Chapter 11
Microstrip Antenna for Internet of Things (IOT) Applications

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Abstract The Internet of Things (IoT) is a technical tool for experts. It does this by using existing network infrastructures to turn physical resources into new things. The primary objective is to provide intelligent and effective services without user disruption. The Internet of Things paradigm aims to build a complex information system by fusing, among other technologies, big data, clouds, machine learning, artificial intelligence, effective data interchange through networking and sensor data collection. The diverse applications and uses of the Internet of Things (IoT) in various industries explain the trend toward IoT acceptability in the modern world. However, as with all IoT requirements, developing an efficient antenna on all relevant IoT frequency bands is necessary. A compact microstrip antenna based on monopole feed and the coplanar ground plane has been designed, optimized and fabricated, operated in dual band of IoT applications. The operating bands of the proposed antenna are 2.5 GHz and 5.2 GHz having a bandwidth of more than 500 MHz and providing the gain of 2.03 dB and 3.37 dB, respectively. Placement of the superstrate into the antenna makes the dual-band operation as well as improves the bandwidth. The proposed antenna is designed on FR4 epoxy, having a dielectric constant of 4.4

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and loss tangent (tan δ) 0.02. The overall size of the antenna is 30 mm x 30 mm × 1.6 mm, which is smaller than the previously published work.

Application of Internet of Thing (IoT)

The primary goal of this section is to explore IoT applications discussed in current studies. The main application fields are healthcare, the environment, intelligent towns, trade, industry and infrastructure (Souri et al. 2017, 2018). The applications and utilization of IoT in the various fields lead and explain the trend towards IoT acceptability for the innovative world (Chettri and Bera 2019). Furthermore, learning the IoT requirements enhances IoT technology's understanding and development and, therefore, develops new systems for new cases (Tun et al. 2021; Kim and Kim 2018).

Environment Applications

Several evaluations of IoT's use in environmental applications have been conducted. To initiate, (Li et al. 2015) designed an internet surveillance system for hen houses that included a WSN and monitored environmental factors such as temperature, humidity, ammonia (NH3) and carbon dioxide. However, the majority of applications in the studies mentioned above, the authors, were tied to the creation of systems, with information transmission reliability not being considered. The authors of this work proposed a transport protocol that focuses on recovering from data loss in an effort to address the issue. In order to predict the data rate and improve the system's dependability, duplicated data was automatically filtered out, and missing data was filled in.

Additionally, the internet remote control system was developed so that administrators could view the data gathered via computers and mobile devices, enabling them to better manage the henhouse environment. Furthermore, future extensions of this research include strengthening the system's data-collecting precision and dependability and lowering tiny update and repairing costs. Energy use, on the other hand, was not assessed in this investigation.

Smart City Applications

Expand the Internet of Things (IoT) for creative city applications. (Montori et al. 2017) presented a SenSquare structural architecture that would provide a mobile sensing population to witness customer tests of existing smart city data flows. To assess the option for the proposed strategy, the present facility structure used a data mining categorization technique. However, the quality of the data and data privacy of the user was not measured. For a specific experimental prototype of numerical forensics, (Zia et al. 2017) developed a software design. In their study, they examine the methodology of forensics to review conventional regulations and production methods. In an Internet of Things numerical forensics solicitation, it assists with data collection, investigation, evaluation, and storage. The suggested methodology was evaluated using three IoT application scenarios: flexible devices, modern houses and shrewd cities. It introduced a paradigm applicable to assessing forensic data collection in an adaptable IoT setting. The presented approach does not account for security measures, although it appears prudent to make the process safer and more efficient.

