REALIZATION OF DUAL MODE BAND REJECTION FILTERS

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I) INTRODUCTION

Band-rejection filters comprise a set of resonant circuits connected to a transmission line and to each other, such that an undesired band of frequencies is selectively removed from the incident spectrum. Commonly, the resonant circuits take the form of cavities, which are iris-coupled to a main line. The cavities are spaced an odd multiple of $\lambda g/4$, where λg refers to the main line guide wavelength. This spacing results in properly phased addition of the attenuation due to each resonant cavity. The amount of attenuation contributed at any frequency is set by the coupling iris, and is pre-determined by the particular network synthesis utilized.

Minimum-phase designs have traditionally been realized by circuits illustrated in Fig. 1a. If the interconnecting main-line lengths are not constrained to be (2N-1) $\lambda g/4$, then additional coupling elements may form a portion of the prototype circuit, with the resultant transfer function containing additional transmission zeroes. Fig. 1d, Ref. 3). Prototype circuits for both minimum phase and for "elliptic" response designs are shown in Fig. 1.

Typically, the resonant cavities support only a single mode of resonance, although the literature (3) has suggested the possibility of realizing finite transmission zeroes using coupled-mode dual-mode cavities as resonant elements. In his interesting paper, Rhodes (3) discusses the difficulty of controlling the mode interaction in dual-mode designs. This paper will describe three new devices:

1) a minimum phase design in which dual mode cavities are used with the orthogonal modes intentionally uncoupled within the cavity. (Fig. 1b)
2) An elliptic design, based on the Rhodes natural Prototype, in which uncoupled mode dual modes are utilized in similar fashion to the minimum phase design. (Fig. 1E)
3) An elliptic response design in which the desired interaction (coupling) between modes is easily and accurately controlled. (Fig. 1C)

Each of the three designs are tunable, in sychronous fashion, across a certain frequency range.

II) MINIMUM-PHASE DESIGN

Fig. 1b illustrates the new configuration for single-cavity (2-pole response) and multiple cavity ($Nc \leq Np \leq 2Nc$) designs. Each cylindrical cavity utilizes a TE_{11N} dominant mode, although, of course, a TM_{11N} set might be employed. In addition, square cross section waveguide can be utilized in dual TE_{10N} or TM mode sets. The essence of this design is contained in the concept of utilizing pairs of essentially uncoupled (within the cavity) orthogonal modes. Mode coupling is accomplished through the interconnecting (2N-1)· $\lambda g/4$ lines, serving the same purpose as the corresponding lines in the single mode cavity designs. The interconnecting line length is adjusted to the correct phase length utilizing either dielectric inserts, tuning screws forming a band pass filter network, reduced cross section guide, or other means for increasing the effective phase length between cavity input ports.

Cavity eccentricity will have the effect of coupling the two modes within any cavity. The result of this coupling is to introduce (in undesired fashion) pair of transmission zeroes in the filter stopband. This limits the amount of attenuation that any cavity will contribute across the entire stopband region.

Dual mode minimum phase bandpass filters suffer from the same intrinsic deficiency. Unwanted mode coupling results in limitation of stopband depth or skirt slope degradation. In (4) properly constructed side-wall coupled dual mode filters have been shown to be virtually indistinguishable from single mode designs down to 80 db.

The interconnecting line is quite interesting. For a fixed center frequency, the required interconnection length is (2N-1) $\lambda g/4$, where λg refers to the interconnecting waveguide. Referring to Fig. 3, if the cavities utilize the TE_{111} mode, Fo=10 GHz, waveguide=WR-90, then:

$$D = 1.000$$
$$L = .786$$
$$3\lambda g/4 = 1.172$$

So, additional phase length is required to make $L_{AV} = (2N-1)\lambda g/4$. This can be provided simply by forming the waveguide as shown, such that the length L_{AV} becomes 1.172".

