Novel periodically loaded E-plane filters.

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***Abstract*—Novel E-plane waveguide filters with periodically loaded resonators are proposed. The proposed filters make use of the slow wave effect in order to achieve improved stopband performance and size reduction of roughly 50% without introducing any complexity in the fabrication process. Numerical and experimental results are presented to validate the argument.**

***Index Terms*—E-plane, filters, half wavelength resonators, periodic structure, ridge waveguide.**

I. Introduction

ALL METAL inserts mounted in the E-plane of a split block waveguide housing is a well established technique for realizing lowcost and mass producible microwave configurations, such as bandpass filters [1]. However, despite their favorable characteristics, E-plane filters suffer from bulky size and stopband performance that may often be too low and too narrow for many applications, such as multiplexers [2]. This letter therefore proposes novel E-plane filter configurations with reduced size and improved selectivity. The improvement is achieved incorporating periodic waveguide structure in the resonator of an E-plane filter.

Periodic structures of various types have been a favorite topic of researchers and are currently enjoying renewed interest in the microwave field for their applications in the microwave and millimeter-wave regime [3]. In filter applications periodic structures have been reported to offer reduced physical size and improved stopband performance [4]–[6]. This is due to the slow-wave effect; the phase velocity and the guided wavelength of the slow wave are significantly reduced relative to those of a wave propagating in a comparable homogeneous line. Hence, the length of a half wavelength resonator is accordingly reduced [7]. Furthermore, due to the dispersion relation of slow waves, improved stopband performance can be achieved [5].

E-plane technology together with ridge waveguide offer a very convenient way of realizing a periodic waveguide structure, by periodically loading the waveguide with reactive obstacles in form of ridges. This letter therefore proposes to replace the homogeneous section of rectangular waveguide in the resonators of E-plane filters with a periodic structure, consisting of a cascade of ridge waveguides with different gaps. The layout of the proposed configuration for a two-resonator filter is shown on Fig. 1. The configuration is similar to standard E-plane resonators, but instead of having a homogeneous waveguide of length Lr between the two septa of length Ls, a cascade of equal lengths of ridge waveguides with different gaps is the resonant section. The proposed structure maintains the low-cost and mass producible characteristics of E-plane filters and achieves improved stopband performance and size reduction up to 50%.

Manuscript received July 19, 2002; revised October 14, 2002. The review of this letter was arranged by Associate Editor Dr. Shigeo Kawasaki.

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Digital Object Identifier 10.1109/LMWC.2003.811046

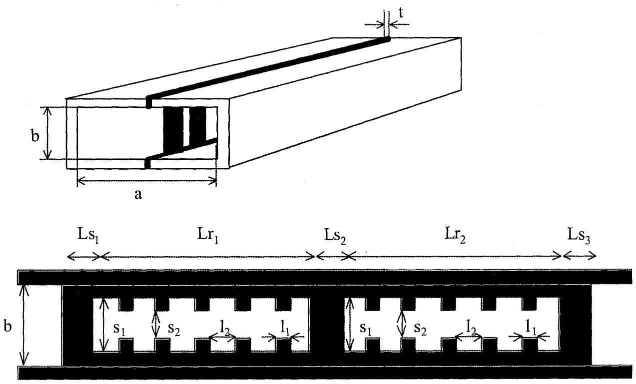

Fig. 1. Layout of the proposed 2 resonator filter.

II. Analysis and Design

The analysis of the proposed structure is conveniently based on a combination of the transverse resonance field matching technique with the mode matching method [8]. Transverse resonance field matching is applied for solving the propagation in ridge waveguide, in order to obtain the cutoff frequency and the field distribution for the fundamental and higher order modes [1]. These can then be used for the application of the mode matching method, including higher order modes, in order to obtain the electromagnetic performance of the proposed structure. Both methods are well-established and therefore expressions are not given here. Note that more higher order modes need to be taken into account for shorter lengths l_1 and l_2. This is because for shorter l_1 and l_2, higher order modes between adjustent cells of the periodic structure can increasingly interact.

The design procedure developed by Rhodes [9] for inductively coupled half wavelength filters is directly applicable to the proposed filter structures. The metal septa of length Ls act as K-inverters, provided an appropriate (usually negative) length of transmission line is allowed at each end [10]. The resonator length is then equal to half guided wavelength plus or minus the required length for the adjustent metal septum to act as a K-inverter. Hence in order to apply this design procedure the propagation characteristics of the slow wave, mainly the guided wavelength, need to be determined. These in turn are determined by geometrical parameters, namely the gaps s_1 and s_2 and the lengths l_1 and l_2. The gaps s_1 and s_2 can be chosen arbitrarily. The periodicity of the structure will be more evident for larger difference between s_1 and s_2, either of which can be chosen equal to the waveguide housing b. The periodicity lengths l_1 and

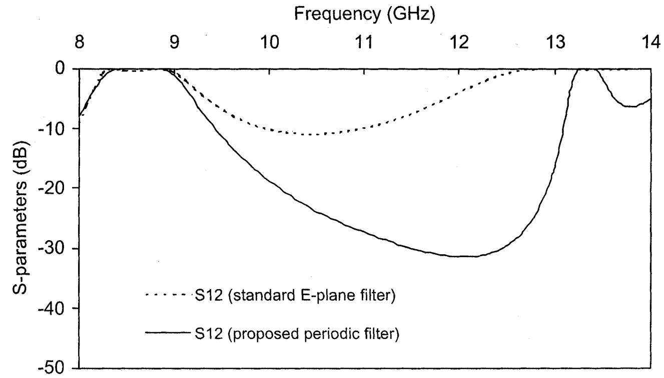

Fig. 2. Comparison between the performance of a two resonator periodic E-plane filter with a standard E-plane filter.

