Ridged waveguide manifold multiplexers with improved performance.

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Abstract **— This paper demonstrates the bandwidth improvement of a multiplexer overcoming the limitations imposed by the poor stopband performance of standard waveguide E-plane filters. Bandwidth improvement is achieved introducing integrated compact ridge waveguide filter in the multiplexer. A four-channel X-band ridged waveguide manifold multiplexer is used as an example. Electromagnetic modelling of the multiplexer and experimental verification of an integrated ridge waveguide filter are presented.**

I. INTRODUCTION

Waveguide manifold multiplexers have been widely used in wireless applications that require high power capability and low insertion loss in the passband of each channel. E-plane integrated quasi-planar printed-circuit technology is a well-established technology for realising microwave and millimetre-wave circuits and offers a convenient low-cost solution for waveguide manifold multiplexers [Uher et al (1)] (Fig. 1). Since the waveguide housing dimensions have been standardised in bands, the available bandwidth for a particular system is generally determined as the range of the corresponding microwave or mm-wave waveguide band.

Conventional E-plane filters exhibit a spurious harmonic passband at a frequency roughly 1.4 times their centre frequency. For such a filter centred at the lower part of a standardised band, the harmonic behaviour is exhibited within the upper part of the same band. Hence, in order to avoid significant cross-talk between the channels at the lower and higher frequency range of a band, the available bandwidth for the multiplexer is reduced to the stopband of the lowest frequency filter.

Improvement in the stopband performance of an E-plane filter was achieved by introducing ridges in the resonators of a conventional E-plane filter [Goussetis and Budimir (2)]. Such configuration, without involving any further complexity in the fabrication process, could shift the spurious harmonic passband of the filter further away from its centre frequency, out of the waveguide band, increasing at the same time the isolation between the channels.

Further improvements can be obtained introducing the new compact ridge waveguide filter. Its integrated technology incorporates a bandpass periodic filter, allowing significant size reduction, and a lowpass structure that is used in order to suppress spurious responses and leads to further improvement of stopband performance of the filter.

Incorporating this integrated compact filter as the 1st channel and ridge waveguide filters for other channels in E-plane manifold multiplexers can thus maximise the available multiplexer bandwidth to the waveguide band.

This contribution demonstrates the significant improvement of the bandwidth of a multiplexer incorporating the novel compact ridge waveguide filter.. A four channel X-band multiplexer is used as an example. Combination of transverse resonance, mode matching and finite element method is used for the electromagnetic modelling of the multiplexer. Fabrication and testing of an integrated ridge waveguide filter demonstrates the bandwidth improvement.

II. THEORY

This section briefly describes the method used for the analysis and synthesis of a manifold multiplexer with both conventional and integrated ridge waveguide filters.

A. Filter Design

Ridge waveguide propagation is solved according to the generalised transverse resonance technique [Bornemann (3)]. Full-wave mode matching method is employed for the simulation and design of the filters [Uher et al (1)]. Comparison between experimental measurement and simulation verifies the accuracy of the method [Goussetis and Budimir (2)]. Conventional E-plane filters are designed according to the procedure described in [Budimir (4)], based on half-wavelength resonator coupled with K-inverters prototype.

The integrated ridge waveguide filter is designed using the properties of slow waves in half wavelength resonators for bandpass component and stepped impedance ridge waveguide configuration as a lowpass structure [MTT-S].

The ridge waveguide cross-section is presented on Fig.1(a).

B. Manifold

The manifold is simulated as a cascade of E-plane T-junctions, with the perpendicular ports facing the same side of the manifold (Fig. 1(b)). Commercial finite element method (FEM) simulator is used to simulate the single E-plane T-junction. The single mode approximation is used, which is valid as long as the distance between elements is larger than a quarter of the guide wavelength, $\lambda g/4$ [Morini et al (6)].

C. Multiplexer Design

For the multiplexer design, the procedure described in [Uher et al (1)] is followed. In the first step, all the filters are designed at the desired passbands. The filters are then connected to the ports and the distances between the ports and each filter from its port are optimised, together with the distance of the short end of the manifold (8 variables). Filters are ordered according to their centre frequency; both configurations with lowest frequency filter closer to the short end of the manifold and the common port have been investigated.

III. Simulation and Experimental Results

In order to demonstrate the improvement using the integrated ridge waveguide filter for the 1st channel was used instead of a conventional E-plane filter, a four-channel X-band (8-12 GHz) multiplexer is chosen as an example. The specifications regarding channels' centre frequencies and bandwidths are shown on Table 1. Fig. 2 shows the simulated response (mode matching 20 TE and 10 TM) of the conventional E-plane filter designed to satisfy the 1st channel's specifications. Fig. 3 shows the simulated response of the resulting multiplexer. Strong interference is observed between the 1st and the 4th channel, which is justified by the poor stopband performance shown in Fig. 2.

The passband specifications for the 1st channel can be improved by the integrated ridge waveguide filter, whose dimensions and simulated response are shown in Fig. 4 (mode matching with 20 TE and 10 TM). The spurious harmonic passband is now shifted well above 12 GHz. The transmission of the multiplexer with this filter assigned to channel 1 is shown in Fig. 5. More than 40dB isolation of the 1st and 4th channel now occurs.

Considering the significant size reduction of the integrated ridge waveguide filter comparing to a conventional E-plane filter the resulting multiplexer incorporating compact ridge waveguide filter can achieve reduction in size of more than 2 times. The spurious harmonic passband for this filter is located 1.77 times its centre frequency, which is an improvement of more than 25% compared to the conventional filter.

