Method of Spurious Mode Compensation Applied to Manifold Multiplexer Design

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***Abstract* — This paper outlines an hybrid circuit/electromagnetic process dedicated to manifold design which take into account spurious modes in the frequency band. The procedure is applied to design an experimental Ku-band triplexer. The multiplexer model and the compensation method are described. Good agreement between theoretical results and measurements ones demonstrates the efficiency of the procedure.**

I. INTRODUCTION

In a satellite communication system, an output multiplexer is necessary to combine the power outputs from the amplifiers. Such a multiplexer require excellent selectivity performances to separate adjacent channels. The more suitable configuration for this application is a waveguide manifold multiplexer. A manifold multiplexer example is presented in Fig.1.

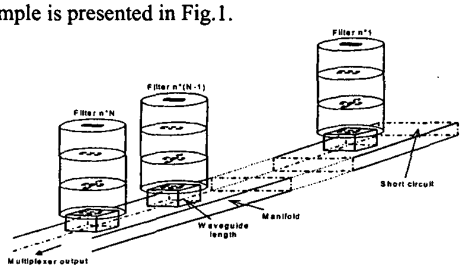

Fig.1. Waveguide manifold multiplexer.

Various methods have been already presented for the design of multiplexers [1]-[4]. The synthesis procedure presented in [2] is based on an analytical prototype of the manifold multiplexer. The filter prototypes and the waveguide lengths are modified trying to preserve the frequencies of perfect transmission of the individual filters. Nevertheless, this method becomes limited when contiguous manifold multiplexers are considered. To overcome this problem, many computer-aided analytical methods for the design of multiplexers were presented [3]-[4].

Nowadays, multiplexers are designed with an increasing number of channels filling the full transmission band. As a consequence, the theoretical spurious mode free range often becomes so narrow and spurious modes can damage the channel transmission. To identify clearly the spurious modes, an electromagnetic analysis of the multiplexer elements, have to be realized. In [5], the authors presented an hybrid circuit/electromagnetic method based on the modelisation of all the components of the multiplexer. The advantage of the model is the analysis over a wide frequency range including all the spurious modes in the frequency band of the multiplexer. If a spurious mode is identified in a transmission band, the geometry of the filter must be changed to place it outside.

In this paper, we focus on a multiplexer composed of a high number of narrow channels, called OMUX-A. The multiplexer is designed in the band [10,5 - 12,7] GHz applying a classical synthesis method [3]-[4]. Spurious modes were identified during the synthesis of the multiplexer and the physical dimensions of the filters were adjusted to place them outside the frequency band.

However, at the stage of the experimental realization of the multiplexer, a spurious mode, hardly coupled on a large band of frequencies, shifts in the frequency band and disturbs the response. The spurious mode effects and the characteristics will be shown in a following section. Because of the frequency band, the high number of channels of the multiplexer and the electrical characteristics of the spurious mode, it is impossible to shift it enough in frequency. To solve the problem, we set up a method showing that spurious modes can be taken into account and compensated during the conception of the multiplexer.

In this paper, the procedure is applied to the design of an experimental Ku-band triplexer. The triplexer frequency band is identical of the OMUX-A one and the three channels are representative of this multiplexer. The good agreement between theoretical results and experimental measurements demonstrates the efficiency of the procedure.

II. MULTIPLEXER MODEL

The multiplexer model is divided in several elements: filters, waveguide lengths and T-junctions. The waveguide lengths are analytical models derived from a two-dimensional (2D) modal decomposition. The T-junctions are analytical models derived from a three-dimensional (3D) electromagnetic analysis applying the Finite Element Method (FEM). The filters can be considered either using lumped element equivalent circuits (EL) or models based on an electromagnetic analysis applying the FEM (EM). The efficiency of the method is demonstrated by designing an experimental Ku-band triplexer.

Each filter is composed of dual mode circular waveguide cavities excited on their TE_{113} mode using two input/output irises. In each cavity, a screw at 45°angle from the polarization axes couples the dual modes and two tuning screws adjust the resonant frequencies. Single and cross irises ensure couplings between adjacent cavities. The filter topology is presented in Fig. 2.

