International Journal of Scientific Research and Engineering Development-– Volume 2 Issue 5, Sep – Oct 2019

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RESEARCH ARTICLE OPEN ACCESS

Quad-band Microstrip Patch Antenna Based on Dual-Cross Slots

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Abstract:

A multiband Microstrip patch antenna is presented in this work. This multiple band is achieved by the use of two identical Cross slots on the rectangular radiating patch. FR4 dielectric with relative permittivity (εr) of 4.4 was used as the substrate with a height (h) of 1.6mm. The total antenna dimension is 32.2mm x 47.6mm. The simulation was done using Ansys® simulator. The proposed antenna resonates at 5.5GHz, 7GHz, 8.4GHz, 12GHz and has a wideband of (14.8 - 19.75) GHz with bandwidth 152.8MHz, 198.1MHz, 328.2MHz, 130.1MHz and 4.95GHz respectively. The proposed antenna finds application in Satellite Communication, Terrestrial communication, Military application, and Radar communication.

Keywords — **Antenna, Multiband, Slot, Microstrip, HFSS.**

I. INTRODUCTION

Antenna basically serves as transceiver i.e. it transmits electromagnetic waves at the transmitter side and receive EM waves at the receiver side. It is a critical component of wireless communication ranges from first generation (1G) to the recently deployed 5th generation 5G. Though, many types of antenna exist but patch antenna has found its way into many applications due to its unique characteristics which are: cost effectiveness, reduction in weight, ease of manufacturing and integration among other stringent demand on the antenna designers to develop a compact antenna [1].

Frequency band 8GHz to 12GHz is said to be X band and is primarily used in radar applications. It has been applied in identification and discrimination of target due to the shortness of X-band wavelength which allowed higher resolution imaging. This band is also assigned for space communication by International Telecommunication Union (ITU). It is worthy of note that the above-mentioned application of X-band required light weight and compact antenna which are some of the characteristics of Patch antenna.

Patch antenna is made up of ground plane, dielectric substrate and radiating plane (patch) all normally edged on a single component called Printed-Circuit-Board as presented in fig. 1. Multiband antenna is of a critical need nowadays, due to the wide range of users' application and more importantly the wireless communication convergency that presently characterized users need. Slot has been used extensively in literature for Bandwidth enhancement, Antenna efficiency improvement, gain enhancement, and to achieve multiband [2].

Some of the slot used in the literature are: rectangular (thin, longer and wider), H, Bowtie and hourglass shapes [3,4].

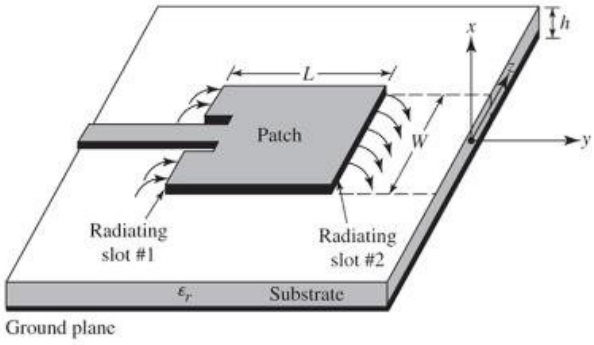

Fig.1: Rectangular Microstrip Antenna [5]

A square-shape microstrip antenna with dimension 40mm x 40mm for X-band application was proposed in [6], it was noted that the proposed antenna only operate within X-band, it does not operate in C-band at all. Also, author in [7] proposed slotted MPA for application in X-band which resonated at 9.0 GHz and 10.14 GHz with - 15.92 dB and -14.84 dB return losses respectively. The author engaged two rectangular slots to achieve multiband. It should be noted that the proposed antenna only resonates in two frequency which are basically in X-Band, it does not resonate in C-band. In this work, a Quad-band Dual-Cross slots based Microstrip Patch antenna is presented.

