An 11-18 GHz Four-Channel DBR Multiplexer for Electronic Warfare Systems

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***Abstract* - This paper deals with the design of a stripline four-channel multiplexer that works in the 11-18 GHz band. It allows the splitting of the input spectrum into four 1-GHz bandwidth channels separated by a 1-GHz band. Good-rejections and -wideband phase management are both ensured by 8th-order Dual Behavior Resonator filters directly interconnected and matched through a single-stub network. To facilitate the overall tuning of this device, new electromagnetic discontinuity models were developed and proved to greatly reduce the EM tuning phase. Finally, a 17.1 cm²-size multiplexer was designed in stripline technology to take profit of its low couplings and high isolation between filters. The performed simulations showed good performances (5 dB in insertion loss and more than 60 dB in wideband rejections).**

I. INTRODUCTION

Over the last years, the multiplication of electromagnetic sources has resulted in a heavy pollution of the microwave spectrum. In this dense environment, Electronic Warfare systems are dedicated to the interception of telecommunication signals, eventually of unknown origin. As such systems are operating in a multi-decade spectrum, they frequently need a splitting of the wideband input signal into several channels. One should note that their bandwidth and inter-channel band are both dependent upon the desired application. Indeed, in that configuration, channels can be interrupted when they are undesired, or eventually isolated for further superheterodyne demodulation. Such a receiver is presented in Fig. 1.

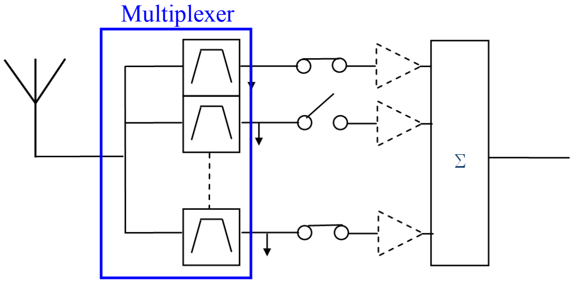


Fig. 1 Example of an Electronic Warfare receiver; the blue square indicates the multiplexer

In the architecture of high-frequency receivers, the multiplexer is the key element. In such systems, channelizing specifications impose more and more drastic filtering constraints about rejections, loss and compactness.

Because of their low loss, waveguide and dielectric resonator technologies have been mostly used in multiplexing. But, they are no longer competitive in terms of size or weight for the design of airborne devices. Superconductors have recently emerged, but cryogenic circuit is always prohibitive. All of these technologies have been especially developed for spatial OMUX [1], but they are unsuitable for Warfare systems. Consequently, planar solutions are preferred for their performances, compactness and low cost.

Today, the challenges are to find new and less bulky multiplexer architectures and filters topologies liable to provide performances as good as those obtained with classical technologies. Among the filters topologies available, some have been employed in multichannel structures [2]-[5].

Fig. 2 gives the specifications to be met by the multiplexer of concern in this study. Furthermore, the wideband rejections must be better than 50 dB, and the insertion losses less than 5 dB. To overcome the drawbacks of parasitic couplings and to ensure compactness and robustness, stripline technology was chosen.

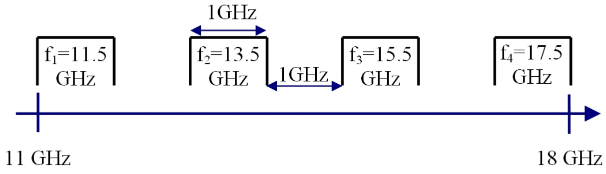


Fig. 2 Specifications on frequency division

Section II deals with the design of the filters to be used in this application. Technological considerations, matching and tuning aspects are dealt in Section III, which also shows how tuning constraints are affected by new discontinuity models and presents the results of simulations. In this study, filters and circuits were designed with ADS™ tools from Agilent.

II. FILTER DESIGN

A. Topology

A difficulty in wideband multiplexing is to choose the filter topology that provides a good in-band and out-of-band control. Another difficulty is the electromagnetic tuning of the structure. On the other hand, the bandwidth and rejections needed here drove us to prefer the transmission-zero topology to classical ones. Indeed, the specifications for the filters under design are to warrant rejections on a 10-GHz band and relative bandwidth from 6 to 10%. Such conditions are met by the Dual Behavior Resonator topology, which is based on the parallel association of two different band stop structures, which implies a constructive recombination. Both high and low frequency stubs allow an independent control of the two attenuated bands. DBR synthesis was developed in [6] and [7]. Figs. 3 and 4 present the topology and ideal electrical response of a DBR, respectively.

