Sensors International 2 (2021) 100090

Contents lists available at ScienceDirect

Sensors International

journal homepage: www.keaipublishing.com/en/journals/sensors-international

FSS superstrate antenna for satellite cynosure on IoT to combat COVID-19 pandemic

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ARTICLE INFO

Keywords:
COVID-19
IoT
Satellite
Antenna
FSS
Sensor

ABSTRACT

The global pandemic, COVID-19 needs joint techniques and technology to combat it. The internet of things (IoT) has been at the forefront in solving problems, not only in the health care sector but in other sectors. It delivers accuracy with robustness in the developing service and application. However, it remains clear that the use of IoT is limited to coverage, longevity, security, connectivity issue, immediacy, and multicasting, we proposed in this paper frequency selective surface (FSS) as superstrate for rectangular microstrip antenna. An FSS design combine with the rectangular microstrip antenna for better performance is placed over FSS parallel configuration. The rectangular microstrip antenna was titled 45 degrees to change the band-stop. Analysis of the proposed performance in terms of gain, return loss, and directivity shows that the FSS structure's integration brings better results. With the help of a 3D electromagnetic computer simulation technology CST studio suite, we model the proposed antenna, perform the simulation with a frequency-domain solver, and validate it with a time-domain solver. The proposed impressive result is suitable for satellite networks, which hybrid with IoT can provide a sustainable long-time solution in fighting the COVID-19 pandemic.

1. Introduction

The frequency selective surface (FSS) is classified as resonant with band-stop, low-pass, band-pass, and high pass with a dependence of performance on shape [1]. It has been widely used in applications like radome and reflectors. Its electromagnetic properties are used for radome, shielding structures for a wireless signal, electromagnetic absorbers, and band-pass filter [2]. FSS can be translucent to the signals in some frequency bands, meanwhile opaque to signals in the other frequency bands. Like the crosses, strips, or ring, the periodical structure is implemented on a thin surface [3]. In improving gain, directivity, bandwidth, beam switching control, and front-to-back ratio form a cavity antenna [4–6]. The reflective transmission assets of these materials can be used in improving the enactment of a conventional antenna. The application of FSS structure as a superstrate in modifying the antenna's performance is becoming trending and has been explored by many researchers [16–52].

Antenna frequency has been designing for IoT, such as L-band, S-band, C-band, and X-band. However, it remains clear with the very high rate of spread of covid-19 that all this frequency band range is limited to a narrow range; therefore, there is a need for a satellite frequency that covers a broader range. We present an antenna design incorporating FSS to enhance the performance and operate at Ku-band frequency for satellite applications. Motivation, the main motivation for this hybridization is in [7].

The support to fight against COVID-19 global pandemic is necessary with a joint effort from various researchers. COVID- 19 pandemic is the current global challenges caused by the severe respiratory syndrome coronavirus creasing a global health crisis since the outbreak [8]. With the World Health Organization report in September 2020, the number of confirmed cases has passed 31 million people worldwide with a massive rate of 960,000 deaths [9]. The disease has familiar flu-like symptoms, high temperature, cough, difficult breathing, headache, dizziness, and fatigue. This is only recognized with early detection and diagnosis [10].

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Production and hosting by Elsevier

https://doi.org/10.1016/j.sintl.2021.100090
Received 13 February 2021; Received in revised form 9 March 2021; Accepted 9 March 2021
Available online 18 March 2021

The incubation period of COVID-19 is from one to fourteen days, and in this period, the system starts developing gradually and might not fully show. It is transferable very fast from a person with a virus to another if the safety precautions are not in place, it spread very fast compared with other diseases. After early detection is necessary to quarantine the affected people [11]. The recovery period's stage depends on the affected patient's previous health condition, age, and how they are treated. Generally, the recovery period takes between 6 to 41 days [12]. There are innovations daily to cured the spread, monitor, and treat the affected. Therefore, this brought about the idea of IoT in supporting the fight against COVID-19. IoT systems perform an enormous operation in wireless communication, searching data, recognizing a hidden object, and many more. The fact is that IoT has several elements for application with enabling massive machine-type communication. The IoT can get to a remote area with no internet, although the internet is accessible where there is a human settlement. IoT is used in the agricultural sector, military, education, health, deliveries, and health care. In some agriculture cases, where under surface soil humidity is done with IoT, this can be done using a sensor under the surface. However, there is a micro monitoring device too. All this supervising the IoT can be done with some communication nodes, satellites, and high altitudes. The technology trend like the IoT, radio-frequency identification and cloud computing provide good monitoring of patient state with access to relevant health information, also it helps the physicians and nurses with challenges or difficulties information access and exchange. The IoT technology trend can improve the health sector, organization performance, and healthcare for society. The new techniques for forwarding link bases satellite IoT system is proposed in [13], the low earth orbit constellation is proposed for IoT applications in [14]. In this work, an antenna model is to operate at the satellite frequency range. The cynosure means based or centre on something. This will be hybridized with IoT. The spectrum allocation constellation structure of low earth orbit satellite is compatible with the satellite IoT network's diverse parts. The sensor number used in IoT networks is high, the energy efficiency in IoT is the main with some cases considering green IoT for applications [15]. Due to the pervasive presence of IoT sensors and actuator components, energy efficiency is an important aspect. The green initiative in IoT is very essentials for long-term suitability. This is a cost-effective and sustainable form of IoT that will really enhance the productivity of satellite-based IoT in the fight against COVID-19.

Problem formulation and potential contribution. FSS attributes can be determined by distributing the current shape elements and the elements' shape. Characteristics such as Low profile, reduction in periodicity, dual-polarization, angular stability, multi-pole frequency response with higher out-of-band rejections, and easy manufacturability achieve all properties mentioned earlier optimized design challenge for FSS. Techniques are needed to solve low gain challenges, narrow bandwidth, which is explored in this paper and presents the hybridization performance enhancement of frequency selective surface (FSS) as a superstrate for rectangular microstrip antenna a ring resonator. This research article focuses on improving gain with the bandwidth of an antenna and producing a frequency that will be hybridized with IoT, The IoT has been delivering accuracy and robustness in different applications. However, it remains clear that there are limitations to coverage, longevity, security, connectivity issue, immediacy, and multicasting. We propose a rectangular microstrip antenna as a shape with a ring resonator. An FSS was designed to combine with a rectangular microstrip antenna to improve performance, the antenna is placed over and above FSS parallel configuration. The hybridization brings the achievement of the targeted results, the unique feature of the proposed provides the reflection coefficient with high reflective predetermine frequency range. The rectangular was titled 45 degrees to change the band-stop, and the ring length played a significant role. Analysis of the proposed performance in terms of gain, return loss, bandwidth, and directivity shows that the FSS structure's integration brings better results. The performance of this design was studied through computer simulation technology microwave studio (CST-MWS). The frequency turning to produce the band-pass or band-stop for good operation, and the gain increased with the loop FSS from 3.74 dB to 6.25 dB and 3.60 dB to 5.86 dB for 12 GHz and 18 GHz, respectively. The proposed model operates at a Ku-band frequency rate and suitable for satellite communication.

This paper proposed frequency selective surface (FSS) as a superstrate for rectangular microstrip antenna to improve the antenna's performance, and it is placed over FSS parallel configuration. The rectangular was titled 45 degrees to change the band-stop, and the ring length plays a significant role. Analysis of the proposed performance in terms of gain, return loss, bandwidth, and directivity shows that the FSS structure's integration brings better results. With the help of a 3D electromagnetic computer simulation technology CST studio suite, we model the proposed antenna, perform the simulation with a frequency-domain solver, and validate it with a time-domain solver. The proposed impressive result is suitable for satellite networks, which hybrid with IoT can provide sustainable long-time solutions in fighting the COVID-19 pandemic and address IoT's weakness. The rest of this paper is structured as follows. Section 2 explores the background of COVID-19 to IoT. Section 3 investigates satellite to IoT, section 4 explains the system modeling analysis. Section 5 enlighten FSS band-stop structure analysis, section 6 study the effect of FSS on an antenna, there result and discussion presented in section 7, section 8 compare the work with other similar related, and the paper was concluded with section 9.

2. Related works

This section discusses some integration of FSS antenna, which have been examined for a very long time with many publications. In [16], the reflective surface has square metallic patches on the superstrate, projected to improve to 12.5 dB. In improving the radiation efficiency with the integration of coplanar waveguide fed antenna is combined with FSS surface reflector in [17], although no remarkable improvement in the gain getting. A double later artificial magnetic conductor configured on a square split ring resonator is anticipated [18]. In [19], a circular loop element was used in the FSS for Terahertz frequency applications, polarization modulation, space-borne passive remote sensing application, material characterization, and balloon-borne telescope. The FSS mentioned above was utilized in switchable polarization, comprising four square electrics structures [20]. The four-fold symmetry was used in the article [21]. It is studies that FSS can utilize mesh filters with cross slots for practical application in radio frequency [22]. Applying FSS to get the best result for it to purpose annular mesh element was utilized, which produces impressive results [23]. The cross shape and wire grid FSS was combined in [24], and the targeted results were achieved. It was investigated in [25] how to see Jerusalem's performance for better results and proven beyond a reasonable doubt. Applying a square loop element got a good result when designing to suit the purpose and mission. Active backscattering approach FSS was applying during the research on Ultra wideband radio frequency identification [26]. The patch FSS investigated in [27] shows a good result after analysis. The metallic meander line impedance loaded with the rectangular metal patch was investigated in [28].

