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OPTIMIZATION AND MINIATURIZATION OF A FILTER ANTENNA MULTI-FUNCTION MODULE USING A COMPOSITE CERAMIC-FOAM SUBSTRATE

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ABSTRACT

In view of optimizing a CPW-fed microstrip patch antenna, a composite ceramic-foam substrate is investigated. using a global synthesis technique, a multilayer multitechnology miniature band-pass filter is integrated on the back-side ceramic while a microstrip patch is laid down on the upper foam dielectric. This combination leads to an efficient and compact multi-function module.

INTRODUCTION

During the last few years, great efforts have been made concerning the optimal integration of antennas and related passive circuits, especially for systems based upon planar antenna arrays. However, such an optimal integration results in particular constraints for each involved basic function; the difficulty lies in the possibility of preserving the electrical performances of the complete system (operating bandwidth, losses, radiation efficiency) as the effective dimensions are significantly reduced, resulting in severe constraints in terms of interconnections and parasitic interferences.

In particular, the performances of planar antennas and associated passive devices are strongly dependant on both the electrical characteristics of the substrates and the intrinsic limitations of the conventionnal planar technologies (resolution, reliability,...). Consequently, planar antennas are usually processed on thick substrates with low permittivity and loss tangent values. On the other hand, passive circuits such as filters require lossless high permittivity substrates (for size reduction) in combination with specific needs in terms of

achievable characteristic impedance values. Therefore, the synthesis of complete RF systems usually results in a necessary arrangement between fundamental opposite requirements, depending on the available technologies and substrates.

In this paper, we propose the use of a composite substrate, by means of a multilayered ceramic/foam structure, in order to optimize simultaneously electrical and dimensionnal characteristics of basic passive RF transceivers. Such a concept is used for the integration of an antenna-filter device, with a solution combining a square microstrip CPW-fed patch antenna connected to a bandpass filter. The radiation efficiency is ensured thanks to the characteristics of the thick foam substrate ($\epsilon_r=1.07$) while the multilayer multitechnology process is efficiently used for implementing an ultra-miniature filter behind the radiating element. Moreover, such an optimal combination (antenna+filter) becomes thinkable just because of the high flexibility of the multilayer multitechnology approach, with significant improvement of the complete multi-function operating bandwidth. Theoretical and experimental results are provided, underlying the validity of this integration technique which can be extended to integrated sub-systems.

A MULTILAYER, MULTITECHNOLOGY MODULE INTEGRATED ON A COMPOSITE SUBSTRATE

CPW-fed microstrip patch antennas are widely used today [1...3]; indeed, the input CPW section appears as a non-parasitic feeding structure while the microstrip antenna can be considered as the most suited radiating integrated element

regarding radiation efficiency and size criteria. In addition, cross-polarization effects can be partially rejected using appropriate techniques [4]. Nevertheless, in such an approach, some contradictions exist between electrical performances and miniaturization constraints, because of the common substrate's electrical characteristics (typically medium to high relative permittivity values).

Therefore, we have decided to use a multilayered ceramic/foam substrate combined with a CPW-fed microstrip patch antenna architecture. This composite structure leads to the design of an efficient antenna, since it can be located on the low permittivity thick substrate (foam : $\epsilon_r=1.07$, $\tan\delta=5.10^{-4}$) while a high integration degree is preserved for the feeding network as it can be implemented on the backside high permittivity layer (alumina : $\epsilon_r=9.6$, $\tan\delta=10^{-3}$). The corresponding topology is presented in figure 1. As mentioned on figure 2, quite a fair agreement is obtained between theoretical (H. P. Momentum) and experimental data.

