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INVESTIGATION OF FSS PERFORMANCE ON FLEXIBLE SUBSTRATES

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ABSTRACT
This paper presents an investigation of the Frequency Selective Surface (FSS) performance on flexible substrates. Four types of flexible substrates are proposed which are Fast Film, Rogers RO3010, Taconic TLY-5, and Denim Jeans. Each type of substrates has different values of dielectric constant and thickness. The value of transmission and reflection of each substrate are evaluated in different FSS frequency response. The structure is integrated at FSS frequency response, 5.8GHz. The best value of transmission is about -43.15dB and the reflection is almost around -0.04dB which evaluated by the FSS structure using Fast Film as a substrate. However the structure operated in narrow bandwidth around 4.66% compared to Taconic TLY-5. This FSS design structure showed excellent performance when used for wireless local area network (WLAN).

Keywords: frequency selective surface, transmission, reflection, WLAN.

INTRODUCTION
Increased interest in the integration of wireless communication system into wearable products has led to various kinds of body worn antenna structures as mentioned in [1]. Research into On-body devices has inspired many new applications, especially in new generation wireless communication systems for multimedia personal entertainment and medical telemetry. Devices that can be realized on flexible substrate have much to offer in the area of wearable. Due to close proximity of human body the efficient performance of a wearable antenna demands special design consideration as mentioned in [2].

Metamaterials are artificially structure that is realized by setting the metallic material with periodic pattern onto the dielectric substrate. The term that usually been used for metamaterials structure are Artificial Magnetic Conductor (AMC), Frequency Selective Surface (FSS) and Electromagnetic Band Gap (EBG)as mentioned in [3]. The electromagnetic properties of periodic surfaces have been widely studied for some time now.

A periodic surface is generally defined as a uniform assembly of elements (or scatter) arranged in one or two dimensional arrays. Basically, these three structures are used to be filters designed which to reveal different reflection and transmission properties as a function of frequency. The difference of these metamaterials is the structure design itself. There are lots of designs which contribute all these metamaterials with the antenna for certain application. The best structure design is perform the high gain to the antenna, less return loss and good radiation efficiency.

Frequency Selective Surface (FSS)
A frequency selective surface (FSS) is a spatial electromagnetic filter, which is defined as a one or two dimensional periodic array of patch elements or aperture elements etched on a dielectric substrateas mentioned in [4]. The geometries of both patch and aperture elements are shown in Figure-1. The patch element array behaves as a band stop filter and the aperture element array acts as a band pass filter.

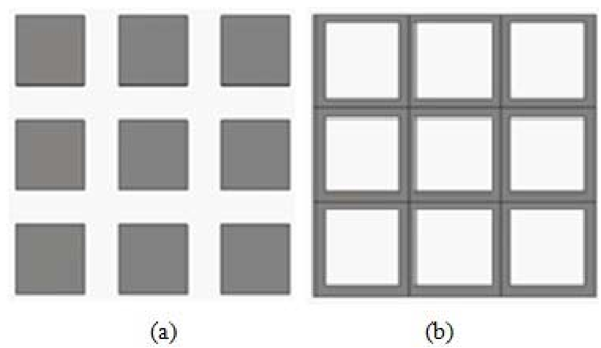

Figure-1. Geometries of (a) patch elements and (b) aperture elements of FSS array as mentioned in [4].

FSS is any surface designed as a filter which has typically narrow band and periodic structure. The capacitive and inductive FSS can be realized over the dielectric substrate without the ground plane.

Several arrays and material layers may be combined to produce resonant structures commonly refer as FSS. These surfaces can be applied over wide range of the electromagnetic spectrum, starting from below ultra-high frequency (UHF) to the far-infrared regions. In microwave regions, periodic surfaces have been used as phased array antennas, artificial dielectrics, diffraction gratings, frequency selective reflector for antenna, dichroic antennas, angular filters and spatial filters.

