A NEW MULTIPLEXING PRINCIPLE

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ABSTRACT

A new multiplexing principle is introduced based on common multimode cavities (CMC) which resonances are excited at dedicated channel frequencies. This method provides conspicuous advantages, especially in combination with degenerate cavities. The principle is explained and experimentally verified by a diplexer design using one CMC with TE_{112} and TM_{110} resonances.

INTRODUCTION

Multiple channel transmission of modern microwave communication systems is obtained by application of multiplex equipments. They provide combination of the individual channel signals at the transmitter and separation of them at the receiver, respectively. In general, there are three different multiplexing methods, namely the application of a circulator chain (each circulator terminated by a channel filter) /1/, interconnection of 3 dB hybrid / filter modules /1/ and the manifold multiplexing technique /2/. Each of them has special properties and, hence, its favorable applications.

This paper presents the introduction of a new multiplexing principle. It takes advantage of common multimode cavities (CMC), i. e. the excited resonance modes are assigned to different channel filters. Since there are, without regard to the channel filters, no additional means required (such as circulators, hybrids, manifold), a compact and low mass multiplexer design is obtained, which provides good properties for satellite applications.

CMC MULTIPLEXING PRINCIPLE

Optimal conducting cavities of various shapes are used for realization of resonance circuits at microwave frequencies. There are an infinite number of independent modes which may be excited within a cavity. Due to appropriate dimensioning of the cavity several independent resonance modes can be utilized (multimode cavity) as the designs of dual–, triple–, and quadruple–degenerate cavities show /3–5/ (degenerate : resonance modes with the same frequency).

The new multiplex principle is also based on independent cavity modes within the CMC. However, the dimensions of the CMC are computed to provide resonance modes assigned to different channel filters (i. e. modes excited at different frequencies) in contrast to the degenerate cavity design. (In the following the principle is explained for a combiner of several input signals to a common output port). A principle circuit diagram of a CMC diplexer is shown in Fig. 1.

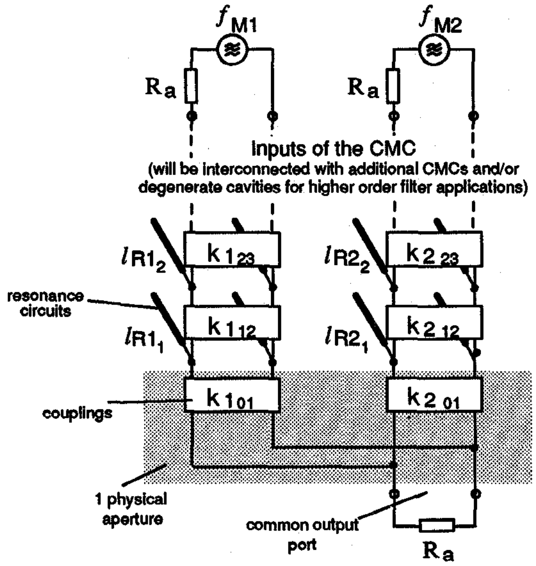


Fig. 1: Principle circuit diagram of a CMC diplexer with only one physical cavity

The precondition of this CMC multiplexing principle is the choice of an appropriate mode set within the cavity which must provide :

- independent tuning of all resonance modes
- independent realization of the individual channel filter functions, i. e. independent control of all couplings
- separate locations for the introduction of the single channel signals into the CMCs (e. g. interconnection with the dedicated inputs or with additional degenerate cavities in case of higher order filters) and one location for the common signal output.

The application of this principle to rectangular or elliptical (cylindrical) CMCs allow a maximum number of 3 multiplexed channels (due to the maximum number of frequency independent cavity modes, which can be obtained by accurate determination of the three cavity variables (dimensions) as well as the independent control of three couplings at the common signal port).

Higher order filters are accomplished by cascading several CMCs, using independent intercavity couplings, similar as e. g. established in /6,7/, or by proper combination of CMCs with conveniently coupled degenerate cavities for each filter. Also, a utilization of dedicated degeneracies within the CMCs is possible.