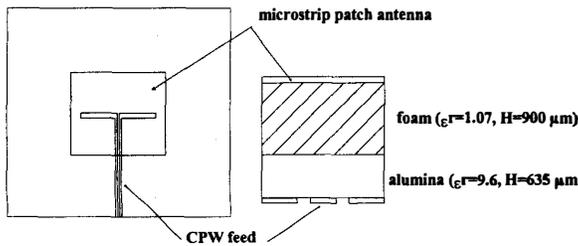


figure 1: topology of the CPW-fed microstrip patch antenna

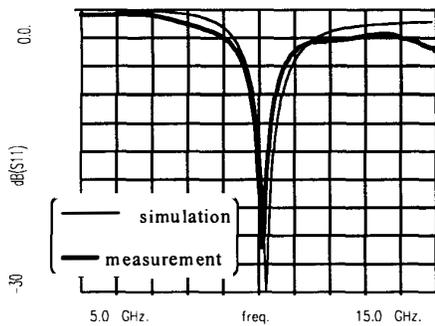


figure 2: theoretical and practical data

MINIATURIZED MULTI-FUNCTION MODULE ON MULTILEVELLED CERAMIC/FOAM COMPOSITE SUBSTRATE

The global performance of the previous defined module can be significantly improved by inserting a bandpass filter behind the antenna instead of a classical feeding network. Van de Capelle et al [5] have first proposed this technique in order to control the radiating conditions over the operating bandwidth of the matching filter.

We have associated a 3rd order Tchebyscheff bandpass filter to the CPW-fed microstrip antenna previously implemented on the composite support. Thanks to the flexibility of the multilayered ceramic/foam architecture (in terms of available permittivities), this function can be fully integrated under the microstrip patch (which makes for optimum integration) using quite a high permittivity bottom layer. Moreover, a global synthesis method [6] is used in order to further improve the size reduction of the module, leading to a multi-function antenna/filter device. The slot-coupled antenna is now regarded as the last pole of the bandpass filter, and its Q factor is used for the determination of the filter's frequency bandwidth.

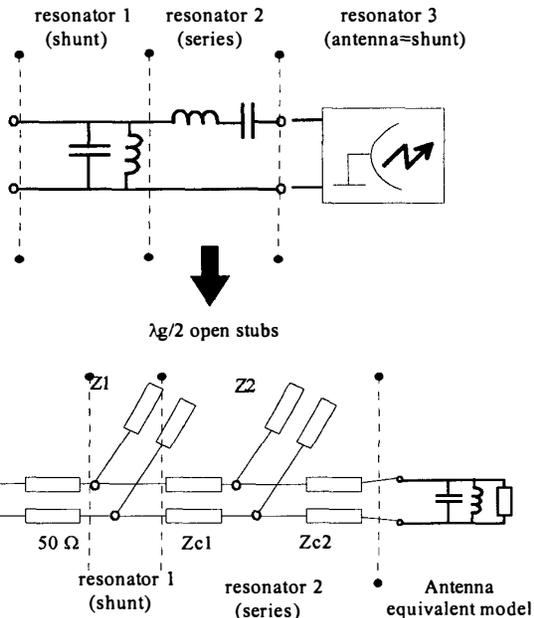


figure 3: integration of the antenna in the filter structure

This in turn, yields the electrical values of the rest of the bandpass filter. The two other poles of the third order Tchebyscheff filter are integrated as regular resonators (figure3). This results in a highly integrated structure, with simultaneously optimized radiating performances, since the radiation impedance of the antenna is matched over a wider frequency band. Indeed, a previous work [6] has shown that radiation is observed through the whole frequency bandwidth of the filter (which is larger than the bandwidth of the single antenna), without significant distortion of the radiation pattern.

However, 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 for the filter. Indeed, low characteristic impedance values are required for the realization of the shunt stubs while 50Ω lines are used for impedance inverters. Those low values are not available in a regular CPW technology. It was therefore decided to design the bandpass filter on the bottom ceramic substrate of the composite structure, through a multilayer multitechnology process (thick-film technology).

This multilayer topology is presented in figure 4, and provides extra design flexibility because of the use of the third dimension [7,8]: in such a configuration, low characteristic impedance stubs (15 to 20Ω) are integrated as TFMS lines (Thin Film MicroStrip lines), while impedance inverters (about 50Ω) are synthesized as multilevelled CPWs.

Table 1 shows the electrical and physical parameters of the global structure. Simulations were performed using HP Momentum software and a comparison between theoretical data and measurement is given in figure 5. As expected, a good agreement is achieved. Radiation phenomena was also noticed through the whole bandwidth of the Tchebyscheff filter (figure 6), which makes for a significant improvement of the antenna's performances (simple antenna: 7.5% BW, antenna + filter: 10.8% BW).

