2. MATLAB Basics

2.1 *(a)* The size of `array1` is 4×5. *(b)* The value of `array(4,1)` is –1.4. *(c)* `array(:,1:2)` consists of the first two columns of `array1`:

```
» array1(:,1:2)
ans =
    1.1000         0
         0    1.1000
    2.1000    0.1000
   -1.4000    5.1000
```

(d) `array1([1 3],end)` consists of the elements in the first and third row on the last column of `array1`:

```
» array1([1 3],end)
ans =
    6.0000
    1.3000
```

2.2 *(a)* Legal *(b)* Illegal—names must begin with a letter. *(c)* Legal *(d)* Illegal—names must begin with a letter. *(e)* Illegal—the apostrophe and the question mark are illegal characters.

2.3 *(a)* This is a three element row array containing the values 1, 3, and 5:

```
» a = 1:2:5
a =
     1     3     5
```

(b) This is a 3×3 element array containing three identical columns:

```
» b = [a' a' a']
b =
     1     1     1
     3     3     3
     5     5     5
```

(c) This is a 2×2 element array containing the first and third rows and columns of `b`:

```
» c = b(1:2:3,1:2:3)
c =
     1     1
     5     5
```

(d) This is a 1×3 row array containing the sum of `a` (= [1 3 5]) plus the second row of `b` (= [2 2 2]):

```
» d = a + b(2,:)
d =
     4     6     8
```

(e) This is a 1 × 9 row array containing:

```
» w = [zeros(1,3) ones(3,1)' 3:5']
w =
     0     0     0     1     1     1     3     4     5
```

Note that the expression `3:5'` is the same as `3:5`, because the transpose operator applies to the single element 5 only: `5' = 5`. Both expressions produce the row array `[1 3 5]`. To produce a column array, we would write the expression as `(3:5)'`, so that the transpose operator applied to the entire vector.

(f) This statement swaps *the first and third rows in the second column* of array `b`:

```
» b([1 3],2) = b([3 1],2)
b =
     1     5     1
     3     3     3
     5     1     5
```

2.4 *(a)* This is the third row of the array:

```
» array1(3,:)
ans =
    2.1000    0.1000    0.3000   -0.4000    1.3000
```

(b) This is the third column of the array:

```
» array1(:,3)
ans =
    2.1000
   -6.6000
    0.3000
         0
```

(c) This array consists of the first and third rows and the third and fourth columns of `array1`, with the third column *repeated twice*:

```
» array1(1:2:3,[3 3 4])
ans =
    2.1000    2.1000   -3.5000
    0.3000    0.3000   -0.4000
```

(d) This array consists of the first row *repeated twice*:

```
» array1([1 1],:)
ans =
    1.1000         0    2.1000   -3.5000    6.0000
    1.1000         0    2.1000   -3.5000    6.0000
```

2.5 *(a)* This statement displays the number using the normal MATLAB format:

```
» disp (['value = ' num2str(value)]);
value = 31.4159
```

(b) This statement displays the number as an integer:

```
» disp (['value = ' int2str(value)]);
value = 31
```

(c) This statement displays the number in exponential format:

```
» fprintf('value = %e\n',value);
value = 3.141593e+001
```

(d) This statement displays the number in floating-point format:

```
» fprintf('value = %f\n',value);
value = 31.415927
```

(e) This statement displays the number in general format, which uses an exponential form if the number is too large or too small.

```
» fprintf('value = %g\n',value);
value = 31.4159
```

(f) This statement displays the number in floating-point format in a 12-character field, with 4 digits after the decimal point:

```
» fprintf('value = %12.4f\n',value);
value =      31.4159
```

2.6 The results of each case are shown below.

(a) Legal: This is element-by-element addition.

```
» result = a + b
result =
     3    -3
    -1     4
```

(b) Legal: This is matrix multiplication

```
» result = a * d
result =
     2    -2
    -1     2
```

(c) Legal: This is element by element array multiplication

```
» result = a .* d
result =
     2     0
     0     2
```

(d) Legal: This is matrix multiplication

```
» result = a * c
result =
```

```
     6
    -5
```

(e) Illegal: This is element by element array multiplication, and the two arrays have different sizes.