The FSS is basically a filter designed to reveal different reflection and transmission properties as a function of frequency. Normally the FSS consists of slot element is composed of arbitrarily shaped perforations in a metallic screen which support magnetic currents. Surfaces comprised of wire elements act as band stop filters and surfaces comprised of slot elements act as band pass filters as mentioned in [5].

Figure-2 shows four different types of possible element-type FSS array which are center connected or N-poles, loop, solid interior or plate and combinations. Depending on the physical construction and geometry of the surface, the FSS can efficiently control the transmission and reflection of the incident electromagnetic plane wave and may have low pass, high pass, band pass and band stop behavioursas mentioned in [6].

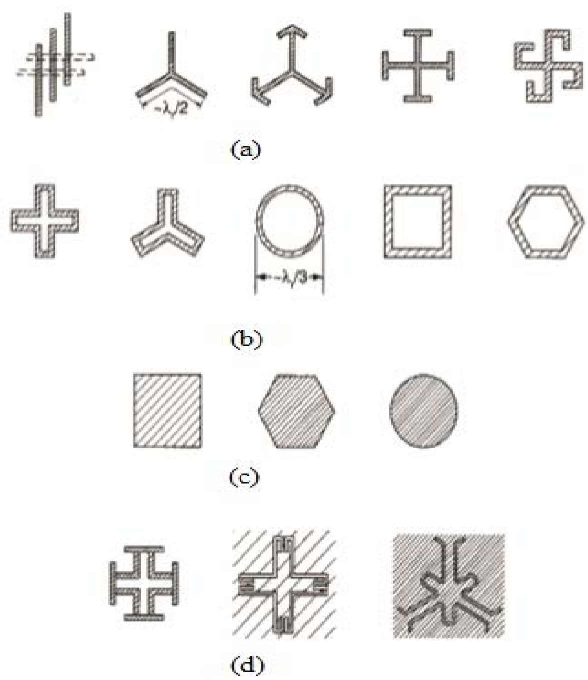

Figure-2. Four different types of possible element-type FSS arrays (a) Group 1: Center Connected or N-Poles (b) Group 2: Loop Types (c) Group 3:Solid Interior or Plate Type (d) combinations as mentioned in [6].

The frequency behaviour of the FSS is entirely determined by the geometry of the surface in one period (unit cell), the size of the FSS, the way the surface is exposed to the electromagnetic wave (incidence angle of the incoming wave), substrate parameters, inter-element spacing and material used. To achieve a certain spectral response for the FSS, many parameters can be adjusted such as the dimension of periodicity, element shape, dielectric thickness and constant, and number of periodic screens as mentioned in [7].

This paper will investigate the transmission and reflection of FSS structure by using four different types of substrates. The substrates involved considering the flexible material which are Fast Film, Rogers RO3010, Taconic TLY-5, and Denim Jeans. The optimization of the FSS structure is done to achieve the FSS frequency response at 5.8GHz.

Design and consideration

This paper will investigate the transmission and reflection of FSS structure using four types of substrates to achieve a certain spectral response for the FSS. The substrates proposed in this paper are considering the flexible materials which are Fast Film as mentioned in [8], Rogers RO3010 as mentioned in [9] and Taconic TLY-5 as mentioned in [10]and Denim Jeans as mentioned in [11].

The FSS layers configuration is shown in Figure-3 is involved only substrate and FSS patch layers. Four different types of materials will be used as a flexible substrate with different thickness,t. The material used for the FSS patch is Perfect Electromagnetic Conductor (PEC) with thickness,h is 0.035mm.

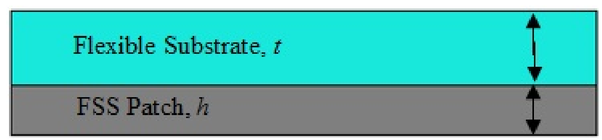

Figure-3. FSS layers configuration.