Similarly, the cross dipole and ring patch elements reigned in [29] to get good required results. We study how the circular ring was used in [30, 31] old FSS paper to broaden how the ring works for desired results. It was investigated and presented in [32] how band-pass FSS with an array of nanoscale slotted antenna elements perform on the beam switching application for pulsed, high power microwave. Radio astronomy was investigated by [33] with the Jerusalem cross array to meet the desired results. Complementing and getting microwave lenses to perform better using band-pass FSS is a phase shifter used in [34] and has a satisfactory target. The purpose of the dipole and loop element's satellite application was to get an essential requirement for targeted application [35]. All the literature was done to conduct and design the antenna incorporating the FSS superstrate to reach the targeted result for this research.

The gain increases to 5dBi with good directive radiation. A monopole antenna is designed with hybridizing with FSS in [36], the ultra-wide stop-band layer FSS with the conversion of omnidirectional pattern monopole into unidirectional with significate gain. The single transmission pass-band type FSS is investigated in [37] to control the antenna's radiation pattern. The dimension unit cell of materials in [38] is quite big, with an operating frequency that leads to an increase in the combined cavity antenna's size. The dual-band monopole antenna is loaded in the cylindrical FSS screen, which is done in [39]. A reflector that consists of double-layer Jerusalem FSS is placed at the back of a reconfigurable dipole that enhances the antenna's performance in [40]. An introduction of two over-lapped FSS reflectors in beam control demonstrated three frequency bands in [41]. An FSS reflector with a parabolic profile is investigated, the reflector can focus and reflect in the band signals.

Meanwhile, the out-band signals are absorbed into the antenna radar in [42]. FSS reflected is proposed to convert the in-band incident wave of linear polarization to reflected wave. Further, the FSS is placed in front of the radiating element as a superstrate [43]. The FSS superstrate and square loop pattern are adopted in improving the directivity of aperture coupled microstrip antenna in [44]. The algorithm, which is the name parallel micro genetic algorithm, is investigated in optimizing the design of FSS superstrate [45]. The double-layer FSS superstrate, which consists of square shape ring and a square loop slot, is examined in [46]. The implementation of FSS and superstrate are done in [47].

In the configuration of all these, the FSS is part of the antenna, and it is used to improve or enhance the radiation performance than operating individualistic as a filter in incident plane waves. FSS arrangement in an explored design is position on the same plane of the frequency modulation (FM) antenna. They can operate on their own for various functions at the same time. Designing an FM radio antenna on a transparent substrate like the glass window is challenging because the antenna is limited, and the blockage of light is minimized. The only skinny conductive strip will be adopted; this will restrict the choice of antenna. Many applications' window size is small than the FM radio signal wavelength with the antenna's height limited. Folded monopole is very good for cases like that, and some of the design is done in [48,49]. The strong demand from automotive industries and the offspring in new coating techniques has led to this antenna's development [50]. The superstrate plays a good role in the antenna as it was used in this paper design. In [51], the superstrate is applied to the electromagnetic band-gap antenna, the gain increases by 75 dB, the varactor uses the FSS supertaster to change the beam width dynamically with voltage adjustment. In fighting COVID-19 [52], antenna node and LiFi were used for preserving intelligence of the pandemic in hospital management.

3. Background of COVID-19 IoT

There is a need to understand the COVID-19 pandemic concerning the IoT. The internet of things is the interconnected process conformed with network elements such as software, hardware, electronics, computer means, and network connectivity untimely support data altercation with the collection. IoT is all about billion devices that are inter-connected collecting and sharing data; the arrival of super cheap to support wireless net-work is possible through it. Small and big data connections make it viable, aiding sensors with various objects to the level of digital intelligence with devices that enable it to communicate with less human interaction. In this situation, most issues arise because of non-effective in reaching the patients; this is a significant issue to developing a vaccine to fight the COVID-19 pandemic [53]. The use of IoT helps a lot in fighting the pandemic; IoT gives access to reaching the patient with physical contact; it helps monitor contact tracing and quarantine state monitoring. The problem with this pandemic is that it increases daily globally; there is a need to utilize the IoT methodology more globally to control the spread and reduce the number of contacts as we prevent the medical personnel. In [54], explain the concept of the Internet of Medical things (IoMT) how it works with Fig. 1. This could create a medical platform that will help the patient get medical attention at home; this will help reduce the virus's spread. Follow the guideline provided will he the IoMT to get cases to reduce and to spread.

4. Satellite for IoT

There is a need to have an overview of the satellite. This is the geosynchronous orbit. The satellite IoT hybrid is paramount because satellite provides large terabytes in their direct home demand broadcast capacity. The geosynchronous satellite orbit (SGO) constellations are not suitable for critical mission applications because they have high latency. After all, the path is a loss between the earth and satellite with the geostationary orbit's satellite internet of things sIoT nature. The antenna system terminal with high gain will be close the link with more high directivity avoiding interference with the adjacent satellite system. There are types of orbit in space: medium earth orbit MEO, the geostationary orbit GEO, polar orbit PO with synchronous sun orbit SSO, low earth orbit LEO, Lagrange points LP, and transfer orbit too, which can be said as geostationary transfer orbit GTO [55]. The geostationary orbit is compared to low earth orbit satellite constellation has the advantage of low propagation delay. The global coverage with small propagation loss is the primary demand for fighting against the COVID-19 pandemic. With the low orbit altitude, the round trip turnaround time for low earth orbit constellation is about 100 m/s; the geostationary orbit is about 600 m/s. Also, low earth orbit with some highly elliptical orbit satellite EOS operates very close to earth compared to geostationary orbit. This offer some advantage of low path loss, low latency, less cost, and lighter. The low earth orbit constellation and highly elliptical orbit have drawbacks with their location changing with high opinion points. This gives rise to the high time-variant communication channel, which needs an excellent directional antenna such as this design.

An IoT terminal in the low earth orbit network or highly elliptical orbit network demands tailored waveform to take care of the antenna design that will be good for the variant communication channel. The satellite constellation explained in [56], the IoT requires excellent, dependable, high productivity connections and low latency. The requirement can be achieved using a high throughput satellite, which is utilized with concentrated spot beams. Frequency reuse increases the speed, high-frequency bands, low earth orbit capacity, highly elliptical orbit, and geostationary orbit satellite constellations. Combating the COVID-19 pandemic needs a specific application like a signal-to-noise ratio, link budget, and time-variant channel for communication standards. The integration of low earth orbit combines with geostationary earth orbit (hybrid) constellation is a potential solution to numerous applications. This hybrid will benefit flexibility, scalability of low earth orbit, and the lower latency satellite. The high capacity with wide-range coverage of existing geostationary earth orbit constellation can be accomplished. This system will also demand an optimization routing system that will routes to the low earth orbit when it demands low latency with geostationary earth orbit in transmitting a large volume of data during the day.

Inspiration for satellite IoT communication plays a vital role in connecting the smart things scattered in many geographical areas. There are many instances where the cover-age area of critical applications like COVID-19 has to be large. Furthermore, the longevity multicasting facility for large coverage areas is moderately more beneficial with the satellite. Therefore, the satellite can launch cost-effective communication among the smart objects that may inaccessible to the rest of the world. Such a case where a large number of data interconnection is demanded with reliability on the wired and wireless internet connection is not a better option. The satellite can become the alternative and have a cost-effective solution. The bandwidth of the satellite narrow can be recycled for IoT applications [57]. The strong demand for satellite communication seems to be extreme topography like the valley, steep slope, and cliff. The chances of failure geological disasters are more in the network with the satellite IoT, which

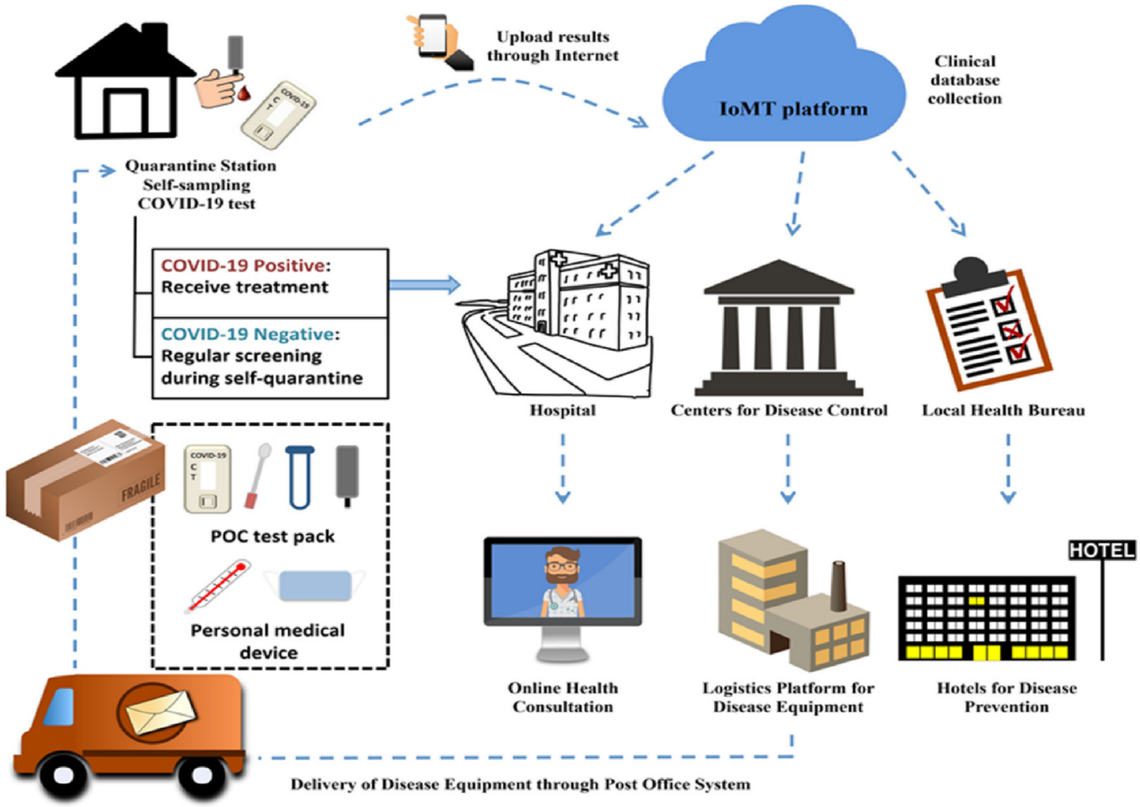

Fig. 1. Schematic IoMT medical eco-system in fighting COVID-19 pandemic.

