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FOUR BRANCHES YAGI ARRAY OF MICROSTRIP PATCH ANTENNA'S DESIGN AND ANALYSIS FOR WIRELESS LAN APPLICATION

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ABSTRACT

This paper presents the design and analysis of a new kind of Yagi array microstrip patch antenna which appropriate for wireless LAN application. The design is a derivative of the original microstrip Yagi antenna of two branches that comprises of two elements including driven and parasitic elements which consists of reflector and directors. The analysis has been carried out to identify the effect of adding another two more branches in comparison to the microstrip Yagi structure of one branch and two branches. The four branches of this microstrip Yagi antenna has been connected using two branches that are cooperated to each other in a composite array format using corporate-feed network. The proposed antenna design is fed by microstrip line that based on quarter wave impedance matching technique and simulated using Computer Simulation Tool (CST) Microwave Studio. The simulation result of return loss has shown the operated frequency at 5.6 GHz that is appropriate coverage standard of IEEE 802.11 in 5 GHz band between 5.15-5.875 GHz. The proposed four branches Yagi array of microstrip patch antenna can also achieve a gain above 10 dB and a high front-to-back (F/B) ratio as much as 13 dB.

Keywords: microstrip Yagi antenna, array antenna, gain, branches, wireless LAN

INTRODUCTION

Antenna is a transitional structure between free space and a guiding device, this is to ensure the efficiently of radiate and receive radiated electromagnetic wave (Goshwe *et al*., 2012) and this has been used in advance wireless communication system because of its low profile, less weight, low cost and easily manufacturable (Raj *et al*., 2007, DeJean *et al*., 2007, Jothi *et al*., 2012, Deal *et al*., 2000, Thai *et al*., 2008). There are many applications of antenna due to the increasing of their usage, such as mobile and satellite communication application, Global Positioning System (GPS) application, Radio Frequency Identification (RFID) application, radar application and so on. The rapid growth of various wireless communication systems demand efficient antenna to establish a sufficient communication link (Padhi *et al*., 2002).

The wireless Local Area Network (LAN) is one of the application where the base and peripheral stations require suitable antennas to maintain and error free communication connection (Jafar *et al*., 2013). Most wireless LAN applications utilize omnidirectional antennas (Jafar *et al*., 2013, Mamdouh *et al*., 2010, Wu *et al*., 2007) and have been one of the most significant wireless technologies which gain its popularity by leaps and bounds since the decade (Mun *et al*., 2010). However, some of the application needs directional antenna (Mamdouh *et al*., 2010, Ankit *et al*., 2013) such as Yagi antenna and log periodic antenna.

A Yagi antenna commonly used widely in wireless communication because it is simple to build and can provide desirable characteristics for many application. The Yagi antenna consists of three elements (Raj *et al*., 2007) which are driven, director and reflector element. The driven element is a driven element directly connected to the transmission line and received power from or is driven by the source (Tomasi, 2004). The director and reflector is a non driven or parasitic element (Neelgar *et al*., 2011). The reflector is a parasitic element that is longer than the driven element from which it receives energy. A parasitic element that is shorter than it associated driven element is called director. The number of directors in the antenna depends on the gain requirements. In the microstrip antenna, parasitic elements can be placed around a driven element in order to enhance the gain of the single driven element by several decibels.

In this paper, a new design of microstrip Yagi antenna for wireless LAN application is proposed which is derived from original concept of microstrip Yagi antenna designed in (Nuraiza *et al*., 2012). The proposed antenna structure is called four branches Yagi array of Microstrip patch antenna; where the four branches are connected to reflector element that are placed side by side on a dielectric substrate using corporate feedline network. This antenna has been designed like an array format (4x1), aiming to enhance gain (dB) with additional branches in other to compare with previous work in (Nuraiza *et al*., 2012) which are comprise of two design called one branch and two branches microstrip Yagi antenna. The proposed antenna design achieves the highest gain of 11.95 dB compared to the one and two branches which is 6.89 dB and 9.5 dB respectively.

