MODAL ANALYSIS AND DESIGN OF THE DUAL-BAND ORTHOMODE JUNCTION

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Abstract: An analysis and design concept for the dual-band orthomode junction is presented. The center-piece of the design is a waveguide six-port cross junction. Its modal analysis is verified by measurements available in the literature. After introducing appropriate symmetry planes for the orthomode junction, a principal design approach is outlined. The entire procedure is demonstrated for a K/Ka-band design example. The final design is compared to results from the commercial software package HFSS and is found to be in good agreement.

I. INTRODUCTION

Waveguide-technology-based antenna feed system for communication links often require capabilities to simultaneously combine orthogonally polarized signals in the receive and trans mit frfequency bands. To facilitate such an approach, the dual-band orthomode junction has been proposed in [1]. The pricipal structure of [1] is reproduced in Fig. 1 for illustration purposes. Its operation is as follows:

In the lower frequency band (f_L), the horizontal and vertical polarizations at the square input port are directed toward the vertically and horizontally branching waveguides, respectively. Identical lowpass or band-reject filters in all four branching ports isolate the signals of the upper frequency band. Identical waveguide runs are used to combine the respective signals in order to create a single port each for lower-band vertical and lower-band horizontal polarizations.

The upper frequency band (f_U) is available at the through port. A matching transformer acts as a high-pass filter by allowing the waveguide dimensions to be sufficiently reduced so that the lower frequency band is operated below cutoff at this port. The upper-band signal can then be connected to a standard orthomode transducer or, if the upper band operates in left-hand/right-hand circular polarization, to a septum polarizer. The reader is referred to [1] for more details on such components.

Although it is immediately obvious that the dual-band orthomode junction of Fig. 1 will perform the tasks outlined above, itsperformance with respect to achievable bandwidths and matching levels is still unclear. Therefore, this paper presents a first attempt to analyze and optimize such a component for K/Ka-band application. The design goal is set for a 2-GHz bandwidth centered at 19.5/29.5 GHz and return-loss levels of 20 dB or better.

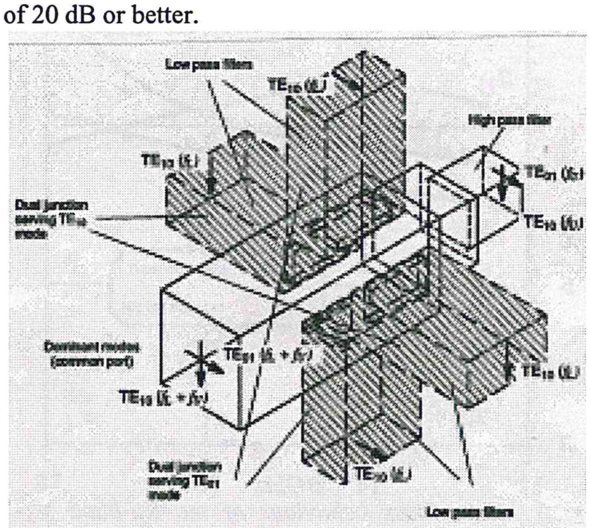

Fig. 1 *Principal layout of the dual-band orthomode junction [1].*

II. THEORY

The centerpiece of the orthomode junction is thewaveguide six-port cross junction depicted in Fig. 2. Based on the resonator approach within the mode-matching technique (MMT), which was originally proposed in [2], a TE_{mn}-TM_{mn}-mode routine for the six-port cross junction was developed and the results compared to measurements presented in [3]. After renumbering the respective ports in [3] with respect to Fig. 2, the direct comparison is shown in Figs. 3 and 4, thus validating the modal analysis of the six-port cross junction.

