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A NEW CLASS OF OPTIMIZED FINLINE AND E-PLANE METAL INSERT FILTERS WITH IMPROVED CHARACTERISTICS

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ABSTRACT

A new class of optimized finline and metal insert filters is introduced. In these filters, the ladder-type insert is located in a waveguide section which is either wider or narrower than the embedding standard waveguide. An abrupt step junction at each end forms the transition to the standard waveguide and is included in the analysis. Both filter types provide a better suppression of spurious passbands and have significantly improved stopband attenuation. Filters with enlarged section are useful for design at the lower end of the waveguide band, whereas the narrower version is apropriate for bandend design.

INTRODUCTION

Conventional finline and metal insert filters consist of a ladder type insert centered in the E-plane of a standard waveguide. They have good performance when the passband is situated in the middle of the operating bandwidth of the waveguide and are suitable for both broadband and narrowband applications. However, their performance deteriorates when they operate either at the higher or at the lower end of the waveguide band.

In the first case the dominant mode in the subregions between the filter septa and the waveguide walls becomes propagative and transports an increasing percentage of the power. This destroys the inductive coupling between the resonators, reduces the stopband attenuation sigificantly, and lowers the spurious second passband. To alleviate this problem three different solutions have been proposed previously [1],[2]:

1. Increase the thickness of the metal insert.

2. Use a narrower waveguide for the filter section which is matched to the standard waveguide with a taper at each end.

3. Use a twin metal insert rather than a single one.

The first two solutions require precision machining and are therefore no longer realizable with low cost techniques. Furthermore, the addition of a taper section increases the length of the filter component. The third solution requires a greater effort in the mounting and adjustment of the twin metal inserts in the waveguide mount. The present paper proposes a fourth solution which combines the advantages of the previous attempts without complicating the realization of the filter.

REALIZATION OF THE NEW FILTERS

The main feature of this solution is to reduce the width of the filter section as in solution 2, but to replace the taper by a single step transition (see Fig. 1b).

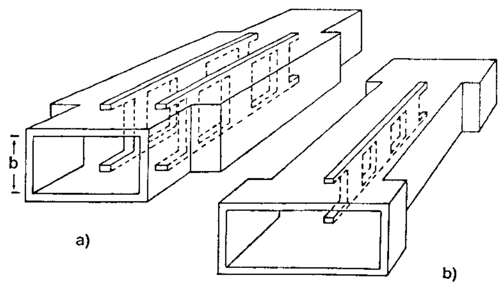

Fig. 1 Twin metal insert filter in an enlarged waveguide section a) and single metal insert filter in a narrower waveguide section b).

The effect of this step is included in the filter analysis and optimization. The realization of such filters is straightforward because the narrower filter section can simply be inserted between two standard waveguide flanges. In this way, the essential advantages of these filters, namely high design accuracy and low cost manufacturing, are preserved. Furthermore, the filter component is kept as short as possible.

Fig. 2 compares a conventional single metal insert filter designed for the bandend (curve 1) with the new design featuring a narrower filter section (curve 2). Note the increased stopband attenuation and the shift of the spurious second passband towards 55 GHz. Fig. 3 shows that the

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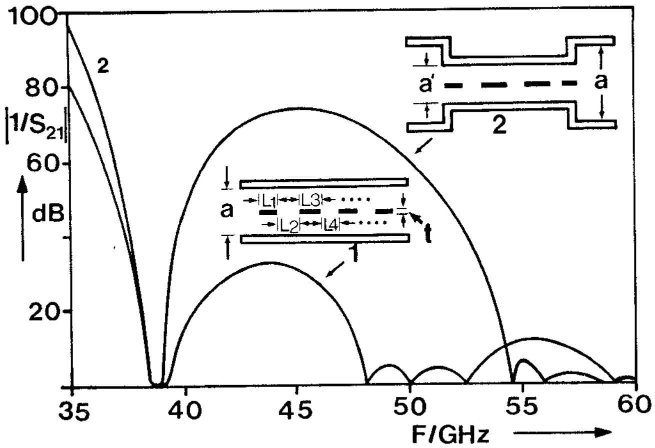

Fig. 2 Four resonator single metal insert filter t=50. µm, waveguide height b=3.556 mm. Filter 1: a=7.122 mm; Filter 2: a=7.112 mm, a'=5.689 mm.

