Chapter 7

Microstrip Antennas

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CONTENTS

7.1 INTRODUCTION

Microstrip antennas (often called *patch* antennas) are widely used in the microwave frequency region because of their simplicity and compatibility with printed-circuit technology, making them easy to manufacture either as stand-alone elements or as elements of arrays. In its simplest form a microstrip antenna consists of a patch of metal, usually rectangular or circular (though other shapes are sometimes used) on top of a grounded substrate, as shown in Figure 7-1. In this chapter the basic principles of operation are discussed, and CAD formulas are given for the microstrip antenna. The CAD formulas are fairly accurate for thin substrates and illustrate the basic principles. For thin substrates the CAD formulas may even be accurate enough for final design purposes. For thicker substrates these formulas can still be used for initial design work, with full-wave simulation tools used to complete the final design.

History

The origin of microstrip antennas apparently dates back to 1953, when Deschamps proposed the use of microstrip feed lines to feed an array of printed antenna elements.[1,2] The printed antenna elements introduced there were not microstrip patches, but flared planar horns. The microstrip patch antenna was first introduced by Munson in a symposium paper in 1972,[3] which was followed by a journal paper in 1974.[4] These papers discussed both the wraparound microstrip antenna and the rectangular patch. Shortly after Munson's symposium paper, Howell also discussed rectangular patch antennas in another symposium paper[5] in which he credits Munson with the basic idea by referencing a private communication. In a later journal paper, Howell introduced the circular patch as well as the circularly polarized patch antenna.[6] Soon after the introduction of the microstrip antenna, papers appeared describing methods of analysis for these antennas, including the transmission-line model,[7] the cavity model,[8] and the spectral-domain method.[9] A good review of the early history of microstrip antennas is provided in the article by Carver and Mink.[10] A discussion of microstrip antennas may be found in a variety of books devoted to this type of antenna[11–22] as well as in more general antenna books and handbooks.[23–27]

Feed Methods

Various methods may be used to feed the microstrip antenna, as shown in Figure 7-2 for the rectangular patch. The coaxial probe feed shown in Figure 7-2*a* is one of the most common feeds for a stand-alone element. The inset feed in Figure 7-2*b* is common for array applications. The proximity-coupled feed in Figure 7-2*c* requires multilayer fabrication,

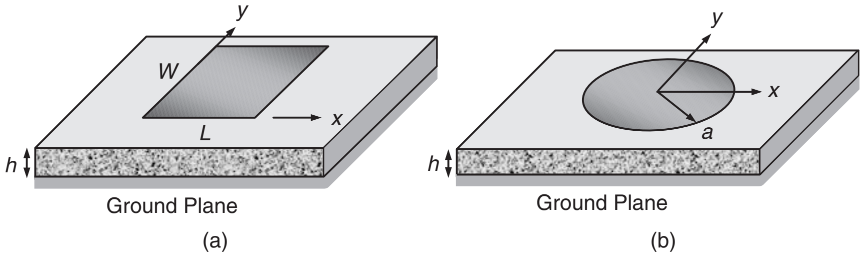

FIGURE 7-1 (*a*) Rectangular microstrip patch antenna and (*b*) circular microstrip patch antenna

$$c_1 = 1 - \frac{1}{n_1^2} + \frac{2/5}{n_1^4} \tag{7-38}$$

where $n_1 = \sqrt{\varepsilon_r \mu_r}$ is the index of refraction of the substrate. The other constants are

$$a_2 = -0.16605$$
$$a_4 = 0.00761$$
$$c_2 = -0.0914153$$

Surface-Wave *Q* Assuming that the substrate is infinite (or that there is an absorber to absorb the surface wave), so that surface-wave power is a loss from the antenna radiation point of view, the surface-wave excitation represents a loss mechanism, and the Q for this loss is given by

$$Q_{\text{sw}} = Q_{\text{sp}} \left(\frac{e_r^{\text{sw}}}{1 - e_r^{\text{sw}}} \right) \tag{7-39}$$

where e_r^{sw} denotes the radiation efficiency of the patch when accounting for only surface-wave loss, and not dielectric or conductor loss. That is,

$$e_r^{\text{sw}} = \frac{P_{\text{sp}}}{P_{\text{sp}} + P_{\text{sw}}} \tag{7-40}$$

