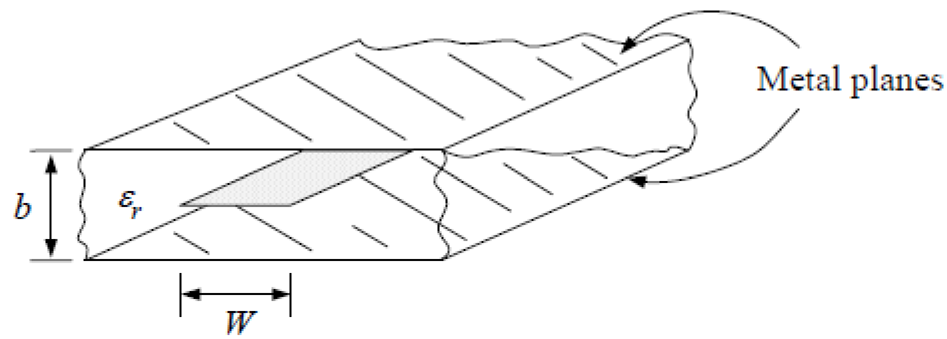
# STRIPLINES




A stripline is a planar type transmission line which is well suited for microwave integrated circuitry and photolithographic fabrication.

It is usually constructed by etching the center conductor of width $W$, on a substrate of thickness $\frac{b}{2}$ and then covering with another grounded substrate of the same thickness.

With the voltage applied between the center strip and the pair of ground planes, current flows down the center strip and returns by means of the two ground planes.

Although the structure is open at the sides, it is basically a non-radiating TL. The fields are found to decrease quite rapidly away from the center conductor. In practice, however, any unbalance in the line causes energy to be radiated out the sides. To prevent this, the ground planes are shorted to each other with screws.

The number and spacing of the shorting screws are adjusted to prevent higher-mode propagation in the frequency range of interest.

Since stipline has two conductors and a homogeneous dielectric, it can support a TEM wave and this is the usual mode of operation.

Higher order TM and TE modes can also be supported. In practice, these, are avoided with shorting screws and by restricting the ground plane spacing to less than $\frac{\lambda}{4}$.

Advantage:

Since a two-conductor line has no low frequency cut-off, it can be utilized over a very broad frequency range, from f=0 up to the cutoff of the 1st TE mode.

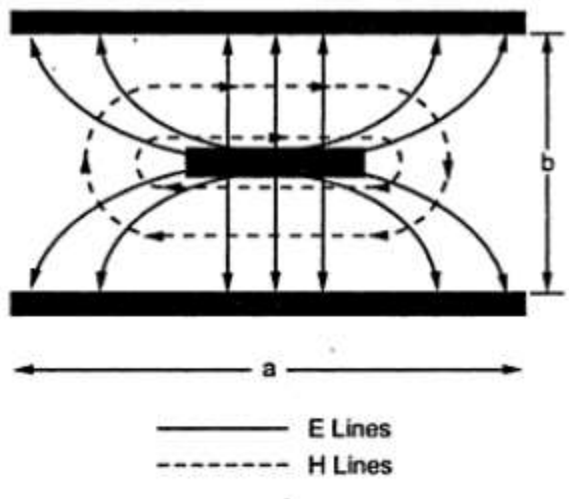
DISATVANTAGE

It is more difficult to connect electrically two conductors that a single one; hollow WG's are more easily joined to each other than coaxial lines, which require high precision and hence expensive, connectors.

DISADVANTAGE

In a two conductor line, the fields tend to concentrate next to the conductors, mainly near the one having a smaller cross-section. This limits the power handling capability of the line. The break-down field is reached for a lower power level that in hollow WG's of the same cross-section. The heating-up of the center conductor also limits the power handling. In hollow WG's, on the other hand, the fields spread more evenly, resulting in larger power-handling capabilities than the in two-conductor lines, for similar sizes.

