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Abstract

A new type of waveguide circuit element has been described that has a number of desirable electrical and mechanical properties. These include ease and accuracy of adjustment, and simple analytical expressions for some of the more important properties.

The capacitive junction allows the practical construction of capacitively coupled resonant cavities. Such cavities have a relatively constant bandwidth over their tuning range, as compared with the more commonly used inductively coupled cavities.

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Introduction

The microwave circuit designer has at his disposal a number of different mechanical forms with which to produce lumped capacitive or inductive reactances. One can produce a capacitive shunt reactance across a waveguide by means of a tuning screw whose axis is parallel to the electric field lines in the guide, or by means of an iris or partition across the guide, Fig. 1a. Similarly, inductive shunt reactances can be realized by posts across the guide, or by irises, Fig. 1b. Mechanically, the capacitive screw and

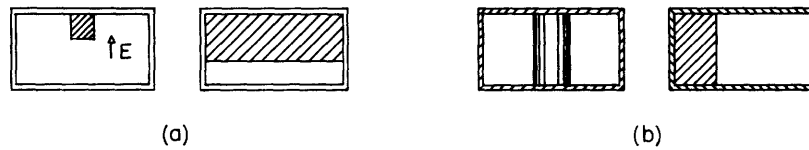


Fig. 1 Conventional forms of capacitive and inductive elements used in waveguide.

the inductive post are nice to use, but the susceptance that can be produced by them is limited to a few times Y_0 . The capacitive iris is difficult to make for large values of B/Y_0 , because gaps of the order of a few thousandths of an inch are required. The inductive iris, though not requiring such small gaps, is still difficult to make to close tolerances.

The offset waveguide junctions described in this paper are characterized by a rugged mechanical construction. Figure 2 illustrates the three basic forms of these junctions: capacitive, inductive, and resonant. They are made from sections of waveguides having plain flanges, clamped or soldered together at the desired offset. This simple construction allows gaps to be adjusted to extremely close tolerances by means

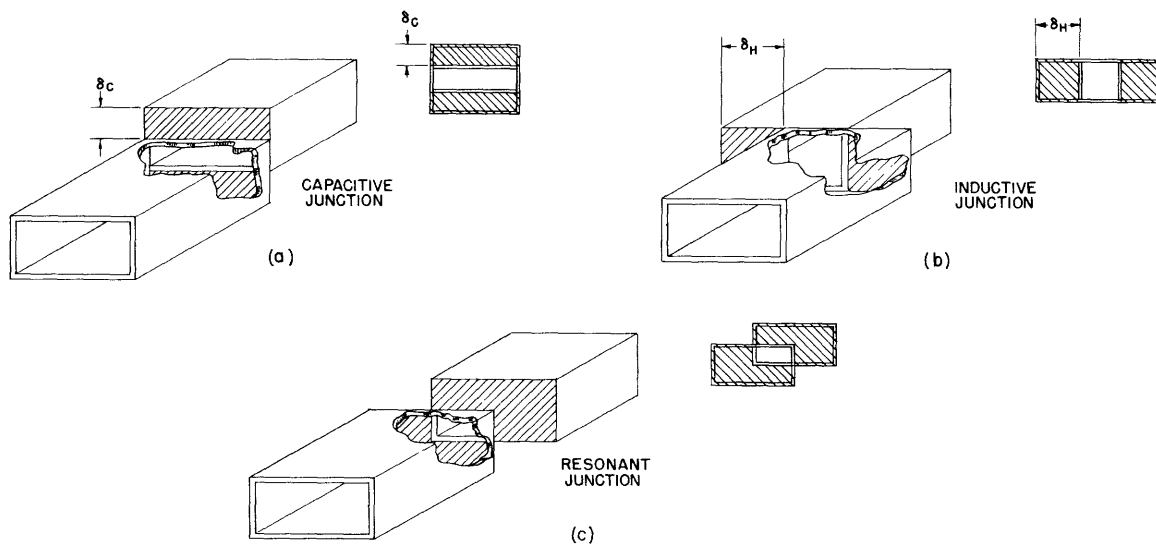


Fig. 2 The three principal forms of the offset waveguide junction.

of "feeler-gauges", so that a 0.005-inch capacitive gap in a waveguide that is 1 inch \times 1/2 inch becomes rather easy to make. Similarly, very narrow resonant gaps can be made without the difficulties from warping that are encountered in conventional irises.

