Antenna and Free-Space Propogation

Problem 01: Computing the wavelength and E-Field Amplitude

Suppose that an EM-plane wave has:

- Power flux density is 1nW/m^2
- Freq = 2.3

```
clc
clear all
P = 1e-9;        % 1 nW/m^2 of Power
eta = 120*pi;    % Charateristic impedance

% The power flux is P = E0^2/eta/2. Note the factor of two!
% Invert this equation:
E0 = sqrt(2*pi*eta);
fprintf(1, 'E0 =%12.4e V/m', E0);
```

```
E0 =  4.8669e+01 V/m
```

```
% For the wavelenght, we lambda = c/f
f = 2.3e9;
c = physconst('Lightspeed'); % Using the physconst('Lightspeed') cppmmand to get the speed of l
lambda = c/f;
fprintf(1, 'lam =%12.4e m', lambda);
```

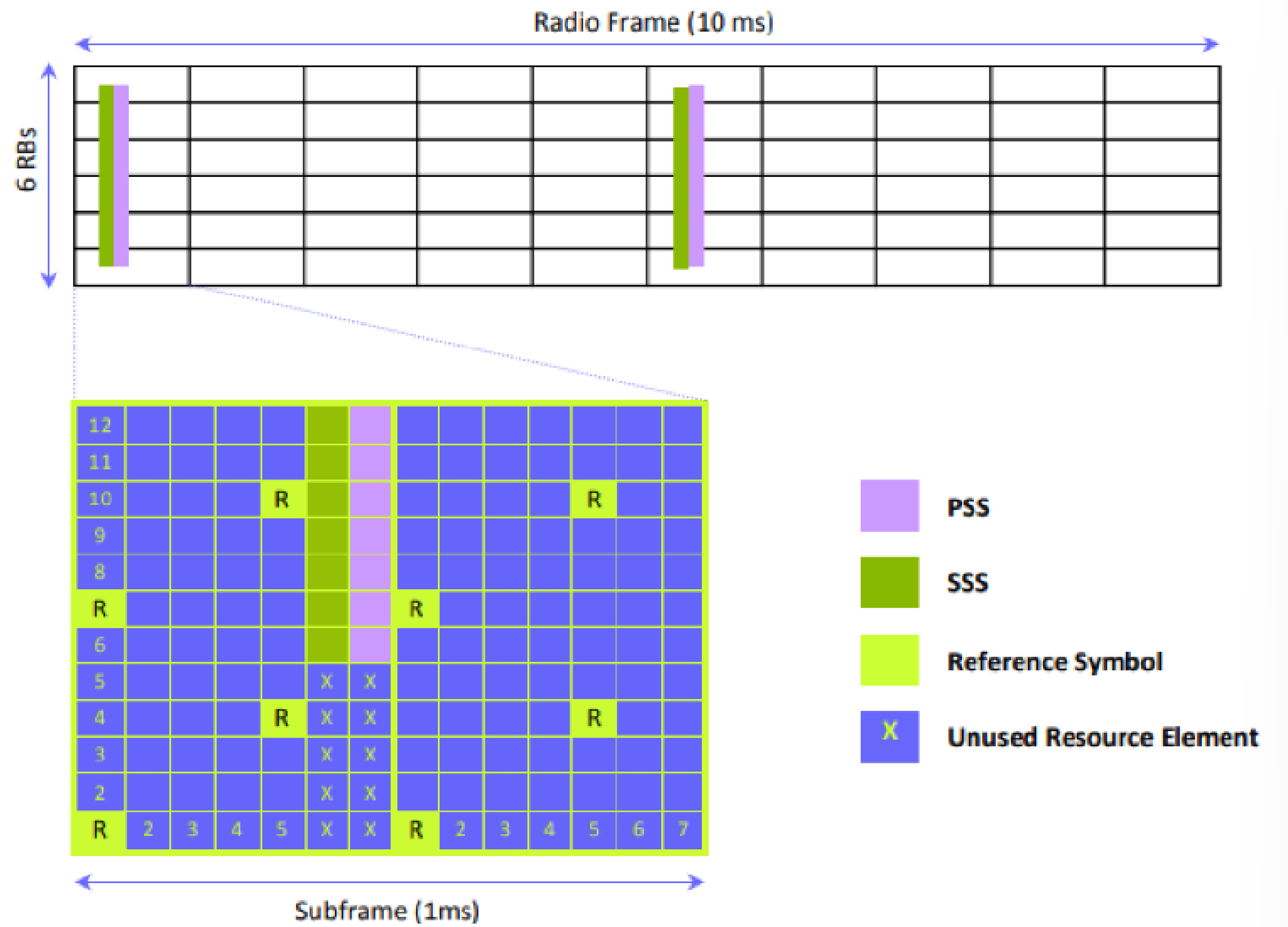
```
lam =  1.3034e-01 m
```

Problem 02: Computing Power in LTE PSS

In an LTE system, each base station (called eNB in 3GPP terminoly) periodically transmits a Primary Synchronization Signal (PSS) so that mobiles (caled UE or User Equipment) can detect the base station. The PSS occupies:

- In frequency: 72 sub-carrier at 15 kHz per sub-carrie
- In time: One OFDM symbol = 2048 samples at 30.72 Ms/s

The following digram shows the transmission of the PSS when it is configured to be transmitted every 5ms. Other synchronization and reference signals are also show.



