Integration of an antenna filter device using a multilayer - multitechnology process

Thierry Le Nadan, Jean-Philippe Coupez, Serge Toutain, Christian Person

INTEGRATION OF AN ANTENNA/FILTER DEVICE, USING A MULTI-LAYER, MULTI-TECHNOLOGY PROCESS

T. Le Nadan, J. P. Coupez, S. Toutain, C. Person
LEST - UMR CNRS 6616 - ENST Br - BP 832 - 29285 BREST CEDEX - France
tél : + 33 2 98 00 13 19 - Fax : + 33 2 98 00 13 43 - email : Christian.Person@enst-bretagne.fr

ABSTRACT:

In this paper, we discuss about the synthesis and the implementation of a multi-function antenna/filter device, which appears as an optimum response in relation with the system's physical and electrical evolutions. Due to the extensive development of the uniplanar technology, our investigations concern the integration of a uniplanar slotline dipole directly in a standard Tchebyscheff band-pass filter. As a result, such a combination appears like a convenient solution for improving the performances of the basic antenna. To overcome technological constraints, we show that an optimum approach consists in the use of a multi-layer, multi-technology process. Preliminary experimental results prove the validity of this approach, and allow some extensions to more complex sub-systems.

INTRODUCTION:

In the last time, a lot of RF designer works have been developed to improve the performances of telecommunication systems, especially in terms of bandwidth capacities, operating frequency range and size reduction, thereby explaining, for instance, the recent emergence of millimeter wave applications in this domain (MMDS, millimeter wave LAN, and so on).

Because of these miniaturization and electrical specifications, important problems are often encountered when designing such systems through a classical cascaded basic function approach. As an alternative, a simultaneous design procedure can be used, resulting, for example, in the direct association of filters and radiating elements as new compact multi-function devices. In fact, this new synthesis technique also leads to a significant improvement of the performances, compared to those of the initial basic elements. In the past, H. F. Pues [1] and H. An [2] have been among the first people to investigate the bandwidth enhancement of resonant antennas using an impedance matching method, without altering the element's radiating characteristics. However, this technique has been mainly applied to microstrip antennas.

In this paper, we demonstrate that such an approach can be extended and efficiently used to enhance the operating bandwidth of some alternative radiating elements, such as uniplanar slotline dipoles, when incorporating them directly as resonators in a band-pass filter network. As a consequence, it should also provide a significant size reduction of the resulting multi-function device. Consecutively, we emphasize on the necessity of proposing an appropriate technological process, in order to meet electrical and physical requirements imposed by such a design procedure. Some authors, such as W. Menzel [3] and Ch. Person [4] have proposed a multi-layer technology approach to increase the flexibility for circuit integration. This has been applied to basic elements (like filters), but we investigate here its application to multi-function components.

To validate this work, the implementation of an integrated slotline dipole in a band-pass filter, using a multi-layer, multi-technology process, is presented. For this antenna/filter device, the experimental results, obtained in X band, are representative of the possibilities and advantages offered by this multi-function design.

PRESENTATION OF THE ANTENNA/FILTER MULTI-FUNCTION CONCEPT.

In comparison with a standard procedure, for which the usual front end devices are separatly designed and then cascaded together for building the overall system, the approach proposed here consists in a multi-function global synthesis, which allows an optimization of the system's performances. In this study, this concept has been carried out on an antenna/filter device, with very simple modeling approach, where the selected resonant antenna is considered as a lossy lumped element resonator. It thereby corresponds to a combination of a L_a C_a resonant structure and a resistive element R_a, which accounts for the radiated losses. Concerning the intrinsic operating bandwidth of such an antenna, it directly depends on the selectivity of the structure (i.e. Q factor), but it remains narrow in any way. On the other hand, a band-pass filter is basically composed by series and parallel LC resonators. Furthermore, it is classically designed on a 50 Ω input-output matching load value. In our case, to optimize the multi-function circuit design, the radiating resistance of the antenna is considered as the output load impedance of the filter structure, and the L_a C_a resonator as the last resonator of the lumped equivalent network of this filter. In these conditions, the reactive part of the antenna's electrical model corresponds to one of the poles of the filter, which must also satisfy, if necessary ($R_a \neq 50\ \Omega$), the impedance transformation between the R_a load and the 50 Ω input impedance level. Because of the integration of several functions in a same device, the advantages induced by this approach are numerous: first, it provides a great compacity, in agreement with the system miniaturization. Moreover, it leads to an optimization of both the function combination and the electrical performances, especially concerning the losses and the bandwidth values. Indeed, the antenna/filter device, which basically corresponds to a multi-cell function, presents a higher bandwidth than the one of a single matched dipole for example.