Four substrates will be proposed in this paper which are Fast Film, Rogers RO3010, Taconic TLY-5, and Denim Jeans. Each substrate has different characteristics in term of the value of dielectric constant,ε_r and thickness,t. Fast Film substrate with ε_{r1}=2.7 and t_1=0.13mm, Rogers RO3010 substrate with ε_{r2}=10.2 and t_2=1.28mm, Taconic TLY-5 substrate with ε_{r3}=2.2 and t_3=1.12mm while Denim Jeans substrate with ε_{r4}=1.67 and t_4=0.85mm. The analysis and design of FSS has been carried out in Circuit Simulation Technology (CST) Microwave Studio.

This structure has a combination of rectangular ring patch alternately with split rectangular ring patch within the gap,g is 0.5mm. Each slot width,w is 0.5mm. There is one solid rectangular patch at the center and there are four connected branch patch at the edge of rectangular ring patch as shown in Figure-4.

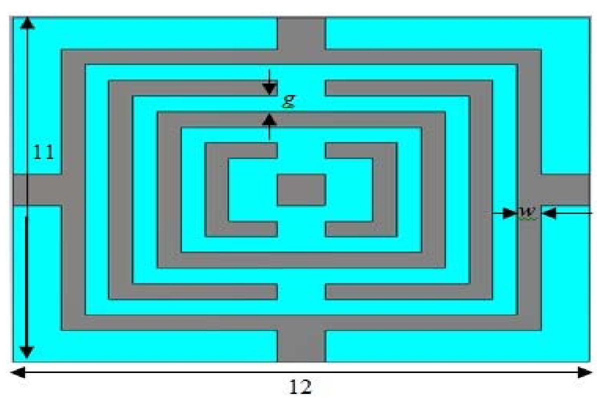

Figure-4.A unit cell of 5.8GHz FSS (the main rectangularringpatch size is 12mm x 11mm, slot width,w=0.5mmwhile thesolid rectangular patch size is 1mm x 1mm).

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RESULTS AND DISCUSSIONS

There are four types of substrates that will be investigated in this paper to achieve a certain spectral response for the FSS. The substrates selected are considering the flexible materials which are Fast Film, Rogers RO3010, Taconic TLY-5, and Denim Jeans.

The primary interest in this case is the S-parameter results, which represent the reflection and transmission through the FSS. The co-polar reflections and transmissions of both modes are almost identical due to the symmetrical rectangular slot. The transmission and reflection is almost completely blocked at frequency response.

Table-1 shows the simulated results of transmission and reflection at different FSS frequency response by using different substrates. For the same size of FSS structure, the transmission and reflection are evaluated at different frequency response of FFS for each substrate. From the table, the FSS structure using Fast Film as a substrate evaluatedthe best transmission atthe highest FSS frequency response obtained at 10.34GHz. While the FSS structure using Rogers RO3010 as a substrate evaluated the lowest transmission at the lowest FSS frequency response obtained at 8.46GHz. With the same size of FSS structure, different frequency response is achieved by different types of substrates. Different substrates having different values of dielectric constant and thickness which contribute to different spectral response for the FSS.

Table-1. Simulated results of transmission and reflection at different FSS frequency response.

Subs-trate	Frequency response (GHz)	Transmis-sion (dB)	Reflec-tion (dB)
Fast Film	10.34	-49.03	-0.03
Rogers RO3010	8.46	-35.41	-0.09
Taconic TLY-5	9.46	-36.27	-0.08
Denim Jeans	10.10	-38.71	-0.04

Table-2 shows the new substrate sizes for FSS structure at 5.8GHz. From the table, the bigger size integration is led by the FSS structure using Fast Film as a substrate according to the highest FSS frequency response achieved at 10.34GHz. While the smallest size integration is led by the FSS structure using Rogers RO3010 according to the lowest FSS frequency response achieved at 8.46GHz. From the observation, the bigger size integration of FSS structure evaluated the smallest FSS frequency response and vice versa.

