Frequency-domain reconfigurable antenna for COVID-19 tracking

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A B S T R A C T

The COVID -19 outbreak since inception has put the whole world in an unprecedented difficult situation by bringing life around the world to a frightening halt and claiming thousands of lives. Due to COVID-19's spreading across 212 countries globally, an increasing number of infected cases and death tolls rose to 146,841,882, and 3,104,743 (as of April 26, 2021), this remains a real threat to the public health system. This paper presents a novel design for the frequency-domain reconfigurable antenna at Ku and K-bands for satellite-internet of thing (IoT) tracking applications. Four reconfigurable antenna is proposed with the use of four different switch mechanisms. Furthermore, switches are used to change resonance frequency to Ku- and K-bands on the antenna surface with four stages. With the help of the 3D electromagnetic computer simulation technology (CST) studio suite, we model the proposed antenna, perform the simulation with a frequency-domain solver, and validate the results with a time-domain solver with both results obtained in agreement as the proposed reconfigurable antenna operates over a wide frequency range for the satellite-IoT network to track COVID-19 pandemic.

1. Introduction

The novel Coronavirus SARS-CoV-2 surfaced in December 2019, initiating the virus which is responsible for respiratory illness pandemic knows as COVID-19. This showed itself in a tricky illness that can develop in different methods and levels of harshness from minor to very severe high risk of organ failure and death. The slight self-limiting respiratory tract illness is traced to a very severe advanced pneumonia, multi-organ failure, and death [1,2]. The increase in the pandemic and the number of confirmed cases on patients suffering severe respiratory failure with cardiovascular complications is the solid reason to be extremely worried about, with the consequences of this viral infection [3]. Some diagnostic devices are coming up in reducing the concern of rising cases of the global pandemic crises [4].

The overall figure of confirmed cases is eighth march 2021 is 117,469,698 with the World Health Organization (WHO) [5], with the total vaccine of 249, 160, 837 does administer.

The global pandemic coronavirus is spreading from a person to another transmission by droplet and aerosols. In controlling the coronavirus pandemic, (WHO) has given some measures and guidelines such as social distancing, mask-wearing, hand sanitizing, and keeping isolations [6,7]. The coronavirus's key protein configuration is single-stranded RNA, that contains main actions in the COVID-19 epidemic [8]. Even though normal persons following the WHO guideline concerning social distancing feasible, maintaining social distancing in the hospital is not possible and in the isolation centers in city and remote areas. In these hospitals and centers, there are high risks that health workers easily get affected in the course of treating patients [9]. Therefore, to prevent the spread of virus inside the hospital and remote isolation centers where infected people are quarantine, some tracking or monitoring system is required to be controlled by satellite-IoT sensor node and where there is no electromagnetic interference with the medical equipment. The motivation for satellite-IoT is in Ref. [10]. There is a need to design a reconfigurable antenna with a switch mechanism that can turn over the required frequency to suit this specific application. We have a model 4 set of reconfigurable antennas that obtain a suitable
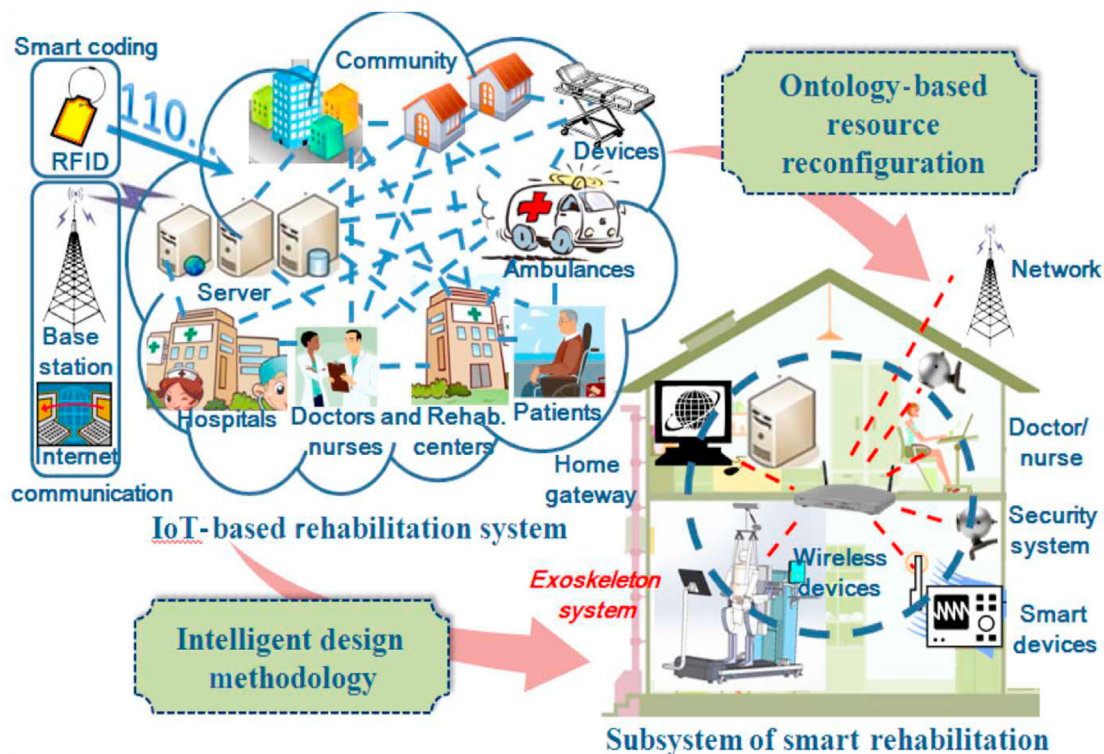
Fig. 1. Frame work IoT health care system [26].

satellite application that will hybridize with IoT for the COVID-19 tracking system.