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ANTENNA DESIGN AND STRUCTURE

The proposed of four branches Yagi array of microstrip patch antenna design is a derivative from the original microstrip Yagi antenna array (Nuraiza *et al.*, 2012)where the antenna design of one branch is compared with two branches. Illustrations of these antennas of one and two branches are depicted in Figure-1 and Figure-2 respectively. The microstrip Yagi antenna of one branch consists of four resonant radiators patch elements along with the feeding structure. The four elements in the array position are denoted as follows; the driven element (D), the gap loaded reflector element (R), the first director (D_1) and the second director (D_2). This antenna structure is designed to operate at a resonant frequency, f_r = 5.8 GHz using Flame Retardant 4 (FR-4) substrate material. The dielectric constant of the substrate is ε_r = 4.7, the tangent loss 0.019 and thickness of the substrate h = 1.6 mm. For the two branches of microstrip Yagi antenna, it consists of two microstrip Yagi antenna of one branch which is connected in an array format using one corporate-feed network. The size of the substrate is 65x80 mm^2. This antenna consists of eight patch elements which are doubled for each element in one branch.

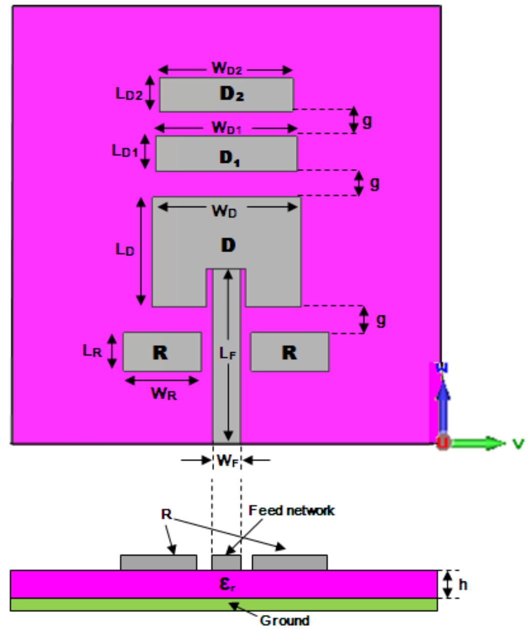

Figure-1. Geometry of the microstrip Yagi antenna (one branch).

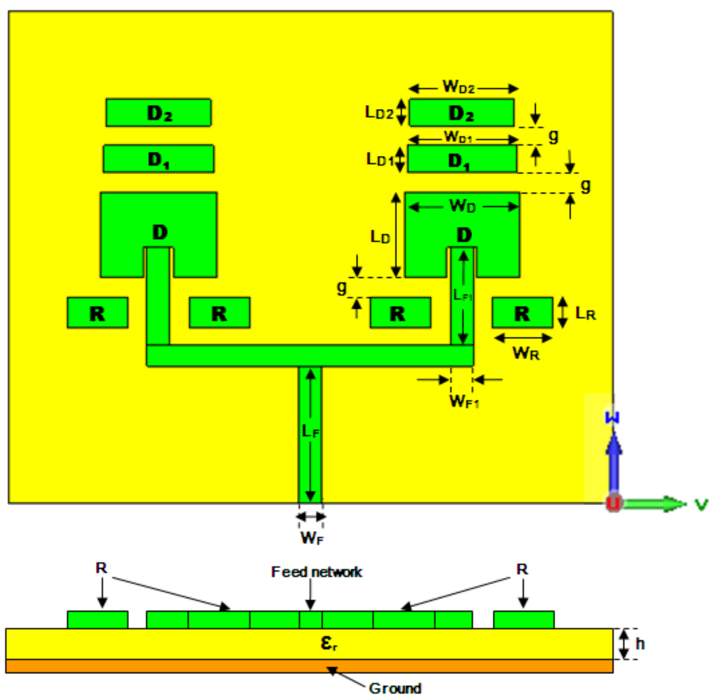

Figure-2. Geometry of the microstrip Yagi antenna (two branches).

