Microstrip Antenna

Antenna

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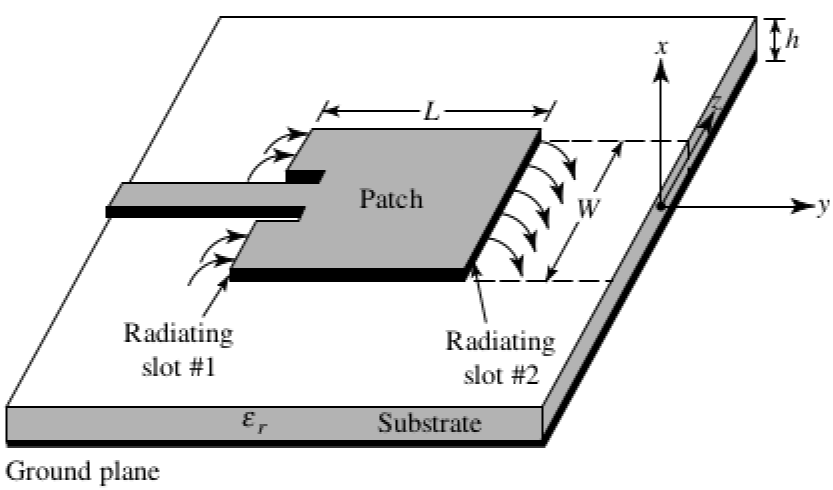
I– Introduction

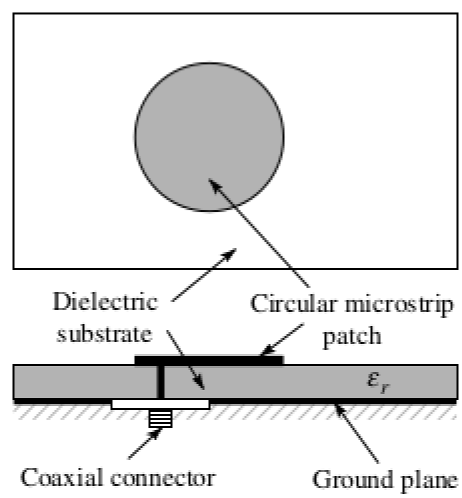
In high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low-profile antennas may be required.

Presently there are many other government and commercial applications, such as mobile radio and wireless communications, that have similar specifications. To meet these requirements, microstrip antennas can be used. These antennas are low profile,

II– Construction and working of microstrip antenna

Microstrip antennas received considerable attention starting in the 1970s, although the idea of a microstrip antenna can be traced to 1953 and a patent in 1955. Microstrip antennas, as shown in the next figure.





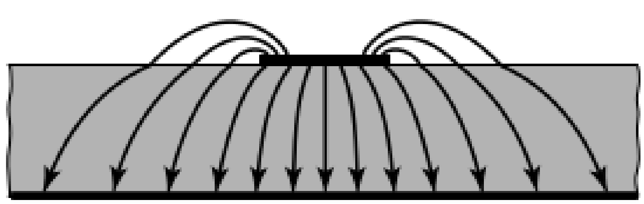
Micro strip antenna consists of a very thin metallic strip placed on a ground plane with a di-electric material in-between. The radiating element and feed lines are placed by the process of photo-etching on the di-electric material. Usually, the patch or micro-strip is chosen to be square, circular or rectangular in shape for the ease of analysis and fabrication.

Usually ($0.003\lambda_0 \leq h \leq 0.05\lambda_0$). The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$.

The strip (patch) and the ground plane are separated by a dielectric sheet (referred to as the substrate), as shown. There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 \leq \text{epsilon} \leq 12$.

Excitation guides the electromagnetic energy source to the patch, generating negative charges around the feed point and positive charges on the other part of the patch. This difference in charges creates electric fields in the antenna that are responsible for radiations from the patch antenna.

Three types of electromagnetic waves are radiated. The first part is radiated into space, which is 'useful' radiation. The second part is diffracted waves, which are reflected back into space between the patch and the ground plane, contributing to the actual power transmission. The last part of the wave remains trapped in the dielectric substrate due to total reflection at the air-dielectric separation surface. The waves trapped in the substrate are generally undesirable.



(b) Electric field lines

III– Considerations when designing

Because the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing, the amount of fringing is a function of the dimensions of the patch and the height of the substrate. Since for microstrip antennas L/ h >> 1, fringing is reduced, however, it must be taken into account because it influences the resonant frequency of the antenna. The same applies for the width.