The conception and advancement of the Internet of things in health care, was primarily projected [11,12] by Ashton and Brock respectively, who instituted the Auto-Id center in the Massachusetts Institute of Technology. Auto-ID embodies any proof of identity technologies for numerous applications, such as decreased effectiveness and automation development. The Auto-ID code network in symposium [13] show that object can be tracked when it moves from one place to another [14]. Electronic product code network realizes and allows single, comprehensive, and large IoT standards as a worldwide mainstream for suitable means, which the microchip networking together to form an excellent and reliable IoT [15]. The successful development of radio frequency identification (RIFD) indicates that IoT will lead the IT era in engineering, agriculture, academics, industries, economy, and education [16]. In the reported article [17] by the National science foundation published, made available online on convergent technology that focused on hybridizing nanotechnology with information and communication technology to improve the productivity of the nation and economy dramatically. It is suggested that combining technologies in object identification, sensors, and wireless network connection worldwide will bring better performance for specific task [18]. This will make things to be tagged, controlled, and sensed on the internet. The IoT comprises of numerous technologies which will support, perform efficiently, reliable and durable for communication among a wide-ranging of network devices with utilizations [19]. The IoT system has been established for numerous applications [20], such as the health care system [21], industrial environment [22], and public transportation [23]. Many big companies have associated with this development and implementation and the government widely supports this for expansion [24].

The IoT in healthcare is recently introduced to improve scaring resources due to an increase in the world population [25]. This is viewed as sustainability under the smart city, furthermore, the IoT healthcare-system connects with all the device networks in performing health care activity. This connection will ease how the patient is diagnosed, monitored, and performance of surgery. The IoT play a vital role

in the heath tracking and monitoring [26], the IoT framework health care system topology is shown in Fig. 1. This is show how the cycle of operations within the hospital, IoT rehabilitation system, communication and the sub system rehabilitation dedicated to frontline health workers working hard to make sure people are treated when needed for safety. The wireless technology has been extensively applied to incorporate tracking devices, a front end with a treatment network manager. This system will connect all the available healthcare resources and devices with patients. The server centralized server is responsible for data analysis, rehabilitation strategies, partnership, and discovery. There is networking of all this thing to the internet with the support of RFID techniques [27]. There will be an auto resource allocator in figuring rehabilitation solutions to meet specific demand from patients. The standard of IoT health-system is steadily forming, this will consist of the master, server, and things, the master will include the medical practitioners and patients that will have specific task system has to end-user such as IoT devices. The server will act as the dominant part of the whole health care system and be in charge for data management, medicament generation, and data analysis. This will be referred to as a physical object that includes patient and human resources, which will be connected by wireless. There is no doubt that IoT has been performing better, but due to the recent COVID-19, it is obvious that IoT needs to be hybridized with satellite to be able to monitor the virus spread and reduction no matter the locations of health workers people. As earlier mention in the motivation, the deficiency IoT will cover up, reduce, and monitor the spread of the global pandemic in the hospital and remote area isolation centers. There is a critical need to model a frequency suitable for the satellite to support the spread of COVID-19.

The concept of configurable antennas emerged a few years ago due to various functions and their performance. These antennas were given considerable attention. It is showed that wireless applications in communication need a modern and advanced system that will satisfy the demand. Also, the wireless system has multiple standards requiring an excellent antenna with multi-function capability without much enlargement. The reconfigurable antenna offers a solution by integrating more than one radios in a single platform. A good reconfigurable antenna can
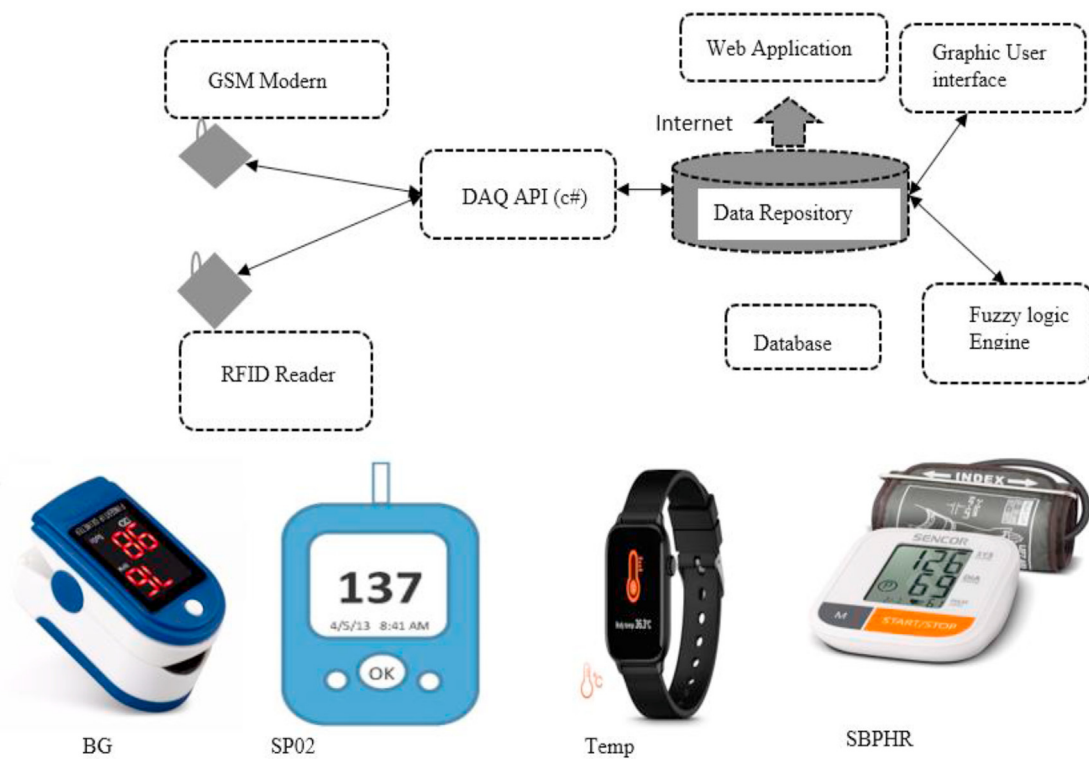
Fig. 2. Patient monitor system and device architecture.