SYNTHESIS SPECIFICATIONS FOR A SLOTLINE DIPOLE / TCHEBYSCHEFF FILTER EXAMPLE.

The synthesis method exposed in the previous section is applied to a CPW-fed wide-slotline dipole antenna and a Tchebyscheff band-pass filter. In this case, the principal aim is to enhance the radiation bandwidth of the resulting device, with respect to a single dipole antenna. Concerning the electrical modeling approach, such an antenna and its feeder can be regarded as a parallel type resonator, which is integrated as the third resonator of a Tchebyscheff band-pass filter (n=3, bandwidth >15%, 0.1 dB band-pass ripple). The final topology, based on a distributed solution, including $\lambda_g/4$ stubs and $\lambda_g/4$ impedance inverters, is shown in figure 1, where Z_{ci} and Z_i are respectively the characteristic impedance of the i^{th} impedance inverter and of the i^{th} stub.

In relation with the antenna's electrical response, mainly the selectivity factor, this approach leads to strong design constraints, especially regarding the characteristic impedance values to be synthesized. Table 1 shows a set of Zc which meets the specifications previously described.

Series $\lambda_g/4$ inverters			parallel $\lambda_g/4$ shorted stubs	
Z_{c1}	Z_{c2}	Z_{c3}	Z_1	Z_2
48 Ω	42 Ω	35 Ω	6.9 Ω	5.5 Ω

Table 1 : Set of characteristic impedance values for the structure design.

As shown, both high and low impedance transmission lines are needed to realize the complete structure. With regular technologies, like microstrip or CPW, this wide characteristic impedance range is a real problem, given the achievable Z_c values in each of these technologies. Therefore, in this work a multi-layer multi-technology integration is proposed. By use of the third dimension, extra design flexibility is provided, in terms of discontinuity minimization and available characteristic impedances (low Z_c are achievable with TFMS lines (Thin Film MicroStrip lines), while high Z_c can be realized in a coplanar topology for example). As a matter of fact, such an approach allows a lot of combinations and interconnexions between different kinds of transmission lines for the implementation of a microwave function, leading to optimal solutions with regards to size reduction and to electrical performances enhancement.

A MULTI-LAYER, MULTI-TECHNOLOGY IMPLEMENTATION OF THE SLOTLINE DIPOLE/ TCHEBYSCHEFF FILTER.

The circuit, synthesized with the impedance values given in table 1, consists of three impedance inverters, realized in a multi-layered coplanar configuration, and two double parallel shorted stubs, using a TFMS approach, while the slotline dipole and its feeder are realized in a standard uniplanar technology. In such a topology, the TFMS lines make use of the coplanar ground planes for their own grounding plane. The layout and dimensions of the antenna/filter circuit are presented in figure 2. This circuit is realized on an alumina substrate (ε_r=9.6, H=635 µm), using a thin dielectric film (ε_r=9.5, H=30 µm).

Concerning the preliminary experimental results, figure 3 gives a comparison between S_{11} measurements for a single matched slotline dipole and the antenna/filter device. As illustrated, a significant increase of the bandwidth can be observed (over 15%), without disturbing the radiation characteristic of the slotline dipole. Indeed, a first transmission measurement between two such circuits shows a constant gain response, through the whole bandwidth (figure 4).

