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# Reconfiguring the Transmission Capability of Broadband FSS for 5G and satellite communication

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## Abstract

This work presents a frequency selective surface (FSS) implemented with an absorbing material to reconfigure the transmission properties of that material. The proposed FSS is implemented using the periodic structure of slot openings on the absorbing fabric material. Two different FSS are presented for reconfiguring the power transmission from 10 dB to 60 dB at different frequency ranges. The concept is presented for controlled power transmission or isolation of an area from the outer radiation. To validate the idea, the measurements are performed for 12-18 GHz and 24-40 GHz frequency bands used for satellite and 5G mobile communications respectively.

**Keywords:** Frequency selective surface; microwave absorber; reconfigurable transmission

## 1. Introduction

The modern communication system has evolved and most of the communication devices are shifted to wireless transmission. A wireless transmission requires transmitting and receiving antennas for electromagnetic (EM) wave propagation that are designed with different operating parameters based on the applications. These parameters are gain, directionality, efficiency, polarization, and coverage area [1]. With the technological revolution, there arises a need to control the radiation characteristics and therefore, several rules and regulations are imposed to control the effects on humans. These rules limit the input RF power level; however, as the RF propagates, the power level degrades with distance. For example: the radiation strength of a mobile tower is strong in nearby areas, whereas, the signal gets weaker as it propagates away from the tower. Therefore, we can say that there is a trade-off between input power and the coverage area. The signal strength in nearby areas is so strong that attenuated signal strength could be working properly. Similarly, satellite communication covers a large area; however, this could be an unwanted monitoring by the enemies on security offices. Therefore, an absorber layer is required with complete shielding or partial shielding where transmitting and receiving instruments are placed. Recently, several techniques are introduced in wireless communication to control the radiation characteristics of the trans-receivers [1-4]. Some of these most recent techniques are reconfigurable intelligent surface (RIS), electromagnetic band gap (EBG) structure, surface integrated wave (SIW) structure, metamaterials, and frequency selective surfaces (FSS) [5-9]. Most of these methods employed electronics circuits and external power supplies to perform the operation. However, a passive FSS structure is the least complex and cost-effective solution in wireless and satellite communication. It is a two-dimensional metallic structure designed with dielectric substrate that is used to enhance various parameters of the antennas and other wireless devices. There are two types of FSS structures, i.e. active and passive. Generally, the active frequency selective surfaces given in the literature also use electronic controlling circuit and the external DC supply to function [10-11]. Therefore, authors have chosen to work on passive type frequency selective surfaces.

This work presents the design and analysis of a cost-effective FSS surface that has the capability of reconfiguring the transmission parameters of the propagating wave. The designed surface is basically a structural arrangement of slots fabricated on the microwave absorbing material. The shape and size of the slotted structure control the percentage transmission. The easy design structure and cost-effective solution make it advantageous to be used in shielding of large buildings and blocks to isolate them from unauthorized monitoring from satellite and RF drones. Moreover, the surface with partial transmission can be used for the area where the receiver and transmitter are placed and require the EM transmission. Therefore, the proposed surface can be used as an EM absorber surface for covering large objects.

### 2. Material and methods

The presented Frequency selective surface is basically the periodic slot openings integrated on to the commercially available shielding absorber. The cross sections of these slots are in multiple of the operating wavelength. These slots couple the incident RF signals to the other side of surface- Y shield®'s shielding film RDF72. The designed FSS is analyzed for its transmission properties for matched and cross polarized situations. Figure 1 gives the structure of the proposed FSS. The dimensions of this integrated structure are calculated for the dominant mode at the operating frequency using equation (1).

$$f = \frac{c}{2W} \tag{1}$$

Where, $c$ is the speed of light, $f$ is operating frequency, and $W$ is the broader dimension of the standard waveguide for the operating frequency band. Whereas, the dimension of slot is related to $W$ as given in equation (2).

$$W = 3W_a = 6W_b = 3\frac{W_c}{2} \tag{2}$$

(a)

(b)