change the functions with the required demand, allowing it to dynamically change in multiple wireless systems without requiring more antennas [28]. Multi-band ability concerning reconfigurable antenna utilizes a more efficient radio frequency spectrum to facilitate a better wireless service in the radio transceivers to meet the demand [29]. Designing a two-switch reconfigurable antenna is an excellent solution to the most enumerated problem and represents this paper's focus.

A multi-band antenna operates over more than one frequency. Therefore, a multi-band antenna transmits electromagnetic waves simultaneously to support a desire and the targeted frequency. Systems that acquire configuration track intend to see benefit from active bandwidth control. With the utilization of active antenna bandwidth control, just one antenna is functioning for the wideband, and narrowband configuration provides rejection of the un-needed signal with the antenna hardware. Therefore, the reconfigurable antenna characteristic is complicated when designing and developing a realistic predictable reconfiguration state.

Moreover, the way to reconfigure antenna is gotten with re-arranging antenna current state or the radiating edges. It is proven that a reconfigurable antenna mitigates problems that are associated with the multiple bands. The reconfiguration is achieved with the introduction of switches within the radiating elements in antenna. The reconfigurable antenna decreases the adjacent interfering bands that are not used to minimize the filter requirement on the circuits in the front end, making the structure compact [30]. Some of the literature shows that frequency ability is realized with the use of different types of switching. Such as the varactor diodes [31]. The varactor diode is used to reconfigure non-linear antennas with the continuous turning range, the FET switches [32], and the pin diodes [33]. The switches among many bands require a number of pin diodes to operate correctly and satisfy the demand. It is noted in Ref. [34] that Microstrip antenna with pattern reconfigurable antenna utilizes more than four pins in achieving the desired results. This has two operating modes omnidirectional and unidirectional frequencies. In Ref. [35], a microstrip-based frequency reconfigurable antenna uses six switchable to achieve its results, while there were drawbacks in the large dimension, limited impedance bandwidth. In this paper, we address

these challenges. Every reconfigurable antenna intention is starting by the pre-determined objective to fulfil the current technical constraints. The bandwidth of a reconfigurable antenna is always selected for the reason that the miniaturization, cost-efficiency, capability to turn in between the frequency bands, and the gain with the radiation pattern's stability unchanged. Numerous feeding methods have been used in flexible antennas, but the coplanar waveguide feed is working great, and this is preferable because it reduces the complication with the placement of antenna elements on the patch side-by-side the substrate. In Ref. [36], a T-shape antenna with one pin-diode for dual application is used. This paper presents a novel T-shape antenna designed to solve most problem of compact size with single frequency and low gain. We achieve reconfigurability through the switching mechanism.

The resonance frequency changes with integrating two switches in the antenna surface with four stages. We simulate the proposed antenna with the help of computer simulation technology (CST). We exploit both frequencies and time-domain in solvers to simulate and validate the obtained results. These results show that the proposed antenna operates in a wide range of frequencies, allowing it to be exploited in Ku- and K-bands applications. To this end, our contributions are summarized as follows. (i) first, we proposed a novel design for frequency reconfigurable antennas at Ku- and K-bands that suit satellite application to hybridize with IoT for COVID-19 tracking system, (ii) second, we project a prospective framework on how a frequency band is achieved, (iii) finally, we discuss an exploit attribute dynamically frequency variation without using multiple antennas. The structure of this paper as follows. Section 2 explores satellite-IoT for COVID-19 tracking, section 3 expatiate on antenna system configuration, section 4 investigates the system model, section 5 explains simulated results with antenna analysis, and section 6 concluded the paper with the summary.

