

Textile Integrated Frequency Selective Surface (FSS) for Sub-6 GHz 5G Shielding

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Abstract— A textile-integrated frequency selective surface (FSS) for the reflection of sub-6GHz 5G is proposed. By utilizing a 100% jersey knit cotton T-shirt as the substrate, and silver flake ink to screen print conductive apertures, the frequency selective surface becomes textile-integrated. Simulations in Ansys HFSS achieved reflection in S_{11} across the frequency range 3.84 – 6.06 GHz. The finalized design applies a hexagonal aperture with a diagonal length of 17.25 mm and a line thickness of 0.87 mm.

I. INTRODUCTION

With the introduction of sub-6 GHz 5G in the past few years many major cellphone companies have begun to utilize the faster speeds. Sub-6 GHz 5G is favored over mmWave 5G due to its balance of capacity and cover [1]. This new band utilizes a low-band, 600 MHz - 2.4 GHz, and a mid-band, 1 GHz - 6 GHz, depending on the service provider [2]. Additionally, embedded into the mid-band there are frequencies responsible for WIFI and LTE service [3]. When these frequencies are blocked, upload and download speeds are significantly reduced.

Frequency Selective Surfaces (FSS) are flat structures that allow for frequency filtering with either a reflection or a transmission response [4]. Often created for RF signal filtering, band-stop FSS designs have been integrated into buildings to absorb non-ideal signals and reflect ideal signals [5]. Radar and antenna applications utilize a FSS consisting of multiple layers including a base plate, a ground plane, and the aperture of choice [6]. The latter causes these structures to be constructed of rigid and bulky material. By creating a FSS on a flexible substrate, such as fabric, shielding can be applied to any object. Furthermore, by applying the FSS to window treatments the frequency shielding can be temporarily added to a building. The use of conductive ink allows the textile-integrated FSS to keep its flexibility and remain a uniform thickness.

II. FREQUENCY SELECTIVE SURFACE DESIGN

A. Simulation

The design process began with using a N1505A high temperature probe provided by Keysight to measure the dielectric properties of the textile substrate. For this particular application, a 100% jersey knit cotton T-shirt material was used due to its low surface roughness and high flexibility. The extracted relative permittivity and dielectric loss tangent data was then used to create a frequency dependent material in Ansys HFSS. Additionally, the textile substrate's thickness was

measured using calipers and inputted into the simulation. Since the design will be screen printed using silver flake ink from ACI Materials, the silver material properties from the Ansys library were used to simulate the conductive apertures.

A loop type hexagonal aperture was created with the exact measurements denoted in Table 1. To produce the most accurate results, the aperture is created as an infinitely repeating pattern. To achieve the latter, a hexagonal base was created with two sides of three apertures strategically placed to create a Y-shape shape in the middle of the base, pictured in Fig. 1. The center point of each hexagonal loop was determined by half of the length of the hexagon plus the thickness of the line. Adjustments to the aperture's length, line thickness and the space between elements were done during simulation to ensure the reflection of the appropriate frequency band.

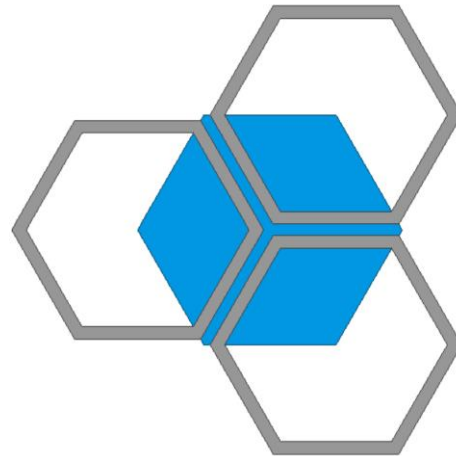


Figure 1. Ansys HFSS aperture setup for infinite repetition.

TABLE I. DIMENSIONS OF THE FSS DESIGN

Element	Variable	Measurement (mm)
Aperture Length	a	17.25
Distance between Apertures	b	0.75
Line Thickness	c	0.87

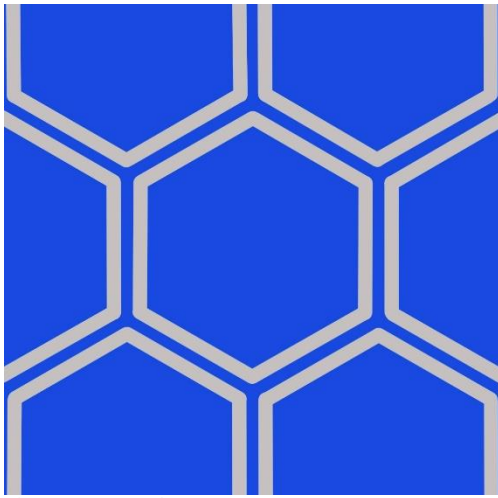


Figure 2. Repeated aperture pattern.

