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Insert-Fed Microstrip Patch Antenna

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ABSTRACT: This paper presents the design of rectangular microstrip patch antenna operates at the frequency range of 4.9GHz. A single-layer microstrip-fed patch is light weight, compact, cost effective and has the capability of bandwidth enhancement. The bandwidth of the proposed patch antenna is 2.7 times higher than the traditional patch antenna. The wideband property can be obtained by using two resonances caused due to the radiating patch and non-radiating resonator. The proposed patch antenna requires electrically thin substrate and has low-profile property which helps in bandwidth enhancement. The performance of the antenna is studied in terms of parameters like reflection coefficient, bandwidth, beamwidth, VSWR and radiation pattern. These results are simulated using HFSS.

KEYWORDS: Patch antenna, VSWR, Bandwidth enhancement, Resonator.

I. INTRODUCTION

Today in the world of communication systems the most widely researched area is of wireless technology and a study of communication systems is incomplete without an understanding of the operation of the antenna. In general the rectangular patch antenna design depends on the desired resonant frequency, dielectric constant of the substrate, length of the patch, width of the patch, feed location design and ground dimensions.The microstrippatch antenna usually suffers from several inherent drawback of narrow bandwidth because of its resonant property with a high Q. Due to this the efficiency of the antenna is reduced.

To enhance the bandwidth of patch antenna aperture coupling feed and proximity coupling feed. Aperture feed and proximity feed both are difficult to fabricate. These techniques requires multi-layer substrates. However they are quite difficult and results in high cost. The same is done in single-layer substrate as depicted in Fig.1, which reduces the cost effectiveness and simple to fabricate. Hence microstrip-fed is used because the substrate thickness can be reduced so that the bandwidth is enhanced. In addition harmonics can be fully suppressed.

The microstrip feeding network and patch radiating elements can be fully integrated on a single-layer substrate and the entire antenna can be fabricated simultaneously by using the printing technology. This helps to design a wideband microstrip-fed patch antenna on a single-layer substrate. A pair of $\lambda/4$ resonators is employed and placed in proximity to the radiating patch for wideband radiation under dual resonances. The advantages of this method are as follows: (1) Operating bandwidth of a single-layer patch antenna is enhanced even for an electrically thin substrate, and it can be further controlled to some extent by adjusting the gap width between the patch and the $\lambda/4$ resonators; (2) Harmonic radiation at high frequency is effectively suppressed thanks to the characteristics of capacitive feeding structure and λ $\lambda/4$ resonators; (3) The feeding-line section is small in size so as not to increase the overall size of the patch antenna in array applications; (4) The whole antenna structure is geometrically symmetric so as to maintain a low cross-polarization level.

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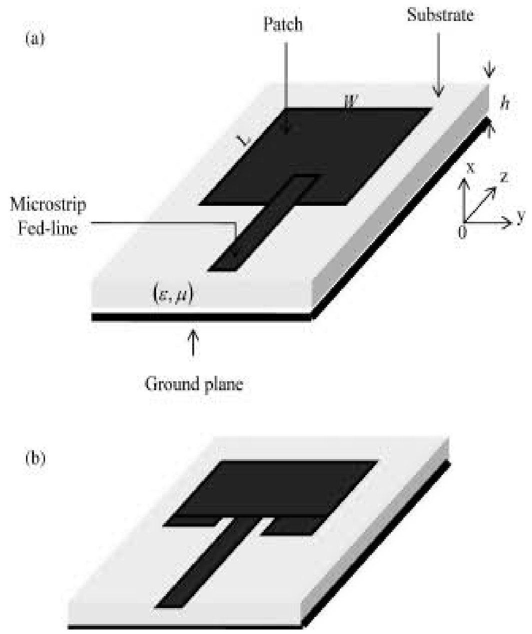

Fig.1. Inset-fed microstrip patch antenna

II. RELATED WORKS

A single-layer microstrip-fed patch antenna with capabilities of both bandwidth enhancement and harmonic suppression is proposed. The wideband property is obtained using λ/4 resonator. It also reported dual-resonance patch antennas, the proposed antenna does not require the electrically thick substrate[1].A size-miniaturization method is reported in [2], but the patch configuration is destroyed by an extra T-shaped resonator. Moreover, the harmonic radiation cannot be suppressed because this T-shaped resonator operates as a λ/2 resonator. Optimally designed impedance-matching network, the bandwidth can be increased by a factor of at least 3.9, the exact value depending on the degree of matching required.

