Patch Antenna

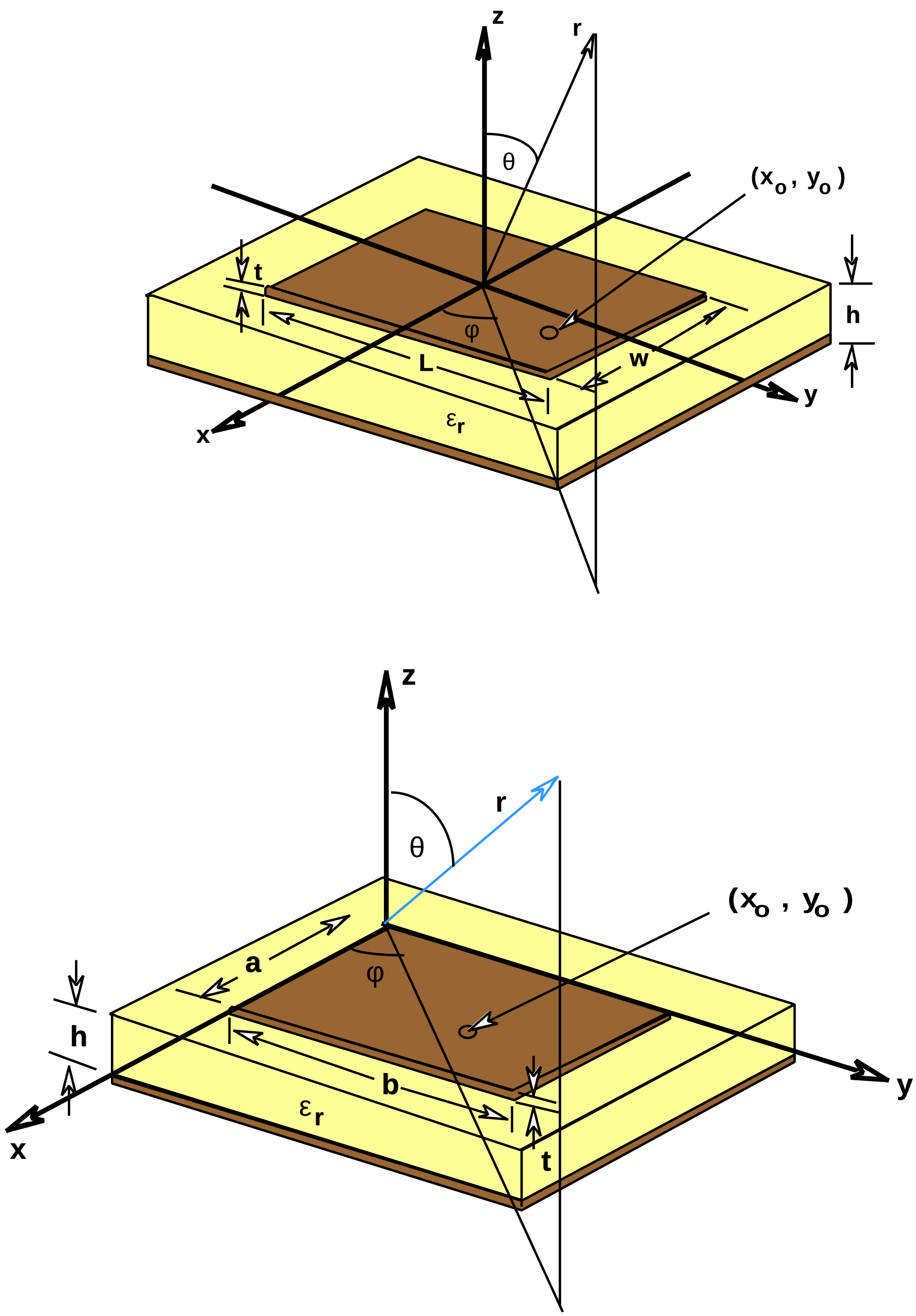

Figure 1. Overall dimensions of the rectangular patch. The antennas is fed by a coaxial line at the position (x_0,y_0).

