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# Feed Analysis of a Hexagonal Microstrip Patch Antenna

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**Abstract**

The feeding methods of coaxial, microstrip line, and proximity-coupled feeds significantly influence the performance of microstrip patch antennas. While proximity-coupled microstrip patch antennas have been explored for various applications, there remains a lack of understanding regarding the optimal positioning and length of the proximity-coupled feed. This study investigates the impact of feed line length on the performance of a proximity-coupled microstrip patch antenna. The findings reveal that the resonance frequency is directly affected by the length of the feed line; specifically, as the feed line length increases, the antenna resonates at a higher frequency.

**Keywords:** Microstrip Patch Antenna, Feeding Techniques, Proximity Coupled Feed, Feed Analysis.

## 1. Introduction

The microstrip patch antenna is a widely utilized planar antenna, particularly favored in contemporary wireless communication systems due to its compact size, lightweight design, and straightforward fabrication process. It consists of a metallic patch, which may be rectangular or circular in shape, printed on a dielectric substrate and fed by a microstrip transmission line. The inherent simplicity of this design not only makes it cost-effective to produce but also facilitates easy integration into other components for mass production. Its low profile and lightweight structure render it ideal for portable devices.

Microstrip patch antennas can be engineered to operate over a broad range of frequencies, from kHz to GHz, allowing for customization to achieve high gain and directivity. These antennas are commonly employed in mobile phones, GPS devices, Wi-Fi routers, satellite communication, and radar systems. Despite their numerous advantages, microstrip


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patch antennas exhibit relatively narrow bandwidth limitations and are sensitive to environmental factors such as temperature and humidity. Additionally, the properties of the substrate material can significantly influence the radiation pattern. Various excitation methods, as discussed by Chen et al. [1], Balonis [2], and Amur et al.[3], include coaxial feed, microstrip line feed, aperture-coupled feed, and proximity-coupled feed. The following points will explore the principles, characteristics, and applications associated with enhancing antenna performance.

### 1.1 Coaxial Feed

The coaxial feed is one of the most commonly utilized feeding mechanisms in microstrip patch antennas. It consists of a coaxial cable connected to the antenna patch via a hole in the substrate. The inner conductor of the coaxial cable is linked to the patch, while the outer conductor is grounded. The book by Garg et al. [7] offers comprehensive design procedures for coaxial-fed microstrip patch antennas (MPAs) and their applications. The main advantages are ease of fabrication, effective impedance matching, and wide bandwidth, along with challenges such as complex manufacturing process required for precise impedance matching.

### 1.2 Microstrip Line Feed

The microstrip line feed, as described by Kushwaha et al. [8], is a widely employed technique in which a microstrip line (a metal strip on the surface of a dielectric substrate) is directly connected to the patch. This feeding method is favored for its simplicity and ease of fabrication. The main advantages such as they are simple in design and easy integration with other microwave circuits. Challenges includes arrow bandwidth and the necessity for careful impedance matching.

### 1.3 Aperture Coupled Feed

This technique involves feeding the microstrip patch through an aperture in a ground plane. It decouples the feeding network from the radiating patch, thereby providing better isolation between the feed and the patch and mitigating the effects of spurious radiation, as noted by Jour et al. [9]. Modifications, such as gap formation based on specific applications, are discussed in the work of Anand Kumar et al. [13]. The main advantages include enhanced bandwidth, improved isolation, and reduced spurious radiation. Challenges include the requirement for more complex fabrication.

### 1.4 Proximity Coupled Feed

The proximity-coupled feed, as discussed by Inclan-Sanchez et al. [6] and Amir et al. [10], is a non-contact feeding technique that excites the patch through the coupling effect between two closely spaced substrates: the radiating patch and a microstrip line on the bottom substrate. The Advantages are superior bandwidth in comparison to coaxial and microstrip line feeds, accompanied by efficient impedance matching. Challenges such as greater complexity in fabrication and design.

## 2. Antenna Design

In this paper, we compare various feed methods for a microstrip patch antenna in the Ansys HFSS simulation environment. These dimensions can be selected to resonate at the required frequency of 2.4 GHz.