2. Satellite-IoT for COVID-19 tracking

A recent forecast indicates that in 2021, the connected wireless device is estimated at around fifty billion [37], following exponential growth predicted to be maintained beyond 2030. It interests that personal
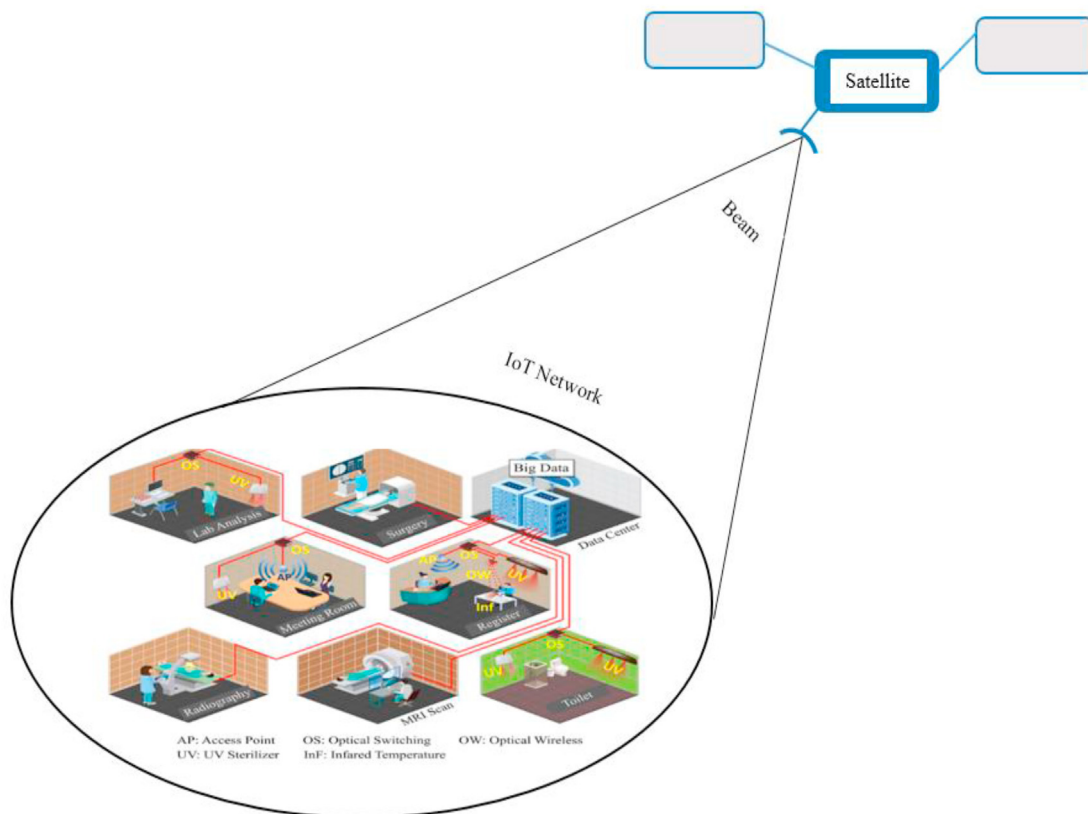
Fig. 3. COVID-19 monitoring in hospital architecture [45].

hand-held devices will not dominate this trend but the use of sensor nodes and some other communication tools. Typically, there are small, low power, low cost, which refers to machine type devices (MTDs). Importantly, it knows that the concepts of IoT cover a wide-ranging diversity applications. An emblematic MTM network would be tranquil of numerous MTDs producing a minimal message with short duty-cycles. The characters have significant implications concerning energy effectiveness, which is paramount in up-to-date with prospect IoT/MTM in the system engineering. Presently numbers of satellite communication service provider that is offering global coverage. Some of these structures have been functioning since the nineties, but utilization has not changed meaningfully recently compared to the terrestrial counterparts. Hence there is a huge amount of MTMs associated with one access point satellite, it is, therefore, imagine that satellites play a vital role in the provision of comprehensive coverage for the IoT to perform better. The satellite IoT hybrid is paramount because satellite provides large terabytes in their direct demand broadcast capacity. The antenna terminal system with high gain will be close the link with more high directivity avoiding interference with the adjacent satellite system. When the number of objects is large and wide, it is reasonable to adopt satellite communication to expand and provide support [38]. explain the use of satellite structures to deliver global IoT to MTM connectivity.

With the rise in the COVID-19 pandemic, it is necessary to set up a tracking sensor node system that will protect the health workers from contacting the coronavirus through human interaction and curb the virus's spread. The tracking system works within the hospital, remote areas, and all other locations. The hybridization of satellite and IoT will cover a wider area and solve the challenges of IoT. The virus can survive a while on a dry surface, a comparative study is presented for MARS (middle east respiratory syndrome) and SARS (severe acute respiratory syndrome) [39]. To stop the spread of the virus, killing is one of the disinfectant options [40].

Along with the disinfectant, a temperature sensor will be needed to

monitor the temperature in the hospitals. In Ref. [41], the patient monitor system architecture in Fig. 2 was proposed, this consists of significant software, which is data acquisition unit for application program interface, the second is a fuzzy logic engine, the third is database manager, the fourth is a graphical user interface, and finally a web application. This unit is use to collect real time data of patient. The application program interface allows the communication with the manager in charge to gather real patient time important signs. This is a front-end tracking with the functioning system, the other software is developed as echo modules used to profile the user, store vital signs, and enable interaction with the system through the web [42]. The fuzzy logic has 3 sequence processes such as fuzzification, rule-based structure, with defuzzification.

The temperature acquirement system using a wireless sensor network is projected [43]. Recently hospitals are equipped with recent types of machinery where big broad data plays a significant role in health care. With the use of big data, doctors analyses the patient health past with routine; giving that, improved treatment can be completed where many data are managed with artificial intelligent software [44]. In Ref. [45] proposed hospital monitoring with metamaterial antenna in Fig. 3, this COVID-19 monitoring in hospital use antenna node wifi network with optical wireless OW, optical switching OS, the access point AP, UV sterilizer, and (Inf) infrared signal that can be used within the hospital and in intensive care unit ICU.

