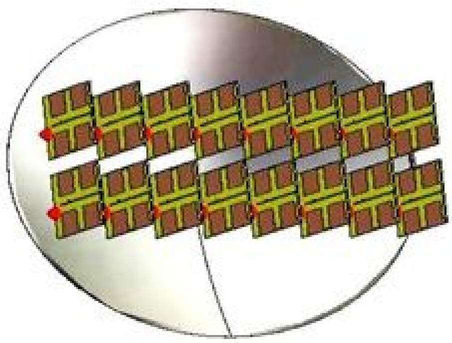


Figure 10

2 × 8 STDA reflector

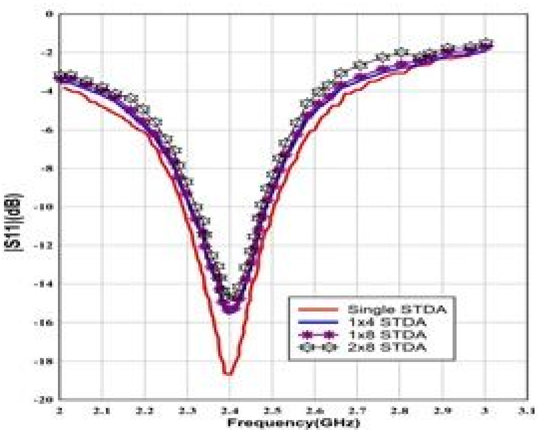


Figure 11

Return loss of the single SDTA, 1×4, 1×8,2×8 SDTA without Reflector

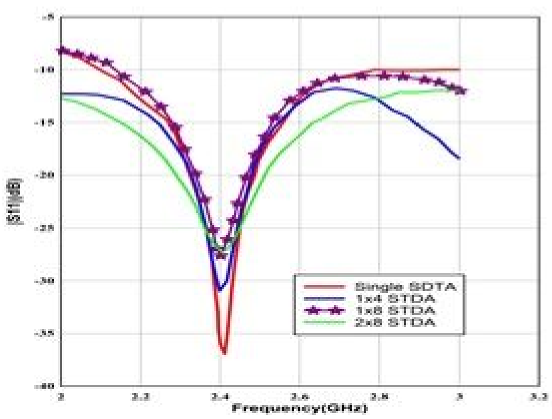


Figure 12

Return loss of the single SDTA, 1×4, 1×8, 2×8 SDTA with Reflector

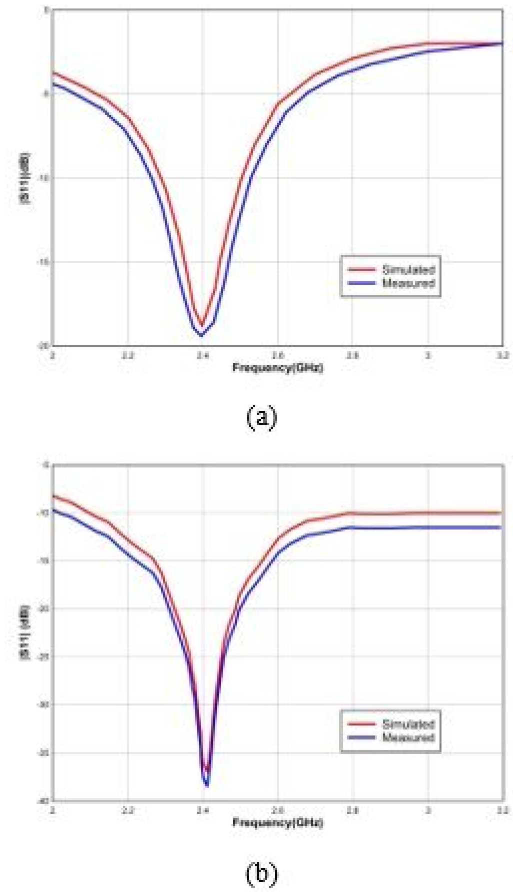
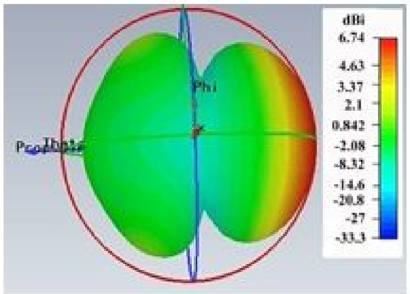