In [3] order to overcome the bandwidth limitation a capacitive element, such as an annular gap or parallel plate, in series with the probe inductance is inserted to remove its effect. A new variation in the capacitive feed probe for patch antennas on thick substrates. It consists of a small circular probe-fed capacitor patch[4].

A coplanar capacitive fed microstrip antenna suspended above the ground plane is presented. Themodel of the antenna incorporates the capacitive feed strip which is fed by a coaxial probe using equivalent circuit approach, and matches simulation and experimental results. The capacitive feed strip used here is basically a rectangular microstrip capacitor. The antenna configuration can be used where unidirectional radiation patterns are required over a wide bandwidth[5]. Proximity-coupled microstrip patch antenna capable of 13%bandwidth. The impedance match (VSWR < 2), co-polarised radiation patterns and cross polarised radiation were measured over this bandwidth to confirm operation. The construction is quite simple, consisting of a microstripfeedline on a substrate proximity-coupled to a rectangular microstrippatch on a covering substrate,a small open-circuit tuning stub is connected in shunt with the feed line[6].

In order to obtain a stable radiation across the passband. The L-probe does not have much effect on the resonant frequency. The performance of this new feeding technique is quite similar to that of the U-shaped slot patch antenna. The bandwidth and gain of the proposed antenna are36% and 7 dBi, respectively[7]. In order to control the

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radiation performance, it explores the relationship required between the dielectric layers to achieve broadband behavior and also how the dimensions of the stacked radiators and the relative location of the feed can influence the impedance response[8].

It relates the antenna thickness and radiation performance, an antenna thickness of 0.13 times the free-spacewavelength of the center operating frequency, the proposed antenna can achieve a bandwidth of 30% and produce a monopole-like conical radiation patterns.The measured gain is in the range of 5.0 - 6.5 dBi in the passband. A wide-band circular patch antenna with conical-pattern radiation is reported in the utilization of an L-shaped probe feeding. Such a technique was mainly employed to produce a broadside pattern radiation[9].

In order to achieve a wideband performance and size reduction. The patch size is reduced to 25% of the full size patch with over 30% matching bandwidth. A hook shape probe excites the patch proximately.The parameters of the hook probe on the input impedance performance were also analyzed[10].Simulation of a rectangular micro strip patch array antenna at 2.4 GHz for wireless communications that provides a radiation pattern along a wide angle of beam and achieves a gain of 11.6 dBi.The rectangular micro strip patch antenna was analysed using Ansof/Ansys HFSS. The performance parameters was achieved with gain 12 dB and beamwidth 40 degrees in E-plane and 26 degrees in H-plane for patch array antenna[11].

In [12] and [13], a half-wavelength (λ/4) resonator and a composite right-/left-handed resonator are employed, respectively, to achieve the wideband performance. Since the sizes of the feeding networks are significantly enlarged, these approaches can hardly be applied in the design of an array.

In addition to bandwidth enhancement, the proposed feeding method can effectively suppress the spurious radiation caused by harmonic resonant modes of the patch radiator. It can be intuitively explained in the following two aspects. On the one hand, the patch antenna is capacitively fed through a pair of λ/4 resonators. In this case, the energy can only be transmitted to the patch in discrete frequencies where both the patch and λ/4 resonators are resonating, which is completely different from the traditional insert-fed patch antenna [14]. On the other hand, all the even-order resonant modes could not be excited in the /4 resonators because of the shorting pin introduced in the central plane. As discussed in [15]-[16], the 2nd-order mode is the most harmful mode, but it can be naturally suppressed because of its even symmetrical property in the transverse plane.