can be tremendously useful with an extensive area coverage network. Several IoT devices are located in the urban area like the desert, forest, and ocean to cover specific application; the IoT sensors can be set for internet connectivity by satellite. It is preferable to construct a wireless communication system for the terrestrial network than investing in the base station. Any can opt for a satellite because the wireless communication infrastructures can be easy to damage with natural catastrophes. The multi-satellite coverage is very reliable for IoT COVID-19 applications. Some many wireless networks use in providing interconnectivity for a lot of many users. Such is ZigBee, Wi-Fi, Near Filed communication, and Bluetooth, which partakes in the essential parts of the recent IoT bio-network. It is noted that the ability of the network is only narrow down to the exact area covered. Probably the foremost challenges are the capacity of this network to handle numerous things, which make simultaneously interconnectivity with system communication a certainty.

Satellite IoT can be the furthermost appropriate choice for these problems [58]. The anticipation from the upcoming wireless communication is pointing to a very high data percentage for operators and machines in meeting the great spend difficulties of million users. The satellite can achieve the need of smart IoT, with the investigation done in several countries, demonstrating that countryside areas with the tribal area agonize from low-slung internet connectivity. Deficient internet connectivity has an impart significance on business progress. Therefore, a high request in meeting the interconnectivity demand an enormous number of IoT devise which project in reaching a billion units in 2021, even in the corporate enterprise's application like the oil and gas sector where numerous monitoring is needed for operation and security. Therefore, there is a high need for good, reliable, and high-speed internet access, making the study focusing on high throughput satellites [59]. There is a need to understand the power budget of IoT for each of the applications. The total power demand for satellite IoT with the link is more than the totality of the threshold power retaliated by the IoT sensor and the power loss lengthwise pathway with the IoT system boundary and noise margin. The equation for those above can be presented as

$$PWT \geq PWIoT, Th + PWL + PWNM + PWSB \quad (1)$$

The sign's meaning is presented below.
PWT: Total power transmitted by space.
PWIoT, Th: threshold power needed by IoT device.
PWL: Power loss along the channel.
PWNM: Noise margin.
PWSB: System boundary.

The low earth orbit satellite is mainly used for IoT applications that are not constant from IoT. The power budget presented in the above equation is not constant apart from PWIoT; Th rather, they are variable of distance and time concerning the satellite location and IoT network. The PWT is variable with the right-hand side parameters. Simultaneously it has to be high value so that the IoT sensor terminal can always get the minimum power PWIoT, Th. Furthermore, the IoT network's energy efficiency has a bandwidth efficiency, which is available for deployment.

In [60], there is the transmission of two levels in the hybridization aspect of narrow-band IoT, and the receiver is -65Bm compared to IoT. However, the IoTs need a small amount of power with bandwidth. The sensors can be power by solar, which the battery can last for ten years more. This can be applying to the COVID-19 fighting apparatus and use in developing countries.

4.1. *Application of satellite IoTs system*

There are many applications possible with the satellite IoT network. Space provides an extensive and comprehensive coverage area, better availability than a cellular network, the better interconnection between IoTs with the internet. To extend IoT coverage beyond cities, the hybrid of IoT and satellite together helps to cover all. In [61], the integration network covers the most part, which is explained in Fig. 2, showing typical satellite network architecture. Furthermore, the mission to fight COVID-19 with IoT is more reliable with the cellular network's

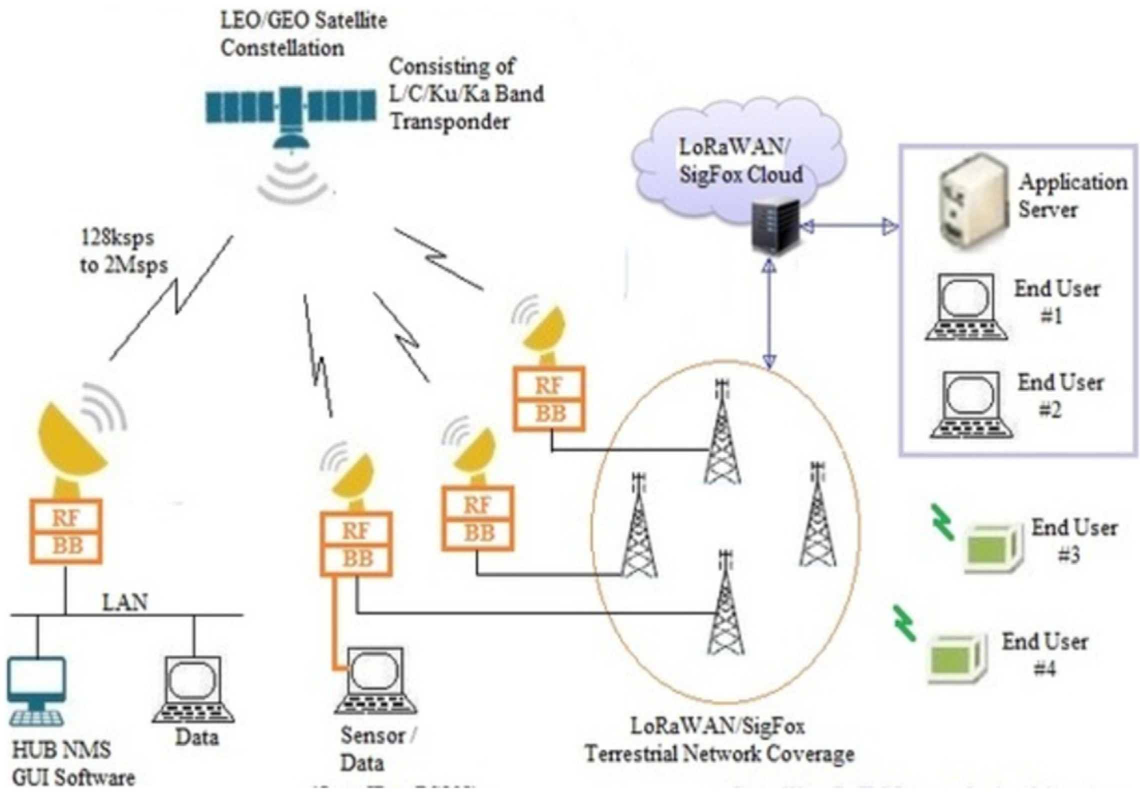

Fig. 2. Satellite IoT network architecture.

availability. There is a typical application of satellite IoT net-works; such is a precarious application where it involves the natural disaster like a hurricane, flood, tornadoes, earthquakes with tsunamis, in the case the cellular infrastructure suffer significant damages which can cause the network to go out of operation for a very long period. The satellite, in other words, is not affected by those natural tragedies. Like-wise, the appropriate deployment of IoT sensors can be made invulnerable to the problem. It is recommended that a hybrid satellite IoT network is better and ideal for these natural tragedies.

Another application deals with location, which deals with the destination's position to provide the service. The cellular network and the global position system (GPS) satellite are used for location determination. The results from GPS with the cellular network combination are not accurate, but the IoT network, together with satellite support, will produce a better outcome [62]. The GPS with satellite with IoT is better and serves as an alternative for accuracy. Further, another application is surface with air navigation system. This deals with the particular motion location-related information concerning the severe nature; there is a need for timely information about their system operations. The real-time information can be provided through the specific precarious applications of satellite IoT. This system needs the harmonization between satellites with ground information. In space, IoT, satellite, and IoTs can be so perfect. The dual operation of ground-based IoT sensors with the satellite providing better accuracy when compared. In the application of satellite IoT to smart agriculture, it is widely known that agriculture is a vital sector in any economy because it is the nation's food basket. This sector brings revenue to many nations.so there is a need for smartly IoTs to actualize the nation's goal and increase productivity.

The IoT's medical sensor network devices are discovered to be vulnerable to more security attacks than other network devices. Some solutions can protect patient's data during the transmission to some extent, although it may not be a guarantee but can prevent some attacks. The patient database administrator will not disclose sensitive physiological patient data, just anyhow only on a special mission. In protecting patients' data in IoT, some solution has been developed, such as secret keys for encryption and authentication, public key cryptosystem, message authentication code, etc.