A Circular patch antenna is designed according to Balonis [2] transmission line solution for a circular patch antenna.

$$a_h = \frac{F}{\sqrt{\left\{1+\frac{2h}{\pi\varepsilon_r F}[\ln\left(\frac{\pi F}{2h}\right)+1.7726]\right\}}} \tag{1}$$

Where,

$$F = \frac{8.791\ X\ 10^9}{f_0\sqrt{\varepsilon_r}} \tag{2}$$

The side length of the hexagonal patch antenna is designed using the equations from Kushboo et al. [11] and Kanika et al. [12] as follows:

$$\pi\ a_h^2 = l^2\,\frac{3\sqrt{3}}{2} \tag{3}$$

The height of the patch is defined as

$$L = \sqrt{3}\ a_h \tag{4}$$

The patch antenna design will have the following dimensions: 17.66 x 18.46 mm2, substrate thickness (h) of 1.28 mm, and a silicon dioxide substrate dielectric constant (εr) of 3.9. The feed methods being considered will be, but are not necessarily limited to, the inset feed, coaxial probe feed, and proximity coupling. Each feed method has specific advantages and disadvantages in terms of impedance matching, bandwidth, fabrication complexity, and spurious radiation, using in-depth simulations. We are comparing and contrasting the performance of the hexagonal antenna, as shown in Figure 1. in terms of parameters like return loss, VSWR, radiation pattern, gain, and bandwidth. This will provide insight into the choice of feed network to use in order to attain the desired antenna performance parameters for an application at hand.

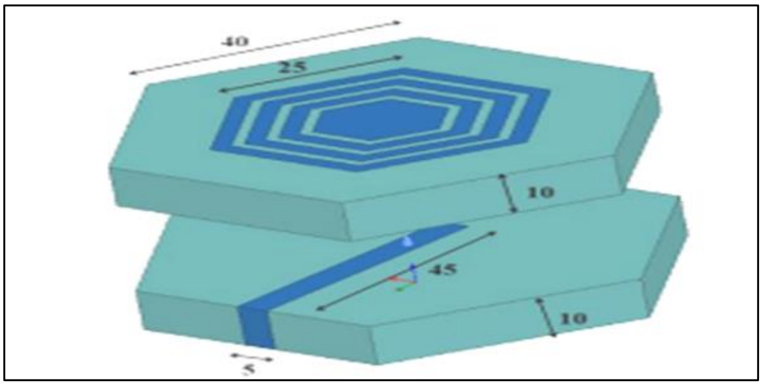
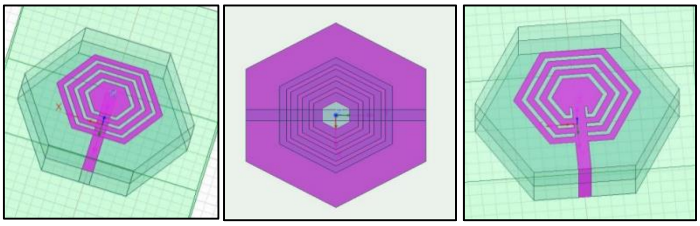



**Figure 1.** Hexagonal Patch Antenna

## 3. Feed Analysis

The antenna designs proposed in Figure 2 have a range of performance attributes to suit various application requirements. The hexagonal patch antenna is designed in various configurations, including simple microstrip line-fed antennas, proximity-coupled fed antennas, and aperture-coupled feeding techniques. These designs prioritize signal integrity and minimum backward radiation.



(a) (b) (c)