Figure 13

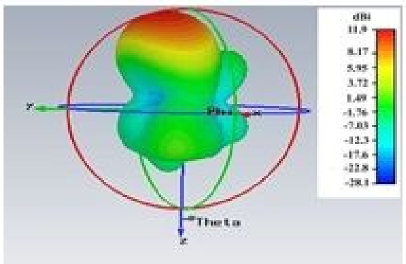
Return loss of the proposed antenna (a) single STDA without reflector and (b) single STDA with reflector

Figure 14

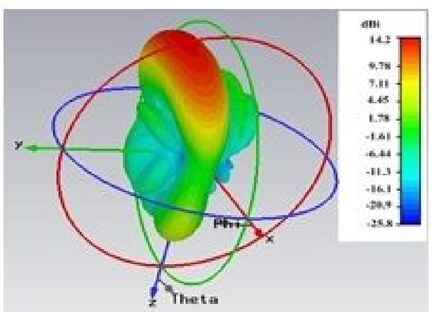
Photograph of the STDA with VNA measurement



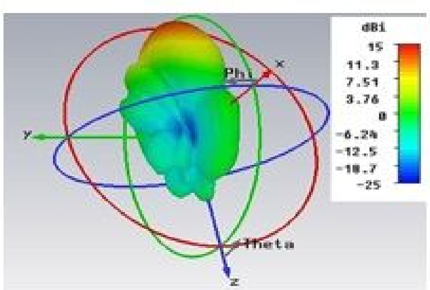
(a)



(b)



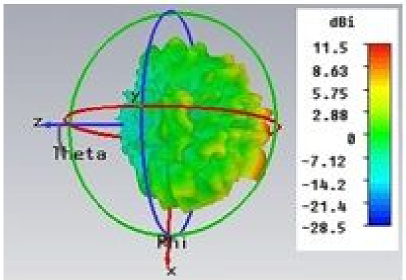
(c)



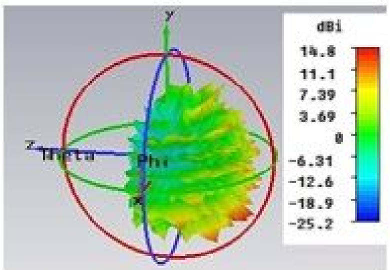
(d)

Figure 15

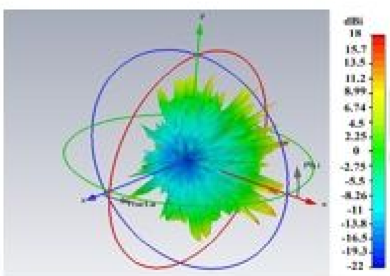
3D Radiation Pattern without reflector for (a) single STDA (b) 1 × 4 STDA (c) 1 × 8 STDA and (d) 2 × 8 STDA



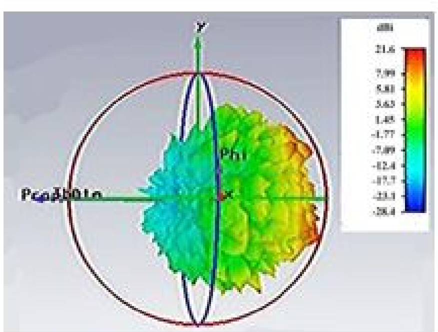
(a)



(b)



(c)



(d)

Figure 16

3D Radiation Pattern with reflector for (a) single STDA (b) 1 × 4 STDA (c) 1 × 8 STDA and (d) 2 × 8 STDA

