

Lecture-3

5.6 Methods of Analysis

There are many methods of analysis for microstrip antennas. The most popular models are:

- Transmission-line model
- Cavity model
- Method of moments
- FDTD method
- Finite Element method

The transmission-line model is the easiest of all, it gives good physical insight, but is less accurate and it is more difficult to model coupling. Compared to the transmission-line model, the cavity model is more accurate but at the same time more complex. However, it also gives good physical insight and is rather difficult to model coupling, although it has been used successfully. In general when applied properly, the full-wave models (which include primarily integral equations/Moment Method) are very accurate, very versatile, and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements, and coupling. However they are the most complex models and usually give less physical insight.

5.7 Transmission line Model – The Rectangular Patch

The TL model is the simplest of all, representing the rectangular patch as two slots, separated by a low-impedance (Z_c) transmission line of length L .

A. Fringing Effects

The dimensions of the patch are finite along the length and width, so the fields at the edges of the patch undergo fringing. This is illustrated along the length in Figures 5.9 for the two radiating slots of the microstrip antenna. The amount of fringing is a function of the dimensions of the patch and the height of the substrate. For the principal E-plane (xy-plane) fringing is a function of the ratio of the length of the patch L to the height h of the substrate (L/h) and the dielectric constant ϵ_r of the substrate. Since for microstrip antennas $L/h \gg 1$, fringing is reduced. However, it must be taken into account because it influences the resonant frequency of the antenna. Due to the fringing effect some of the waves travel in the substrate and some in air, an effective dielectric constant ϵ_{reff} is introduced to account for this effect.

The effective dielectric constant is defined as the dielectric constant of the uniform dielectric material so that the electric field lines has identical electrical characteristics, particularly propagation constant, as the actual field line.

For low frequencies the effective dielectric constant is essentially constant. At intermediate frequencies its values begin to increase monotonically and eventually approach the values of the dielectric constant of the substrate. The initial values (at low frequencies) of the effective dielectric constant are referred to as the static values, and they are given by

$$v_{r_{eff}} = \frac{v_r + 1}{2} + \frac{v_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \frac{h}{w}}} \right) \quad (5.1)$$

B. Effective Length and Resonant Frequency

In the transmission line model, the antenna is represented by two radiating slots ($W \times h$) separated by a low impedance transmission line (Z_c) of length L . The slots represent very high-impedance terminations from both sides of the transmission line (almost an open circuit). Thus, we expect this structure to have highly resonant characteristics depending crucially on its length L . The resonant length of the patch, however, is not exactly equal to the physical length due to the fringing effect. The fringing effect makes the effective electrical length of the patch longer than its physical length. The dimensions of the patch along its length have been extended on each end by a distance ΔL , which is a function of the effective dielectric constant $\epsilon_{r_{eff}}$ and the width-to-height ratio (W/h). A very popular and practical approximate relation for the normalized extension of the length is:

$$L_{eff} = L + 2\Delta L$$

$$\text{where } \Delta L = 0.412h \frac{\left(v_{r_{eff}} + 0.3 \right) \left(\frac{W}{h} + 0.264 \right)}{\left(v_{r_{eff}} - 0.258 \right) \left(\frac{W}{h} + 0.8 \right)} \quad (5.2)$$

For dominant TM_{010} mode f_r is:

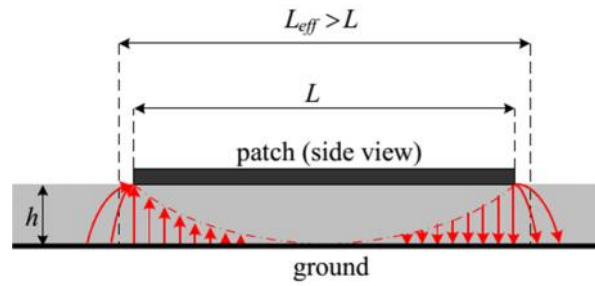
$$(f_r)_{010} = \frac{1}{2L\sqrt{v_r}\sqrt{\epsilon_{r_{eff}}}} = \frac{v_0}{2L\sqrt{v_r}}$$

where v_0 is the speed of light in free space. Since (5.2) does not account for fringing, it must be modified to include edge effects and should be computed using

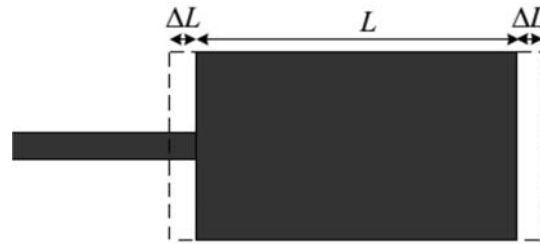
$$(f_{rc})_{010} = \frac{1}{2L_{eff}\sqrt{v_r}\sqrt{\epsilon_{r_{eff}}}} = \frac{1}{2(L + 2\Delta L)\sqrt{v_r}\sqrt{\epsilon_{r_{eff}}}} = q \frac{v_0}{2L\sqrt{v_r}} \quad (5.3)$$

$$q = \frac{(f_{rc})_{010}}{(f_r)_{010}}$$

The q factor is referred to as the fringe factor (length reduction factor). As the substrate height increases, fringing also increases and leads to larger separations between the radiating edges and lower resonant frequencies.



(a) Side view



(b) Top view

Fig.5.10 Physical and effective lengths of rectangular microstrip patch.

C. Effective Width

$$W = \frac{1}{2f_r \sqrt{\epsilon_r}} \sqrt{\frac{2}{\epsilon_r + 1}} = \frac{v_o}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (5.4)$$

Expression (5.4) makes the width W equal to about half a wavelength. It leads to good radiation efficiencies and acceptable dimensions. Thus, the patch can be viewed as a continuous planar source consisting of infinite number of infinitesimally thin half-wavelength dipoles.