In addition to their mechanical features, the offset junctions have some interesting electrical properties. The capacitive junction turns out to be the equivalent of an infinitely thin asymmetrical capacitive iris, and can be described by the same equation. It behaves as a simple shunt capacitance across the waveguide, located in the plane of the junction. The inductive junction, because of the asymmetry of the H field on opposite sides of the junction, must be described by a T of inductances. The shunt element varies as predicted by the equation for an infinitely thin, asymmetric, inductive iris. Finally, the resonant junction can be described in terms of loci of constant resonant frequency with varying Q. These loci turn out to be hyperbolas, but no expression from the loaded Q has yet been obtained.

Characteristics of Offset Junctions

All measurements were made at wavelengths around 3.3 cm with an RG-52U waveguide. Depending upon the range of susceptance to be determined, measurements were made with either a precision magic T or with a slotted line.

Figure 3 is an admittance plot for the capacitive and inductive junctions, in parallel with a matched termination. The offset distances, δ_H for the inductive, and δ_c for the capacitive

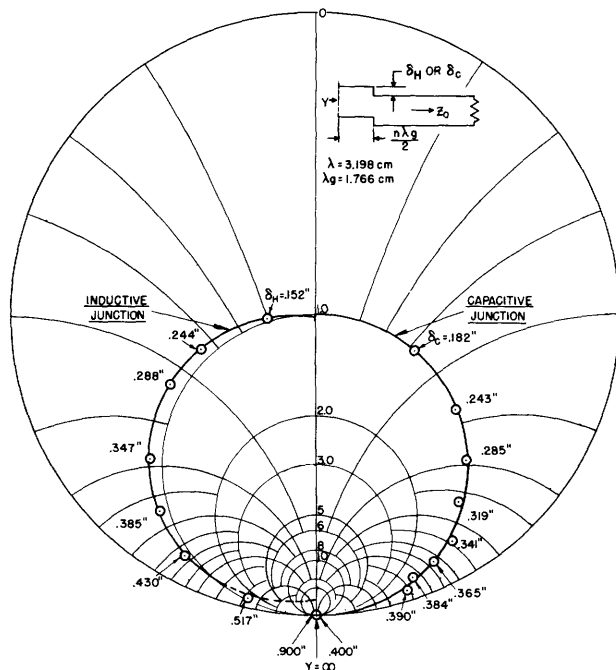


Fig. 3 Admittance vs. offset (δ_H or δ_c) of the inductive and capacitive junctions, in parallel with Y_0 .

junction, are indicated along the curves. It can be seen that the points for the capacitive junction lie very closely on the $1 + jb$ circle, corresponding to a pure shunt capacitance. This is not true of the points for the inductive junction. According to Dicke (1) a waveguide obstacle may be described as a simple shunt element if it is possible to make the field at the junction zero by sending two waves of appropriate magnitude and phase from opposite sides. Since the variation of the electric fields is the same on both sides of the junction, and the x variations are the same except for sign, this test is met by the capacitive junction. In the inductive junction, this condition cannot be satisfied because of the reversed variation of H_x on opposite sides of the junction.

Figure 4 is a plot of the normalized

shunt susceptance of a capacitive junction, compared with the expression for an asymmetrical iris (1)

$$b = \frac{B}{Y_0} = \frac{8b}{\lambda_g} \ln \left(\csc \frac{\pi d}{2b} \right)$$

where d is the iris opening, and b the guide height. The agreement is well within the experimental error. Figure 5 is a plot of b vs. $1/\lambda_g$ for one value of offset; the points represent a straight line, in agreement with the equation.