Commercial Applications

In recent years, the prevalence of commercial Internet of Things demand has grown. (Alodib 2016) derived a framework method for automating the Quality of service-familiar facility construction and incorporating actual-time control into an experiment. The writer expressed grave concerns on the violation of Service Level Agreements. As a result, the Service Level Agreement was developed to link the Petri net to the Unified Modelling Language Quality of Service model via a user indicator. The discrete event system (DES), which demonstrates that the suggested technique may be utilized to develop a shared facility for the Petri network model, is an essential concept to consider. It developed a review for the cost-effective evaluation of implementation to meet QoS; the scalability in the research was not considered. In another research endeavour, (Han and Crespi 2017) presented the model for semantic maintenance provisioning for intelligent devices. The main aim was to create a Internet service that was compatible with the limits of smart devices, such as their limited resources (Read Only Memory, Random Access Memory and Central Processing Unit), sluggish communication channels and microcontrollers. Utilizing a number of conventional application programming interfaces, this was accomplished (API).

ContikiCooja tested it in a variety of scenarios using samples and web functions (simulator). The conclusions of this study have influenced the development of important service delivery features for IoT applications on the web, such as security, dependability and scalability.

Industrial Applications

The industrial sector is another key use of Internet of Things technology (Park 2019). The application of Internet of Things in this area has necessitated numerous investigations. (Li et al. 2014) created a 3-stage process for enhancing Quality of Service using the top-down judgment-making methodology in Markov. With the help of MATLAB, the authors made a model for the situation and tested the suggested method. During the assessment, various Quality of Service factors were taken into account, such as the latency, one-way delay, ease of access and transmission capacity. The recommended approach to resource planning was assessed to lower the overall latency of the network. Venticinque and Amato have studied a new strategy (Venticinque and Amato 2019) to answer and clarify the issue of Fog service deployment to Internet of Things Fog applications. It will be decided on the ideal component for processing power and IoT applications, like those in the intelligent energy sector. This study is significant because it makes use of numerous computational resources to better programme planning and analyse energy profiles. A CONCISE-based subject-based multidimensional framework for Internet of Things applications is proposed in another paper by Jin et al. (2017). It provides a standard that supervises and gathers data/Information using Time Synchronized Channel Hop-Ping (TSCH) planning. The outcomes include decreased end-to-end latency, enhanced communication dependability and decreased network traffic congestion.

Infrastructural Applications

At the same time, Programmable Object Interface/Internet of Things can be used for a variety of purposes. As a result, this section goes over the research that has been done on IoT infrastructure. For IoT/Fog and SDN, (Diro et al. 2018) developed a combined framework. Important factors like lowering packet delay, eliminating the chances of lost packets, avoiding space conflicts and achieving the maximum output are all aided by this. The importance of flow space allocation in producing both critical and dangerous flows is highlighted in this study. It illustrates how the Fog communication paradigm balances the programmability of SDN processes with conventional packet flows. This structure selects a level of flow space distribution variation based on the Quality of Service requirements. According to the findings, critical flow classes provided more proficient support. The main focus of the research is on improving QoS elements such data rate, delay and likelihood. However, we did not examine cases involving several virtualized devices. A technique for resource management of fog computing with energy efficiency was another option put up by Naranjo et al. (2018). To maintain interacting virtualized assets alive, the suggested structure utilizes middleware and has quick clearance. It has acceptable QoS characteristics, especially in terms of energy consumption, however there are no prior data or proof. A novel resource processing model for IoT intelligent applications was lastly proposed

by Chen et al. (2018). The researchers created a technique for resource-efficient computation offloading using a hybrid approach.

Healthcare Applications

From the perspective of the provider, (Kim and Kim 2018) is a manual for users of Internet of Things healthcare services. The research identifies some key characteristics that substantially impact users, allowing them to authenticate healthcare services. The procedure includes looking at elements like account risks and privacy in order to qualify and validate services.

This research serves as a roadmap for manufacturers looking to improve the dependability and trustworthiness of IoT healthcare services. In (Damis et al. 2018), three epidermal loop antennas were theoretically and experimentally studied for the purpose of detecting biological factors in Internet of Things healthcare applications. The purpose of this research is to support the accuracy of GSM and BLE communications by examining the bit BER and error-vector magnitude (EVM) characteristics in quadruple loop antennas. The results reveal that the reflection factor and radiation forms are trustworthy and steady. Additionally, the data transmission assessment demonstrates that the BER is capable of working in quadrature amplitude modulation and fits what is known about the antenna (QAM).