The integration of e-health systems monitors healthcare with real-time statistics using biomedical data acquisition, this process is appropriate for aged people telemedicine via the wifi [46]. The electronic well-being-system preserves the patient's data meanwhile; other data sources are unrestricted health archives with clinical data. One key task in using big data is data security [47]. The patient data can be secure with significant communication [48], it is reported that medical diagnosis can be secured using quantum encryption and decryption technique on the cloud [49]. The projected structure is a central feature that can be executed in the hospital region for monitoring or observation
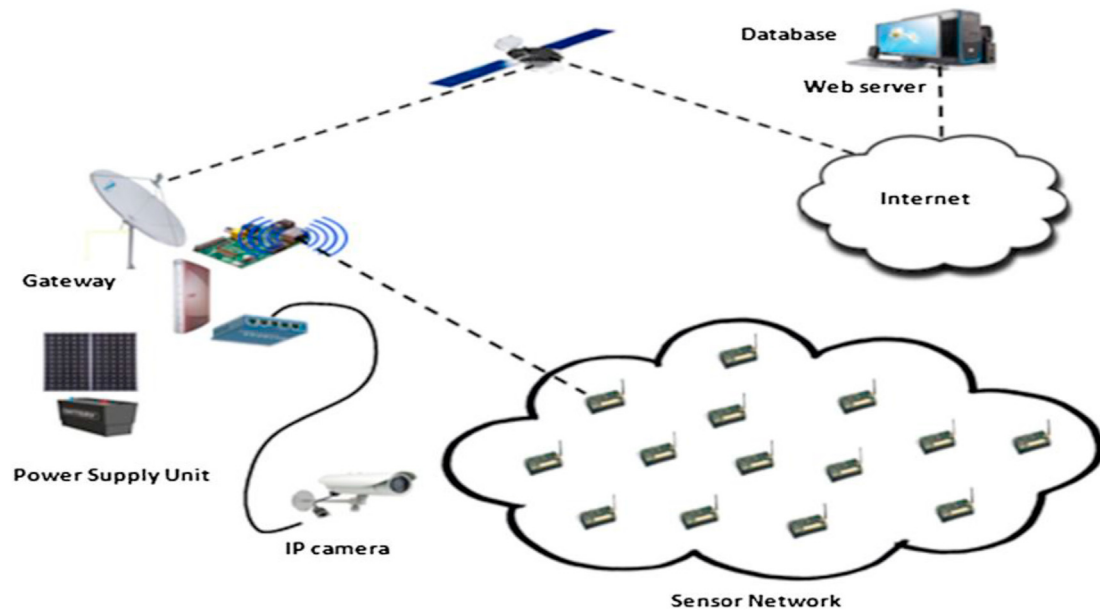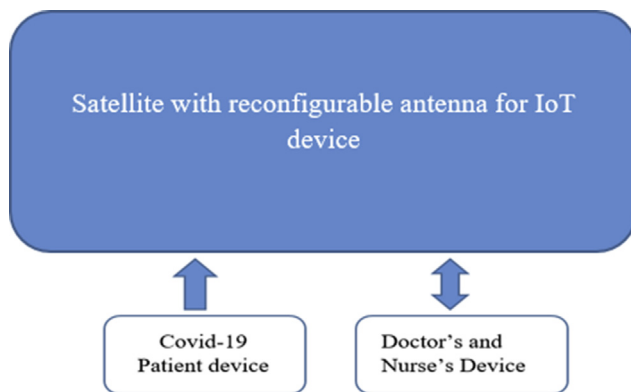
Fig. 4. Remote system tracking architecture [51].

Fig. 5. System infrastructure.

Fig. 6. Reconfiguration techniques.

applications. In the remote area for the patient of COVID-19, the system will use a sensor and multiple cameras connected through the gateway, the gateway controller system [50] monitors and control the system, an indoor satellite unit, and a site-local area network equipment. As proposed by Ref. [51], a network sensor node monitors the gateway's area vicinity, the system monitoring architecture in Fig. 4. The sensor may be wired or connected via low power wireless monitor for the environment and perform detection, this will limit human interaction and reduce the spread of the coronavirus. The system infrastructure functional block diagram in Fig. 5, this show the reconfigurable antenna which provide the frequency that suit satellite operation hybridizing with IoT. The IoT device will communicate through sensor for decision about COVID-19 patients and notify the doctors and nurses.

We model an antenna with the reconfigurability to change frequency to suit specific applications through a switch mechanism in this work.

Furthermore, the switches are used to change resonance frequency to Ku- and K-bands on the antenna surface with four stages. With the help of the 3D electromagnetic computer simulation technology (CST) studio suite, we model the proposed antenna, perform the simulation with a frequency-domain solver, and validate the results with a time-domain solver with both results obtained in agreement as the proposed reconfigurable antenna operates over a wide frequency range for the satellite-IoT network for tracking the COVID-19 pandemic.
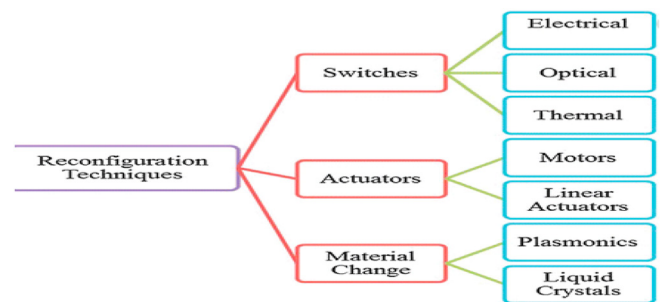
3. Antenna system configuration

Depicts antenna design techniques, which deal with the material's characteristics and properties to make the antenna.

