Design and Implementation of a Multiband Quasi-Yagi Antenna

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***Abstract*— in this paper, a coplanar waveguide-fed planar monopole antenna for multiband operations is presented. The antenna consisting of a multistrip quasi-yagi element and a coplanar waveguide to coplanar slot fed line, and the electric fields at the coplanar slot line can be excited through the CPW feed line. The proposed antenna can be used in multiband operations with directional radiation patterns. It generate four resonant frequency bands determined by -10dB reflection coefficient, it can cover number useful wireless communication systems; the structure plan of the antenna facilitates its integration with the other circuit components.**

Key words*— *Quasi-Yagi Antenna, Multiband Antenna, CPW.

I. INTRODUCTION

Antennas have become the essential element for wireless communication systems; the future of the antenna lies in its small size and easy manufacturing. There are several types of antenna with promising applications in various fields [1]. Microstrip patch antennas are one of them. They are simple antennas, low profile and less expensive, several geometries have been explored with many features to achieve the desired results.

Considerable effort has been consecrated to the design of multiband antennas, and to create the multiband characteristics of antennas, various techniques have been suggested in this area, in several studies, people reported applications and technologies for the design of multiband antennas, including the internal antenna of the four-band handset compact antenna size [2], (PIFA) planar inverted F antennas [3]-[5], triple-band compact notched and ultra-wide band printed antenna [6], and multiband multiple ring antenna [7], different from the wide band antenna, the designs of multiband antennas are also applied extensively to achieve the requirements of multiband and multi-service communication systems, the antenna with multi-functionality characteristics are designed for high-capacity multiband services and high-speed transmission rates. However few internal multiband antennas can cover both WiMAX and WLAN bands [8, 16].

The quasi-yagi planar antenna is widely used in wireless communication systems because of its multiband functionality and its good radiation performance [17], [18]. This type of antenna is easily integrated with other circuit components and can be supplied by different transitions. The quasi-yagi antenna was designed using micristrip-to-coplanar-slots (CPS) transitions in [19] and a coplanar waveguide (CPW) feeding line in [20]. However, the complex transition structure in [19] would be affected by several parameters and the quasi-yagi antenna in [20] generates only one frequency band. Various dual-band printed quasi-yagi antennas operating at two different frequency bands are studied in [21]-[25]. For instance, in [24], the director of the printed quasi-yagi antenna is replaced by two split ring resonators with tow resonant modes for dual- band applications. In [25] a compact dual band quasi-yagi antenna is presented, where the roles of director and the driven dipole operating at the first frequency band are changed into driven dipole and reflector at the second frequency band, respectively, In addition, some tri-band printed quasi-yagi antennas are studied and presented to meet the intensively and rapid-progress requirement of wireless communication systems [26]-[29]. In [26], a tri-band quasi-yagi antenna with coplanar waveguide-to-coplanar strip transition is also proposed, where the even-mode E field at the coplanar-waveguide feed line smoothly transformed to the odd-mode E field at the coplanar-strip line. Based on the conventional Yagi antennas, in [27]-[29], the additional operating modes are introduced by the changes of the drivers, directors or reflectors to obtain three desired frequency bands.

In this communication, a new design for the quasi-Yagi multiband antenna is presented and studied, the antenna provides good performances in terms of reflection coefficient and also a directional radiation patterns, it can also transform even mode electrical field of the CPW line into odd mode electrical field at the coplanar-slot line, and it can be easily manufactured. The proposed antenna, with four -10dB reflection coefficient operating bands around 3.9, 5.15, 7.5 and 9.2 GHz and good directional radiation performance is achieved with a small size covers several useful frequency bands, including the Wireless LAN (WLAN, 5.07-5.35GHz). X-band (7.25-7.75 GHz) of satellite communication, and Global Interoperability for microwave access (WiMAX, 8.7-9.78 GHz) and directional radiation performance is optimal thanks to the characteristics of the Yagi antenna.

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II. ANTENNA DESIGN AND CONFIGURATION

In this section, we describe the structure of the antenna geometrical configuration and details of the proposed design, for multiband applications. The concept of designing this antenna is based on principle of yagi antenna shaped structure.

