Inductive Iris Band-Pass Filter Integrating Floating Inserts for Pseudo-Elliptic Response

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Abstract — **This paper presents a new type of pseudo-elliptic filter. It consists of the insertion in the waveguide of floating printed elements that generate transmission zeros. The design method is described first then the performance of one filter in the 30GHz band as well as its realization mode is presented.**

I. INTRODUCTION

Wireless communication systems have high filtering constraints, especially at millimeter-wave frequencies. Specifications of filters can even be severe with high rejection close to the pass-band and low losses, that implie high quality factors. For this reason, filters are usually realized in waveguide, using for example the Chebychev synthesis method [1]. Nevertheless, sometimes, specifications are too strict to be achieved using the synthesis cited above, with a suitable reduced order. Instead, filters with pseudo-elliptic response can be a solution, as transmission zeros at finite frequencies can be introduced.

In order to generate transmission zeros, the use of short-circuited stubs is well known [2]: the main drawback of this method is that stub insertion increases the size of the filtering structure and number of zeros introduced is limited.

From another point of view, stop-band, low-pass or high-pass filters can be realized using floating inserts in a waveguide [3]-[4]. But to design band-pass filters, it is necessary to cascade a low-pass with a high-pass filter, which also leads to a non compact structure.

The purpose of this paper is to present a new kind of compact pseudo-elliptic band-pass filter that can be realized at low cost. It consists of the design of a classic Chebychev band-pass filter with inductive irises and of the insertion of floating printed elements in front of the coupling irises, to introduce the transmission zeros.

This paper first focuses on the filter design itself, then presents performance of several filtering structures, and gives a realization mode of such structures.

II. PSEUDO-ELLIPTIC FILTER DESIGN

In order to facilitate the pseudo-elliptic filter design, the floating insert behaviour has been studied.

A. Floating Inserts Study

Floating insert is the name given to a metal element placed in a waveguide. The term of "floating" comes from the fact that the insert is not in contact with any waveguide wall, as shown in Fig.1. Several types of insert are described in this figure.

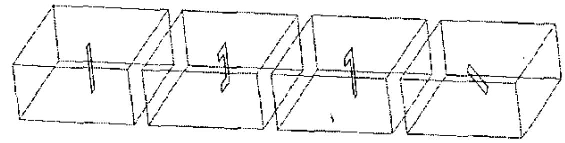

Fig. 1 Several types of insert.

This element creates a transmission zero at one frequency in the waveguide frequency band. As we were interested in designing pseudo-elliptic band-pass filters, the behaviour of the floating insert has been studied in a classical Chebychev filter. Bearing in mind the idea of minimizing the size of the filtering structure, we placed the floating insert in front of one of the coupling inductive irises used in the waveguide filter (Fig.2). First, the study has been realized on a single inductive iris with one insert.

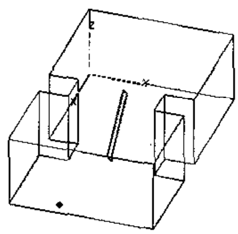

Fig. 2 Floating insert faced to an inductive iris.

Several parameters influence the frequency response of the floating insert (Fig.3):

- width (W)
- length (L)

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- slant angle / vertical axis (α)
- distance from the longitudinal axis of the waveguide (d)

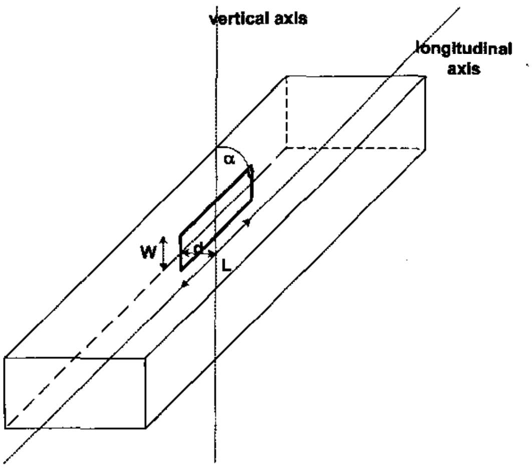

Fig. 3 Insert parameters.

Several simulations have been realized using the 3D electromagnetic simulator HFSS Ansoft, to study the behaviour of the insert. The structures have been modeled with perfect conductor and without any material to maintain the floating insert. Fig.4 shows the typical frequency response of a floating insert placed in front of an iris. In order to compare with the behaviour of the iris itself, the frequency response of a single iris is also described on the figure.

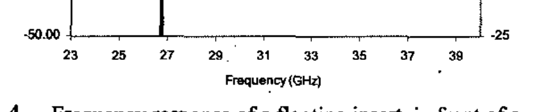

Fig. 4 Frequency response of a floating insert, in front of an iris.