(f) Legal: This is matrix left division

```
» result = a \ b
result =
    1.0000    1.0000
    0.5000    1.5000
```

(g) Legal: This is element by element array left division: `b(i) / a(i)`

```
» result = a .\ b
result =
    0.5000    0.5000
         0    1.0000
```

(h) Legal: This is element by element exponentiation

```
» result = a .^ b
result =
    2.0000   -0.5000
    1.0000    4.0000
```

2.7 *(a)* 8.2 *(b)* 8.2 *(c)* 1.0 *(d)* 729 *(e)* 6561 *(f)* 729 *(g)* 4 *(h)* 4 *(i)* 3

2.8 *(a)* 18.0 + 38.0*i* *(b)* -0.6224*i*

2.9 The solution to this set of equations can be found using the left division operator:

```
» a = [ -2.0 +5.0 +1.0 +3.0 +4.0 -1.0; ...
         2.0 -1.0 -5.0 -2.0 +6.0 +4.0; ...
        -1.0 +6.0 -4.0 -5.0 +3.0 -1.0; ...
         4.0 +3.0 -6.0 -5.0 -2.0 -2.0; ...
        -3.0 +6.0 +4.0 +2.0 -6.0 +4.0; ...
         2.0 +4.0 +4.0 +4.0 +5.0 -4.0 ];

» b = [ 0.0; 1.0; -6.0; 10.0; -6.0; -2.0];
» a\b
ans =
    0.6626
   -0.1326
   -3.0137
    2.8355
   -1.0852
   -0.8360
```

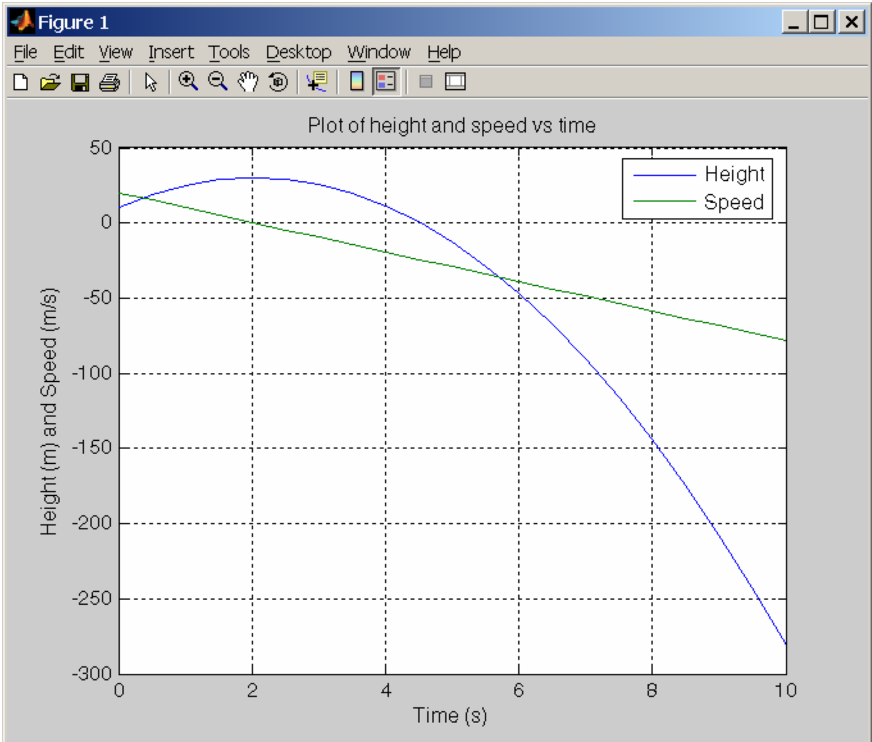
2.10 A program to plot the height and speed of a ball thrown vertically upward is shown below:

```
%  Script file: ball.m
%
```

```
%  Purpose:
%    To calculate and display the trajectory of a ball
%    thrown upward at a user-specified height and speed.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   g         -- Acceleration due to gravity (m/s^2)
%   h         -- Height (m)
%   h0        -- Initial height (m)
%   t         -- Time (s)
%   v         -- Vertical Speed (m/s)
%   v0        -- Initial Vertical Speed (m/s)

% Initialize the acceleration due to gravity
g = -9.81;

% Prompt the user for the initial velocity.
v0 = input('Enter the initial velocity of the ball: ');

% Prompt the user for the initial height
h0 = input('Enter the initial height of the ball: ');

% We will calculate the speed and height for the first
% 10 seconds of flight.  (Note that this program can be
% refined further once we learn how to use loops in a
% later chapter.  For now, we don't know how to detect
% the point where the ball passes through the ground
% at height = 0.)
t = 0:0.5:10;
h = zeros(size(t));
v = zeros(size(t));
h = 0.5 * g * t .^2 + v0 .* t + h0;
v = g .* t + v0;

% Display the result
plot(t,h,t,v);
title('Plot of height and speed vs time');
xlabel('Time (s)');
ylabel('Height (m) and Speed (m/s)');
legend('Height','Speed');
grid on;
```