If the susceptive loading effects of the irises are taken into account, the required L_{AV} is reduced. If the filter is to be tunable over a wide band, either the connecting line length must be adjustable or the degradation due to improper phase addition of the cavities must be tolerated or compensated. Although some small compensation is achievable through iris shaping, (i.e., intentionally employing a frequency sensitive iris configuration), computations and measurements show that a change in center frequency of $\pm 8\%$, with an instantaneous bandwidth of less than 1% does not degrade the filter skirt characteristics significantly.

III) ELLIPTIC DESIGN UTILIZING UNCOUPLED DUAL MODES

This design is achieved through the use of the structure shown in Fig. 1e. Network synthesis is that of Ref. 3. Coupling and interconnection considerations are the same as for the minimum phase design.

IV) ELLIPTIC DESIGN UTILIZING COUPLED DUAL MODE

This design utilizes the network of Fig. 1c. All interconnecting lines are effectively (2N-1) $\lambda g/4$. Referring to Fig. 6, the means for adjustment of transmission zero location is illustrated. The tracking screws are located opposite the irises and enable the resonant frequencies of each mode to be adjusted. The screw susceptance affects (to first order) only the mode coupled into the iris opposite. To maintain maximum orthogonality, it has been found useful to shape the tracking "screws" such that the cross-section conforms to the shape of the opposite iris. The coupling screw enables adjustment of the Q associated with each pair of transmission zeroes.

V) TUNABILITY

The filter described herein can be synchonously tuned over a reasonably wide bandwidth while maintaining an approximately constant percentage bandwidth. Utilizing the formulation of Ref. 4, the iris and screw coupling coeffecients can be derived, for sidewall coupling cavities. It is then possible to locate the irises for minimum coupling coefficient change as center frequency is varied. It is found that the input iris is centered about 0.67L from the fixed end of the cavity, while the center iris is located at approximately 0.63L. The other irises and screws fall between these values. Ganged-tuning is accomplished through the use of gear-coupling, just as in dual mode band pass filter.

VI) CONCLUSIONS

It is now feasible to build compact band reject cavity filters using dual mode techniques. Both minimum phase and elliptic responses are achievable, the latter utilizing both conventional and natural prototypes. Other networks based upon combinations of direct, cross-coupling and main line coupling are also thought feasible. Filters of this type can be made absorptive, rather than reflective, if each of the dual mode cavities is provided with an exit port and load for each of the supported modes (Fig. 4). Another possible implementation of the design utilizes end wall coupling. In this case, orthogonal irises are used to couple the modes. (Fig. 5).

REFERENCES

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3. J. D. Rhodes, "Waveguide Bandstop Elliptic Function Filter," TRANS. MTT-20, Nov., 1972.

