A Dual Mode Filter with Trifurcated Iris and Reduced Footprint

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ABSTRACT — **This paper presents a novel configuration for dual mode filters operating in the TE11n modes. The use of the proposed configurations in the design of dual mode filters leads to a significant reduction in the filter footprint. Techniques to suppress the TE21n modes in a TE113 cylindrical cavity filter are proposed by using a trifurcated iris arrangement. Simulated and experimental results are presented to verify the validity of the proposed configuration.**

I. INTRODUCTION

A dual mode filter using TE11n mode is one of the most important filter types for (narrow band) satellite splitting and combing networks. Numerous papers were published in the past mainly using longitudinal end-coupled [1] configuration as shown in Fig. 1. The side-coupled configuration [2] as shown in Fig. 2 was not seen as often probably due to the difficulty of design and poor spurious performance. Since the filter is often used in a multi-channel configuration, a minimum spurious free band between 500MHz to 1GHz is desired depending on the specific application. This paper presents a novel configuration for dual mode resonators operating in the TE11n modes. A new set of I/O and inter-cavity iris arrangement was introduced to suppress the TE21n mode. The use of the proposed configurations in the design of dual mode filters leads to a significant reduction in the filter footprint while keeping unwanted spurious out of operating band from 11.4GHz to 12.4GHz. Simulated and experimental results are presented to verify the validity of the proposed configurations using both mode-matching technique and finite element method.

II. THE NEW CONFIGURATION [3]

For high Q applications, the cavity diameters are intentionally made bigger which results in several higher order modes such as TM01 and TE21 to be propagating inside the cavity. In [2], a similar iris arrangement as in [1] was used. This often reduces the filter performance since the spurious power escapes through the coupling irises cut between cavities. In the proposed configuration the input and output coupling slots were chosen be parallel to the axis of the cylinder (about 1/6th of cavity length from the bottom). Since the TM01 mode has no magnetic field component along this direction, this input and output arrangement does not let any power to leak through the filter in TM01 Mode, virtually eliminating it. It should be noted that the input/output slots however allow power to be coupled into the TE21 mode.

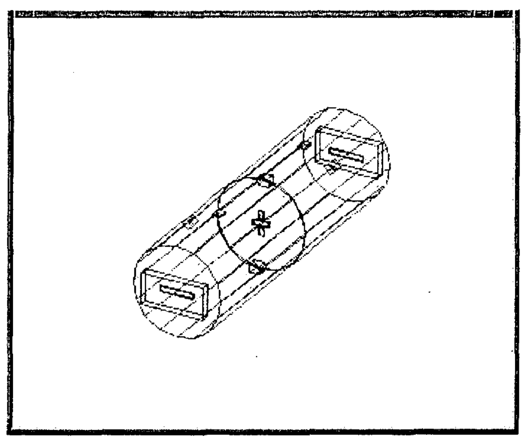

Fig. 1 TE113 Longitudinal End-coupled Filter

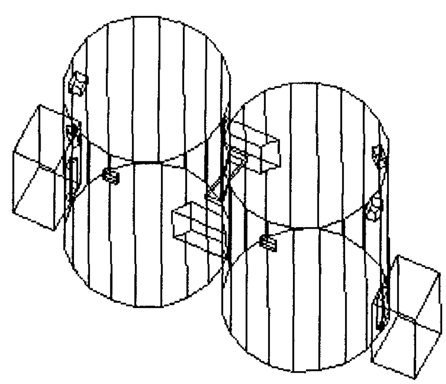

Fig. 2 Wire Frame view of a Side Coupled Filter

In order for the dual mode filter to operate, couplings have to be provided for between cavities for the TE11 modes, which are parallel (also called primary) and orthogonal (also called secondary) to input TE11mode. A cross iris slot was often used as shown in Fig. 1 (wire frame view of RF representation). The key concept behind the azimuthally trifurcated iris slot in Fig. 2 is to provide the necessary coupling to the TE11 modes while suppressing the unwanted coupling between TE21 modes. Fig. 3 shows a cross section view (from a real filter) of trifurcated iris arrangement of 20 and 22 that reduce the influence of TE21 mode.