When this program is executed, the results are:

```
» ball
Enter the initial velocity of the ball: 20
Enter the initial height of the ball: 10
```



2.11 A program to calculate the distance between two points in a Cartesian plane is shown below:

```
%  Script file: dist2d.m
%
%  Purpose:
%    To calculate the distance between two points on a
%    cartesian plane.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/04    S. J. Chapman        Original code
%
% Define variables:
%   dist      -- Distance between points
%   x1, y1    -- Point 1
%   x2, y2    -- Point 2

% Prompt the user for the input points
x1 = input('Enter x1: ');
y1 = input('Enter y1: ');
x2 = input('Enter x2: ');
y2 = input('Enter y2: ');

% Calculate dBm
dist = sqrt((x2-x1)^2 + (y2-y1)^2);

% Tell user
disp (['The distance is ' num2str(dist)]);
```

When this program is executed, the results are:

```
» dist2d
Enter x1: 2
Enter y1: 3
Enter x2: 8
Enter y2: -5
The distance is 10
```

2.12 A program to calculate power in dBm is shown below:

```
%  Script file: decibel.m
%
%  Purpose:
%    To calculate the dBm corresponding to a user-supplied
%    power in watts.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   dBm       -- Power in dBm
%   pin       -- Power in watts

% Prompt the user for the input power.
pin = input('Enter the power in watts: ');

% Calculate dBm
dBm = 10 * log10( pin / 1.0e-3 );

% Tell user
disp (['Power = ' num2str(dBm) ' dBm']);
```

When this program is executed, the results are:

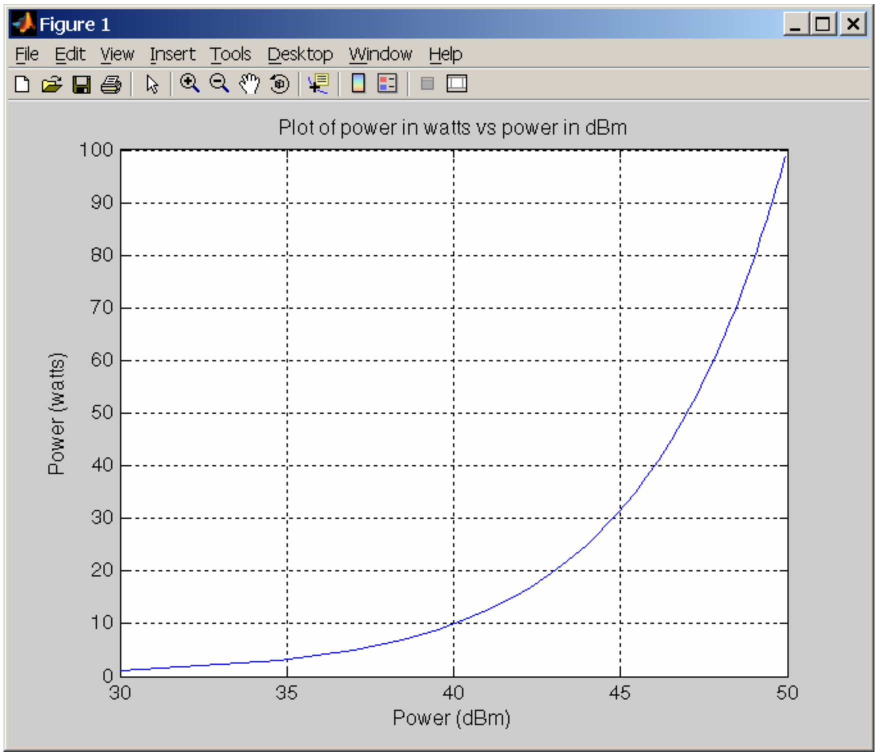
```
» decibel
Enter the power in watts: 10
Power = 40 dBm
» decibel
Enter the power in watts: 0.1
Power = 20 dBm
```