. Figure 2 show various feed mechanisms for a rectangular patch antenna. These are:
(a) Coaxial probe located at a distance (X_0,Y_0) from the center,
(b) Slot coupled antenna,
(c) Microstrip line direct coupling and
(d) Side coupled microstrip line.

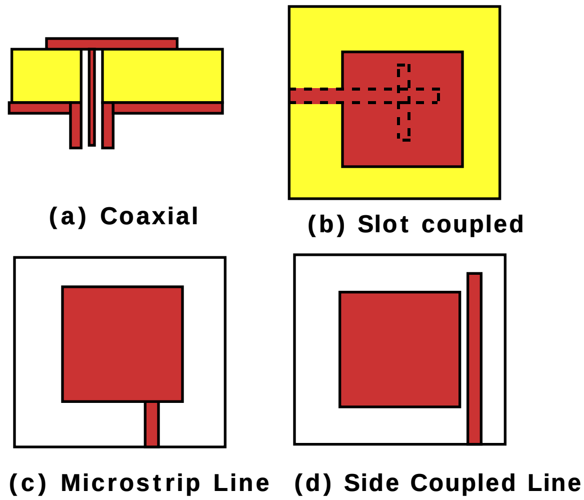

Figure 2. Various antenna excitation schemes for a patch antenna.

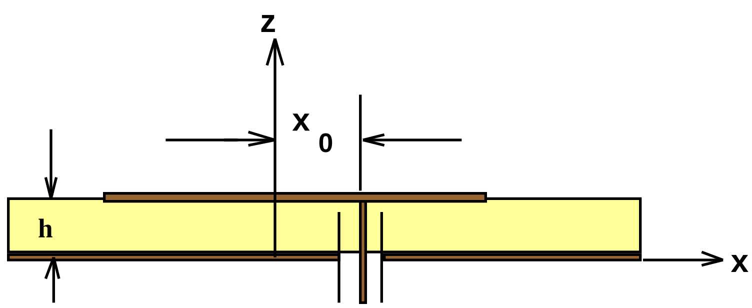

Figure 3. Position of the coaxial feed probe. Y_0 is chosen at w/2

For the substrate, polyimide is chosen and ε_r is taken to be equal to 3.0. The design frequency is f_0=10 GHz. The only variable taken in the design is the thickness of the polyimide substrate and the thickness is incremented by 10 μm starting from 10 μm up to 200 μm.

The following parameters of the patch antenna are investigated for the design purposes.
(a) Dimensions of the antenna.
(b) Radiation efficiency
(c) Input resistance
(d) Probe Reactance
(e) Antenna Q
(f) Radiation pattern

Dimensions of the antenna.

The value of W can be optimized to increase the radiation efficiency and other parameters of the antenna.In order to excite the fundamental TM_{010} mode, the condition (L > w > h) has to be satisfied. The initial length L is chosen using

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \qquad (1)$$

Here f_0 is the resonant frequency of the antenna.

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 2\Delta L \qquad (2)$$

Equivalent Circuit of the Patch Antenna.

A simplified equivalent circuit for the input impedance of the probe fed antenna is shown in Figure 5. In this figure, X_f is the probe reactance, L and C are the equivalent inductance and capacitance of the antenna, and R is the equivalent resistance of the antenna at resonance. This circuit is used to calculate the Q and frequency bandwidth of the antenna.

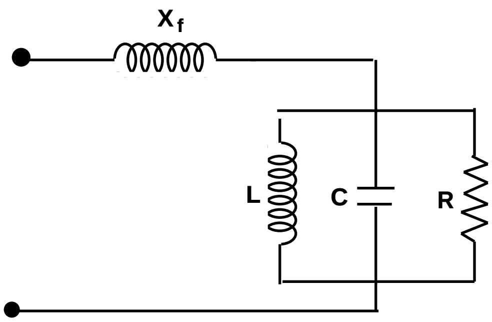

Figure 5. Equivalent circuit of the probe fed antenna.