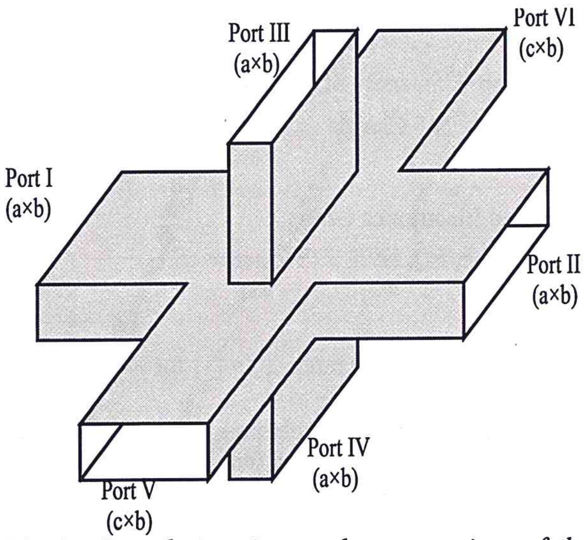

Fig. 2 *Port designations and cross sections of the waveguide six-port cross junction.*

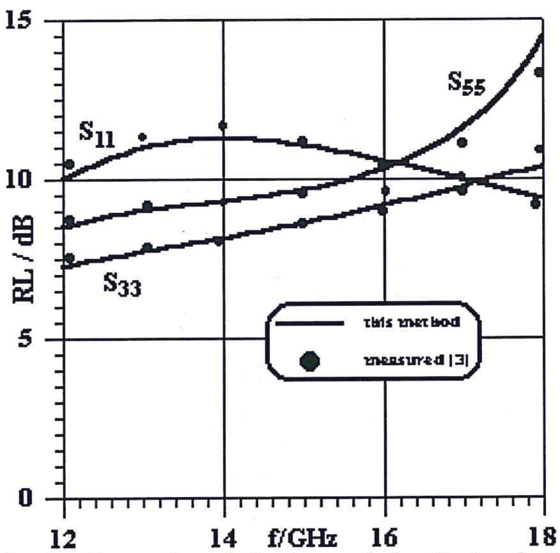

Fig. 3 *Return-loss behaviour of the Ku-band six-port cross junction and comparison with measurements in [3]; a=c=2b=0.622".*

One of the salient features of the dual-band orthomode junction is its symmetry. Due to this property, only those modes, which fit the symmetry conditions will be excited, thus permitting operation over a relatively wide bandwidth. This symmetry is also reflected in the analysis and design procedure. Fig. 5 shows the reduction of the six-port junction of Fig. 2 to a four-port junction with a magnetic wall at x=a/2 and an electric wall at y=b/2. Due to the different (square) waveguide connections to the four-port junction (common port at port I and the transformer to the upper frequency band at port II; c.f. Fig. 1), symmetry in z direction cannot be assumed.

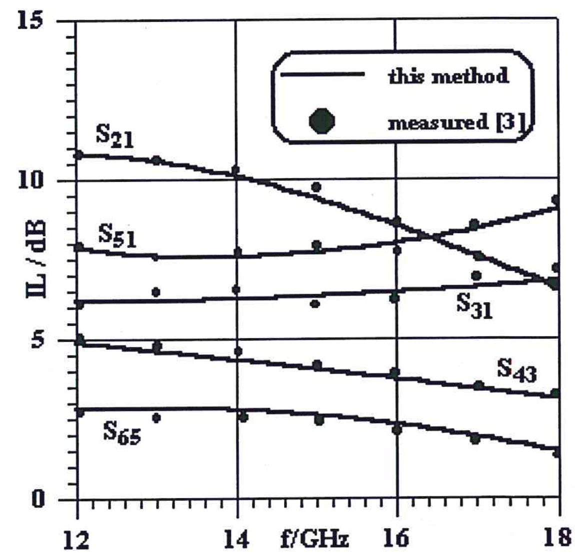

Fig. 4 *Insertion-loss behaviour of the Ku-band six-port cross junction and comparison with measurements in [3]; a=c=2b=0.622".*