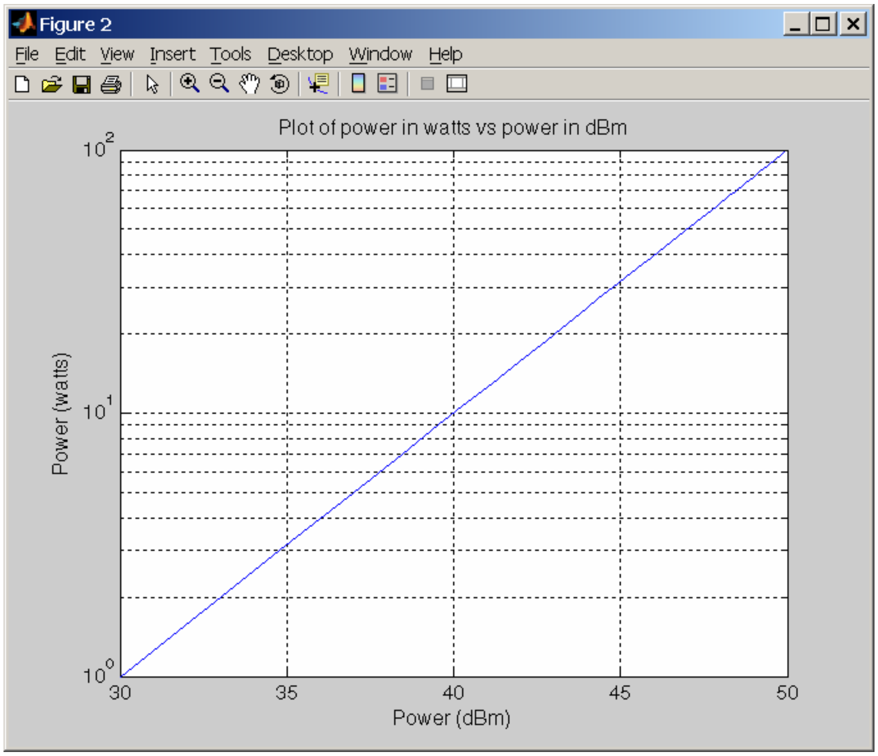
When this program is executed, the results are:

```
%  Script file: db_plot.m
%
%  Purpose:
%    To plot power in watts vs power in dBm on a linear and
%    log scale.
```

```
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   dBm       -- Power in dBm
%   pin       -- Power in watts

% Create array of power in watts
pin = 1:2:100;

% Calculate power in dBm
dBm = 10 * log10( pin / 1.0e-3 );

% Plot on linear scale
figure(1);
plot(dBm,pin);
title('Plot of power in watts vs power in dBm');
xlabel('Power (dBm)');
ylabel('Power (watts)');
grid on;

% Plot on semilog scale
figure(2);
semilogy(dBm,pin);
title('Plot of power in watts vs power in dBm');
xlabel('Power (dBm)');
ylabel('Power (watts)');
grid on;
```

When this program is executed, the results are:





2.13 A program to calculate cosh(x) both from the definition and using the MATLAB intrinsic function is shown below. Note that we are using `fprintf` to display the results, so that we can control the number of digits displayed after the decimal point:

```
%  Script file: cosh1.m
%
%  Purpose:
%    To calculate the hyperbolic cosine of x.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   x         -- Input value
%   res1      -- cosh(x) from the definition
%   res2      -- cosh(x) from the MATLAB function

% Prompt the user for the input power.
x = input('Enter x: ');

% Calculate cosh(x)
res1 = ( exp(x) + exp(-x) ) / 2;
res2 = cosh(x);

% Tell user
fprintf('Result from definition = %14.10f\n',res1);
fprintf('Result from function   = %14.10f\n',res2);
```

When this program is executed, the results are:

