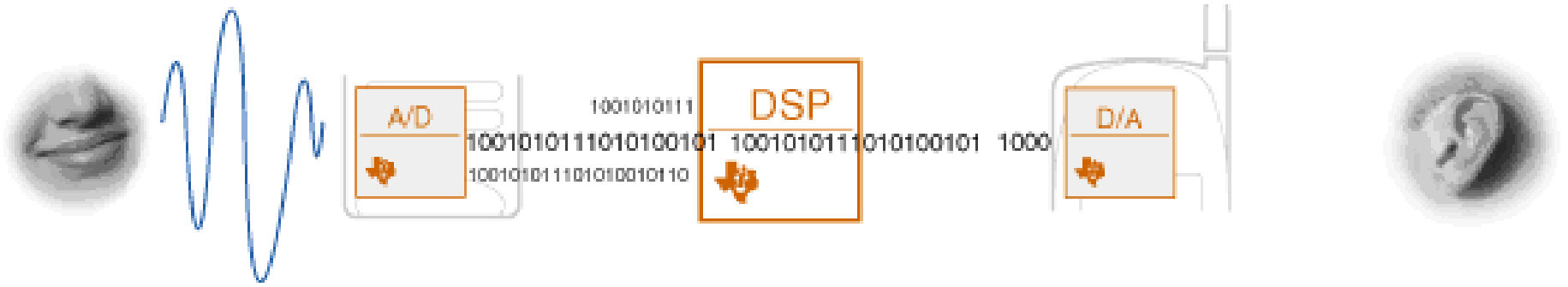


When you speak, your voice is picked up by an analog sensor in the cell phone's microphone.

An analog-to-digital converter chip converts your voice, which is an analog signal, into digital signals, represented by 1s and 0s.

The DSP compresses the digital signals and removes any background noise.

In the listener's cell phone, a digital-to-analog converter chip changes the digital signals back to an analog voice signal.

Your voice exits the phone through the speaker.

EHM 310
SAYISAL İŞARET İŞLEME
MATLAB UYGULAMALAR (1)

$$x(n) = \{2, 1, -1, \underset{\uparrow}{0}, 1, 4, 3, 7\}$$

```
>> n=[-3,-2,-1,0,1,2,3,4];   x=[2,1,-1,0,1,4,3,7];
```

$\delta[n]$

```
n=-10:10;
x=n.*0;
 for i=1:length(n)
 if(n(i))==x(i)=1;
 end
end
stem(x, x ‘filled’)
```

x[n]=0.9^n

```
n=-10:10;
x=0.9.^n;
stem(n, x,’filled’)
```

x[n]=0.9sin(2.pi.n/10)

```
n=-20:20;
x1=0.9.^n;
x=x1.*sin(2*pi*n/10);
stem(n,x, 'filled')
```

$$x_1(n) = e^{j(\pi/6)n}$$

```
n=[0:20*pi];x1=exp(j*pi/6.*n);% zaman vektörü n ve x1 oluştur
subplot(2,1,1); stem(n,real(x1));
title('x1 işaretinin gerçel bölümü');xlabel('n')
subplot(2,1,2); stem(n,imag(x1));
title('x1 işaretinin sanal bölümü');xlabel('n')
```

Konvolüsyon

```
n=-10:10;
x=[0 0 0 0 1 2 0 -1 0 0 0];
h=[0 0 0 0 3 2 1 0 0 0],
y=conv(x,h);
stem(n,y, ‘filled’)
```

$$x(n) = e^{(-0.1+j0.3)n}, \quad -10 \leq n \leq 10$$

```
>> n = [-10:1:10]; alpha = -0.1+0.3j;
>> x = exp(alpha*n);
>> subplot(2,2,1); stem(n,real(x));title('real part');xlabel('n')
>> subplot(2,2,2); stem(n,imag(x));title('imaginary part');xlabel('n')
>> subplot(2,2,3); stem(n,abs(x));title('magnitude part');xlabel('n')
>> subplot(2,2,4); stem(n,(180/pi)*angle(x));title('phase part');xlabel('n')
```