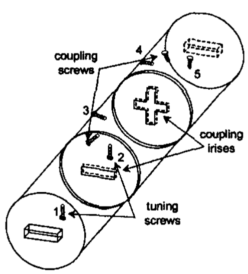

Fig.2. 5-pole circular waveguide filter.

The three filters, representative of the OMUX-A, are 5-pole filters having 36 MHz equiripple bandwidths. The center frequencies of the filters are:

- Filter 1 (channel 1): f_{01}=10,804GHz (low frequency)
- Filter 2 (channel 2): f_{02}=11,564GHz (average frequency)
- Filter 3 (channel 3): f_{03}=12,350GHz (high frequency)

III. Synthesis Of The Multiplexer

The first stage of the method is the analytical synthesis of the multiplexer considering the lumped element filter models. The multiplexer model is presented in Fig. 3.

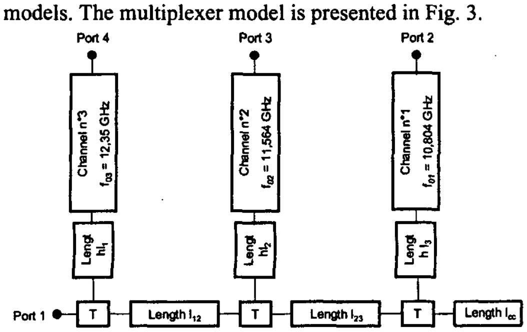

Fig.3. 3-channel output multiplexer in Ku-band.

This first stage permits to optimize the waveguide dimensions of the manifold and the coupling matrices of the three filters. The optimized response defines the theoretical response of the multiplexer.

The second stage of the synthesis is the analysis of the multiplexer considering the electromagnetic models of the filters. The filters are tuned separately applying an electromagnetic optimization described in [6]. Then, the electromagnetic models of the filters are connected to the manifold. The reflexion coefficient at the common port of the manifold is presented in Fig. 4, comparing the two multiplexer models.

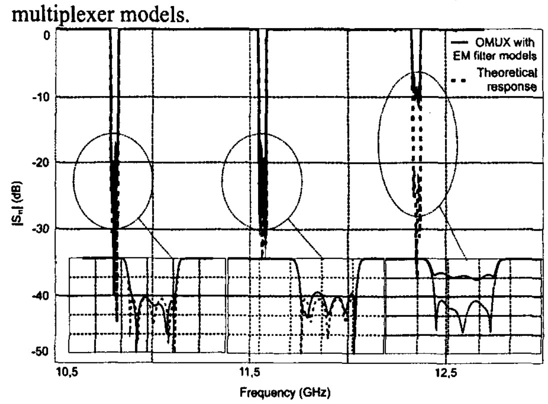

Fig.4. Influence of the spurious mode on the OMUX.

This analysis shows that a spurious mode disturbs the channel 3. To characterize the spurious mode, each filter is analyzed separately in the whole frequency band of the multiplexer using the FEM. Fig. 5. shows the phases of the reflexion coefficients of filters 1 and 3. One can notice that a spurious mode at 12,4 GHz in filter 1 can disturb the behavior of filter 3.

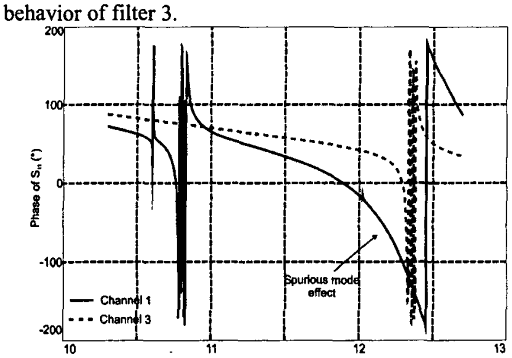

Fig.5. Presence of a spurious mode in filter 1.