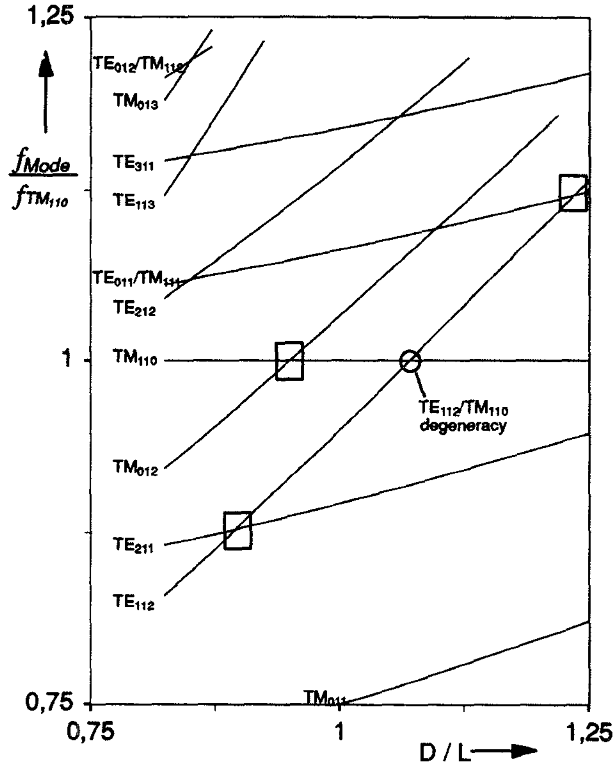


Fig. 2: Relevant mode chart section for a TE_{112}/TM_{110} combination

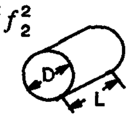
APPLICATION

Though a triplexer design is feasible it makes only academical sense due to the complex structure of interconnecting waveguides and/or cavities as well as the difficult control and realization of the independent output couplings.

Hence, the CMC multiplexing method is illustrated by a diplexer design based on a cylindrical cavity. The use of a TM_{ijp} resonance mode at channel one frequency f_1 and a TE_{mnq} resonance mode at channel two frequency f_2 leads to the cavity design formulas :

$$D = \frac{c}{\pi}\sqrt{\frac{\chi_{ij}^2 - (p/q)^2 \chi'^2_{mn}}{f_1^2 - (p/q)^2 f_2^2}}$$

$$L = \frac{c}{2}\sqrt{\frac{p^2 - (\chi_{ij}/\chi'_{mn})^2 q^2}{f_1^2 - (\chi_{ij}/\chi'_{mn})^2 f_2^2}}$$



c : $\sqrt{(\mu_0 \cdot \varepsilon_0)^{-1}}$
χ'_{mn} : n th zero of Bessel function $J'_m(\chi)$
χ_{ij} : j th zero of Bessel function $J_i(\chi)$
p, q : Integer of $c / (2 \cdot f_{1,2})$ along L

An essential task in the design of CMCs is the detailed investigation of the spurious cavity modes. The choice of an appropriate mode set including the assignment of the resonances to the dedicated frequencies must provide spurious free bands near the transmission channels.

The careful design and locating of the apertures and tuning screws enhance the suppression of the spurious modes within the overall band. The interconnection of the CMC with dedicated degenerate cavities for each channel leads to additional rejection at the spurious bands since, due to the different cavity dimensions, the spurious modes of the CMC and the degenerate cavities have usually different resonance frequencies. The design of interconnected degenerate cavities must also take care of spurious free bands at *both* channels.

Fig. 2 shows for example the relevant mode chart section for a (TE_{112}/TM_{110}) mode combination. In general, multiplexed channels are assigned to the same transmission bands which have less than 25% relative bandwidth. The diagram depicts the mode frequencies relative to the TM_{110} resonance frequency ($f_{Mode}/f_{TM_{110}}$) depending on cavity dimensions (D / L).

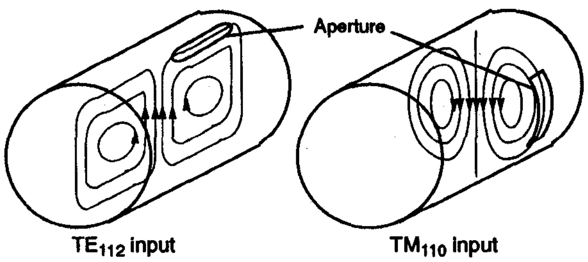


Fig. 3: Principle magnetic field pattern and locations of the respective coupling apertures