Elappila et al. 2018) conducted yet another research on healthcare applications, in which an improvement in interference, energy efficiency after blocking, and interface perception of energy efficiency were the main goals of a routing approach for Wireless Sensor Network. Due to excessive network traffic and delays connecting devices, many IoT devices share a single focal point. Because multiple Internet of Things devices use the similar emphasis, the network experiences high traffic and delays in connecting devices. The method that was made uses a function to find the next party node. This function is controlled by three factors: (1) the signal-to-interference-plus-noise ratio, (2) the route's ability to stay up and (3) the node's ability to be blocked. As shown, the data provided using the suggested way increased data rate while lowering energy use and packet loss. Additionally, (Jebadurai and Peter 2018) proposed a brand-new architecture for Internet of Things healthcare applications that allows the processing of retinal pictures obtained by a smartphone fundoscopy. A super-resolution approach based on the Kernel support vector regression procedure was suggested to improve the image quality. The collected findings suggest that the proposed approach outperforms several current super-resolution algorithms in terms of effectiveness. For the study (Malik et al. 2018), the authors investigated the performance of an IoT (NB-IoT) narrowband, which requires effective communication for simple captors and long-term batteries with low performance. The research aims mainly to examine and assess NB-IoT latency and performance in health services.

Additional study by Hamdan (2018) examined the human elements in the healthcare setting that affect information exchange. The project's goal was to collect information from healthcare professionals and disseminate it so that new applications for

the Internet of Things in healthcare might be developed. Additionally, LoRa and My Signals made use of the body temperature, oxygen saturation, electrocardiograms and pulse speed sensors.

Many antennas have been proposed for wireless and satellite applications (Jilani and Alomainy 2018; Patel et al. August 2017; Kachhia et al. 2015; Patel et al. 2016). However, we have proposed the design of a multilayer antenna for IoT applications here, which resonates at 2.5 GHz and 5.2 GHz frequencies. The suggested antenna is built on a FR4 material, which is cost-effective and easy to fabricate. Moreover, the gain and the radiation efficiency of the proposed antenna are suitable for the proposed applications (Smart Antennas 2022; Malik et al. 2021; Rahim and Malik 2020).

Design of Antenna

In Fig. 11.1, the suggested antenna is shown, it is a multilayer structure designed on FR4 substrate with a ε_r of 4.4 and tan δ of 0.02. The antenna's top view, bottom view and perspective view are represented in Fig. 11.1a, b, c, respectively. As shown in Fig. 11.1, it contains a monopole feed with a coplanar ground plane. The dimensions of the monopole have been optimized using CST Microwave Studio software. Initially, we have kept the entire ground plane and vary the width of the monopole from 2 to 6 mm. The same return loss is represented in Fig. 11.2, which shows that the optimum value of return loss at 3.2 mm width. Next, we have optimized the monopole's width, and a similar approach is applied for the length of the monopole. The length of the monopole feed is tuned from 15 to 29 mm. That is derived that the dual-band response is achieved at the length of 29 mm that is illustrated in Fig. 11.3. However, the return loss is shallow, so we need to think in another direction to improve the antenna's performance.

Next, we have fixed the width and the length of the monopole feed as 3.2 mm and 29 mm and changed the length of the ground plane (Jilani and Alomainy 2018). The width of the ground plane is kept fixed at 30 mm because the reduction causes too much degradation in the return loss. Hence, the ground plane length changes from
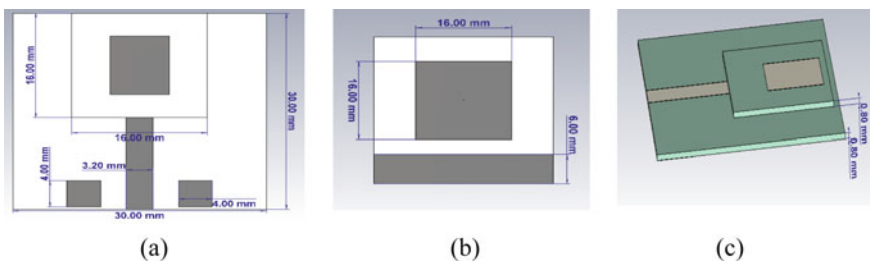