Figure 6 is a plot of the values of the shunt and series elements of the equivalent circuit of an inductive junction. The theoretical value of the shunt susceptance of an infinitely thin asymmetrical iris is also plotted (1) in Fig. 6a

$$b = \frac{B}{Y_0} = - \left(\frac{\lambda_g}{a} \cot^2 \frac{\pi d}{2a} \right) \left(1 + \csc^2 \frac{\pi d}{2a} \right)$$

where a is the guide width.

Figure 7 is a plot of the loci of constant resonant wavelength of the resonant junction, in which the guides were displaced diagonally, with their transverse axes parallel. The intercepts at which the vertical opening just vanishes, are very nearly equal to half of the air wavelength, as indicated in the table:

$2a'_0$	λ
3.124 cm	3.136 cm
3.328	3.359
3.532	3.613

These curves are very closely described by hyperbolas of the form

$$\frac{a'}{a} \frac{\sqrt{1 - \left(\frac{\lambda}{2a'}\right)^2}}{\sqrt{1 - \left(\frac{\lambda}{2a}\right)^2}} = \frac{b'}{b} \quad .$$

No extensive measurements of loaded Q of these junctions were made. It is known, however, that Q_{L_2} , the Q of the junction loaded by $2Y_0$, is low; and for a horizontal offset $\delta_H = 0.21$, $Q_{L_2} \approx 3$.

Applications to Filters

It is to be expected that these junctions will find their greatest usefulness in the design and construction of microwave filters. A typical set of building blocks for a quarter-wave coupled filter is shown in Figure 8. These are simply waveguides cut to the desired length (approximately $\lambda_g/2$ and $\lambda_g/4$ respectively) and equipped with plane flanges. The theory of multiple cavity filters is well developed (2), so that, given the characteristics of the elements, one can predict the filter performance with a high degree of precision.

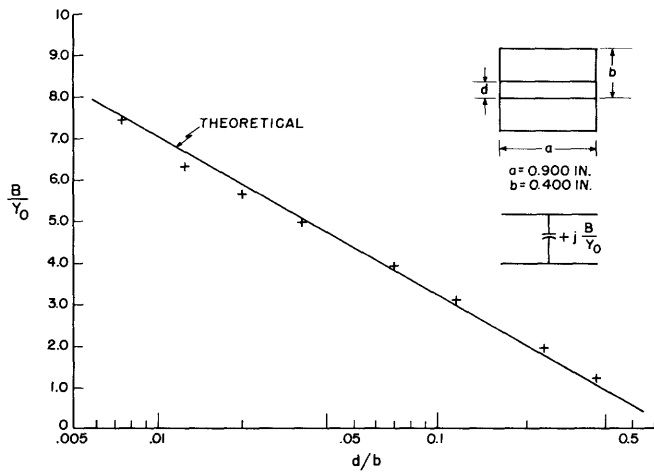


Fig. 4 Susceptance vs. offset of the capacitive junction, $\lambda = 3.315$ cm.