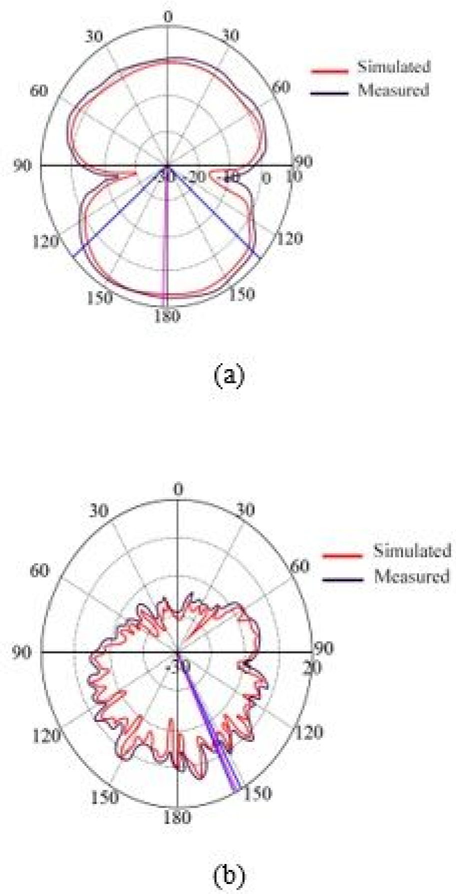


Figure 17

Radiation pattern of the proposed (a) single STDA without reflector (b) single STDA with reflector

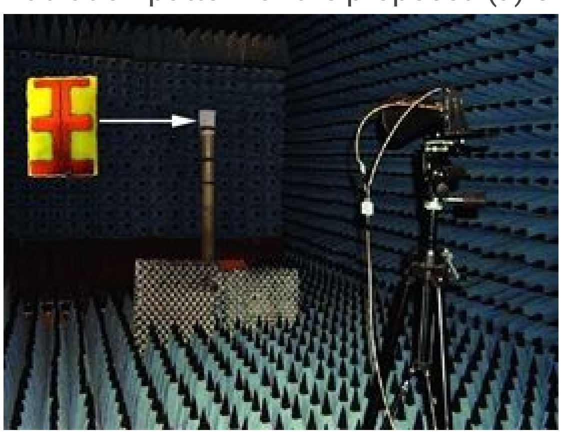


Figure 18

Photograph of the anechoic chamber with STDA

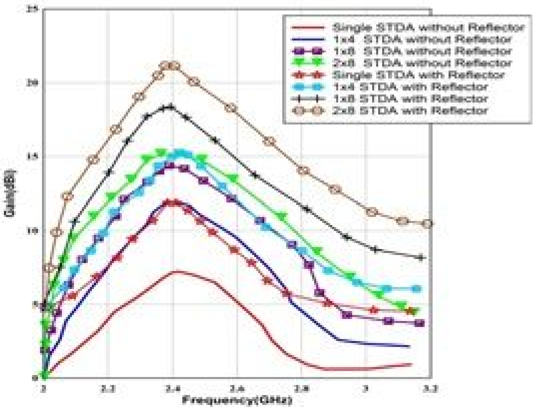


Figure 19

Gain comparison of single STDA, 1×4 STDA, 1×8 STDA and 2×8 STDA array with, without Reflector

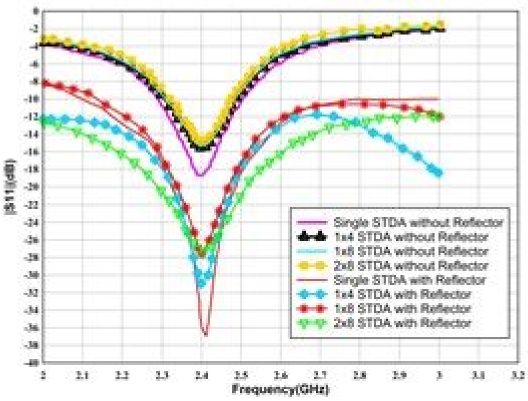


Figure 20

Return loss comparison of single STDA, 1×4 STDA, 1×8 STDA and 2×8 STDA array with, without Reflector