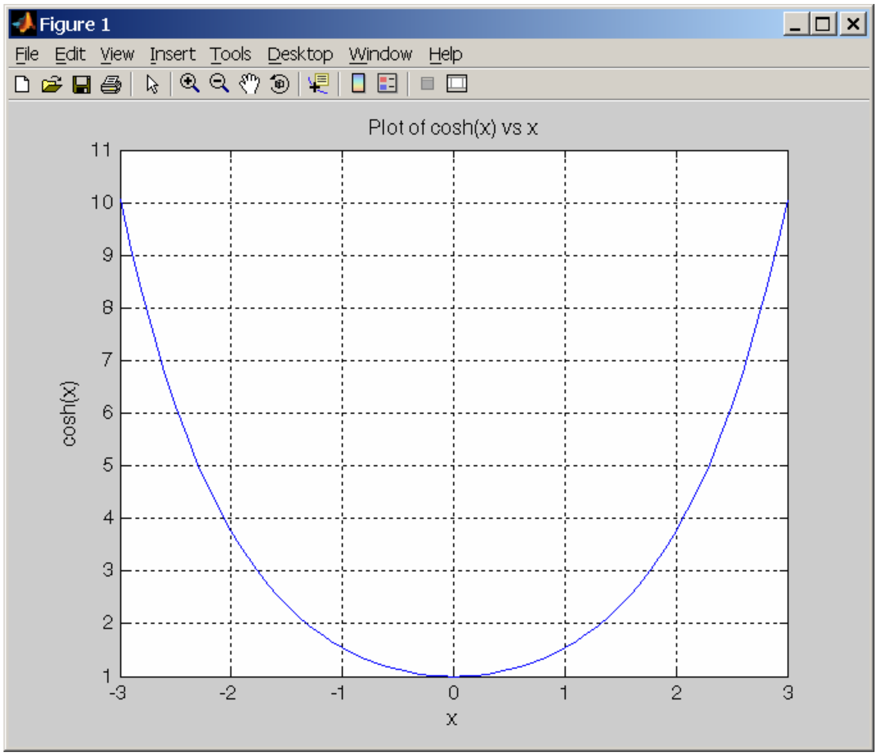
```
» cosh1
Enter x: 2
Result from definition =   3.7621956911
Result from function   =   3.7621956911
```

A program to plot cosh *x* is shown below:

```
%  Script file: cosh_plot.m
%
%  Purpose:
%    To plot cosh x vs x.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   x         -- input values
%   coshx     -- cosh(x)

% Create array of power in input values
x = -3:0.1:3;

% Calculate cosh(x)
```

```
coshx = cosh(x);

% Plot on linear scale
plot(x,coshx);
title('Plot of cosh(x) vs x');
xlabel('x');
ylabel('cosh(x)');
grid on;
```

The resulting plot is shown below. Note that the function reaches a minimum value of 1.0 at $x = 0$.



2.14 A program to calculate the energy stored in a spring is shown below:

```
%  Script file: spring.m
%
%  Purpose:
%    To calculate the energy stored in a spring.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   energy    -- Stored energy (J)
%   f         -- Force on spring (N)
%   k         -- Spring constant (N/m)
%   x         -- Displacement (m)
```

```
% Prompt the user for the input force and spring constant.
f = input('Enter force on spring (N): ');
k = input('Enter spring constant (N/m): ');

% Calculate displacement x
x = f/k;

% Calculate stored energy
energy = 0.5 * k * x^2;

% Tell user
fprintf('Displacement = %.3f meters\n',x);
fprintf('Stored energy = %.3f joules\n',energy);
```

When this program is executed, the results are as shown below. The second spring stores the most energy.

```
» spring
Enter force on spring (N): 20
Enter spring constant (N/m): 500
Displacement = 0.040 meters
Stored energy = 0.400 joules
» spring
Enter force on spring (N): 24
Enter spring constant (N/m): 600
Displacement = 0.040 meters
Stored energy = 0.480 joules
» spring
Enter force on spring (N): 22
Enter spring constant (N/m): 700
Displacement = 0.031 meters
Stored energy = 0.346 joules
» spring
Enter force on spring (N): 20
Enter spring constant (N/m): 800
Displacement = 0.025 meters
Stored energy = 0.250 joules
```

