NEW POSSIBILITIES OF CAVITY-FILTER DESIGN BY A NOVEL TE-TM- MODE IRIS-COUPLING

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ABSTRACT

TE-TM resonances, being located in adjacent (physical) cavities are coupled by an iris. This new method is shown to provide realization of advantageous new coupling structures in dual- triple- mode cavity filter design. First experimental results obtained by a 7- pole filter (dual- / triple- mode cavities) are presented.

INTRODUCTION

Communications satellites have grown in transmission capacity from generation to generation. Hence, the requirements on channelizing filters have been increased steadily, both in number and performance. By this, a host of new design ideas has been created since the late sixties.

An essential breakthrough to a low-mass filter design was achieved by the development of the dual-mode technique, using TE_{11n} modes /1,2/. The introduction of this technique has led to a mass and size reduction by 50 % compared to previously used single-mode filters. Additionally, dual-mode filters provide the possibility to realize non-adjacent couplings, so that an elliptic-function response with a minimum number of cavities can be obtained by special arrangements of dual-mode cavities /3,4/. A further step towards mass savings was the development of triple-mode cavities /5/. However, the extension to more than two adjacent triple-mode cavities will lead to an unpractical filter design. This applies also to the quadruple-cavity filters, which were investigated by Bonetti and Williams /6/.

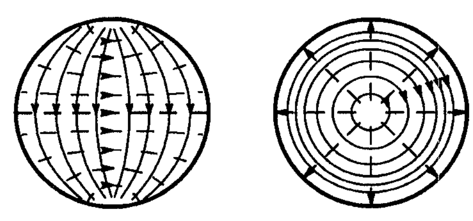
All above filter types require irises to realize the couplings of resonance modes in adjacent (physical) cavities. Up to now, only couplings of equal modes have been performed, i. e. only equally polarized TE- modes or TM- modes, respectively, have been coupled by the used irises (see for example fig. 4 in /6/).

This paper presents a coupling method of TM- and TE- cavity resonances, which are located in adjacent physical cavities, by means of an iris. It is introduced for TE_{11n}- and TM_{01m}- modes. These modes are well suited for dual- and triple- mode cavity filters, so that the application of this method provides the realization of new coupling structures for such filters.

THEORETICAL CONSIDERATIONS

An iris coupling of two modes can only be obtained if there are equal field components of both modes within the aperture region. This is trivial for equal modes having the same polarization. As well known, TE- modes are only coupled by their magnetic fields, being parallel to the aperture, while TM-mode coupling is obtained by the parallel magnetic field and additionally the perpendicular electric field in the aperture region.

Since TE- modes do not have an electrical field component perpendicular to the iris, a coupling of a TM- mode and a TE- mode in adjacent cavities can only be achieved by equal magnetic field components in the aperture region.



TE_{11n} TM_{01m}

Fig. 1: Field pattern (cross sectional view)
(— H-field at iris plane, - - - E-field)

Fig. 1 shows the field patterns of the TE_{11n}- and TM_{01m}- modes. A coupling of these modes can be performed by slot apertures (fig. 2), which are parallel to the horizontal diameter with a distance from it (/y/ > 0). For that reason, only the magnetic H_x- field in

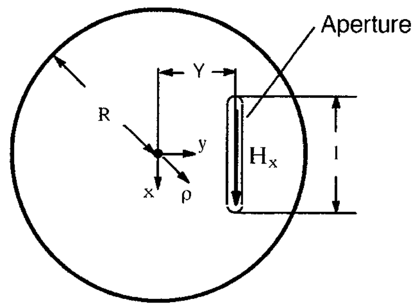


Fig. 2: Iris geometry for TE_{11n} – TM_{01m} mode coupling

slot direction is relevant for the coupling of these modes. The H_x-field within the iris plane is given by:

$$H_{xTE} \sim \frac{R}{\chi_{11}\,\rho} J_1(\chi_{11}\rho/R) \cdot \sin^2\phi + J'_1(\chi_{11}\rho/R) \cdot \cos^2\phi$$