Suppose the eNB has a total transmit power of 43 dBm uniformly over 20 MHz. The path loss between the eNB and UE is 100 dB. What is the received energy per PSS?

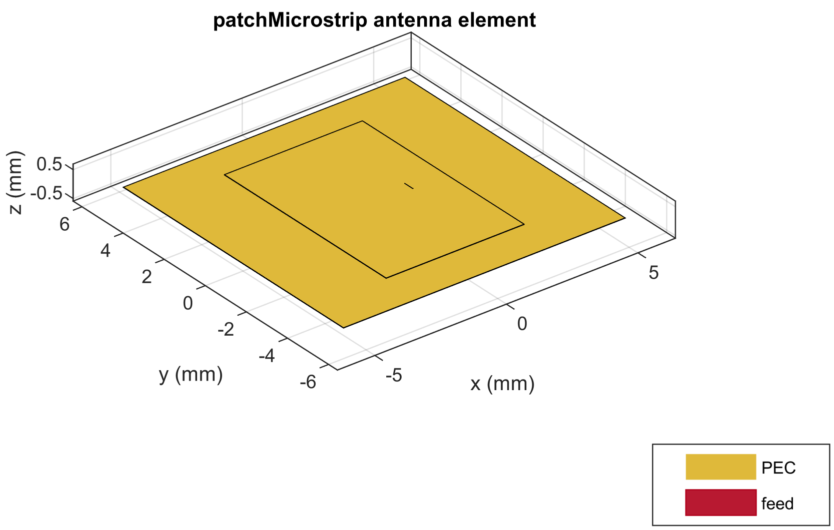
```
fSamp = 30.72e6;
T_PSS = 2048/fSamp;      % time of PSS signal
bw_PSS = 72*15e3;        % Bandwidth of the PSS in Hz
bw_tot = 20e6;           % total BW in Hz
PL = 100;                % Path loss in dB

Ptx_tot = 43;            % Total Transmit power
Erx_PSS = Ptx_tot + 10*log10(bw_PSS/bw_tot) - PL + 10*log10(T_PSS);

fprintf(1, 'Erx_PSS = %12.4e dBmJ', Erx_PSS)
```

```
Erx_PSS =  -1.1144e+02 dBmJ
```

Problem 03: Creating and Displaying a Patch Antenna

Create the 28 GHz patch antenna as follows:

```
% Compute the wavelength
fc = 28e9;
c = physconst('Lightspeed');
lambda = c/fc;

% Create the patch antenna
len = 0.49*lambda;
groundPlaneLen = lambda;
ant = patchMicrostrip(...
    'Length', len, 'Width', 1.5*len,...
    'GroundPlaneLength', groundPlaneLen,...
    'GroundPlaneWidth', groundPlaneLen,...
    'Height', 0.01*lambda,...
    'FeedOffset', [0.25*len 0]);

ant.show()
```



Now suppose the TX is at the origin and we have a RX terget at the following position:

```
rxPos = [1000, 500, 100];
```

Find the azimuth and elevation angle and distance to the RX.

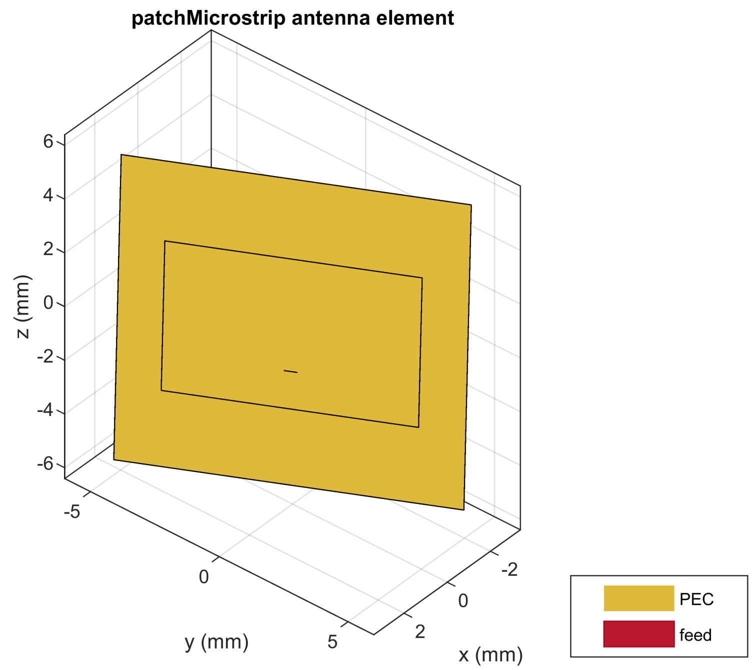
```
[az0, el0, rad0] = cart2sph(rxPos(1), rxPos(2), rxPos(3));
az0 = rad2deg(az0);
el0 = rad2deg(el0);

fprintf(1, 'az=%f el=%f\n', az0, el0);
```

```
az=26.565051 el=5.111090
```

