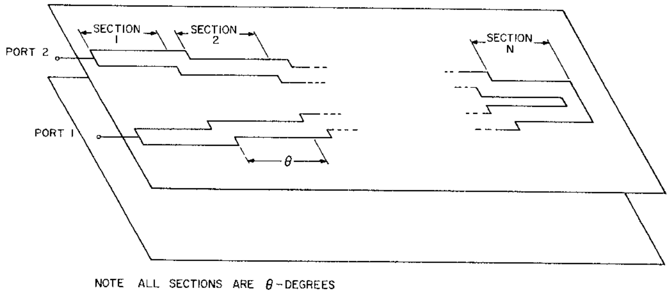

Fig. 1. Band-stop spurline resonator and its open-wire-line equivalent network.

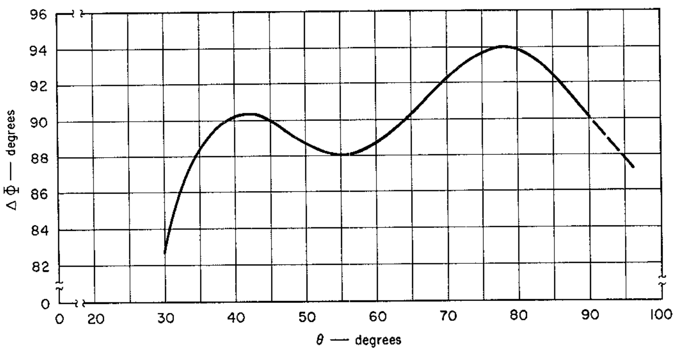

Fig. 2. Band-pass spurline resonator and its open-wire-line equivalent network.

It has been shown [8] that the quantity k^2 is the power-coupling coefficient of lines a and b had these lines been designed to be a nonsymmetrical [8] or conventional directional coupler. Hence, this parameter is useful in aiding the designer to visualize the degree of "coupling" between the two lines.

Design Equations for Band-Pass Spurline Resonators

For physical realizability, choose

$$k^2 < (1 + Y_{12}/Y_1)^{-1}. \quad (10)$$

Then,

$$A = \left(\frac{k}{\sqrt{1-k^2}}\sqrt{Y_1} + \sqrt{Y_{12}}\right)^2 \quad (11)$$

$$B = \frac{Y_1}{1-k^2} \quad (12)$$

$$D = k\sqrt{AB}. \quad (13)$$

The inverse relationships are

$$Y_1 = \frac{AB - D^2}{A} \quad (14)$$

$$Y_{12} = \frac{(A-D)^2}{A} \quad (15)$$

$$N = \frac{A}{A-D}. \quad (16)$$

For symmetrical lines (i.e., $A = B$), Y_1 must be greater than Y_{12} and

$$k = \frac{Y_1 - Y_{12}}{Y_1 + Y_{12}}. \quad (17)$$

An alternative set of equations for band-pass spurline resonators in which N, the transformer turns ratio, is an independent variable is

$$A = Y_{12}N^2 \quad (18)$$

$$B = Y_1 + Y_{12}(N-1)^2 \quad (19)$$

$$D = Y_{12}N(N-1). \quad (20)$$

Here, for physical realizability, N must satisfy

$$1 \leq N \leq 1 + Y_1/Y_{12}. \quad (21)$$

Design Equations for Band-Stop Spurline Resonators

For physical realizability, choose

$$k^2 < (1 + Y_1/Y_{12})^{-1}. \quad (22)$$

Then,

$$A = \frac{Y_{12}}{1-k^2} \quad (23)$$

$$B = \left(\frac{k}{\sqrt{1-k^2}}\sqrt{Y_{12}} + \sqrt{Y_1}\right)^2 \quad (24)$$

$$D = k\sqrt{AB}. \quad (25)$$

The inverse relationships are

$$Y_1 = \frac{(B-D)^2}{B} \quad (26)$$

$$Y_{12} = \frac{(AB - D^2)}{B}. \quad (27)$$

For symmetrical lines (i.e., $A = B$), Y_{12} must be greater then Y_1 and

$$k = \frac{Y_{12} - Y_1}{Y_{12} + Y_1}. \quad (28)$$

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Two Nomograms for Coupled-Line Sections for Band-Stop Filters