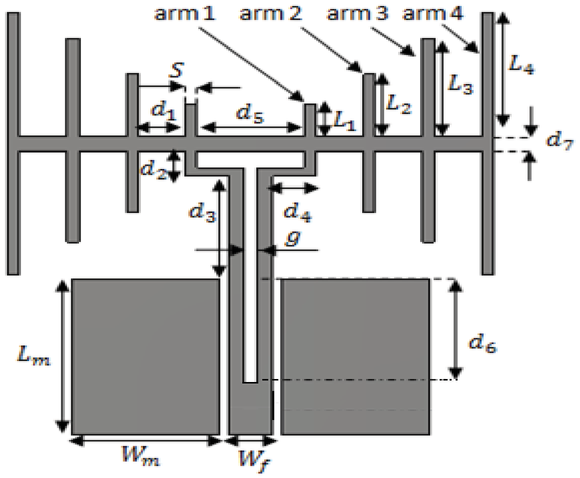

Fig.1. Geometry of the proposed antenna.

A. Antenna Configuration

The 2D simulation model of the final proposed designed antenna structures is shown in figure 1, it is printed on the front side of FR4 dielectric substrate of thickness 1.6 mm with relative permittivity ε_r 4.4 and dielectric loss tangent of 0.02, the total substrate footprint ($L_{sub} \times W_{sub}$) of all antenna is 35.4x32mm², the radiating patch is constructed as a quasi-yagi, the coplanar waveguide (CPW) structure, characterized by ground length (Lm) and width (Wm), the gap distance (S) between feeding strip line length (L_f) and width (W_f), was used for feeding these antenna through sub miniature (SMA) connector. The optimized values of antenna parameters are listed in table 1.

B. Design Procedure

the antenna is a symmetrical structure, Construction of its geometry begins with a simple horizontal microstrip line midpoint containing vertical bars (stubs) spaced between them with the same distance d, they are placed from top to bottom symmetrically relative to the horizontal bar, two rectangles of the same size are placed symmetrically with respect to the CPW fed line, figure 1 show the layout of the antenna structure. The distance between the dipole elements d is fixed, arm 1 to arm 4 will be excited at different frequencies as half wave dipoles, while the non excited elements, shorter or longer than the excited element, works as directors or reflectors, respectively, the length of the driver dipole elements, L1 to L4 are approximately equal to λg/4 (λg is the operating wavelength in the substrate) at their resonance frequencies, according to principle of the yagi antenna, the total size of the antenna is 35.4x32 mm². After adjustment and optimization, the final optimal dimension values are obtained as shown in Table 1.

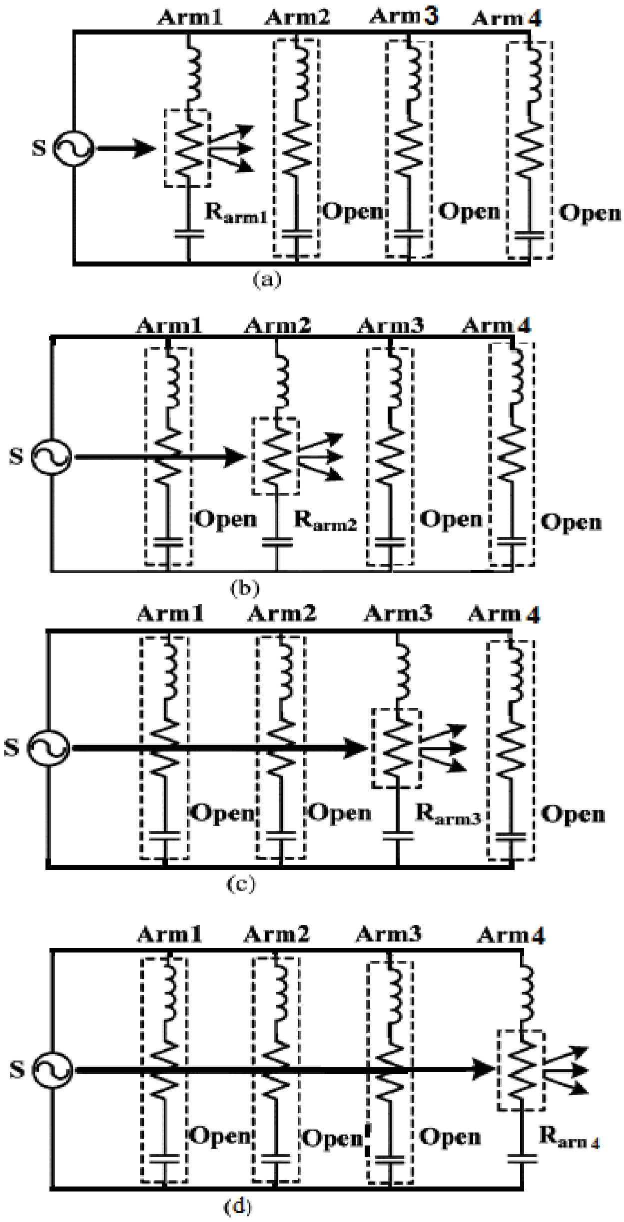

Fig. 2. transmission line model for the antenna at (a) 3.9, (b) 5.15, (c) 7.5, (d) 9.2 GHz, S energy of source and R_{arm1}, R_{arm2}, R_{arm3}, R_{arm4}antenna resistances.

