Design of micro-strip patch antenna for C – band applications

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Abstract: This paper presents the design of a horizontal slot micro-strip Patch antenna with a dual slot inset feed mechanism. The antenna is resonating at 4.28 GHz, with reflection coefficient of -16.32 dB, and a Bandwidth of 1 GHz. Rogers RT580 dielectric is used as substrate having relative permittivity of 2.2 and tan δ value of 0.0009. The gain of the antenna is 6.46 dBi and the cross-polarization levels are reduced to -16.4 dB. The micro-strip antenna can be used for C Band applications such as satellite communication between ground station and satellite.

KEYWORDS- Micro-strip patch antenna, Slot, Dual slot inset feed, Wireless communication.

I. Introduction

The foundation of a communication system is the antenna, which has undergone substantial innovation as technology has developed. In addition to sending and receiving signals, an antenna is a smart device that can also act as a transducer. In general, various types of antennas are used for communication depending on applications. Nonetheless, a micro-strip patch antenna in rectangular shape was utilized in research. With the aid of CST Software, micro-strip patch antenna was designed to analyse several factors, including efficiency, bandwidth, directivity, gain, and return loss. There are four different feeding methods: coaxial feed and micro-strip feed are contacting, while coupled and proximity feed are not in contact. When in touch, the emitting patch receives RF power directly. Moreover, power is transferred to both micro-strip lines and radiating patch to obtain electromagnetic field coupling without contact. Anywhere inside the patch, the feed of micro-strip patch antenna can be positioned to fit the input impedance.

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There are various reference antenna designs are taken into consideration to design an effective antenna with improved results. The authors etched a semi-circular slot in the primary radiator and added a second resonator nearby that emits electromagnetic energy to generate the dual-band response. [1]. To improve the impedance match and broaden the bandwidth, the scientists adopted a circular-E patch geometry and an electrically thick dielectric. [2]. The paper proposes a new approach to antenna design using the Theory of Characteristic Modes and uses this approach to analyse different patch slot designs. The U-slot patch design is identified as having the highest radiating structure, which makes it a promising candidate for achieving the highest impedance bandwidth [3]. The paper suggests that using slotted micro-strip patch antennas in combination with other methods can extend the impedance bandwidth beyond what would be possible with either method alone [4]. The unique characteristic of the micro-strip patch antenna is that the impedance matching feature is included right into the antenna design, and we create a 1 mm gap between the patch and the inset feed [5].

II. Antenna Design

Due to their low profile, simplicity in production, and design flexibility, micro-strip patch antenna is frequently employed in multiple communication systems which are wireless. The following steps are involved in antenna design, Choosing the operating frequency: The antenna's operating frequency is chosen depending on the requirements of the application. The substrate material must to be exceptionally thermally stable, have a low dielectric constant, and have a small loss tangent. Substratum materials like FR4, Rogers, and Duroid are frequently employed. Calculating the patch dimensions: The required resonant frequency and impedance matching are used to establish the patch dimensions, which include length, width, and feed placement. Deciding on the feeding mechanism: The intended bandwidth and radiation pattern are taken into consideration when choosing the feeding mechanism, which includes the type of feed (such as coaxial cable) and feed location on the patch. Designing ground plane: The ground plane is designed to provide a low impedance path for the return current and to reduce surface wave radiation.

The structure of the suggested dual point-fed micro-strip patch antenna which has a slot on antenna patch is shown in Fig 1. This patch antenna is designed for C-band applications and operates at 4.33 GHz frequency.

The Rogers RT5880 dielectric substrate, with a thickness 0.707mm and having permittivity(εr) of 2.2, is used for the micro-strip antenna's design. Designing ground plane, substrate, patch are all parts of aerial design.

Length of antenna is chosen as half the wavelength i.e, $L = \lambda/2$

Width of substrate

$$W = (c/2f) * \mathrm{sqrt}(2/(\varepsilon r+1)) \quad [10]$$

Effective dielectric constant for substrate

$$\varepsilon eff = (\varepsilon r + 1)/2 + (\varepsilon r - 1)/2 * (1/\mathrm{sqrt}\,(1 + 12h/W)) \quad [10]$$

Rogers RT5880 was used to design the substrate, which has a relative permittivity of 2.2. The patch is a thin copper metallic layer (annealed). Copper makes comprises the ground plane, which is constructed on the substrate's back.

The values of substrate length, thickness, width, length, and width of patch, rectangular shape slot width, slot length, feed line length, and width can be observed in table 1.