**Figure 2.** Schematic of Feed Analysed (a) Proximity Coupled (b) Aperture Coupled (c) Inset Feed

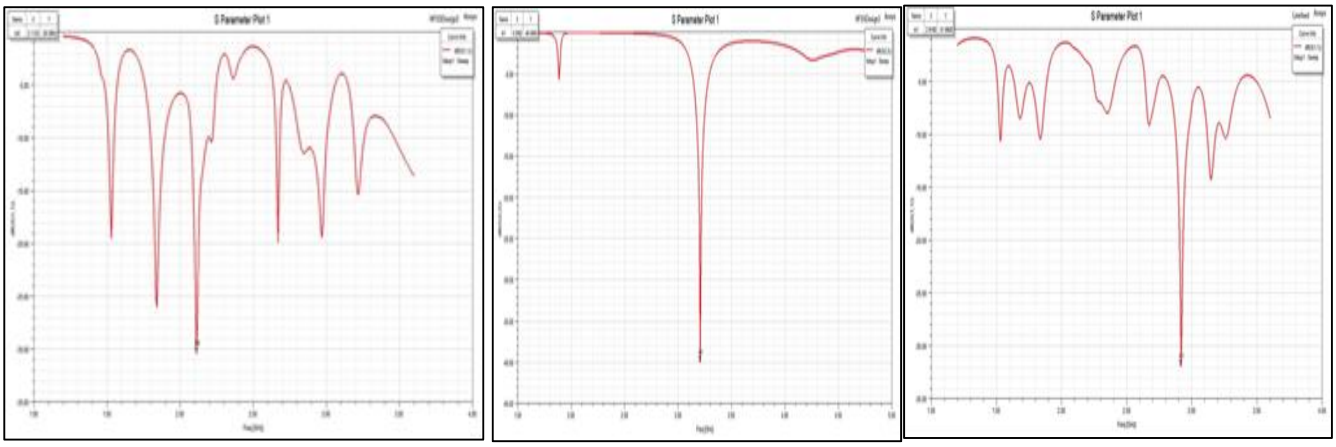
## 4. Result and Discussion

### 4.1 S - Parameter

The designed antenna in three different configurations is validated with ANSYS HFSS software R2 version. The parameters S11 and VSWR and gain patterns in 3-dimensional and 2 dimensional readings are taken. Return loss is the power loss in the signal that is reflected or returned in a transmission line or optical fiber due to discontinuity. This discontinuity can occur with an inserted device in the line or with the mismatch in the terminating load, this discontinuity can happen. Return loss is given by the equation.

$$RL = -10\log\left(\left|\frac{P_{ref}}{P_{inc}}\right|\right) = -20\log\left(\left|\frac{V_{ref}}{V_{inc}}\right|\right)$$

$$RL = -20\log(|\Gamma|)$$



(a) (b) (c)

**Figure 3.** S11(dB) vs Frequency for Different Feeding Systems (a) Proximity Coupled (b) Aperture Coupled (c) Inset Feed

Return loss pictures are shown in Figure 3 and their corresponding values are listed in Table 1.

The aperture-coupled feed at 3.28 GHz excels through its high return loss, good radiation efficiency, and high front-to-back ratio but at the cost of some gain.

**Table 1.** Return Loss Analysis of Different Feeding

| Type of Feed | Return Loss (dB) | Frequency (GHz) |
|---|---|---|
| Proximity Coupled | 31.9609 | 2.9160 |
| Aperture Coupled | 40.05 | 3.28 |
| Insert Feed | 30.39 | 2.11 |

## 4.2 VSWR Plot

The Voltage Standing Wave Ratio (VSWR) is a critical parameter indicating the impedance matching between the proposed antenna and the connected transmission line. VSWR serves as a benchmark for determining the efficiency of power transfer from the source to the antenna. The proposed antenna achieves a VSWR of 1.0952 at 2.14 GHz which is low. The VSWR Plot provides a visual representation of the antenna's impedance behavior across a range of frequencies, with lower values corresponding to better matching. This suggests that the proposed antenna design is efficient and suitable for its intended application, meaning very little power is reflected back to the source.

The proposed proximity feeding method yields remarkable VSWR results, as shown in Figure 4, and Table 2 indicates excellent impedance matching in the transmission line. In conclusion, the VSWR validates the efficiency of power delivery to the proposed antenna.