In this design, the long slot line is used for exciting the radiating patch element; the transition is designed to excite the pair-mode at the coplanar slot line in order to provide a phase delay of 180˚ from the CPW line as it can also transform unbalanced input signal at the driver dipole element to a balanced signal.

The radiating elements at different positions can be simply modeled by four half-wave dipoles in a transmission line as shown in Fig. 2. As is known, the equivalent circuit is a series network RLC for a dipole antenna. At the first resonant frequency, when, Larm 1 =2L1= λg/2, ARM 1 works as a half-wave dipole, satisfying the condition of resonance. However, arms 2, 3 and 4 behave as a parallel open circuit stubs with infinite input impedance, resulting in a total impedance mismatch between the radiating elements and feed line. As a result, reflection coefficients in the frequency band of arm 1 of the antenna become smaller, and appearance of the first desired band, as shown in Fig. 2(a). Similarly, at the second ,third and four bands, arms 2, 3 and 4 operate in a manner analogous to arm 1 when Larm2 =2L2= λg/2, Larm3 =2L3= λg/2 and Larm4 =2L4= λg/2 respectively, as in Fig. 2(b),2(c) and 2(d). During this time, the not excited elements, which works like open parallel sections, can act as parasitic elements with the director or reflector functions.

TABLE 1: OPTIMIZED PARAMETRES OF THE PROPOSED ANTENNA.

Parameter	Value (mm)	Parameter	Value (mm)
W_m	10	d_2	2.15
L_m	13	d_3	8.65
W_f	2.94	d_4	2.92
L_1	2.75	d_5	7.2
L_2	5.2	d_6	5.6
L_3	8.25	d_7	1.2
L_4	10.4	S	0.8
d_1	3.2	g	0.8

III. RESULTS AND DISCUSSION

The CST micro-wave studio simulator is used to simulate the proposed antenna, the performance characteristics of proposed antenna have been analyzed on basis of parameters like reflection coefficient, radiation pattern and total gain, The bandwidths of 0.18, 0.20, 0.26 and 1.12 GHz are achieved for the four bands of 3.81–3.99, 5.05–5.25, 7.38–7.64 and 8.69-9.81 GHz, respectively, with The condition of coefficients performance lower than -10 dB.

A. Return Loss

In this section, the influence of geometric parameter for a return loss is discussed and investigated in details, It is clear that the resonant frequency varied according to the geometric parameters of the antenna, they are changed in length and width of the patch in order to see the effects of different parameters on frequency, the target is to find appropriate parameters to meet the requirement in size and resonances frequencies.

Figure 3(a) shows the results obtained through simulation of the return loss characteristic according to the geometry change of L1 while all other parameters are kept constants.

As the value of L1 increases, both high resonant frequencies shift toward the lower frequencies. Thus, by increasing length of arm 1, the electric current gets lengthened on the arm1 which causes the resonant frequency to decrease. It is clear that the two resonances are centered at 7.5GHz and 9.2GHz, with a good impedance matching when L1 equal to 2.75 mm. Therefore, arm1 is primarily responsible for controlling the fourth frequency band 9.2 GHz and less can contribute to the control of the 7.5 GHz frequency band, and the current distribution in Figure 4(d) confirms this hypothesis.

In order to avoid redundancy, a recapitulation study in the following points,

- Frequency band (7.25 - 7.75 GHz):
  L2±1mm, Figure 3 (b).
- Frequency band (5.07 – 5.35 GHz):
  L3±1mm, Figure 3 (c).
- Frequency band (3.81–3.99 GHz):
  L4±1mm, Figure 3 (d).