III. GEOMETRY AND WORKING PRINCIPLE

A. Geometry

The proposed single-layer microstrip-fed patch antenna with bandwidth enhancement and harmonic suppression is depicted in Fig:2. The antenna is composed of a rectangular patch and two λ/4 resonators in the feeding line section. The two λ/4 resonators share a shorting pin with a radius of r. The dimensions of the patch are $L_p \times W_p$ and those of each λ/4 resonator are $L_r \times W_r$. Different from the traditional insert-fed method, the radiating patch and feeding line are interacted through the λ/4 resonators which are located at a distance d from the patch. All of them can be fabricated on a single-layer substrate with a thickness of $h$and a relative permittivity of ε_r.

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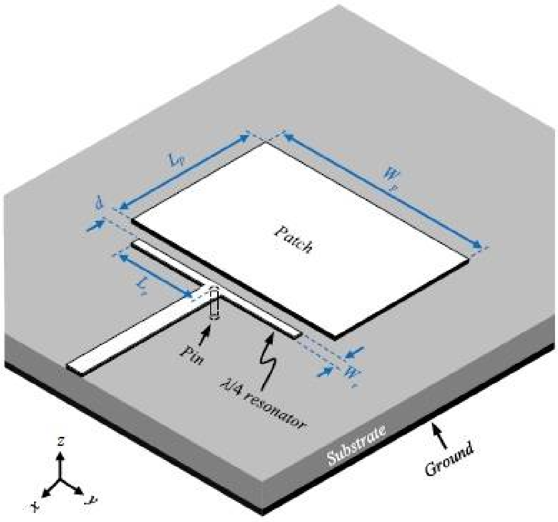

Fig:2Geometry of the proposed wideband patch antenna.

B. Working Principle

In order to construct resonator type antenna, electrically thin substrate is required. Generally it suffers from a problem of narrow bandwidth. For the purpose of bandwidth enhancement dual-resonance structure. The dual resonances introduced by the patch and the extra resonating circuit could be adjusted close to each other; thus, a wideband performance could be achieved. For a thin substrate used mostly in microstrip patch antennas, the reactance of the probe is too small to excite the extra resonance.

Instead of using lumped resonator used in thick substrate a pair of λ/4 resonator is used to form a coplanar distributed structure. The coupling gap helps in achieving the wideband performance. The gap width makes the two resonant frequencies close to each other.These two narrow bandwidth are combined to a single wideband. In addition to bandwidth enhancement, the proposed feeding method can effectively suppress the spurious radiation caused by harmonic resonant modes of the patch radiator. It can be explained in two aspects: (1) On the one hand, the patch antenna is capacitively fed through a pair of λ/4 resonators. Therefore , the energy can only be transmitted to the patch in discrete frequencies where both the patch and λ/4 resonators are resonating, which is completely different from the traditional insert-fed patch antenna.

(2) The second aspect is, all the even-order resonant mode could not be excited in the λ/4 resonator because the pins are shorted in the central plane.

The second resonance only relates to the λ/4 resonator and the coupling gap, this proposed method is valid for varied substrate thicknesses.In addition to bandwidth enhancement, the proposed feeding method can effectively suppress the spurious radiation caused by harmonic resonant modes of the patch radiator. The 2nd-order mode is the most harmful mode, but it can be naturally suppressed because of its even symmetrical property in the transverse plane.

