Hybrid mode matching method for the efficient analysis of rods in waveguided structures

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Abstract

Circular metallic and dielectric rods inside a rectangular waveguide are frequently found in the geometry of many passive microwave devices, such as passband or stopband filters, diplexers or oscillators. Ceramic dielectrics with high dielectric constant and temperature stability are commercially available. They allow the replacement of bulky and expensive waveguide resonant cavities in microwave filters or oscillators by low-cost, small size, good temperature stability, and high-Q dielectric resonators. If the height of the dielectric posts is the same as the height of the waveguide, that is, if the posts are all inductive or H-plane, better out of band rejection and multipactor response can be obtained.

The authors have developed a technique for the analysis of these passive devices which consists on dividing the device in simpler building blocks: empty waveguides, steps and sections of waveguide loaded with the dielectric or metallic posts. The generalized scattering matrix are the parameters that characterize the frequency response of the structure. The matrix of each block is obtained by the most suitable analysis method, and then all the matrices are connected by a new and efficient iterative technique that provides the generalized scattering matrix of the whole filter.

For instance, the generalized scattering matrix of the empty sections of the waveguide is well known from the literature , and the waveguide step can be analyzed by means of several modal techniques, such as the well know mode matching method or the integral equation technique.

However, the analysis of waveguide sections loaded with circular obstacles is far more complex. In order to characterize these structures, circular and rectangular geometries must be considered at the same time. This complexity in the geometry makes it difficult to use purely analytic techniques, while the numerical methods are highly time-consuming. This is a serious drawback when using the simulator in a design process, since it typically demands a huge number of simulations before it finds a suitable design that fulfils the specifications. For this reason the accurate and efficient analysis of H-plane circular rods inside rectangular waveguides has received considerable attention for more than 60 years.

In this paper the authors propose a method for this analysis of the strucutre by decomposing the electromagnetic fields in two different regions: near the cilindrical post as cylindrical modes and far away as guided modes. The cylindrical field waves are series expansions of Bessel and Hankel functions and the field guided waves are series expansions of sinusoid functions. Then a circular boundary is used to match cylindrical and guided waves. The method increases the accuracy and stability of the analysis, no matter the number of modes or the nature of the H-plane problem under study. This is accomplished with a new mode matching procedure which uses the fast Fourier transform to solve the matching between cylindrical and guided modes. Analytical expressions are used to characterize the circular posts in the inner region, thus resulting in a highly efficient technique for the analysis of single or multiple posts inside a rectangular waveguide.

The results of the work were assessed by the automated design of a filter with dielectric rods by a CAD tool, the manufacture of a prototype and the measument of its frequency response.

Index Terms

Microwave filters, Rectangular waveguides, Applications of the fast Fourier Transform, Bessel and Hankel functions, Mode matching methods, Dielectric loaded waveguides.