A common form of microwave band-stop filter consists of open-circuit shunt stubs separated by lengths of transmission line, all one quarter wave long at band center. Two equivalent but more compact types derivable from the former are the spurline and the parallel-coupled resonator form of band-stop filter.[1] Since the process of designing a filter starting with the prototype and ending with practical physical dimensions can be time consuming and tedious, two nomograms are here presented to speed one step in that process, viz., conversion of the stub type filter into one containing either spurline or coupled-resonator sections (or both).

Equations for the spurline resonator are given in Fig. 1 and those for the coupled-line resonator in Fig. 2. In each case the distributed capacitances between neighboring lines normalized to that of the medium are given in terms of the characteristic admittances of the equivalent stub and connecting line. The method of using the nomograms, Figs. 3 and 4, is explained in the small skeleton nomograms in the lower left corners of those figures. The nomograms have been designed for an impedance level $Z_0 = 1/Y_0 = 50$ ohms, and for $\epsilon_r = 1$ (air dielectric); however, other values may be used by applying multiplicative factors. For example, where an impedance level $Z_0' \neq 50$ ohms is desired, multiply all values of C/ϵ determined in the above manner by $(50/Z_0')$, and where a relative dielectric constant $\epsilon_r \neq 1$ is to be used, divide all values C/ϵ by $\sqrt{\epsilon_r}$. Once the final values of C/ϵ are determined, they may be translated into physical dimensions of round[2] or rectangular[3] coupled striplines from published graphs. The range of the

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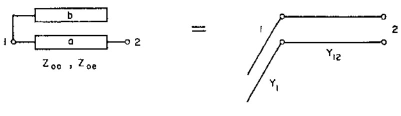


(a)

FOR SYMMETRICAL SPUR-LINE SECTIONS (LINES a AND b ARE EQUAL)

$$\frac{C_a}{\epsilon} = \frac{C_b}{\epsilon} = \frac{\eta_0 (Y_1 + Y_{12})}{2\sqrt{\epsilon_r}} \qquad \frac{C_{ab}}{\epsilon} = \frac{\eta_0}{4\sqrt{\epsilon_r}}\left(\frac{Y_{12}^2 - Y_1^2}{Y_1}\right)$$

(b)

FOR ASYMMETRICAL SPUR-LINE SECTIONS (LINES a AND b ARE UNEQUAL)

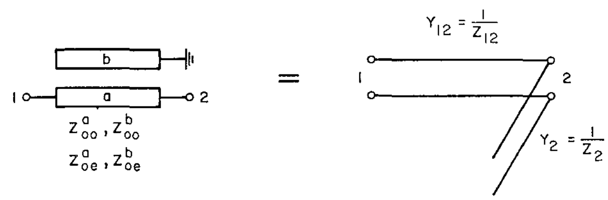
$$\frac{C_a}{\epsilon} = \frac{\eta_0 (Y_{12} - RY_1)}{\sqrt{\epsilon_r}} \qquad \frac{C_b}{\epsilon} = \frac{\eta_0 (1+R) Y_1}{\sqrt{\epsilon_r}} \qquad \frac{C_{ab}}{\epsilon} = \frac{\eta_0 Y_1 (R+R^2)}{\sqrt{\epsilon_r}}$$

WHERE $R = \frac{C_{ab}}{C_b}$

REALIZABILITY CONDITION $\frac{\eta_0 Y_1}{\sqrt{\epsilon_r}} < \frac{C_b}{\epsilon} < \frac{\eta_0 (Y_1 + Y_{12})}{\sqrt{\epsilon_r}}$

(c)

Fig. 1. Spurline section and equivalent section of stub filter.