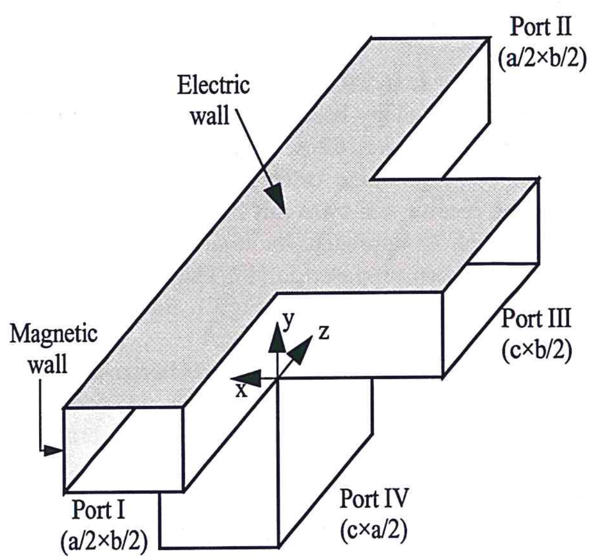

Fig. 5 *Symmetry conditions and port dimensions for six-port junction in Fig. 1.*

1. Initial Design

The design proceeds as follows: First of all, the common-port and through-port square waveguide dimensions are chosen such that, considering the symmetry planes, the common port supports both frequency ranges in its mono-mode bandwidth, whereas the high-frequency (through) port only operates the upper frequency band above cutoff. Secondly, equivalent-circuit synthesis techniques combined with accurate MMT algorithms are used to design an E-plane band-reject stub filter, e.g. [1]. The constant width of the stub filter is usually, but not necessarily, identical to the width of the common port. Thirdly, a similar procedure is applied to the initial design of the transformer at the through port [1].

2. Optimization

In order to allow for a reasonable match, two extra sections of initially identical cross sections and reasonable lengths are each added at ports I and II (Fig. 4). The E-plane filter is initially interfaced with an iris (Fig. 1). For the initial set of parameters, the generalized scattering matrices of the common-port discontinuities, the through-port transformer and the two braching stub-filters are connected, under consideration of the individual symmetry conditions, to the scattering matrix of the four-port junction to obtain the overall scattering matrix of the entire structure. In order to obtain the final design, the individual dimensions are varied by a MiniMax-based optimization routine [4]. The function to be minimized is set as

$$F = \sum_i \Big\{ [(RL_L/RL_{11}(f_i)]^2 + [IL_L/IL_{21}(f_i)]^2 + [RL_U/RL_{11}(f_i)]^2 + [IL_U/IL_{31}(f_i)]^2 \Big\} \quad (1)$$

where $RL_{L,U}$ and $IL_{L,U}$ are the desired return and insertion losses in lower, upper frequency bands. $RL_{11}(f_i)$, $IL_{21}(f_i)$ and $IL_{31}(f_i)$ are the respective actual values at frequency f_i. The design is deemed to be accomplished once every single term in (1) is less than unity.

III. RESULTS

Using the procedure outlined in the previous section, a dual-band orthomode junction was designed for 20 dB return loss and 2 GHz bandwidth for the 19.5/29.5 GHz range. The high-frequency port dimensions are 0.224"× 0.224" which corresponds to the width of a standard Q-band waveguide. At the common port, the cross section was chosen 0.38"× 0.38" in order to maintain monomode operation over both frequency bands. For the same reason, the ports of all branching ports are 0.38"× 0.19". Under these conditions and assuming the symmetry conditions outlined above, the two horizontal branching ports are completely decoupled from the two vertical ones. Fig. 6 displays a to-scale sketch of the optimized component.

As a first verification of the design, a computation with the commercial software package HFSS was performed in and around the two frequency bands centered at 19.5 GHz and 29.5 GHz.

The results are compared in Fig. 7. Very good agreement is obtained for the lower band return loss and the upper band insertion loss. The upper band return loss of the HFSS calculation is, however, slightly shifted toward lower frequencies.

