DESIGN OF MIC BROADBAND CONTIGUOUS MULTIPLEXERS

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ABSTRACT

A novel design and construction technique for MIC broadband filters and contiguous multiplexers is presented. A contiguous multiplexer having outputs 4-8, 8-12 and 12-18 GHz has been constructed on a single substrate only 2" x 1¾", with low passband loss in each channel and highly selective responses at the bandedges. The multiplexer meets most environmental conditions and is very reproduceable.

INTRODUCTION

Microwave broadband contiguous multiplexers are required for front end signal sorting in ESM receivers. Printed circuit multiplexers have the advantages of small weight and volume and inherent reproduceability. The basic arrangement to be used here for a n channel multiplexer is shown in Fig. 1. The multiplexer consists of a cascade of diplexers each containing a lowpass and a highpass filter. The cascade may begin with a lowpass filter and end with a highpass filter to provide the skirt responses and rejection at the edges of the multiplexer bandwidth.

SUSPENDED SUBSTRATE REALISATION

The filters are based on the nth degree (n odd) generalised Chebyshev lowpass prototype filter [1] which has a transmission zero of order (n-1) at a finite frequency, ω_0, close to bandedge and a single zero at infinity, with an optimum equiripple passband. (See Fig. 2) Its selectivity is therefore close to the same degree optimum elliptic function filter, but is much easier to realise in printed form. This is due to the fact that impedance variations in the prototype are of the order of 2:1 as compared with greater than 10:1 in a normal elliptic function design.

Suspended substrate broadband lowpass filters

Using Richards transformation, $p \rightarrow \tanh(a_L p)/\alpha_L$, with a_L and α_L constants, the lumped lowpass prototype is transformed into a distributed quasi lowpass prototype filter. The suspended substrate realisation of this distributed filter is shown in Fig. 3. By appropriately choosing a_L and α_L, the distributed shunt resonators can be realised exactly by uniform impedance open circuited stubs which are half of a wavelength long at the stopband centre frequency. These resonators become short circuits to ground at a single frequency close to bandedge producing a very selective response. The short high impedance lines joining these resonators approximate the series open circuited stubs of the distributed prototype. Experimental results for a nineth degree filter with 1 dB bandedge frequency at 8 GHz show a passband return loss of at least 16 dB and a stopband insertion loss greater than 40 dB from 8.68-12 GHz. It should be noted that this device requires no tuning.

Suspended substrate broadband highpass filters

By applying the frequency transformation $p \rightarrow \alpha_H/[\tanh(a_H p)]$, the lumped generalised Chebyshev lowpass prototype is transformed into a distributed quasi highpass prototype. Fig. 4 shows the printed circuit for this highpass. Again the shunt resonators can be realised exactly by uniform impedance open circuited stubs which are now half of a wavelength long at the passband centre frequency. Complex inhomogeneous sections are used to produce the series elements of the filter and are formed by coupling to another circuit on the other side of the dielectric; these sections synthesise a series open circuited stub beyond its quarter wavelength frequency and thus produce a broadband match. Results on a nineth degree 8 GHz highpass show a passband return loss of at least 15 dB maintained up to 20 GHz and a stopband insertion loss greater than 40 dB from 7.6 GHz down to d.c.

Single suspended substrate multiplexers

To form an 8 GHz diplexer, the two 8 GHz filters have been integrated onto the same substrate, using a parallel connection at the input. By modifying the first series and first shunt elements of each filter, the diplexer can be matched to the source impedance at the critical resonant frequencies of the two filters. Indeed experimental results show a common port return loss of at least 12½ dB from d.c. - 18 GHz, being greater than 25 dB at crossover. A 12 GHz diplexer has shown similar results.

The two diplexers and a 4 GHz highpass have been cascaded together and integrated onto a single suspended substrate as shown in Fig. 5, with a box size of 2.4" x 1.45" x depth of .25". Results show an input port return loss greater than 11 dB from 4-18 GHz and the insertion loss response shown in Fig. 6. The loss in any channel is less than 1 dB apart from within 5% of the crossover frequencies and is less than 4.5 dB at crossover.