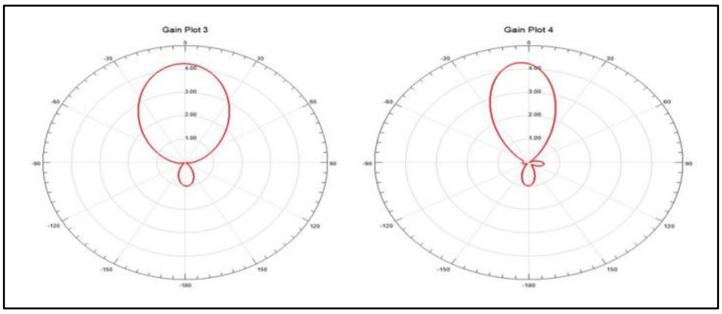

**Figure 4.** VSWR Plot for Different Feed (a) Proximity Coupled (b) Aperture Coupled (c) Inset Feed

**Table 2.** Comparison Table of VSWR for Different Feeds

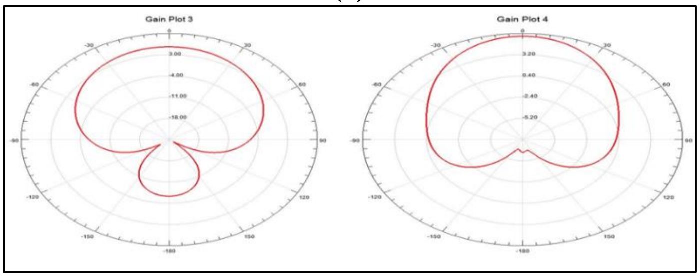
| Type of feed | VSWR (dB) | Frequency (G Hz) |
|---|---|---|
| Proximity Coupled | 1.0623 | 2.9160 |
| Aperture Coupled | 1.0201 | 3.20 |
| Insert Feed | 1.0618 | 2.11 |

## 4.3 Radiation Pattern

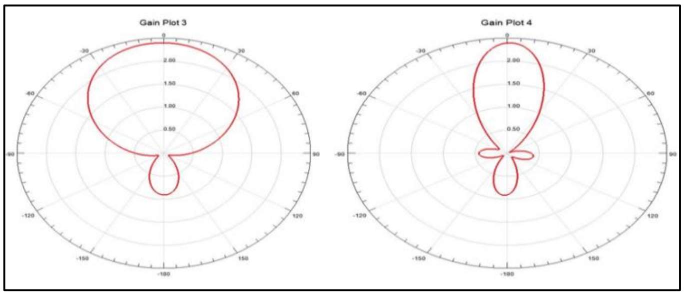
The radiation pattern reveals the spatial distribution of radiated energy from the proposed antenna. Polar plots represent the radiation pattern in both E-field (Phi=0 degree) and H-field (Phi=90 degree) planes. The radiation pattern includes a distinct main lobe, indicating the direction of maximum signal transmission. The radiation pattern is an essential tool for optimizing antenna placement to achieve the desired coverage area. It is revealed that the radiation patterns of antennas vary in different structures. The reference in this depiction is usually the best emission angle. In the proposed antenna, the best emission angle is between 2 and 4. Directivity can be understood through the radiation pattern. In short, the proposed antenna has a good pattern in terms of radiation. It can be used in various applications of communication, as shown in Figure 5.




(a)




(b)

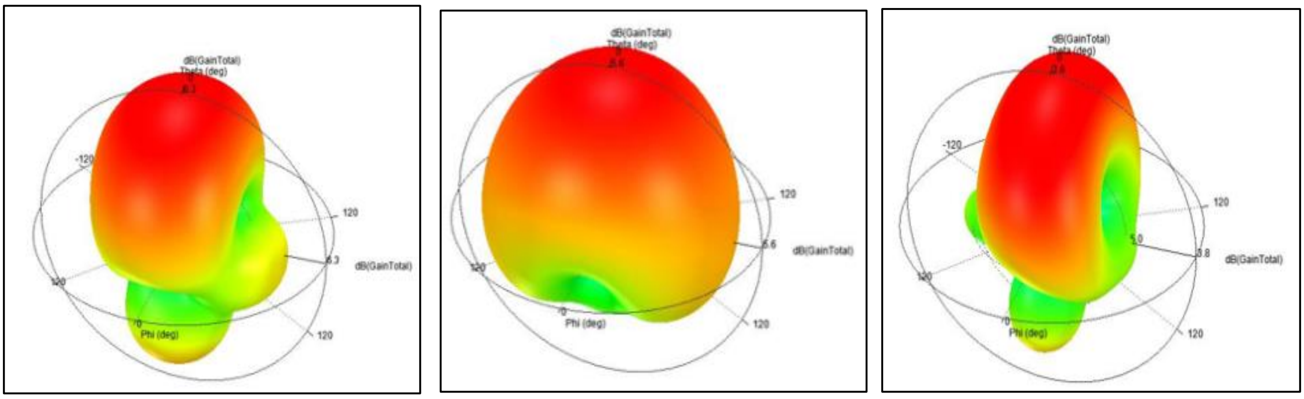



(c)

**Figure 5.** Radiation Pattern for Different Feed (a) Proximity Coupled (b) Aperture Coupled (c) Inset Feed.

### 4.4 Gain Plot

The gain plot for the proposed antenna illustrates its directive capabilities, showcasing the signal strength in different directions relative to an isotropic radiator. The proposed antenna exhibits a peak gain of 2.2767 dB. A review of the gain plot reveals the distribution of radiated power, with the highest intensity concentrated in the primary direction. The gain plot has maximum point at 1.6 and minimum at -5.6. The antenna's overall gain characteristics are critical for effective wireless communication, influencing the signal strength and reliability in the intended coverage area. The front-to-back ratio also contributes to the performance of the antenna. Examining the gain plot in conjunction with the radiation pattern provides a comprehensive understanding of how the antenna focuses its energy and the resulting signal coverage shown in Figure 6.