Apart from the band where the transmission zero is achieved, the insert response can be close to the iris response, as we optimize the parameters, especially in the pass band of the filter.

The parameters have different effects on the response of the floating insert:

- When insert length L increases, the transmission zero frequency decreases,
- When the distance (from longitudinal axis) d increases, the transmission zero frequency increases, to a lesser degree,
- The width W parameter doesn't have an important influence on the zero frequency,
- The slant angle α also has an influence on the zero frequency, when it decreases, the zero frequency increases.

The type of the insert is chosen relatively to the length needed to realize the desired zero: if the insert length is superior to the waveguide height, an insert of "L" or "C" shape can be chosen.

B. Filter Design

In order to design the pseudo-elliptic filter, the first step consists of designing a classical band-pass filter using the Chebychev synthesis [1]. Next, the floating insert is introduced in the waveguide and dimensioned so as to generate the transmission zero at the desired frequency.

III. Performance

The use of a floating insert allows to reduce the required order of the filter. In this paragraph, several design of pseudo-elliptic filters are given with their performance.

For the first example, a filter centered at f=29.75GHz with a bandwidth of 1.5GHz and a rejection of 60dB at 26.5GHz is presented. With a conventional Chebychev response, these specifications would have implied a 5th order filter, while with a floating insert generating a transmission zero at 26.5GHz the order is reduced to 3. The filter has been designed in a WR28 guide. Table 1 gives the dimensions of the inductive iris filter and of the floating insert. The chosen insert is "C" shape (Fig.5), because of the total needed length to generate a zero at 26.5GHz.

TABLE 1
DIMENSIONS OF THE PSEUDO-ELLIPTIC FILTER

Iris	Thickness (mm)	Opening (mm)
1	1	4.386
2	1	3.312
3	1	3.312
4	1	4.386

Cavity	Length (mm)
1	5.149
2	5.808
3	5.149

Insert	L (mm)	W (mm)	α (°)	d (mm)
1	6.2	1	0	2.093

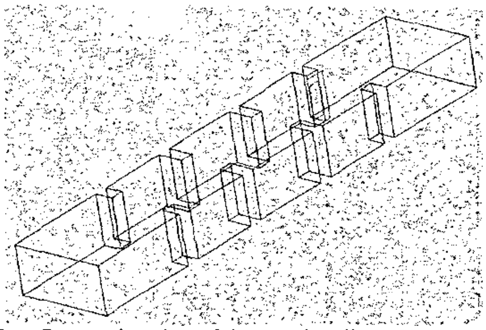

Fig. 5 Perspective view of the pseudo-elliptic filter.

Fig.6 illustrates the simulated performance of this pseudo-elliptic filter. As for the study of the floating insert in front of a single iris in the waveguide, the simulation and optimization of the filter have been performed with the help of HFSS™. Perfect conductor is used for the waveguide wall as well as for the metal insert. And no material is modeled to maintain the floating insert in the waveguide.

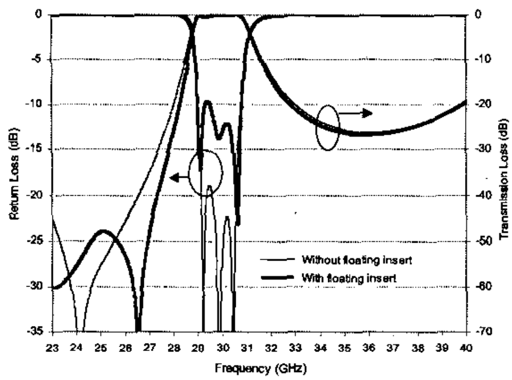

Fig. 6 Response of the first optimized pseudo-elliptic filter with one transmission zero.

As shown in Fig. 6, the performance of the filter are very interesting with a rejection superior to 70dB achieved at 26.5GHz, and with a quite similar response to the Chebychev one in the pass band.

The precedent filter presents a transmission zero at a frequency inferior to the pass band, but it is also possible to introduce a transmission zero at a frequency above the pass band, as shown in Fig.7.

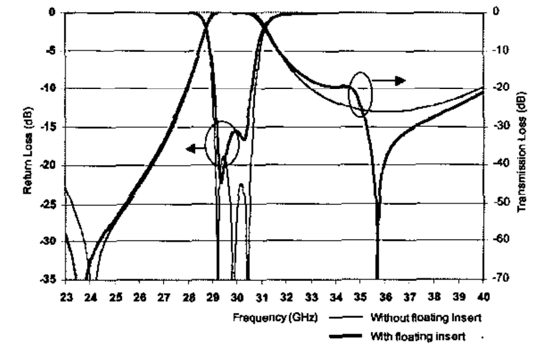

Fig. 7 Response of a second filter, with one transmission zero.

