

PATENT SPECIFICATION

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(54) WAVEGUIDE FILTERS

- (71) We, POST OFFICE, a British body corporate established by Statute, of 23 Howland Street, London, W1P 6HQ, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to improved waveguide filters of the type using plural dual mode resonant cavities.
- British Patent Specification No. 1,301,972 describes a dual mode circular and/or square waveguide filter having input and output ports located at the two physical ends of the filter. More specifically, the Blachier and Champeau filter uses N physical waveguide cavities which resonate in two independent orthogonal modes and are coupled together to provide the filtering capacity of $n=2N$ electrical cavities resonating in a single mode. Intra cavity coupling is provided by a structural discontinuity such as a screw mounted in the cavity wall. Inter cavity coupling is provided by means of selective polarization discriminating couplings between the N cavities to transfer energy between identical modes in the coupled cavities. A particular feature of the Blachier and Champeau filter is the use of a phase inversion means in coupled cavities to provide a subtraction capability between identical modes in the coupled cavities. This subtraction capability can provide steep response skirts for the passband of the filter.
- The Blachier and Champeau filter has significant advantages not only in an improved passband response but also in economies in weight and volume and in the case of fabrication which results from the realization of two electrical cavities in one physical cavity. However, the Blachier and Champeau filter structure will not realize the general class of coupled cavity transfer functions since no provision to couple electrical cavities 1 and n , 2 and $n-1$ and so forth are provided. For a development of a synthesis procedure for the general class of canonical waveguide filters, the reader is referred to the article by Atia, Williams and Newcomb entitled "Narrow-Band Multiple-Coupled Cavity Synthesis" published in the *IEEE Transactions on Circuits and Systems*, Vol. CAS—21, No. 5, September 1974, at pages 649 to 655. The Blachier and Champeau filter is not capable of generating the optimum response and, therefore, the full potential of this particular waveguide cavity structure is not realized.
- The present embodiments shown in Figures 2 to 8 are an improvement in the Blachier and Champeau filter using either square and/or circular dual mode waveguide cavities. As in the Blachier and Champeau filter, intra-cavity coupling is provided by structural discontinuities, and inter cavity coupling is provided by selective polarization discriminating irises or circular holes between the cavities. The improvement is the provision of a reflective plate in one end cavity and both input and output ports in the other end cavity of the cascaded waveguide cavities. More specifically, the input and output filter ports are connected to the same physical cavity, but the input port is coupled to electrical cavity No. 1 and the output port is coupled to electrical cavity No. n . As a result of the improvement, it is possible to couple electrical cavities 1 and n , 2 and $n-1$ and so forth thereby permitting the realization of the general class of coupled cavity transfer functions. Moreover, advantages associated with the Blachier and Champeau filter are retained.
- The present invention provides a plural cavity waveguide filter comprising a plurality of cascaded waveguide cavities each arranged to resonate at its resonant frequency in a first and a second independent orthogonal mode, first coupling means in each of said cavities for intra cavity coupling of said first mode to said second mode, and second coupling means connecting successive ones of said cavities for inter cavity coupling like oriented modes in said successive cavities, and in which a reflective plate is provided in one end cavity and both input and output ports are provided in the other end cavity of said plurality of cascaded waveguide cavities.
- By way of example only, certain illustrative

embodiments of the invention will now be described with reference to the accompanying drawings, in which:

5 Figure 1 is a generalized illustration of a prior art Blachier and Champeau dual mode filter employing circular waveguide sections;

Figure 2 illustrates a canonical dual mode filter embodying the present invention using circular waveguide sections;

10 Figure 2A illustrates a modified form of the filter shown in Figure 2;

Figure 3 is an illustration of a canonical dual mode filter embodying the present invention using square waveguide sections;

15 Figure 4 illustrates the use of perpendicular coaxial probes in the same end physical cavity to provide the input and output ports for a filter embodying the invention;