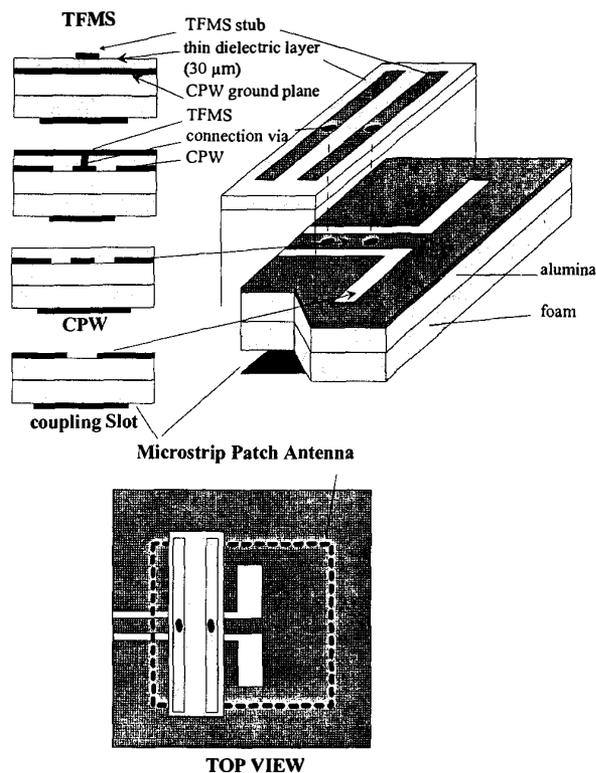


figure 4: the multilayer, multitechnology antenna/filter module

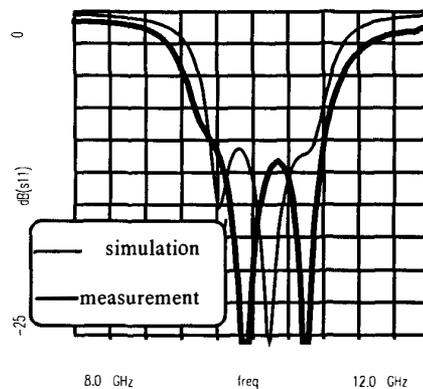


figure 5: comparison between simulation and experimental results

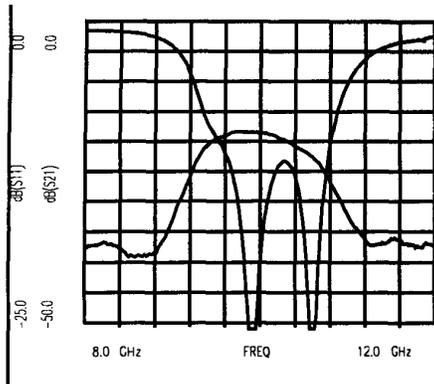


figure 6: transmission measurement between two antenna/filter devices

transmission line	W (μm)	S (μm)	L(mm)	Z (Ω)
Z_{c1} (CPW)	95	52	2.7	48
Z_{c2} (CPW)	85	57	0.4	46
Z_1 (TFMS)	135	----	5.88	21
Z_2 (TFMS)	185	----	5.85	17
coupling slot	----	200	6.34	----
patch	9.3 (mm)	----	9.3	----

Table 1: electrical and physical parameters of the global structure

CONCLUSION AND FURTHER DEVELOPMENTS

In view of optimizing the electrical and physical characteristics of printed antennas (radiation efficiency, operating bandwidth, size, reliability,...), a multilayered composite substrate made of both low and high permittivity layers has been proposed, by means of screen-printing and press-moulding techniques. Basic functions, like filters and antennas, can therefore be independently optimized on appropriate dielectric sheets. In addition, they can be efficiently combined, because of the great flexibility of the multilayer multitechnology approach, leading to multi-cell antenna/bandpass filter modules. A global synthesis technique was also simultaneously applied. This results in an ultra-miniature RF front-end, since the filter structure is fully integrated under the

microstrip patch, with enlarged radiating performances.

This work can now be applied to the development of complex antenna arrays, in view of integrating successfully both the radiating network and the complete associated feeding sub-system on composite substrates, under severe electrical and dimensionnal constraints.

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