Fringing in this case makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant epsilon_reff is introduced to account for fringing and the wave propagation in the line.

$$\underline{W/h > 1}$$

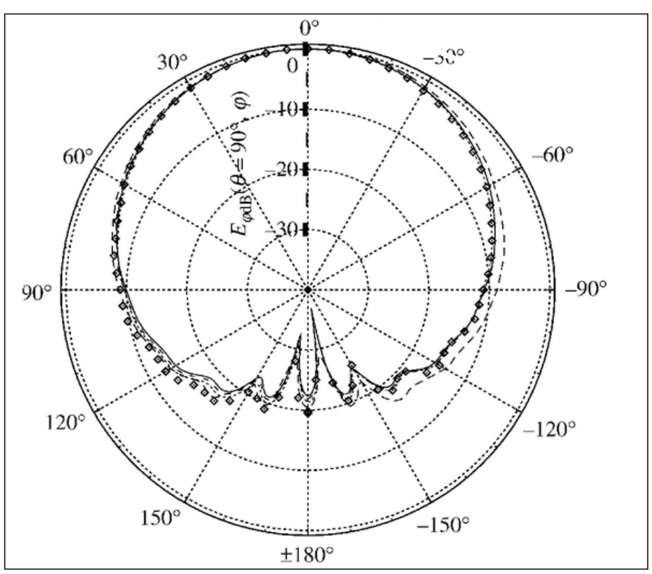
$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{\text{reff}} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{\text{reff}} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

$$L = \frac{1}{2 f_r \sqrt{\epsilon_{\text{reff}}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L$$

$$(f_{rc})_{010} = \frac{1}{2L_{\text{eff}}\sqrt{\epsilon_{\text{reff}}}\sqrt{\mu_0\epsilon_0}} = \frac{1}{2(L + 2\Delta L)\sqrt{\epsilon_{\text{reff}}}\sqrt{\mu_0\epsilon_0}}$$

The radiation pattern of microstrip or patch antenna is **broad**. It has low radiation power and narrow frequency bandwidth.