Achieving the required configuration purpose requires appropriately selecting the mechanism that will complete the desire functionally. A reconfiguration mechanism is selected to satisfy the imposed constraints while complementing the antennas efficiently. The reconfiguration method is divided into three categories, and the subdivision shown in Fig. 6.

In respect to this paper, this technique paves ways to design a reconfigurable antenna with outstanding results. This technique is used for the reconfigurable antenna via an active switches-based micro-electromechanical system (MEMS). The PIN diode or the mechanical movement of different patches uses stepper motors to bend one or more with photoconductive switches. At various times, the basement of different antenna parts, through an appropriately fed antenna array, is reconfigured with a feeding network for a controllable antenna [52].

4. System model

In this work, Rogers RT 5880 (lossy) is used as a substrate. The dielectric of thickness 0.508 mm^2 has a substrate constant of 2.2, and the target loss is 0.0009. The proposed antenna has a compact size of 23 mm^2 x 23.4 mm^2, as shown in Fig. 7. The antenna is fed on 50 Ω microstrip lines, and the coplanar waveguide feedline width is 1 mm^2, connected to the primary radiation. The inner and outer radiators are connected to the
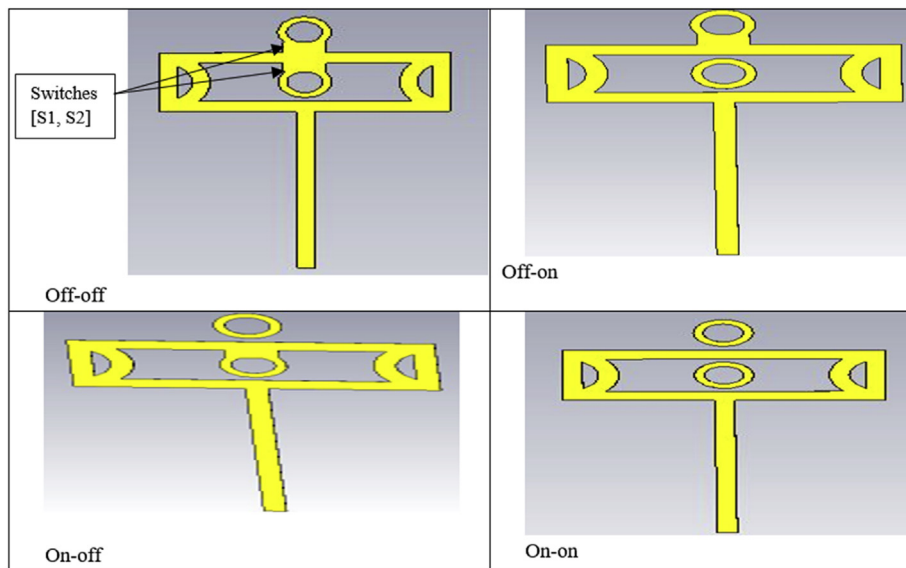
Fig. 7. States of the CST 3D antenna's unit cells.

Table 1
Value of parameters.

Parameters	Values	Parameters	Values
Wsub	23.4	H	0.508
Lusb	23	F	1
Lg	14.642	G	0.358
t	0.035	Wg	13.45
Wp	16.2	Lp	5.65
d	1	R1	1.5

Table 2
Model switching stages.

state	S1	S2	Frequency (GHz)	Bandwidth (MHz)
1	on	on	21.9	824
2	on	off	16.5	429
3	off	on	21.7	655
4	off	off	16	428

primary radiation using switches (Switches 1 and 2). The circular is introduced both inner and outer radiator to get more frequencies. Table 1 shows the parameter table. The width controls the current intensity in minimizing it works majorly on the return loss. The lumped component

borderline situation is used for implementing the switches. The microwave studio is used in designing simulation with the stages of switches, which are 16.5 GHz, 21.9 GHz, 16 GHz, and 21.7 GHz, respectively, and it was validated with a time-domain solver.

5. Simulated results and analysis

The actualization of the switch both for "on" and "off" expresses the electrical distance of the antenna organization. This subsidizes to the radiating at a given frequency band. Both Switch 1 and Switch 2 are implemented using a conductor, and the diode provides the path. In Table 2, we display the switching stages. When both switches are shorted concurrently, the existing flows in the foremost radiator with the inside with outside radiator. When the switches open, the current mingles only in the central radiator and leads to better results. The radiation pattern in Fig. 8 shows the directional dependence strength of the radio wave. The return loss in Fig. 9 shows the frequency of 21.9 GHz, 16.5 GHz, 21 GHz, and 16 GHz, the bandwidth at 824 MHz, 429 MHz, 655 MHz, and 428 MHz for Switch 1 and Switch 2.

