Accurate CAD for dual mode filters in circular waveguide including tuning elements

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Abstract

Dual mode filters in circular waveguide are very extensively used in multiplexers for modern communication satellites. Their industrial manufacture requires the use of tuning screws to be manually adjusted as well as significant experimental effort. In this paper we present an accurate CAD tool for dual mode filters in circular waveguide that can take into account the effect of tuning elements. The CAD tool is based on a multimode admittance matrix formulation and can effectively be used to reduce the filter development effort. In addition to theoretical results, measured results are also presented thus fully validating the CAD tool discussed.

I Introduction

[1] Dual mode filters in circular waveguide are commonly used in the input/output multiplexers of communication satellites, and their basic features are now well understood (see [1], [2] instance). In the most common industrial implementation, a dual-mode filter uses cross shaped irises for the inter-resonator couplings and will in general have a minimum of three tuning screw per cavity that need to be adjusted manually. Furthermore, a significantly experimental characterization effort is generally required for the dimensioning of the coupling irises.

To reduce (or eliminate) the manual tuning effort and the experimental characterization, what would be needed is a full-wave representation of the cross irises and of the tuning screws. Recently, an attempt has been made to model tuning screws using, for instance, a circular ridge waveguide [3] in connection with finite elements. This approach is viable, however, the use of finite elements requires a very large computational effort so that this approach is in practice of limited use. The modeling of cross irises is also possible in terms of a cross shaped waveguide section. The related modal analysis, however, again requires substantial computational effort.

In this paper we describe a CAD tool for dual mode filter in circular waveguide that is based on the use of cascaded sections of circular, elliptical, and ridge circular waveguides. The modes of the elliptical and ridge circular waveguide are obtained very efficiently following [4] and [5]. The complete device is then analyzed using the admittance matrix formulation [9] so that a very accurate CAD tool is obtained. The basic structure of the dual-mode filter is described in this paper together with the measured and simulated performance of a typical four-pole filter thus fully validating the CAD tool developed.

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II Filter structure and the CAD tool description

The structure under investigation is the dual mode filter shown in Fig. 1. It is composed of cascaded sections of rectangular, elliptical, circular and ridged circular waveguides.

To understand the basic operation of the structure proposed, let us consider a centered, thick elliptic iris inserted inside a circular waveguide. If one of the axis of the elliptical waveguide is aligned with the electric field incident from the circular waveguide region, no coupling is introduced between the orthogonal modes of the circular waveguide. However, because of the difference in dimension between the two axis, the two polarizations will emerge on the other side of the elliptical iris with different phases and intensities. An elliptical iris can therefore effectively replace the traditional cross shaped iris.

Furthermore, in a typical dual mode filter, each circular cavity has there tuning screws, the tuning screw assembly (TSA), placed in a plane where the electric field has a maximum (Fig. 1). To model the TSA we have replaced each tun

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ing screw with a conical ridge in a section of uniform ridged circular waveguide. The problem is now reduced to finding the modes of this waveguide together with the coupling integrals between this waveguide and a circular waveguide. This has been done following the very efficient approach described in [5] and [10]

As previously mentioned, the electromagnetic study of the junctions between different waveguides can be conveniently carried out using the multimode admittance matrix formulation, as described in [9], for instance. Following [9], the problem is reduced to the computation of the coupling integrals between the modes of the waveguides involved in the junction. Once this is done, cascaded junctions can be easily studied by writing a global equivalent network representation, as shown in Fig. 2. From the network we can easily obtain a banded linear system that can be inverted very efficiently to compute the electrical behavior of the complete structure.

III Application examples

As an application example we will discuss a dual mode a four-pole filter centered at 11 GHz and with a bandwidth of about 200 Mhz. The structure of the filter is shown in Fig. 1 while the results of the computer simulation are shown in Fig. 3

The possibility of eliminating completely the need for manually adjusted tuning screws is certainly very attractive. On the other hand, for specific applications, it may result in very expensive hardware implementations because, in general, this type of filters require high mechanical accuracies. This point is clearly demonstrated by the measured results shown in Fig. 4. The curves shown are the insertion and return losses of the structure in Fig. 1 manufactured with a standard accuracy of ± 10 microns. As we can see, the basic filter behavior is correct but the return loss is degraded due to the insufficient mechanical accuracy.

It is therefore clear that for low-cost dual mode filter applications, manually adjusted tuning screws are required. However, in order to correctly dimensions all of the parts of the filter, a CAD tool capable of a full-wave analysis is always required. On the other hand, circular tuning screws are very difficult to analyze efficiently but, using the TSA assembly described in this paper, the complete filter can be dimensioned even though circular tuning screws are used at the end.

As a demonstration of this last point, we show in Fig. 5 the measured response of the same filter but where the TSA assembly has been replaced with three tuning screws. As we can see, a much better return loss can now be achieved.