2.15 A program to calculate the resonant frequency of a radio is shown below:

```
%  Script file: radio.m
%
%  Purpose:
%    To calculate the resonant frequency of a radio.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/11/05    S. J. Chapman        Original code
%
% Define variables:
%   c         -- Capacitance (F)
%   freq      -- Resonant frequency (Hz)
%   l         -- Inductance (H)
```

```
% Prompt the user for the input force and spring constant.
l = input('Enter inductance in henrys: ');
c = input('Enter capacitance in farads: ');

% Calculate resonant frequency
freq = 1 / ( 2 * pi * sqrt(l*c) );

% Tell user
fprintf('Resonant frequency = %.1f Hz\n',freq);
```

When this program is executed, the results are:

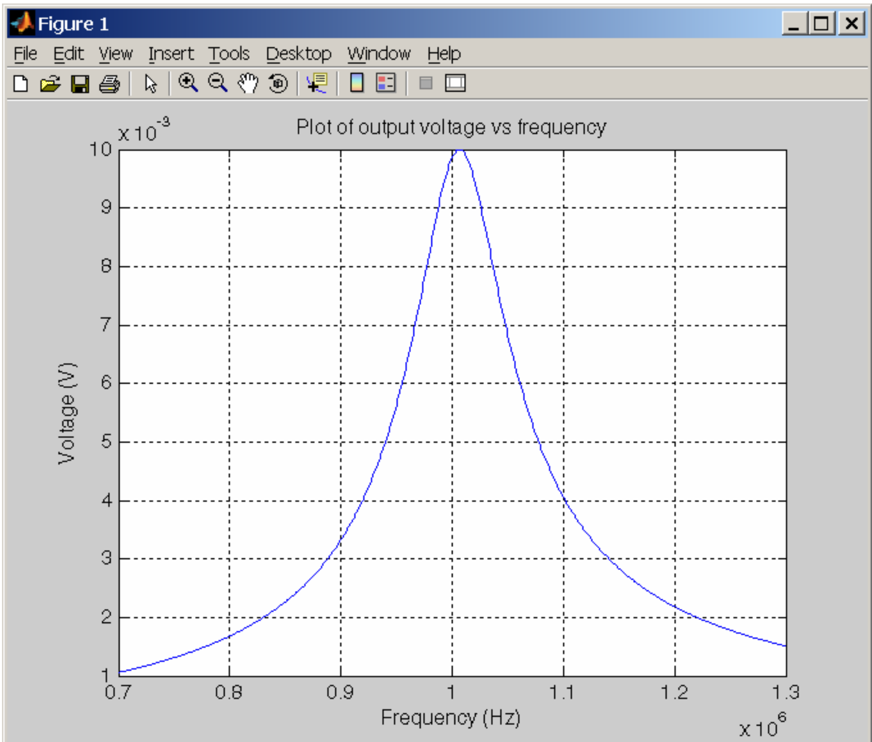
```
» radio
Enter inductance in henrys: 0.1e-3
Enter capacitance in farads: 0.25e-9
Resonant frequency = 1006584.2 Hz
```

2.16 *(a)* A program to calculate the frequency response of a radio receiver is shown below:

```
%  Script file: radio2.m
%
%  Purpose:
%    To plot the frequency response of a radio receiver.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/12/05    S. J. Chapman        Original code
%
% Define variables:
%   c         -- Capacitance (F)
%   freq      -- Resonant frequency (Hz)
%   l         -- Inductance (H)
%   r         -- resistance (ohms)
%   v         -- output viltage (V)
%   v0        -- input voltage (V)
%   w         -- Angular frequency (rad/s)

% Initialise values
c  = 0.25e-9;
l  = 0.1e-3;
r  = 50;
v0 = 10e-3;

% Create an array of frequencies centered on 1 MHz,
% which is the resonant frequency
freq = (0.7:0.001:1.3) * 1e6;

% Calculate w
w = 2 * pi * freq;

% Calculate output voltage
v =  v0 .* r ./ sqrt( r^2 + (w.*l - 1./(w.*c)).^2 );
```

```
% Plot on linear scale
plot(freq,v);
title('Plot of output voltage vs frequency');
xlabel('Frequency (Hz)');
ylabel('Voltage (V)');
grid on;
```

The resulting frequency response is shown below. Note that the function reaches a minimum value of 1.0 at $x = 0$.



(b) The resonant frequency of this circuit is about 1 MHz. If the frequency is changed to 1.1 MHz, the output voltage will be 4 mV instead of the 10 mV at the resonant frequency. This receiver is not very selective—real radios do *much* better.

