THE HYBRID INTEGRATED PLANAR/NRD-GUIDE TECHNOLOGY: A NEW CONCEPT FOR LOW-COST APPLICATION OF MICROWAVE AND MILLIMETER-WAVE CIRCUITS

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ABSTRACT

A novel hybrid integrated planar/NRD-guide architecture is proposed. This technology offers a unique feature of exploiting inherent advantages of planar structures and NRD waveguide for low-cost wireless applications. Experimental results show that the hybrid technology promises to be useful in the design of future microwave and millimeter-wave circuits and systems.

INTRODUCTION

The NRD-guide based technology becomes attractive for use in a variety of microwave and in particular millimeter-wave circuits and systems. Since its inception in 1981 [1], this technology has been used in the design and fabrication of a large class of integrated circuits and antennas which offer superior electrical performance at millimeter-wave frequencies [2]. Compared to the conductor-based planar structures, the NRD-guide has low transmission losses and presents an integrated format of multiple circuits which are sandwiched between two parallel metallic plates. The spacing between two parallel plates should be always smaller than a half of free-space wavelength.

Over the past years, a number of two-terminal active devices have been used in the NRD-guide-based circuits and systems. These devices of which most are the beam-lead diodes [2] may be inserted into the NRD's dielectric strip through a piece of planar surface mount. The RF, microwave or millimeter-wave signals are usually directed from the NRD to the planar circuit on which the active devices are incorporated. However, an effective coupling from the NRD-guide to the planar circuits requires an additional effort since the impedance mismatch for this hybrid geometry is a headache problem. On the other hand, the another serious problem is the fundamental limit of the spacing between the two metallic plates, thereby restricting the allowable cross-sectional surface or lateral dimension of the planar mount because the spacing should in any case be smaller than a half of free-space wavelength. This may lead to some extremely difficult situation as the operating frequency goes up even only the two-terminal devices are considered. In most practical applications, three-terminal devices such as FETs, HEMTs and HBTs are essential in the design of oscillators and amplifiers as well as other active circuits. However, it may be very difficult to integrate these active devices into a planar circuit mount that fits physically the spacing of the NRD-guide. This is in particular true when the packaged devices are used. Consequently, an alternative technique for effective integration of active devices with the NRD-guide is desired.

The present paper proposes a new scheme that effectively integrates the NRD-guide based components with the planar circuits. In this new hybrid technology, the NRD-guide is more and less responsible for the construction of passive components while the planar geometry is primarily used to design active devices. The integration between the two dissimilar structures is achieved by a class of aperture couplings

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which have recently been proposed by the authors. We will emphasize in this paper the electrical and mechanical performance of the proposed hybrid technology as well as its potential applications. A number of passive and active experimental prototypes will be presented and discussed. This will reveal the interesting and attractive aspects of the new technology for microwave and millimeter-wave applications.

DESCRIPTION OF THE NEW HYBRID TECHNOLOGY

Fig. 1 shows a general view of the proposed hybrid NRD/planar architecture using a series of integrated transitions which connect a planar structure coherently with the NRD-guide. The planar structure may be in the form of microstrip line or coplanar waveguide or even slot line. In our example of Fig. 1, only the microstrip line is considered for the following discussion although other alternative planar structure can be used in the design and fabrication of such transitions. It is seen that the integrated transition of microstrip line to NRD-guide in this case is made through a magnetic aperture coupling. The microstrip line is placed at the perpendicular direction to the dielectric strip of the NRD-guide. The length of the open-ended microstrip with respect to the coupling rectangular slot is crucial in the design of good quality transitions. The microstrip line can be relocated at either side (unilateral and antilateral located) of the parallel metallic plates of the NRD-guide. In this way, the microstrip line shares the common ground plane with the NRD-guide which is actually one of the parallel metallic plates. The coupling aperture is made on the ground plane (the parallel plate).

Obviously, a number of microstrip lines can be attached on the both sides of the NRD-guide simultaneously. This consideration gives rise to some interesting feature of the proposed hybrid technology. First, the both sides can be effectively used such that a complete integrated system can be designed as compact as possible and no space is wasted. On the other hand, there are always possibilities of unwanted interference or cross-talk between two individual circuits or two groups of circuits in a designated system or subsystem. The proposed hybrid technology can be used to suppress partly or completely such unwanted effects by a special arrangement that the circuits or groups of concern can be placed on different side of the NRD-guide. They may be linked or interconnected through a NRD-guide bandpass filter or an appropriate direct transition. In this way, the spurious coupling and parasitic interference can be reduced to extremely low level without using additional packaging effort.

Clearly, the proposed hybrid technology removes completely the space constraint imposed by the existing hybrid technique, and allows one to design active and passive circuits in a very flexible way with added attractive features such as the above-mentioned space-saving and interference reduction. The integrated transition between the NRD-guide and planar structure is the key to successful applications of this new hybrid technology. The design issue and performance discussion are presented for both microstrip line in [3] and coplanar waveguide in [4]. Obviously, the proposed hybrid technology is potentially low-cost since the basic design of the NRD-guide based components is related to a series of mechanic fabrications and assembling. In the following, we will show the usefulness and the potential applications of the proposed hybrid technology through three distinct experimental examples encompassing passive and active circuits.

EXPERIMENTAL EXAMPLES AND RESULTS

Two wideband transitions of microstrip line-to-NRD-guide and the multi-pole bandpass filters are illustrated and condensed the same figure as shown in Fig. 2. Note that the transition in Fig. 2 is different from that shown in Fig. 1 in which the NRD-guide becomes simply a underpassing transmission line. Fig. 2 presents two different topologies (a) and (b) which may be arranged for unilateral and antilateral interconnections. It is seen that the design is so flexible that one can relocate planar circuits with a great freedom, and achieve potentially the maximum isolation.