IV. Conclusion

Ridged waveguide manifold multiplexers with improved bandwidth and channel isolation have been proposed. Improvement is achieved incorporating integrated compact ridge waveguide filters. The limitations imposed by the conventional waveguide E-plane filter technology and the benefits of the proposed solution are demonstrated by means of a four-port X-band multiplexer. Combination of mode matching and finite element method has been used for the electromagnetic modelling of the multiplexer. The simulation response for the integrated compact ridge waveguide filter demonstrates the improved stopband performance and the dimensions of the filter presented lead to the multiplexer size reduction in result.

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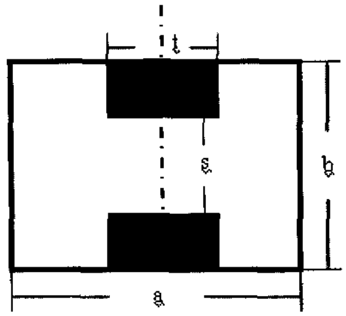

Fig. 1a Cross-section of ridge waveguide

Table 1: Channel bandwidth specifications

	Ch1	Ch.2	Ch.3	Ch.4
F_{low} (GHz)	8.5	9.3	10.4	11.6
F_{high} (GHz)	8.8	9.6	10.7	11.9

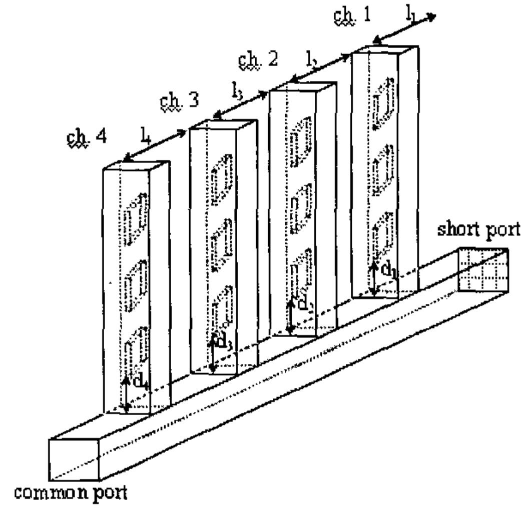

Fig. 1b Configuration of a 4-channel E-plane multiplexer

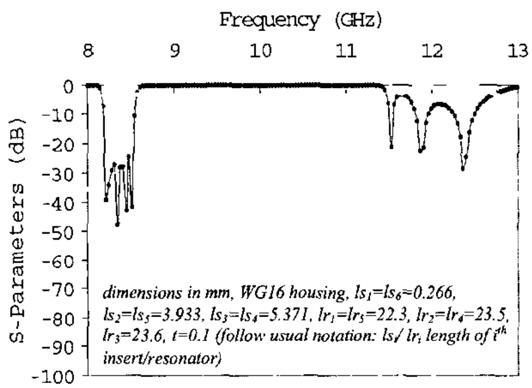

Fig. 2: Simulated S-parameters for 5-resonator conventional metal insert filter 1

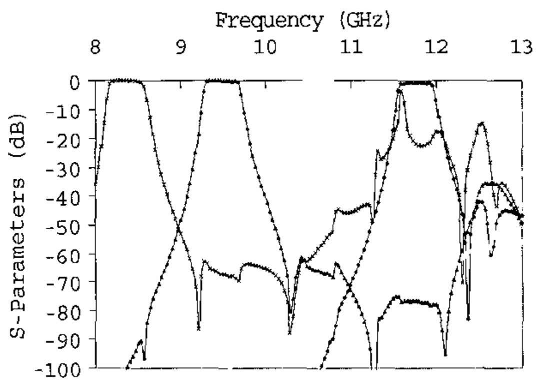

Fig. 3: Simulated transmission coefficients for the 4-channel multiplexer with conventional filters

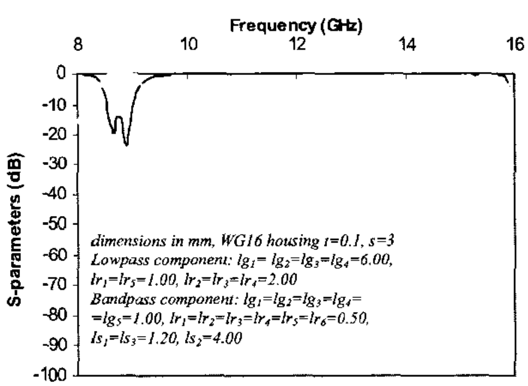

Fig. 4 Simulated S-parameters for the integrated compact ridge waveguide filter

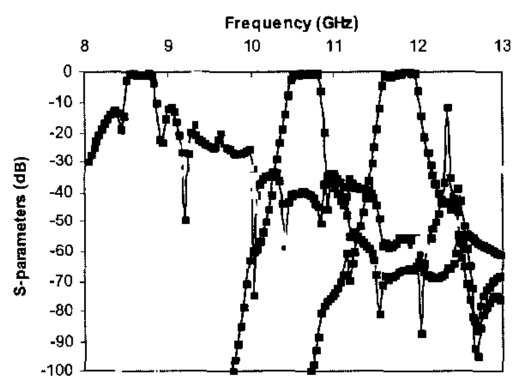

Fig. 5 Simulated transmission coefficients for the 4-channel multiplexer with integrated ridge waveguide filter as the 1st channel