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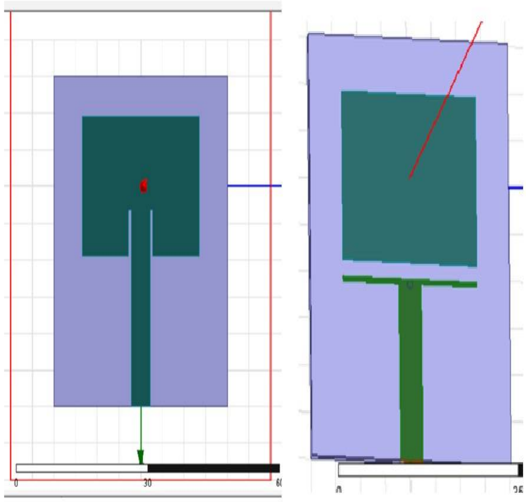

Fig:3 Patch Antenna(a) Proposed & (b) Traditional

IV. RESULTS AND DISCUSSION

Cut-Off Frequecy :

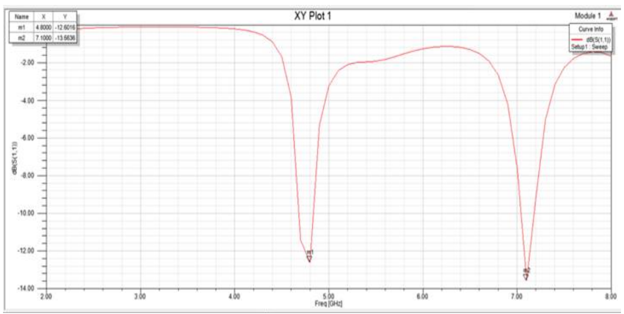

Fig.4 (a). Proposed

VSWR

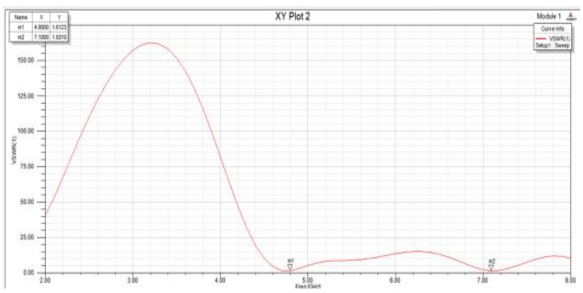

Fig.5 (a). Proposed

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Radiation Pattern

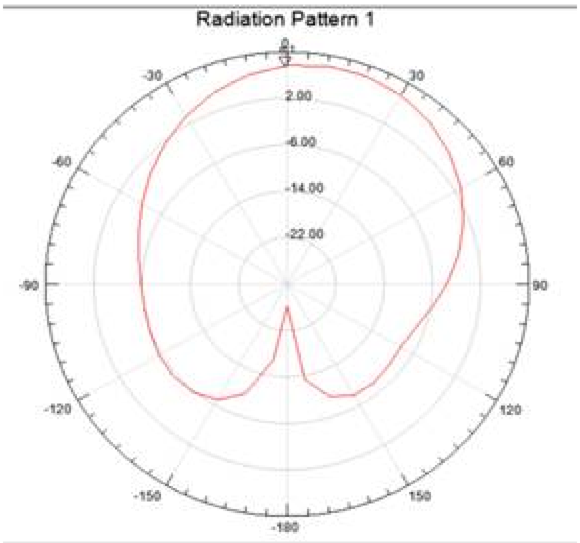
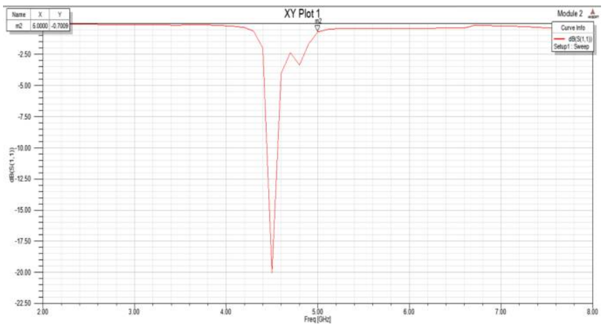
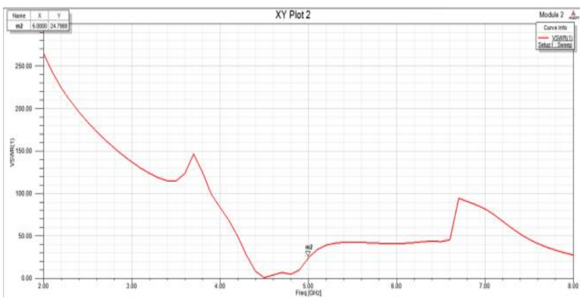