20 Figure 5 illustrates the use of a coaxial probe and an end slot in the same end physical cavity to provide the input and output ports of a filter embodying the invention;

25 Figure 6 illustrates the use of a cross slot in an end cavity and an orthogonal mode transducer to provide the input and output ports for a filter embodying the invention;

30 Figure 7 illustrates the use of an end slot and a shunt port in the sidewall in the same end physical cavity to provide the input and output ports of a filter embodying the invention;

35 Figure 8 illustrates the use of sidewall waveguide couplings oriented at 90° with respect to one another in the same end physical cavity to provide the input and output ports of a filter embodying the invention; and

40 Figures 9 and 10 are graphs showing the experimental response characteristic of fourth and eighth order elliptic function bandpass filters, respectively, built according to the invention.

45 Since the present embodiments may be generally considered as improvements in the basic Blachier and Champeau dual mode filter, this filter will be first with reference to Figure 1 of the drawings. The filter comprises a plurality of cascaded waveguide cavities 11, 12 and 1N. As illustrated in Figure 1, these cavities may be cylindrical waveguide sections connected end to end. It will be understood, of course, that the filter could comprise a plurality of square waveguide sections connected in line. Each of the cylindrical waveguide cavities is capable of resonating at its resonant frequency in first and second independent orthogonal modes. Thus, if the filter comprises N physical cavities, then there are $n=2N$ electrical cavities. If cylindrical waveguide cavities are used, each of the electrical cavities resonates in the TE_{111} mode, whereas if square waveguide cavities are used, each electrical cavity resonates in the TE_{101} mode.

65 Coupling between the electrical cavities within each physical cavity is provided by a

physical discontinuity such as a screw in the side wall. The intra cavity coupling screws 21, 22 and 2N are mounted in their respective cavities at an angle of 45° between the two orthogonal modes supported by the cavity. In addition, certain ones of the coupling screws such, for example, as coupling screws 21 and 22, may be shifted by 90° with respect to one another. As a result, the coupling provided by screw 22 has an opposite sign to the coupling provided by the screw 21. This difference in sign in the coupling is a particular feature of the Blachier and Champeau filter which permits the achievement of the particular function response of the filter. 70

Inter cavity coupling is provided by the plates 31, 32 and $3(N-1)$ which define the common end walls of successive cavities in the filter. Each of these plates is provided with a cross slot iris which couples like oriented modes in the successive cavities. These irises are polarization discriminating to transfer energy between identical modes in the coupled cavities. Energy is coupled into the filter by means of a slot in the exposed end wall 41 of the first cavity 11, and energy is coupled out of the filter by means of a similar slot in the exposed end wall 4N in the last cavity 1N. The slots in the end walls 41 and 4N are oriented to maximize the coupling of any incoming and outgoing waves having the proper polarization but to minimize the coupling of waves of all other polarizations. 75

80 With the Blachier and Champeau filter as illustrated in Figure 1 as background, an improved filter embodying the invention will now be described with reference to Figure 2 wherein like reference numerals designate identical or corresponding parts. Referring to Figure 2, the exposed end wall of the last cavity 1N is a reflecting plate 5N. At the other end of the filter, the exposed end wall of the first cavity 11 is shown as a plate 51 with a cross slot iris. The purpose here is to illustrate that input and output energy is taken from and coupled to the same end physical cavity 11 of a cascaded set of dual mode cavities. The manner in which the input and output ports of the filter are actually implemented will be described in more detail hereinafter. The cavity couplings which are made possible by the filter structure shown in Figure 2 can be represented in the matrix form known as a canonical coupling matrix. A development of this matrix form is provided in the article by Atia, Williams and Newcomb referenced hereinabove. A similar filter composed of square waveguide cavities 61, 62 and 6N is illustrated in Figure 3. 85