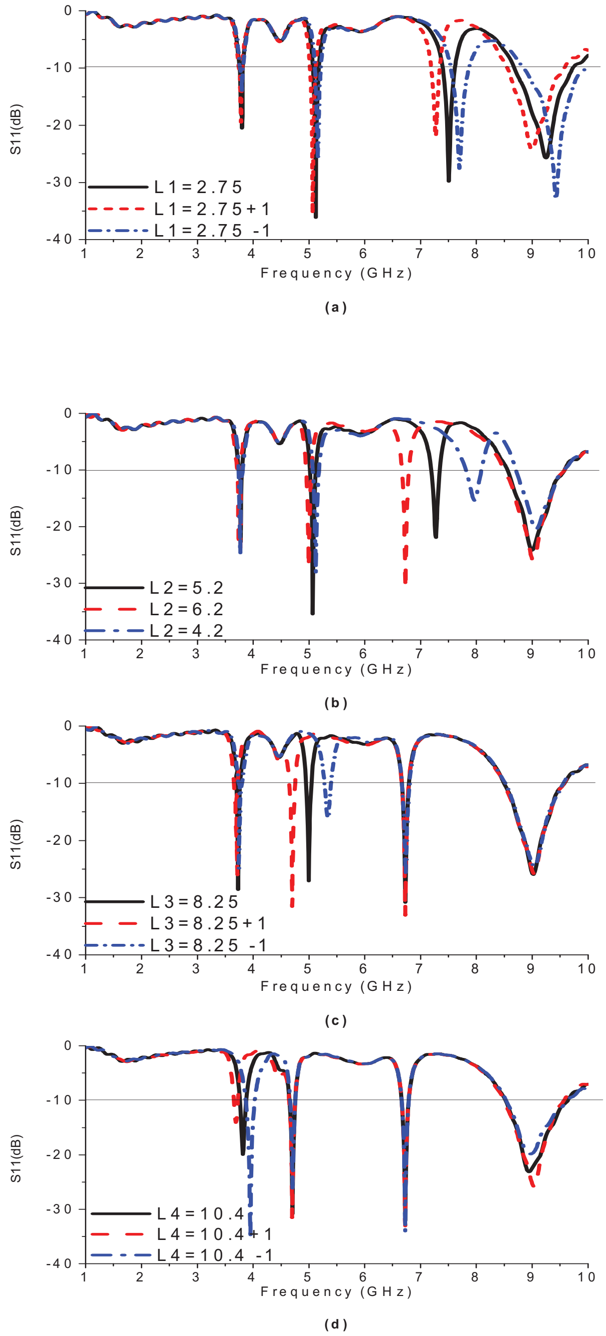

Fig.3. parametric study, the figures illustrates the change of s11 as a function of the geometry, the continuous black curve is our curve of s11 desired, (a) s11 versus Frequency on the influence of L1, (b) influence of L2,(c) influence of L3,(d) influence of L4.

B. Surface Current Distribution

To further understanding the antenna operating mechanism, the surface current distributions at four different resonant frequencies are depicted in Figure 4. Current distribution graduation on the radiating elements of the antenna at four frequencies bands is shown in Fig. 4. Note that, the current density at each resonant frequency is indeed higher on the certain part of the antenna compared to the other part whose dimensions are supposed to control that particular frequency. the distribution of the surface current at the frequency band 3.9 GHz, is shown in Fig. 4(a), and so are the frequencies of 5.15, 7.5 and 9.2 GHz in Fig. 4(b), (c) and (d) respectively. at the radiating elements, It is clearly seen that there are stronger concentration of current distributions at the center frequency of the corresponding operating band, However, the surface current is directed in the same directions, indicating that the elements actually function as half-wave dipoles. On the other hand, the current distributions are lower at the non-excited elements as a parallel stubs open-circuit and its input impedance is infinite, which is corresponding to a transmission line model with previously mentioned series networks RLC. However, it is clear that there is still a considerable distribution current on the unexcited element, which is induced by the driver dipole element. It

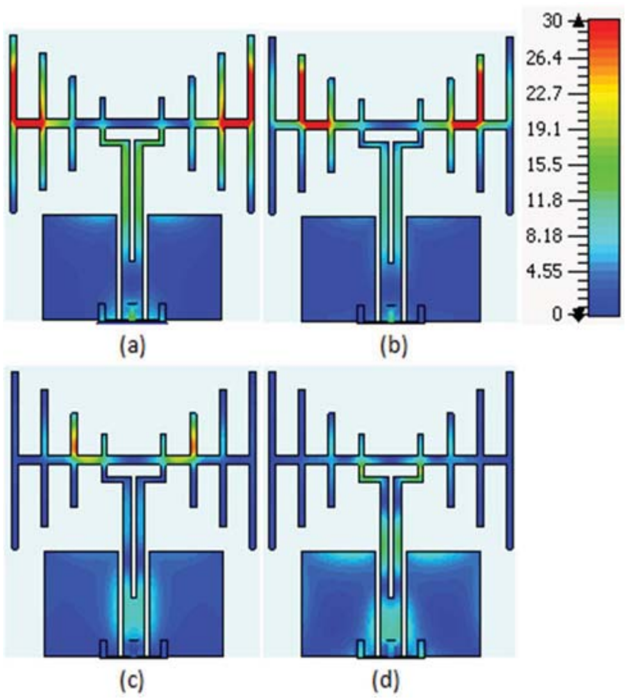

Fig.4. Current distributions at four different frequency bands, (a) at 3.9 GHz, (b) at 5.15 GHz, (c) at 7.5 GHz and (d) at 9.2 GHz.