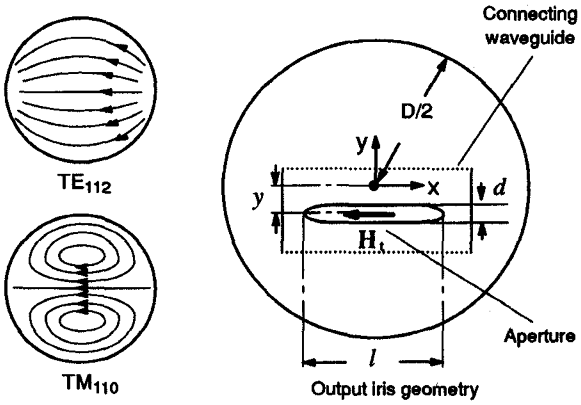


Fig. 4: Principle magnetic fields of TE_{112} and TM_{110} modes, respectively, within the top–wall cross section and output iris geometry

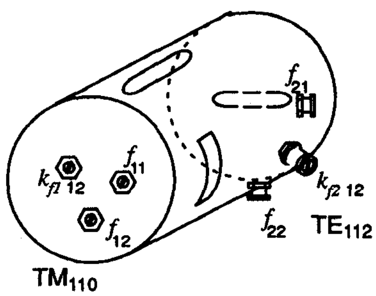


Fig. 5: Location of tuning and coupling screws of the two independent filters within the CMC

The intersection of the TE_{112} and the TM_{110} curves represents the D / L relation for the degenerate mode condition. Both curves exhibit also some cross points with other modes. The CMC design at these points is not feasible if these modes cannot conveniently be employed in one filter function. However, multiplexing of these combinations ($TE_{112}/TM_{110} \Rightarrow f_1/f_2$) can be obtained by changing the mode – frequency assignment (f_2/f_1) or by application of a different mode set.

The TE_{11q} as well as the TM_{11p} modes provide additional dual mode degeneracies which differ only in the angular field variations ($\sin\phi / \cos\phi$). Hence, these modes are favorably suited for CMC designs, since these degeneracies can be utilized for the dedicated filter functions. For example, a diplexer design with two 2–pole filters can be accomplished by one physical cavity.

All ports (inputs and output) are coupled to the end wall of standard waveguides by irises using magnetic couplings /8/. Independence of the individual filter functions and good decoupling between the input ports is obtained by locating the input coupling iris of each filter at field zeros or perpendicular to the magnetic fields of the remaining cavity modes (Fig. 3).

Both filters are coupled by an iris to a common waveguide, which is connected to one top wall of the cavity. The different output coupling factors are accomplished by proper location (x,y) and dimensioning (d,l) of the coupling slot, due to the different magnetic field variation of the modes (Fig. 4). For example, the tangential magnetic field (H_t) of the TE_{11q} modes varies from a max. value at the iris center to a min. value at the circumference, while H_t of the TM_{11p} modes changes from a max. positive value also at the iris center to a max. negative value at the circumference and pass through zero at x = 0.24 D.

The tuning screws of each mode are located at electrical field zeros of the other modes to obtain independent tuning. Appropriate located screws (45°) provide the required intermode couplings of the degeneracies without affecting the tuning of the remaining filter (Fig. 4).

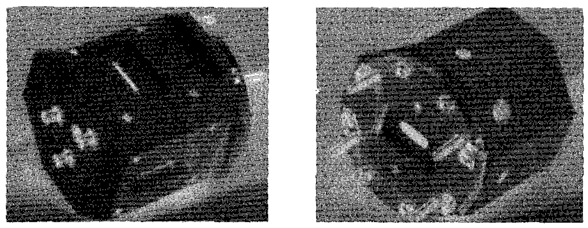


Fig. 6: Photographs of the realized diplexer

EXPERIMENTAL VERIFICATION

The above considerations have been applied to a first diplexer design to verify the CMC multiplexing principle. One cylindrical CMC comprises two 2–pole narrow band filters (equiripple bandwidth 7 MHz). One is performed by the TE_{112} dual mode degeneracies at frequency f_1 = 11.05 GHz, while the other is realized by the TM_{110} dual mode degeneracies at f_2 = 11.50 GHz. Fig. 6 shows two views of the diplexer.