The utilization of resources for agricultural smart IoTs needs precision farming that knows the exact amount of resources with the provision optimized harvest, known as smart agriculture, which can be gathered from the sensors of satellite IoT networks. This will make the farmer monitor many features like humidity, temperature, fertilizer concentration, and many more. Another application is location tracking, which is used for security, like police, military, and navy, to track down criminals on the spot assessment. Kids are tracked too by the parents. The logistic company, goods, consignment, and deliveries can be tracked by the recipients and sender; the air traffic control tracked for flight movement, pets, and animals are tracked by the owners. There is a need for tracking operation, which needs to be accurate and resource-efficient. There will be achieved with satellite cynosure on track because of its efficiency and accuracy.

4.2. Application of satellite IoT to COVID-19

Recently, at the beginning of 2020, the whole world is battling the pandemic, which is caused by the new severe respiratory syndrome coronavirus, which has the first wave of the pandemic that started in 2019. The second wave was visible in 2020. The world is striving to control the unprecedented of spreading the virus with the development of vaccines [63]. The hybridizing satellite and IoT will help a lot to combat the COVID-19 further. Satellite IoT is best to prefer to cover a large area than other IoT with a cellular network. The satellite application domain is huge to list all utilities. Fig. 3 shows satellite-based IoT for COVID-19 pandemic schematic, and the satellite covers a wide earth surface area with interconnected. The sensor is coordinated and interconnected in the sensing area to support the base station uplink communication. The earth station is interconnected with the satellite for smooth operation. A yearly emerging application is added to what is

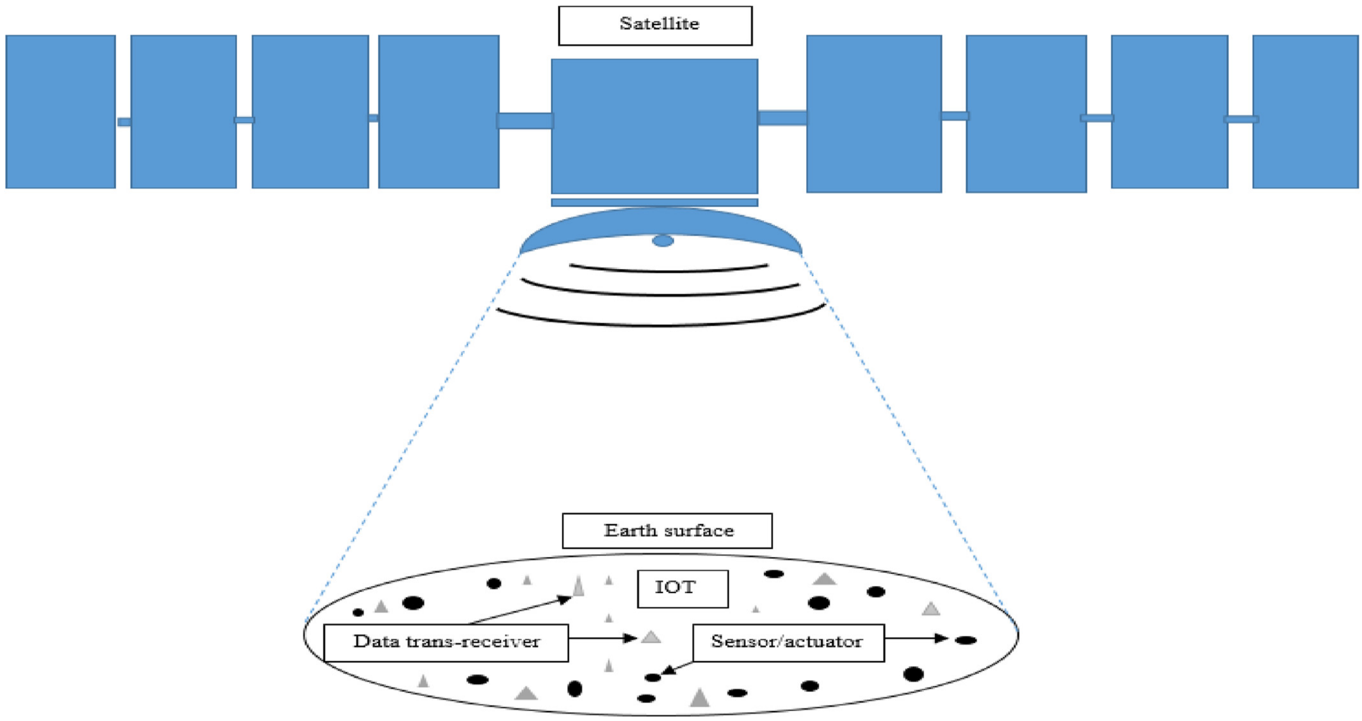

Fig. 3. Schematic satellite-based IoT for COVID-19.

existing. The low earth orbit satellite is broadly used for satellite IoT-based applications. Even recently, the deployment of a very low earth orbit satellite for operation. The power budget for low earth orbit and very low earth orbit satellites is much lower in the geostationary earth orbit satellite. Many medical experts expect solutions and treatment to control the spread of the COVID-19, which does not show acceptable results for now. There is a global requirement for monitoring patients with symptoms of COVID-19 infections to control infected populations. IoT technology received significant attention in the health system in recent years, where it plays a significant role in different phases of several diseases [64]. This current COVID-19 pandemic has a possibility of a high rate of being contagious; there is an essential need for patients to be connected with and be monitored by the physicians to be proactive in any case. This study designs an antenna model with a KU/K- band frequency best used for satellite-based IoT. We investigate the role of IoT in response to COVID-19. These pandemic are in phases: early diagnosis, the quarantine state, and the recovery stage. In the early stage of COVID-19 diagnosis [65], an early essential need to diagnose faster with the high rate of the contagious where patients are to avoid the spread of this deadly virus. Early diagnosis of patients curbed the spread of the virus, and this is the one good way of controlling measure with the patient receiving adequate treatment. The fact remains that the IoTs device will speed up detection processing in capturing the patient information. A typical example is capturing the patient's temperature using many devices and taking a sample of suspicious cases. The second phase is the quarantine time [66], which is an important period of this ease. After the patient has been diagnosed with COVID-19, it simply means the patient needs to be isolated for urgent treatment after the diagnosis. With the satellite IoT device, the patient can be monitored remotely [67]. In some nations, once you are diagnosed, you are ordered by the authorities to stay at home for isolations if no isolations centers. Without human interaction, fumigation of the area can be done. Such of these is the implementation of tracking wearable bands and disinfecting devices [68]. Although most people whose symptoms are mild can recover by staying at home without the treatments, the guarantee is not certain after recovery. There can be reinfection with different symptoms of COVID-19 [69]. There is a high probability of returning symptoms with potential infectivity for the recovery phase [70]. In other to avoid happening, social distancing is vital with the deployment of the satellite-IoT device, with the inclusion of bands and crowd monitoring, ensuring adequate distance is maintained. It has been seen that IoT technology with the reinforcement of satellite has proven it relevant in assisting in fighting COVID-19, including the help of the medical practitioner and the authorities in getting the updated data of pandemic levels. As we have explained, the satellite's role and need to complement and aid IoT (hybrid satellite and IoT) deliver accurate and efficient service. In this healthcare service like COVID-19, as mentioned before and other health issues, several aspects like nursing, hospitalization, surgery, and monitoring are supported with satellite-based IoT, a case scenario telemedicine pre-hospitalization can be provided with the IoTs. Many IoT devices are hybridizing with satellite help more, such as drones, wearables, robots, IoT buttons, smartphones, and cellular applications, which are majorly used in combating COVID-19 presented in Table 1. In [71,72], a survey shows that app-enabled computed techniques that received and process inputted data while they either worn or stick to the body bands, watches, and glasses. This smart wearable is designed for different purposes depending on the particular domain, such as health care, fitness, lifestyle, and many more. Meanwhile, the privacy of data is a significant issue in the development of these devices. It is forecast that health care's service provider will spend approximately $20 billion-plus yearly till 2023 on wearable IoT device monitoring [73]. The IoT wearable can cover a wide range of areas with satellite application, with different wearable tools like smart thermometer [74] the smart helmets (33), proximity trace [75] satellite IoT such as this paper antenna frequency range from ku/k-band upward satellite communication. The drone application is a major technique without human or small operation for remotely monitoring [76]. There was a case scenario in Italy and Austria when the first drone use in 1849 with bombs [77]. The drone is an uncrewed aerial vehicle that works with sensors, communication services, and GPS. Implementing IoT with drones will make it possible for proper monitoring, tracing, search, and deliveries [78]. The smart drone will operate with a little controller, and limited-time energy is required. This is good and efficient for general health care services, fire service, military, and agricultural sectors. There are different types of IoT drones, such as medical drones [79],

Table 1
Applications of technologies to Covid-19.