The substrate used is .005" RT/duroid† 5880 and meets most environmental requirements. Also since the ground plane spacing is much greater than the dielectric thickness, the filter resonators are essentially in air and tests show that the shift in crossover frequency is only about ±.3% for a $-35^{\circ}C \rightarrow 65^{\circ}C$ change of temperature.

Recently the design of the lowpass filters has been extended by using the generalised Chebyshev

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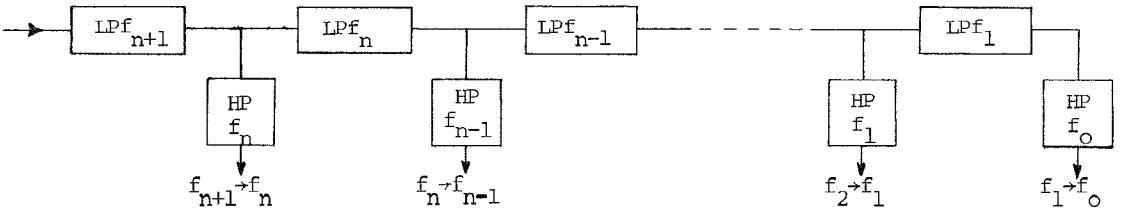
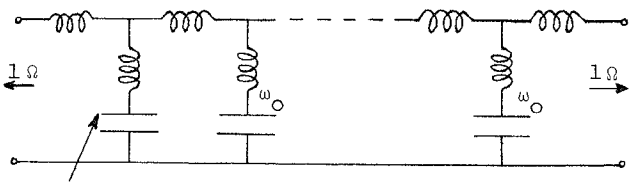


Key: LPf_n = Lowpass filter with cut-off frequency f_n.
HP_{fn} = Highpass filter with cut-off frequency f_n

Fig. 1 Block diagram of a general contiguous n channel multiplexer using highpass and lowpass filters

prototype with three transmission zeros at infinity and a transmission zero of order (n-3) at a frequency close to bandedge. Suspended substrate lowpass filters based on this prototype have the theoretical stopband insertion loss maintained up to 2½ times the bandedge frequency, which means that any channel in the multiplexer can cover at least an octave.

Several devices have been constructed to the same specification and as expected a high degree of population tracking can be achieved for both amplitude and phase. Although fine tuning at the crossover frequencies was used in the 4-18 GHz triplexer, filters are now being developed which do not require tuning and are extremely reproduceable. The examples quoted above were designed to meet a particular specification. However, by increasing the number of resonators, very selective low loss devices with 60 dB out of band rejection have been constructed with performances superior to those produced by the more common discrete component technology in a fraction of the size and weight.



Resonant frequency = ω_o

Fig. 2 The generalised Chebyshev prototype with a single transmission zero at infinity.

ACKNOWLEDGEMENTS

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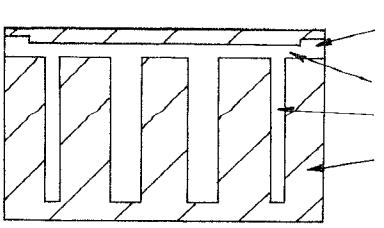
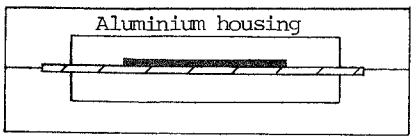
REFERENCES

[1] J.D. Rhodes and S.A. Alseyab; 'The Generalised Chebyshev Lowpass Prototype', International Journal of Circuit Theory and Applications, (in press)



Printed circuit



Cross section of housing

Fig. 3 Suspended substrate realisation of broadband lowpass filters.

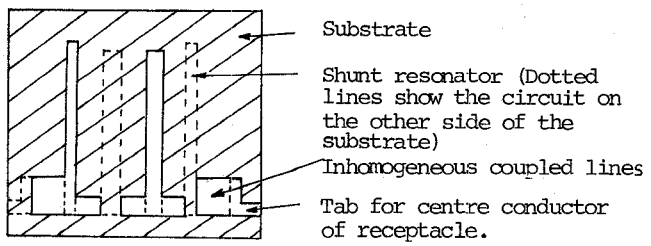


Fig. 4 Printed circuit for broadband highpass filters, which is suspended inside a small aluminium housing