The electromagnetic analysis of filter 1 shows that the electromagnetic field of the spurious mode is enclosed in the output cavity of the filter. The electric field distribution of the spurious mode, identified as a TE_{110} mode, is presented in Fig. 6.

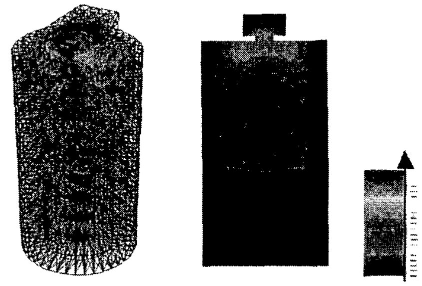

Fig.6. Electric field distribution of the spurious mode.

Then, we now describe a compensation method of the spurious mode that is identified.

IV. SPURIOUS MODE COMPENSATION

The aim of the procedure is to compensate for the influence of the spurious mode optimizing the waveguide lengths, the tuning screws and the coupling screws.

At the first step of the procedure, we have to model the spurious mode that is enclosed in the output cavity of the filter 1. As a consequence, one can model the spurious mode coupled with the TE_{113} mode with a short-circuited cavity, characterized by either an electromagnetic model or a lumped element one. The two models are presented in Fig.7a. Fig.7b compares the phase responses of the two models. More over, one can notice that the phase introduced by the input/output iris is taken into account through an equivalent waveguide length L_{eq}.

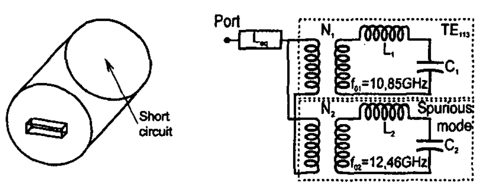

Fig.7a. Electromagnetic and lumped elements models of the output cavity.

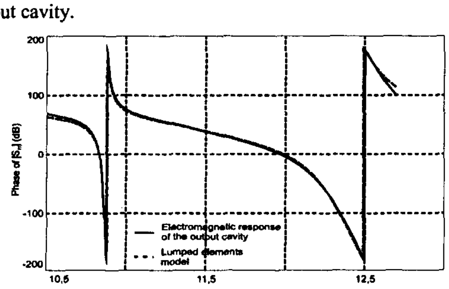

Fig.7b. Comparison between the response of the model and the electromagnetic one.

At the second step, we consider the output multiplexer analytical model, taking into account the spurious mode equivalent circuit that is presented in Fig.8.

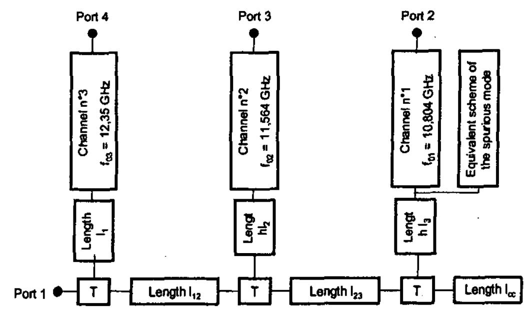

Fig.8. Multiplexer analytical model with the spurious mode equivalent circuit.

The multiplexer analytical model is optimized considering:

- the resonance frequencies and the coupling terms M_{23} and M_{45} in filter 2 and 3 models, that are related respectively to the tuning and to the coupling screws,
- the manifold waveguide lengths.

The optimized reflexion coefficient at the common port of the multiplexer model is presented in Figs.9a to 9c.