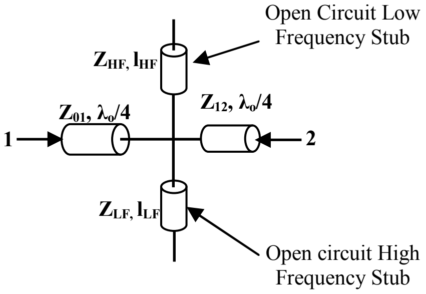


Fig. 3 Dual Behavior Resonator topology

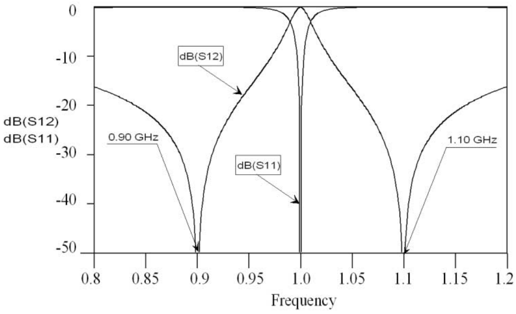


Fig. 4 Ideal electrical response of a Dual Behavior Resonator

B. *Rejections and wideband management*

DBR topology offers other advantages:

- The independent control of attenuated bands allows a free positioning of transmission zeros to manage close and wideband rejections.
- At each zeros frequency, both high and low frequency stubs bring an electrical short circuit. Thanks to central-frequency quarter-wavelength inverters, DBR filters present at zeros frequencies an I/O impedance more or less close to an open circuit.

DBR filters are well suited to a multichannel connection and an 8th-order filter seems to be a good compromise between loss and rejections. Figs. 5 and 6 respectively present the layout and the model electrical response of such a filter centered at 11.5 GHz. Wideband and narrowband rejections are respectively better than 55 dB over the 13-20 GHz band and than 30 dB at 500 MHz from the band edge.

Each filter is designed by positioning zeros at frequencies of adjacent bands.

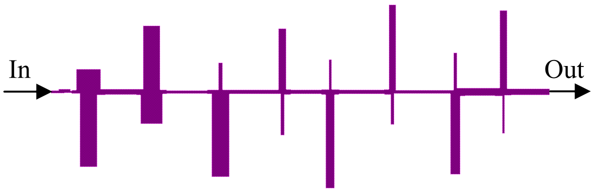


Fig. 5 Layout of an 8th-order DBR filter

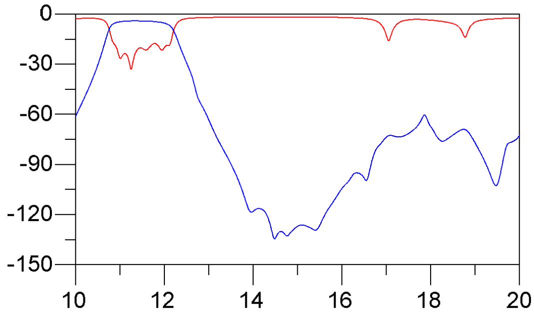


Fig. 6 Model electrical response of an 8th-order DBR filter

C. *Filter bending*

It is worth noting that a DBR filter of high order can be easily bent by inverting stubs and inverters connection at a junction (circles in Fig. 7). The electrical response is unaffected by this modification, which however slightly modifies the layout and, thus, the electromagnetic response. Moreover, high and low frequency stubs can be reversed at a same junction with no detrimental impact on the response. It means that the designer can optimize the footprint of the future multiplexer by moving the different filters so as to customize its final geometry.

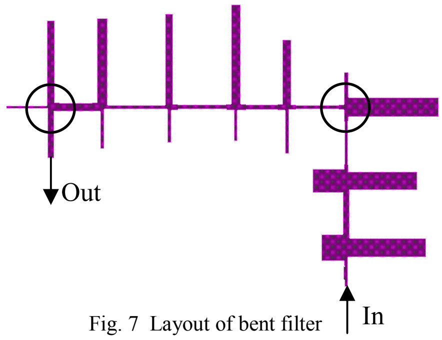


Fig. 7 Layout of bent filter

III. MULTIPLEXER DESIGN

A. *Technology*

To avoid usual parasitic couplings and ensure the compactness of the structure, the stripline technology depicted in Fig.8 was chosen. The substrate thickness is about 500 µm and its relative permittivity is about 4. Layer ④ is an additional 100 µm-thickness prepreg (glue) layer with the same relative permittivity. This robust technology also allows the superposition of different isolated circuits, which highly improves compactness of the structure.

