II-3 RADIAL-LINE BAND REJECTION FILTERS IN COAXIAL WAVEGUIDES

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Among the simplest and least expensive structures which serve as band rejections filters in the microwave region is the coaxial waveguide with a cylindrical cavity forming a discontinuity in the outer conductor, (Figure 1). When the outer conductor of a coaxial waveguide is perturbed by a shorted radial transmission line, the structure acquires a zero of transmission for the TEM mode at a resonant frequency that depends on as many as six parameters. Experience indicates that in restricted regions certain approximate methods, in which one or several of the parameters are neglected, produce fairly accurate results. However, discrepancies of 5% or more are encountered in other regions where the same approximations ought to be valid. The approximations most frequently used correspond to either one of the following situations: (a) total disregard of the fringing fields caused by the two close discontinuities, in which case the cylindrical cavity is represented by a series impedance equal to the input impedance of a shorted radial transmission line [1]; (b) consideration of the fringing fields associated with each discontinuity, but neglect of the inter-action between the two [2]. In the latter, the discontinuities are accounted for by equivalent shunt lumped reactive elements, however, they must be far enough apart so that the interaction is indeed negligible.

The analysis and subsequent results given in this paper are motivated by the objective of gaining further understanding of the relationship between the rejection frequency and the physical parameters of the structure, in particular the width of the cavity. This is accomplished by taking into consideration all the pertinent parameters, neglecting only second order effects such as losses in conductors and dielectrics. As a result, new quantitative data is obtained over a very wide band in the microwave region, where coaxial lines are of practical use.

The analysis includes a representation of the double discontinuity by a symmetric two-port, whose admittance matrix, Y, is derived from a variational principle. Through application of the Rayleigh-Ritz method, the points of infinite transmission loss are computed, by finding the zeros of the y_{12} element of Y.

Families of curves were computed on a normalized basis, with the resonant wavelength, λ_r, in the cylindrical cavity as the natural unit of length. In each one of Figures 2-6, the normalized length of the cavity, $L = (d-b)/\lambda_r$, is plotted against the normalized outer radius of the coaxial line, $B = b/\lambda_r$, for various values of the normalized half-width of the cavity, $H = h/\lambda_r$. Each set of curves is plotted at constant characteristic impedance, Z_o, of the coaxial line. The results are compared in Figure 7 with an asymptotic curve [1] for $H \to o$ which is derived from an analysis which entirely neglects the effect of the fringing fields. This figure together with Figure 8, demonstrates a newly discovered dependence of the resonant frequency on the width of the cavity.

The calculated results are also given in restricted regions by simple formulas of the following general form

$$L = \alpha_o + \alpha_1 H - \alpha_2 B + \alpha_3 HB$$

The coefficients $\{\alpha_i\}$, $i = 1, 3$ are given in Tables I-III. The calculated rejection frequencies agree within 1% with experimental measurements published by B.C. DeLoach, Jr. [3], also with those performed by the author (Table IV).

References

1. S.A. Schelkunoff, "Electromagnetic Waves", D. Van Hostrand Company, Inc, 1943.
2. J.R. Whinnery, H.W. Jamieson, T.E. Robbins, "Coaxial-Line Discontinuities". Proc. I.R.E., volume 32, November, 1944, pp. 695-709.
3. B.C. DeLoach, Jr., "Radial-Line Coaxial Filters in the Microwave Region", IEEE Trans. on Microwave Theory and Techniques, volume MTT-11, No. 1, January 1963, pp. 50-55.

TABLE I

$Z_0 = 50\Omega$, $\varepsilon_g = 1.00$						
ε_t	R_H *	R_B †	α_0	α_1	α_2	α_3
1.00	I	II	0.363	0.356	0.564	-0.952
1.00	I	III	0.343	0.412	0.364	-1.577
1.00	II	I	0.375	0.219	0.879	3.108
1.00	II	II	0.365	0.322	0.659	0.901
1.00	II	III	0.343	0.429	0.432	-0.329
2.32	I	II	0.361	0.384	0.520	-1.480
2.32	I	III	0.338	0.439	0.306	-1.970
2.32	II	I	0.375	0.220	0.872	3.051
2.32	II	II	0.364	0.329	0.632	0.719
2.32	II	III	0.336	0.482	0.363	-0.874
5.00	I	II	0.359	0.407	0.486	-1.881
5.00	I	III	0.336	0.447	0.269	-2.160
5.00	II	I	0.375	0.221	0.868	2.949
5.00	II	II	0.363	0.335	0.611	0.579
5.00	II	III	0.335	0.464	0.342	-0.810

* R_H = I: $0.03 \leq H \leq 0.05$
II: $0.05 \leq H \leq 0.10$

† R_B = I: $0.01 \leq B \leq 0.05$
II: $0.05 \leq B \leq 0.10$
III: $0.10 \leq B \leq 0.20$; $L \geq 0.290$