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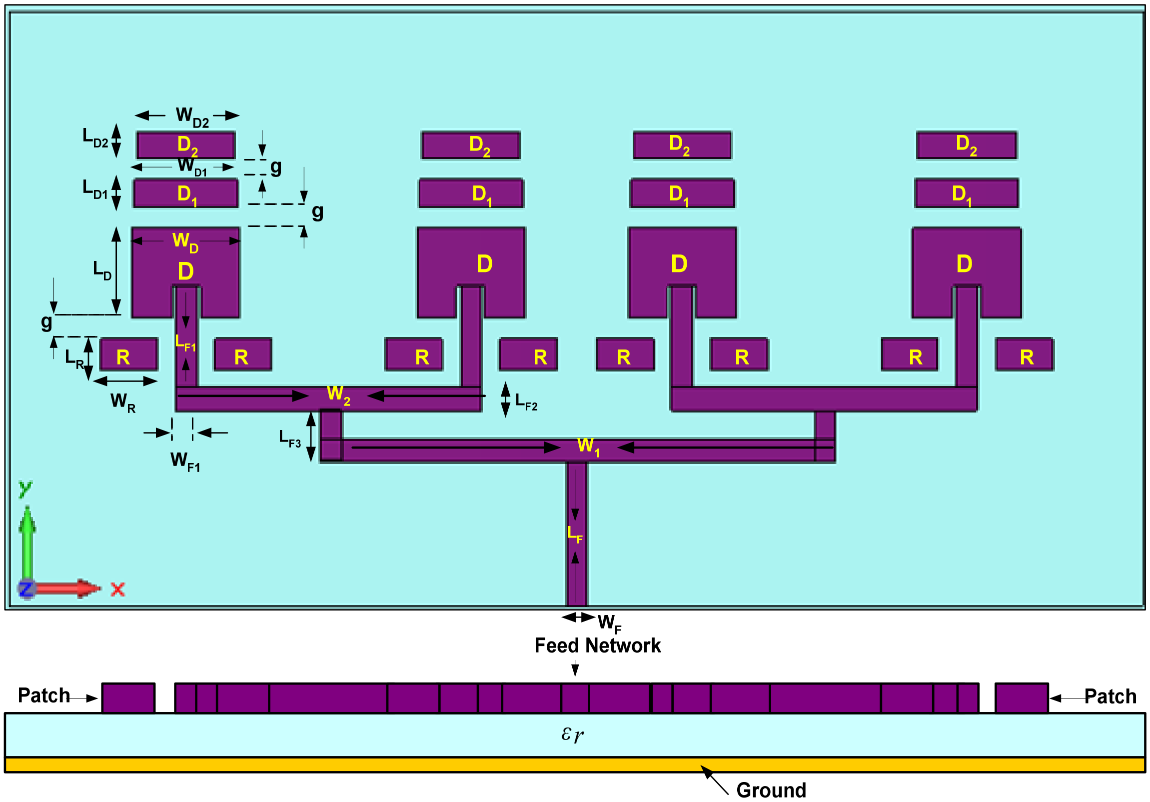

Figure-3. Geometry of the proposed four branches microstrip Yagi array antenna.

Based on the simple illustration of two branches, the analysis is extended to propose an antenna structure which has a four branch element uniform linear array as shown in Figure-3. A uniform array consists of equal-spaced elements, which are fed with current of equal magnitude (i.e. with uniform weightily) and can have progressive phase-shift along the array. The four branches Yagi array of microstrip antenna consists of 16 elements: four driven patches, four gap loaded reflectors and eight director elements. The elements are placed on either sides of the origin at distance λ/2 from it. By design a linear polarized microstrip antenna array achieves high efficiency by having the proper impedance matching (50 Ω) by properly using the corporate feeds.

The feeding method that is used to feed the proposed microstrip Yagi antenna is microstrip line which is similar to previous work (Nuraiza *et al*., 2012). The microstrip line feed is chosen because it is simple to match by controlling the inset position and rather simple to model. The quarter-wavelength impedance transformer technique is used to match the antenna to the transmission line. In order to match array arrangement of four branch elements to 50 Ω matching characteristic impedance of microstrip line, the equation (1) is used by simply varying the width (w) of the center conductor.

$$Z_o = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left[\frac{5.98h}{0.8W}\right] \quad (1)$$

In the proposed microstrip Yagi antenna design, two microstrip Yagi antennas of two branches have been connected in a composite array format by combining two corporate-feed networks of the two branches. The center-to-center spacing between the driven elements is $1.57\lambda_g$. The size of the substrate is 160x75 mm^2. All values were chosen to optimize gain of the antenna with return loss more than 10 dB. The spacing between elements, g is $0.1\lambda_g$ where λ_g is given by the following equation:

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{reff}}} \quad (2)$$

The major advantage of proposed antenna design in comparison to both designs of one branch and two branches in the previous work is the enhancement gain by 11.95 dB while maintaining the return loss greater than 10 dB. Throughout simulation, the dimensions of the optimization microstrip Yagi antenna of four branches are shown in Table-1.

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RESULTS AND DISCUSSIONS

The design process is started using CST simulator, aiming a return loss bigger than 10 dB and operating frequency at 5 GHz band for wireless LAN application. The simulated return loss plots versus frequency and VSWR of four branches microstrip Yagi antenna is shown in Figure-4 and Figure-5, respectively comparing the previous work of one branch and two branches. All simulated results for the three designs are tabulated in Table-2 in terms of frequency, return loss, VSWR, gain and bandwidth.