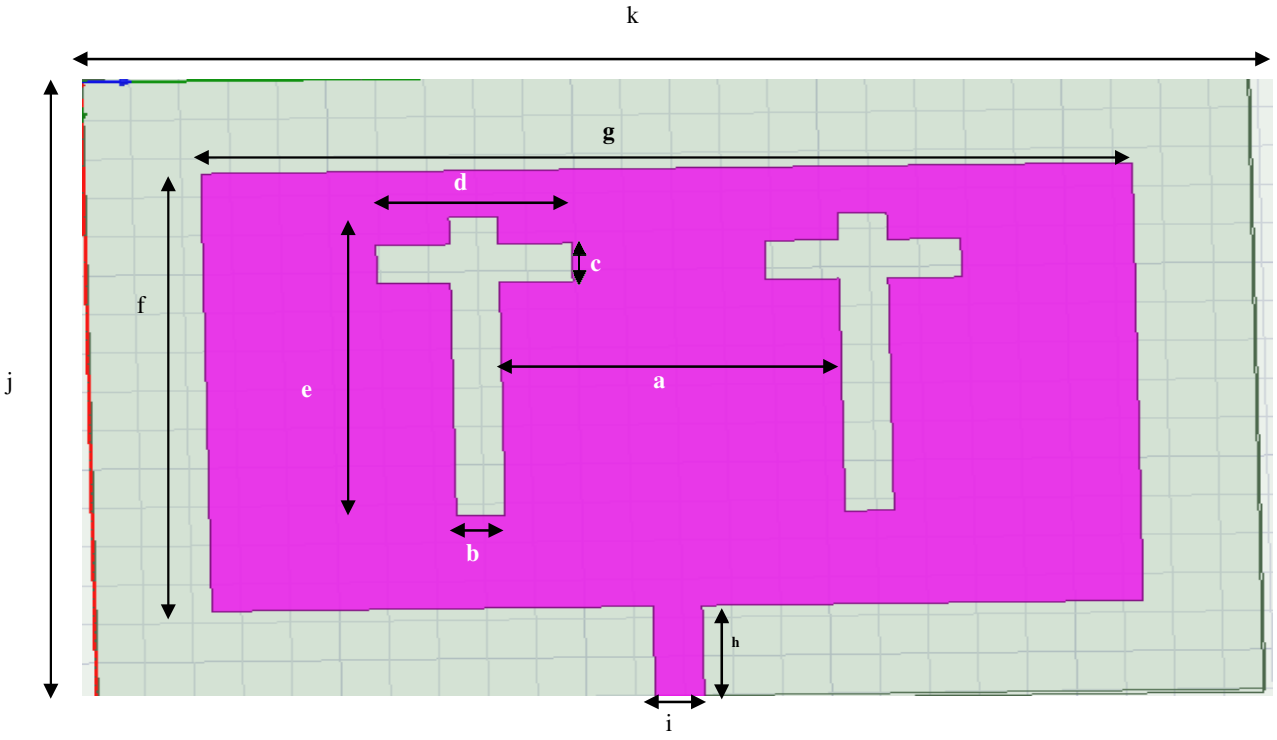

Fig. 2: Proposed Multiband Antenna

II. ANTENNA DESIGN AND CONFIGURATION

A rectangular patch of dimension 22.6mm x 38mm was design with the ground plane dimension of 32.2mm x 47.6mm as shown in figure 2. The A rectangular patch of dimension 22.6mm x 38mm was design with the ground plane dimension of 32.2mm x 47.6mm as shown in figure 2. The substrate material employed in this design is FR4 Epoxy (εr = 4.4) and thickness (h) of 1.6mm. The propose antenna was design and

simulated using High Frequency System Simulator (HFSS) ANSYs®. The design parameters are as shown in table 1.

This design was developed in HFSS 2019 simulator and the performance analysis was done. The results obtained were presented and discussed in next section.

