# D-6

# MATCHED FOUR PORT HYBRID FILTERS

C. I. Mobbs

Filtronic Components Ltd. Shipley, W. Yorks. U.K.

## Abstract

A method is present for the design of matched filters using 3dB hybrids which are suitable for channeliser/multiplexer applications. A procedure for integrating the hybrids into the channel filters has been devised, which when applied to printed circuit filters having good amplitude and phase tracking, leads to low loss, high performance devices which are easy to manufacture and align.

## Introduction

Recent work on narrowband multiplexers and channelisers has concentrated on design methods which acccount for the interactions between all channels on a reactively terminated manifold. Such methods become impractical if the multiplexer is required to cover an overall bandwidth in excess of one octave or is required, as in a switched multiplexer, to be electronically switched.

The use of printed circuit techniques allows accurate matching between filters and therefore makes a multiplexer using 3dB hybrids of the form of Fig. 1 practical. This method of producing a filter matched in both passband and stopband has been used for some time (1) but the matching of bandwidth and centre frequency required between the two filters leads to manufacturing difficulties unless printed devices are used.

## Realisation

Although the individual channel filters may be realised using suspended substrate stripline (SSS) techniques to give adequately high Q's. the 3dB hybrid couplers are rather more difficult. The traditional forms of Lange coupler and branch line coupler are not immediately appropriate, the Lange not being practical on the soft boards used for the SSS channel filters, making integration difficult, and the branch line coupler being limited in bandwidth.

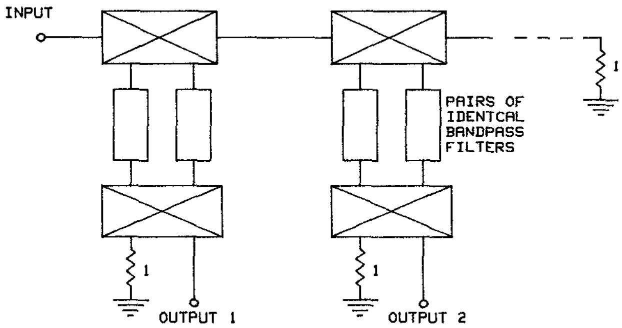


Fig. 1 Multiplexer based on hybrid channel filters

These problems may be resolved by the integration of the hybrid into the channel filters. An ideal 3 dB branch line coupler consists of a ring of impedance inverters as shown in Fig. 2. Realising the inverter between ports 1 and 2 with a conventional 1Ω (normalised) line, 90° long at bandcentre, the other elements may be realised as follows. The inverters between ports 1 and 3 and ports 2 and 4 are realised using a pi network of capacitors with negative shunt arms. The inverter between ports 3 and 4 is realised by a pi of inductors, again with negative shunt arms. By placing parallel LC resonant circuits at ports 3 and 4, and scaling the impedance level at these ports, the circuit of Fig. 3 may be derived, the negative inductors and capacitors being absorbed into the LC resonators.

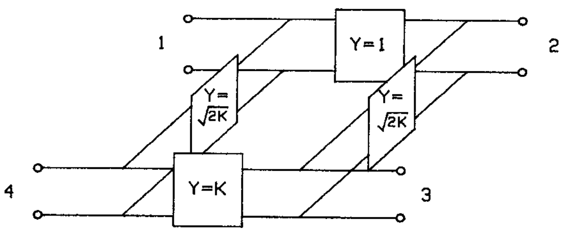


Fig. 2 Impedance scaled hybrid

If the impedance level at ports 3 and 4 is high enough, the negative shunt capacitors across the unity impedance line may be accounted for by thinning the line in the region of the coupling. Furthermore, the inductor, L, may be made to have a more practical value by tapping down the shunt inductors at ports 3 and 4.

The circuit of Fig. 3 has the required properties for the hybrids shown in Fig. 1. It has a very broadband characteristic between ports 1 and 2 and a narrowband response at ports 3 and 4. If the LC circuits at these ports are used as the first and last resonators of each channel filter, the circuit impedance being scaled accordingly, a very compact circuit may be constructed.