The current follows the more extended patch. The Fairfield gain in Fig. 10 shows improvement in the gain, 4.34 dB, 5.42 dB, 4.70 dB, and 5.11 dB. The current distribution in Fig. 11 on each state suggests that the inner radiator radiates around the central radiator's wall. Furthermore, the main radiator, together with the outer radiator, radiates. The current
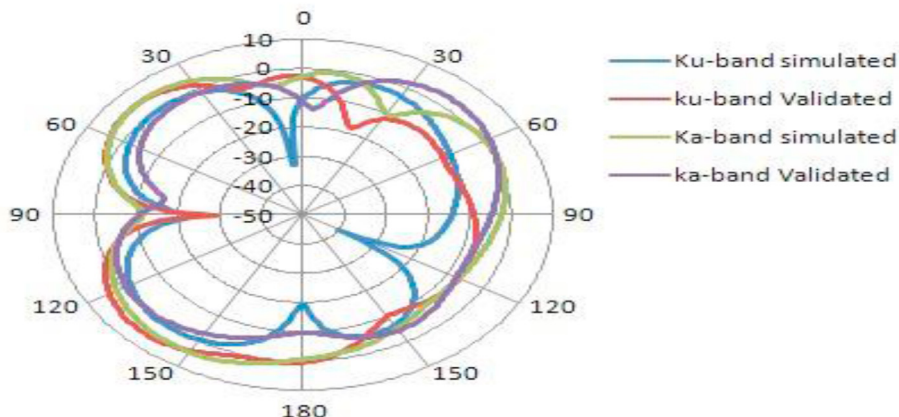

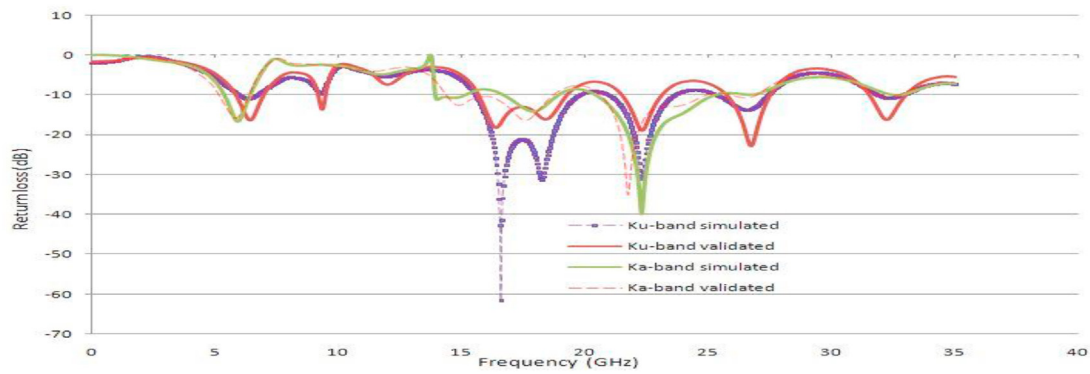
Fig. 8. Radiation pattern at states.

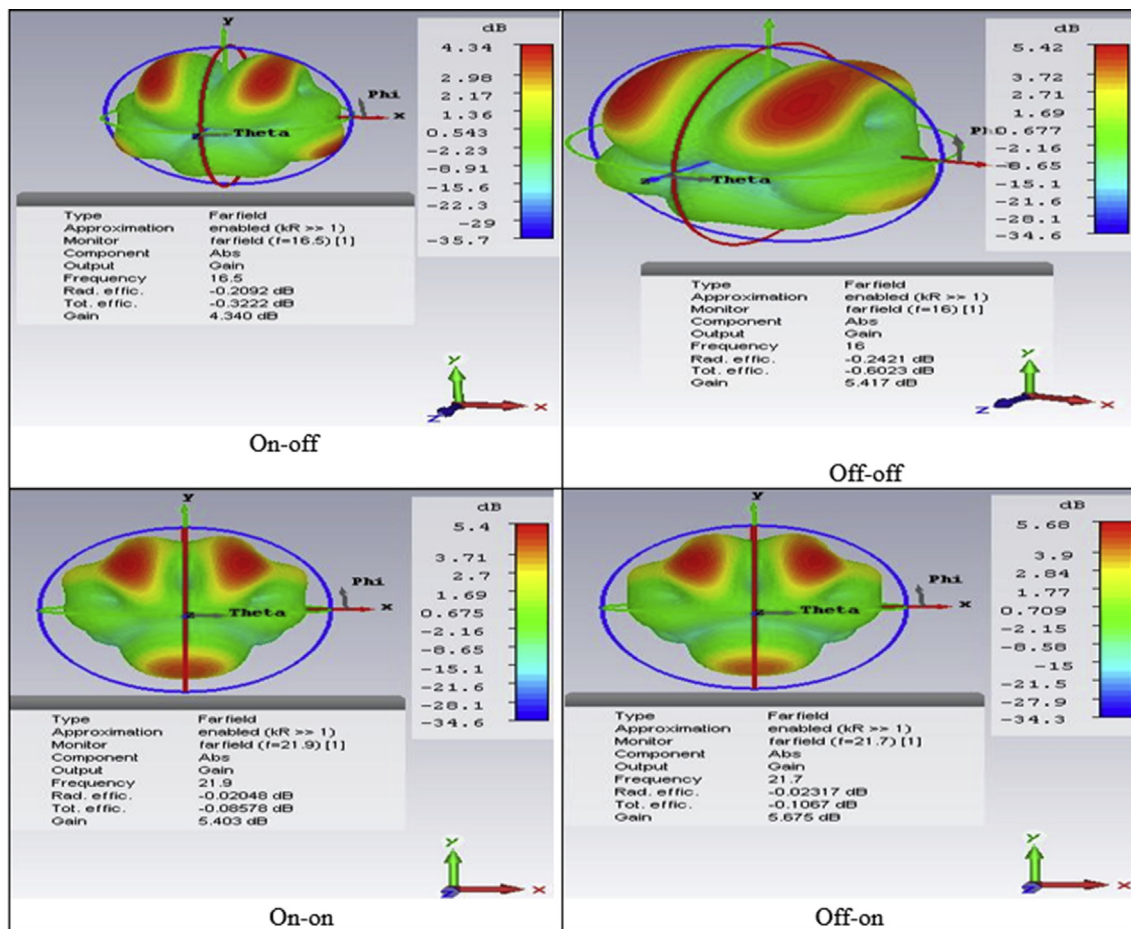**Fig. 9.** The return loss of stages merged.