As in the Blachier and Champeau filter, inter cavity coupling is provided by plates 31, 32 and $3(N-1)$ having cross slot irises. For most practical applications, a symmetrical filter structure can be used. In such cases the 90

cascade couplings between electrical cavities 1 and 2 equals that between cavities $n-1$ and n , the couplings between electrical cavities 2 and 3 equals that between cavities $n-2$ and $n-1$, and so forth. These cascade couplings are provided by the cross slot irises in plates 31, 32 and $3(N-1)$. Because of the symmetry of these slots in a symmetrical filter structure, the cross slot irises can be replaced by circular holes. The circular holes have great advantages in the manufacturing and machining process of those filters as contrasted to the cross slot irises. Figure 2A illustrates a plate 31 having a circular hole. The same modification can be made in the structure shown in Figure 3.

A cross slot in the exposed end wall of the first waveguide cavity by itself does not provide a practical means for independently coupling the input and output ports to the filter. Figures 4, 5 and 6 illustrate three different ways in which the input and output ports are coupled independently to the two orthogonal electrical cavities within the first physical cavity of the filter structure. In Figure 4, the exposed end wall of the first cavity 11 is blank and two coaxial probes 71 and 72 are connected to the side wall of the cavity. More specifically, the coaxial probes 71 and 72 are mutually perpendicular with respect to one another and with respect to the longitudinal axis of the filter. Moreover, these coaxial probes are oriented to be in line with the two orthogonal modes in the cavity 11.

In the arrangement shown in Figure 5, the first cavity 11 is provided with a coaxial probe 71 as before, but instead of a second coaxial probe, the exposed end wall 51 of the cavity 11 is provided with a slot 73. The slot 73 is oriented so as to couple energy orthogonally to the energy coupled by the coaxial probe 71.

In Figure 6, the cross slot 74 in the end wall 51 of the first cavity 11 as shown in Figure 3 is retained. An orthogonal mode transducer 75 is connected to this end wall 51. As is well known in the art, an orthogonal mode transducer is capable of independently coupling orthogonally polarized waves. To this end, the orthogonal mode transducer 75 is provided with a shunt port 76 and a series port 77.

In Figure 7, the first cavity 11 is provided with a shunt port 77 in the sidewall, and the end wall 51 is provided with a slot 73. In this case the slot 73 is oriented so as to couple energy orthogonally to the energy coupled by the shunt port 77.

In yet another variation shown in Figure 8, two shunt ports 77 and 78 are provided in the sidewall of the first cavity 11. The shunt ports 77 and 78 are oriented about the axis of cavity 11 90° with respect to one another so as to couple energy in two orthogonal modes.

Experimental verification of the fourth and eighth order elliptic function bandpass filter transfer functions has been made at 4GHz, and the results as shown in Figures 9 and 10, respectively. As will be seen from those figures, theory and experiment were in excellent agreement. In the described filters embodying the invention, the realization of virtually optimum filter responses is achieved by allowing the input and output ports to be coupled to the same end physical cavity of a cascaded set of dual mode cavities.

The following paragraph summarizes the described embodiments of the invention.

A plural cavity waveguide filter comprising a plurality of cascaded waveguide cavities 11, 12, $1N$ each resonating in first and second independent orthogonal modes is disclosed. The cavities may be either square and/or circular resonating in the TE_{101} or TE_{111} modes, respectively. The filter makes it possible to realize the general class of coupled cavity bandpass transfer filter functions by providing that the input and output couplings to the filter be physically connected to the first physical cavity. A general set of canonical couplings can then be achieved within the structure.

WHAT WE CLAIM IS:—

1. A plural cavity waveguide filter comprising a plurality of cascaded waveguide cavities each arranged to resonate at its resonant frequency in a first and a second independent orthogonal mode, first coupling means in each of said cavities for intra cavity coupling of said first mode to said second mode, and second coupling means connecting successive ones of said cavities for inter cavity coupling like oriented modes in said successive cavities, and in which a reflective plate is provided in one end cavity and both input and output ports are provided in the other end cavity of said plurality of cascaded waveguide cavities.