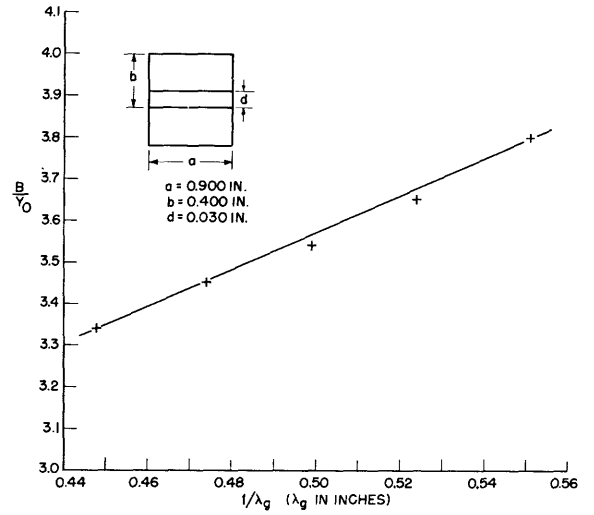
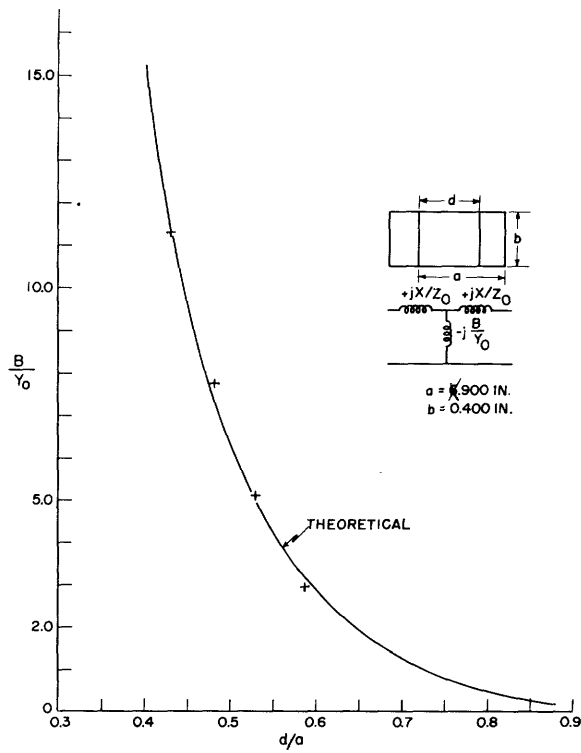
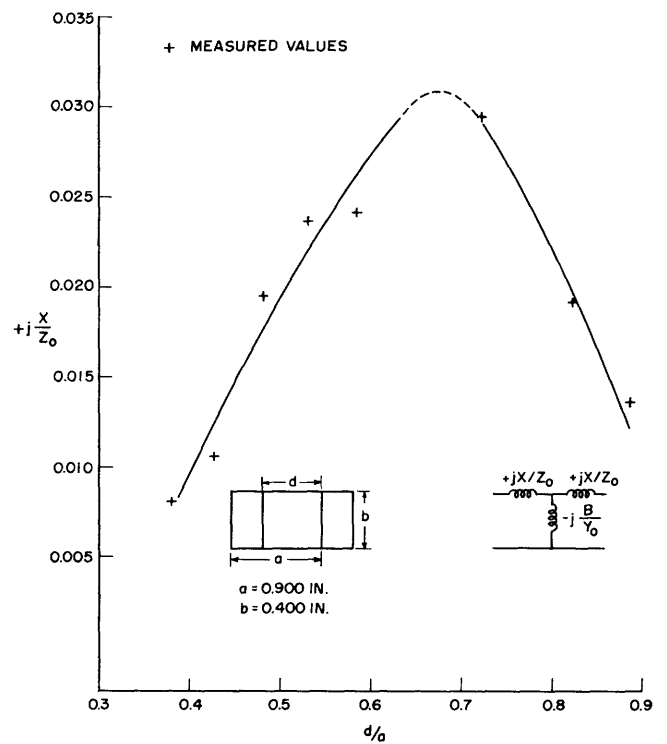


Fig. 5 Susceptance vs. $1/\lambda_g$ of a capacitive junction.



(a)



(b)

Fig. 6 Equivalent circuit of the inductive junction, $\lambda = 3.321$ cm.