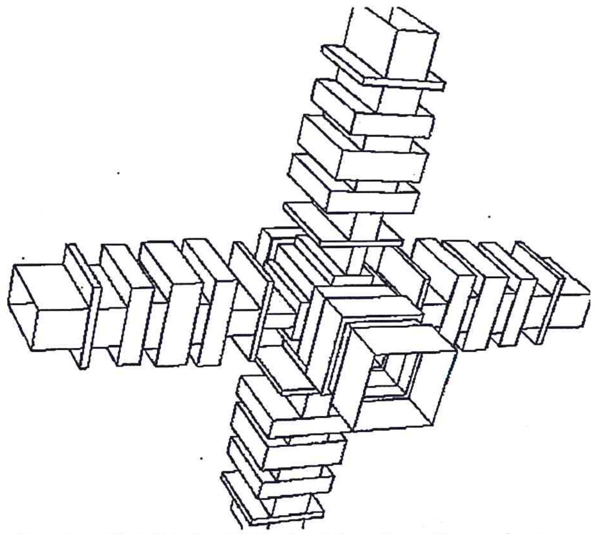

Fig. 6 *19.5/29.5 GHz dual-band orthomode junction.*

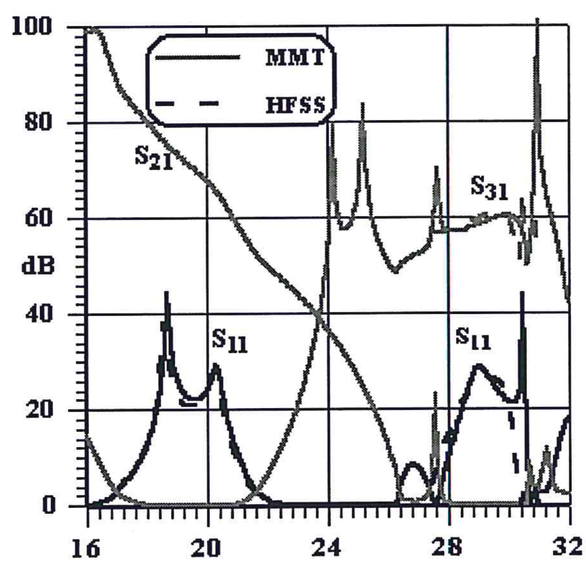

Fig. 7 *Input return loss and insertion losses to through and branching ports of the 19.5/29.5 GHz dual-band orthomode junction.*

Due to the choice of port dimensions and monomode operation as explained above, the return loss performances of the high-frequency (through) and low-frequency (branching) ports are identical to the input return loss with respect to the different calculations using the MMT or HFSS. This is demonstrated in Fig. 8.

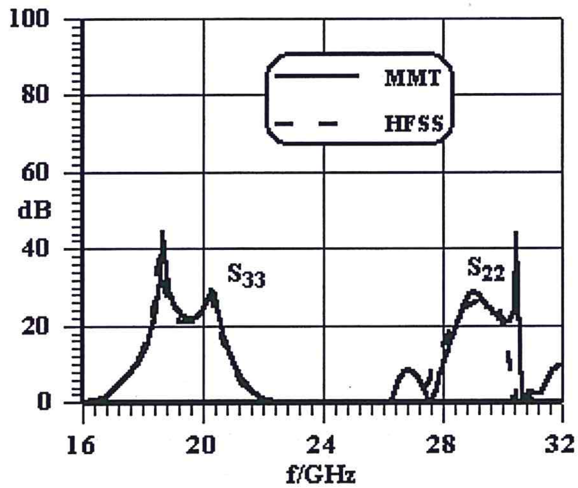

Fig. 7 *Return-loss performance at through and branching ports.*

IV. CONCLUSION

It is demonstrated that the dual-band orthomode junction can be employed for applications involving polarization discrimination in relatively widely separated frequency bands. Reasonable bandwidths, e.g. 2 GHz centered at 19.5 GHz and 29.5 GHz, and an acceptable return loss of 20 dB can be achieved. The design concept outlined, the MMT-based analysis procedure and the optimization strategy turn out to be a viable option for the design of the dual-band orthomode junction.

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