for the TE_{11n}- modes and

$$H_{xTM} \sim J'_0(\chi_{01}\rho/R) \cdot \cos\phi$$

for the TM_{01m}- modes with

- R : radius of cavity
- ρ : distance from iris center ($\sqrt{X^2+Y^2}$)
- χ_{11} : 1.814
- χ_{01} : 2.405
- $\sin\phi = X / \sqrt{X^2+Y^2}$
- $\cos\phi = Y / \sqrt{X^2+Y^2}$

The max. H_x- field of the TE_{11n}- mode is located at $\rho = 0$, while the max. H_x- field of the TM_{01m}- mode is at $X = 0$, $Y/R = 0.76$.

H_x of both modes has been computed for lines ($x = X/R$) being parallel to the horizontal diameter ($y = Y/R$ = const.) (fig. 3). The max. field variation along a line x within the iris region with y = const is about 35 % for both modes. However, the H_x- variations of both modes are less than 5 % for typical aperture lengths (about $l/R = 0.5$, i. e. $x = 0.25$), i. e. nearly constant.

It should be noted, that the H_x- field of the TM_{01m}- mode changes its direction (180 °) at $Y = 0$. Hence, it has a positive and a negative maximum across the diameter of the cavity ($-R \leq Y \leq R$), but the absolute values are identical.

The coupling factor depends on the H_x- field within the aperture region. Therefore, the coupling coefficient between these two modes can be varied by the distance Y and the aperture length l. Since H_x of the TE_{11n}- modes has only one direction within the iris region, while H_x- of the TM_{01m}- modes changes its direction over the cavity diameter by 180 °, positive and negative couplings ($-M_{max} \leq Y \leq M_{max}$) can be obtained by appropriate dimensioning of the aperture (Y and l).

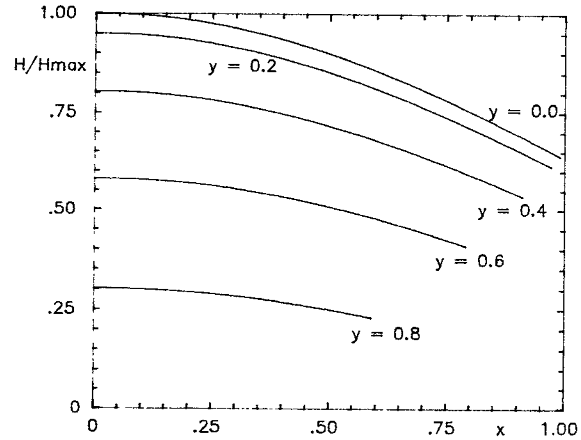


Fig. 3a: Computed H_x– field of the TE_{11n}– modes (Iris cross section)

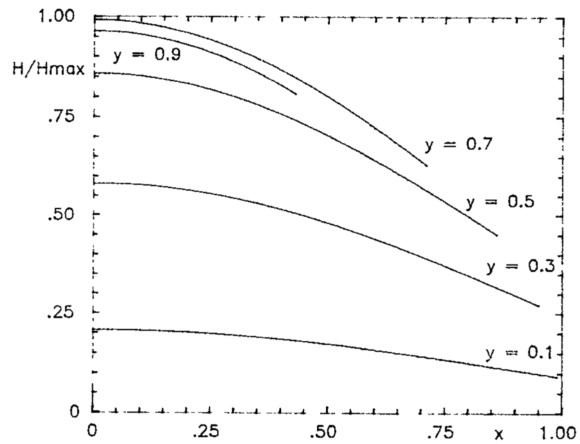


Fig. 3b: Computed H_x– field of the TM_{01m} – modes (Iris cross section)

NEW COUPLING STRUCTURES

This coupling method can advantageously be implemented in a filter design using adjacent dual (TE_{11n})- and triple (TE_{11n}/TM_{01m}) mode cavities. As well known, equally polarized TE_{11n}- modes, being located in adjacent cavities are coupled by a single slot aperture (which is parallel to the H- field). Hence, a coupling between the TM- mode of the triple- mode cavity and one TE- mode of the dual- mode cavity, as introduced above, can be performed on the premises of a second coupling between the concerning TE- mode of the dual- mode cavity and the equally polarized TE- mode of the triple- mode cavity.