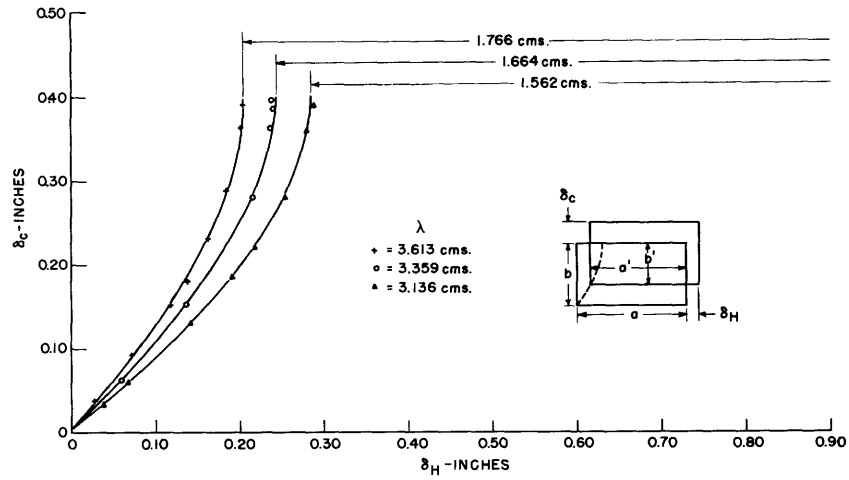


Fig. 7 Loci of constant resonant wavelength for the resonant junction.

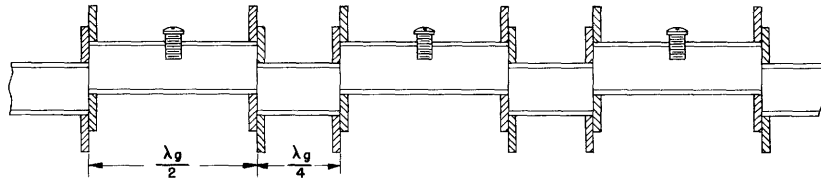


Fig. 8 Multiple cavity filter assembly.

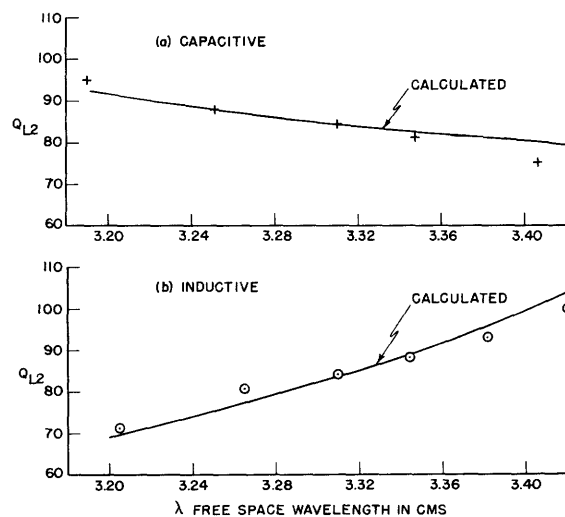


Fig. 9 Q_{L_2} vs. tuning of capacitively and inductively coupled cavities.

- (a) $\delta_c = 0.005''$, $2l = 0.952''$.
 (b) $\delta_H = 0.430''$, $2l = 0.798''$, $g_c \ll 1/b_1^2$.

The accuracy with which the elementary resonant cavity can be designed is illustrated in Fig. 9. These curves are for inductively and capacitively coupled tunable cavities. The tuning was accomplished by means of screws at the centers of the respective cavities. The loaded Q was calculated (3) from the equation

$$Q_{L2} = \frac{(b_o^2 + 1) \theta_g \left(\frac{\lambda}{\lambda_g}\right)^2 + b_o}{\frac{1}{b_1^2} + \frac{1}{b_2^2} + g_c}$$

where b_1 and b_2 are the normalized coupling susceptances, g_c is the normalized conductance of the cavity at its mid-point, the tuning screw susceptance is

$$2b_o = \frac{b_1 + \tan \theta}{b_1 \tan \theta} + \frac{b_2 + \tan \theta}{b_2 \tan \theta}$$

where

$$\theta = \frac{2\pi l}{\lambda_g} \quad \text{and} \quad 2l = \text{cavity length.}$$

These curves illustrate the advantage of using capacitively coupled cavities for tunable cavities or filters; the variation in loaded Q with tuning is considerably less than for an inductively coupled cavity (4).

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