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REGULAR ARTICLE

A Meta Surface Based Patch Antenna for Wireless Space Craft 5G Communication Systems

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In recent years, as per the modern technology and expansion, wireless sensor-based spacecraft design techniques are being used to detect the geometric parameters of humans, becoming a future of innovative research. The meta surface is a two-dimensional periodic structure intended to interact with electromagnetic waves for the control of the presentation of an antenna. The radiating properties of the meta surface-based antenna could easily assess the performance of 5G and space crafts. The operating range of the antenna would be in the band of 5G to fulfill the expected performance of the radiator which is being designed. Meanwhile, the meta surface can restrict the electric and magnetic dipoles functions to interact with the studied antenna. Moreover, the dielectric structured meta surface material having a high refractive index for the detection of wireless sensor systems. In this article, we are going to existing a dielectric FR4 epoxy structure-based meta surface patch antenna to highlight that the proposed radiator has a highest reflection coefficient of – 40 dB, with a valued gain of 7 dBi and a specified bandwidth at different resonating bands. Our results demonstrate that the meta surface has a promising ultra-sensitive qualitative exposure in chemical and temperature sensing, also had a low profile along with size of $0.71\lambda_0 \times 0.71\lambda_0 \times 0.03\lambda_0$ which were measured and fabricated.

Keywords: 5G, Meta surface, Space craft, Wireless.

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1. INTRODUCTION

As per the modern technology space science occupied the highest stream of research given the technical future formulations to move this world with powerful wireless sensor communication systems [1]. To improve the scientific activities in the area of research in various sectors, wireless sensors have become the primary source of study to elaborate on the scientifically significant factors related to space science [2] The technical development in all the areas is the mostly inherent to improving the sensing qualities of the proposed systems [3]. The wireless sensors can detect the wireless sensing to work without power supply capabilities [4]. The main function of these sensors is strategic evaluation to detect humans and monitor the space related activities related to a particular area [5]. The space science technology would be applicable only under the scientific factors of humans and space at equal rate, there are very close resembling factors that exist between humans and space [6]. As per satellite astronomy, it was given clear confirmation that the satellite sends certain spiritual sensors to humans along with the nature gravity [7].

The space research was intended to depict each and every technical gravitational change of our universe and introduce a new technology as per the scientific space design principles [8]. The presentation of the meta surface radiator with its sensing properties can be explained in Section I, Section II elaborates on the innovative scientific and technical importance of the wireless sensors for the patch antenna. The integration of scientific space technology with 5G advanced networks discussed in Section III. The meta surface-based micro-strip antenna design parameters and their relevant significance are mentioned in section IV, the simulated variations are exposed in Section V, and Section VI illustrates the conclusion for this paper.

2. PERFORMANCE OF META SURFACE BASED PATCH ANTENNA

The patch antenna is a latest invention that can integrate the radiator resembling wireless sensor-based communication on a semiconductor chip [9].

The integrated circuit technology allows the high dimensional accuracy for the proposal of the radiator. The geometry of the microstrip antenna entails whole metallization on one of its surfaces and a metal patch on the other side with a dielectric substrate of convinced thickness ‘*d*’. The length of the resonant radiator is $\lambda/4$,

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Table 1 – The proposed antenna parameters

Parameter	L_G	W_G	H_S	L_{S1}	W_{S1}	L_{S2}	W_{S2}	L_P	W_P	h_1
Value (mm)	30	30	1.6	30	30	30	30	24	24	1.6
Parameter	A	B	C	D	E	F	G	H	I	J
Value (mm)	12	4	5	2	3.5	3	9	8	0.5	1