However, it should be noted that such filter design can only be performed, since the iris geometry (fig. 2) provides the TE- TE- mode and the TE- TM- mode coupling by maintaining good decoupling between the degenerate TE- mode of the dual- mode cavity and the degenerate TE- mode as well as the TM- mode of the triple- mode cavity.

This means, that the two different couplings are provided by a single slot aperture. The different factors for the TM - TE as well as the TE - TE couplings are obtained by the two parameters Y (parallel distance of the slot aperture from the cavity center) and l (slot length). Normally, the TM - TE coupling will be used for the realization of cross couplings.

The implementation of this TM - TE coupling method in the dual- triple- mode filter design provides an infinite number of new feasible coupling structures to obtain optimal filter responses. This relates to the control of spurious modes (e. g. spurious modes will be better suppressed by single slot aperture than by two crossed slots) as well as to the design of the filter function. Fig. 4 shows some of the new coupling structures for higher order filters. For example elliptic-function responses can be obtained for odd order filters up to the 11th order. The coupling matrix and the computed response of a 9th order elliptic function filter with such novel configuration is presented in Fig. 5.

[M] =

	1	2	3	4	5	6	7	8	9
1	0	0 890	0	-0.163	0	0	0	0	0
2	0.890	0	0 707	0	0	0	0	0	0
3	0	0 707	0	0.518	0	0	0	0	0
4	-0 163	0	0.518	0	0 513	0	0	0	0 152
5	0	0	0	0.513	0	0 626	0	0	0
6	0	0	0	0	0.626	0	0.182	0	-0.707
7	0	0	0	0	0	0.182	0	0.989	0
8	0	0	0	0	0	0	0.989	0	0.544
9	0	0	0	0.152	0	-0.707	0	0 544	0