The measured common port return loss and the near band selectivity (about ± 150 MHz) of both channels agree closely with the theoretical filter responses (Figs. 7, 8, 9). Though the filters and, hence, all input and output ports share the same physical cavity about 20 dB decoupling between both channel input ports is obtained. The spurious performance of both channels (Fig. 8, 9) exhibits some differences resulting from the different input aperture locations but in both cases the spurious modes within about ± 1 GHz are suppressed by more than 40 dB.

It should be noted that these values are not limitations for a practical CMC multiplexer design. The decoupling as well as the spurious performance will essentially be improved for higher order filter applications using CMCs and dedicated degenerate mode cavities for each channel.

CONCLUSION

One favorable extended design of the numerous possibilities is shown in Fig. 10, a diplexer with two 6–pole pseudo elliptic function filters with only three physical cavities (one CMC and two dedicated quadruple degenerate mode cavities). Hence, advantageous designs can be obtained for different applications under consideration of electrical and mechanical aspects.

Due to the compact and low mass design this multiplex principle is well suited for satellite applications. Though it allows only a max. number of 3 multiplexed channels it can easily be combined with other multiplexing methods leading to overall essential mass reduction of multichannel multiplexer equipments.

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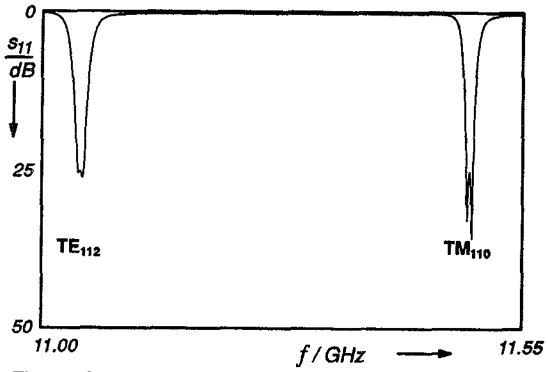

Fig. 7: Measured return loss of the CMC diplexer

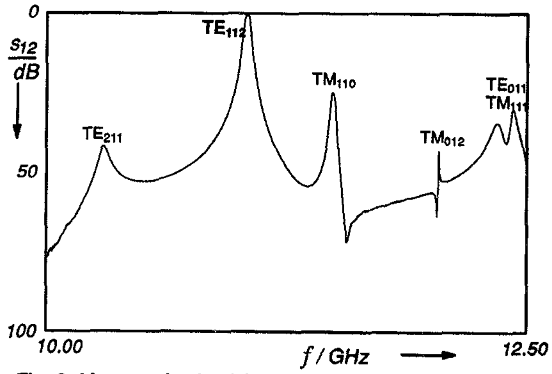

Fig. 8: Measured selectivity of the TE_{112} filter channel

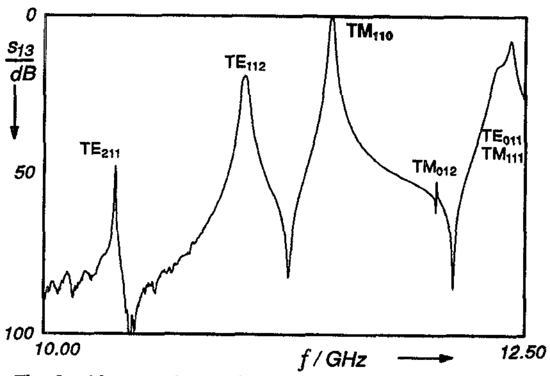

Fig. 9: Measured selectivity of the TM_{110} filter channel

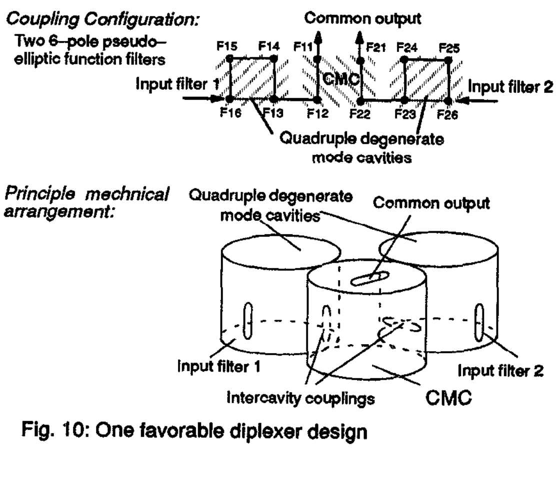

Fig. 10: One favorable diplexer design