Fig. 11.1 (**a**) top view, (**b**) side view and (**c**) perspective view of the proposed antenna

Fig. 11.2 Reflection coefficient performance with the width variation of monopole feed
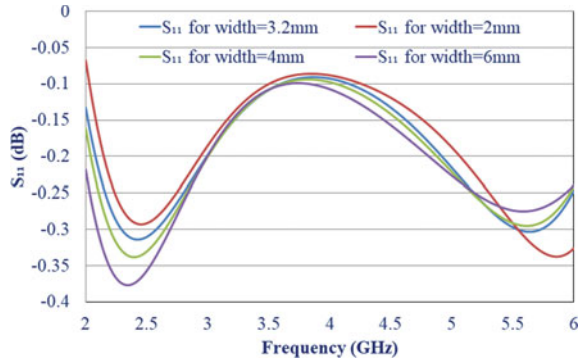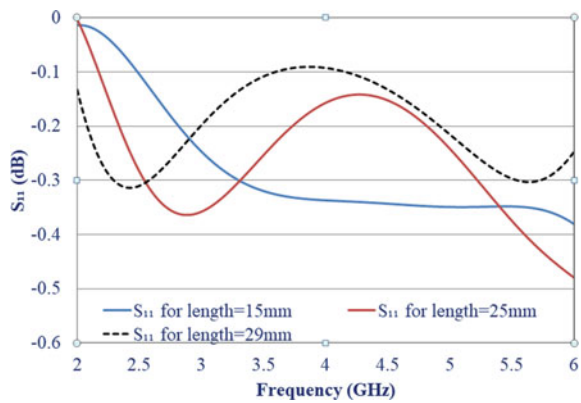

Fig. 11.3 Reflection coefficient performance with a variation of monopole feed length

30 to 3 mm and simulates the structure using CST software. The simulation result of the S_{11} is illustrated in Fig. 11.4. It shows that for the variation in length for 3 mm, 6 mm and 10 mm, the antenna is resonated at 2.45 GHz, 2.62 GHz and 3.05 GHz with the return loss of 16.5 dB, 47 dB and 25 dB, respectively. So we have now fixed the width and length of the ground plane as 30 mm and 6 mm. The 3D gain plot of the antenna at 2.62 GHz is shown in Fig. 11.5. It gives a gain of 2.31 dBi. However, the performance is not achieved as per the mentioned specifications.

