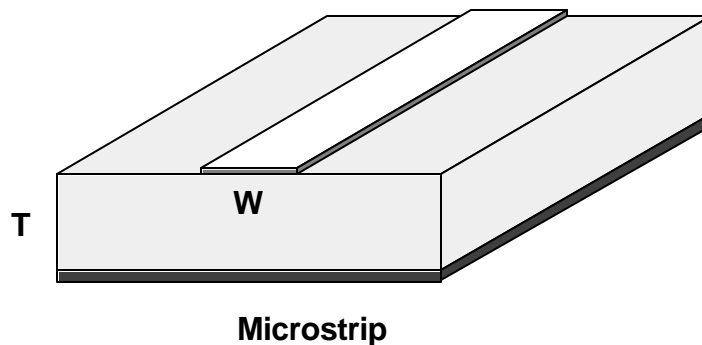


Microstrip Transmission Lines

As circuits have been reduced in size with integrated semiconductor electron devices, a transmission structure was required that was compatible with circuit construction techniques to provide guided waves over limited distances. This was realized with a planar form of single-wire transmission line over a ground plane, called microstrip¹. Microstrip employs a flat strip conductor suspended above a ground plane by a low-loss dielectric material. The size of the circuit can be reduced through judicious use of a dielectric constant some 2-10 times that of free space (or air), with a penalty that the existence of two different dielectric constants (below and above the strip) makes the circuit difficult to analyze in closed form (and also introduces a variability of propagation velocity with frequency that can be a limitation on some applications). The advantages of microstrip have been well established, and it is a convenient form of transmission line structure for probe measurements of voltage, current and waves. Microstrip structures are also used in integrated semiconductor form, directly interconnected in microwave integrated circuits.



Waves and Impedances in Microstrip

Although the presence of two dielectric regimes in microstrip precludes the strict propagation of TEM waves, the same type of transmission-line characteristics are present, as can be seen from the fact that microstrip can propagate energy down to zero frequency (direct current). Microstrip construction lends itself to small structures that can carry semiconductor devices and surface-mount lumped elements, which can be attached by automatic means.

This extreme usefulness of microstrip makes the lack of an elegant closed-form solution acceptable, and accurate approximations based on the velocity/capacitance method described above are used to estimate Z_0 and other parameters. Unwanted modes are dealt with in part by using material with a relatively high dielectric constant, but waveguide modes are present and represent an upper frequency limit. The effects of unwanted waveguide modes can be restricted by choosing dielectric thickness less than $\lambda/4$ and strip width w less

¹ See for example: Vendelin, G., Pavio, A., and Rohde, U., *Microwave Circuit Design Using Linear and Nonlinear Techniques*, J. Wiley, 1990, pg. 37-44

than $\lambda/2$ at the highest frequency of interest. Thus, for a maximum frequency of interest f_{\max} , we chose

$$T < \frac{c}{4f_{\max}\sqrt{\epsilon_r}} \quad \text{and} \quad W < \frac{c}{2f_{\max}\sqrt{\epsilon_r}}$$

The velocity of propagation in microstrip is relatively constant with varying w/h , and Z_0 can be estimated accurately using a number of methods. Downloadable software applications that provide quick analysis of microstrip and other planar transmission lines include AppCad², Txline³, Microstrip Calculator⁴ and Sonnet⁵.

² <http://www.hp.com/HP-COMP/rf/hprfhelp/design/appcad.htm>

³ <http://www.nonlintec.com/tline.zip>

⁴ <http://www.nonlintec.com/tline.zip>

⁵ <http://www.engineers.com/software/sonnet.htm>