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COPLANAR WAVEGUIDE RADIAL LINE STUB

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A coplanar waveguide radial line stub resonator is experimentally characterised with respect to stub radius, sectoral angle, substrate thickness and relative dielectric constant. A simple closed-form design equation, which predicts the resonance radius of the stub, is presented.

Introduction: Coplanar waveguide (CPW) technology is emerging as a viable alternative to stripline and microstrip line for monolithic microwave integrated circuits [1]. There are several applications in which a CPW radial line stub resonator is necessary; these include: bias line filters requiring a point of virtual RF ground, mixer and frequency multiplier circuits that require a reactance to terminate the diodes and the harmonics, respectively. In addition, a grounded CPW

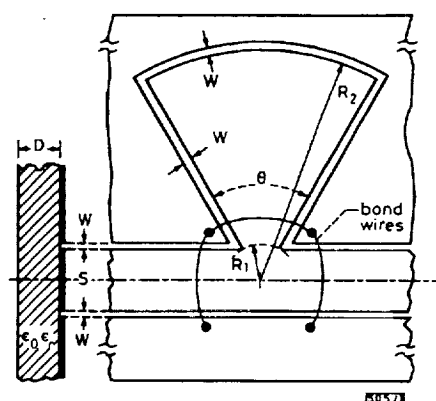


Fig. 1 Schematic diagram of CPW radial line stub

(GCPW) radial line stub resonator has application in oscillator circuits for active antennas [2]. In general, the advantages of a radial line stub over a straight 50Ω stub are the smaller resonance length, wider bandwidth and smaller discontinuity reactance at the junction with the main line [3].

This Letter presents, for the first time, CPW and GCPW radial line stub resonators, characterised by measuring the resonance frequency. The resonance frequency is measured for stubs with different radii, sectoral angles, substrate thicknesses and substrate relative dielectric constants. A closed-form design equation, which predicts the resonance radius of the

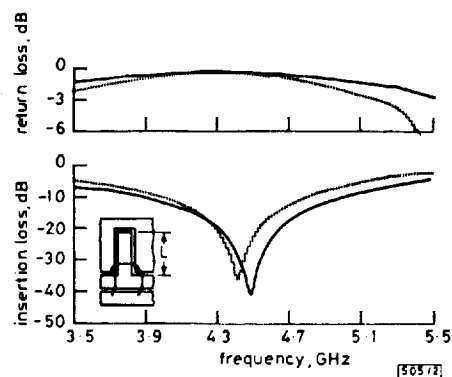


Fig. 2 Measured return loss and insertion loss of CPW radial line stub and CPW straight stub

$S = 0.33$ mm, $W = 0.234$ mm, $D = 0.635$ mm, $\epsilon_r = 10.5$, $R_1 = 0.191$ mm, $R_2 = 5.08$ mm, $\theta = 60^\circ$, $L = 7$ mm
 — radial line stub
 straight stub

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stub, for a given set of parameters, is also presented.

Design and fabrication: Fig. 1 shows a schematic diagram of the CPW radial line stub resonator. The inner and outer radius of the stub are denoted as R_1 and R_2 , respectively. The sectoral angle is denoted as θ . The CPW stubs are fabricated on Duroid (relative dielectric constants $\epsilon_r = 6$ and 10.5) and on high resistivity silicon ($\epsilon_r = 11.7$, $\rho = 5000-10\,000\Omega\text{cm}$) substrates. The GCPW stubs are fabricated on Duroid with $\epsilon_r = 2.2$. Three bond wires near the plane of discontinuity ensure equal potential at all ground planes. The CPW centre strip conductor with width S and slot width W , are chosen to be compatible with the coaxial launchers of the Wiltron universal test fixture. Thus, the characteristic impedance Z_0 of the main line is 55Ω .

Experimental results and closed-form equation: The measured return loss and insertion loss of a CPW radial line stub are compared with those of a straight CPW stub in Fig. 2. In this experiment θ and R_2 for the radial stub are arbitrarily chosen as 60° and 5.08 mm, respectively. The length L of the radial stub is 7 mm. The measurements show that for identical ϵ_r and resonance frequency f_0 , the radius R_2 is 37% smaller than the length L . Further, the radial line stub has a wider bandwidth. The bandwidth of the two structures as a function of the attenuation is compared in Table 1. The excess loss defined as $1 - |S_{11}|^2 - |S_{21}|^2$, and determined from the measured S parameters, is small. It is of the order of 0.09 and 0.05 for the radial line stub and straight stub, respectively.

A GCPW radial line stub with $\epsilon_r = 2.2$, $D = 0.254$ mm and θ and R_2 the same as for the CPW radial line stub, has a much wider bandwidth. The characteristics for the GCPW radial line stub are also included in Table 1. The excess loss is of the order of 0.04 .