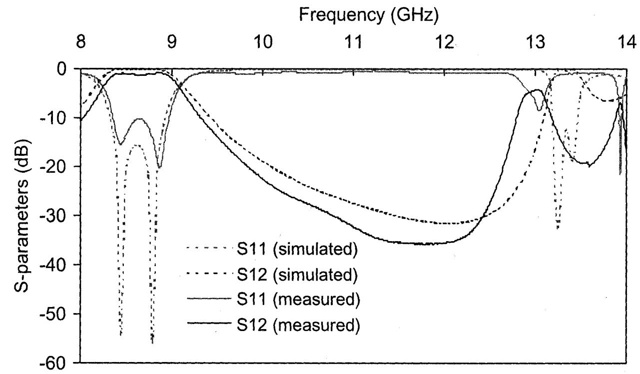

Fig. 3. Comparison between simulated and measured response for the fabricated filter prototype.

TABLE I
DIMENSIONS (IN MILLIMETERS) OF FILTERS COMPARED IN FIG. 2

	Conventional	Periodic	
A	22.86	22.86	
B	10.16	10.16	
T	0.10	0.10	
Ls1=Ls3	0.31	1.20	
Ls2	1.68	4.00	
Lr1=Lr2	20.10	8.00	s_1= b=10.16
			s_2= 1.00
			l_1= 1.00
			l_2= 0.50
Total Length	42.50	22.40	

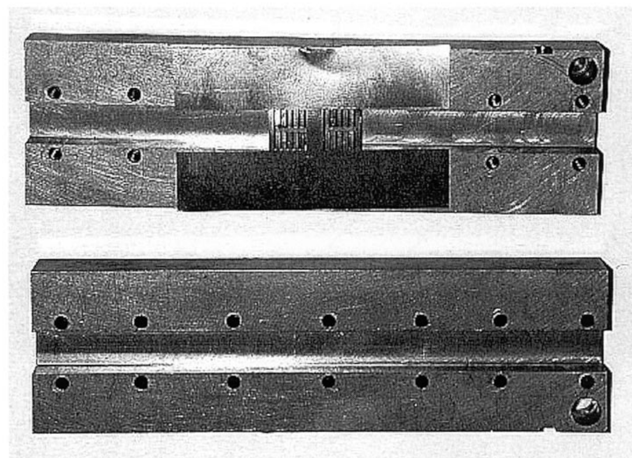

Fig. 4. Photograph of fabricated prototype.

l_2, together with the chosen gaps s_1 and s_2 will effectively determine the slow wave wavelength; this in term should determine the length Lr, as this is (almost) equal to half wavelength.

III. NUMERICAL AND EXPERIMENTAL RESULTS

In order to demonstrate the improvement in both physical dimensions and stopband performance, a two-resonator periodic filter has been designed and its performance and size is compared with a standard E-plane filter of the same passband. The insertion loss for the two designed filter is shown on Fig. 2. The dimensions of both designed filters are shown on Table I. Mode matching method with 30 TE and 20 TM odd modes has been used for the simulation of the periodic filter while 20 odd TE modes have been used for the simulation of the standard E-plane filter. The improved stopband performance of the proposed periodic filter is evident from Fig. 2. The proposed filter has better selectivity and wider stopband than its standard E-plane counterpart. Table I furthermore reveals the major size reduction of the proposed filter. As shown on this table, the resonator length is more than halved, corresponding to wavelength reduction of the slow wave. The overall periodic filter is 47% shorter than the standard E-plane filter.

In order to experimentally validate the improvement, a periodic filter prototype has been fabricated and measured. The comparison of the simulated with the experimental result is shown on Fig. 3. A picture of the fabricated prototype is shown on Fig. 4. Good agreement is observed. Any disagreement is attributed to mechanical tolerances but most importantly to the requirement for increased number of modes, that arises due to the short distances l_1 and l_2; this allows increased higher order mode interaction.

IV. CONCLUSION

A novel compact and stopband improved E-plane filter configuration is proposed. Improvement is achieved upon periodically loading the resonators of standard E-plane filters with ridges. A size reduction of roughly 50% is observed together with improved stopband performance. The structure is compatible with the split block housing and metal insert E-plane technology, thus maintaining the low cost and mass-producible characteristics. Numerical and experimental results are presented to validate the argument.

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