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Bandstop Filter Design for GSM Shielding Using Frequency Selective Surfaces

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ABSTRACT

In this paper, the performance of bandstop Frequency Selective Surface (FSS) is presented which can be used to provide wireless security on airports and other sensitive places, where a mobile phone can be used to set-off an explosive device. It can also be used to block the mobile signals at the places of worship, hospitals and cinemas where the annoying voice of a mobile phone may irritate the masses. The FSS unit cell consists of two metallic square-loop elements printed on FR-4 substrate with different periodicities. The outer and inner square-loop elements are tuned to 900 MHz and 1800 MHz, respectively. It has a stable frequency response at oblique incidences for both perpendicular (TE) and parallel (TM) polarizations. Simulation results are presented to give an overview for the performance of proposed FSS design.

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1. INTRODUCTION

GSM-900 and GSM-1800 are the most popular frequency bands in mobile communication which are commonly used in Asia, Europe, Africa, Middle East and Oceania. GSM-850 and GSM-1900 frequency bands are used in Canada, United States and some other countries of the world. In United Kingdom, GSM-1800 is also called Digital Cellular System (DCS). GSM-450 uses the same band of Nordic Mobile Telephone (NMT) system which is the first generation in Nordic countries, Benelux, Russia and Eastern Europe. T-GSM which is also known as Trans European Trunked Radio GSM (TETRA-GSM) is a two way transceiver mobile radio also known as Walkie Talkie. In Asia, Africa, Middle East and Europe TETRA-GSM system is used by police forces, government agencies, transport services and military. Therefore, a multiband FSS is required to provide security or shielding for mobile phone signals.

The voice of ringing mobile in the places of worship, hospitals and theaters can be very annoying. Also from security point of view, a mobile phone signal can be used to detonate an explosive device in an indoor environment like airports and other highly sensitive areas. Most of these areas used jammers and reflectors to block GSM signals. But their use can also disturb other personal communication within the environment. So, there is a need of such type of reflector which can only block desired communication signals. This can be done by designing Frequency Selective Surfaces (FSSs) which can behave as a band-stop filter. Frequency Selective Surfaces (FSSs) act as a spatial electromagnetic filters for microwave and millimeter wave signals. They are the periodic structures of the same element arranged in one or two dimensional infinite array but finite arrays are used in practice [1]. Therefore, an FSS may provide isolation or security. Recently, the application of FSS as a spatial filters and their use in wireless security has been investigated [2]-[6]. Moreover, FSS has also been considered for many other applications such as antenna radomes [7], dichroic reflectors [8], waveguides [9] and telecommunication [10], [11].

An FSS with multiband response can be obtained by using different techniques. A substrate with the elements having the identical geometry but with diverse sized [12] or with fractal geometry [13]-[15]. Perturbation of a single-layered FSS [16] or the use of multi-resonant elements such as the concentric ring is also used to obtain multiband resonances [17]. Multi-resonant elements are generally used because of lighter structure and simplified design. In [18], the authors presented a new element for FSS with dual-bandstop behavior for GSM bands at normal incidence. Most of these researches did not consider the aspect of angular stability of FSS for different polarizations.

This paper presents the performance of dual-band FSS providing security or isolation at GSM-900 and DCS-1800 mobile bands which cover almost the major GSM frequency bands used in major parts of the world. It has a stable frequency response for both TE and TM polarizations at oblique incidence up to 70^0. Such kind of FSS can be used to design for WLAN security [2]-[6].

2. BANDSTOP FSS CONFIGURATION

The unit cell dimensions of bandstop FSS are shown in Figure 1. The bandstop characteristics are achieved by designing two square-loop elements of different dimensions on FR-4 substrate. The periodicity of unit cell is 45×45 mm^2. The circumference of the outer square-loop element is 172 mm (side length 43 mm) which is tuned to 900 MHz while the circumference of the inner square-loop element is 132 mm (side length 33 mm) which is tuned to 1800 MHz. The width of both square-loop elements is 0.5 mm. The thickness of FR-4 substrate is 1.6 mm having a relative permittivity (ε_r) and a loss tangent (δ) of 4.9 and 0.02, respectively. Improved frequency stability at oblique angles has been achieved by reducing the inter element spacing between the FSS elements. The length and width of the square-loop elements is calculated as:

$$L = W = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} \tag{1}$$

where,

$$\varepsilon_{eff} = \sqrt{\frac{\varepsilon_r + 1}{2}} \tag{2}$$

where, L is the length of square-loop element, W is the width of square-loop element, c is the speed of light in free-space, f_r is the resonant frequency, ε_r is the dielectric constant of the material and ε_{eff} is the effective dielectric constant of the material, respectively.