S/N	Satellite- IoT Machinery	Specification	Implementation
1	Low earth orbit satellite	Satellite communication can be form hybrid with IoT to cover a large area, used for health care service, military, and other applications.	Function in hybridizing satellite and IoT will help a lot to combat the COVID-19. Satellite IoT covers a large area than other IoT with the cellular network.
2	Drones	This is a sensor-equipped with sensor aircraft that uses a camera, GPS, and satellite communication system. This is flown with fewer human interactions.	Function in tracking, monitoring, searching, and delivery. Ability to reach remote locations. Less human Interaction.
3	Smartphone	A software application designed within a mobile device	Function in monitoring and tracking. Cost-effective
4	Wearables	App build techniques in receiving and processing data, this is worn on a patient	Role in monitoring, reducing hospital visit, an improvement in the quality of health care for sick people, safer and efficient
5	Robots	A machine programmed in complex handling action like a human.	Function in maintaining, disinfecting, reducing human interaction, and reduction in mental health problems

surveillance drones [80] disinfectant drones [81], all of these are used in fighting against COVID-19. Another application is the robots [82]. A robot is a machine that resembles a creature and is capable of moving independently. The implementation of internet-based robots will make things done more comfortable and faster, with less human effort and the emergence of network-based robots [83]. These pandemics need techniques that will have less human interaction for the safety of both the health workers and the patients. Robots will help a lot in fighting COVID-19, there are categories of robots such as tele robots [84], autonomous robots [85], and collaborative robots [86]. As we advance in application to COVID-19, IoT buttons, this deals with the satellite's program through wireless communication [87]. The code is written on the cloud with the device performing the different repetitive tasks with buttons pressing. In such cases, the IoT button will enable the patients to complain in any hospital restroom or any point with just pressing of buttons [88]. Another application is the smartphone software designed within a mobile device [89]. We had about 4 billion active smartphones in 2020, and this will make the efficiency of satellite IoT in various sectors like health care, fighting diseases, COVID-19, not only that even in retail and agriculture [90]. There are many smartphone application which with the use of satellite IoT deployed in fighting COVID-19 such as, Stope corona [91], stay home safe [92], trace together [93], detect a chem [94], social monitoring [95] and be aware [96]. Therefore, it is required that with satellite or satellite cover a more comprehensive range with hybridizing with IoT will help fighting, motoring, treating, and take data records of the global pandemic with limited human interaction.

5. System model analysis

This design consists of a circular ring in a rectangular tilt resonator. The FSS is the superstrate. The main aim of this design is the enhance the gain and bandwidth of the proposed antenna. The design flow chart in Fig. 4 shows how it models, and Fig. 5 present the proposed antenna's schematic. In this design, radiation properties improve with the FSS due to controlling current distribution that reduces the energy leakage near antenna edges. The intensification of the antenna proves the efficiency using FSS configurations. The FSS focused on the radiation to the broadside direction and reduced it at the back. It is noticed that the hybrid of FSS is more directive with the comparison to only design. Surface wave reduces, and the power of the boreside is also increased. With this, it shows that the FSS enhances the radiation properties, directivity, and gain. In the near field, the performance demonstrates that the antenna becomes unidirectional with the hybrid to FSS as the main lobe direction fixed the broadside, leading to E and H radiation improvement. This model has a dimension of 1.6 x 1.6 mm^2, an optimized size of 23.4 x 25mm2. The antenna is fed with a 50 Ω microstrip line. The dielectric is constant with the loss tangent numerical value, which defines the dielectric material's permittivity.

Furthermore, it is denoted by 'ε.' tan δ. The antenna's conceptualization takes process with each state simulated to get the desired result, and the initial stage is the development of an antenna in a rectangular shape, two semi-circular arcs were added to each end with the ring at the center of the patch. In the process, the parameter does not change, leading to each impedance bandwidth till the original aim was achieved with the process of design simulated primary model final return loss is shown in a result of antenna 1 to 4 final. The FSS was made up of dielectric substrate with roger R03003(lossy) the dimension 2 .9 mm x 9 mm, the cylinder shape is made up of copper annealed (lossy metal), the outer radius (r) is 3.95 mm, the inner radius is (ri) 3.5 mm, the right height is 0.035 mm, the brick line is (ri) 1.5 mm the structure unit cell band-stop is designed. The simulation was done with CST; the radiation pattern shows that the distribution radiated and earlier explained the diagrammatical representation. The integration of FSS enhances the gain and directivity. The current was examining before integrating FSS, and after also FSS, it shows how the efficiency of power transfer from the transmitter. This model operates at 12 GHz to 18 GHz, which is the Ku-band spectrum. All this demission in this paper is chosen by parameter sweet of the CST-MW.

6. FSS band-stop structure analysis

We design a band-stop FSS, this design evolution starts with the implantation of the outer ring shape. One of the objectives is for the FSS to serve as a band-stop, not allow the band to pass a specific range. Minimize visible light blockage and enhance the rejection of the specific GHz signal of the polarization, a circular tiled shape FSS element is selected. The inner line interface to combine with the shape in miniaturization purpose of the unit cell size. It is titled at 45 degrees. The radiation increases the gain but reduces the bandwidth of the antenna and the phase wave propagation. The design FSS unit-cell band-stop structure for Ku-band designs, simulated with CST microwave studio software. This designed structure is designed to act as a filter, the unit cell dimension determines the resonance frequency, the demission is chosen by parameter sweep optimization showing in Fig. 6 and the final 3D view in Fig. 7 from the CST-MW. The permittivity of the substrate is controlled filtering action. The dielectric substrate is made of roger R030003(lossy) with 9 x 9 mm, the outer radius = 3.95 m, inner radius = 3.5 m.

6.1. Effect of FSS on antenna

In this paper, the FSS array works as a superstrate over the proposed antenna design to improve the gain. The superstrate introduces cavity height is adjusted for the optimizing process. The FSS is placed with requires spacing and adjustment for further gain enhancement. The ground plane acts as a shield against the back radiation, with the ground plane and superstrate acting parallel reflected. The resonances occurred when the radiation and reflected wave one round trip are in phase and act as a resonating cavity. Further, a high power signal will emerge from the antenna that will result in high gain. The simulation process shows that the proposed superstrate antenna provides bandwidth coverage with improvement in gain. This is with the height of the superstrate layer from the ground plane estimating with the equation

$$h= (\varnothing\_FSS+\varnothing\_GND)\ \lambda\_0/6\pi+\lambda\_0/3\ N \quad (2)$$

In this, the ∅_FSS is the reflector phase of the unit while ∅_GND is the

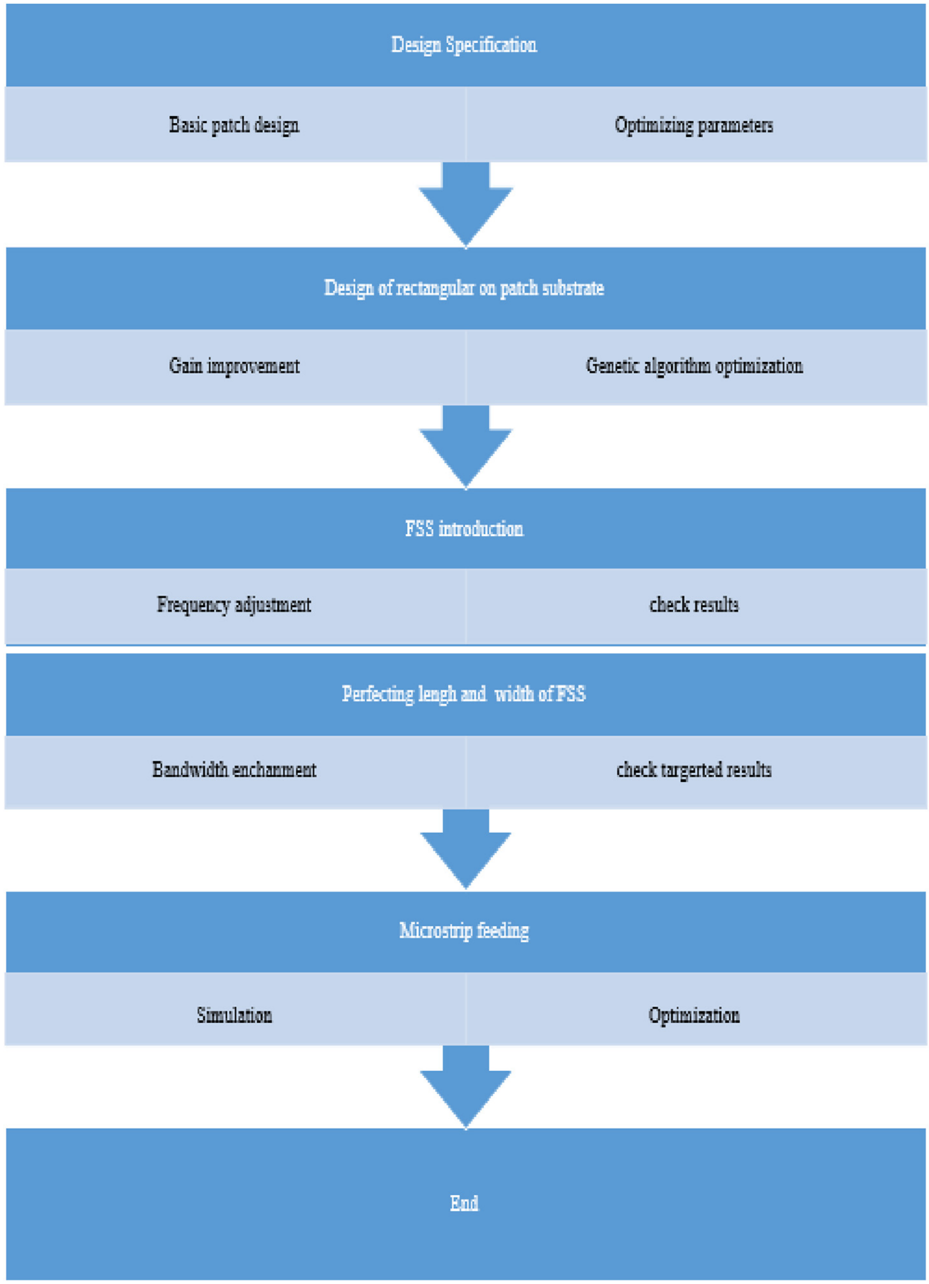

Fig. 4. Design flow chat.