Now rotate the antenna to point towards the target.

Where yRot and zRot are the angles to rotate the element in the y and z axes. Select yRot and zRot, run the command to point to the target and display the antenna. You may want to use the view([...]) command to select a good view point so you can see the front of the antenna.

```
yRot = 90-el0;      % Rotate in the y axis by the inclination angle
zRot = az0;         % Rotate in the z axis by the azimuth
ant.set('Tilt', [yRot, zRot], 'TiltAxis', [0 1 0; 0 0 1]);
ant.show();
view([130 37]);
```



Problem 04: Plotting the Far Field Radiation Pattern

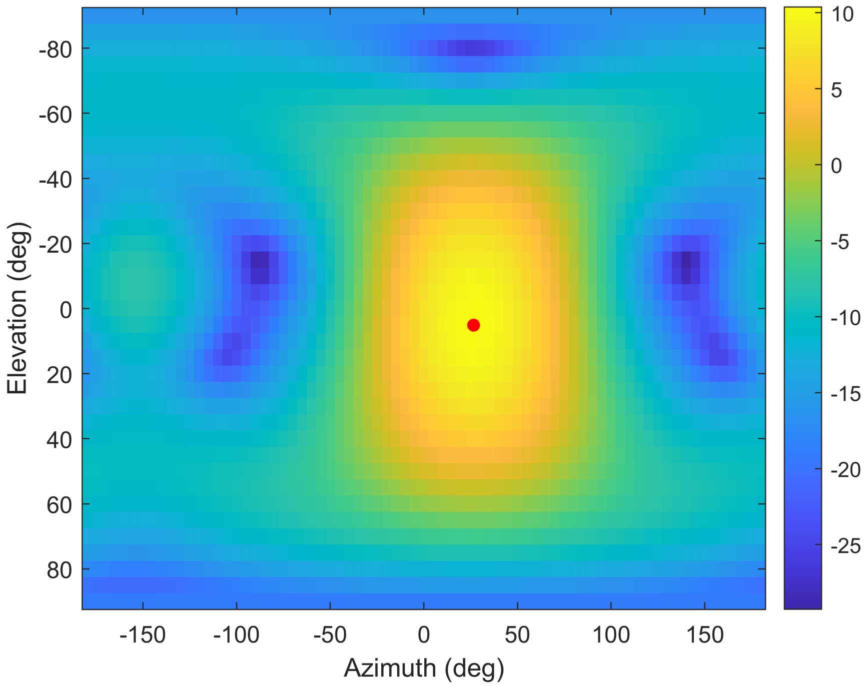
Use the ant.pattern command to get the pattern of the rotated antenna

```
[dir, az, el] = ant.pattern(fc, 'Type', 'directivity');
```

Use the imagesc command to plot the antenna pattern as a function of the azimuth and elevation angles. Add a colorbar, label the axes. Place a marker at the location [az0, el0], the desired direciton.

```
% Plot the directivity
imagesc(az,el,dir);
colorbar();
xlabel('Azimuth (deg)');
ylabel('Elevation (deg)');
hold on;

% Add a marker on the desired target
plot(az0, el0, 'ro', 'MarkerSize', 5, 'MarkerFaceColor','r');
```

```
hold off;
```



Use the griddedInterpolant object with the directivity data. Then use the gridded interpolant to find the directivity to the target at [az0, el0].

```
F = griddedInterpolant({el,az},dir);

% Compute the directivity using the object
dir0 = F(el0, az0);
```

Compute the free space path loss including the TX directivity to the target.

```
plOmni = fspl(rad0, lambda);
plDir = plOmni - dir0;
fprintf(1, 'Omni PL = %12.4e\n', plOmni);
```

```
Omni PL =   1.2239e+02
```

```
fprintf(1, 'PL with directivity = %12.4e\n', plDir);
```

```
PL with directivity =   1.1203e+02
```