Moreover the new concept allows also the introduction of more than one floating insert, in order to generate more than one transmission zero. The inserts can be placed in front of the same iris or in front of different irises (Fig. 8, Fig. 9). If the introduction of the transmission zeros corrupts the frequency response of the filter in the pass band, it is possible to re-optimize also the dimension of the irises where floating inserts were placed. The response of this filter is represented in Fig. 10.

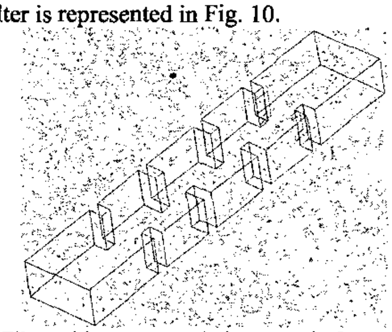

Fig. 8 Filter with two transmission zeros in front of the same iris.

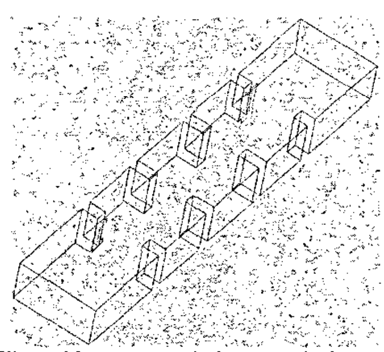

Fig. 9 Filter with two transmission zeros in front of different irises.

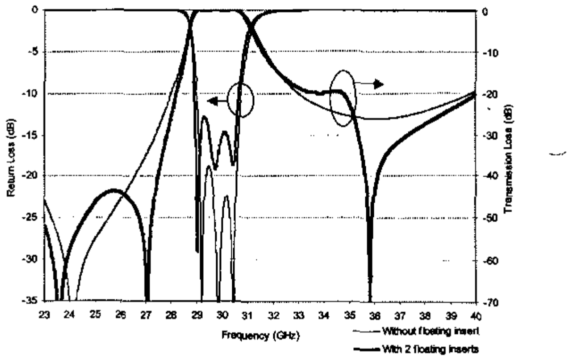

Fig. 10 Response of a filter with two floating inserts face to the same iris.

The examples presented above (Fig. 8, Fig 9 and Fig. 10) illustrate another interest of this concept: several zeros can be introduced without notable degradation of the pass band filter response. And the number of zeros you can introduce is greater than the one you can introduce with stubs, as the global structure size is not increased by the insertion of the floating printed elements.

IV. REALIZATION MODE

To maintain the floating insert in its position, it has to be printed on a substrate. But in order to minimize its effect, and especially the losses added, foam material is used. Many types of foam can be used but it must present a dielectric constant (ε_r) the closest to 1, with a low dissipation factor ($\tan\delta$). Several printed methods have already been patented to print metal elements on foam substrate. Fig. 11 shows some types of printed foam block that can be inserted in a waveguide.

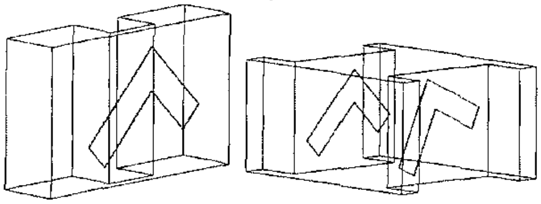

Fig. 11 Types of printed foam block

New simulation has been performed to evaluate the impact of the presence of the foam in the filter response. With a material foam ROHACELL™ (ε_r=1.08, $\tan\delta=10^{-4}$), simulation results presented in Fig.12 demonstrate low incidence with no significant degradation of the insertion loss and a shift of 500MHz of the zero frequency. That can be readjusted by re-optimizing the insert initial length.

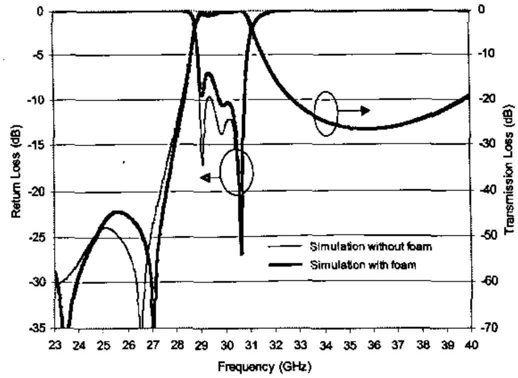

Fig. 12 Performance of a pseudo-elliptic filter with floating insert printed on foam material.

V. CONCLUSION

A new type of pseudo-elliptic band-pass filter has been described in this paper. The structure presents several advantages such as high performance, compactness and can be manufacturable with mass production techniques. Insertion of floating metal elements in the filter allows the introduction of more than one transmission zero, at several different frequencies. Also, this structure is suitable in the design of diplexers for microwave and millimeter-wave applications, especially for Ka band satellite communication terminals for which this study has been carried out.

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