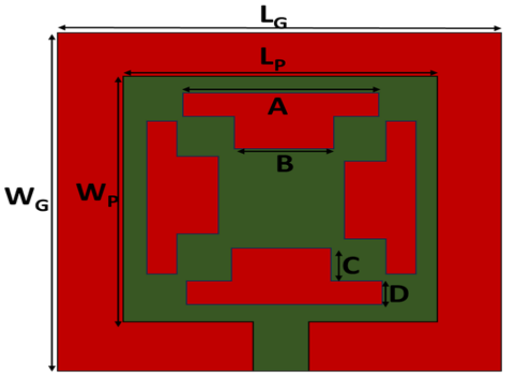

Fig. 1 – Patch for the proposed antenna

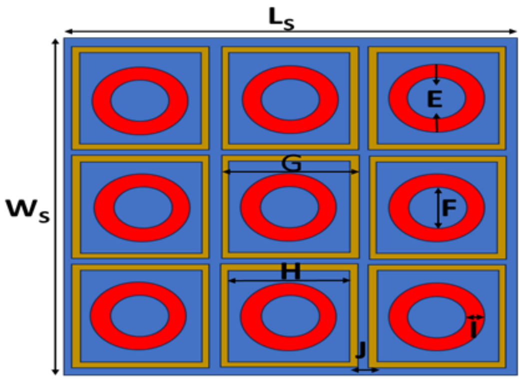

Fig. 2 – Meta surface for the proposed antenna

with a thin dielectric substrate $d << \lambda$. With these variations, the antenna is buried inside the material, as shown in Fig. 1. The micro-strip line is joined to a feeding circuitry that is fed by linking a signal across the patch line and the ground plane. The proposal parameters of a meta surface related patch radiator are listed in Table 1. The patch radiator is a small shape, a less weight, can compatible with microwave integrated circuits hence used in the higher frequency range along with high dielectric constant substrates (Ga, As, Si) that suffer low efficiency and poor radiation pattern. In this study, we are going to elaborate on how the patch radiator improves the sensing properties of the meta surface. The main purpose of using meta surfaces in patch antennas is that the meta surfaces are the artificially structured materials, as shown in Fig. 2, engineered to get beneficial and stringent assets that are not existing in natural materials. Meanwhile, the countless potential of meta surface for using at extreme range of frequencies to predict the amplitude, phase and polarization of the electromagnetic waves for both incident and reflected waves as shown in Fig. 3 [10].

Fig. 3 – Intelligent meta surface

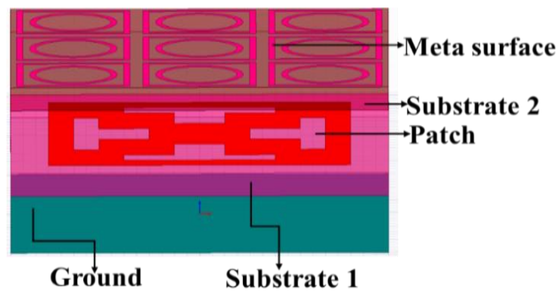

Fig 4 – Layers for the proposed antenna

3. WIRELESS SENSOR FEATURES FOR SPACE CRAFTS

Imagine a world surrounded by orbiting satellites provided with fast communication payloads to depict network information, at all the points on earth at the speed of light with multi-spectral sensors. [5] The wireless sensor space craft's enable space networking and high featured advanced digital signal processing on orbiting satellites [11]. Space officials are putting lots of efforts into the modern 5G technology with the use of advanced, determined wireless sensors to move data fast and securely through the sensor networks [12, 13].

4. ANTENNA DESIGN

The micro-strip patch antenna along with the meta surface is designed as per the geometric operating parameters has 5 layers as shown in Fig. 4. The antenna design consists of the ground plane with the measurements $L_G = 30$ mm, $W_G = 30$ mm. The antenna is reproduced between the two selectively high-frequency substrate layers of FR4 $\varepsilon_r = 4.4$, $\tan\delta = 0.02$, $H_S = 1.6$. The size of the antenna is $0.71\lambda_0 \times 0.71\lambda_0 \times 0.03\lambda_0$ with FR4 epoxy of – 50 dB, as the substrate material, at the nearest operating frequency is 7 GHz, having bandwidth 3 GHz 7 GHz band having the bandwidth 3 GHz with a valued gain of 7 dBi.