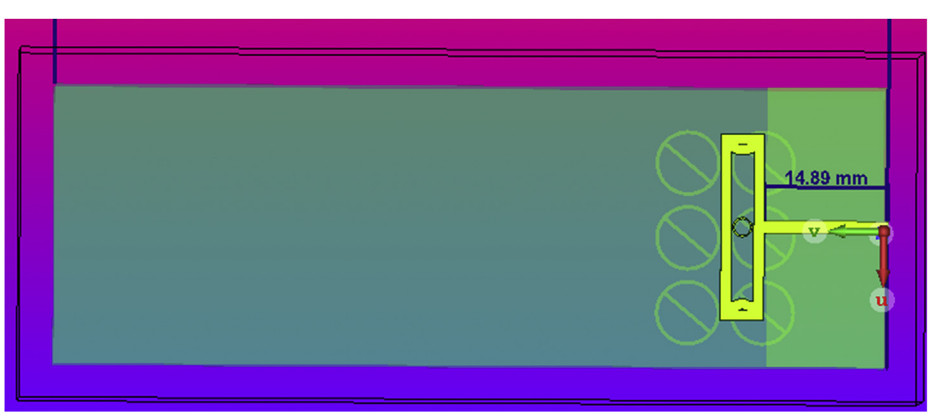

Fig. 5. The proposed antenna.

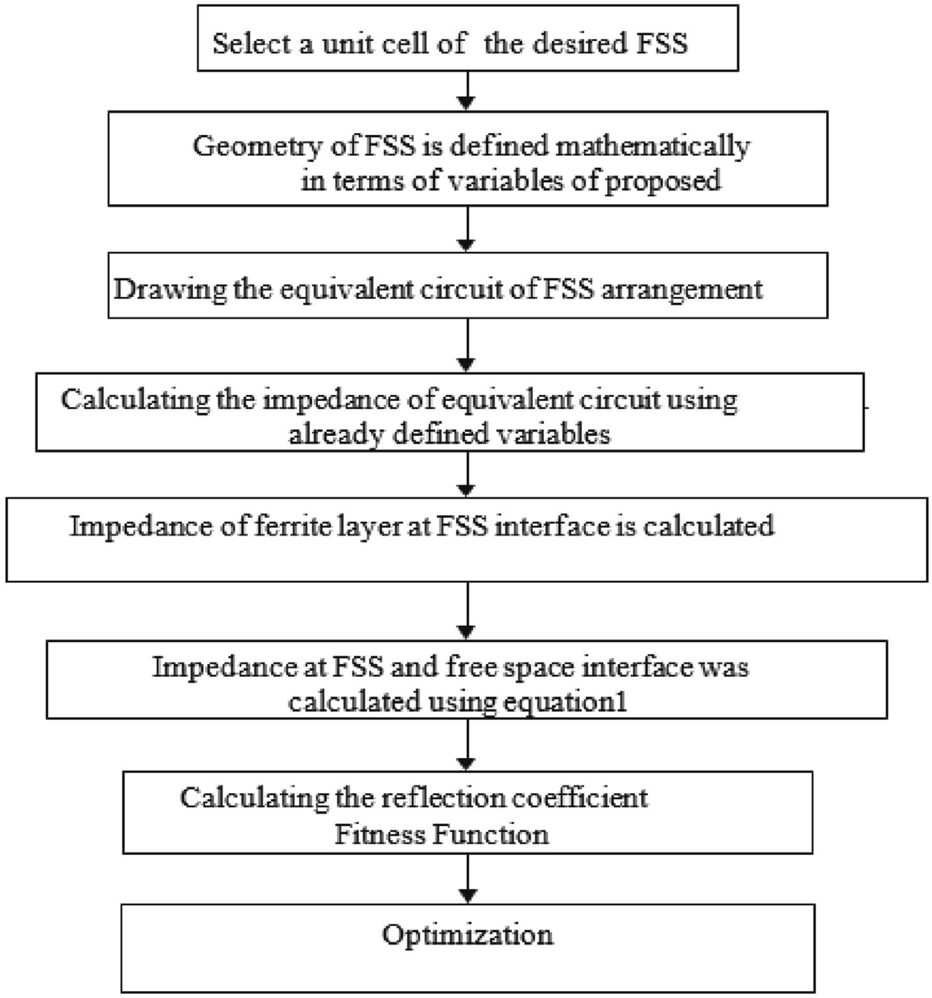

Fig. 6. Step to optimization FSS.

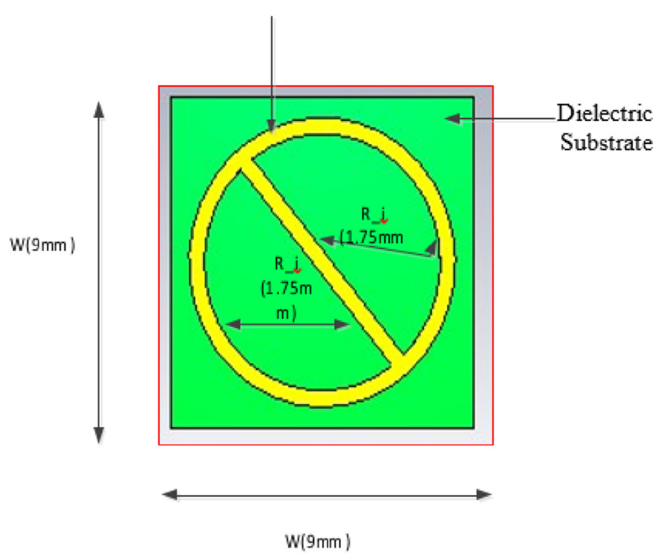

Fig. 7. Unit band-stop cell FSS.

reflection phase of the ground plane. The π in the case λ_0 is the free space wavelength and the superstrate height from the antenna ground plane with an integer ranging from 1 to 2. The superstrate layer's height is calculated considering free space wavelength λ_0 corresponding to the resonance frequency. The results show that with FSS, it was enhanced, the reflection coefficient obtains exciting with a port that terminates on 50 Ω. When the antenna is loaded with FSS superstrate at λ_0/6π and λ_0/3 from the proposed antenna's ground plane, the bandwidth improved. The antenna geometry is symmetric with the center, reflection coefficient from the port provides a good result.

7. Result and discussion

This model results show satisfactory performance shown in Table 2. The process of designing before arriving at the final was simulated in Fig. 8. The return loss of the antenna process. The antenna's simulated reflection coefficient was loaded with FSS superstrate with an optimized height from the antenna's ground plane; as discussed in the previous session, that antenna hybrid with FSS covers a wideband compared to antenna alone. The simulated return loss from the antenna without FSS and FSS in Fig. 9 shows that the antenna without simulation depth was at -23 dB at 10 GHz, and the antenna with FSS has a depth simulation -49 at

Table 2
Performance of the proposed on gain and directivity.

Frequency (GHz)	Gain without FSS dB	Directivity without FSS dB	Gain with FSS dB	Directivity with FSS dB
12	3.74	4.09	6.26	6.62
13	4.94	5.14	6.00	6.41
17	4.03	4.25	4.77	5.43
18	3.61	3.79	5.86	6.63

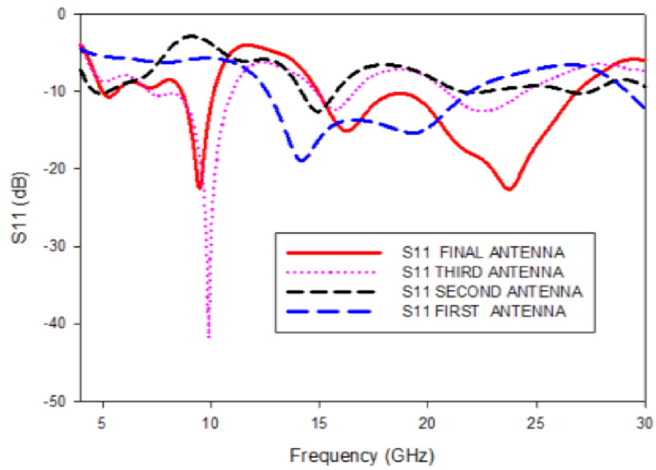

Fig. 8. The return loss of the Antenna process.

14 GHz, which is the frequency of interest. The simulated radiation in Fig. 10 for the proposed model, as said before the FSS surface, focuses on the radiation to broadside direction and reduce it. The current distribution in Fig. 11 demonstrates a reduction near leakage of antenna edges, as previously mentioned. The directivity and gain without plus with FSS in Fig. 12 also Fig. 13 show that the FSS layer's antenna is more directive with low interference where directivity is enlarged. The gain is enhanced with the integrating of FSS. This model was simulated with CST micro-wave studio 2019, and in other to get better validation, it is validated with the frequency domain solver. As explained result show, after adding the FSS, it improved more to desirable and exciting results than the ordinary with a bandwidth of 3.63%. The proposed impressive result is suitable for satellite networks, which hybrid with IoT can provide sustainable long-time solutions in fighting the COVID-19 pandemic and address IoT's weakness. Satellite communication plays a major role by providing the interconnectivity between the smart thing scattered over many geographical areas, several instances in which the coverage of health sector application has to be wide area. The longevity and multicasting facilities of the wide area are comparatively more beneficial through the satellite. The satellite can establish a cost-effective communication between the smart objects, which may be inaccessible to the rest of the world. In some cases, where huge data interconnection is needed with the wired and wireless internet connection's reliability is not a good option, but the satellite can become the alternative cost-effective solution. Therefore, the proposed antenna with satellite frequency with the hybridization with IoT will enhance the fight against COVID 19 pandemic.