Table I

Design parameters of the proposed Antenna

Parameter	Description	Value (mm)
a	Distance between the slotted Cross	13.86
b	Width of the vertical rectangle that makes the cross	2.00
c	Length of the horizontal rectangle that makes the cross	2.00
d	Width of the horizontal rectangle that makes the cross	8.00

e	Length of the vertical rectangle that makes the cross	15.40
f	Length of the Radiating Patch	22.60
g	Breadth of the Radiating Patch	38.00
h	Microstrip Feed line Length	4.80
i	Microstrip Feed line Width	2.00
j	proposed Antenna Length	32.2
k	proposed Antenna Breadth	47.6

The design equations are as presented in equation 1 to 7.

$$w = \left(\frac{c}{2f_r}\right)\sqrt{\frac{2}{\varepsilon_r+1}} \quad \text{.....(1)}$$

$$\varepsilon_{eff} = \left(\frac{\varepsilon_r+1}{2}\right) + \left(\frac{\varepsilon_r-1}{2}\right)\sqrt{1+\frac{12h}{w}} \quad \text{.....(2)}$$

$$l_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad \text{.....(3)}$$

$$\Delta l = 0.412h\frac{\left(\varepsilon_{eff}+0.3\right)\left(\frac{w}{h}+0.264\right)}{\left(\varepsilon_{eff}-0.258\right)\left(\frac{w}{h}+0.8\right)} \quad \text{.....(4)}$$

$$l = l_{eff} - \Delta l \quad \text{.....(5)}$$

$$l_g = 6h + l \quad \text{.....(6)}$$

$$w_g = 6h + w \quad \text{.....(7)}$$

Where,

w = patch radiating width
εeff =effective permittivity
h =antenna height
c = speed of light
leff = effective length of patch antenna
Δl = length extension due to fringe fields
l = actual radiating patch length
lg = Ground plane length
wg =ground plane width

III. RESULT AND DISCUSSION

The result of the proposed antenna is as presented in fig 3 – 8. Figure 3 shows the resonant frequencies of the proposed antenna. It is worthy of note that, the proposed antenna resonates at 5.5GHz, 7GHz, 8.4GHz, 12GHz and has a wideband of (14.8 - 19.75) GHz with bandwidth 152.8MHz, 198.1MHz, 328.2MHz, 130.1MHz and 4.95GHz respectively. This implies that, the proposed antenna can operate in C-Band, X-Band and Ku-band and K-band. Therefore, the propose antenna finds application in several field such as Direct Broadcast Satellite, Wireless Local Area Networks, Military and so on.

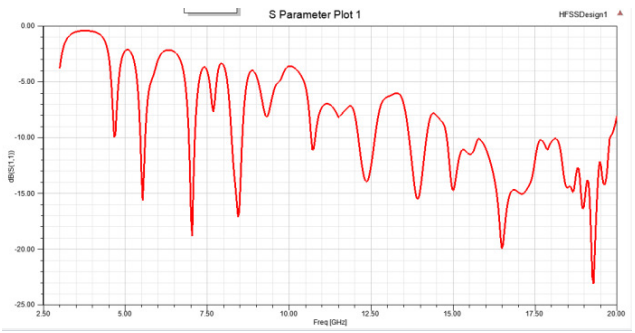

Fig. 3: S- Parameter Plot

Figure 4 shows the Voltage standing wave ratio (VSWR) of the proposed antenna. It was noted that the VSWR at the resonant frequencies is less than approximately 1 which is the acceptable value of VSWR.

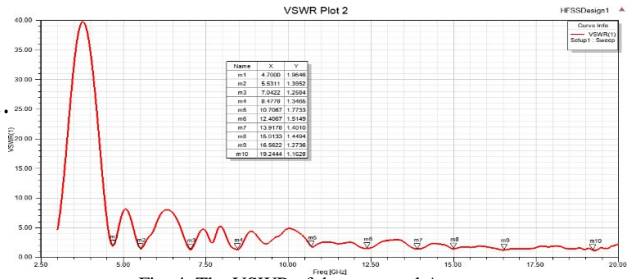

Fig. 4: The VSWR of the proposed Antenna

Figure 5 shows the Overall or total gain of the proposed antenna. It was noted that the proposed has a very good gain in terms of radiation pattern.

