Compact ridged waveguide filters with improved stopband performance.

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Abstract **— A novel ridged waveguide bandpass filter configuration is proposed. The proposed filter has comparable size to standard E-plane filters while having suppressed spurious resonance. Compactness is achieved taking advantage of the properties of slow waves in half wavelength resonators, while spurious behaviour suppression is achieved by means of an integrated lowpass structure. Periodicity is readily imposed upon cascading ridge waveguide with rectangular waveguide. The structure is simple and compatible with E-plane technology. Numerical and experimental results are presented to validate the argument.**

I. Introduction

All metal inserts mounted in the E-plane of a split block waveguide housing is a well-established technique for realising low-cost and mass-producible microwave configurations, such as bandpass filters. However, despite their favorable characteristics, E-plane filters suffer from poor stopband performance, that may often be too low and too narrow for many applications, such as multiplexers [1].

In order to address the problem of spurious passband, of E-plane filters, earlier work [2] proposed to integrate the standard bandpass E-plane filter with a periodic lowpass E-plane structure. This configuration can suppress the spurious passband of the bandpass filter. However, the disadvantage of this configuration is increased physical length. This paper proposes a new configuration that without any concession in the stopband performance, it significantly reduces the physical dimension. The improvement is achieved taking advantage of the properties of periodic structures and slow waves in the resonators of bandpass filters [3]-[6].

Periodic structures of various types have been a favourite topic of researchers and are currently enjoying renewed interest in the microwave field for their applications in the microwave and millimeter-wave regime [3]-[6]. It is well known [7] that periodic structure possess distinct passband stopband characteristics, based on which lowpass or highpass structures are feasible.

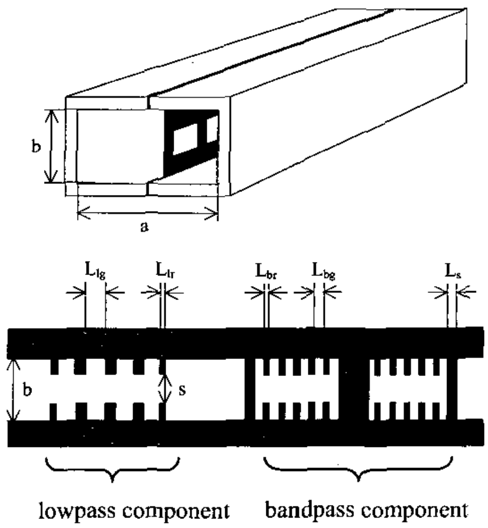

Figure 1: Configuration of the proposed structure

In filter applications, periodic structures when introduced in the resonators of bandpass filters have been reported to offer reduced physical size and improved stopband performance [4], [5], [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 selectivity can be achieved [5].

E-plane technology together with ridge waveguide offers a very convenient way of realising a periodic waveguide structure, by periodically loading the waveguide with reactive obstacles in form of ridges.

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Table 1: Dimensions (in mm) of filters compared in Figure 2			
a	22.86	s	1.00
b	10.16	t (thickness of insert)	0.10
Lowpass Component		Bandpass component	
$L_{lg1} = L_{lg2} = L_{lg3} = L_{lg4}$	6.00	$L_{bg1} = L_{bg2} = L_{bg3} = L_{bg4} = L_{bg5}$	1.00
$L_{lr1} = L_{lr5}$	1.00	$L_{br1} = L_{br2} = L_{br3} = L_{br4} = L_{br5} = L_{br6}$	0.50
$L_{lr2} = L_{lr3} = L_{lr4}$	2.00	$L_{s1} = L_{s3}$	1.20
		L_{s2}	4.00
Total Length	32.00	Total Length	22.40

This paper therefore extends the work in [2] by proposing 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. This would drastically reduce the size of the filter. Furthermore as in [2], the problem of spurious harmonic passband is addressed by integrating a periodic lowpass structure in the filter.

II. PROPOSED CONFIGURATION

The layout of the proposed configuration for a 2 resonator filter is shown on Figure 1. It consists of a lowpass and a bandpass component. The latter is designed so that it satisfies the specification for the desired passband and selectivity, while the former has its cutoff frequency close but before the spurious resonance of the bandpass component, in order to suppress it.

The bandpass component configuration is similar to the standard direct-coupled half-wavelength E-plane resonators filter, 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 forms the resonant section. This configuration establishes the periodic boundary conditions required for slow wave propagation within the resonators. The size reduction derives from two factors; firstly, the size of half wavelength resonators of a periodic resonator is reduced compared to a homogeneous one according to the guided wavelength reduction. Secondly, the improved selectivity of a periodic filter, due to the dispersion relation of the slow waves, is such that same out of band specifications can be achieved with a lower order periodic filter than a homogeneous filter.