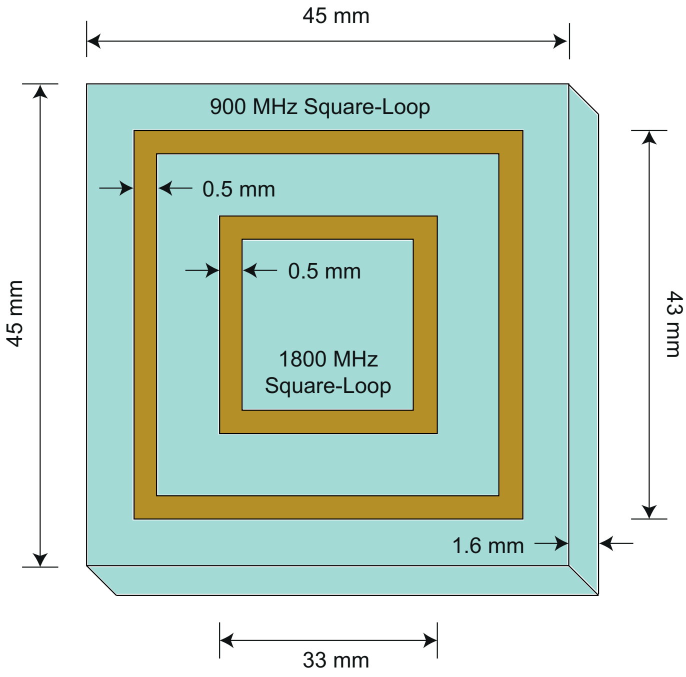

Figure 1. Unit cell dimensions of bandstop FSS

3. SIMULAITON RESULTS AND DISCUSSION

The unit cell of FSS which is shown in Figure 1 is simulated by applying periodic boundary conditions using CST Microwave Studio, commercially available electromagnetic software. The transmission and reflection coefficients are obtained from 600-2200 MHz for both TE and TM polarizations at oblique incidences.

In Figure 2, the transmission and reflection coefficients are presented for TE polarization for 0^0 and 70^0 angle of incidence. The resonant frequencies at 0^0 are 885 MHz and 1800 MHz, while at 70^0, these are 915 MHz and 1775 MHz, respectively. The corresponding transmission coefficinets are -38 dB, -35 dB, -42 dB and -39 dB, respectively. The shif in resonant frequency from 0^0 to 70^0 is about 3% at 900 MHz. This shows that FSS has a stable frequency response as the angle of incidence varied from 0^0 to 70^0. Also, the reflection coefficients on the resonant frequencies for both the presented oblique incidences are almost 0 dB.

In Figure 3, the transmission and reflection coefficients for TM polarization are presented. The resonant frequencies at 0^0 are 880 MHz and 1820 MHz, while at 70^0, the resonant frequencies are 925 MHz and 1770 MHz, respectively. The transmission coefficients at the resonant frequencies are -38 dB, -42 dB, -35 dB and -38 dB, respectively. In this case, the shift in resonant frequency from 0^0 to 70^0 is about 5% at 900 MHz and 3% at 1800 MHz. Therefore, it can be seen that the FSS response is sufficiently stable for both TE and TM polarizations as the angle of incidence is varied. Also, it is demonstrated that the shift in resonant frequencies is occurred due to the mutual coupling between the FSS elements.

One of the important factor is to maintain the bandwidth of required frequency bands while designing FSS. The required bandwidth for GSM-900 is 540.8 MHz (from T-GSM to E-GSM) and for DCS-1800 and PCS-1900, it is 169.6 MHz and 140 MHz. It is noticed from Figure 2 and 3 that the proposed dual-band FSS provides sufficient bandwidths for both TE and TM polarizations to cover the required bands. However, this may also attenuate VHF and UHF television signals for which a trade-off has to be made. For TE polarization, the -10 dB stop-band bandwidths at 900 MHz and 1800 MHz for 0^0 and 70^0 are 325 MHz, 525 MHz, 390 MHz and 465 MHz, while for TM polarization, the -10 dB bandwidths noted at 900 MHz and 1800 MHz for 0^0 and 70^0 are 325 MHz, 190 MHz, 400 MHz and 215 MHz, respectively. For the ease of readers, the overall bandwidths are shown in Table 1 and 2.