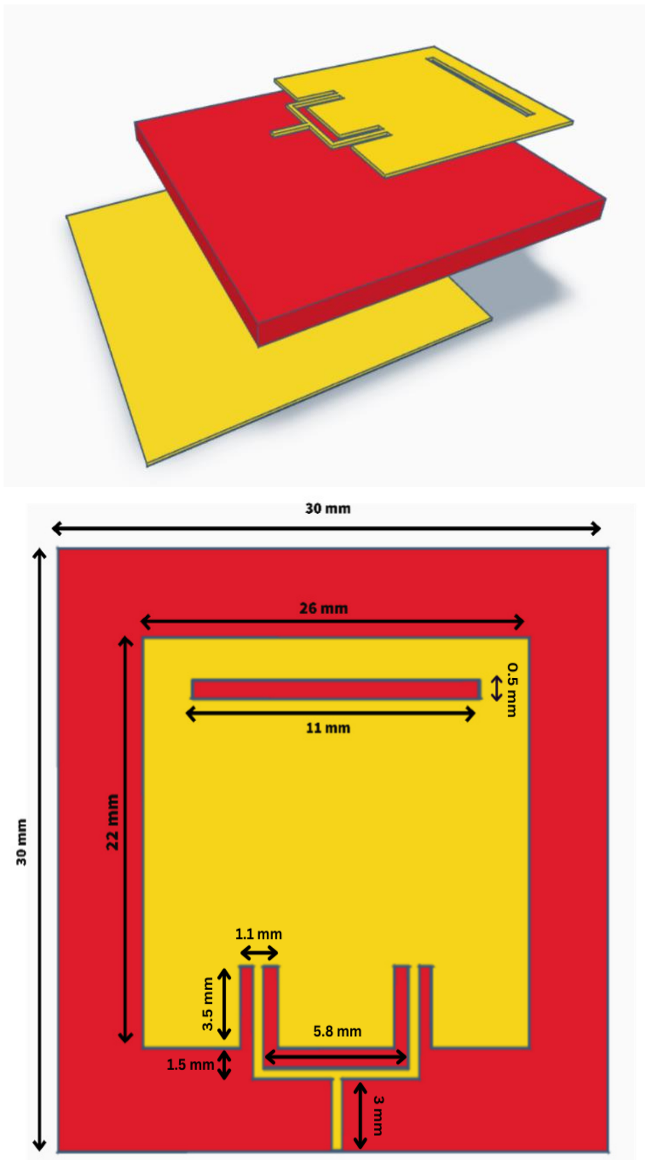

Fig 1: Schematic view of Antenna

Table 1: Dimensions

Parameter	Dimension(mm)
lp	26
wp	22
tp	0.017
fl	7.5
sl	11
fw	6
sw	0.5
ft	0.017

Where,

- lp : Patch length
- wp : Patch width
- tp : Patch Thickness
- fl : Length of feed line
- sl : Slot length
- fw : Feed line width
- sw : Slot width
- ft : Feed line thickness

III. Simulation Results

The end results of antenna such as directivity, gain, return loss and 0 dB bandwidth are analysed respectively using CST software.

The fig 2 shows the parameter sweep analysis. It shows the respective return loss for different values of slot length (sl). We can observe that the lowest return loss (s11) can be seen at 4.28 GHz when the length of slot is set to 11 cm. Hence the antenna is designed by taking that slot length into consideration.

