$$k_9 = \frac{2.0\sqrt{a\,b}}{a+b} \quad (4.4.2.11)$$

$$k_8 = \frac{k_9}{\sqrt{1.0 - \frac{(b-a)^2}{(2.0\,c)^2}}} \quad (4.4.2.12)$$

These equations assume loose coupling and that the substrate is infinitely thick.

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[2] Chang, Ching Ten, and Graham A. Garcia, "Crosstalk Between Two Coplanar Waveguides," *Archiv Für Elektronik und Übertragungstechnik*, Band 43, Heft 1, 1989, pp. 55–58.

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4.4.3 Edge-Coupled CPWG

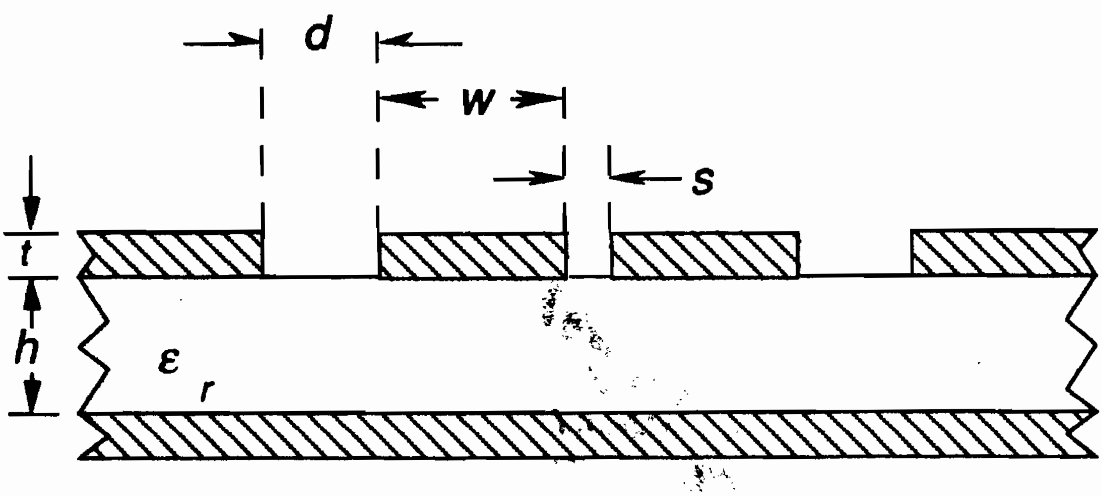

Figure 4.4.3.1: Edge-Coupled CPWG

$$Z_{0,o} = \frac{\eta_0}{\sqrt{\varepsilon_{eff,o}}} \left[\frac{1.0}{2.0 \frac{K(k_o)}{K'(k_o)} + \frac{K(\beta_1)}{K'(\beta_1)}} \right] \quad (\Omega) \qquad (4.4.3.1)$$

$$Z_{0,e} = \frac{\eta_0}{\sqrt{\varepsilon_{eff,e}}} \left[\frac{1.0}{2.0 \frac{K(k_e)}{K'(k_e)} + \frac{K(\beta_1 k_1)}{K'(\beta_1 k_1)}} \right] \quad (\Omega) \qquad (4.4.3.2)$$

$$\varepsilon_{eff,o} = \frac{2.0\ \varepsilon_r \frac{K(k_o)}{K'(k_o)} + \frac{K(\beta_1)}{K'(\beta_1)}}{2.0 \frac{K(k_o)}{K'(k_o)} + \frac{K(\beta_1)}{K'(\beta_1)}} \qquad (4.4.3.3)$$

$$\varepsilon_{eff,e} = \frac{2.0\ \varepsilon_r \frac{K(k_e)}{K'(k_e)} + \frac{K(\beta_1 k_1)}{K'(\beta_1 k_1)}}{2.0 \frac{K(k_e)}{K'(k_e)} + \frac{K(\beta_1 k_1)}{K'(\beta_1 k_1)}} \qquad (4.4.3.4)$$

where

$$k_o = \Lambda \frac{-\sqrt{\Lambda^2 - t_c^2} + \sqrt{\Lambda^2 - t_B^2}}{t_B \sqrt{\Lambda^2 - t_c^2} + t_c \sqrt{\Lambda^2 - t_B^2}} \qquad (4.4.3.5)$$

$$k_e = \Lambda' \frac{-\sqrt{\Lambda'^2 - t'_c{}^2} + \sqrt{\Lambda'^2 - t'_B{}^2}}{t'_B \sqrt{\Lambda'^2 - t'_c{}^2} + t'_c \sqrt{\Lambda'^2 - t'_B{}^2}} \qquad (4.4.3.6)$$

$$\Lambda = \frac{\sinh^2 \left[\frac{\pi\ (s\ /\ 2.0 + w + d)}{2.0\ h} \right]}{2} \qquad (4.4.3.7)$$

$$t_c = \sinh^2 \left[\frac{\pi\ (s\ /\ 2.0 + w)}{2.0\ h} \right] - \Lambda \qquad (4.4.3.8)$$

$$t_B = \sinh^2 \left(\frac{\pi\ s}{4.0\ h} \right) - \Lambda \qquad (4.4.3.9)$$

$$\Lambda' = \frac{\cosh^2\left[\dfrac{\pi\,(s\,/\,2.0 + w + d)}{2.0\,h}\right]}{2.0} \tag{4.4.3.10}$$

$$t'_C = \sinh^2\left[\frac{\pi\,(s\,/\,2.0 + w)}{2.0\,h}\right] - \Lambda' + 1.0 \tag{4.4.3.11}$$

$$t'_B = \sinh^2\left[\frac{\pi\, s}{4.0\,h}\right] - \Lambda' + 1.0 \tag{4.4.3.12}$$

$$\beta_1 = \sqrt{\frac{1.0 - y^2}{1.0 - {k_1}^2\, y^2}} \tag{4.4.3.13}$$

$$y = \frac{s}{s + 2.0\,w} \tag{4.4.3.14}$$

$$k_1 = \frac{s + 2.0\,w}{s + 2.0\,w + 2.0\,d} \tag{4.4.3.15}$$

To guarantee coplanar propagation,

$$s + 2.0\,w + 2.0\,d \le h.$$

The analysis is a conformal mapping technique, so the equations are exact for low frequency calculation.

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[1] Chang, Ching Ten, and Graham A. Garcia, "Crosstalk Between Two Coplanar Waveguides," *Archiv Für Elektronik und Übertragungstechnik*, Band 43, Heft 1, 1989, pp. 55–58. (Edge-coupled CPW's separated by ground plane.)

[2] Hanna, Victor Fouad, "Parameters of Coplanar Directional Couplers with Lower Ground Plane," *15th European Microwave Conference Proceedings*, 1985, pp. 820–825. ([2] dropped primes in (8), corrected here.)