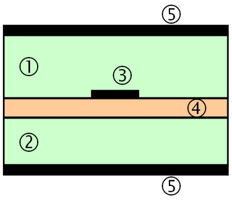


Fig. 8 Stripline technology used for this design

B. Connection and matching networks

Among all multiplexer architectures, the best-known use manifold, "branch line" couplers, high/low pass filters and circulators [8]-[11]. But, with the DBR topology, the parallel connection of channel filters is easy. Indeed, a judicious positioning of transmission zeros and a relevant length of the first inverter are often sufficient to tune the overall structure. When the number of channels exceeds three, the tuning procedure becomes more complex and critical; here, it was done by replacing the first inverter with a single-stub matching network as illustrated in Fig. 9.

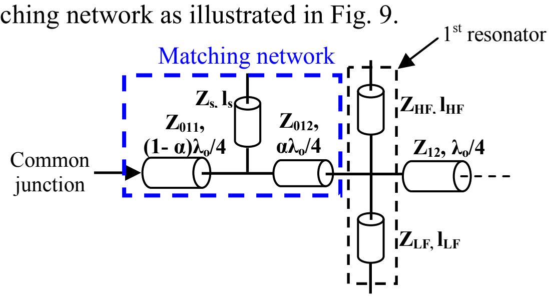
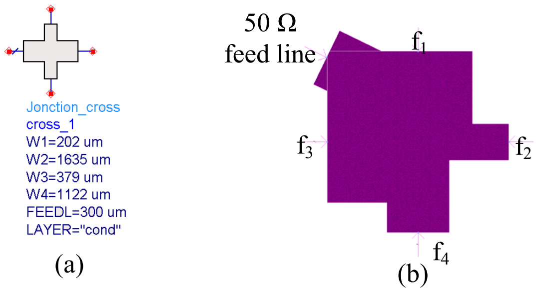


Fig. 9 Matching network of each channel

In practice, the impedances brought by filter at transmission zeros frequencies are finite. Therefore, contributions by a given filter in adjacent bands need to be compensated. A single-stub matching network matches each channel filter to common junction impedance, which depends on all other filters impedances. The length and width of matching networks lines are now the main tuning parameters. The first resonators of each channel are also tuned as described in [11].

C. Models of discontinuities and common junction



(a) (b)

Fig. 10 Electromagnetic models of cross discontinuity (a) and common junction (b)

Usually, electromagnetic tuning is the most time-consuming phase in the design of microwave devices. It becomes prohibitive with such complex circuits. This is why the discontinuity models used in ADS have to be as accurate as possible: a good model that takes into account electromagnetic effects is the warrant of a good correlation between electrical and electromagnetic responses. In this study, electromagnetic models were generated by the *Model Composer* tool in ADS™ [12] from existing discontinuities with the chosen-substrate and -geometrical dimensions (Fig. 10 (a)). Moreover, channel filters were connected through a particular five-port common junction; the *Advanced Model Composer* and *Graphical Cell Compiler* tools were used to electromagnetically model this junction for good fitting with the connected filters. Indeed, these tools allow the generation of EM models from any custom shape of discontinuity (Fig. 10 (b)).

D. Multiplexer global tuning

Thanks to these new models, tuning can be totally realized at a circuit level, which greatly shortens the electromagnetic tuning step. Fig. 11 depicts the hybrid EM/circuit schematic used to tune the final structure.