FURTHER DEVELOPMENTS: REALIZATION OF AN ARRAY/FILTER DEVICE

The synthesis method developped in the previous sections is applied to the conception of an antenna-array / Tchebyscheff filter device, using a combination of two CPW, series-fed, slotline dipoles, and a TFMS shunt resonator. The multilayered topology used for this example is slightly different from the one used to realize the antenna/filter circuit. The quarter wavelength impedance inverters are implemented as regular CPW lines, while the TFMS resonator is designed on top of a thin dielectric overlay. Distance between the two radiating devices is roughly $\lambda_0/2$. Figure 5 shows a photograph of the realized circuit. Preliminary measurements (figure 6) show a good agreement with the synthesis theory, and a large SWR bandwidth can be observed. Still, radiation pattern measurements are needed to validate such an approach.

CONCLUSION :

In this paper, a multi-layer, multi-technology antenna/filter device has been proposed as a convenient answer to future system performances requirements. The design procedure, based on a very simple modeling approach for both the selected uniplanar slotline dipole and the distributed Tchebyscheff band-pass filter has been described. Technological constraints have been highlighted, and a solution using multilayered topologies has been proposed. Preliminary experimental results, i.e. a large bandwidth matching and a good radiation characteristic in the whole band of this multi-function device, illustrate the validity of our approach.

As a future extension of this work, this multi-function concept, based on a multi-layer, multi-technology process, opens a lot of new perpectives for the integration of sub-systems, such as antenna array/filter or CPW-to-slotline transition/filter/antenna structure for example.

BIBLIOGRAPHY :

[1] H. F. PUES, A. R. VAN DE CAPELLE, "An Impedance-Matching Technique for Increasing the Bandwidth of Microstrip Antennas", IEEE A&P, Vol. 37, No 11, pp. 1345-54, Nov. 1989.

[2] H. AN, B. NAUWELAERS, A. VAN DE CAPELLE, "A New Approach of Broadband Microstrip Antenna Design", IEEE AP-S 1992, pp. 475-478.

[3] W. MENZEL et al., "Compact Multilayer Filter Structures for Coplanar MMIC's", IEEE Microwave and Guided Wave letters, Vol. 2, No. 12, pp 497-498, Dec. 1992.

[4] Ch. PERSON et al., "Multilayer Thick Film Technology: a Convenient Way to Design Compact and Efficient Microwave Components", Proc. 22nd EuMc, Helsinki, Finland, pp. 1176-80, Aug. 1992.