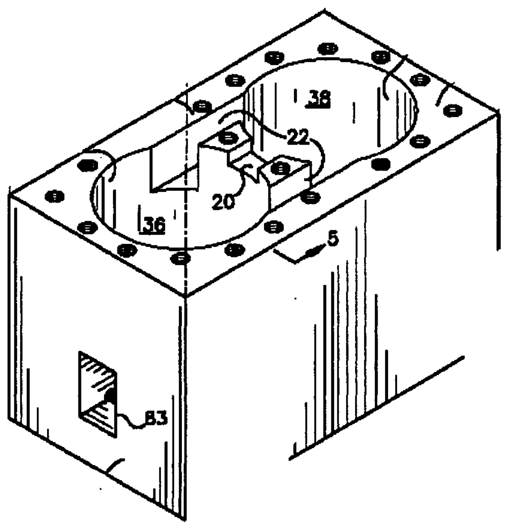

Fig. 3 Trifurcated Iris arrangement of a Practical Filter

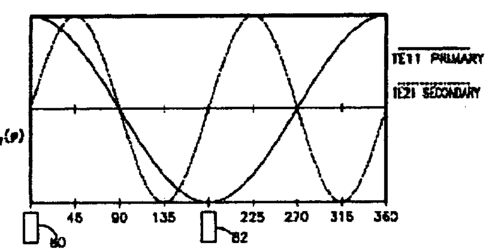

Fig. 4 Hz field of Primary TE11 and Secondary TE21

Fig. 4-6 set forth distribution of the strength of the magnetic field in the azimuthal direction for TE11 and TE21 modes. If the input iris is taken as the 0° measurement, then the central iris 20 is located at 180° and the peripheral irises 22 are located at 135° and 225° respectively.

In Fig 4, the field Hz of TE11 primary mode and TE21 secondary mode are shown with respect of the input iris 80 and output iris 82 (no shown, same type as 80 in Fig. 3). The magnetic filed of TE21 secondary mode is null at the input and output iris, therefore no energy from the TE21 secondary mode enters the filter. Within the filter, the TE11 primary mode is coupled to the TE11 secondary mode by the coupling screw at 45° [1-2]. Neither the coupling screws nor frequency tuning screws at 90° couples TE21 modes because they always are located at nulls for either primary of secondary field components.

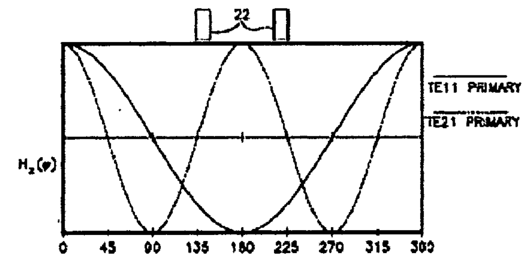

Fig. 5 Hz field of Primary TE11 and TE21

Fig. 5 plots the magnetic field Hz as function of the azimuth angle ϕ for the TE11 primary and TE21 primary modes. This energy is coupled to the output cavity through the peripheral irises 22 as shown in Fig.3, which extend in the axial direction. The TE11 primary mode has a non-zero value at the peripheral iris. The TE21 primary mode has zeros magnetic field at both of these irises. If the filter is perturbed slightly, and the curves in Fig. 5 shift either to the left or to the right, the magnitude of the TE21 primary mode would be non-zero and equal in magnitude with opposite signs. Therefore, the peripheral iris 22 in Fig.3 will not couple TE21 primary mode effectively.

The curves in Fig. 6 plot the magnetic field Hϕ as a function of the azimuth angle ϕ for the TE11 secondary and TE21 primary modes. This central iris 20 in Fig.3 couples TE11 secondary nicely while canceling TE21 primary field because of the null at the center.

The curves of Fig. 4-6 thus show an iris configuration where energy from the TE11 modes are fully coupled to the filter and then coupled between the two cavities. This iris configuration further reduces the propagation of TE21 modes by cancellation effects of the irises in the center wall and through the use of null field points.

