Frequency Dependent Surfaces: A Boon in Spatial Filtering

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Abstract.

In present period, wide variety of technologies are enforced in order to enhance the data rate for better quality of services. In this paper, an elaborated study has been done that substantially focuses on the need and the comparative analysis between different designs of spatial filters. At present, frequency dependent surfaces are used in variety of fields such as satellite communication, radome operation, wireless communication and numerous others.

Keywords. Frequency Dependent Surface (FDS), Resonance frequency, Spatial filter, Polarization, Radome.

1. INTRODUCTION

Frequency dependent surfaces (FDSs) are a type of periodic structures which can act as both band pass as well as band stop filter. These periodic structures are identical and repetitive in their geometry. FDS are planer structures in one or two dimensions. In case of electromagnetics, FDS are called as spatial filters which transmit the desired signals and obstruct the undesired signals. In FDS, transmission and reflection happen when the frequency of incident wave tunes with the frequency of the element which is used for its construction. FDS can be subdivided into two categories on the basis of their geometries that is inductive FDS and capacitive FDS. Inductive FDS often act as a high pass filter and capacitive FDS acts as low pass filter. Coming towards the applications, FDS finds its application in enormous fields in present times such as military, commerce, RCS (Radar Cross Section Control), satellite applications and many more. In order to increase the data speed and to enhance the quality of services, advance antennas are used but they prove to be less sufficient in order to meet the demands. Use of FDS has improved all the antenna parameters by reducing the interference. FDS provides huge dual band separations in order to reduce the risk of being detected by a Radar. It is widely used in military applications. [1-6]

Primarily, FDS is a periodic surface comprises of 2D arrays of components on a dielectric substrate that exhibits transmission and reflection at a certain resonant frequency. When the frequency of an incoming plane wave matches the resonance frequency of FDS, transmission or reflection occurs. FDS has spatial filtering properties and can be implemented as a bandpass or band stop filter with least attenuation of 20dB. When FDS and antenna is integrated gain will increase. The frequency response of FDS is a function of incident angle, frequency and polarization of incident plane wave. These FDS's are also useful in filtering out unwanted EMI signals and for this purpose fan shaped FDS has been mostly used. [7-11]

For some applications, FDS is required to have an ability of changing the frequency with the change in time. For this purpose, active elements are being inserted inside the structure of FDS surfaces making it as active frequency dependant surfaces (AFDS). AFDS consists of a metallic grid engraved on a dielectric substrate. The geometry of the FDS also plays an important role in its frequency response and radiation characteristics [12-13].

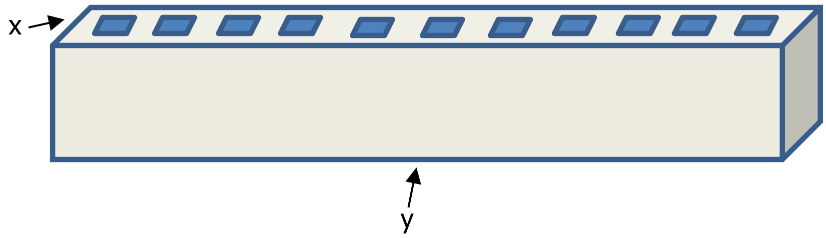

Fig. 1.1 Geometry of FDS

When an EM wave strikes on a unit cell of FDS, then it can be seen as an equivalent lumped circuit comprising of a LC circuit, whose resonance frequency can be calculated on basis of the values of lumped circuit elements [7].

$$f_r = \frac{1}{2\pi\sqrt{LC}} \tag{1.1}$$

$$f_r = {fo}\Big/{\frac{\sqrt{\epsilon r+1}}{2}} \tag{1.2}$$

The absorption factor (A) can be given as –

$$A = 1-|\Gamma|^2-|T|^2 \tag{1.3}$$

where, Γ is reflection coefficient and T is transmission coefficient.