UNSYMMETRICAL CASE

$$\frac{C_a}{\epsilon} = \frac{\eta_0}{\sqrt{\epsilon_r}}(Y_{12} + Y_2) - \frac{C_{ab}}{\epsilon}$$

$$\frac{C_b}{\epsilon} = \frac{\sqrt{\epsilon_r}}{Y_2 \eta_0}\left(\frac{C_{ab}}{\epsilon}\right)^2 - \frac{C_{ab}}{\epsilon}$$

with C_{ab} arbitrary[1]

SYMMETRICAL CASE

$$\frac{C_a}{\epsilon} = \frac{C_b}{\epsilon} = \frac{\eta_0}{\sqrt{\epsilon_r}}\left[Y_{12} + Y_2 - \sqrt{Y_2(Y_{12} + Y_2)}\right]$$

$$\frac{C_{ab}}{\epsilon} = \frac{\eta_0}{\sqrt{\epsilon_r}}\sqrt{Y_2(Y_{12} + Y_2)}$$

Fig. 2. Parallel-coupled transmission-line section and equivalent section of stub filter.

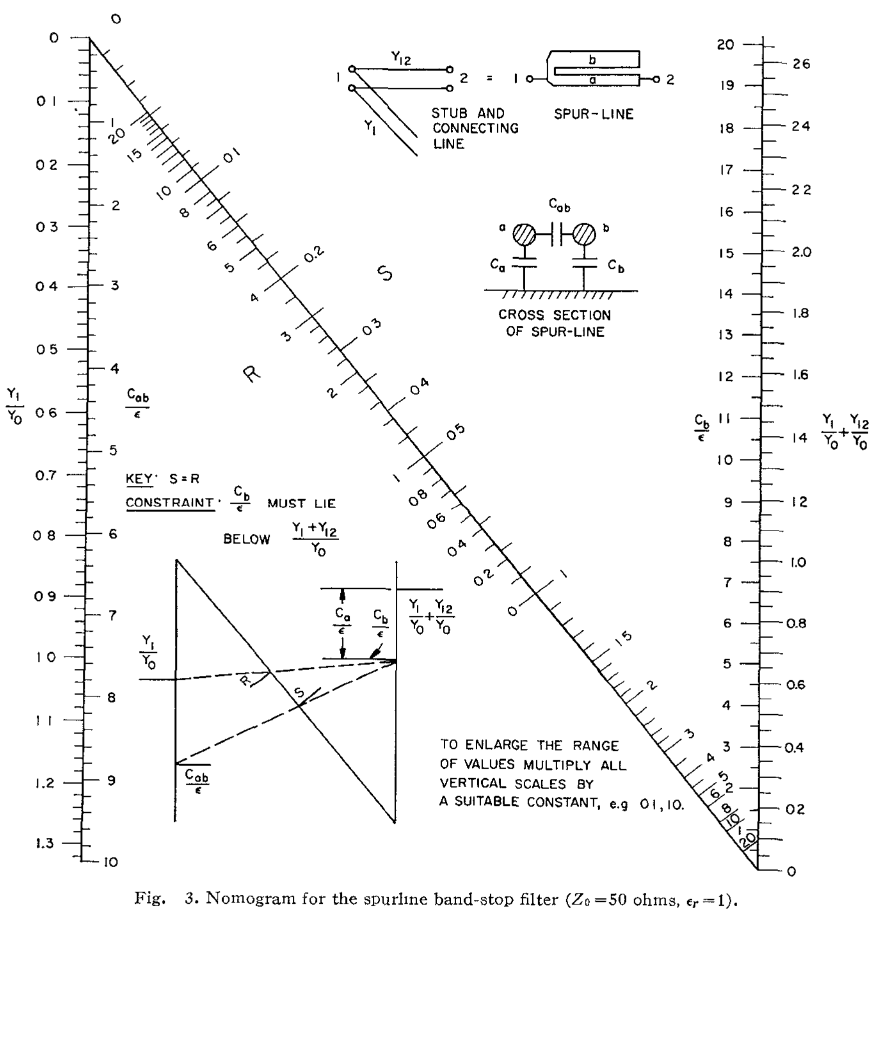


Fig. 3. Nomogram for the spurline band-stop filter ($Z_0 = 50$ ohms, $\epsilon_r = 1$).