The Parameter specification obtained from the simulated structure shows good directivity of 6.25 dBi, the gain pf 6.64 dBi, Voltage standing

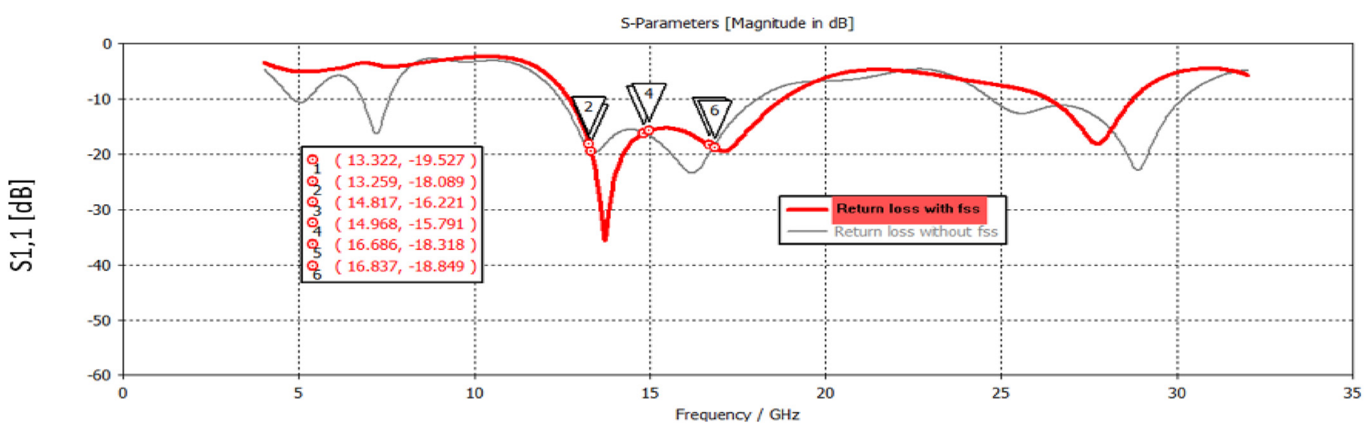

Fig. 9. Antenna without FSS (a) and antenna with FSS (b).

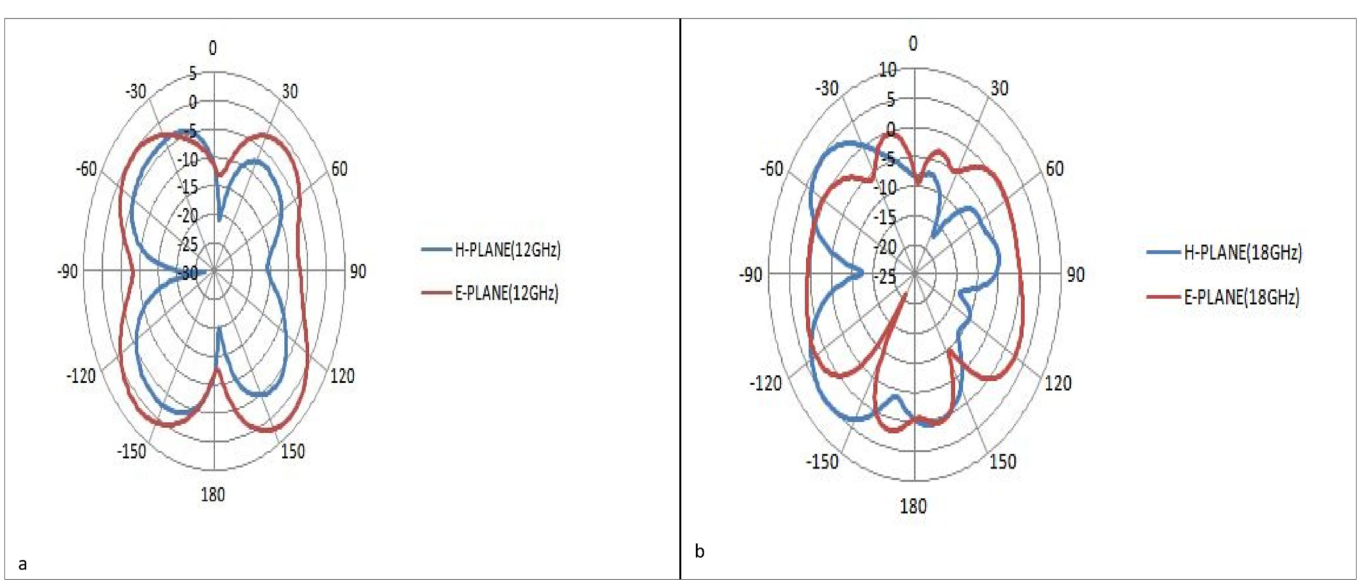

Fig. 10. FSS polar H and E Plane 12 GHz (a) and 18 GHz (b).

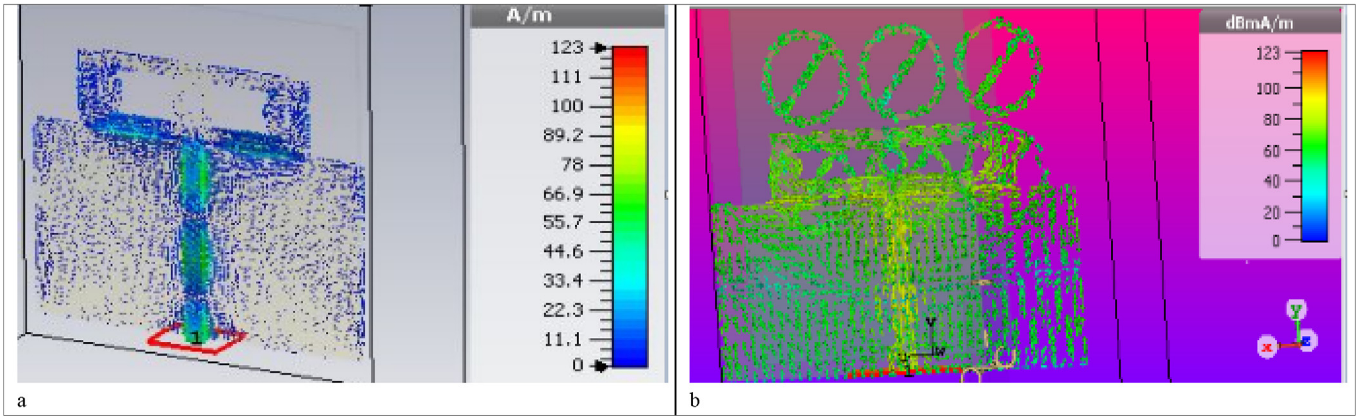

Fig. 11. The current distribution of antenna (a) without FSS (b) with FSS.

