A Dual-Frequency Band Waveguide Using FSS

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Abstract— **A waveguide is described that propagates at two-frequency bands with low loss and good bandwidth. The structure is achieved by the simple insertion of a frequency selective surface to form a guide within a guide. The transmission response is tailored by the response of the FSS. The technique lends itself to other waveguide geometries and many combinations of frequencies can be accommodated.**

I. Introduction

Simple rectangular and circular waveguides are limited to a single mode bandwidth of between 30 and 40% due to the propagation of higher order modes at high frequencies. In some applications it is desirable to propagate more than one frequency band in the same waveguide to save space and weight. One possibility is to use ridge guide although this is complex to manufacture and is inflexible in terms of the bandwidth offered. In this letter experimental results are presented for a waveguide structure which can be operated at two different frequency bands by employing a frequency-selective surface within the waveguide. The technique can also be extended to create dual-band horn antennas fed directly from the waveguide.

II. Design

Frequency selective surfaces (FSS) are filters. Electromagnetic waves incident on the FSS are either reflected by it or pass through it with little attenuation, dependent on the frequency of the wave. One possible arrangement for a dual waveguide is shown in Fig. 1, where a frequency selective section is placed longitudinally within an existing waveguide. The principle of operation is as follows. The outer guide has conventional metallic walls. The frequency selective surface is placed parallel to one of the narrow walls at a distance such that it will form one broad wall of a higher frequency guide, wg2. The frequency transmission response of a typical FSS is shown in Fig. 2. At the operating frequencies of the metallic outer guide near f_t, the surface is transparent and the propagating wave passes without interference, effectively not seeing the FSS. At higher frequencies near f_r, the FSS reflects, appearing like a metallic wall. A wave introduced into this smaller guide wg2, enclosed by the FSS, will therefore propagate down it. The dimensions of the inner guide are designed such that it operates at the band centered on f_r. The signal can be excited by a suitably dimensioned coaxial probe introduced through the narrow wall of the outer guide, as in a conventional waveguide launcher. This has no significant effect on the performance of the larger guide.

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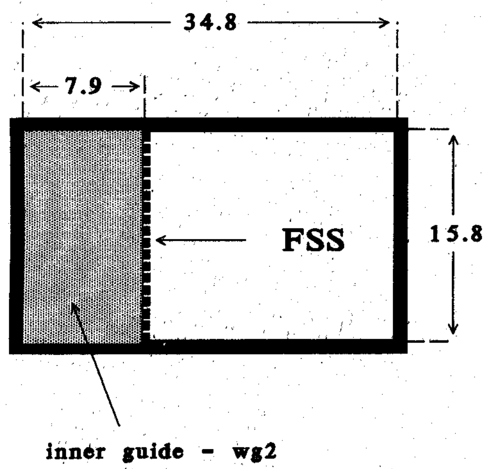

Fig. 1. Cross-section of dual-band waveguide.

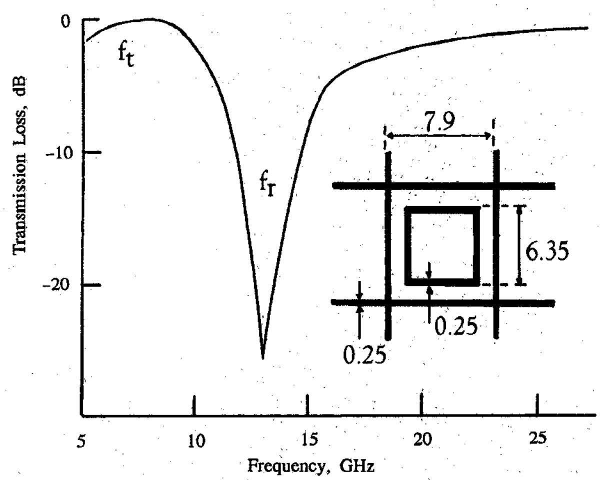

Fig. 2. Frequency response and geometry of gridded square FSS.

Multiple images of the FSS are reflected in the broad walls of the metallic guide so that it appears to be infinite in extent in that dimension. Therefore this constrains the periodicity of the FSS array to be an integer multiple of the narrow wall dimension of the outer guide. The FSS must be accurately aligned within the structure so that an exact image is created. Waveguide simulators make practical use of this infinite imaging principle to make measurements on small sections of antenna arrays and FSS [1].

III. Results

A series of measurements have been made, using a vector network analyzer, on a dual-frequency waveguide designed to operate at bands centered on 8 and 13 GHz. The dimensions of the guides are given in Fig. 1 and are standard WR137 and WR62 cross-sections. The FSS element used in this study was a gridded square [2] shown in Fig. 2 together with its measured frequency response. The response meets the required design of a transmission band at 8 GHz and a reflection band at 13 GHz. The FSS was printed on a thin 0.012 mm thick supporting dielectric and this was bonded to one side of a former made from a low dielectric constant foam ($\epsilon_r \approx 1.1$) measuring 15.8×7.9 mm in cross-section and 300 mm long. The former with FSS was a push fit into the waveguide.

At the lower band the loss of the metal waveguide was compared with and without the FSS structure in it. Fig. 3 shows the results. The inclusion of the FSS within the guide had little effect on the transmission properties, the losses introduced over the FSS pass band were less than 0.5 dB from 7 GHz to 9 GHz. The high frequency signal was excited in the guide using coaxial probes inserted through the narrow guide wall. Loss measurements were made by substituting another foam former into the guide with a metallic plate replacing the FSS. Fig. 3 shows the measurements for the higher band where again the response is clearly shaped by that of the FSS. The signal passes down the inner guide with little attenuation, with a usable bandwidth for a 0.5 dB loss from 12 to 15 GHz.

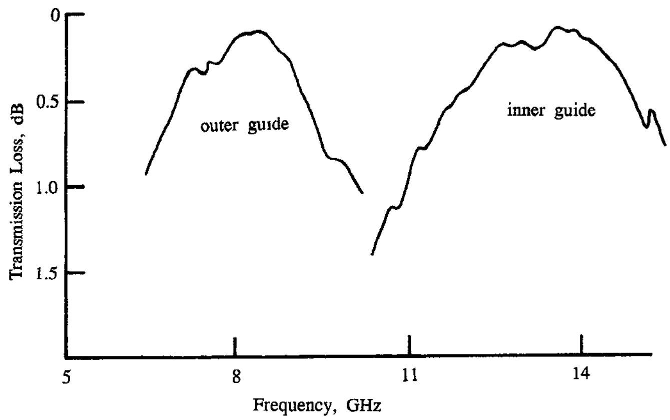

Fig. 3. Transmission loss measurements at two frequency bands.

IV. Discussion

A dual-band waveguide has been described that allows signals centered on 8 and 13 GHz to be transmitted with little loss and good bandwidth. The structure is achieved by the simple insertion of a frequency selective surface to form a guide within a guide. The transmission response is tailored by the response of the FSS. The technique lends itself to other waveguide geometries and many combinations of frequencies can be accommodated.

References

[1] P. W. Hannan and M. A. Balfour, "Simulation of a phased-array antenna in waveguide," *IEEE Trans. Antennas Propagat.*, vol. AP-13, pp. 342–353, May 1965.

[2] C. K. Lee and R. J. Langley, "Design of a single layer frequency selective surface," *Int. J. Electron.*, vol. 63, no. 3, pp. 291–296, 1987.