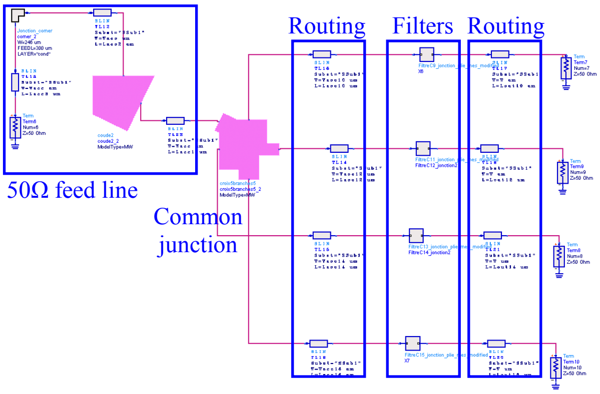


Fig. 11 Hybrid EM/circuit ADS schematic

E. Electromagnetic simulated results

Layout generated from previous hybrid schema is depicted at Fig. 12. The 3.8x4.5 cm² (excluding SMA connectors) component can be measured thanks to the right positioning of feed and routing lines. EM simulation results exhibits 5 dB losses and wideband rejections are better than 60 dB (Fig. 13). Narrowband rejections (cross of two adjacent filters) are about 30 dB. A sensitivity study was carried out and showed that this structure is less sensitive to substrate dispersion than to engraving precision. It, therefore, validated the choice of the DBR topology.

F. Multiplexer flexibility

In DBR filters, central frequency is controlled by lengths. Unlike traditional planar topologies, DBR filters, even within a complex structure, are easy shiftable (a frequency shift of more or less 1 GHz only needs a slight tuning of matching networks and filters first elements).

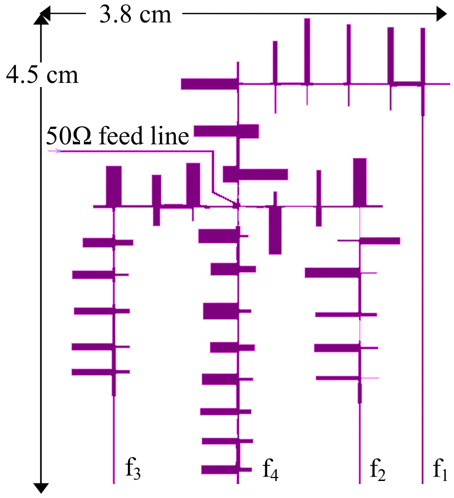


Fig. 12 Layout of the 11-18GHz multiplexer

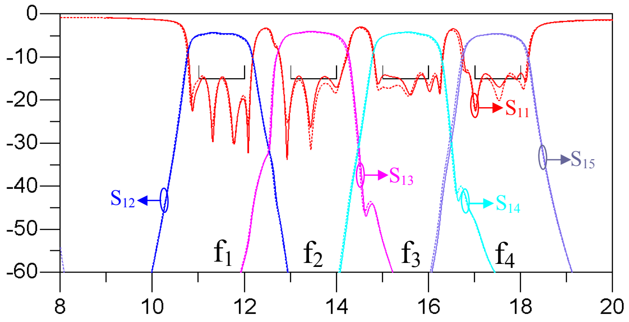


Fig. 13 Model (solid lines) and electromagnetic (dotted lines) electrical responses of 11-18 GHz multiplexer

A second multiplexer that works in the 10-17 GHz band was created by taking profit of this flexibility. Fig. 14 depicts the simulated results of this device. In comparison to the initial circuit, rejections are equivalent but losses are lower.

IV. CONCLUSION

In this paper, two four-channel multiplexers of sizes 17.1 and 19.2 cm², respectively, were designed. Different tools were also presented to define a design flow suitable for multichannel multiplexers. Indeed, the chosen -topology, - good discontinuity modelization and -technology highly simplified the design and the electromagnetic tuning of such a complex device. Simulated insertion losses are less than 5 dB, adjacent band isolation and wideband rejections are better than 50 dB and 60dB, respectively.

Devices are under realization and measurement results will be presented during the conference.

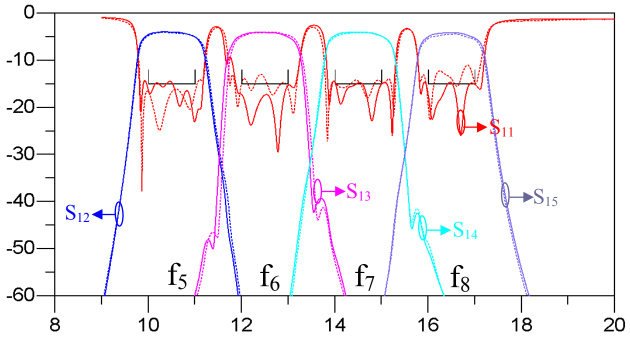


Fig. 14 Model (solid lines) and electromagnetic (dotted lines) electrical responses of 10-17 GHz multiplexer

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