where P_{sp} is the power radiated into space and P_{sw} is the power launched into the surface wave. This efficiency is well approximated by that of a unit-amplitude infinitesimal horizontal electric dipole (*hed*) on the substrate. (Unit amplitude means $I\,l = 1$, with the current amplitude I expressed using peak phasor notation, not rms, and the length l of the small dipole measured in meters.) Therefore this efficiency is given by the approximate expression

$$e_r^{\text{sw}} = e_r^{\text{hed}} = \frac{P_{\text{sp}}^{\text{hed}}}{P_{\text{sp}}^{\text{hed}} + P_{\text{sw}}^{\text{hed}}} \tag{7-41}$$

A calculation that is accurate for thin substrates reveals that

$$P_{\text{sp}}^{\text{hed}} = \frac{1}{\lambda_0^2} (k_0 h)^2 \left(80\pi^2 \mu_r^2 c_1\right) \tag{7-42}$$

and

$$P_{\text{sw}}^{\text{hed}} = \frac{1}{\lambda_0^2} (k_0 h)^3 \left[60\pi^3 \mu_r^3 \left(1 - \frac{1}{n_1^2} \right)^3 \right] \tag{7-43}$$

which results in the expression

$$e_r^{\mathrm{sw}} = e_r^{\mathrm{hed}} = \frac{1}{1+(k_0 h)\left(\frac{3\pi}{4}\right)\mu_r \frac{1}{c_1}\left(1-\frac{1}{n_1^2}\right)^3} \tag{7-44}$$

For nonmagnetic substrates, a more accurate expression that has been found by Pozar[33] for the surface-wave power of the unit-amplitude dipole is

$$P_{\mathrm{sw}}^{\mathrm{hed}} = \frac{\eta_0 k_0^2}{4} \frac{\varepsilon_r \left(x_0^2-1\right)^{\frac{3}{2}}}{\varepsilon_r [1+x_1]+(k_0 h)\sqrt{x_0^2-1}\left[1+\varepsilon_r^2 x_1\right]} \tag{7-45}$$

where

$$x_1 = \frac{x_0^2-1}{\varepsilon_r - x_0^2}$$

and

$$x_0 = 1 + \frac{-\varepsilon_r^2 + \alpha_0\alpha_1 + \varepsilon_r\sqrt{\varepsilon_r^2 - 2\alpha_0\alpha_1 + \alpha_0^2}}{\left(\varepsilon_r^2 - \alpha_1^2\right)}$$

with

$$\alpha_0 = s\tan[(k_0 h)s]$$

$$\alpha_1 = -\frac{1}{s}\left[\tan[(k_0 h)s] + \frac{(k_0 h)s}{\cos^2[(k_0 h)s]}\right]$$

and

$$s = \sqrt{\varepsilon_r - 1}$$

Using Eqs. 7-45 and 7-42 in Eq. 7-40 results in an expression that is more accurate than Eq. 7-44, especially for thicker substrates.

Bandwidth

The bandwidth of the patch may be defined from the frequency limits at which the standing-wave ratio (SWR) reaches a maximum threshold, assuming that the feeding transmission line

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Microstrip Antenna Design. Although the previous text and equations have indicated a significant performance dependence on the width of the microstrip conductor, the astute reader may recognize that no guidelines or formulae have been offered for the width calculation. A practical starting point has been suggested by Bancroft in the following equation:6. The procedure for the design of a single-element, rectangular microstrip antenna is summarized in Table 1. Microstrip Antenna Design Example. Microstrip Patch Antennas (or simply patch antenna) are increasingly useful because the antenna is printed directly onto a circuit board. Additional benefits of patch antennas is that they are easily fabricated making them cost effective. Their low profile design, often square or rectangular, allows them to be mounted to flat surfaces. Pasternack carries a variety of panel and patch antennas which can be seen here. **Note: All of our calculators allow SI prefix input. For example, if you wish to input "25000000", just type "25M" instead. Design of microstrip antenna for wireless applications. A thesis submitted in partial fulfillment of the requirements for the degree of. Bachelor of technology in. Electronics and Communication Engineering By. KIRTI SAI SHUKLA (Roll No: 111EC0262). Under the supervision of Prof. S. K. Behera.