III. DESIGN, SIMULATION AND MEASUREMENT

A TE113 dual mode filter was designed [1-5] for 11.7GHz band using a cavity diameter of 1.07 inch. The design bandwidth is 36MHz. A quick mode analysis using theoretical formulas [6] reveals the existence of spurious mode TE211 (11.2GHz), TE212 (12.55GHz) and TM012 (11.1GHz). Fig. 2 and Fig. 3 illustrates the proposed configuration for a four-pole dual mode filter where the cavities are placed upright and side by side. Since the cavities in this case have a 1.68:1 diameter to length ratio, the cavity footprint will be reduced by the same ratio. The couplings are realized by apertures in the sidewall of the cavities thus leaving the end walls available for a temperature compensation apparatus, which will be discussed in another paper. Mode Matching Techniques were used to design the iris and cavity dimensions, which can be found in many recent MTT publications [4, 5]. The central iris is used to realize the sequential coupling (M23) between the secondary mode in cavity one and primary mode in cavity two. Splitting and moving the cross coupling (M14) to the 135° and 225° degree position (measured from input slot as 0°) is designed to reduce the TE21n modes to an acceptable level. If one utilizes a cross slot in the center of the common wall as in [1, 2], the coupling of these spurious modes will be excessive. A simplified model as set up also using Mode Matching Technique to assess the effect of cross coupling (M14), which is realized by a vertical slot 45° from central slot (M23, or 135° measured from input slot). Fig.7 show the simulated transmission (IL or S21 in dB) of a conventional cross slot at center and a proposed slot 45° from center. It is obvious that the 45° slot (as shown with marker) is much more effective in term of suppressing TE21 modes. The simulation was done at a slightly different center frequency without loss of generality.

Commercial software based on Finite Element Method [7] was used to simulate frequency response of the whole filter. Simulated (labeled as Maxwell from Ansoft HFSS) and measured insertion loss and return loss are shown in Fig. 8. Close agreement between the simulated and measured response including far out of band spurious is shown. Although the effect of TE21 modes can still be seen around 11.2 and 12.55GHz, they are controlled under -25dB reduction. Without the trifurcated iris, the spurious could have no or very little attenuation at all and will "pull up" the rejection skirt of the filter at 11.7GHz. This novel iris arrangement ensures the designed filter will have a spurious free window up to 1GHz. Fig.9 shows a filter response tested over 60°C. A less than 0.5ppm frequency drift was achieved using a set of end cap compensators.

IV. CONCLUSION

A novel configuration for the dual mode TE11n cavity filter has been presented which can reduce the filter footprint by 25 % for TE113 with no sacrifice in filter Q. Simulated and measured responses have shown that the design is feasible. By using a trifurcated iris, a mode suppression technique for the TE21n modes has been presented with 1GHz spurious free window in Ku-band. This technique is not only suitable for to TE11n filters but also can be extended to TE10n type of filters with slight modification of irises. The proposed configuration promises to be useful for satellite multiplexers having extremely stringent mass, size and thermal requirements.

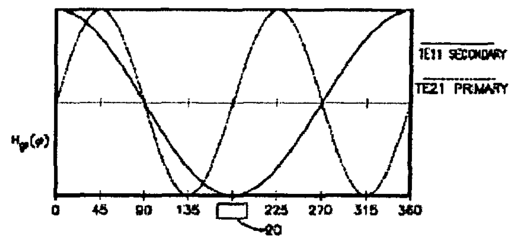

Fig. 6 Hϕ field of Secondary TE11 and Primary TE21

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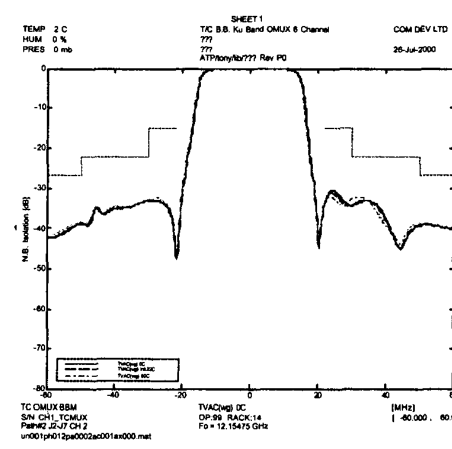