TABLE II

$Z_0 = 50\Omega$, $\varepsilon_g = 2.32$						
ε_t	R_H *	R_B †	α_0	α_1	α_2	α_3
2.32	I	I	0.379	0.145	0.849	1.463
2.32	I	II	0.362	0.280	0.564	-1.085
2.32	II	I	0.376	0.203	0.884	2.166
2.32	II	II	0.361	0.319	0.624	-0.014
2.32	II	III	0.342	0.387	0.437	-0.843

* R_H = I: $0.03 \leq H \leq 0.05$
II: $0.05 \leq H \leq 0.10$

† R_B = I: $0.005 \leq B \leq 0.06$
II: $0.06 \leq B \leq 0.11$
III: $0.11 \leq B \leq 0.185$; $L \geq 0.285$

TABLE III

$Z_0 = 92.0\Omega$, $\varepsilon_g = 1.00$						
ε_t	R_H *	R_B †	α_0	α_1	α_2	α_3
1.00	I	I	0.378	0.126	0.873	1.297
1.00	II	I	0.374	0.216	0.805	0.962
1.00	II	II	0.344	0.407	0.450	-1.423
5.00	I	I	0.377	0.150	0.799	0.101
5.00	II	I	0.374	0.201	0.822	1.320
5.00	II	II	0.344	0.375	0.408	-1.397

* R_H = I: $0.03 \leq H < 0.05$
II: $0.05 \leq H \leq 0.10$

† R_B = I: $0.005 \leq B \leq 0.070$
II: $0.070 \leq B \leq 0.150$

TABLE IV

$\varepsilon_g = 1.00$ $\varepsilon_t = 1.00$						
2a	2b	2d	2h	f_c†	f_m‡	$(f_m-f_c)/f_m$
in.	in.	in.	in.	GHz	GHz	%
0.217	0.500	6.000	0.772	1.557	1.557	·0.00
0.217	0.500	6.000	1.455	1.623	1.622	0.06
0.869	2.000	6.000	1.196	1.829	1.828	-0.05
0.869	2.000	6.000	0.054	1.770	1.767	-0.17
0.869	2.000	6.000	0.802	1.770	1.771	0.06
0.087	0.200	8.000	2.017	1.185	1.186	0.08
0.087	0.200	8.000	0.322	1.133	1.136	0.26
0.869	2.000	6.590	0.724	1.563	1.563	0.00
0.869	2.000	7.749	0.724	1.284	1.285	0.08