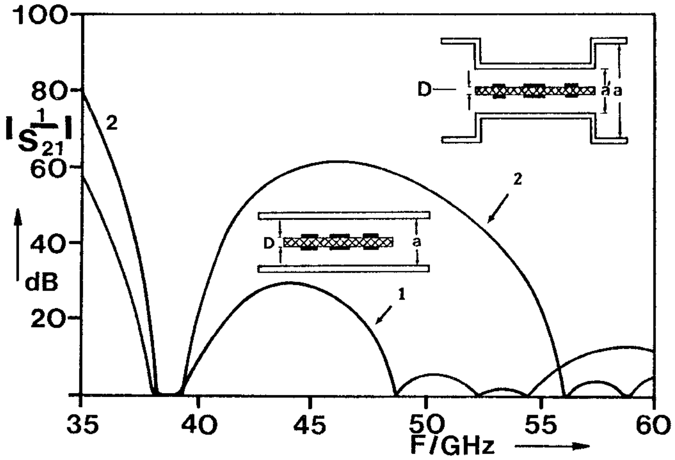

Fig. 3 Four resonator finline filters t=10. µm, D=127. µm, ε_r=2.22 (RT-Duroid) waveguide height b=3.556 (mm). Filter 1: a=7.112 mm; Filter 2: a=7.112 mm, a'=5.689 mm.

same effect occurs in finline filters.

The same design principle applies to the realization of filters for the lower end of the waveguide band. In this frequency range, the resonators of a filter in standard waveguide become relatively long because of the rapid increase of the guided wavelength towards cutoff. Increasing the resonator length, however, lowers the spurious second passband significantly. Moreover, because of the high waveguide attenuation close to cutoff, the resonators are relatively lossy.

To overcome this problem, the filter section is widened such that the passband is now centered in the single mode range of that section. By inserting the filter directly between two standard waveguide flanges (see Fig. 1a), we are able to improve the Q-factor, shorten the filter length and push the spurious second passband up in frequency without complicating the realization of the filter component (Fig. 4 , curve 2).

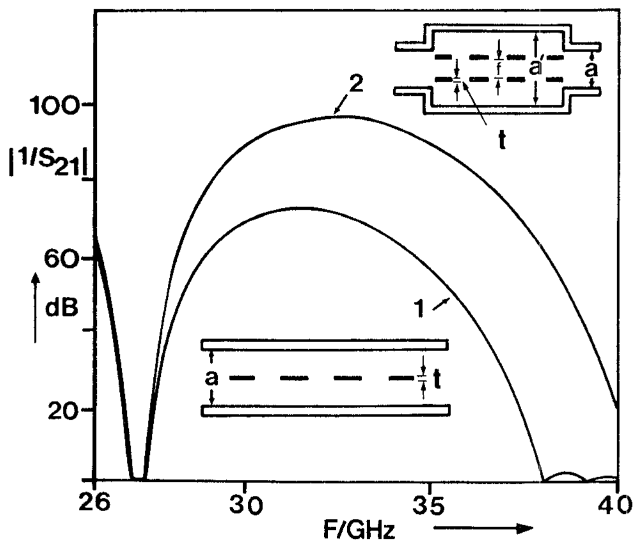

Fig. 4 Curve 1: Four resonator single metal insert filters, t=100. µm, a=7.112 mm. Curve 2: five resonator twin metal insert filter, t=50. µm, f=1 mm, a=7.112 mm, a'=7.8 mm. The waveguide height in curve 1 and curve 2 is b=3.556 mm.

Stopband attenuation and spurious responses can be improved even further by using twin metal inserts instead of single inserts. In these filters, propagation of higher order modes along the inserts is suppressed up to very high frequencies resulting in a higher stopband attenuation. Both filter types are optimized with the procedure described in [1]-[3].