It is important to note that having used an elliptical iris for the inter-cavity couplings, we can obtain two types of response from the structure, namely, with or without transmission zeros. In fact, if the tuning screws of the two cavities are in the same relative position, we obtain the responses in Fig. 5. On the other hand, if the tuning screws are placed as to invert the resonant fields in the cavities (mirror position), we obtain the response in Fig. 6, where we can clearly see two transmission zeros

Another point that is interesting to note is that the penetration of the tuning screws is not exactly identical to the height of the ridges. All of the other dimensions, however, are identical so that the CAD tool developed can, in fact, be used to design the complete filter structure, even though at the end the TSA assembly is replaced, for manufacturing reasons, with manually adjusted tuning screws.

IV Conclusion

An accurate CAD tool has been described for dual-mode circular waveguide filters including the effect of tuning screws. The cross shaped intercavity coupling irises have been replaced by elliptical irises and the tuning screw assembly (TSA) has been replaced by a section of ridged circular waveguide. The admittance matrix procedure has then been used to obtain a very accurate CAD tool. In addition to theoretical results, measured results have been presented indicating that the CAD tool is indeed accurate and can be used even if circular tuning screws are used in the final hardware implementation.

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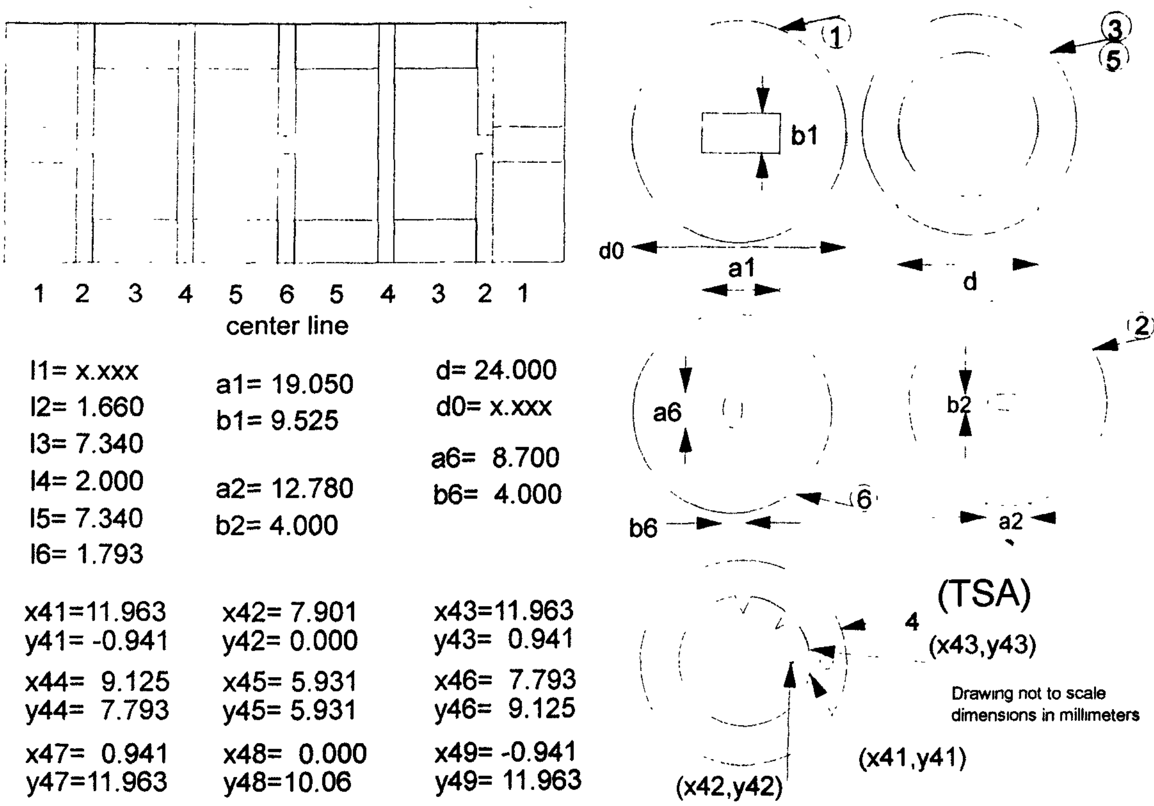

Fig. 1 Four-pole dual-mode filter in circular waveguide.

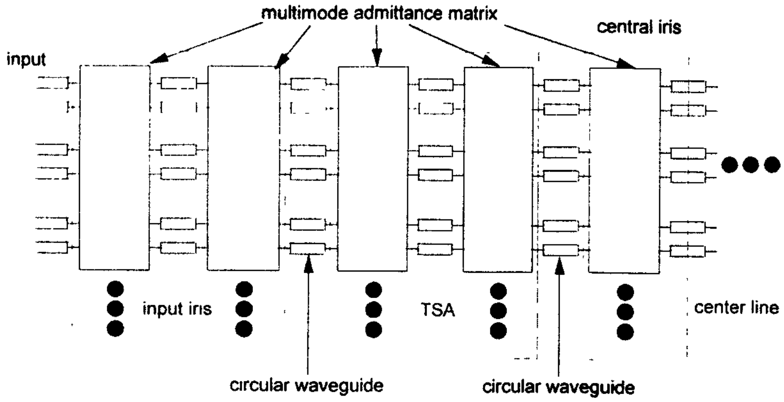

Fig. 2 Multimode equivalent circuit of the filter in Fig. 1.