† Calculated resonant frequency

‡ Measured resonant frequency

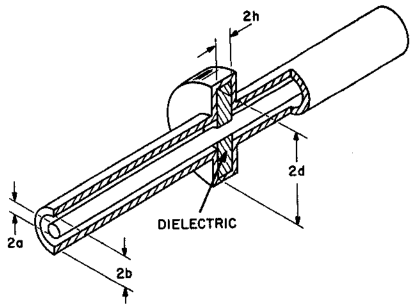

FIG.1 RADIAL-LINE COAXIAL FILTER

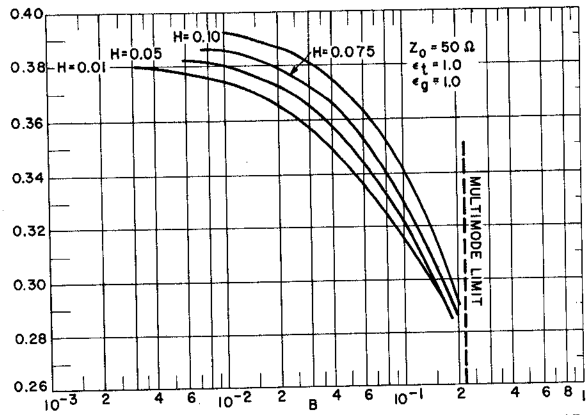

FIG. 2 NORMALIZED CAVITY LENGTH VS NORMALIZED OUTER RADIUS OF COAX

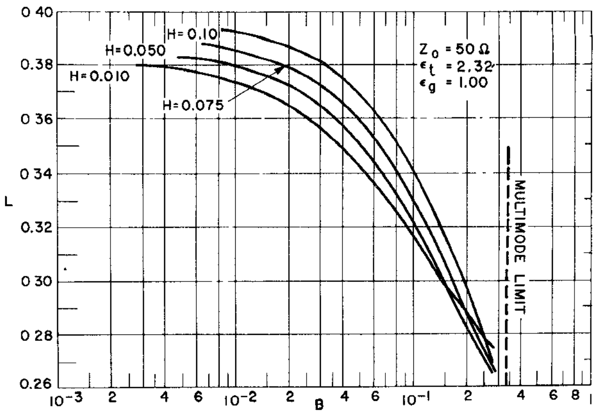

FIG. 3 NORMALIZED CAVITY LENGTH VS NORMALIZED OUTER RADIUS OF COAX

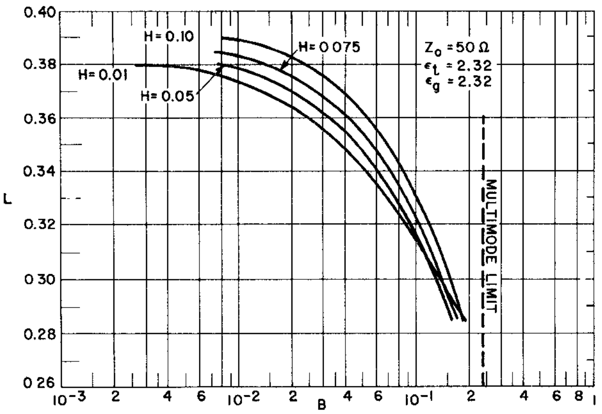

FIG. 4 NORMALIZED CAVITY LENGTH VS NORMALIZED OUTER RADIUS OF COAX

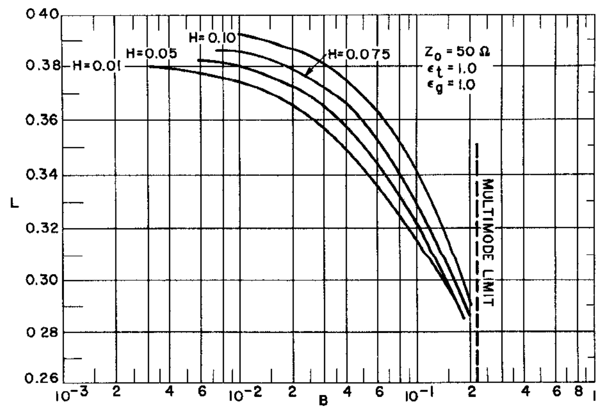

FIG 5 NORMALIZED CAVITY LENGTH VS NORMALIZED OUTER RADIUS OF COAX

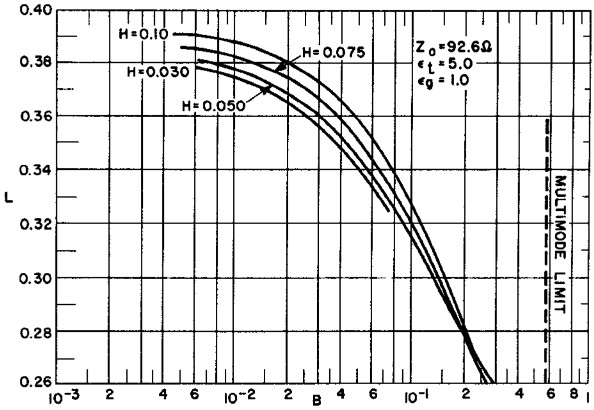

FIG 6 NORMALIZED CAVITY LENGTH VS NORMALIZED OUTER RADIUS OF COAX

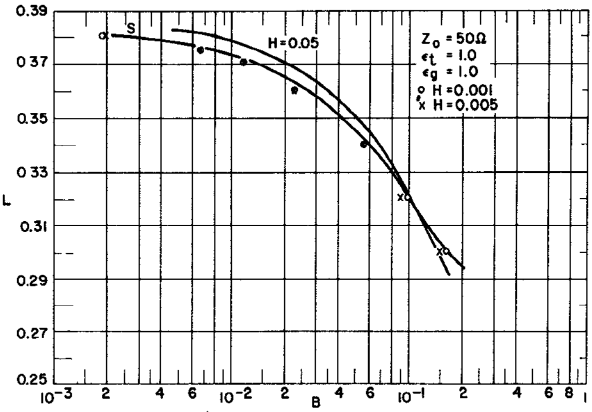

FIG. 7 SCHELKUNOFF'S CURVE (S)- THE ASYMPTOTE FOR H→0

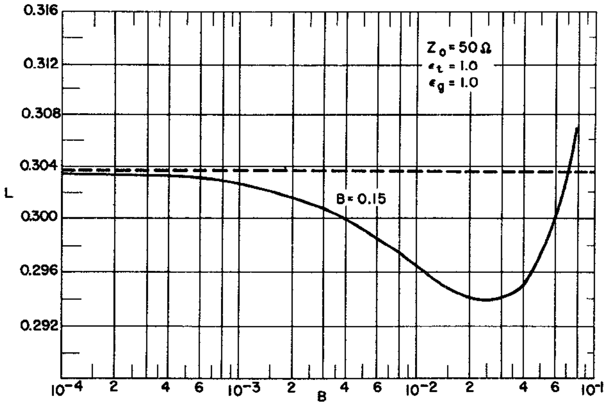

FIG.8 NORMALIZED CAVITY LENGTH VS NORMALIZED HALF-WIDTH OF CAVITY