4. R. V. Snyder, "The Dual Mode Filter-a realization," Microwave Journal, Dec., 1974.

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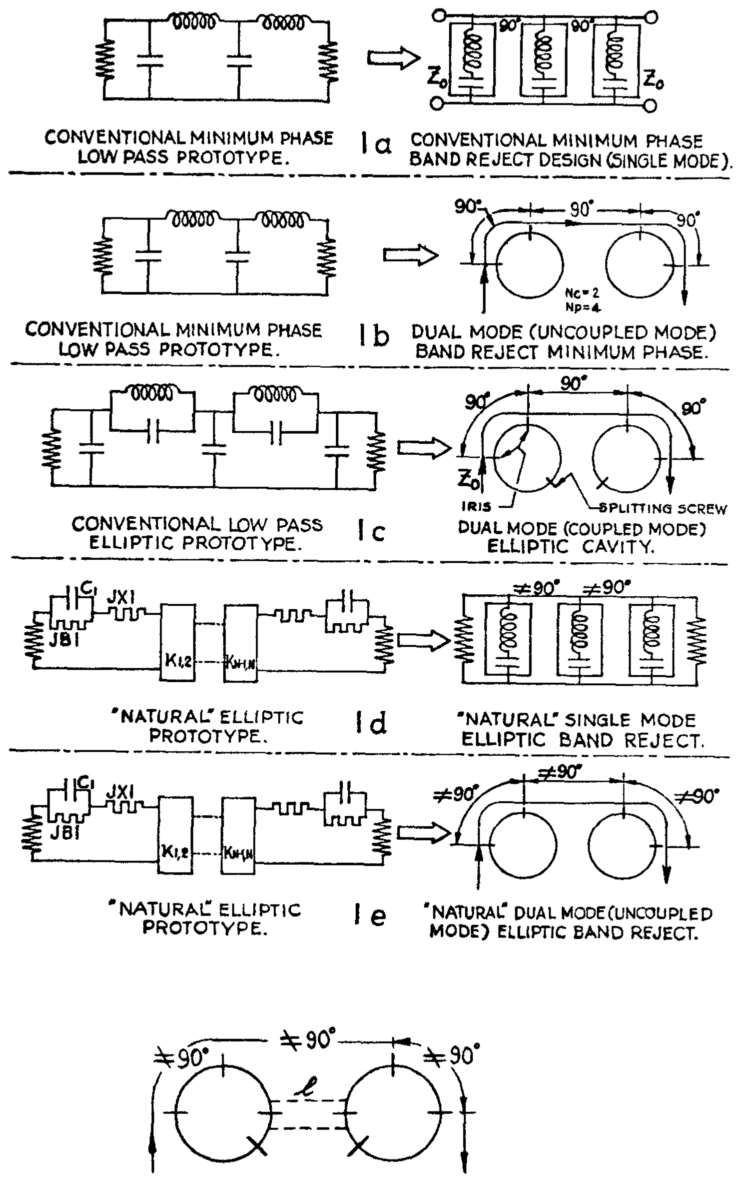
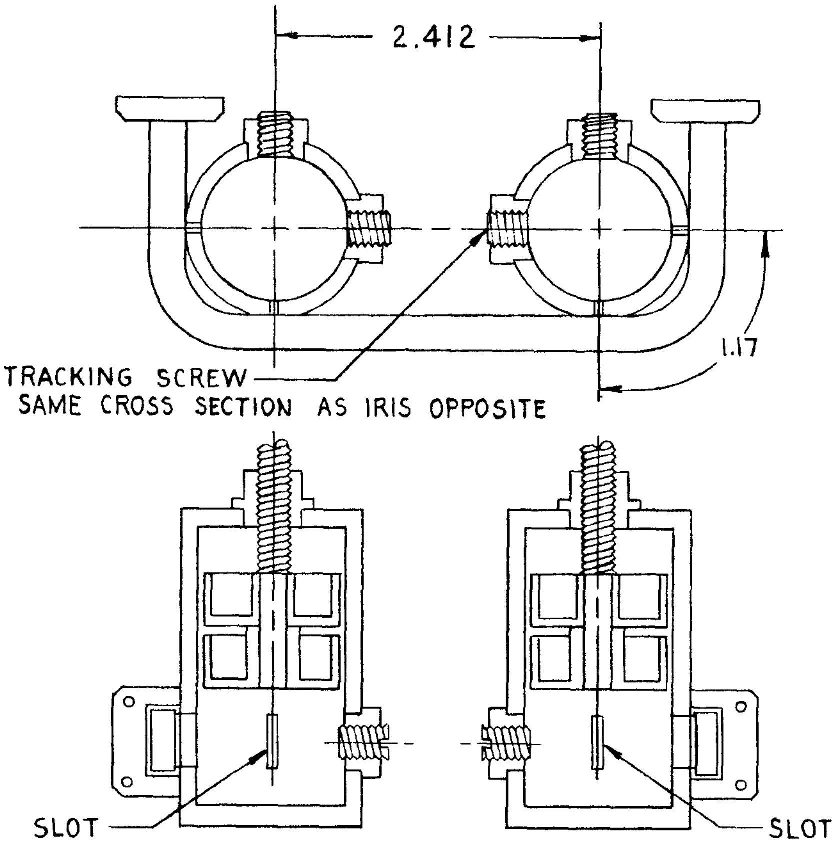