Table-1. Dimensions of the optimization antenna.

Parameter	**Dimension** (mm)
W_D	15.30
W_{D1}	14.54
W_{D2}	13.81
W_R	8.03
W_F	2.89
W_{F1}	3.00
L_D	11.37
L_{D1}	3.63
L_{D2}	3.45
L_R	4.02
L_F	12.80
L_{F1}	18.10
L_{F2}	2.89
L_{F3}	12.8
g	2.56
W_1	36.50
W_2	21.60

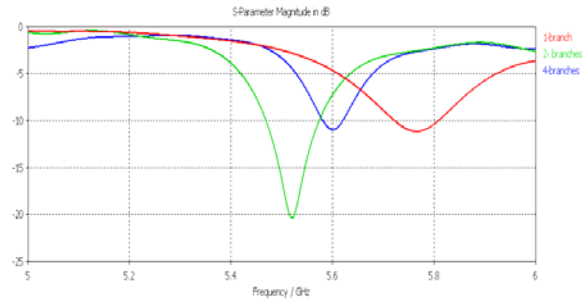

Figure-4. Simulated return loss of one branch and two branches comparing with proposed antenna of four branches.

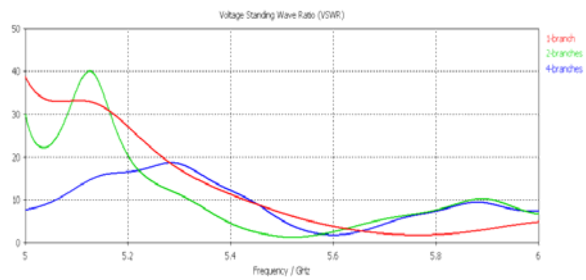

Figure-5. Simulated VSWR of one branch and two branches comparing with proposed antenna of four branches.

The simulation results indicate that all three designs of microstrip Yagi antenna array has return loss more than 10 dB at frequency between 5.52 GHz until 5.72 GHz which is cover upper frequency of 5GHz Wireless LAN band (5.26 GHz - 5.725GHz). The simulated result of two branches microstrip Yagi antenna is found that the return loss of 20.38 dB and antenna gain of 9.5 dB is much better compared to one branch. The antenna designed of two branches shows that the gain is increased by 2.61 dB from 6.89 dB of one branch. Hence, the percentage of gain enhancement from one branch to two branches is 37.9 %. Meanwhile, when the two branches are cooperated to become four branches, the return loss is decreased to 10.97 dB but the gain is greater than the two branches. The proposed antenna's gain is increase up to 11.95 dB; hence the percentage enhancement is 25.8% from two branches. In comparing the three designs, it seems that the gain is increasing from one branch to four branches but the bandwidth tends to decrease as more microstrip Yagi arrays are added to produce a larger array. High gain antennas is preferred because it have the benefit of longer range and signal quality is better compared to low gain. The smaller bandwidth of the four branches array could be due to the shift of the lower resonance of the driven element to a higher frequency.

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Table-2. Tabulated results of simulated return loss, VSWR, gain and bandwidth.

Elements	Parameters				
	Frequency (GHz)	S_{11} (dB)	**VSWR**	**Gain** (dB)	**Bandwidth** (%)
One branch	5.72	-11.17	1.76	6.89	1.89
Two branches	5.52	-20.38	1.21	9.50	2.00
Four branches (Proposed)	5.60	-10.97	1.79	11.95	1.71

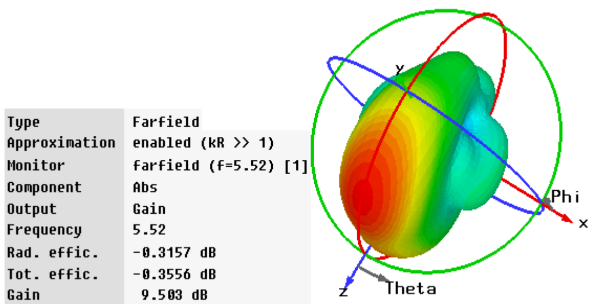

Figure-6. Simulated three dimensional radiation pattern of the microstrip Yagi antenna (two branches).