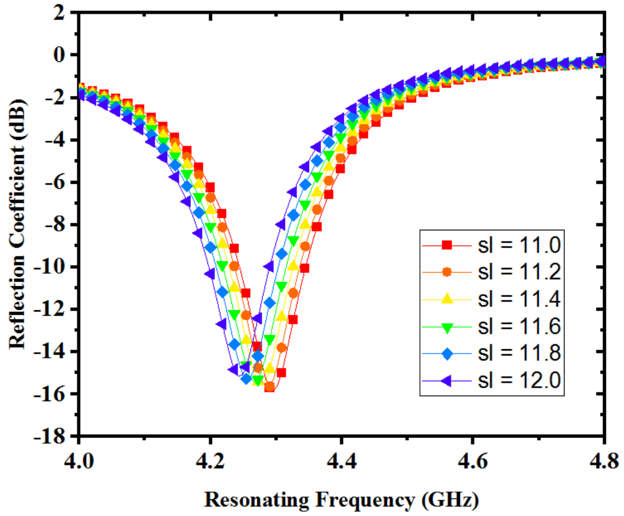

Fig 2: Parameter Sweep Analysis

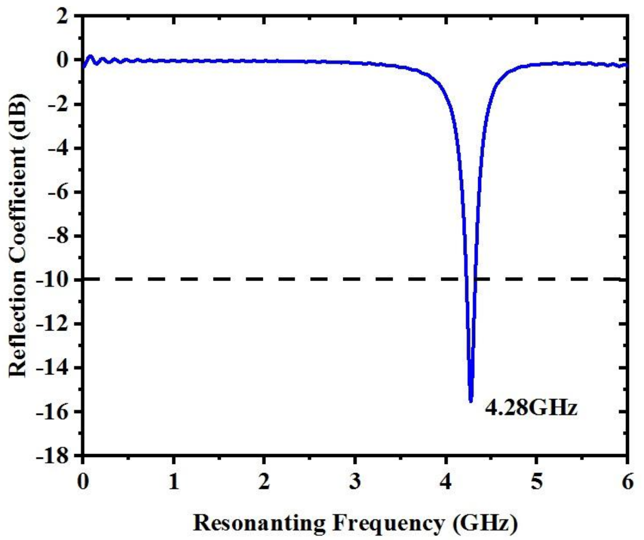

Fig 3: Simulated return loss of antenna

Fig 4 shows both Co-polarisation (red) and Cross-polarisation (blue). We can observe that it has very less cross-polarisation levels (-16.4) and high gain (6.46 dBi). The designed antenna is broadside as it is radiating perpendicular to plan of antenna. From the fig 2, we can find the 0 dB bandwidth (1 GHz). Fig 5 and Fig 6 show the gain vs frequency and radiation pattern of antenna. We can observe the gain (6.46) is maximum at 4.28 GHz frequency.

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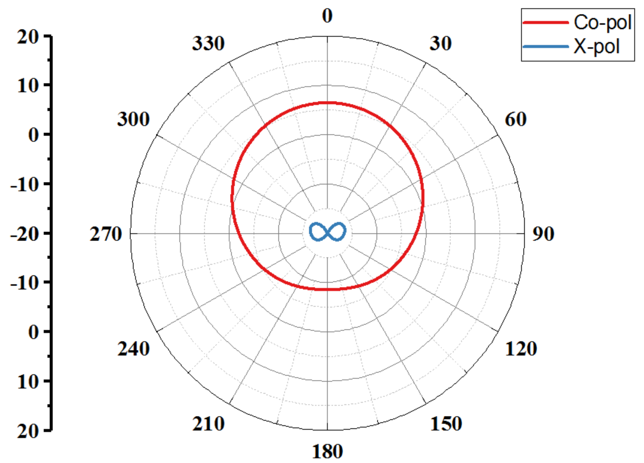

Fig 4: Polar plot at 4.28 GHz

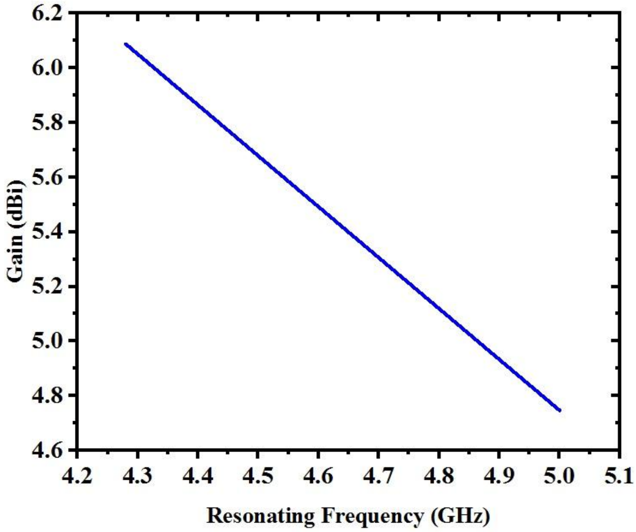

Fig 5: Gain vs Frequency

This table shows the results obtained from various reference papers and our current design. It is evident that our design has relatively higher bandwidth, gain, and lesser cross-polarisation levels. “CP” refers as Cross-polarisation levels.

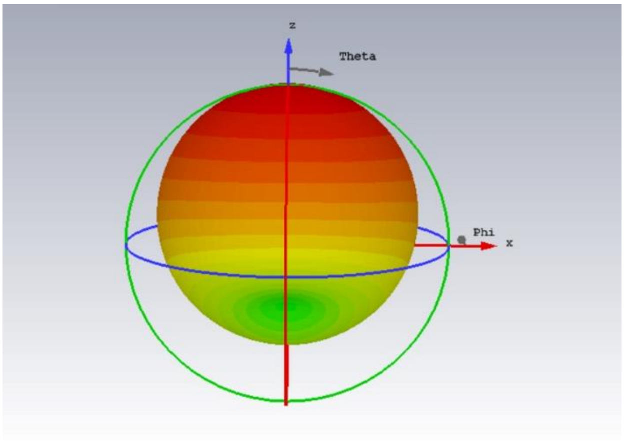

Fig 6: 3D Radiation Pattern

Table 2:

Ref. No.	Frequency (GHz)	Design Complexity	Gain (dBi)	CP level	BW (GHz)
4	2.8	Medium	1.25	-	0.24
5	2.45	Easy	7.67	-6.86	0.5
6	3.5	complex	4.45	-	1.13
7	2.25	complex	10	-	0.59
8	2.16	Medium	4.01	-	0.53
	4.28	Medium	6.46	-16.4	1

IV. Conclusion

Hence by using a dual feed mechanism an antenna that is operating at 4.28 GHz frequency is successfully designed. It has been found that the patch's horizontal slot and dual point feed increased bandwidth and improve return loss by 16.32 dB. The width of the slot was increased to reach the maximum bandwidth; hence, the horizontal slot is a bandwidth-effective characteristic.

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