(a) (b) (c)

**Figure 6.** Gain Plot for Different Feed a) Proximity Coupled (b) Aperture Coupled (c) Inset Feed

Collectively the parameters for all feeding techniques are tabulated in the Table 3 below:

**Table 3.** Various Parameters for Different Feeding Techniques ($\phi=0^\circ$)

| S.No | Feeding type | Return loss ($S_{11}$) | Frequency (GHz) | VSWR | Peak Directivity (dB) | Peak Gain (dB) | Radiated power (mW) | Front to back ratio (dB) | Radiation Efficiency (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Line Feed | 31.95 | 2.91 | 1.0618 | 2.854 | 2.40 | 619.15 | 2.6332 | 84.13 |
| 2 | Aperture coupled | 40.07 | 3.28 | 1.02 | 3.767 | 3.66 | 728.85 | 15.749 | 97.24 |
| 3 | Proximity feed | 30.09 | 2.11 | 1.06 | 4.97 | 4.28 | 419.86 | 4.39 | 86.1 |

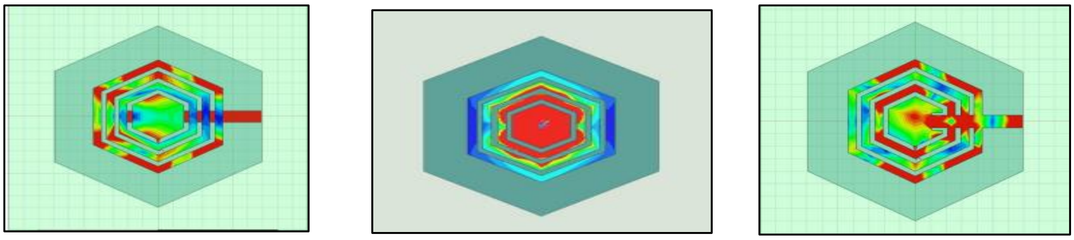
But in three-dimensional view, Max gain achieved at random angles are tabulated in Table 4.

**Table 4.** Comparison Table of Gain for Different Feeds

| Type of feed | Max gain (dB) |
|---|---|
| Proximity Coupled | 6.3 |
| Aperture Coupled | 5.6 |
| Insert feed | 3.8 |

## 4.5 Field Distribution

The proposed line feed is at 2.91 GHz with fairly average performance parameters all around. The "proposed" proximity feed is in the middle ground, providing a fair balance of parameters at a low frequency. The coaxial feed has the highest frequency (7.12 GHz) but shows a low directivity (0.9956) and gain (0.94526). Thus, the selection of feed significantly affects the operating frequency of the antenna and overall performance parameters, as shown in Figure 7.



(a) (b) (c)

**Figure 7.** Field Patterns of (a) Proximity Coupled (b) Aperture Coupled (c) Inset Feed

Some of the antennas and its feeding techniques and its results are given in Table 5.

**Table 5.** Comparison with Previous Works

| References | Type of feeding | Resonant frequency | Return loss ($S_{11}$) | VSWR | Gain (dB) |
|---|---|---|---|---|---|
| Bakariya et al.[4] | Proximity coupled feed | LTE2300 (2300–2400 MHz), Bluetooth (2400–2485 MHz), WiMAX (3.3–3.7 GHz), WLAN (5.15–5.35 GHz, 5.725–5.825 GHz) | -32 | - | - |
| Nasimuddin et | Proximity | 2.4 GHz | -32.5 | - | 6 |

| | | | | | |
|---|---|---|---|---|---|
| al.[5] | coupled feed | | | | |
| Kushboo et al [11] | Microstrip Line feeding | 3.2 GHz | -30 | 1 | 5.85 dB at 6.85 GHz |
| | | 9 GHz | -26 | | |
| Joshi et al.[12] | Proximity coupled feed | 2.76, | -35 | - | - |
| | | 5.66 | -34 | | |
| | | 11.52 | -28 | | |
| Amanda Kumar et al.[13] | Aperture coupled feed | 1.495 | 19.43 | < 2 | 10.23 |
| Proposed | Inset feed | 30.39 | 2.11 | 1.0618 | 3.8 |
| | Aperture coupled feed | 40.05 | 3.28 | 1.0201 | 5.6 |
| | Proximity coupled feed | 31.9609 | 2.91 | 1.0623 | 6.3 |

Applications: This kind of hexagonal antenna can be designed and applied for various wireless communication systems, satellite communication, and RFID tag applications.

