EE307 Homework 6

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Problem：PP. 112-113, use Matlab or a programming language to verify the results.

Solution：

1) Calculate the following

- **Firstly, we define some constants as follow:**

```
clear
clc
%定义一些常量
er=2.33;
e0=8.854187817e-12;
gamm=0.577216;
miu0=(4*pi)*1e-7;    %定义磁导率常量
yita0=376.7303;
sigma=3e7;
f= 1.575e9;
h=1.575e-3;
c= 3e8;
lambda0=c/f;
w=2*pi*f;
k0=2*pi/lambda0;
W_divi_L=1.5; %定义长与宽相除的常量--1.5
sigm=3e7;
tand=0.001;
Rin=50;    %在该频率下的输入阻抗是50欧
R_resonance = 50; %在指定频点处的谐振阻抗
a=0.635e-3;
```

- **Then, we can verify the variables one by one:**

  1. The final patch dimensions *L* and *W* (in cm)

```
% 第一问:计算贴片的长与宽
L=lambda0/(2*sqrt(er));
W=L*1.5;
L_cm = L*100
W_cm = W*100
```

Result:

```
L_cm =

    6.2393


W_cm =

    9.3589
```

Of course, there are other more accurate ways to calculate the length and width of microstrip lines, as follows:

- 设计微带天线的第一步是选择合适的介质基片，然后再估算出辐射贴片的尺寸。
- 设介质基板的介电常数为ε_r，矩形微带天线工作频率为f，光速为c，辐射贴片的宽度w根据下式确定：

$$w = \frac{c}{2f}\left(\frac{\varepsilon_r + 1}{2}\right)^{-\frac{1}{2}}$$

- 辐射贴片的长度一般为$\lambda_e/2$，λ_e是介质内的导波波长， $\lambda_e = \frac{c}{f\sqrt{\varepsilon_e}}$
- 考虑到边缘缩短效应后，实际的辐射贴片长度L为，

$$L = \frac{c}{2f\sqrt{\varepsilon_e}} - 2\Delta L$$

式子中，ε_e是有效介电常数，ΔL是等效辐射缝隙长度，分别可以用下式计算：

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-\frac{1}{2}} \qquad \Delta L = 0.412h\frac{(\varepsilon_e + 0.3)(w/h + 0.264)}{(\varepsilon_e - 0.258)(w/h + 0.8)}$$

Therefore, our MATLAB program is as follows:

```
W=c/(2*f) * sqrt(2/(er+1));
ereff=(er+1)/2 + (er-1)/2 * (1+12*h/W)^(-1/2);
Leff=c/(2*f*sqrt(er));
dL=h*0.412*(ereff+0.3)*(W/h+0.264)/((ereff-0.258)*(W/h+0.8));
L=(Leff-2*dL);
W=L*1.5;
L_cm = L*100
W_cm = W*100
```

Result:

```
L_cm =

    6.0751


W_cm =

    9.1127
```

---

2. The feed location *x*0 (distance of the feed from the closest patch edge, in cm)

MATLAB codes:

```
%第二问:计算馈电位置--x0
Re=(4*yita0/pi)*(1/W_divi_L)*(h/lambda0)/(tand+(Rs/pi/yita0)*(1/(h/lambda0))+(16/3)*(p*c1/er)*(W_divi_L)*(h/lambda0)*(1/e_rhed));
x0=(L/pi)*acos(sqrt(Rin/Re))*1e2;
x0
```

Result:

```
x0 =

    1.8451
```

---

3. The bandwidth of the antenna (SWR < 2 definition, expressed in percent)

MATLAB codes:

```
%计算带宽与辐射效率
BW=1/(sqrt(2))*(tand+(Rs/pi/yita0)*(1/(h/lambda0))+(16/3)*(p*c1/er)*(h/lambda0)*(W_divi_L)*(1/e_rhed));
BW=BW*100;  %转化为百分比
BW
```

Result:

```
BW =

    1.2505
```

4. The radiation efficiency of the antenna

MATLAB codes:

```
%计算贴片天线的辐射效率
eff=e_rhed/(1+e_rhed*(tand+(Rs/pi/yita0)*(1/(h/lambda0)))*(3/16)*(er/p/c1)*(1/W_divi_L)*(1/(h/lambda0)));
effiency=eff*100;
effiency
```

Result:

```
effiency =

   83.0922
```

---

5. The probe reactance Xp at the operating frequency (in Ω)

MATLAB codes:

```
%计算probe reactance
Xp=(yita0/2/pi)*(k0*h)*(-gamm+log( 2/(sqrt(er)*k0*a)));
Xp
```

Result:

```
Xp =

   11.0859
```

---

6. The expected complex input impedance (in Ω) at the operating frequency, accounting for the probe inductance

MATLAB codes:

```
%第六七八问
%计算输入复阻抗
Zin=Rin+1i*Xp;
Zin
```

Result:

```
Zin =

  50.0000 +11.0859i
```

---

7. Directivity

MATLAB codes:

```
%计算方向性与增益
k1=k0*sqrt(er);
D=(3/p/c1)*(er/(er+(tan(k1*h)^2))*(tan(k1*h)/(k1*h))^2);
D
```

Result:

```
D =

    5.8046
```

---

8. Gain

MATLAB codes:

```
%计算天线增益，在上一问的基础上
k1=k0*sqrt(er);
D=(3/p/c1)*(er/(er+(tan(k1*h)^2))*(tan(k1*h)/(k1*h))^2);
G=D*eff;
G
```

Result:

```
G =

    4.8231
```

Through the above analysis and calculation, our results fit with the results on the course ppt very well.

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2) Plot the input impedance vs. frequency.

MATLAB codes:

```
f_test=linspace(1.5e9,1.65e9,2000);  %对频段进行扫描
k_test=2*pi*f_test/c;  %由频率推出k值
Q=1/(BW/100*sqrt(2));
Q
R=R_resonance./(1+(Q*(f_test./f-f./f_test)).^2);  %计算在某一频率处天线端的阻抗
Zin_test = 1i*Xp + R_resonance./(1+1i*Q.*(f_test./f-f./f_test));
Xin = imag(Zin_test);
plot(f_test, R,'linewidth',2)
hold on
```

```
plot(f_test, Xin,'-r','linewidth',2)
axis([1.5e9,1.65e9,-10,50]);
% set(gca,'ytick',-20:10:60);
grid on
set(gca, 'FontWeight','bold','LineWidth',2);
title('Relationship between Input Impedance and Frequency')
xlabel('Frequency');
ylabel('Input Impedance');
legend('Rin','Xin');
```

Result:

- **Q-factor**

```
Q =

    56.5439
```

- **Relationship between Input Impedance and Frequency**