FIG. 1f

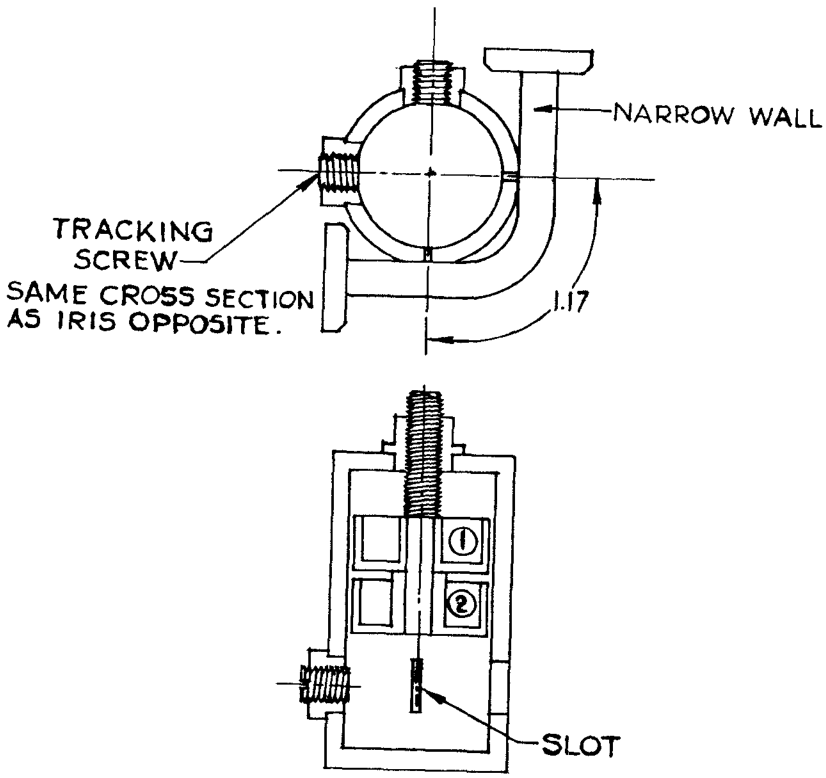
GENERALIZED DUAL-MODE BAND REJECT

LENGTH ℓ INTERCONNECTS EITHER OF TWO MODES (DEPENDING ON COUPLING IRIS ORIENTATION) IN 1st CAVITY TO EITHER OF TWO IN SECOND CAVITY, THUS ALLOWING RELOCATION OF PASSBAND ZEROES OR STOPBAND POLES. THIS APPROACH ENABLES SOME INDEPENDENT ADJUSTMENT OF AMPLITUDE AND PHASE.