Stepped impedance ridge waveguide configuration is used as lowpass structure (see Figure 1). This is a version of corrugated waveguide with thin ridges with lowpass characteristics, [8].

The proposed structure maintains the low-cost and mass producible characteristics of E-plane filters while achieves significant size reduction.

III. 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 between successive surface discontinuities. This is because for shorter length, higher order modes excited between adjacent cells of the periodic structure can increasingly interact.

The design of the bandpass and the lowpass components is essentially independent provided the distance between them is at least □g/4, sufficient to avoid higher order mode coupling. The bandpass component is essentially a direct-coupled half wavelength resonator filter. Hence in order to apply this design procedure the propagation characteristics of the slow wave, mainly the guided wavelength, need to be determined numerically. The lowpass component is designed so that its cutoff is before the spurious harmonic passband of the bandpass component.

IV. NUMERICAL AND EXPERIMENTAL RESULTS

In order to demonstrate the feasibility of the lowpass component as well as the accuracy of developed mode matching simulator, a fifth order lowpass prototype has been designed and fabricated. The dimensions are given in Table 1. Figure 2 shows the measured and simulated results. Mode matching with 20 TE and 12 TM modes has been used. Good lowpass performance is demonstrated. Furthermore, good agreement between the theoretical and experimental results is observed, thus verifying the accuracy of the developed tool.

In order to demonstrate the performance of the proposed integrated filter, a 2 resonator X-band filter has been chosen as an example with 0.5dB ripple, passband between 8.4GHz and 9.0GHz, and 15dB rejection at 9.5GHz. The dimensions of the designed filter are given on Table 1. A prototype has been fabricated and measured on a network analyzer. The measured response is shown on Figure 3 while a picture of the prototype is shown on Figure 4. The improved stopband performance of the proposed periodic filter is evident from Figure 3. Leaving 17.00mm between the two components brings the total length of the integrated filter to 71.40 mm.

In order to demonstrate the compactness of the proposed structure, a comparison with an equivalent structure containing a standard E-plane bandpass filter is made. In order to satisfy the upper stopband specification (15dB loss at 9.5GHz), a standard E-plane filter with the same passband and ripple should be of the third order, with a total length of 67.50 mm. Its simulated response is also shown on Figure 3. Assuming same size for the corresponding lowpass component and same distance between the two components, the total length of an integrated filter with suppressed spurious passband would be 116.50mm. A size reduction of more than 40% is achieved.

V. Conclusion

A novel ridged waveguide bandpass filter configuration is proposed. The proposed filter is compact, a feature achieved taking advantage of the properties of periodic structures in the resonators of bandpass filters, while it has suppressed spurious resonance, achieved upon the integration of a lowpass component in the filter. The proposed structure is compatible with E-plane technology and maintains the low-cost and mass-producible characteristics. Numerical and experimental results have been presented to validate the argument.

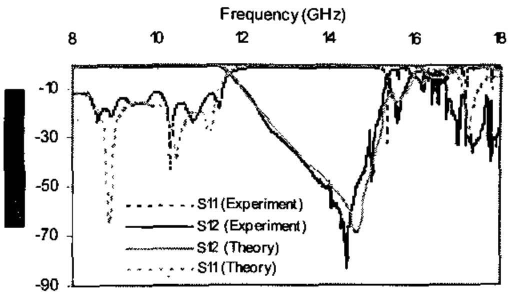

Figure 2: Simulated and measured response of the lowpass component

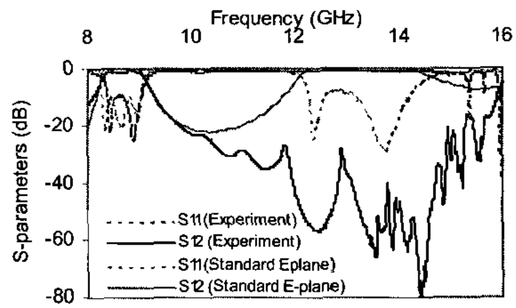

Figure 3: Measured response of the fabricated prototype (dimensions as in Table 1)

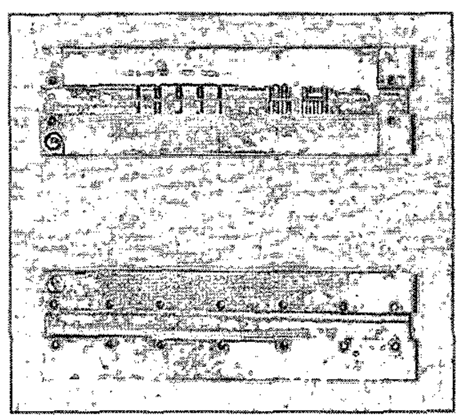

Figure 4: Photograph of the fabricated prototype

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