(c) The output voltage drops from 10 mV to 5 mV at 0.94 MHz and 1.08 MHz.

2.17 A program to calculate the output power of the receiver for a given input voltage and frequency is shown below:

```
%  Script file: radio3.m
%
%  Purpose:
%    To calculate the output power of a radio receiver.
%
%  Record of revisions:
%      Date        Programmer          Description of change
%      ====        ==========          =====================
%    07/12/05    S. J. Chapman         Original code
%
% Define variables:
```

```
%   c         -- Capacitance (F)
%   freq      -- Resonant frequency (Hz)
%   l         -- Inductance (H)
%   r         -- resistance (ohms)
%   p         -- output power (W)
%   v         -- output viltage (V)
%   v0        -- input voltage (V)
%   w         -- Angular frequency (rad/s)

% Initialise values
c  = 0.25e-9;
l  = 0.1e-3;
r  = 50;

% Get voltage and frequency
v0 = input('Enter voltage (V): ');
freq = input('Enter frequency  (Hz): ');

% Calculate w
w = 2 * pi * freq;

% Calculate output voltage
v =  v0 .* r ./ sqrt( r^2 + (w.*l - 1./(w.*c)).^2 );

% Calculate output power (=v^2/r)
p = v^2 / r;

% Tell user
fprintf('Output power = %f W\n',p);
```

When this program is executed, the results are:

```
» radio3
Enter voltage (V): 1
Enter frequency  (Hz): 1e6
Output power = 0.019464 W
» radio3
Enter voltage (V): 1
Enter frequency  (Hz): 0.95e6
Output power = 0.006360 W
```

The power ration in dB is

```
» dB = 10*log10(0.019464/0.006360)
dB =
    4.8577
```

The second signal is *suppressed* by about 5 dB compared to the first signal.

2.18 *(a)* A program for calculating the turning radius of the aircraft is shown below:

```
%  Script file: turning.m
%
%  Purpose:
```

```
%    To calculate the turning radius of an aircraft flying
%    in a circle, based on speed and max g.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/12/05    S. J. Chapman        Original code
%
% Define variables:
%   g         -- Max acceleration (g)
%   grav      -- Acceleration of gravity (9.81 m/s2)
%   mach1     -- Speed of sound (340 m/s)
%   radius    -- Turning radius (m)
%   speed     -- Aircraft speed in Mach

% Initialise values
grav  = 9.81;
mach1 = 340;

% Get speed and max g
speed = input('Enter speed (Mach): ');
g = input('Enter max acceleration (g): ');

% Calculate radius
radius = (speed * mach1).^ 2 / ( g * grav );

% Tell user
fprintf('Turning radius = %f m\n',radius);
```

When this program is executed, the results are:

```
>> turning
Enter speed (Mach): .85
Enter max acceleration (g): 2
Turning radius = 4256.931702 m
```

The turning radius is 4257 meters.

(b) When this program is executed with the new speed, the results are:

```
>> turning
Enter speed (Mach): 2
Enter max acceleration (g): 2
Turning radius = 23567.787971 m
```

The turning radius is now 23568 meters.