Furthermore, to improve the performance, we have added a second substrate on the top of a patch with the dimensions is shown in Fig. 1a. The small square patch with different dimensions is created on this top of a substrate, and its simulated results are represented in Fig. 11.6. However, the return loss performance of the square patch is still improved by transforming it into the rectangle patch. It is now resonated at 2.5 GHz and 5.25 GHz. To measure the -10 dB impedance bandwidth, we have highlighted that region in the dotted box. It gives a bandwidth of 2.38 GHz to 2.64 GHz and 4.94 GHz to 5.65 GHz centre at 2.5 GHz and 5.2 GHz, and gain of 2.09 dBi and 3.48 dBi, respectively, which is represented in Fig. 11.8. Furthermore, to improve the performance of the proposed antenna, the square patch has been created in the
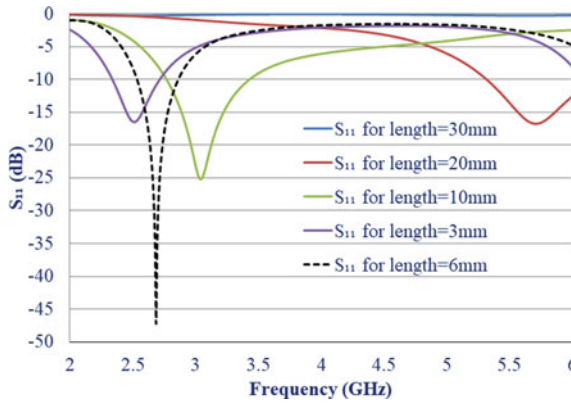
Fig. 11.4 Reflection coefficient performance with variation in ground plane length
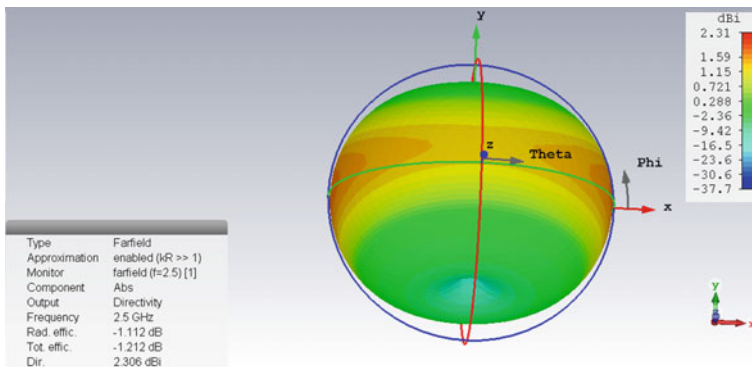

Fig. 11.5 3D gain plot of monopole feed with the partial ground plane at 2.5 GHz

ground plane. Figure 11.9 shows the return loss performance concerning changes in the square patch dimensions at the ground plane. The optimized dimension of the square patch is 8 mm × 8 mm, which gives the -10 dB bandwidth of 2.4 GHz to 2.62 GHz and 4.75 GHz to 5.7 GHz centre at 2.5 GHz and 5.4 GHz, respectively. The 3D gain plot of the proposed antenna at 2.5 GHz and 5.2 GHz is shown in Figs. 11.10, 11.7.

The surface current distribution of the proposed antenna at 2.5 GHz and 5.2 GHz is shown in Fig. 11a and Fig. 11b, respectively. It shows that the current is maximally coupled at those frequencies and also radiates. The voltage standing wave ratio (VSWR) of the proposed antenna is shown in Fig. 11.12. It gives the VSWR of 1.2 and 1.09 at 2.5 GHz and 5.2 GHz, respectively, matching our design specifications. The radiation efficiency plot for the proposed antenna is shown in Fig. 11.12. It represents the radiation efficiency of 92.4% and 94.5% at 2.5 GHz and 5.2 GHz, respectively. To prove the proposed design's superiority, we have compared the simulation results
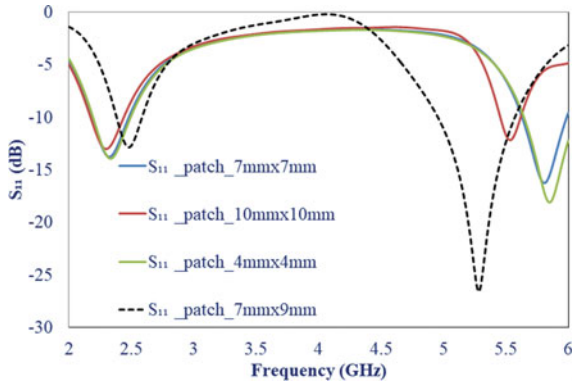
Fig. 11.6 Reflection coefficient variation with respect to variation in top patch dimensions
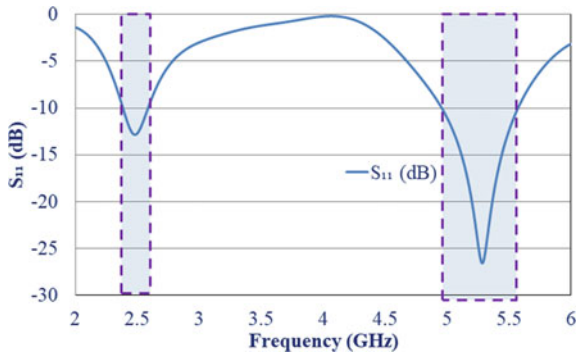