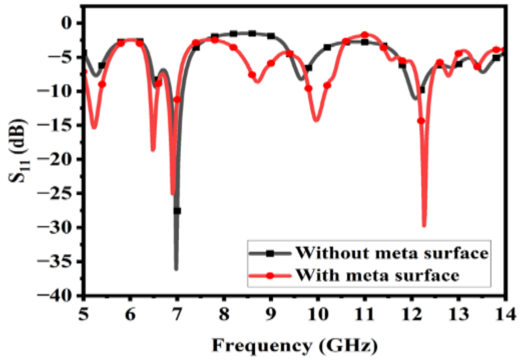

Fig. 5 – S plot for the proposed antenna

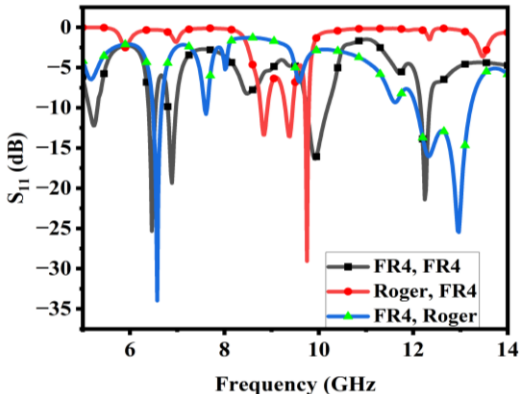

Fig. 6 – Substrate parametric variation

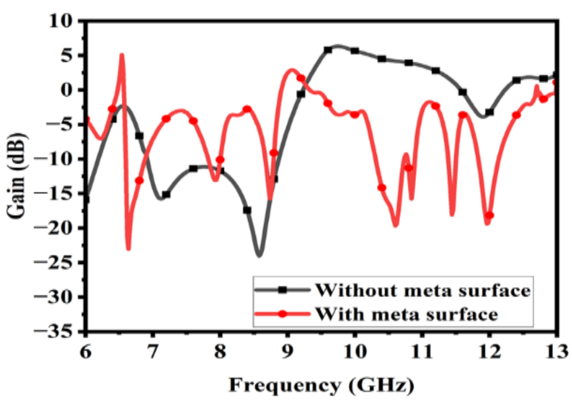

Fig. 7 – Gain plot for the proposed antenna

The substrate 1 has the same dimensions as ground plane, upon this, the slotted patch is designed with the measurements with a height of 1.6 mm. The fractal shaped slotted patch antenna along with rectangular slots have been designed on the radiator to find the gain of the antenna. Another substrate 2 is taken for the grown of meta surface to regulate the radiating assets of the antenna [14, 15].

5. RESULTS AND DISCUSSION

The important radiating elements of the microstrip antenna-based meta surface are the S_{11}, gain, peak gain, axial ratio, current distribution and radiation pattern. The S_{11} parameter delineates the amount of power reflected from the receiver to the transmitter could easily be assessed with the variation of the return loss, as exposed in Fig. 5. The substrate parametric variation decides the performance of the radiator as shown in Fig. 6. The gain is optimised by an array using square patch cells with a feed line of 50 ohms, along with a single patch gain of the antenna could generate of 7 dBi, as shown in Fig. 7, gain of the antenna is represented by the radiated power in different directions. The axial ratio describes electromagnetic radiation with circular polarization, and the amount of reflection that could occur due to the radiation loss can be detected with the axial ratio parameter as shown in Fig. 8. Another essential parameter is the peak gain, which states how much power is released in a particular path with proper polarization, as shown in Fig. 9. After measuring all these parameters, another factor that influences the property of the radiator is the distribution of current. The feed location and radiator element placement with some physical properties improve the amount of current flowing through the meta surface antenna as depicted in Fig. 10. The magnetic and phase variations of the current distribution was defined in terms of the total current flows through the antenna. The radiator radiation, efficiency depicts the amount of radiation intensity required to restrict the power between feed and the radiating elements as revealed in Fig. 11.