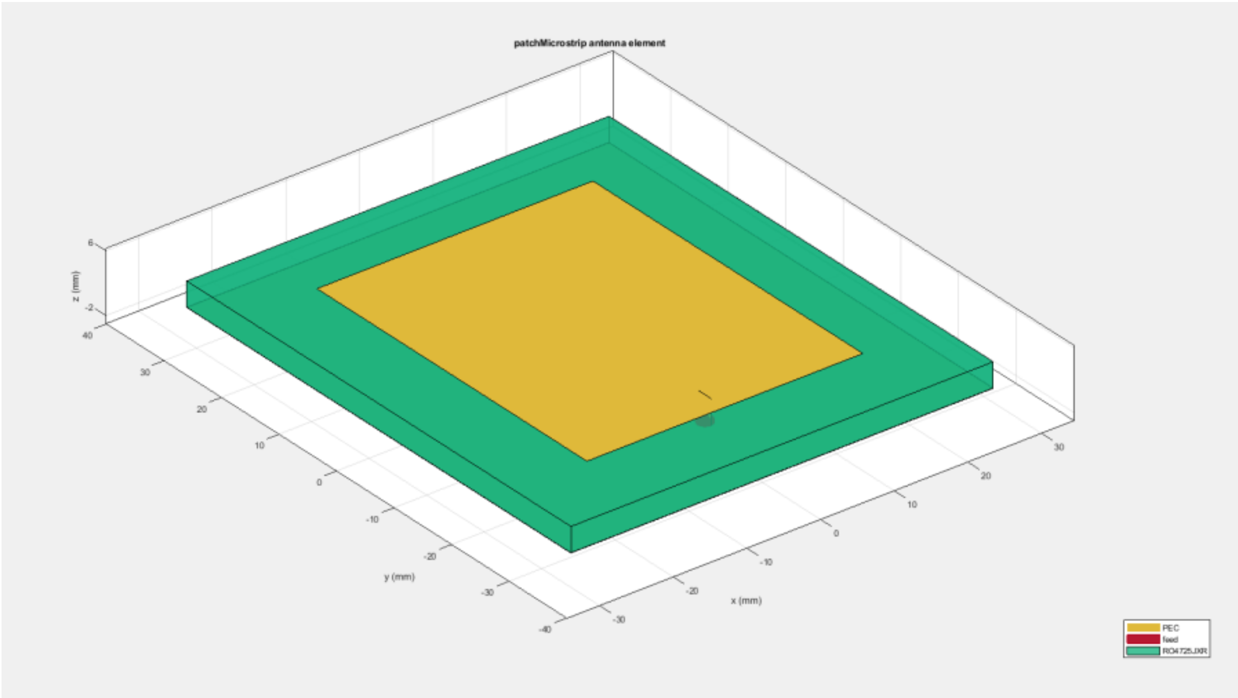


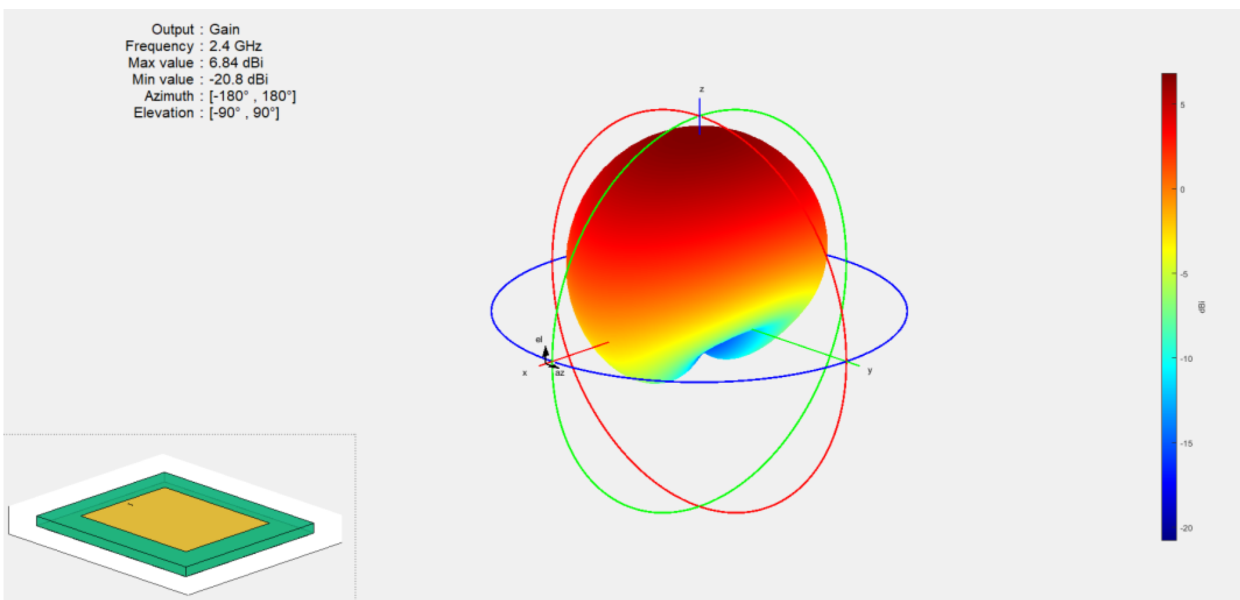
III– Matlab simulation

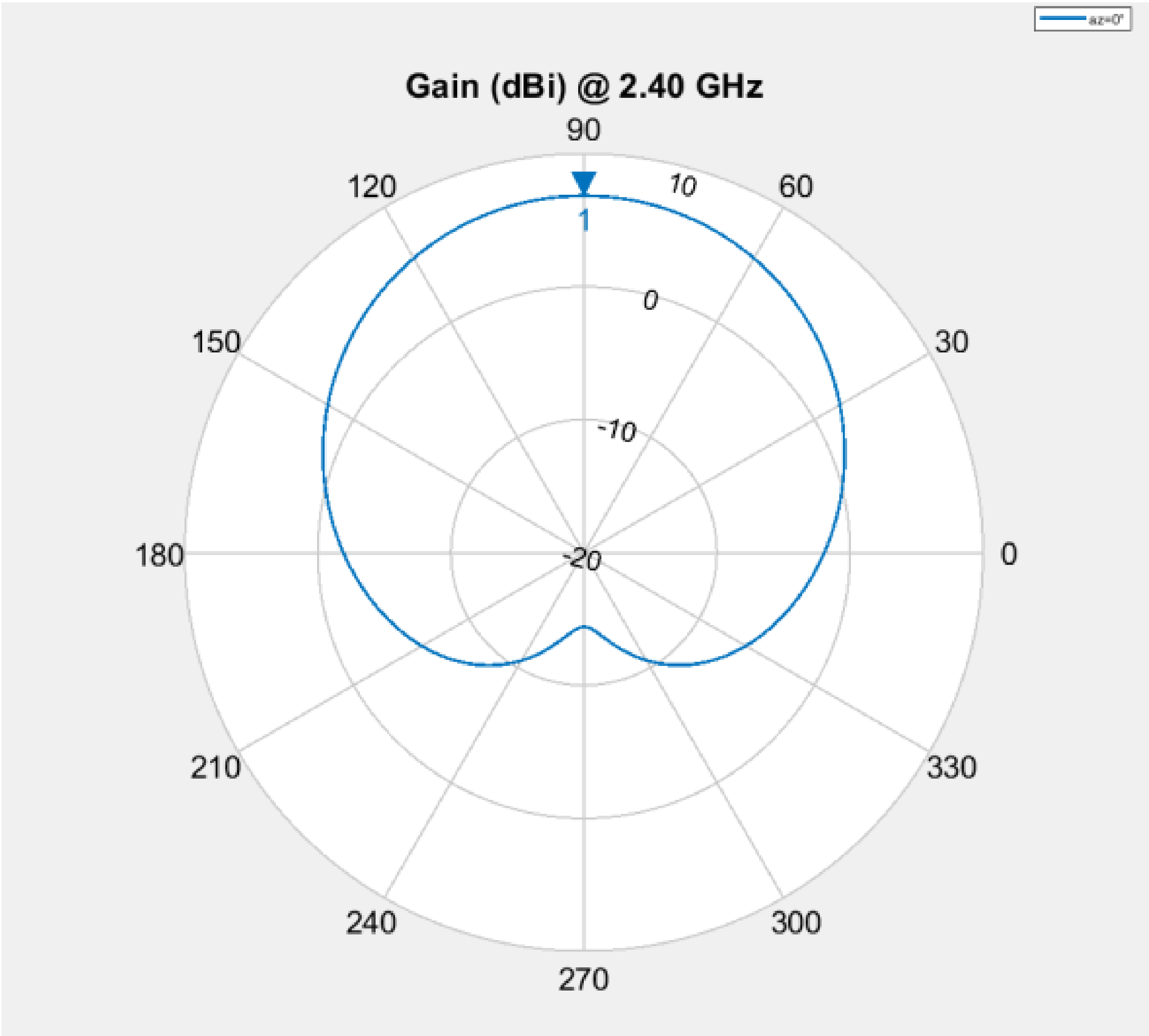
```
%----------------------- Setting up the design parameters ----------------%
frequency = 2.4e9;                     % Desired frequency matching WiFi frequencie 2.4GHz
C = 3e8;                               % Speed of light in free space
lambda = C / frequency;                % Wave Length

% 0.003 lambda < h < 0.05 lambda
min_h = lambda * 0.003;
max_h = lambda * 0.05;
h = (min_h + max_h) / 2;               % Desired height of the dielectric

diel = dielectric('RO4725JXR');        %EpsilonR = 2.55
epsilon_R = diel.EpsilonR;
```

```
%------------------------ Designing paramters  -------------------------%

W = (C / (2 * frequency)) * sqrt(2 / (epsilon_R + 1)); % Width of the Patch
epsilon_R_eff = ((epsilon_R + 1) / 2) + ((epsilon_R - 1) / 2) / sqrt(1 + 12*(h/W));
delta_L = h * 0.412 * (epsilon_R_eff +0.3) * (W/h + 0.264) / ((epsilon_R_eff - 0.258) * (W/h + 0.8));
L_actual = (C / (2 * frequency * sqrt(epsilon_R_eff))) - 2 * delta_L;

Lg = 6*h + L_actual;
Wg = 6*h + W;
```

```
%----------------------- Designing the antennal -------------------------%

antenna = patchMicrostrip('Length', L_actual,    'Width',W, 'Height',h,...
                          'Substrate',diel,      'GroundPlaneLength',Lg,...
                          'GroundPlaneWidth',Wg,'FeedOffset',[0 -20e-3]);

[beamwidth, angles] = beamwidth(antenna, frequency, 0, 1:1:360);
disp("HPBW = " + beamwidth);

figure;
show(antenna);
figure;
pattern(antenna, frequency);
figure;
patternElevation(antenna, frequency);
```


patchMicrostrip antenna element
z (mm)
y (mm)
x (mm)
PEC
feed