THEORY

Since the theoretical treatment of the filter section has already been described in [1]-[3], only the scattering matrix of the single step transition will be given in this paper.

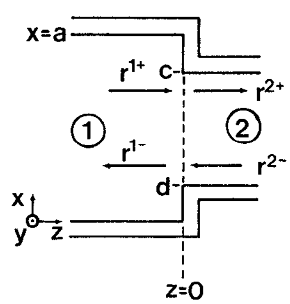

Fig. 5 Step transition from a standard waveguide to a narrow waveguide section. The waveguide height is constant.

The electromagnetic field in each subregion (i=1,2, see Fig. 5)

$$\vec{E}^{(i)} = -j\omega\mu\nabla\times\vec{A}_m^{(i)}; \quad \vec{H}^{(i)} = \nabla\times\nabla\times\vec{A}_m^{(i)} \qquad (1)$$

can be derived from the axial z-component of the magnetic Hertzian vector potential $\vec{A}_m^{(i)}$ • $A_{mz}^{(i)}$ is a sum of orthogonal eigenfunctions satisfying the wave equation and the appropriate boundary conditions.

$$A_{mz}^{(i)} = \sum_n T_{(n)}^{(i)} \cos kx_{(n)}^{(i)} \cdot p^{(i)} \left[r_{(n)}^{(i)+} e^{-jkz_{(n)}^{(i)} \cdot z} + r_{(n)}^{(i)-} e^{jkz_{(n)}^{(i)} \cdot z} \right] \qquad (2)$$

with

$$kx_{(n)}^{(i)} = \frac{n \cdot \pi}{f^{(i)}} ; \quad f^{(i)'} = (a, c-d), \quad p^{(i)'} = (x, x-d)$$

and

$$T_{(n)}^{(i)} = \frac{1}{\sqrt{\omega\mu kx_{(n)}^{(i)2} \cdot S_F^{(i)}}} ; \quad S_F^{(2)} = \frac{(c-d) \cdot b}{2}, \quad S_F^{(1)} = \frac{ab}{2}$$

$r_{(n)}^{(i)+}$ and $r_{(n)}^{(i)-}$ denote the amplitudes of the incident and reflected waves. Since the tangential field components Ey and Hx must be continuous at the common interface z=0, both amplitudes can be related to each other by the scattering matrix of the step junction (Fig. 5) as follows:

$$\begin{bmatrix} \underline{r}^{(1)-} \\ \underline{r}^{(2)+} \end{bmatrix} = \begin{bmatrix} \underline{E} & -\underline{L}_E \\ \underline{L}_H & \underline{E} \end{bmatrix}^{-1} \cdot \begin{bmatrix} -\underline{E} & \underline{L}_E \\ \underline{L}_H & \underline{E} \end{bmatrix} \cdot \begin{bmatrix} \underline{r}^{(1)+} \\ \underline{r}^{(2)-} \end{bmatrix} \qquad (3)$$

with the abbreviations $\underline{LE} = \sqrt{\frac{4 \cdot kz_{(n)}^{(1)}}{a \cdot (c-d) kz_{(n)}^{(2)}}} \cdot \underline{Fs}$ and $\underline{LH} = \underline{LE}^T$. $\underline{Fs}$ denotes the coupling matrix of the common interface [3].

The step transition between a standard waveguide and the enlarged filter section is similar.

Combining the scattering matrix of the filter section with the scattering matrix of the step junction, finally yields the total scattering matrix of the filter component.

The results presented in Figs. 2 to 4 have been generated with a computer program conceived along these lines. Up to 35 modes have been taken into account in the design and optimization of these filters.

CONCLUSION

A new design of finline and pure metal insert filters has been introduced. In comparison with their conventional counterparts, the new types of filters provide better stopband attenuation and spurious second passband suppression. The design theory includes the effect of finite metallization thickness, step junctions and the interaction of the dominant and higher-order modes necessary for accurate design.

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