2. Insight to Fabrication Techniques

FDS is divided into 3 categories;

Based on array element, there are three types –
i) Basic element- which includes centrally connected looped shapes, patch shapes, combination of all FDS,
ii) Convoluted- used where miniaturized FDS are demanded and flexibility is the main challenge and
iii) Fractal type- where size reduction and multiband behaviour of element is required.

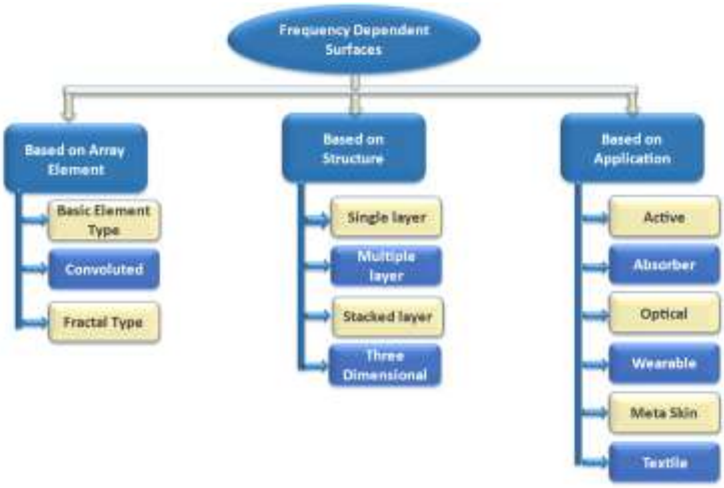

Fig. 2.1 Types of FDS

Based on structure, it can be divided into the following types –

i) Single layer- made up of 2D array of periodic resonant element,
ii) Multilayer- is used when a broadband response is required in a particular frequency range,
iii) AFA - are taken in use to achieve high frequency selectivity and
iv) 3D - grants wide choice of designing methods, sharp cut - off and high flexibility.

On the basis of application, it can be characterized into six different types –

i) Active- are able to control EM performance by tuning the exterior excitation and addition of this element in FDS provides reconfiguration feature,
ii) Absorber- used for absorbing reflected signals in stopband by introducing absorbing array elements,
iii) Optical - used for the applications where a sharp response of frequency is needed with its peak centring the same resonant frequency always,
iv) Wearable- includes temperature sensor which works on modulation of back scatter field and this element can be attained to body,
v) Meta Skin - provides stretchability to the FDS with frequency selectivity and
vi) Textile - used in conferences, screening on clothes and are easy to control.

3. COMPARATIVE ANALYSIS

Ref. No.	Overall Dimensions (mm)	Central frequency (GHz)	ϵr (Relative permittivity)	Substrate material	Bandwidth (GHz)	Remarks
[11]	13 x 13 x 1.6	4.51	4.4	FR4	3.2-5.8	Designed a polarization independent FDS for S and X bands.

[14]	6.5 x 6	9.5	4.4	FR4	5	Designed for frequency range 7.5-11.5 GHz.
[15]	40 x 30	6.6	4.4	FR4	6-8	The proposed model is used for ultra-wideband frequency.
[16]	16 x 16 x 1.57	10.15	2.2	Rogers/RT Duroid 5880	9.5-10.8	High sensitivity, sharp roll-off. Used for designing multi-layer radomes working for X-band frequency.
[17]	7 x 1.41 x 0.5	11	3	Arlon AD300	10-12	Designed FDS for shielding of X-band satellite communication.
[18]	6.2 x 6.2 x 1.6	3.7	4.4	FR4	2.4-5	Proposed design is used for WLAN application.

4. CONCLUSION

This paper dealt with the introduction to different parameters of various frequency dependent surfaces with a classification of them on the basis of various parameters. It showed how the performance of the antennas can be modified and enhanced by using frequency dependent surfaces instead of using traditional antennas. It is interpreted that the parameters and geometry of the frequency dependent surface can be varied according to the requirement, making them particularly application oriented and cost effective. The frequency dependent surface domain holds its use in the coming time and will provide the mankind with a more effective and easily tunable transmission devices.

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