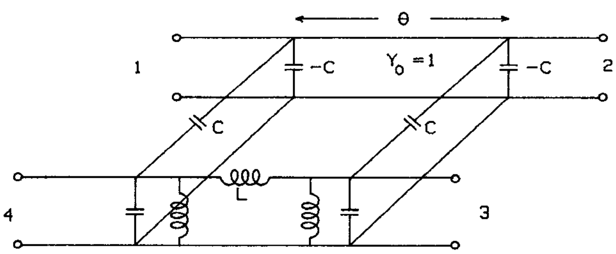


Fig. 3 Practical realisation for scaled hybrid

The resultant channel filter has the advantage that the filters may be internally switched to give isolation between input and output but, due to the nature of the hybrids, maintain a good input match, leaving other filters on the manifold unaffected.

## Printed Circuit Form of Filter

The most convenient distributed realisation of the hybrid circuit is the printed circuit combline filter. The input coupling capacitors, C, of Fig. 3 consist of printed overlaps on to the through transmission line. The distributed form of the hybrid is shown in Fig. 4. Here, the lines of impedance Z' and electrical length $\psi$ are the first combline resonators of each filter, and the line between the two of impedance $Z_1$, and length $\phi$ replaces the coupling inductor 'L' of Fig. 3.

Considering first the pi of inductors of Fig. 3 and neglecting the capacitors, then for an admittance scaling factor, K, at ports 3 and 4 we may derive the equations,

$$\sqrt{(YeYo)} = \frac{1}{j\omega L} \qquad (1)$$

and

$$Ye - Yo = j(2K) \qquad (2)$$

By evaluating Ye and Yo for the tapped combline resonators of Fig. 4, the length $\phi$ and impedance $Z_1$ of the coupling line may be derived numerically.

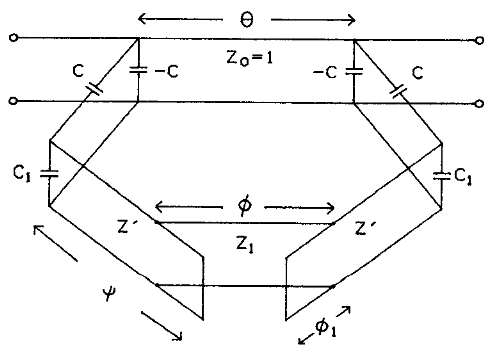


Fig. 4 Distributed form of hybrid

The negative shunt capacitors across ports 1 and 2 may be compensated for over narrow to moderate bandwidths about $\omega_o$ by modifying the length of unity impedance line, $\theta$ , to a length

$$\theta = 2\tan^{-1} (1 - \omega_o C) \qquad (3)$$

Equation 3 may again be derived by considering the even and odd mode admittances at port 1.

The form of a 3rd degree, distributed hybrid channel filter is shown in Fig. 5. The end loading capacitors on the combline resonators are realised by a combination of tuning screws and reduction of ground plane spacing over the ends of the resonators. The short circuits for the combline resonators are provided by plated through holes in contact with upper and lower sections of the housing. Grounded walls are also placed between the end resonators and the through transmission lines to eliminate broadside coupling between line and resonator which would cause incorrect hybrid operation.

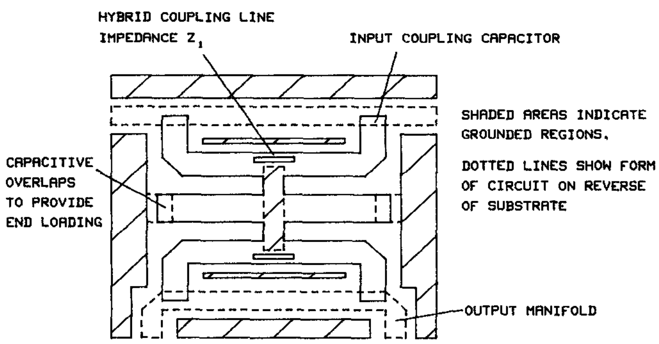


Fig. 5 Substrate for hybrid filter

## Results

The performance of a 3rd degree filter experimental triplexer is shown in Fig. 6, with the notable characteristics being the broad band input VSWR and the asymmetric frequency response of the channels. This asymmetry is dependant on the order in which the channels are cascaded to form the multiplexer. In Fig. 6, the device was connected with the lowest frequency channel nearest the input, with subsequent channels having the input return loss characteristics of the previous channels superimposed on their insertion loss characteristics due to the properties of the hybrid filters.