FIELDS PATTERN FOR THE TEM MODE




PROPAGATION CONSTANT, CHARACTERISTIC IMPEDANCE, ATTENUATION

For the TEM mode; we showed before that:

$$v_p = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{\sqrt{\varepsilon_r \mu_r}}, \quad c = 3X10^8 (m/\sec)$$

$$\beta = \frac{\omega}{v_p} = \omega\sqrt{\varepsilon\mu} = \frac{\omega\sqrt{\varepsilon_r \mu_r}}{c} \ (rad/m)$$

$$Z_0 = \sqrt{\frac{L}{C}} = \frac{1}{v_p C} \ \Omega$$

In order to find $Z_0$, we must know $C$ (capacitance per unit length, farad/m). There are various ways to evaluate $C$. Some of them are:

i) Conformal mapping techniques,
ii) Mode matching techniques,
iii) Finite difference and finite element solutions.

The resulting solutions involve complicated functions; hence for practical computations simple formulas were developed. Below, we give two approximations:

1) HOWE'S APPROXIMATE FORMULAS (in David Pozar)

$$Z_0 = \frac{30\pi}{\sqrt{\varepsilon_r}}\left(\frac{b}{w_e + 0.441b}\right)\ \Omega$$

Where $w_e$ is the effective width of the center conductor, which is given as:

$$\frac{w_e}{b} = \frac{w}{b} - \begin{cases} 0 & \text{for } \dfrac{w}{b} > 0.35 \\ \left(0.35 - \dfrac{w}{b}\right)^2 & \text{for } \dfrac{w}{b} < 0.35 \end{cases}$$

These formulas assume a zero thickness ($t = 0$). Their accuracy is 1% of the exact results. We see that as $w$ increases, $Z_0$ decreases.

When designing stripline circuits, we usually need $w$, given $Z_0$, $b$ and $\varepsilon_r$. We can use the formulas below for this purpose:

$$\frac{w}{b}=\begin{cases} x & \text{for } \sqrt{\varepsilon_r}\,Z_0<120 \\ 0.85-\sqrt{0.6-x} & \text{for } \sqrt{\varepsilon_r}\,Z_0>120 \end{cases}$$

Where $x=\frac{30\pi}{\sqrt{\varepsilon_r}\,Z_0}-0.441$

The attenuation due to conductor losses can be found by a proper perturbation technique. An appropriate result for the attenuation constant is:

$$\alpha_c=\begin{cases} \frac{2.7X10^{-3}R_s\varepsilon_r Z_0}{30\pi(b-t)}A & \text{for } \sqrt{\varepsilon_r}\,Z_0<120\ (Neper/m) \\ \frac{0.16R_s}{Z_0 b}B & \text{for } \sqrt{\varepsilon_r}\,Z_0>120\ (Neper/m) \end{cases}$$

Where,

$R_s$ : Conductor surface resistance.

$$A=1+\frac{2w}{b-t}+\frac{1}{\pi}\frac{b+t}{b-t}\ln\left(\frac{2b-t}{t}\right)$$

$$B=1+\frac{b}{(0.5w+0.7t)}\left(0.5+\frac{0.414t}{w}+\frac{1}{2\pi}\ln\left(\frac{4\pi w}{t}\right)\right)$$

2) COLLIN'S APPROXIMATION FORMULAS

$$Z_0 = \begin{cases} \dfrac{\pi\eta_0}{8\sqrt{\varepsilon_r}\left(\ln 2 + \pi \dfrac{w}{2b}\right)} & for \quad w \geq b \\ \dfrac{\eta_0}{2\pi\sqrt{\varepsilon_r}} \ln\left(\dfrac{8b}{\pi w}\right) & for \quad w \leq 0.2b \end{cases}$$

If we denote the attenuation constant due to the center conductor as $\alpha_{c_1}$ and the attenuation constant due to the ground planes as $\alpha_{c_2}$, then we have the following approximate formulas:

$$\alpha_{c_1} = \frac{R_s\sqrt{\varepsilon_r}}{b\eta_0} \frac{\ln\left(\dfrac{4b}{\pi T_e}\right) + \dfrac{\pi w}{2b}}{\ln 2 + \dfrac{\pi w}{2b}} \qquad for \;\; w \geq b$$

$$\alpha_{c_2} = \frac{\pi R_s \sqrt{\varepsilon_r}\, w}{4\eta_0 b^2 \left(\ln 2 + \dfrac{\pi w}{2b}\right)} \qquad for \quad w \geq b$$

$$\alpha_{c_1} = \frac{2R_s\sqrt{\varepsilon_r} \ln\left(\dfrac{4\pi}{T_e}\right)}{\pi\eta_0 w \ln\left(\dfrac{8b}{\pi w}\right)} \qquad for \;\; w \leq 0.2b$$

$$\alpha_{c_2} = \frac{R_s\sqrt{\varepsilon_r}}{\eta_0 b \ln\left(\dfrac{8b}{\pi w}\right)} \qquad for \;\; w \leq 0.2b$$