Table 1 PERCENTAGE BANDWIDTH OF STRAIGHT AND RADIAL LINE STUB

Attenuation	Stub configurations		
	Straight	CPW radial	GCPW radial
dB	%	%	%
10	18.3	25.7	58.1
20	5.6	8.0	15.8
30	1.6	2.5	3.5

For a CPW radial line stub, the measured f_0 as a function of θ for a fixed R_2 is shown in Fig. 3. The f_0 decreases by 20% as θ increases from 30 to 90° . It is also worth noting that R_1 does not remain constant but increases with θ . The excess loss is small and decreases from 0.12 to 0.06 as θ increases from 30 to 90° .

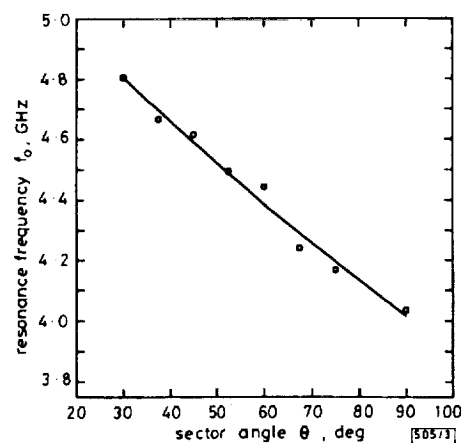


Fig. 3 Measured resonance frequency of CPW radial line stub against sector angle

$S = 0.33$ mm, $W = 0.234$ mm, $D = 0.635$ mm, $\epsilon_r = 10.5$, $R_2 = 5.08$ mm

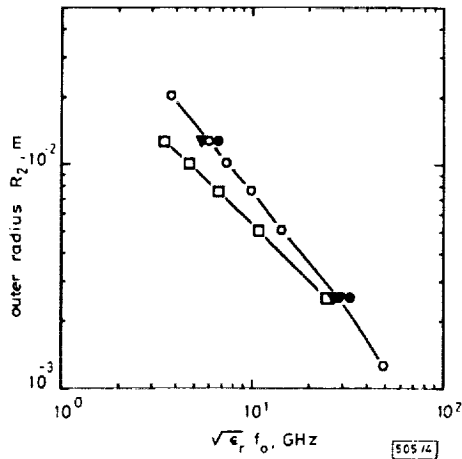


Fig. 4 Measured resonance frequency against outer radius of radial stub for $\theta = 60^\circ$

(i) GCPW:

□ (a) $S = 0.518$ mm, $W = 0.127$ mm, $D = 0.254$ mm, $\epsilon_r = 2.2$, $R_1 = 0.3$ mm

(ii) CPW:

○ (b) $S = 0.33$ mm, $W = 0.234$ mm, $D = 0.635$ mm, $\epsilon_r = 10.5$, $R_1 = 0.191$ mm

● (c) $S = 0.33$ mm, $W = 0.185$ mm, $D = 0.254$ mm, $\epsilon_r = 10.5$, $R_1 = 0.191$ mm

▽ (d) $S = 0.508$ mm, $W = 0.155$ mm, $D = 0.635$ mm, $\epsilon_r = 6$, $R_1 = 0.3$ mm

▼ (e) $S = 0.152$ mm, $W = 0.114$ mm, $D = 0.381$ mm, $\epsilon_r = 11.7$, $R_1 = 0.092$ mm

Fig. 4 shows the product of $\sqrt{\epsilon_r}$ and measured f_0 as a function of R_2 for CPW and GCPW radial line stubs. By curve fitting the measured data, the coefficients of a simple closed-form equation to predict R_2 are determined using a sigma plot. The equations for CPW and GCPW are as follows:

$$\begin{aligned} \log(R_2) &= C_1 \log[\sqrt{\epsilon_r} f_0] \\ &+ C_2 \log(D) + C_3 \log(R_1) + C_4 \\ \log(R_2) &= C_5 \log[\sqrt{\epsilon_r} f_0] \\ &+ C_6[\log(D) + \log(R_1)] \end{aligned}$$

where f_0 is in gigahertz, R_1 , R_2 , and D are in metres. The coefficients were determined to be: $C_1 = -1.0496$, $C_2 = 0.098375$, $C_3 = -0.1401$, $C_4 = -1.297$, $C_5 = -0.82462$ and $C_6 = 0.21201$, respectively. These equations are valid for the geometry and the range of parameters given in Fig. 4. The range of parameters considered are those typically used in microwave circuit design. The standard error of the equation is at most 0.18 and 0.01% for the CPW and GCPW, respectively.

Conclusions: A CPW radial line stub resonator is experimentally characterised in terms of its radius, sectoral angle, substrate thickness and relative dielectric constant. A simple closed-form design equation which predicts the resonance radius of the stub for a given set of parameters is also presented. The radial line stub, when compared to a straight stub, has a wider bandwidth and shorter length.

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