2. A waveguide filter as recited in Claim 1 wherein said waveguide cavities are cylindrical waveguide sections connected end to end by means of said second coupling means.

3. A waveguide filter as recited in Claim 1 or 2 comprising N physical cavities whereby said filter is equivalent to $n=2N$ electrical cavities resonating, in use, in the TE_{111} mode.

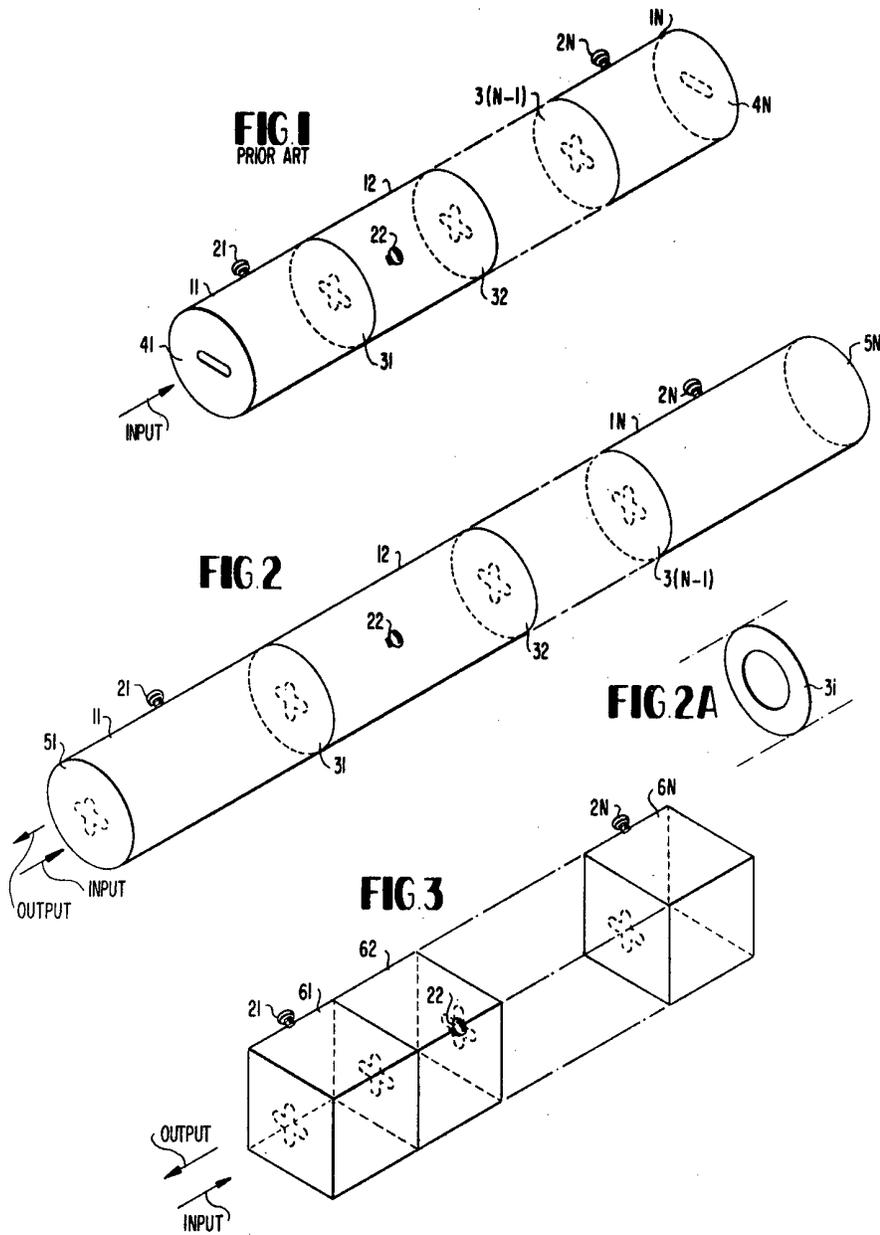
4. A waveguide filter as recited in Claim 1 wherein said waveguide cavities are square waveguide sections connected in line by means of said second coupling means.

