Design and Measurement of Multi-Band, Miniaturized-Element Frequency Selective Surfaces

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Summary

Frequency selective surfaces (FSS's) with multi-band characteristics have a wide range of applications and have received significant attention over the past two decades. Multi-band FSS structures are formed simply based on single-band FSSs'. This method is somewhat limited depending upon the desired response and fabrication difficulties. In a different approach, multi-band designs using multi-resonant elements, as the unit cells of the FSS, have been investigated and reported previously. In [1], a method based on cascading single-band FSS's is used to achieve a multi-band response. It is also shown that by perturbing the unit cell structure of the single-band FSS discussed in [1], additional resonances can be created which produce a dual-band response. In [2], instead of one, two resonant elements are embedded in a single unit cell to produce a dual-band characteristic. Other methods include those employing optimization algorithms (genetic algorithms) to design and refine the unit cell geometry to generate a desired, multi-band frequency response [3].

The class of miniaturized-element FSS's was first introduced in [4]. Two objectives were sought for such structures: 1) achieving a periodicity much smaller than a wavelength to substantially reduce the dependence of response on the incidence angle and eliminating harmonic responses of previous FSS's, and 2) designing the FSS elements (unit cells) with local properties, meaning that each element of the FSS can produce the desired frequency selective behavior with minimal dependence on the neighboring elements. A possible solution was to design such an FSS structure using spatial lumped elements. This way elements can be designed small compared to the wavelength, and established filter theory could be used for synthesis purposes. A salient feature of this design is that the interaction of the surface and incoming plane wave is predominantly in TEM mode. As a result, higher order Bragg modes are suppressed, and harmonic responses are eliminated. Initially, we were able to achieve a compact design with unit cell size dimensions of about $\lambda/5$ [4]. Later on, we improved our approach and were able to demonstrate FSS's with unit cell dimensions that were much shorter than the wavelength ($\lambda/12$) [5].

In this article, the performance of the recently proposed miniaturized-element FSS, [5], in a multi-band arrangement is studied. The first multi-band design presented here is constructed by cascading single-band, two-layer FSS structures, similar to those reported in [5], with dielectric spacers of proper thickness separating them.. A dual-band FSS of the first kind, with four printed faces, was fabricated. The second design aims at reduction of the overall FSS layer thickness and improvement on out-of-band rejection. This method uses modified building-blocks each of which has only a single metal layer. The modified single-face FSS has a slightly degraded performance compared to the original two-face FSS as regards to out of band rejection. However, this degradation in performance is regained and even improved through proper mutual coupling. It is shown that these layers can be arranged in a way to properly couple to neighboring layers in order to generate the desired, multi-band characteristics with improved performance. A dual-band-pass FSS of the second kind using a single substrate was also fabricated and tested.

References

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