Q factors for the Probe Fed Patch Antenna

For the dielectric material and the conductor losses the following formulas are used to calculate the Q factors due to dielectric and conductor losses.

$$Q_d = \frac{1}{tna(\delta)}$$

$$Q_c = \frac{1}{2}\eta_0\mu_r\left(\frac{k_o h}{R_s}\right)$$

The Q factors Q_{sp} and Q_{sw} determine the amount of power radiated into space and surface waves. To relate these a radiation efficiency of e_r^o is defined assuming no dielectric and conductor losses. . This efficiency accounts only for the power loss due to excitation of surface waves, i.e.,

$$e_r^o \approx \frac{Q_r}{Q_{sp}}$$

where the radiation quality factor Q_r is defined as

$$\frac{1}{Q_r} = \frac{1}{Q_{sp}} + \frac{1}{Q_{sw}}$$

Radiation Efficiency and Bandwidth.

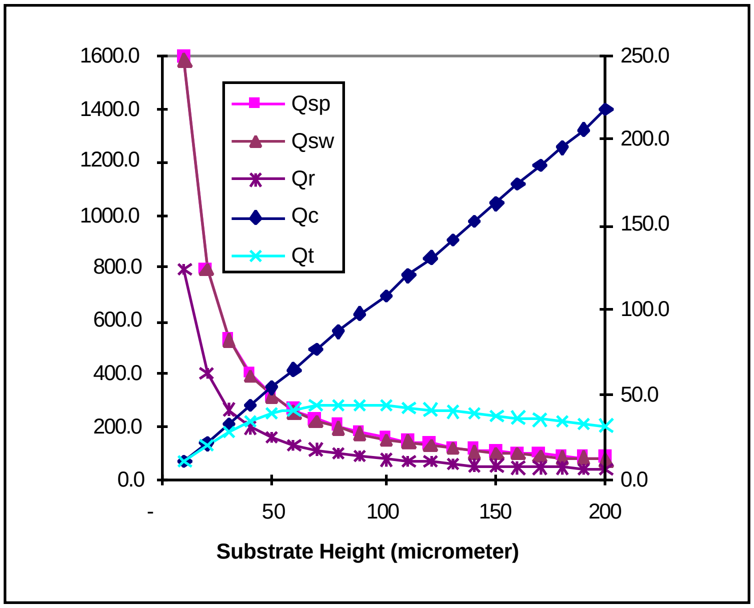

Figure 6, Variation of various Q's as a function of substrate thickness.

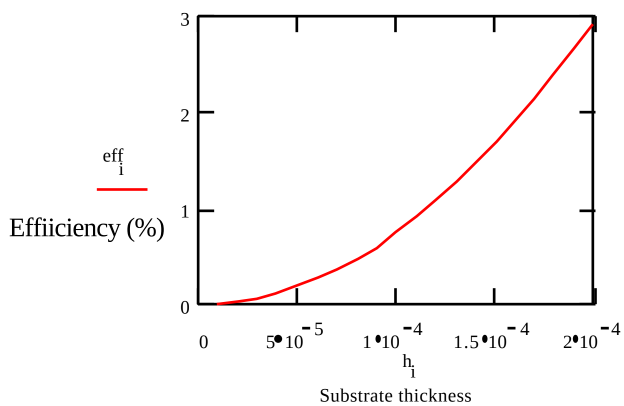

Figure 7. Radiation efficiency as a function of substrate thickness.