Means that the non excited elements work as the parasitic elements. Thus, the radiation patch elements of the antenna follow the theory of the Yagi antenna.

C. Radiation Pattern

Figure 5 shows the radiation patterns of proposed antenna in the E and H planes at 3.9, 5.15, 7.5, and 9.2 GHz. These results confirm that antenna predominately radiates energy omnidirectionally. The front-to-back ratios are almost above 10 dB at desired frequencies and the main beams are toward the endfire direction, which demonstrates the directional radiation property of the proposed antenna.

It can be noticed that at the first resonant frequency the maximum gain is around 1.34 dB in the direction φ of 0° and θ of 49°, at the second frequency the maximum gain is around 1. 14 dB in the direction φ of 0° and θ of 46°, at the third resonant frequency the maximum gain is around 2.38 dB in the direction φ of 0° and θ of 144°, and for the fourth frequency the maximum gain is around 4.01 dB in the direction φ of 0° and θ of 159°, At the high frequency bands antenna exhibit approximately omnidirectional characteristics, and it has a dipole-like property in the low frequency band. The antenna performance confirms its candidature for commercial portable wireless device.

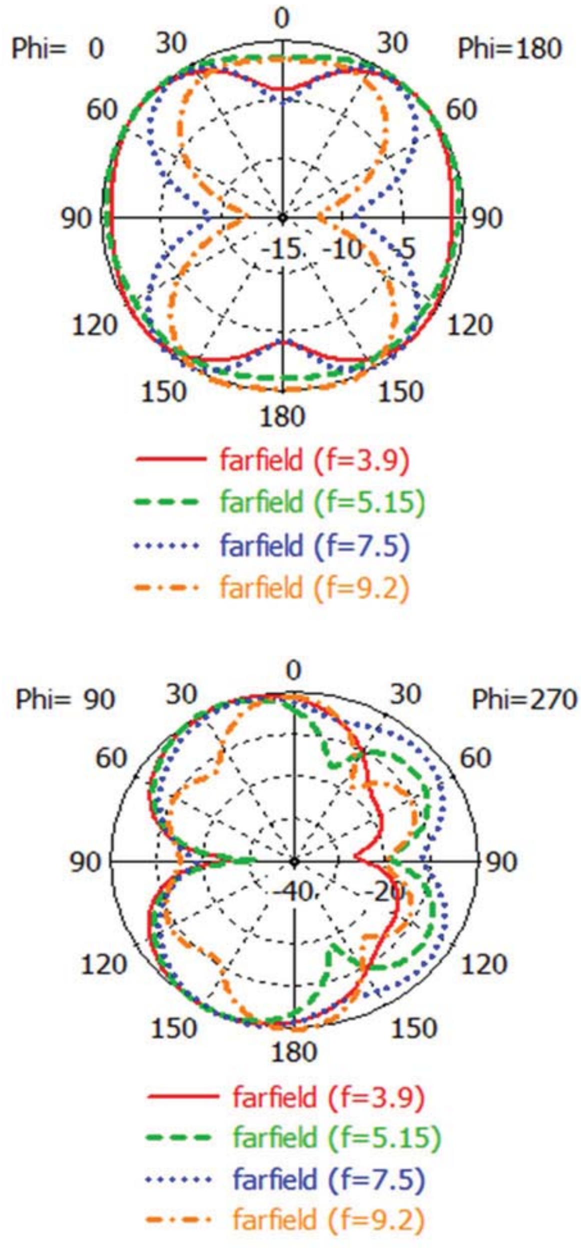

Fig.5. 2D Radiation patterns of the proposed antenna at distncts frequency bands in plans (a) φ=0° and, (b) φ=90°.

CONCLUSION

In this letter a coplanar fed slot-line quasi-Yagi antenna is proposed to achieve multiband characteristic and directional radiation patterns at the whole operating bandwidth, and relatively good directional features. The proposed antenna structure is also easy to manufacture and suitable for WLAN and other communication bands.

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