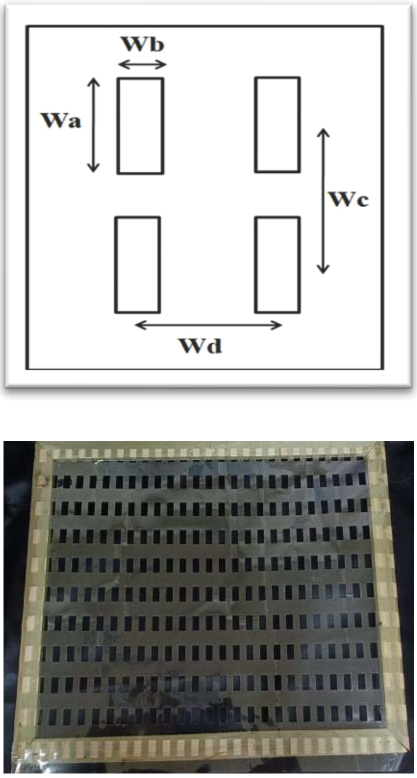


**Fig.1** (a) Proposed structural slots for design of proposed FSS surface; (b) fabricated FSS at absorbing film.

A prototype of the structure is developed and shown in Fig. 1(b). The transmission parameters of the developed surface are measured using the experimental setup given in Fig. 2(a). For the set of measurements in Ku band frequency range, R&S®ZNB 20, a 2-port vector network analyzer (VNA) is connected with the receiving and transmitting horn antennas. The designed FSS is placed in between these two antennas that are placed in far-field distance from each other. The same measurements are done for Ka band (26-40GHz) measurements, where a 4-port VNA used is R&S® ZNA 50.

The measurements are completed with radiative near-field and far-field distances between antennas and with two different orientations of the FSS structures integrated on the absorbing film. The radiative near field and far field of the antenna are calculated using equations (3) and (4) respectively.

$$0.62\sqrt{\frac{D^3}{\lambda}} < Radiative\ Near\ field \leq \frac{2D^2}{\lambda} \tag{3}$$

$$Farfield \geq \frac{2D^2}{\lambda} \tag{4}$$

Where, $D$ is the largest antenna dimension and $\lambda$ is the wavelength in meters.

(a)

(b)

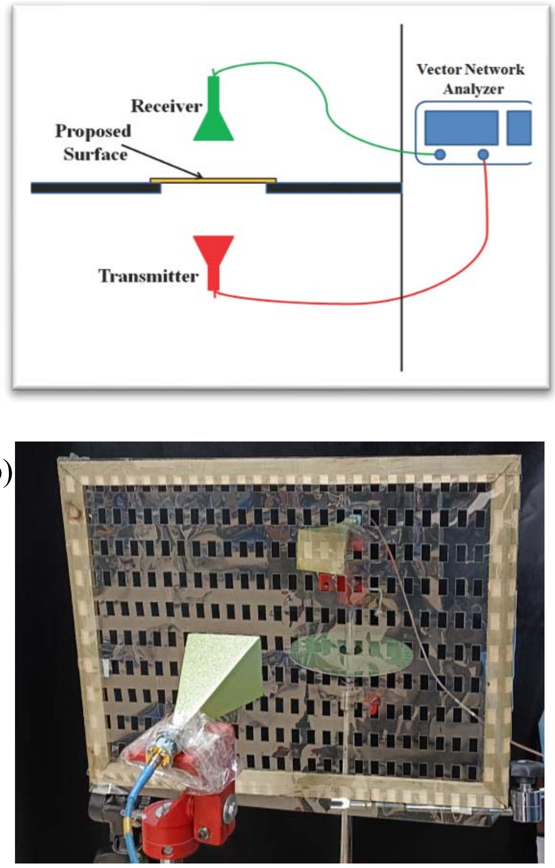


**Fig. 2** (a) Conceptual measurement setup; (b) experimental setup for measurements.

For the Ku-band transmitter, a horn antenna with the largest dimension $D$ being 9.5 cm is used. Using equations (3) and (4), the near field distance for the antenna is between 12 cm to 72 cm, whereas the far-field distance of the antenna is beyond 72 cm. Similarly, for Ka-band antenna, the largest antenna dimension is 6.7cm and the calculated near field range is between 10cm to 78cm. The performances of the proposed surfaces are evaluated for both near-field and far-field operations. The experimental setups of these measurements are shown in Fig. 2(b). The following section describes the performance evaluation of these proposed surfaces.

### *2.1 Near-Field Measurements*

For these measurements, the distance between the transmitter and receiver antennas is kept within near field region. A comparison of the transmission (S21) is presented in Fig 3 for this measurement. Fig 3 (a) shows the results for Ku band in near field. The standard surface sheet shields around 33 dB whereas the proposed surface drops the transmission around 10 dB for both orientations. Fig 3(b) shows the transmission for Ka band in near field. The transmission in standard surface is around 25-30dB whereas it is around 10dB in the proposed surface. The transmission value for air is kept as reference in all the cases.