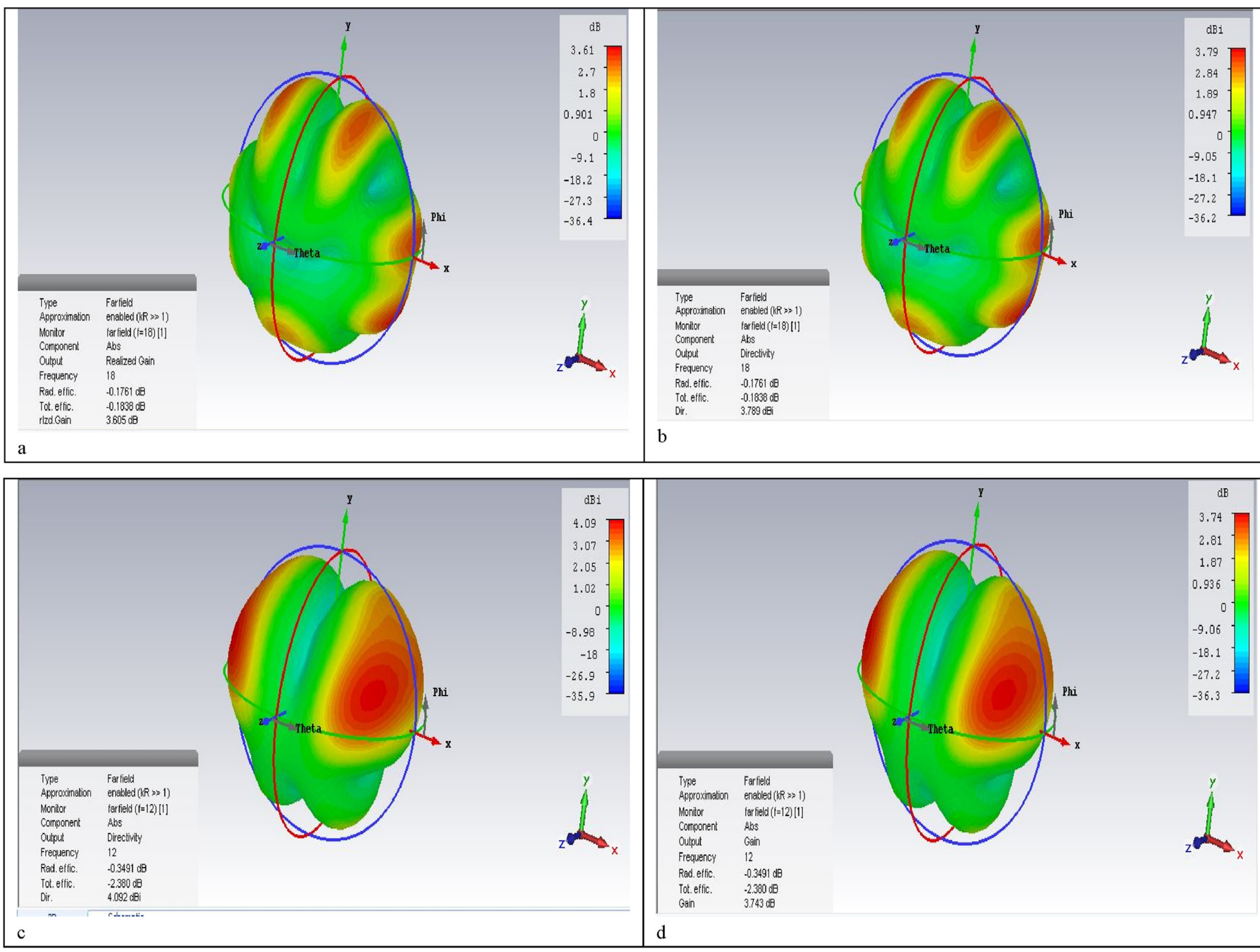

Fig. 12. Gain and directivity without FSS at 12 GHz and 18 GHz Fairfield.

wave ratio 0.09443, Radiated power 0.062198, accepted power 0.06443, Max U is around 0.00332, Incident power 0.06825, and Efficiency (ŋ) achieved at the impressive, reasonable rate of about 92% and this shown in Table 3. To understand how the antenna structure's operating mechanism with or without FSS works, the current distribution of the proposed antenna without FSS and FSS is also presented.

The 3-D view of the Fairfield monitor of gain and directivity clearly shows the components, Abs, frequency, read efficiency, total efficiency, approximation, output and real gain, and total directivity.

8. State of the art model comparison

The state-of-the-art comparison of the proposed FSS is compared with the most relevant literature. In this study, a comprehensive literature

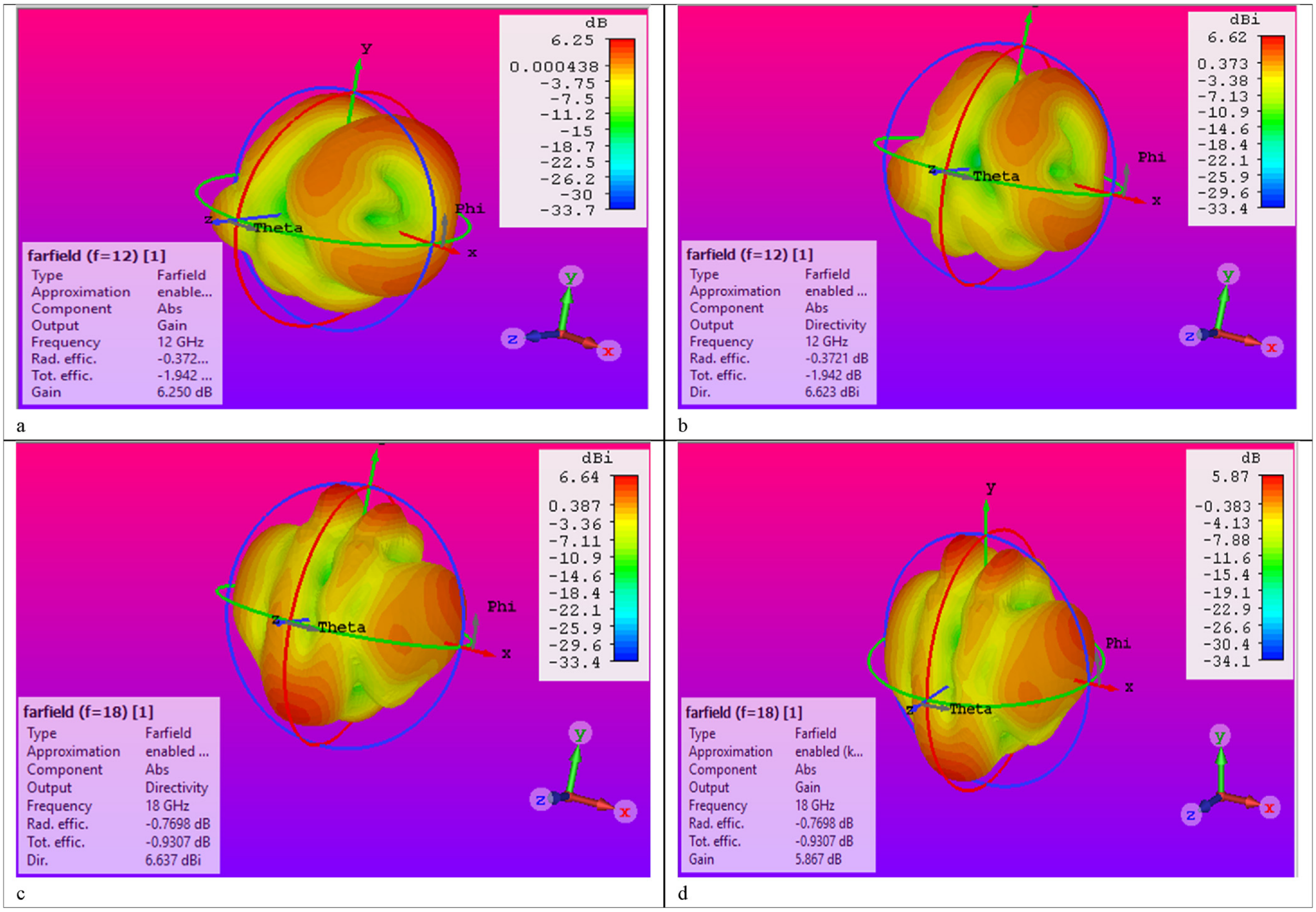

Fig. 13. Gain and directivity with FSS at 12 GHz and 18 GHz Fairfield.

Table 3
Parameter specification.

Specification	Value	Unit
Peak Directivity	6.2534	dBi
Peak Gain	6.6421	dBi
Voltage standing wave ratio	0.09443	%
Radiated power	0.06219	W
Accepted power	0.06443	W
Max U	0.00332	W/sr
Incident power	0.06825	W
Efficiency (η)	0.92353	(J)Joules

review was conducted with depth inside on FSS superstrate application to get a useful purpose. Table 4 expose the proposed FSS with antenna exhibiting a better performance characteristic with a single layer with a novel of titled rectangular FSS superstrate when it was a design and incorporated with the antenna. The antenna design gain at 12 GHz was 3.74 dBi with a directivity of 4.09 dBi the FSS superstrate was added, increasing the gain and poor directivity to 6.26 dBi, 6.62 dBi, respectively. At 18 GHz, the gain without FSS was at 3.61 dBi and directivity at 3.79 dBi, and drastic improvement occurred with incocating the FSS superstrate with gain and directivity enhancing 5.86 dBi 6.63, respectively. The comparison shows that titled rectangular ring FSS superstrate and a single layer incorporating a microstrip antenna structure better gain directivity.

9. Conclusion

This paper presents a frequency selective surface as a superstrate for a

Table 4
Comparison with other work.

S/N	NUMBERS OF LAYERS	FSS TYPE	GAIN WITH FSS dBi	ANTENNA TYPE	REF
1	3	Tuneable sandwiched	3.7	Dipole antenna	[97]
2	2	Sustainable absorber	3.6	Electronically beam steerable antenna	[98]
3	2	Cross shape and wire grid	3	Thin dielectric antenna	[99]
4	2	Holey dielectric	2.3	Microstrip	[100]
5	2	Circular slot	3.25	Resonator	[101]
6	2	Double layer	3.97	Microstrip	[102]
7	2	miniaturized dual-band	3.5	Standard horn antenna	[103]
8	2	Double Layer	3.3	Square	[104]
9	3	square resistor	5.7	Polarized horn antennas	[105]
10	2	Control	3.2	Monopole Antenna	[106]
11	3	Triple band	2.5	Triangle slot antenna	[107]
12	2	Multioctave	3.8	Ultra-wideband	[108]
13	3	Triple band	2.5	Slot antenna	[109]
14	2	Second band-pass	4.0	Wide slot	[110]
15	2	Integrated	2.7	Beam tilting	[111]
16	Single	Tilted Ring Rectangular	5.87, 6.26	Microstrip patch	This work

rectangular microstrip antenna with a ring resonator. The model was analyzed, simulated, and validated. It shows that the integrating of FSS improves the performance of ordinary antenna design. The partial ground plane used, the rectangular was tilted at 45 degrees in changing band-stop. This results in the gain and, directivity is enhanced from 3.74 dBi to 6.26 dBi at 12 GHz, with directivity from 4.09 dBi to 6.62 dBi and at 18 GHz the gain increase from 3.61 dBi to 5.86 dBi, the directivity from 3.79 dBi to 6.63 dBi respectively. The performance was studied through computer simulation technology microwave studio (CST-MWS). The proposed impressive result is suitable for satellite networks, which hybrid with IoT can provide a sustainable long-time solution in fighting the 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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