RO4725JXR


Output : Gain
Frequency : 2.4 GHz
Max value : 6.84 dBi
Min value : -20.8 dBi
Azimuth : [-180° , 180°]
Elevation : [-90° , 90°]
z
x
y
el
az
dBi


az=0°
Gain (dBi) @ 2.40 GHz
90
120
60
10
1
0
150
30
-10
180
-20
0
210
330
240
300
270

III– Applications

Communication-based applications. Microstrip patch antennas find several applications in wireless communication. For example, satellite communication requires circularly polarized radiation patterns, which can be realized using either square or circular patch microstrip antennas. In global positioning satellite (GPS) systems, circularly polarized microstrip antennas are used. They are very compact in size and quite expensive.

Microstrip antennas are also used in the fields of RFID (radio frequency identification), mobile communication and healthcare. Basically, an RFID system consists of a tag and a reader. Generally, it uses frequencies between 30 Hz and 5.8 GHz. In telemedicine applications, microstrip antennas operate at 2.45 GHz.

Some communication-based applications of microstrip patch antenna are command and control systems, remote sensing and environmental instrumentation, feed elements in complex antennae, satellite navigation receivers, mobile radio, integrated antennae, biomedical radiators and intruder alarms, Doppler and other radars, and satellite communication and direct broadcast services.

Mobile communication requires small, low-cost, low-profile antennas. In some mobile handsets, semiconductor-based diodes or detectors are used as antennae. They are much like p-n diode photo-detectors but work at microwave frequency. Many times omnidirectional antenna is used in mobile phones.

III– Reference

Antenna Theory Balanis.