5. A waveguide filter as recited in Claim 4 comprising N physical cavities whereby said filter is equivalent to $n=2N$ electrical cavities resonating, in use, in the TE_{101} mode.

6. A waveguide filter as recited in any preceding claim, wherein said input and out-

- put ports in said other end cavity comprise first and second coaxial probes oriented mutually perpendicular with respect to one another and with respect to the longitudinal axis of said filter.
- 5 7. A waveguide filter as recited in any of Claims 1 to 5 wherein said input and output ports in said other end cavity comprise a coaxial probe—in a side wall and a coupling slot—in the exposed end wall of said other end cavity.
- 10 8. A waveguide filter as recited in any of Claims 1 to 5 wherein said input and output ports in said other end cavity comprise a cross slot—in the exposed end wall of said other end cavity and an orthogonal mode transducer—coupled to said exposed end wall of said other end cavity.
- 15 9. A waveguide filter as recited in any of Claims 1 to 5 wherein said input and output ports in said other end cavity comprise a shunt port—in a sidewall and a coupling slot—in the exposed end wall of said other end cavity.
- 20 10. A waveguide filter as recited in any of Claims 1 to 5 wherein said input and output ports in said other end cavity comprise two side wall shunt ports, said side wall shunt ports being oriented about the axis of said other end cavity 90° with respect to one another.
- 25 11. A plural cavity waveguide filter substantially as herein described with reference to and as illustrated by Figure 2 of the accompanying drawings.
- 30 12. A plural cavity waveguide filter substantially as herein described with reference to and as illustrated by Figure 3 of the accompanying drawings.
13. A waveguide filter as claimed in Claim 11 or 12 having input and output ports substantially as herein described with reference to and as illustrated by Figure 4 of the accompanying drawings. 40
14. A waveguide filter as claimed in Claim 11 or 12 having input and output ports substantially as herein described with reference to and as illustrated by Figure 5 of the accompanying drawings. 45
15. A waveguide filter as claimed in Claim 11 or 12 having input and output ports substantially as herein described with reference to and as illustrated by Figure 6 of the accompanying drawings. 50
16. A waveguide filter as claimed in Claim 11 or 12 having input and output ports substantially as herein described with reference to and as illustrated by Figure 7 of the accompanying drawings. 55
17. A waveguide filter as claimed in Claim 11 or 12 having input and output ports substantially as herein described with reference to and as illustrated by Figure 8 of the accompanying drawings. 60
18. A waveguide filter as claimed in any preceding Claim, wherein the filter is a fourth order elliptic function bandpass filter. 65
19. A waveguide filter as claimed in any of Claims 1 to 17, wherein the filter is an eighth order elliptic function bandpass filter. 70

ABEL & IMRAY,
Chartered Patent Agents,
Northumberland House,
303—306 High Holborn,
London, WC1V 7LH.



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COMPLETE SPECIFICATION

3 SHEETS

*This drawing is a reproduction of
the Original on a reduced scale
Sheet 2*

FIG.4

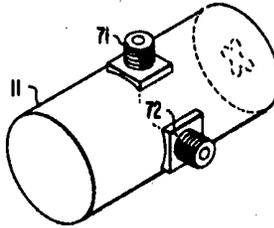


FIG.5

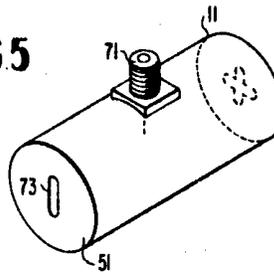


FIG.6