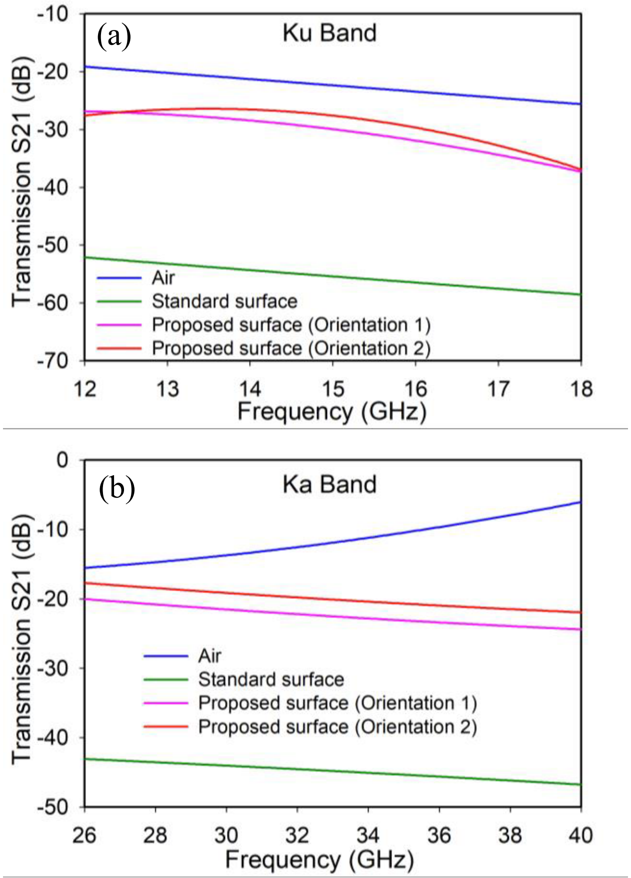


**Fig. 3** Comparison of transmission parameters (S21) of air, standard surface and the proposed surface for proposed absorbing film in (a) Ku band; (b) Ka band in the near field region.

### *2.2 Far-Field Measurements*

The transmission in the far field region behaves in the same manner as in the near field region. The standard surface shielding is around 30-33 dB in both the frequency range and the proposed one is around 10-15 dB. This way, the proposed surface can provide a controlled and application-based shielding.

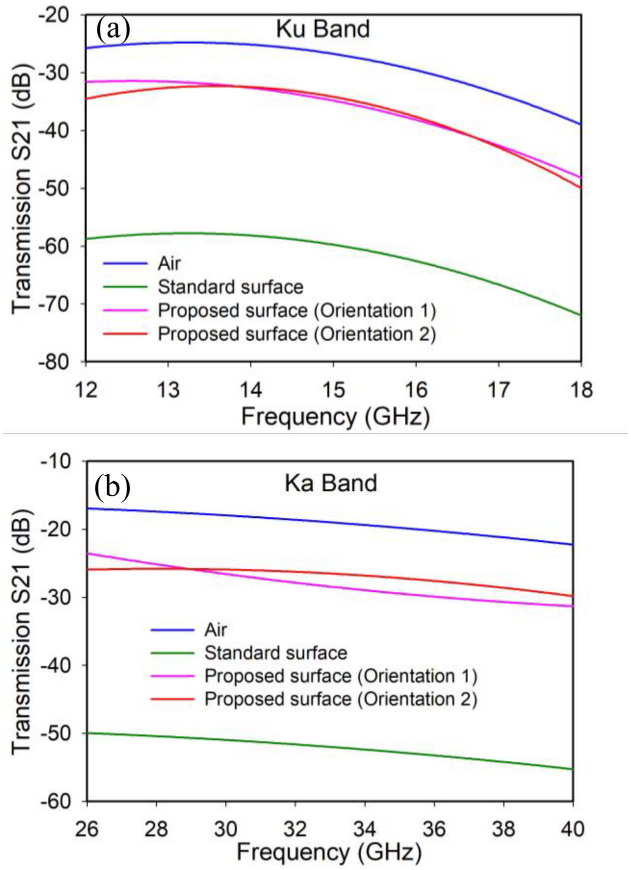


**Fig. 3** Comparison of transmission parameters (S21) of air, standard surface and the proposed surface for (a) Ku band; (b) Ka band in the far field regions.

## 3. Conclusion

This work presented the design of a surface structure that is used to reconfigure the absorption /transmission performance of shielding surfaces without using any external source. A simple design structure gives a good balance to transmitted power of this surface. The designed surface can be used to shield the sensitive area that is required to be hidden from the satellite, whereas, the same surface with the proposed modification can be used where the partial transmission is necessary to receive the information. Further, the authors are working on the surface to make it tunable so that the single surface could work for a large range of transmission levels. Moreover, another advantage of using this surface is that it is a transparent sheet, hence it can be used anywhere and does not affect the visual originality of any structure.

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