Where $T_e = e^{-\frac{\pi}{2}}\sqrt{\frac{4wt}{\pi}}, \quad R_s = \sqrt{\frac{\omega\mu}{2\sigma}}$

<u>Example</u>: A stripline has ground-plane spacing $b = 1cm$ and uses a centered copper conducting strip of width $w = 1cm$ and thickness $t = 0.002cm$. $\varepsilon_r = 2.2$. Evaluate a) $Z_0$, b) $\alpha_c$ at f=10GHz.

<u>Solution:</u>

a) i) Howe:

$$\frac{w}{b} = 1 > 0.35, \quad w_e = w$$

$$Z_0 = \frac{30\pi}{\sqrt{\varepsilon_r}}\frac{b}{(w_e + 0.441b)} = \frac{30\pi}{\sqrt{2.2}}\frac{1}{(1 + 0.441)}$$

$$Z_0 = 44.09\Omega$$

ii) Collin

$$\frac{w}{b} = 1$$

$$Z_0 = \frac{\pi\eta_0}{8\sqrt{\varepsilon_r}\left(\ln 2 + \pi\frac{w}{2b}\right)} = \frac{\pi(120\pi)}{8\sqrt{2.2}\left(\ln 2 + \frac{\pi}{2}\right)}$$

$$Z_0 = 44.7\Omega$$

b) i) Howe

$$\sqrt{\varepsilon_r}\, Z_0 = \sqrt{2.2}(44.09) = 65.396 < 120$$

$$\alpha_c = \frac{2.7X10^{-3} R_s \varepsilon_r Z_0}{30\pi(b-t)} A$$

$$R_s = \left(\frac{\pi\mu f}{\sigma}\right)^{1/2} = 0.026\Omega$$

$$\alpha_c = \frac{2.7X10^{-3} X\, 0.026 X\, 2.2 X\, 44.09}{30\pi(1-0.002)10^{-2}} A$$

$$A = 1 + \frac{2w}{b-t} + \frac{1}{\pi}\frac{b+t}{b-t}\ln\left(\frac{2b-t}{t}\right) = 5.21$$

$$\alpha_c = 0.072X10^{-1} X\, 5.21 = 0.375X10^{-1}(Np/m)$$

ii) Collin

$w = b$, So

$$\alpha_{c_1} = \frac{R_s\sqrt{\varepsilon_r}}{b\eta_0}\frac{\ln\left(\dfrac{4b}{\pi T_e}\right)+\dfrac{\pi w}{2b}}{\ln 2+\dfrac{\pi w}{2b}}$$

$$\alpha_{c_1} = \frac{0.26\sqrt{2.2}}{120\pi X10^{-2}}\frac{\ln\left(\dfrac{4X10^{-2}}{\pi T_e}\right)+\dfrac{\pi}{2}}{\ln 2+\dfrac{\pi}{2}}$$

$$T_e = \exp\left(-\frac{\pi}{2}\right)\left(\frac{4wt}{\pi}\right)^{1/2} = 0.0104\ \ cm$$

$$\alpha_{c_1} = 3.03X10^{-4}(Np/cm)$$

$$\alpha_{c_2} = \frac{\pi R_s\sqrt{\varepsilon_r}\,w}{4\eta_0 b^2\left(\ln 2+\dfrac{\pi w}{2b}\right)} = 7.096X10^{-5}(Np/cm)$$

$$\alpha_{c_1}+\alpha_{c_2} = \left(0.3034+0.07096\right)X10^{-3} = 0.374X10^{-3}(Np/cm)$$