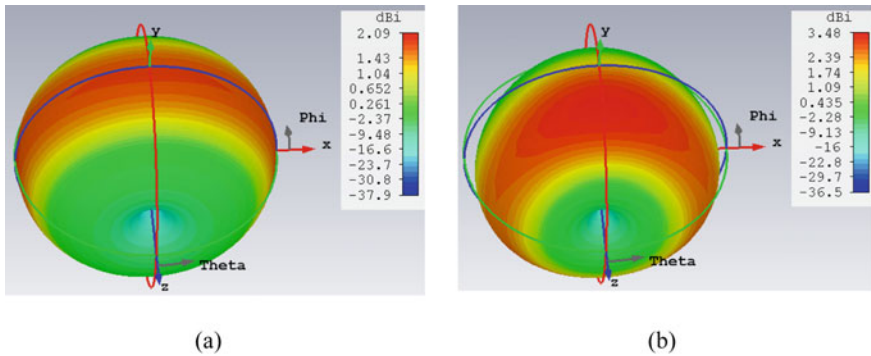**Fig. 11.7** −10 dB impedance bandwidth for the proposed antenna

(a)   (b)

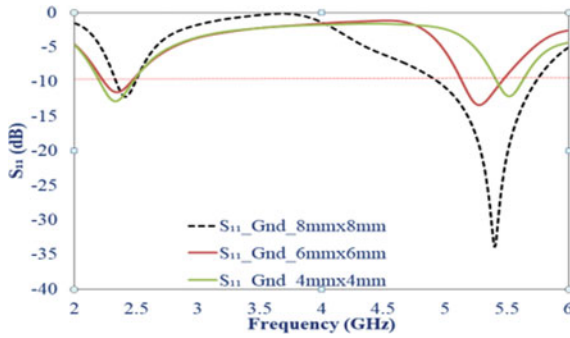**Fig. 11.8** 3D gain plot at (**a**) 2.5 GHz and (**b**) 5.2 GHz

Fig. 11.9 Reflection coefficient performance while variation in ground plane of the patch
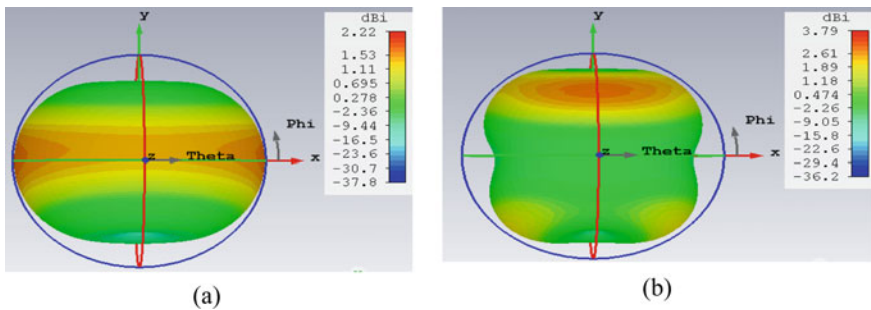

Fig. 11.10 3D gain plot of the proposed antenna at (**a**) 2.5 GHz and (**b**) 5.2 GHz