B. Textile Printing

After being verified in Ansys HFSS, the design was prepared for printing. Screen printed elements were chosen for this particular application to maintain the flexibility of the substrate. To create the pattern for the mesh screen, pieces of glass coated in black spray paint were etched using a LPKF ProtoLaser to expose the positive of the design. A fine mesh screen was then coated on both sides with emulsion and left to dry in a dark box overnight. The pieces of glass were arranged on a lightbox and then covered by the prepped mesh screen. Once the lightbox was switched on, the screen was exposed for 18 minutes. The screen was then rinsed to remove the uncured emulsion and reveal the aperture design. Printing was preformed using the latter and ACI Materials silver flake ink. With the fabric substrate secured under the screen, silver ink was placed on top of the screen and then pressed through the open regions onto the substrate using a squeegee. The sample was placed in a 135 °C convection oven for five minutes to ensure the ink is fully cured.

III. RESULTS

The results shown in Fig. 3 are simulated results for S_{11} from 1-10 GHz. As observed from the results, the textile integrated FSS has produced signal reflection from 3.84-6.06

GHz. The latter frequency range encapsulates the majority of the mid-band. Fabrication and testing results will be presented and discussed at the time of presentation.

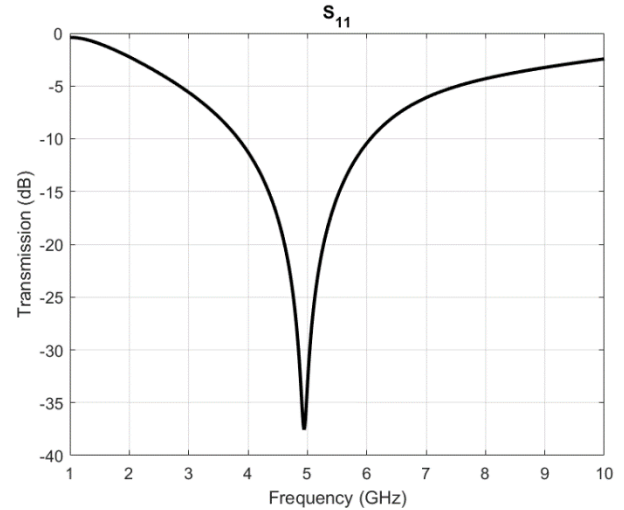


Figure 3. Ansys HFSS Simulation S_{11} Results.

REFERENCES

- [1] R. Dangi, P. Lalwani, G. Choudhary, I. You and G. Pau, "Study and Investigation on 5G Technology: A Systematic Review," *Sensors*, vol. 22, pp. 26, December 2021.
- [2] Y. O. Imam-Fulani, N. Faruk, O. A. Sowande, A. Abdulkarim, E. Alozie, A. D. Usman, et al., "5G frequency standardization technologies channel models and network deployment: Advances challenges and future directions", *Sustainability*, vol. 15, no. 6, pp. 5173, Mar. 2023.
- [3] Le, N.T.; Hossain, M.A.; Islam, A.; Kim, D.; Choi, Y.-J.; Jang, Y.M. Survey of Promising Technologies for 5G Networks. *Mob. Inf. Syst.* 2016, 2016, 1–25.
- [4] B. A. Munk, "Frequency selective surfaces: theory and design.", *New York: John Wiley*, 2000.
- [5] A. Shastri, P. Njogu, B. San-Izquierdo, S. Gao and Z. Chen, "Low-cost Inkjet Printed Paper Poster FSS for 5G," in *European Conference on Antennas and Propagation*, Dusseldorf, Germany, April 2021.
- [6] Y. Ranga, L. Matekovits, A. R. Weily, and K. P. Esselle, "A low-profile dual-layer ultra-wideband frequency selective surface reflector", *Microwave and Optical Technology Letters*, 2013, vol. 55, (6), pp. 1223-1227.