Fig.6 (a). Proposed



(b) Traditional



(b) Traditional

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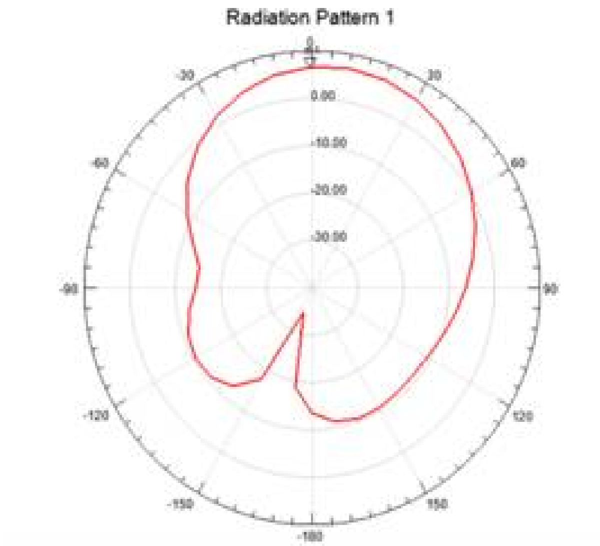


(b) Traditional

3D Polar Plot

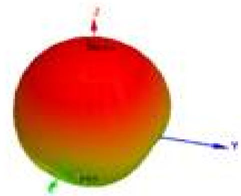
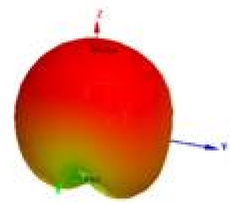


Fig.7 (a). Proposed



(b) Traditional

The substrate used here in the proposed patch antenna is RogersDuroid 5870 with the Relative permittivity of 2.33 and the thickness h=1.57mm. It is followed by air box creation followed by boundary and excitation. The frequency sweep is set with minimum and maximum frequency. It is then continued with the analysis setup. All these condition must satisfy to get the accurate output.

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Parameters	Traditional	Proposed
Patch Length	19.1	18
Patch Width	27	27
Resonator Length	-	11.25
Resonator width	-	0.5
Microstrip width	4.5	4.5
Gap	-	1.75
Substrate	Rogers Duroid 5870	Rogers Duroid 5870
Permittivity	2.33	2.33

The cut-off frequency of the proposed design operates at 4.8GHz as shown in Fig.4(a) whereas the Fig.4(b) in the traditional microstrip patch antenna, the operating frequency cuts at 4.5GHz.

There could be seen a slight variation in the traditional microstrip patch antenna's radiation as shown in Fig.6(b) between -90^0 to -60^0 but that variation seen in Fig.6(b) is not seen in Fig.6(a). The same variation can be noted in Fig.7(a) and Fig.7(b) along the x direction.

The bandwidth is enhanced by using a thin substrate. The measured frequency range of the proposed patch antenna with $|S11|$ lower than -10dB is 4.8 GHz, while that of the traditional patch is 4.82-4.5 GHz. It means that the bandwidth of our proposed antenna has been enhanced by 2.7 times.

All these changes is due to gap adjustments between the radiating patch and non-radiating resonator.

V. CONCLUSION

This paper demonstrates a new compact insert-fed in a single-layer structure. The bandwidth of the microstrip patch antenna is enhanced using $\lambda/4$ resonator. The added advantage to this is the low profile, low cost and easy fabrication adds attraction to the proposed antenna. The bandwidth of the patch antenna can be enhanced by adjusting the gap between the patch and $\lambda/4$ resonator. The proposed design is simulated and the operating frequency is found to be at 4.8 GHz. In order to verify the good performance of the microstrip patch antenna, the proposed model is compared with the traditional insert-fed patch antenna which has an operating frequency of 4.5 GHz. In addition to this more symmetric radiation pattern is obtained.

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