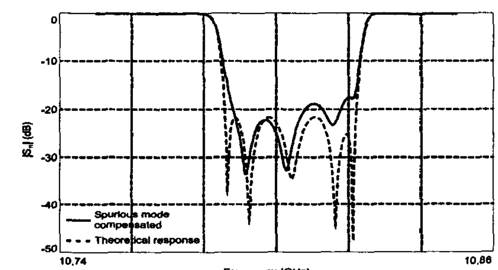

Fig. 9a. Response near 10,8 GHz

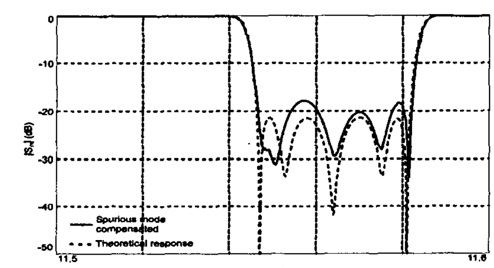

Fig. 9b. Response near 11,5 GHz

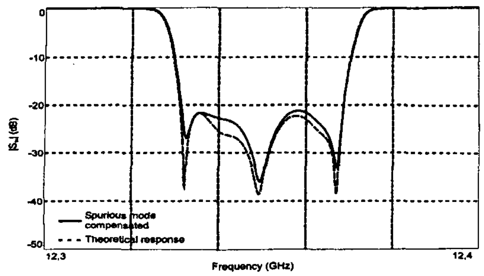

Fig. 9c. Response near 12,35 GHz

The third step is now to validate the procedure considering the electromagnetic models of the filters. The electromagnetic optimization procedure is applied in order to tune filters 2 and 3, considering the resonant frequencies and the coupling coefficients determined previously. The electromagnetic filter models are then connected to the manifold. The reflexion coefficient at the common port is presented in Figs.10a to 10c.

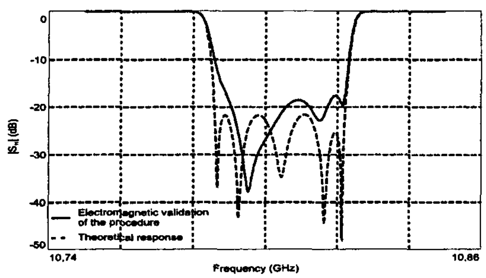

Fig. 10a. Response near 10,8 GHz

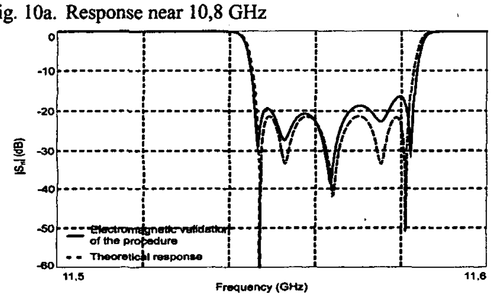

Fig. 10b. Response near 11,5 GHz

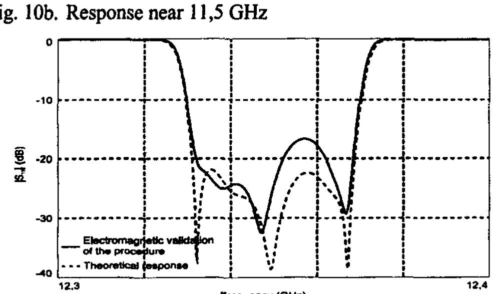

Fig. 10c. Response near 12,35 GHz

The output multiplexer has been built and tested by ASPI. The first experimental results are presented in Fig. 11. The good agreement between experimental results and theoretical ones shows the efficiency of the procedure.

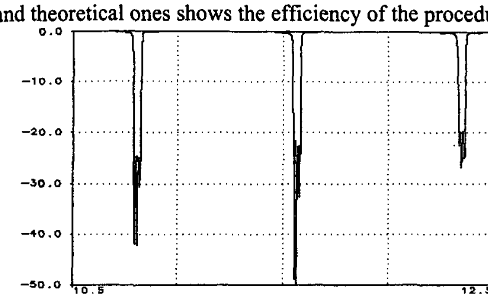

Fig.11. First experimental results of the OMUX

IV. Conclusion

An hybrid circuit/electromagnetic design dedicated to multiplexer design has been presented. Electromagnetic models are introduced to take into account spurious modes in the frequency band that are compensated directly avoiding a new synthesis of the multiplexer. An experimental triplexer has been designed applying this method. The measurements prove the efficiency of the design method.

Acknowledgement

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