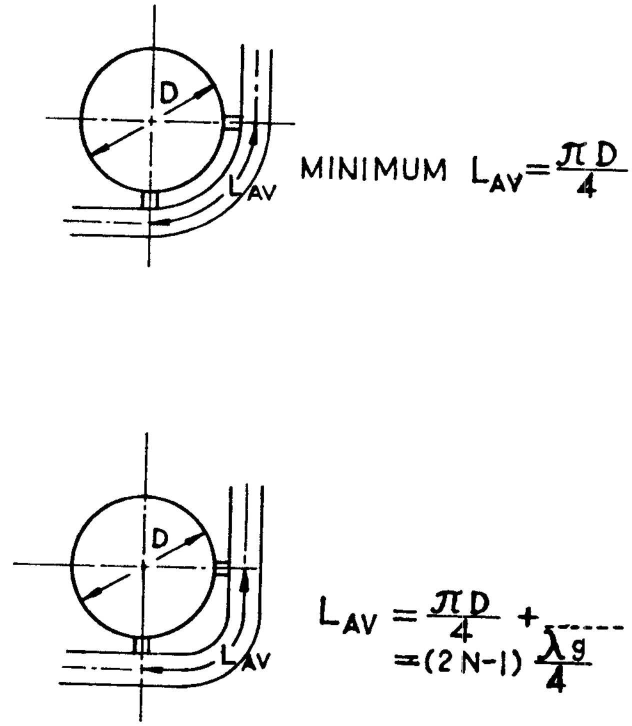


DUAL MODE BAND REJECT
UNCOUPLED MODES
TWO CAVITY
FOUR POLE

FIG. 2B

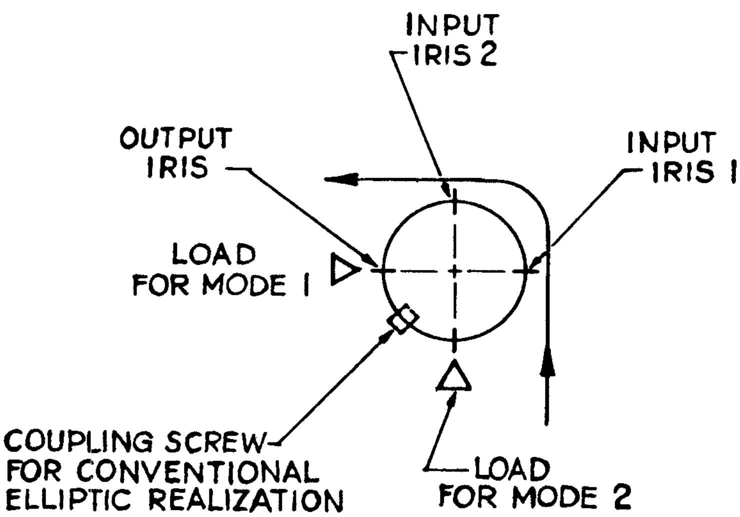


DUAL MODE BAND REJECT
UNCOUPLED MODES.
SINGLE CAVITY
TWO POLE
FIG. 2A



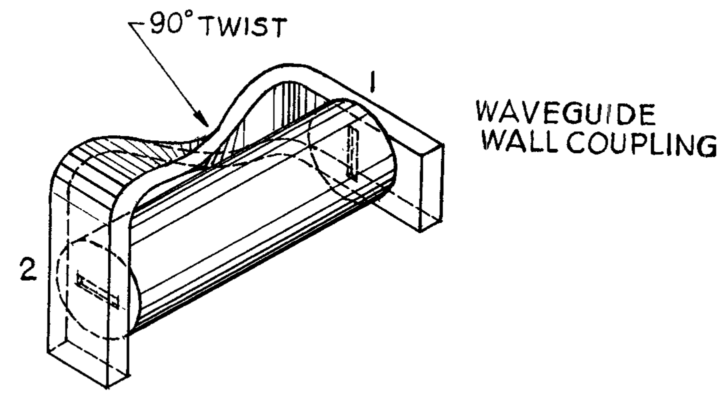
IRIS INTERCONNECTION LENGTH ADJUSTMENT.

FIG. 3.