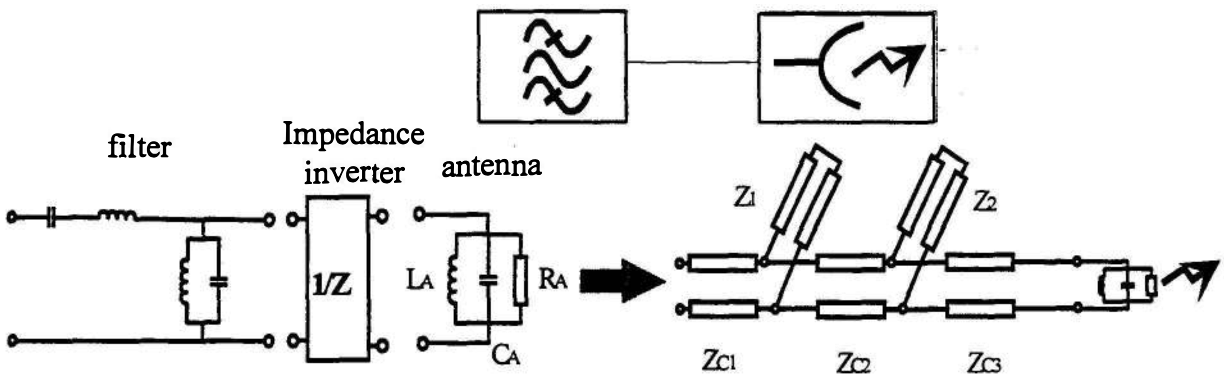


Figure 1 : Distributed topology of the slotline dipole/Tchebyscheff filter

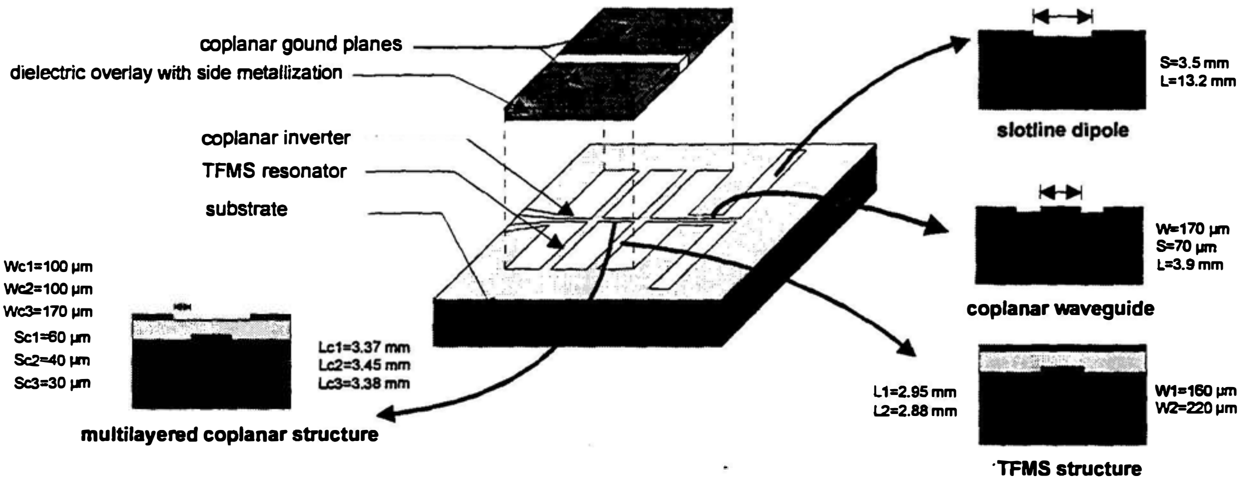
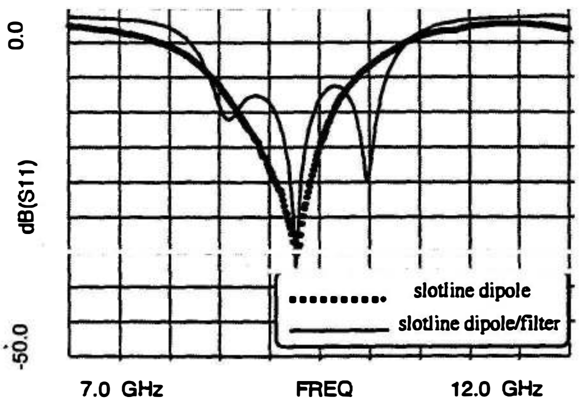


Figure 2 : Layout of the multi-layer, multi-technology slotline dipole/Tchebyscheff filter



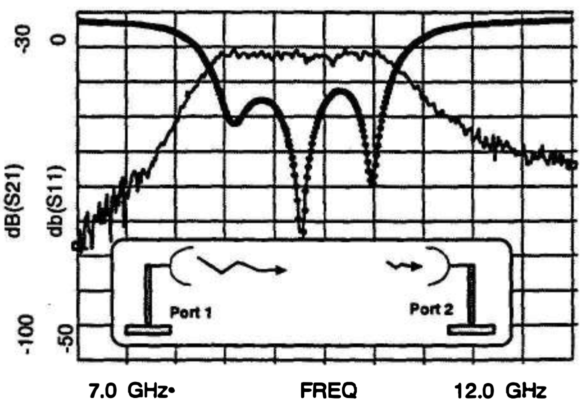


Figure 3 : Comparison between S_{11} measurements of a matched slotline dipole and the antenna/filter circuit