with the other already proposed designs, as illustrated in Table 11.1. The proposed antenna gives higher gain and better radiation efficiency compared to other designs (Fig. 11.13).
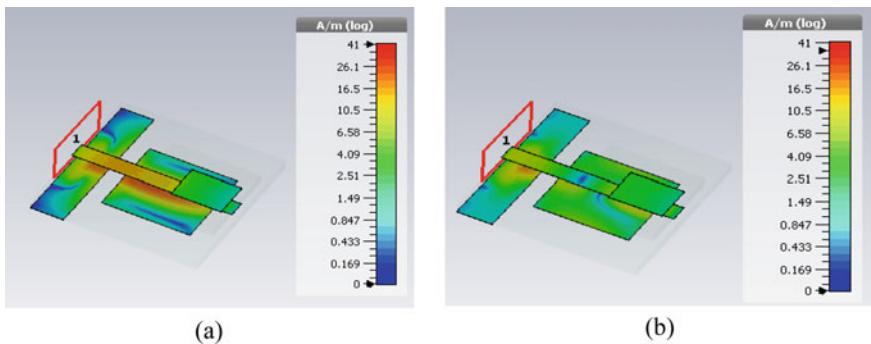

Fig. 11.11 Current distribution of the proposed antenna at (**a**) 2.5 GHz and (**b**) 5.2 GHz
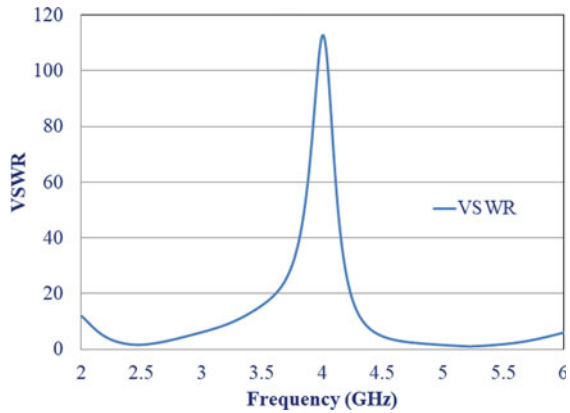
Fig. 11.12 VSWR of the proposed antenna

Table 11.1 Performance comparison of the proposed antenna vs. other models

| Reference	Resonant frequency (GHz)	− 10 dB impedance Bandwidth (MHz)	Gain (dB)	Efficiency (%)	Physical dimensions (mm^3)
Refaat et al. 2021)	2.42, 5.22, 5.92	< 100	1.72, 7.86, 6.97	–	55.5 × 42.75 × 1.5
Kumar et al. 2018)	1.8, 5.2, 7	> 300	1.83,0.73, 3.6	97, 90, 77	30 × 20 × 1.52
Munir and Soba 2015)	1.5, 2.43, 2.86	> 200	> 1	–	78.6X8.4X1.6
Satheesh et al. 2017)	2.38, 1.53	> 200	0.78, 2.5	–	110 × 65 × 1.6
Elijah and Mokayef 2020)	5.775	> 100	2.54	–	24.7 × 20.8x1.6
This work	2.5, 5.2	> 500	2.21, 3.79	92.4, 94.5	30 × 30 × 1.6
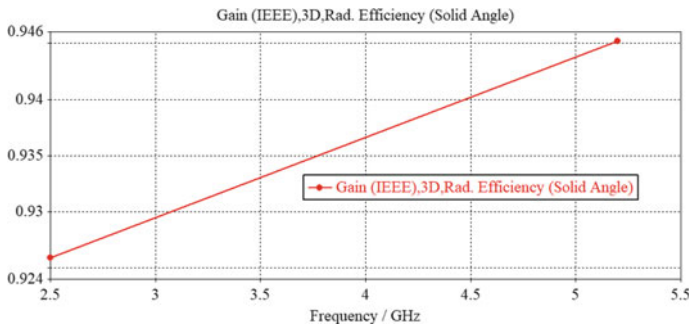
Fig. 11.13 Radiation efficiency of the proposed antenna

Conclusion

The proposed multilayer antenna is resonated at 2.5 GHz and 5.2 GHz for IoT applications. The proposed structure gives more than 100 MHz impedance bandwidth and better radiation efficiency at both the operating bands. The gain of the proposed antenna is 2.21 dBi and 3.79 dBi at 2.5 GHz and 5.2 GHz frequencies. The total volume of the antenna is $30 \times 30 \text{x} 1.6 \text{mm}^3$. The obtained results show the superiority, which can be used in the IoT applications.

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