The structure size is one of many parameters that can be adjustedto achieve a certain spectral response for the FSS. With different values of dielectric constant and thickness, the size of FSS structure can be adjusted to achieve 5.8GHz frequency response. All the frequency responses evaluated by different types of substrates earlier are bigger than 5.8GHz. So, there is increasing of structure size for all types of substrates which contribute to the decreasing of FSS frequency response until at 5.8GHz.

Table-2. New substrate size for 5.8GHz FSS structure.

Substrate	New substrate size (mm x mm)	Size modification (%)
Fast Film	21.23 x 19.46	219.87
Rogers RO3010	17.76 x 16.28	119.04
Taconic TLY-5	19.18 x 17.64	156.31
Denim Jeans	21.44 x 19.66	219.33

Figure-5 shows the transmission and reflection curve of FSS structure using Fast Film as a substrate.. The result shown that the value of transmission for about -43.15dB and reflection for about -0.04dB which is almost completely blocked at frequency response 5.8GHz. Based on -10dB, the value of lower and upper frequency is 5.65GHz and 5.92GHz respectively which contribute to 4.66% bandwidth.

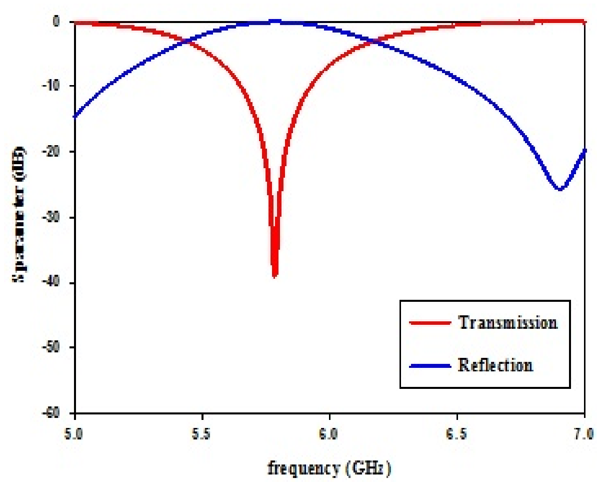

Figure-5. Transmission and reflection curve using Fast Film substrate.

Figure-6 shows the transmission and reflection curve using Rogers RO3010 as a substrate. The result shown that the value of transmission for about -36.69dB and reflection for about -0.08dB which is almost completely blocked at frequency response 5.8GHz. Based on -10dB, the value of lower and upper frequency is5.74GHz and 5.96GHz respectively which contribute to 3.97% bandwidth.

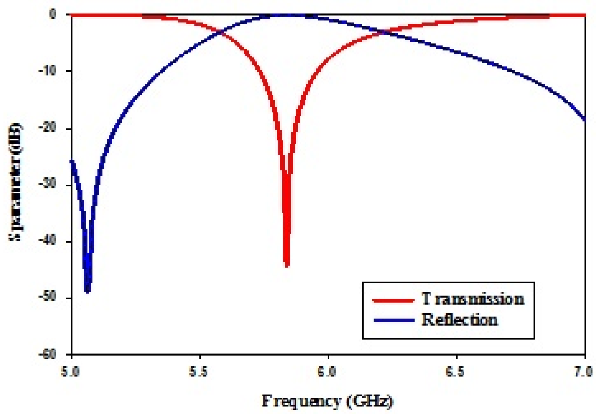

Figure-6. Transmission and reflection curve usingRogers RO3010 substrate.

Figure-7 shows the transmission and reflection curve using Taconic TLY-5 as a substrate. The result shown that the value of transmission for about -38.03dB and reflection for about -0.06dB which is almost completely blocked at frequency response 5.8GHz.Based on -10dB, the value of lower and upper frequency is 5.64GHz and 6.04GHz respectively which contribute to 6.89% bandwidth.