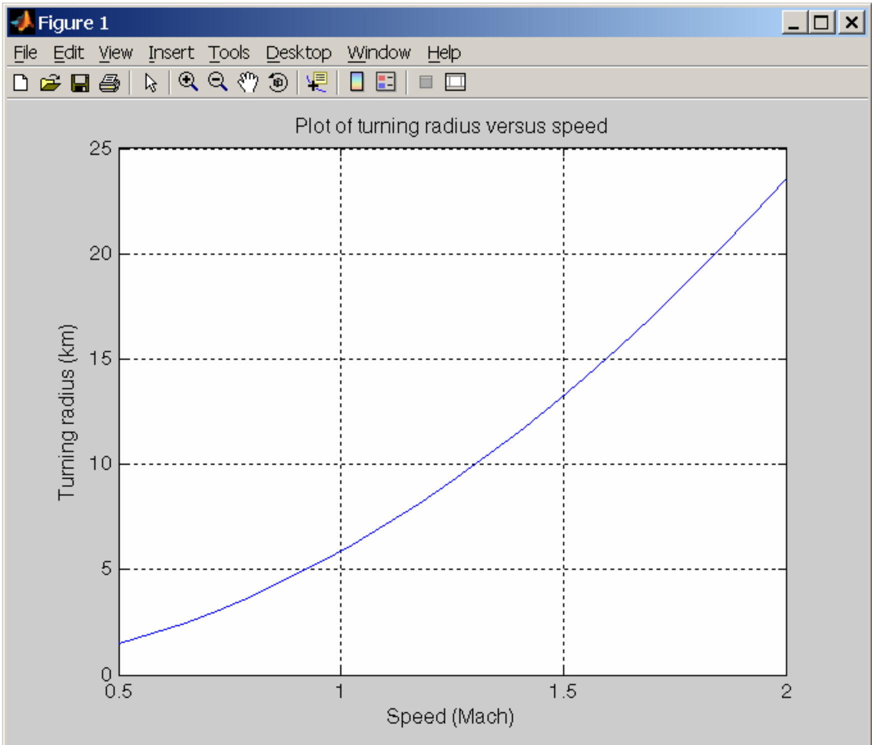
(c) A program to plot the turning radius as a function of speed for a constant max acceleration is shown below:

```
%  Script file: turning2.m
%
%  Purpose:
%    To plot the turning radius of an aircraft as a function
```

```
%    of speed.
%
%  Record of revisions:
%      Date       Programmer          Description of change
%      ====       ==========          =====================
%    07/12/05    S. J. Chapman        Original code
%
% Define variables:
%   g         -- Max acceleration (g)
%   grav      -- Acceleration of gravity (9.81 m/s2)
%   mach1     -- Speed of sound (340 m/s)
%   max_speed -- Maximum speed in Mach numbers
%   min_speed -- Minimum speed in Mach numbers
%   radius    -- Turning radius (m)
%   speed     -- Aircraft speed in Mach

% Initialise values
grav  = 9.81;
mach1 = 340;

% Get speed and max g
min_speed = input('Enter min speed (Mach): ');
max_speed = input('Enter min speed (Mach): ');
g = input('Enter max acceleration (g): ');

% Calculate range of speeds
speed = min_speed:(max_speed-min_speed)/20:max_speed;

% Calculate radius
radius = (speed * mach1).^ 2 / ( g * grav );

% Plot the turning radius versus speed
plot(speed,radius/1000);
title('Plot of turning radius versus speed');
xlabel('Speed (Mach)');
ylabel('Turning radius (km)');
grid on;
```

When this program is executed, the results are as shown below:

```
>> turning2
Enter min speed (Mach): 0.5
Enter min speed (Mach): 2.0
Enter max acceleration (g): 2
```



(d) When this program is executed, the results are:

```
>> turning
Enter speed (Mach): 1.5
Enter max acceleration (g): 7
Turning radius = 3787.680210 m
```

The turning radius is now 3788 meters.

(e) A program to plot the turning radius as a function of centripetal acceleration is shown below:

```
%  Script file: turning3.m
%
%  Purpose:
%    To plot the turning radius of an aircraft as a function
%    of centripetal acceleration.
%
%  Record of revisions:
%      Date        Programmer          Description of change
%      ====        ==========          =====================
%    07/12/05    S. J. Chapman         Original code
%
% Define variables:
%   g         -- Acceleration (g)
%   grav      -- Acceleration of gravity (9.81 m/s2)
%   mach1     -- Speed of sound (340 m/s)
%   max_g     -- Maximum accleration in g's
%   min_g     -- Minimum accleration in g's
%   radius    -- Turning radius (m)
```

```
%   speed     -- Aircraft speed in Mach

% Initialise values
grav  = 9.81;
mach1 = 340;

% Get speed and max g
speed = input('Enter speed (Mach): ');
min_g = input('Enter min acceleration (g): ');
max_g = input('Enter min acceleration (g): ');

% Calculate range of accelerations
g = min_g:(max_g-min_g)/20:max_g;

% Calculate radius
radius = (speed * mach1).^ 2 ./ ( g * grav );

% Plot the turning radius versus speed
plot(g,radius/1000);
title('Plot of turning radius versus acceleration');
xlabel('Centripetal acceleration (g)');
ylabel('Turning radius (km)');
grid on;
```

When this program is executed, the results are as shown below:

```
>> turning3
Enter speed (Mach): 0.85
Enter min acceleration (g): 2
Enter min acceleration (g): 8
```