The simulated far-field radiation pattern as shown in Figure-6 and Figure-7 indicate the value of gain and the forward directional pattern of the microstrip Yagi antenna for two branches and four branches in three dimensional patterns, respectively. The main and side lobes can be observed in the simulated (normalized) two dimensional radiation patterns as shown in Figure-8 and Figure-9 for both two and four branches respectively. From this figure, the front-to-back (F/B) ratio is 13 dB at 5.6 GHz for the proposed antenna. Table-3 shows how the gain various with F/B ratio in comparing the two and four branches. From the table, it is observed that the F/B ratio tends to decrease as more Yagi arrays are included to produce the larger array (from two branches to four branches); however the gain is increased as arrays are added. The F/B ratio decrease as the size of the total array increases probably due to feedline radiation as the complexity of the feeding increases. One possible method of improving the F/B ratio is to connect the reflector patch elements to each other to produce one large reflector patch.

Table-3. Tabulated results of simulated gain and F/B ratio versus frequency of microstrip Yagi antenna.

Elements	Parameters		
	Frequency (GHz)	**Gain** (dB)	**F/B ratio** (dB)
Two branches	5.52	9.50	17.8
Four branches (Proposed)	5.60	11.95	13.0

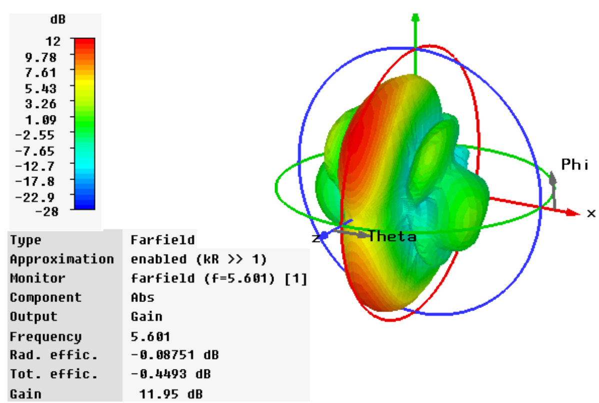

Figure-7. Simulated three dimensional radiation pattern of the proposed microstrip Yagi antenna (four branches).

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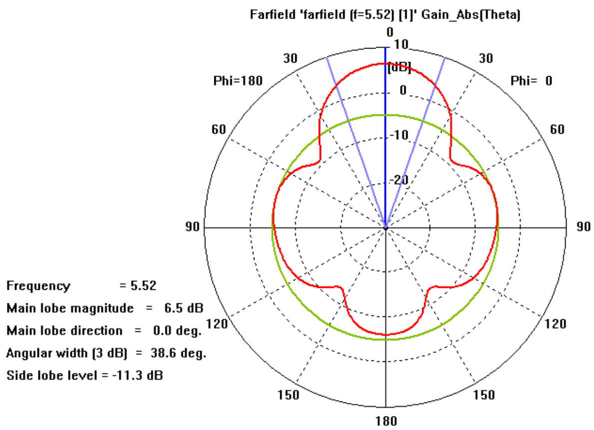

Figure-8. Simulated two dimensional radiation pattern of the microstrip Yagi antenna (two branches).

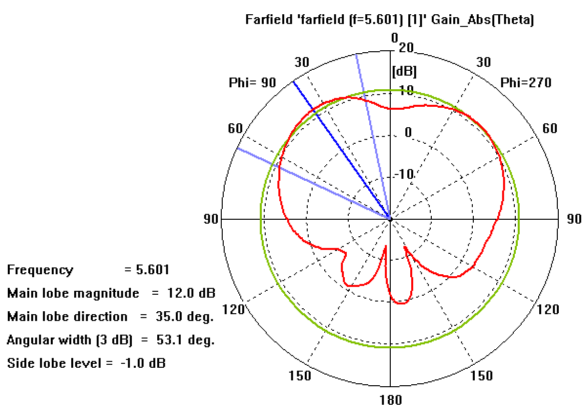

Figure-9. Simulated two dimensional radiation pattern of the proposed microstrip Yagi antenna (four branches).

CONCLUSIONS

In this paper, the new microstrip antenna design based on extension of the original microstrip Yagi antenna (Figure-2) is presented called four branches Yagi array antenna. Results indicate that the proposed antenna design generates a peak gain of about 11.95 dB and is greater than the original microstrip Yagi antenna of two branches (9.5 dB). The percentage gain increment is 25.8%. Hence, it can be conclude that the gain enhancement can be achieved by adding more patches antenna design in composite array format.

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