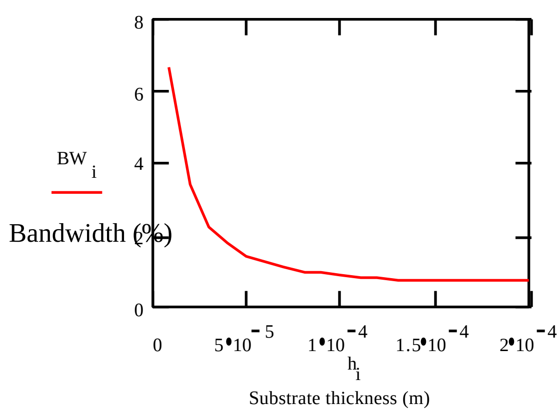

Figure 8. Bandwidth as a function of the substrate height

Input Impedance

.Figure 9 shows the input resistance of the patch antenna as a function of the probe position for various substrate thickness. As the thickness of the substrate increases, the input resistance increases. The thickness of the dielectric should be at least 50 μm in order not to use matching networks and directly connect to a 50 Ω line.

The probe reactance Xf is also calculated as a function of the substrate thickness. Assuming a probe radius of 50 μm. The result is shown in Figure 10.

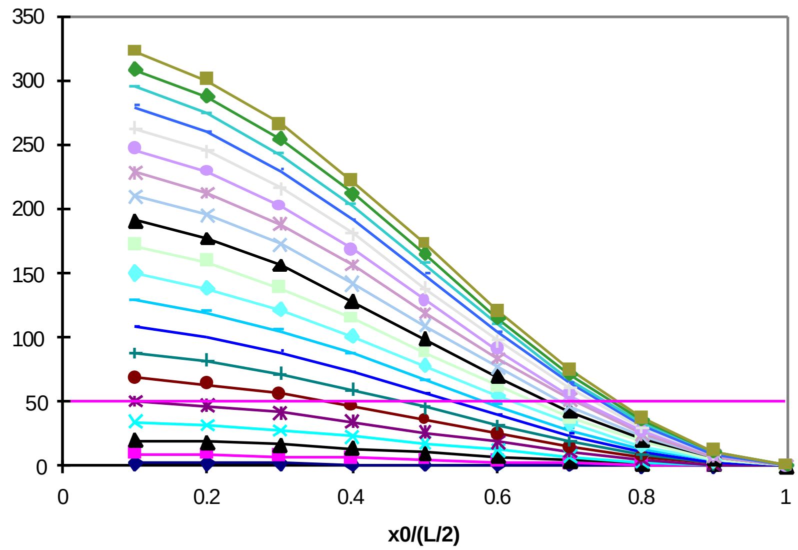

Figure 9. The input resistance as a function of the probe position x0 from the center of the patch. The upper curve is for a substrate thickness of 200 μm and the lower is for 10 μm. The increments are 10 μm.

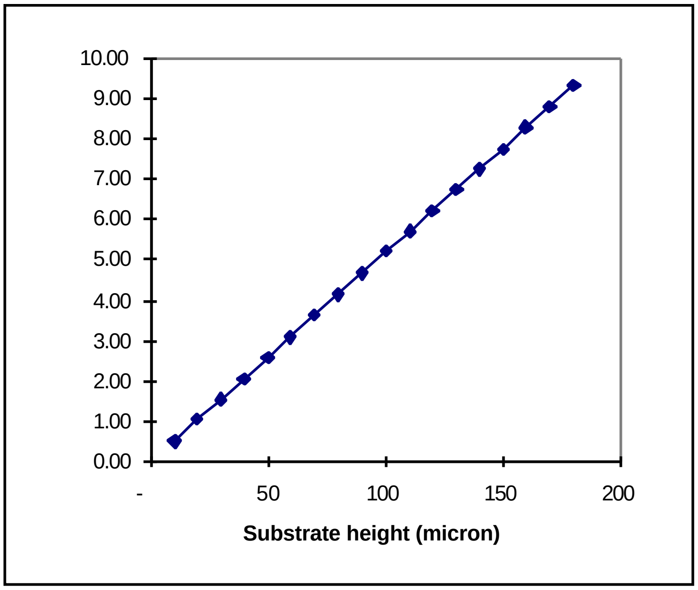

Figure 10. The probe reactance as a function of substrate height.