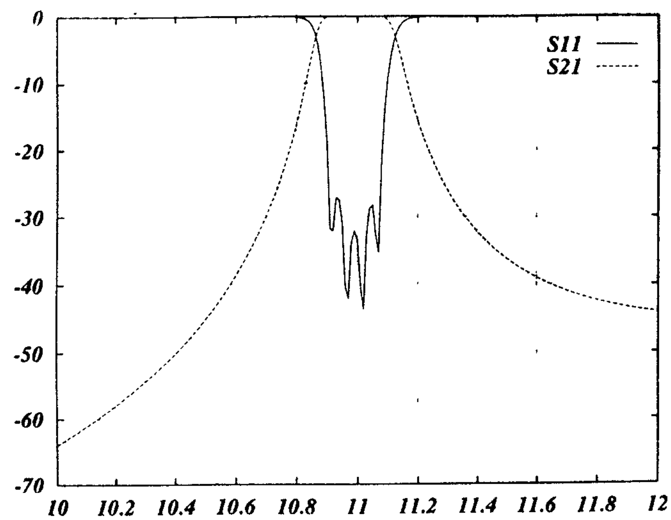

Fig. 3 Simulated response of the filter in Fig.1

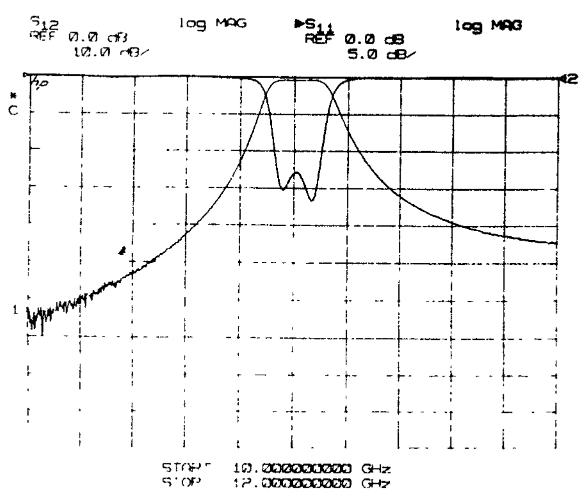

Fig 4 Measured response of the filter in Fig. 1.

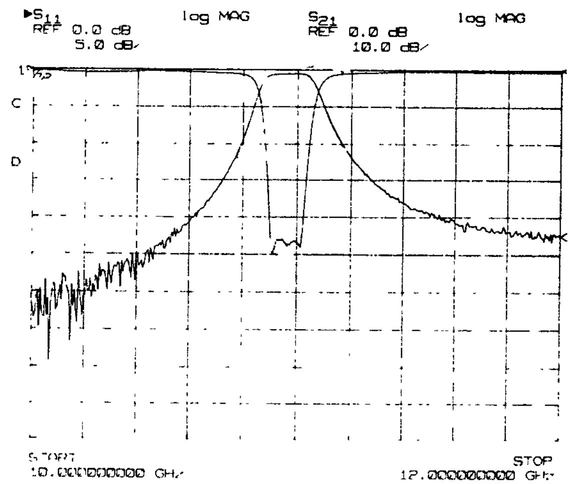

Fig. 5 Measured response of the filter in Fig 1 with the TSA replaced by manually adjusted tuning screws.

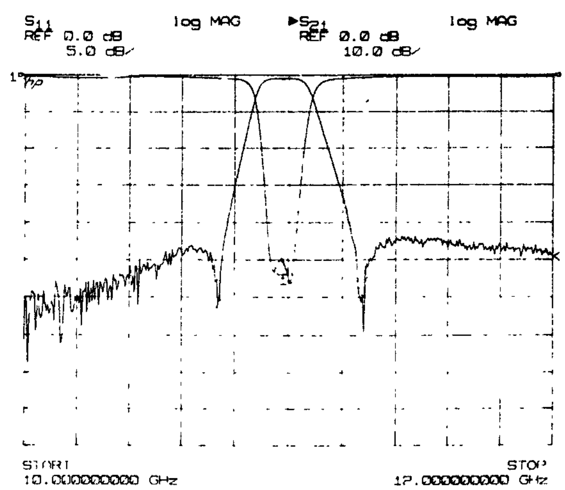

Fig. 6 Same as Fig. 5 but positioning the tuning screws to obtain a pair of transmission zeros.

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