Figure 4 : Transmission measurements between two slotline dipole/filter devices

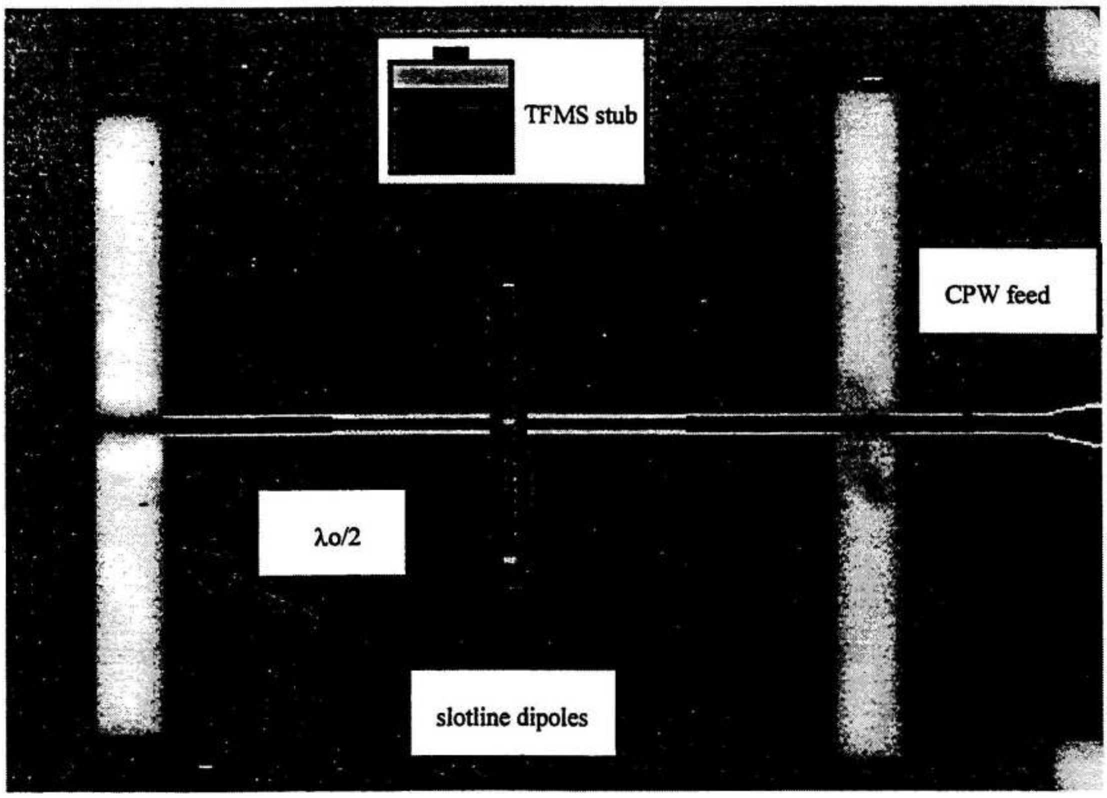


Figure 5: Layout of the Antenna- Array / Tchebyscheff filter

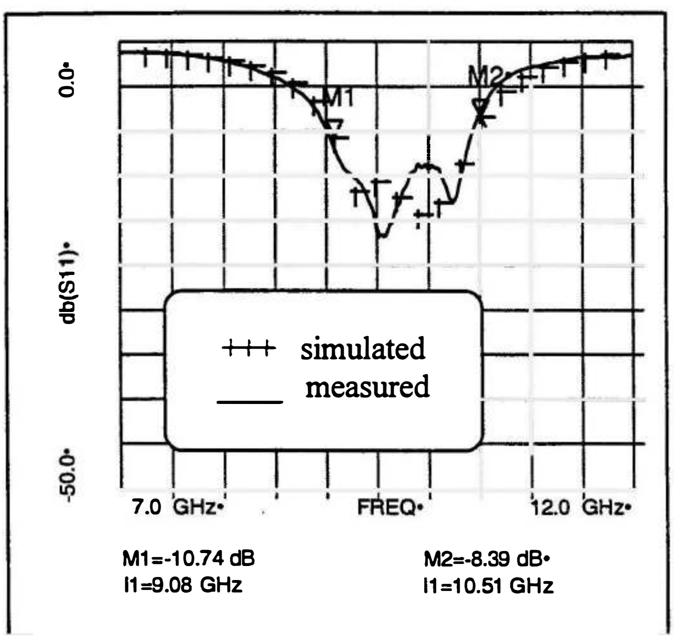


Figure 6: Comparison between simulated and measured data