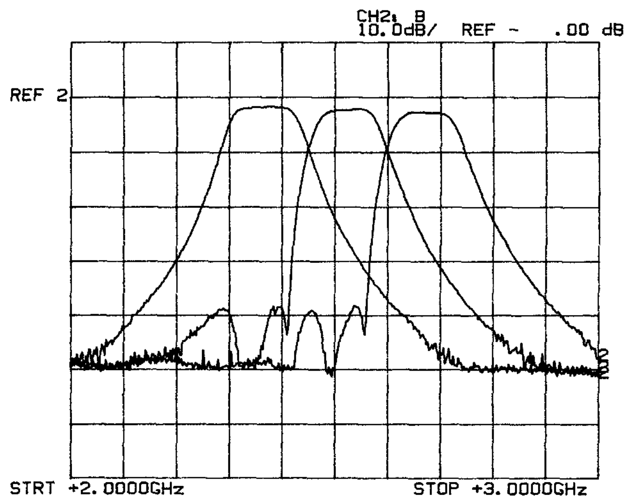


Fig. 6(a) Triplexer performance

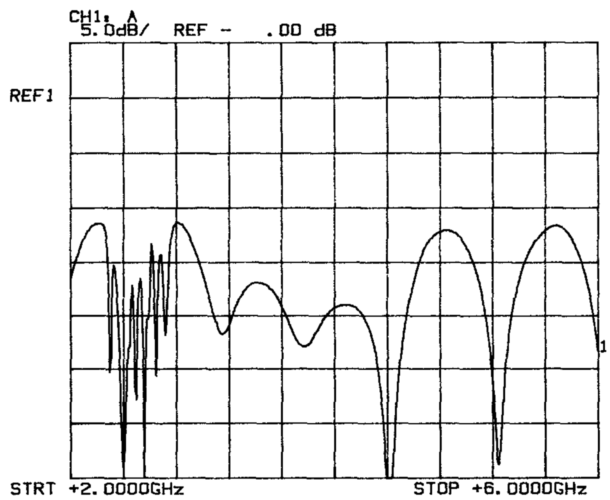


Fig. 6(b) Triplexer performance - broadband input VSWR

## Quasi-Elliptic Filters

To minimise the volume required for the channel filters without reducing the Q of the structure significantly, capacative coupling may be introduced between the resonators of each channel filter. This enables the resonators to be physically much closer for a given bandwidth. The effect of the capacitive couplings is to introduce transmission zeros into the frequency response which may be used to give quasi-elliptic frequency characteristics, increasing the selectivity of the filters. These extra coupling elements, being printed with the rest of the filter, do not increase manufacturing complexity and do not degrade the tracking between the pairs of identical channel filters. Switched multiplexers having larger numbers of such hybrid channel filters show the excellent performance characteristics which may be achieved using this technique.

The inherent balance of the filters in a channeliser allow separate signals to be fed from each of the input manifold, (providing each has a good source match) and appear at separate filter outputs. The isolation between these two signals depends on the balance of the hybrids in each filter and is typically 20 dB. It may be possible to use this mode of operation in direction finding and interfermetary systems where the two signal paths as they are passing through the same filter structure, will have excellent amplitude and phase matching.

## Conclusions

The use of the hybrid four port filter in multiplexer design leads to simple design procedures, easy alignment with no interaction between channels and is particularly suited for use on channeliser/ detector systems and switched multiplexers. Very compact structures are possible using easy to manufacture SSS techniques which lead to excellent reproducability, amplitude and phase tracking. The integration of the hybrid in to the filter structure enables low loss and wide bandwidth to be achieved.

## Acknowledgements

The author would like to acknoweldge the contributions from Prof. J. D. Rhodes during the course of this work.

## References

(1) Matthaei, G.L., Young, L and Jones, E.M.T. "Microwave Filters, Impedance Matching Networks and Coupling Structures" Mc. Graw Hill, 1964.