Fig. 6 shows the total directivity of the proposed antenna. It is worthy of note that, the proposed antenna has the maximum directivity of 5.06dB. Figure 7 presents the current density which shows

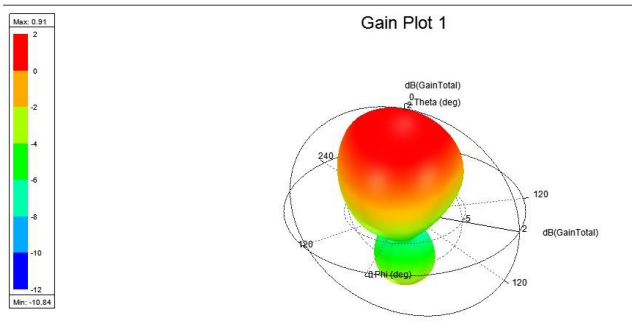

Fig. 5: Proposed Antenna Gain in dB

how the proposed antenna produces beams. and figure 8 presents distribution of field in the proposed antenna.

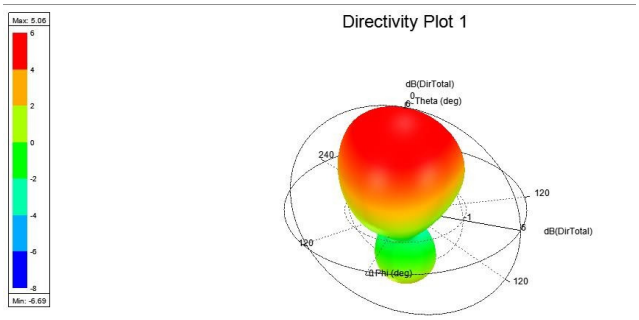

Fig. 6: Total directivity of the proposed antenna

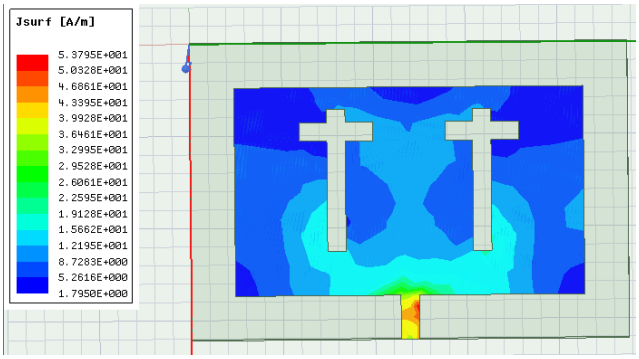

Fig. 7: Current distribution in the proposed antenna

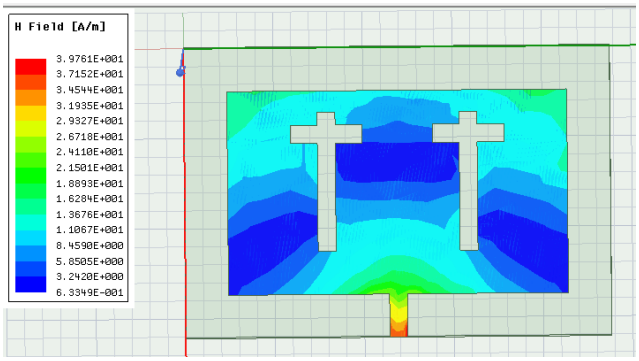

Fig. 8: Field distribution in the proposed antenna

IV. CONCLUSIONS

A dual Cross slotted rectangular patch has been presented in this paper. It has been noted that the proposed Antenna is suitable for C, X, Ku and K bands as it resonates at 5.5GHz, 7GHz, 8.4GHz, 12GHz and has a wideband of (14.8 - 19.75) GHz. The Antenna performance metrics such as S-parameter, 3-D radiation pattern, Voltage standing wave ratio and current density distribution were presented and discussed. Therefore, this antenna is suitable for application such as military, satellite, Radar and so on. In future work, the propose antenna can be implemented and a performance comparison can be carried out, more so, the slot can be modified to achieve wider bandwidth.

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