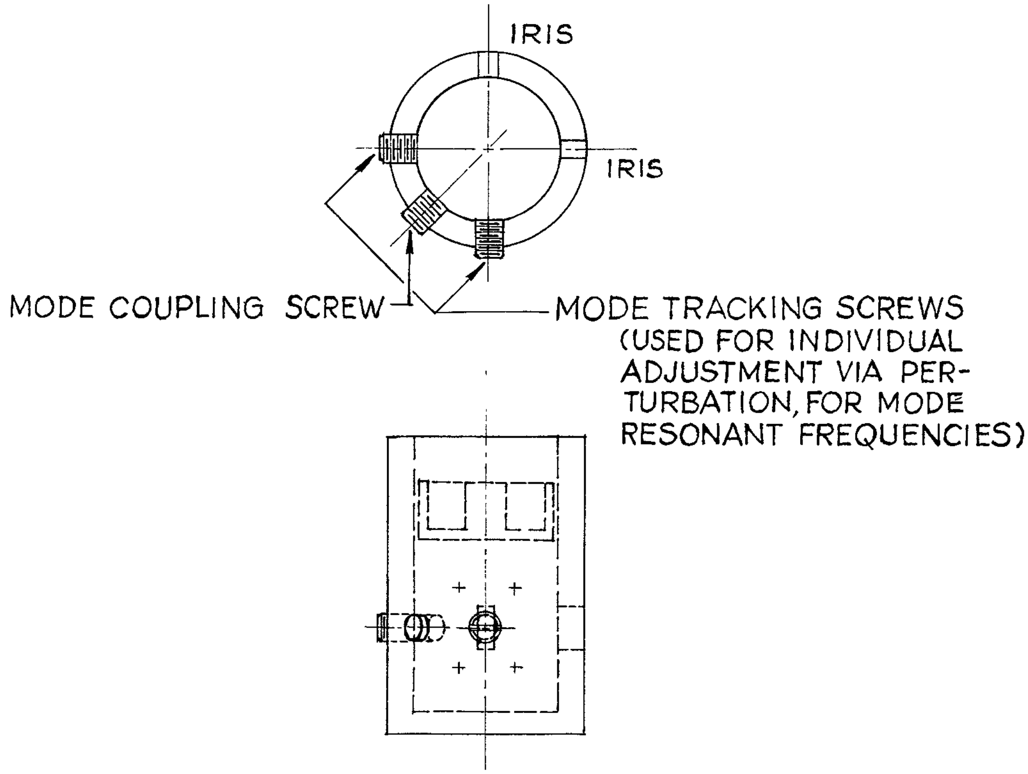
ABSORPTIVE DUAL MODE REJECT.

FIG. 4.



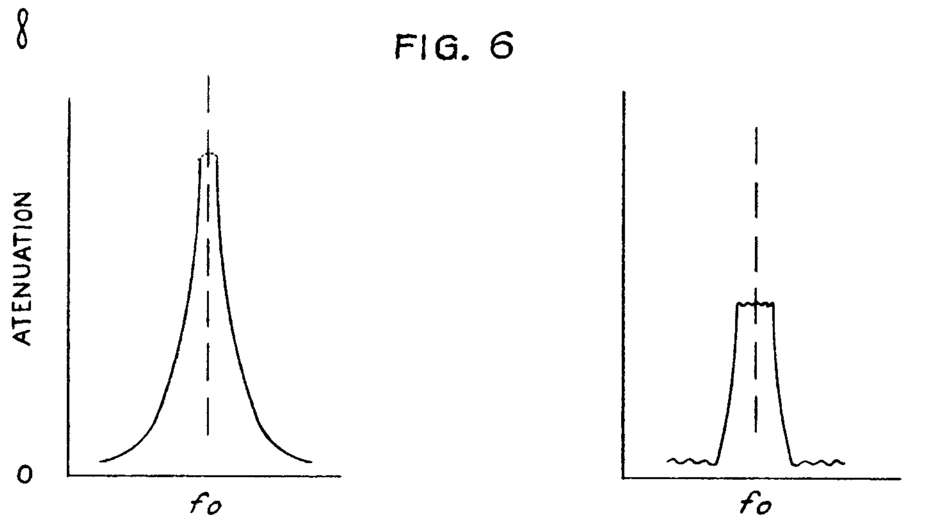
END WALL COUPLED APPROACH.

FIG. 5.



MEANS FOR ADJUSTMENT
OF MODE RESONANT
FREQUENCIES AND COUPLING.

FIG. 6



TYPICAL SINGLE-MODE
BAND REJECT RESPONSE
(MULTPLE CAVITY)

TYPICAL ELLIPTIC
BAND REJECT RESPONSE
(MULTIPLE CAVITY)

FIG. 7