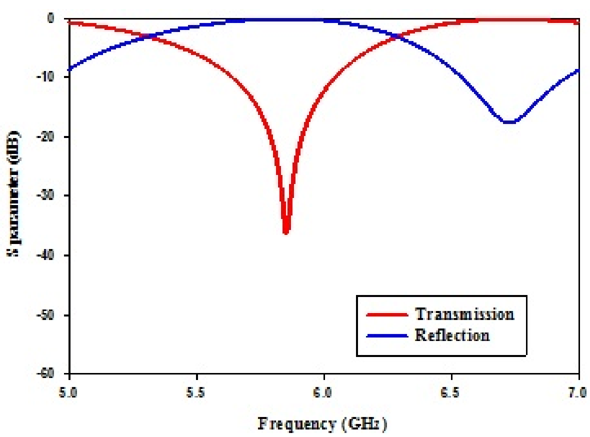

Figure-7. Transmission and reflection curve using Taconic TLY-5 substrate.

Figure-8 shows the transmission and reflection curve using Denim Jeans as a substrate. The result shown that the value of transmission for about -39.70dB and reflection for about -0.07dB which is almost completely blocked at frequency response 5.8GHz. Based on -10dB, the value of lower and upper frequency is 5.69GHz and 5.93GHz respectively which contribute to 4.14% bandwidth.

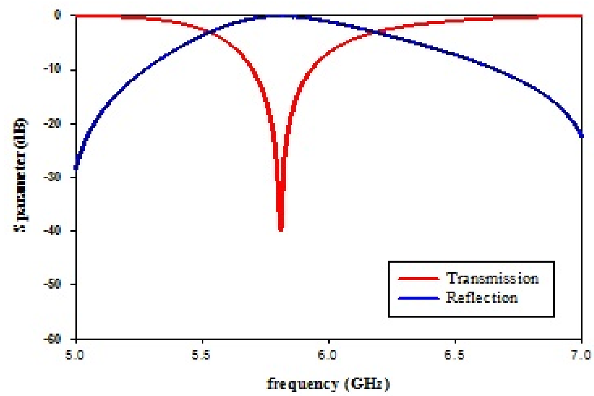

Figure-8. Transmission and reflection curve using Denim Jeans substrate.

Table-3 shows the transmission, reflection and bandwidth using four different substrates. Each substrates have different values of dielectric constant and thickness which is one of the consideration to achieve a certain spectral response for the FSS. From the table, FSS structure by using Fast Film as a substrate evaluate the highest transmission while the lowest transmission is evaluated by using Rogers RO3010 as a substrate. However, the FSS structure by using Fast Film as a substrate operated in narrow bandwidth compared to wider bandwidth evaluated by using Taconic TLY-5 as a substrate. The value of reflection evaluated by four different types of substrates are approximately the same to each other which is below than -0.1dB. From the observation, the size of the FSS structure and dielectric constant and thickness are considered to achieve certain spectral response of FSS structure.

Table-3. Transmission, reflection and bandwidth using four different substrates.

Substrate	Transmission (dB)	Reflection (dB)	Bandwidth (%)
Fast Film (ε_{r1}=2.7, t_1=0.13mm)	-43.15	-0.04	4.66
Rogers RO3010 (ε_{r2}=10.2, t_2=1.28mm)	-36.69	-0.08	3.97
Taconic TLY-5 (ε_{r3}=2.2, t_3=1.12mm)	-38.03	-0.06	6.89
Denim Jeans (ε_{r4}=1.67, t_4=0.85mm)	-39.70	-0.07	4.14

CONCLUSIONS

The design of unit cell FSS structure is initially designed and simulated in this paper by using four types of substrates. The substrates used are considering the flexible materials which are Fast Film, Rogers RO3010, Taconic TLY-5, and Denim Jeans. The integration of FSS structure is being done to achieve FSS frequency response at 5.8GHz. The result shown that the Fast Film substrate evaluated the best transmission for about -43.15dB and reflection for about -0.04dB at 5.8GHz. However the structure operated in narrow bandwidth around 4.66% compared to Taconic TLY-5. This material also suitable as flexible substrate according to the thickness, t_l=0.13mm. So, future work is needed to incorporate this FSS design structure with Fast film as a flexible substrate with antenna as wearable applications.

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