## 5. Conclusion

In summary, the performance analysis of various antenna feed types reveals significant differences that can greatly impact their suitability for specific applications. Aperture Coupled Feeding is characterized by superior return loss, a high front-to-back ratio, and commendable radiation efficiency, making it the optimal choice for applications that demand precision and minimal back radiation. Conversely, the proposed antenna utilizing Proximity Feeding exhibits notable advantages, including low VSWR impedance matching and satisfactory gain and radiated power. This makes it particularly advantageous in scenarios where Coaxial Feeding achieves maximum radiated power, albeit with diminished overall efficiency and directivity. Ultimately, selecting the most appropriate feed type necessitates a thorough evaluation of application requirements, carefully considering the trade-offs among gain, power output, and efficiency to ensure optimal operational performance.

## References

[1] Zhi Ning Chen, Duixian Liu, Hisamatsu Nakano, Xianming Qing, Thomas Zwick., "Handbook of Antenna Technologies". Singapore: Springer: Imprint: Springer, 2016.

[2] Balanis, Constantine A. Antenna theory: analysis and design. John wiley & sons, 2016.

[3] Khashimov, Amur B., and Rinat R. Salikhov. Practical Models of Antenna Systems. Springer, 2022.

[4] Bakariya, Pritam Singh, Santanu Dwari, Manas Sarkar, and Mrinal Kanti Mandal. "Proximity-coupled multiband microstrip antenna for wireless applications." IEEE Antennas and Wireless Propagation Letters 14 (2014): 646-649.

[5] Jie, Ang Ming, Muhammad Faeyz Karim, Luo Bin, Francois Chin, and Michael Ong. "A proximity-coupled circularly polarized slotted-circular patch antenna for RF energy harvesting applications." In 2016 IEEE Region 10 Conference (TENCON), pp. IEEE, (2016): 2027-2030.

[6] Inclán-Sánchez, Luis, José-Luis Vázquez-Roy, and Eva Rajo-Iglesias. "Proximity coupled microstrip patch antenna with reduced harmonic radiation." IEEE Transactions on antennas and propagation 57, no. 1 (2009): 27-32.

[7] Garg, Ramesh. Microstrip antenna design handbook. Artech house, 2001.

[8] Kushwaha, Ram Singh, D. K. Srivastava, J. P. Saini, and Seema Dhupkariya. "Design of a Microstrip Line Fed Slotted Patch Antenna for Wideband Communications." In 2012 Third International Conference on Computer and Communication Technology, pp. IEEE, (2012): 178-182.

[9] Pirhadi, Abbas, Hadi Bahrami, and Javad Nasri. "Wideband high directive aperture coupled microstrip antenna design by using a FSS superstrate layer." IEEE transactions on antennas and propagation 60, no. 4 (2012): 2101-2106.

[10] Jafargholi, Amir, Manouchehr Kamyab, Mehdi Veysi, and Mohammad Nikfal Azar. "Microstrip gap proximity fed-patch antennas, analysis, and design." AEU-International Journal of Electronics and Communications 66, no. 2 (2012): 115-121.

[11] Singh, Khushboo, Sonal Patil, Ashwini Naik, and Sujata Kadam. "Hexagonal microstrip patch antenna design for UWB application." In ITM Web of Conferences, vol. 44, p. 02004. EDP Sciences, 2022.

[12] Joshi, Kanika, Dinesh Yadav, and Dheeraj Bhardwaj. "Design of coplanar proximity coupled feed hexagonal shaped circular polarized microstrip patch antenna." Trends in Sciences 19, no. 10 (2022): 4170-4170.

[13] Anandkumar, D., and R. G. Sangeetha. "Design and analysis of aperture coupled micro strip patch antenna for radar applications." International Journal of Intelligent Networks 1 (2020): 141-147.