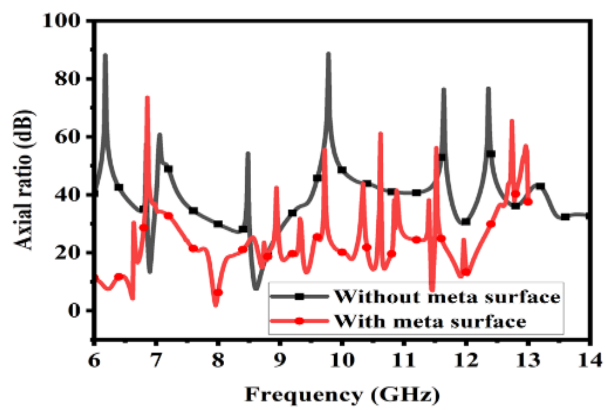

Fig. 8 – Axial ratio for the proposed antenna

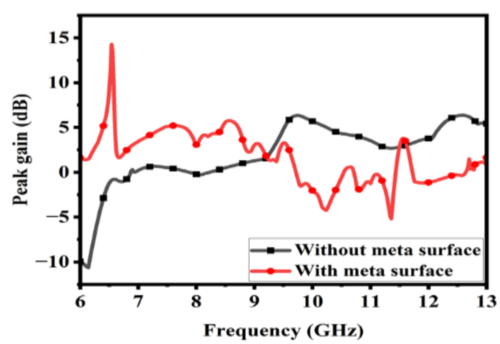

Fig. 9 – Peak gain for the proposed antenna

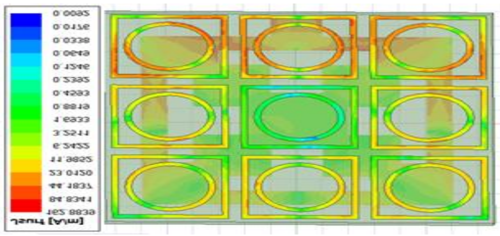

Fig. 10 – Current distribution for the proposed antenna

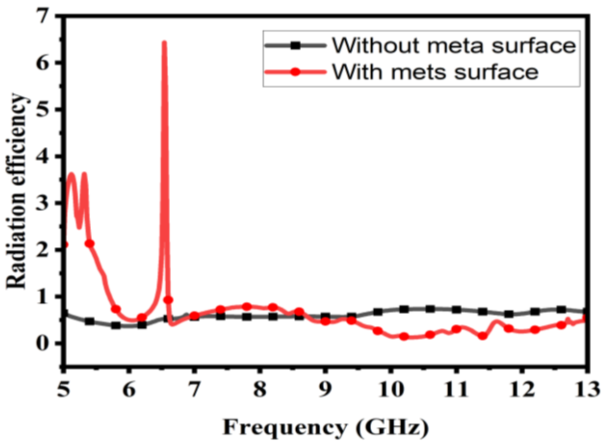

Fig. 11 – Radiation efficiency for the proposed antenna

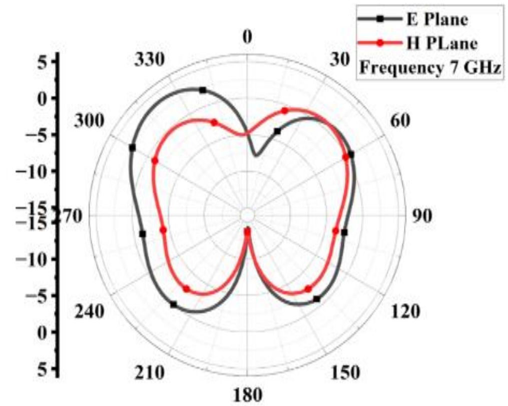

Fig. 12 – Radiation pattern for the proposed antenna

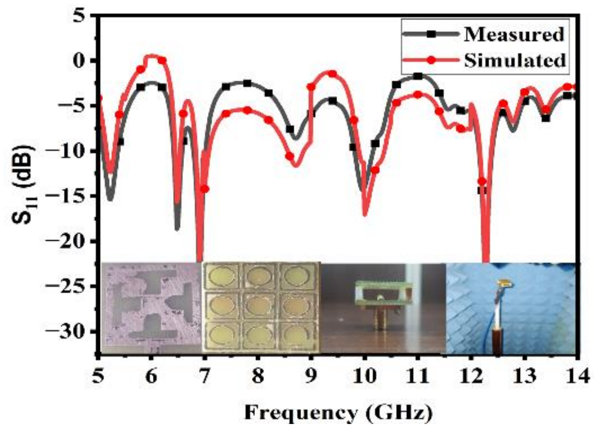

Fig. 13 – Fabrication set up for the antenna

Table 2 – The proposed antenna performance comparison with the other works

Ref	Antenna type	Antenna size (λ_0)	Frequency (GHz)	S_{11} (dB)	ARBW	Gain (dBi)	Layers
5	Fabry parrot	2.5 × 2.5 × 1.27	25	30	3.9	4	3
7	Meta surface	0.71 × 0.71 × 0.06	30	25	7	3	3
8	Stacked patch	2.43 × 2.43 × 0.08	23	26	5	2	2
10	Meta surface	1.13 × 0.63 × 0.25	24	27	6	6	3
Proposed	Meta surface	0.71 × 0.71 × 0.03	7	40	10	7	5

The radiation pattern shown in Fig. 12, for with a meta surface indicates how the electromagnetic wave is transmitted in a designed direction without any loss. The radiating properties of the antenna for both E plane and H plane have been shown in the radiation pattern variation. A five layered meta surface antenna is simulated and fabricated as shown in Fig. 13, with an adequate processing and fabricated steps showing the meticulous performance of the radiating based meta surface radiator. The comparison of proposed work in terms other works has been compared in terms of size, gain and bandwidth are shown in Table 2. It also indicates how well the proposed antenna is attaining its performance in comparison with the splot, gain and other important elements of the other works.

6. CONCLUSION

In this article, a patch antenna based meta surface for wireless sensor space craft systems is discussed. The performance of the MTS dielectric material based meta surface antenna generates multiple bands with a gain of 7 dBi along with a 3 GHz bandwidth at the nearest band operating frequency 7 GHz. The performance of the proposed antenna was depicted as per the variations of antenna radiating elements. The S_{11} has shown the return loss of 35 dB to transmit electromagnetic wave with the less reflections. By assessing all