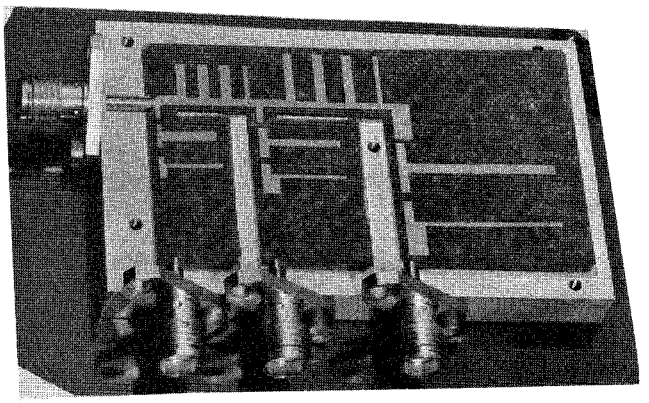


Fig. 5 Photograph of the suspended substrate triplexer covering the bands 4-8, 8-12 and 12-18 GHz. (The top half of the box is not shown).

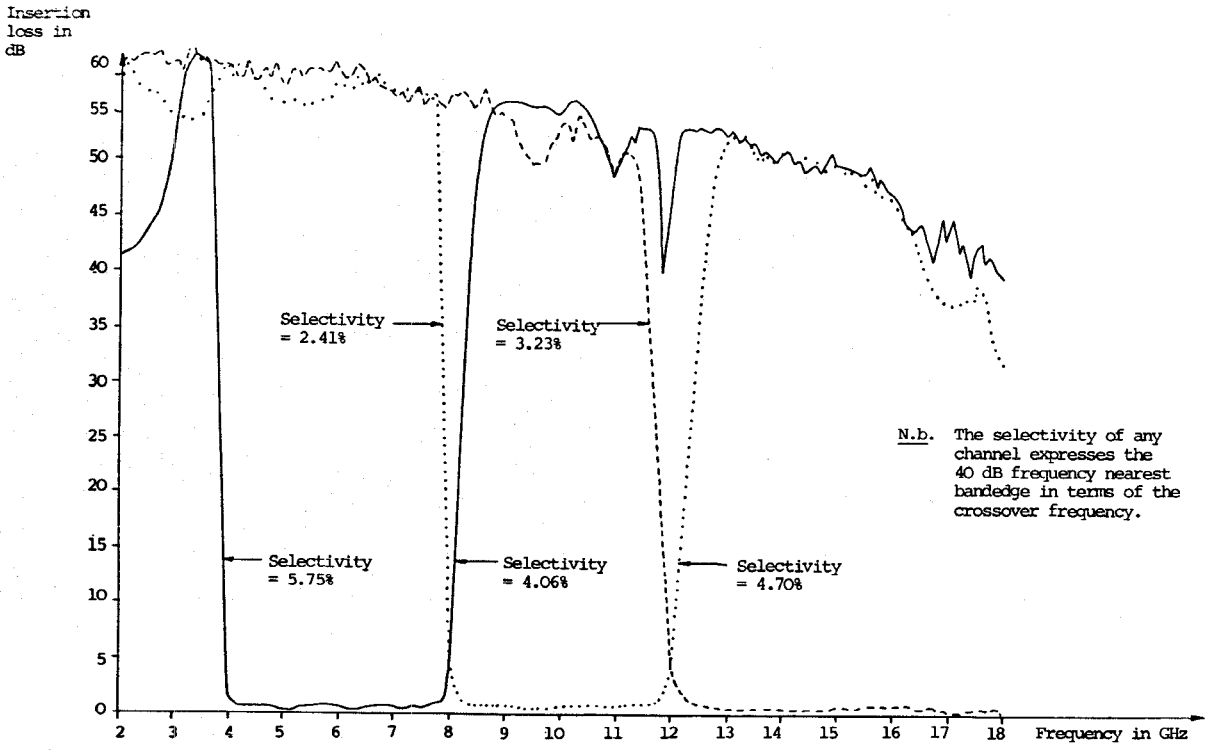


Fig. 6 Measured insertion loss of the three channels of the 4 → 18 GHz single suspended substrate triplexer