To verify electrical performance of the proposed transition, an experimental prototype is made which uses two identical transitions of microstrip line-to-NRD-guide which are interconnected through a simple NRD-guide terminated with two open ends. Fig. 3 show the measurement results (the dotted line) for the designed transitions of microstrip line-NRD-microstrip line as shown in Fig. 2a (replace the filter with a through NRD-guide) which operates at frequencies from 17.5 GHz to 20.5 GHz with 15% effective bandwidth. This coincides with about the same bandwidth as the monomode bandwidth of the NRD-guide available based on our design. The losses of two microstrip feeding lines are involved in the measurement results, and the transitions are not optimized because of the availability of dielectric material (Roger's TMM3) in our laboratory.

It can be expected that electrical performance of the filter is mainly determined by the NRD-guide, and but both its input and output are still in the form of microstrip line. Therefore, this hybrid technology proves itself useful for millimeter-wave applications at which it may be difficult or even impossible to design a high-Q attractive bandpass filter completely with the microstrip line rather than with the NRD-guide except the use of expensive superconductivity technology. The measurement results are shown in Fig. 3 (the solid line) for our design example of a 3-pole bandpass filter working at 19.65 GHz with 2 % of bandwidth. Clearly, the overlapped measurement results for the transitions and the filter confirm that the NRD-guide contributes to the insertion loss at the negligible level while the two transitions and microstrip connection lines are responsible for it.

As the last design example of our proposed hybrid technology, we made a proposal for a new class of planar NRD oscillators which provide a design framework alternative to the conventional oscillator. The structure proposed for the oscillator is not illustrated in the paper due to the limited space, its description of structure together with the details related to its electrical performance will be presented in the Symposium.

CONCLUSION

Through the above discussion and preliminary experiments, we can conclude that the proposed planar/NRD-guide present an attractive features for designing a number of novel passive components and active devices. These passive and active circuits offer potentially low-cost and performance promising solution for microwave and in particular millimeter-wave applications.

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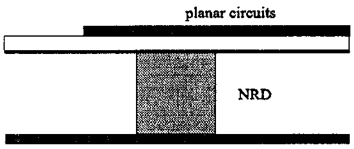
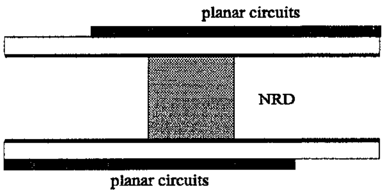
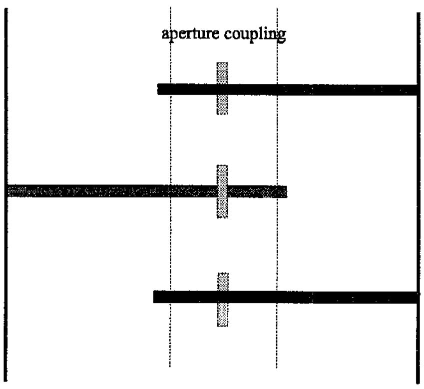


(a) Cross-section of unilateral aperture microstrip-to-NRD coupling scheme

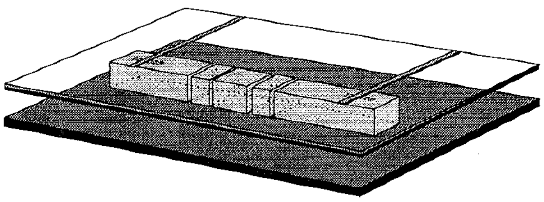


(b) Cross-section of antilateral aperture microstrip-to- NRD coupling scheme

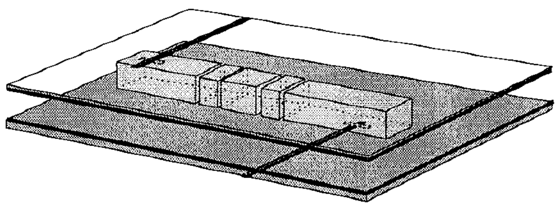


(c) longitudinal-section of multiple-aperture microstrip-to-NRD coupling scheme

Fig.1 Schematic illustration of the proposed hybrid planar/NRD-guide technology



(a)



(b)

Fig.2 Structures of two transitions of microstrip line to NRD-guide with NRD bandpass filters. (a) unilaterally located transitions, (b) antilaterally located transitions.

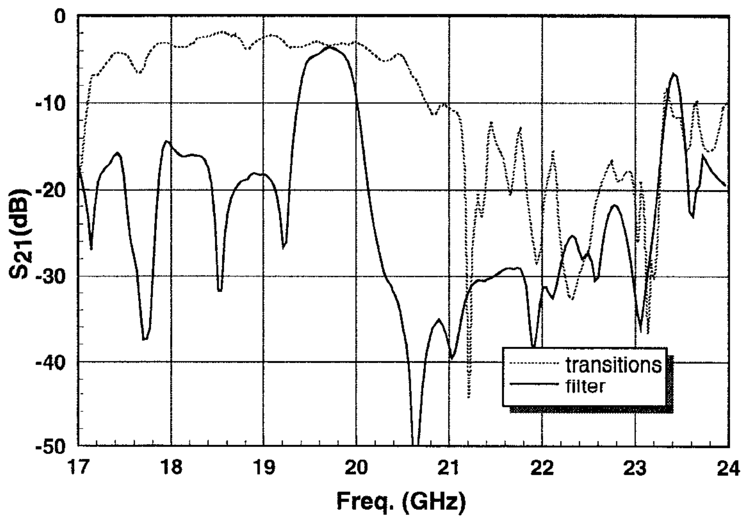


Fig.3 Measured response of a three-pole bandpass filter that is overlapped with the measurement results of the through transition.