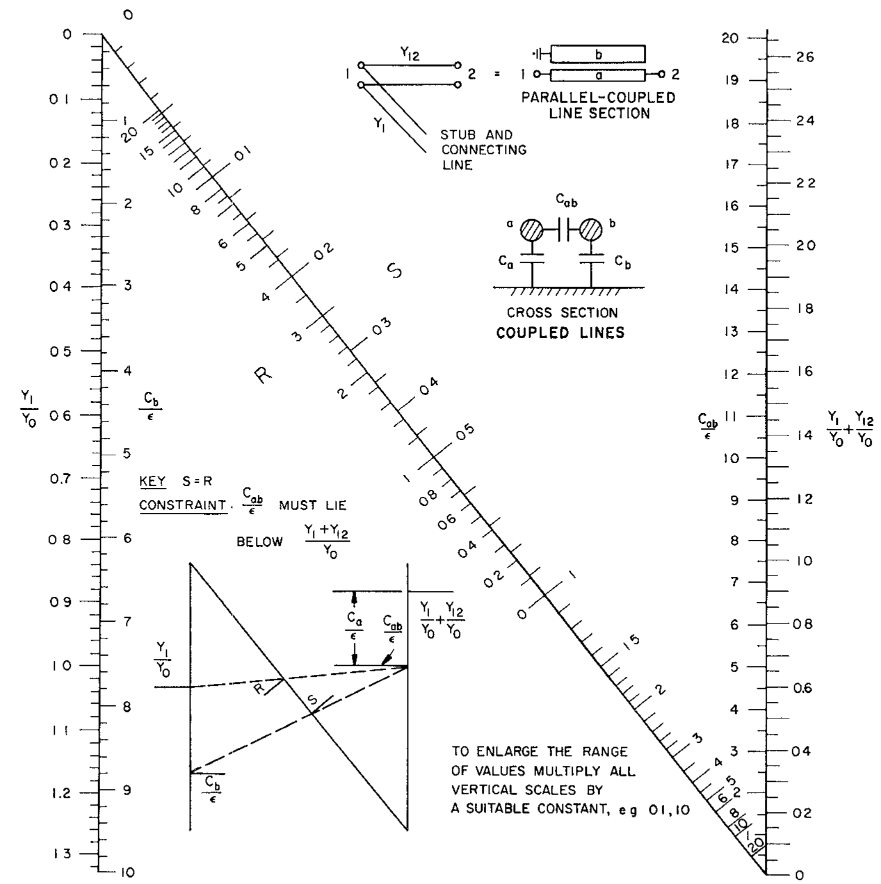


Fig. 4. Nomogram for the parallel-coupled-line band-stop filter ($Z_0=50$ ohms, $\epsilon_r=1$).

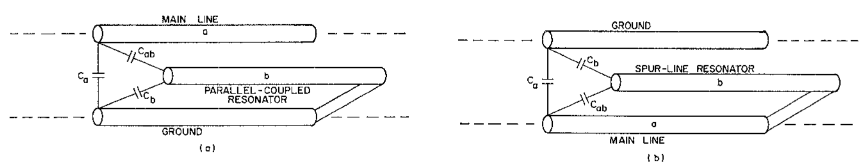


Fig. 5. Comparison of the spurline section and the parallel-coupled resonator section for band-stop filters when drawn in three-wire form.

nomograms may be extended by multiplying all vertical scales by a constant, say 10. Also greater resolution for small values of capacitance may be obtained by dividing all vertical scales by 10.

The first step is to mark the quantities (Y_1/Y_0) and $(Y_1/Y_0)+(Y_{12}/Y_0)$ as indicated. Then a straight-edge is laid across the nomogram connecting (Y_1/Y_0) and an arbitrary point on the opposite scale *below* $(Y_1/Y_0)+(Y_{12}/Y_0)$, thereby yielding two of the desired quantities. The straight-edge must also lie above the zero on the R scale. Then, after noting the R value, the straight-edge is pivoted to intersect that same value on the S scale yielding the third quantity on the left vertical scale in each case.

The similarity of the two nomograms is a result of the topological equivalence of the two types of filter sections. This may be seen more clearly in Fig. 5, which shows the band-stop sections in three-wire form. The figures are identical, and only the marking is different.

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