the radiating parameters of the proposed antenna, we can conclude that radiator is working the stringent functionalities with the relevant properties. The simulation results have been verified with fabrication and measured the prototype results. The measured versus simulated results indicates that the fabrication of an antenna delivers better performance over the simulated one. As per the proposed design we can reveal that the operating frequency range of proposed antenna match up with the integrated space craft 5G systems. The important functions of the studied antenna were described for attaining advanced gain enhancements in 5G space craft communications systems, based on the wireless sensor network operations can extend to the tera hertz antennas.

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Антена на основі метаповерхні для бездротових космічних систем зв’язку 5G

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В останні роки з огляду на розвиток сучасних технологій бездротові сенсорні системи в конструкціях космічних апаратів стають ключовим напрямом інноваційних досліджень, зокрема для виявлення геометричних параметрів об'єктів, включаючи людину. У цьому контексті запропоновано використання антени на основі метаповерхні — двовимірної періодичної структури, що взаємодіє з електромагнітними хвилями з метою керування випромінюванням антени. Такий підхід дозволяє суттєво вплинути на характеристики випромінювання, особливо у діапазоні 5G та для космічних апаратів. Основні характеристики запропонованої конструкції: Підкладка: FR4 epoxy (діелектрик з високим показником заломлення), Розміри антени: $0.71\lambda_0 \times 0.71\lambda_0 \times 0.03\lambda_0$, Максимальний коефіцієнт відбиття: – 40 дБ, Коефіцієнт підсилення: 7 дБі, Працює на кількох резонансних частотах з відповідною смугою пропускання. Крім комунікаційних задач, метаповерхнева структура демонструє високу чутливість до змін хімічного складу та температури, що дозволяє застосовувати таку антену не лише для зв'язку, а й у сенсорних космічних платформах. Метаповерхня також сприяє подавленню електричних та магнітних дипольних збурень, що підвищує стабільність роботи антени у складних умовах космічного середовища.

Ключові слова: 5G, Метаповерхня, Космічні апарати, Бездротовий зв’язок.