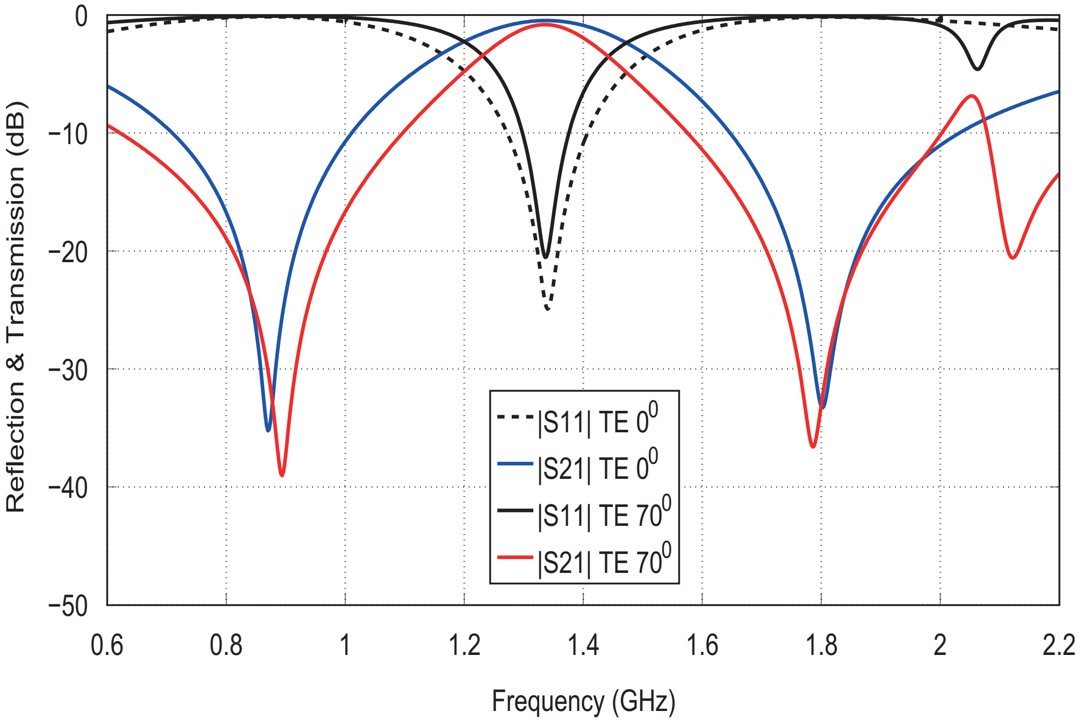

Figure 2. Simulation results of dual-bandstop FSS for TE polarization

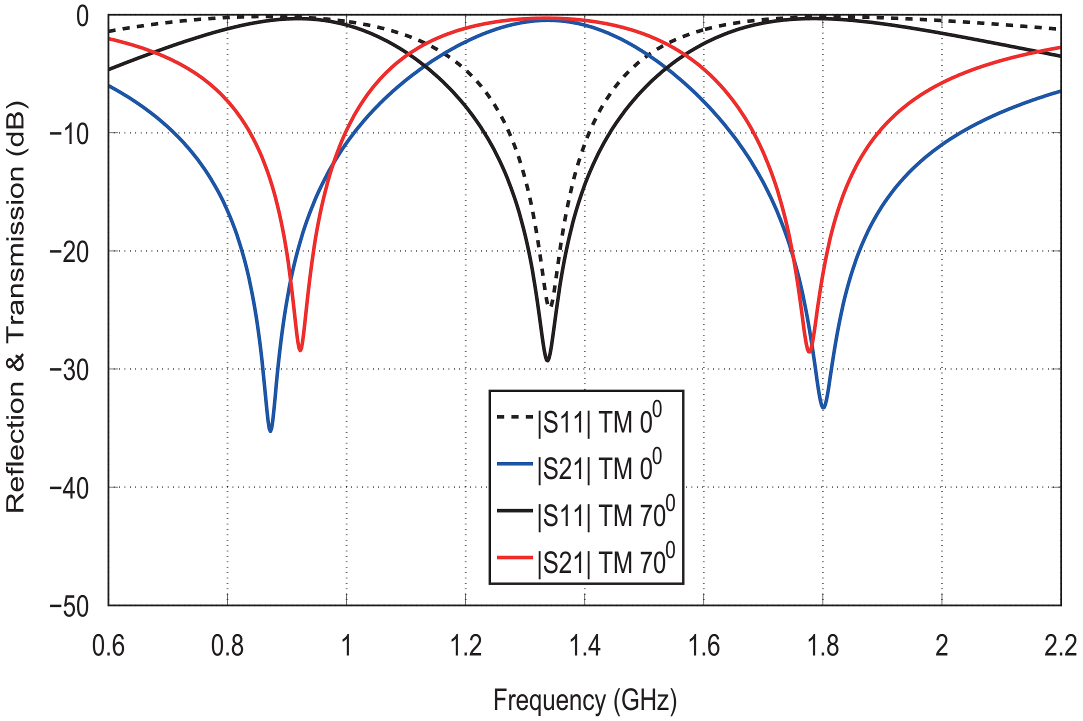

Figure 3. Simulation results of dual-bandstop FSS for TM polarization

Table 1. -10 dB transmission bandwidths at 900/1800 MHz for TE polarization

	900 MHz		1800 MHz	
Angle	Resonant Frequency (MHz)	Bandwidth (MHz)	Resonant Frequency (MHz)	Bandwidth (MHz)
TE 0^0	885	325	1800	390
TE 70^0	915	525	1775	465

Table 2. -10 dB transmission bandwidths at 900/1800 MHz for TM polarization

	900 MHz		1800 MHz	
Angle	Resonant Frequency (MHz)	Bandwidth (MHz)	Resonant Frequency (MHz)	Bandwidth (MHz)
TE 0^0	880	325	1820	400
TE 70^0	925	190	1770	215

4. CONCLUSION

The performance of dual-bandstop FSS is presented which can provide effective shielding against mobile phone signals. It has a stable frequency response for oblique angle of incidence for both TE and TM polarizations. It can be used to provide security to sensitive environments where a mobile phone can be used to detonate an explosive device.

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