Fig. 10. Fairfield gains at stages.

follows the more extended patch. The antenna resonance frequency is 21.9 GHz with an impedance bandwidth of 824 MHz. When Switch 1 is on and Switch 2 is off at stage two, the frequency is 16.5 GHz with an impedance bandwidth of 429 MHz. At Stage 3, when Switch 1 is off and Switch 2 is on, the frequency is 21.7 GHz with an impedance bandwidth of 655 MHz. In the last stage, when both switches are off, the antenna covers 16 GHz with an impedance bandwidth of 428 MHz. Table 3 shows the results and performance of simulated S11. The desire frequency bands are covered, and radiation efficiency is greater than 93% success. Finally, in Table 4, we compared the obtained results to previous work.

In this comparison, we consider the number of switches, substrate, thickness, area, number of resonances, and bandwidth performance. It shows a better thickness of 0.508 mm^2, an area of 538.2 mm^2, and four

resonances. It realized 824 MHz, 655 MHz, 429 MHz, 428 MHz bandwidth better than other works.

6. Conclusion

A novel design for a frequency-domain reconfigurable antenna at Ku- and K-bands for the COVID-19 tracking system is proposed. The reconfigurability was achieved with the use of a switching mechanism. The resonance frequency changes with integrating two switches in the antenna surface with four stages have been monitored. Furthermore, the application of the switches allows a wide tunability in the operating band. The antenna operates successfully at the desired band with a good radiation pattern. The ability to reconfigure, simplicity in designing, and
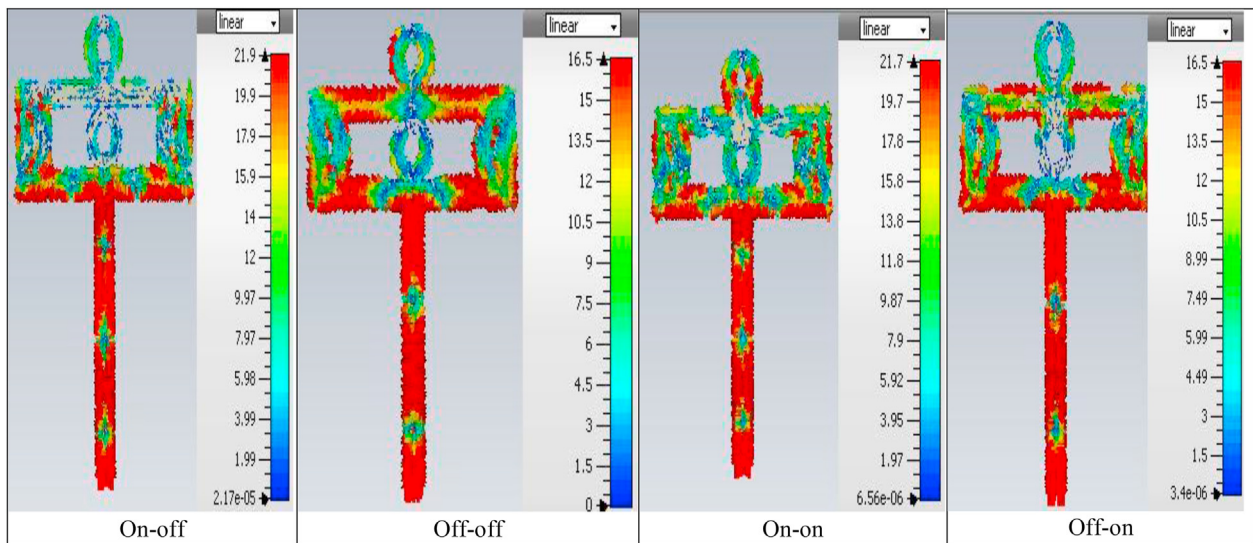
Fig. 11. Current distribution.

Table 3
Performance presentation table.

Frequency (GHz)	16.5	21.7	21.9	16
Gain (dB)	4.34	4.70	5.11	5.42
Directivity (dB)	5.26	5.60	5.71	5.81

Table 4
State of the art comparison.

S/N	No of switches	Substrate	Thickness (mm^2)	Area (mm^2)	No of resonances	Bandwidth at difference resonance (MHz)	Ref
1	2	FR 4	1.56	8580	4	245, 173, 228, 60	[53]
2	3	R04003	1.2	645	4	120, 160, 200, 400	[54]
3	3	FR4	0.8	400	3	210, 400, 580	[55]
4	3	RO4360B	0.8	675	6	100, 120, 280, 220, 100, 320	[56]
5	2	RT5880	0.254	2000	2	192, 168	[57]
6	2	RT5880 (lossy)	0.508	538.2	4	824, 655, 429, 428	This work

flexible of some materials are the component that makes the antenna promising for a desirable satellite-IoT network for tracking COVID-19 pandemic.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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