The frequency variation of the probe resistance is calculated using the expression

$$Z_{in} = jX_f + \frac{R}{1 + j2Q_t(f_r - 1)} \qquad where \qquad f_r = \frac{f}{f_0}$$

Figure 11 show the real part of the input impedance as a function of frequency for a substrate thickness of 50 μm. The -3 dB point is also shown in the same figure.

Radiation Patterns.

The resulting radiation pattern is shown in Figure 13. This is a 3D plot of the radiated E_θ field. For this calculation, a substrate height of 50 μm is chosen.

Figure 14 show the E-plane radiation pattern for the antenna with the same conditions given in Figure 13.

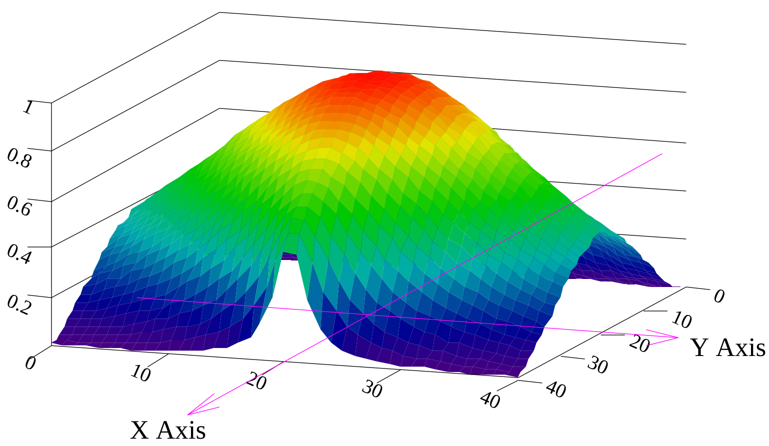

Figure 13. 3D Radiation pattern of the rectangular patch for a substrate thickness of 50 μm.

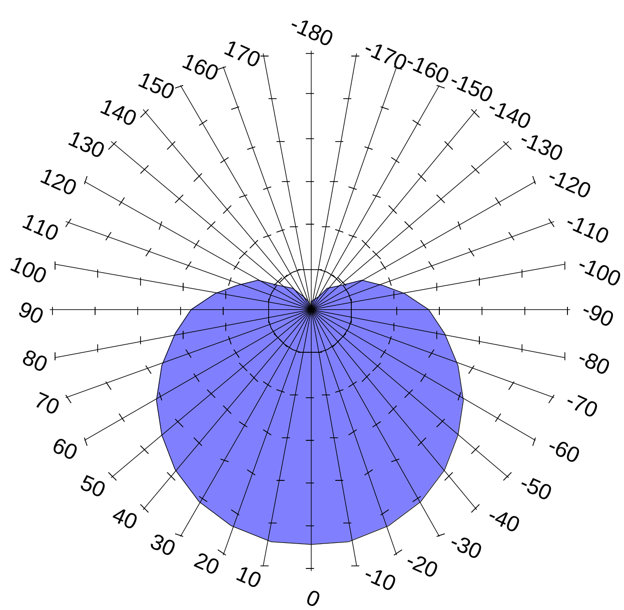

Figure 14. E-plane radiation pattern

References:

(1) D.R Jackson and N.G. Alexopoulus, “Simple Approximate Formulas for the input Resistance, Bandwidth and Efficiency of Resonant Rectangular Patch,” IEEE Trans. Antenna Propagation, Vol. AP-39, pp.407-410, 1991.
(2) D. R. Jackson, Stuart Long, Jeffrey T. Williams & Vickie B. Davis, Advances in Microstrip and Printed Antennas, Ed. By Kai Fong Lee and Wei Chen, Chapter 5. John Wiley and Sons (1997).
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(4) J.R.Carver and J.W.Mink, “Microstrip Antenna Technology,” IEEE Trans. .Antennas & Propagation, Vol-29, pp.2-24 (1981).