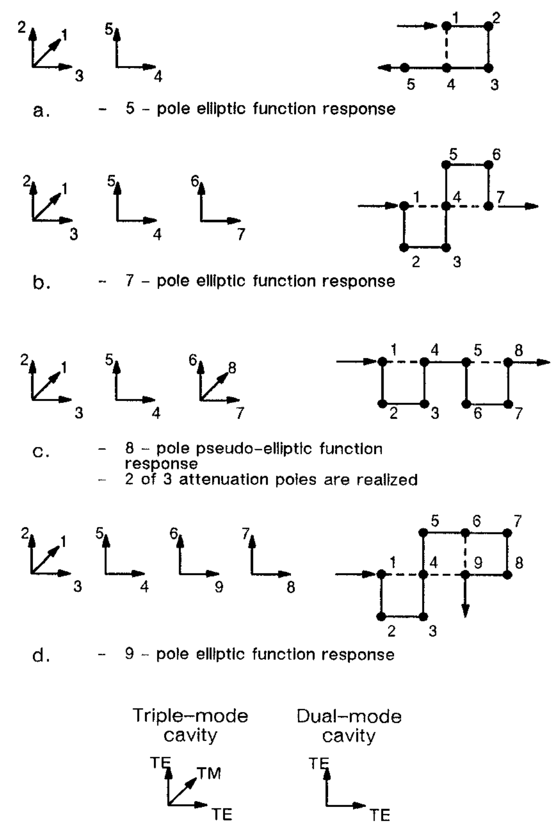


Fig. 4: Some new filter configurations using triple- and dual- mode cavities

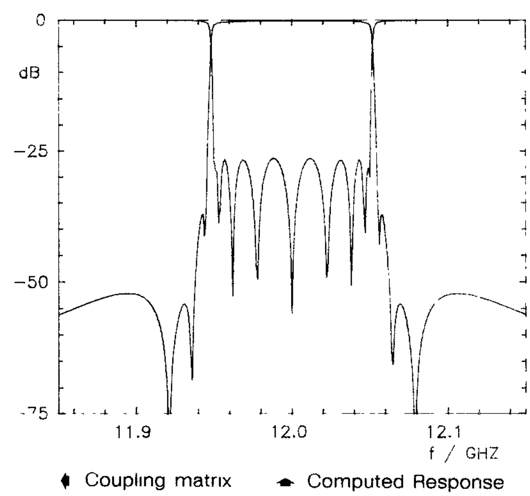


Fig. 5: 9- pole elliptic- function filter based on the novel coupling structure (fig. 4)

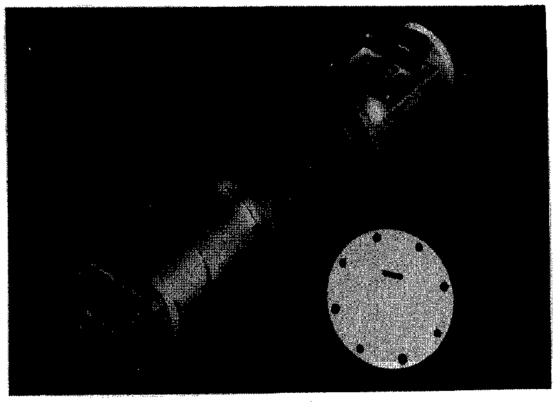
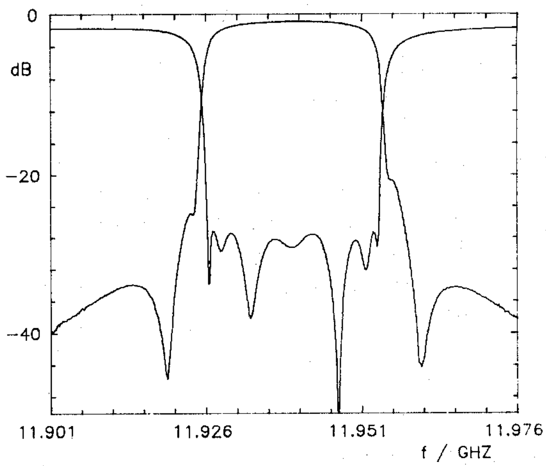


Fig. 6: Photograph of the 7- pole elliptic function filter



Measured return loss and selectivity

[M] =

	1	2	3	4	5	6	7
1	0	0.889	0	-0.218	0	0	0
2	0.889	0	0.749	0	0	0	0
3	0	0.749	0	0.516	0	0	0
4	-0.218	0	0.516	0	0.387	0	-0.507
5	0	0	0	0.387	0	0.902	0
6	0	0	0	0	0.902	0	0.761
7	0	0	0	-0.507	0	0.761	0

Normalized coupling matrix

Fig. 7: Realized 7-pole elliptic- function filter

EXPERIMENTAL RESULTS

First experimental results have been obtained by 5- pole and 7- pole filters. Fig. 6 shows a photograph of the realized 7 pole- filter consisting of one triple- and two dual- mode cavities. Furthermore an iris is shown, providing the above introduced coupling of equally polarized TE- modes and the TE- TM- mode coupling between the adjacent dual- and triple- mode cavities.

Due to this novel coupling method, it has been possible to realize a 7- pole elliptic- function filter based on the coupling structure given in fig. 4b. The coupling matrix and the obtained responses of the realized filter is given in fig. 7.

CONCLUSIONS

The presented coupling method provides new possibilities in the area of mixed- mode- cavity filter design. It can be employed advantageously for the generation of symmetric and asymmetric filter responses. The principle may also be applicable for other mode combinations.

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