Fig. 9

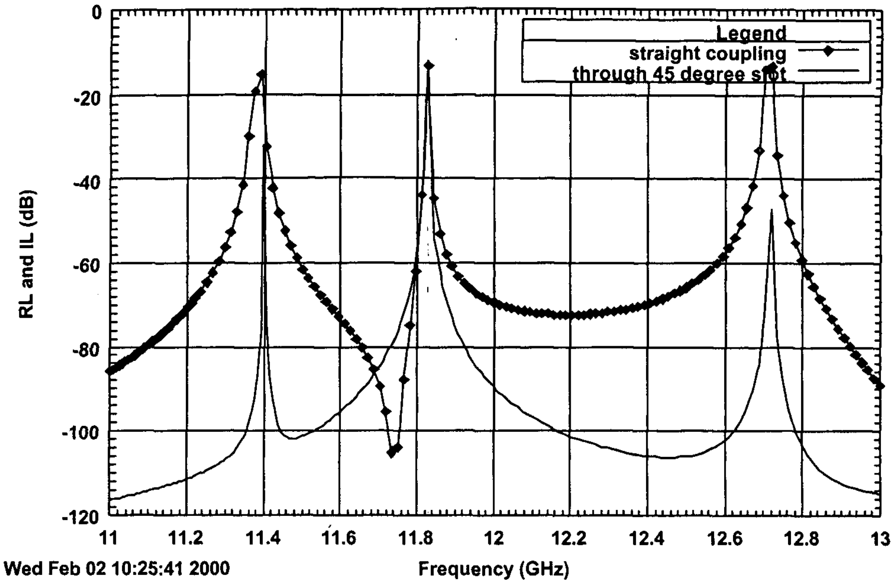

Fig. 7: Simulation and Measurement of a TE113 Filter

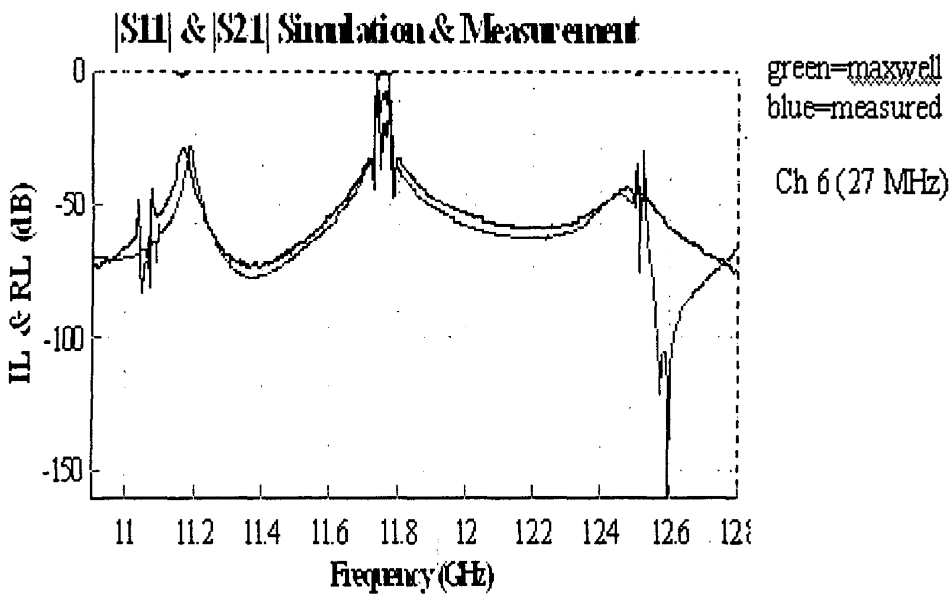

Fig. 8. Simulation and Measurement of a TE113 Filter