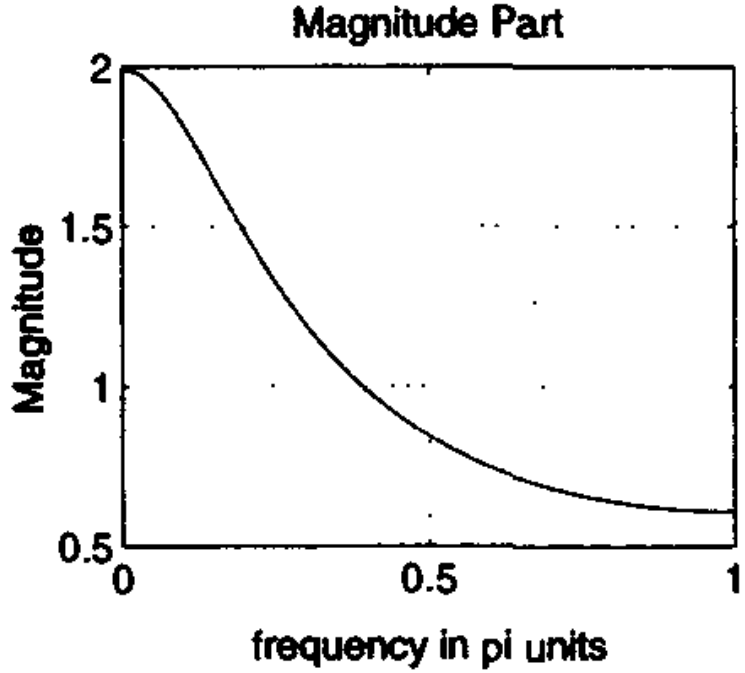
Fourier Dönüşümü

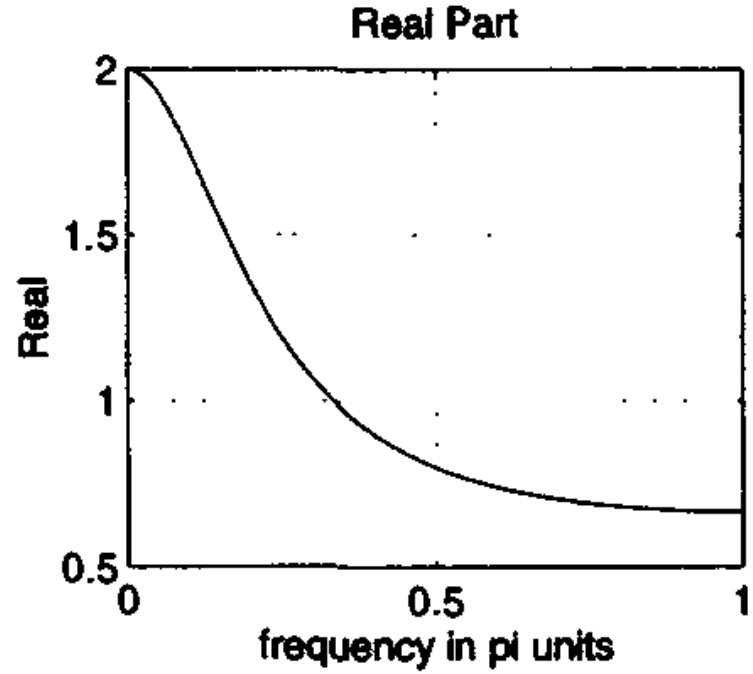
$$x(n) = (0.5)^n u(n)$$

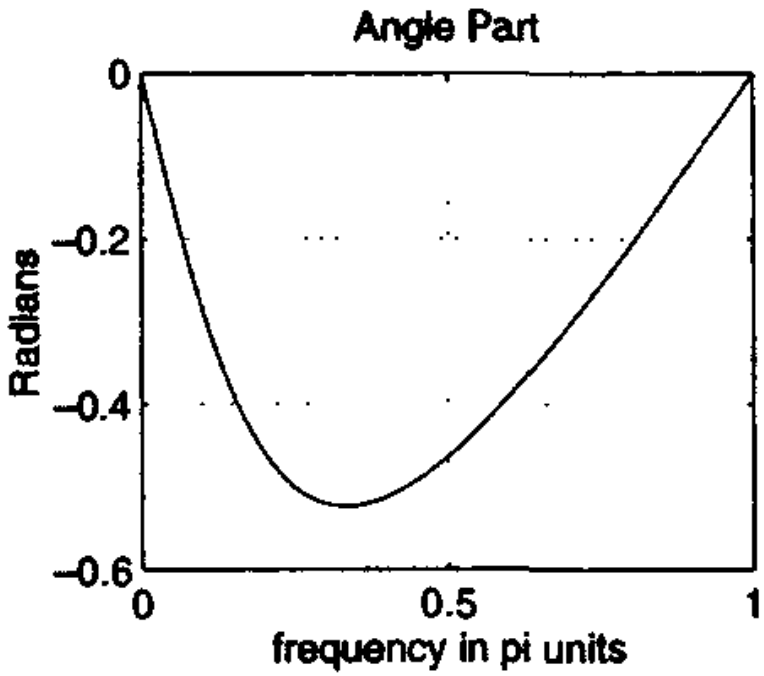
$$X(e^{j\omega}) = \sum_{-\infty}^{\infty} x(n)e^{-j\omega n} = \sum_{0}^{\infty} (0.5)^n e^{-j\omega n}$$

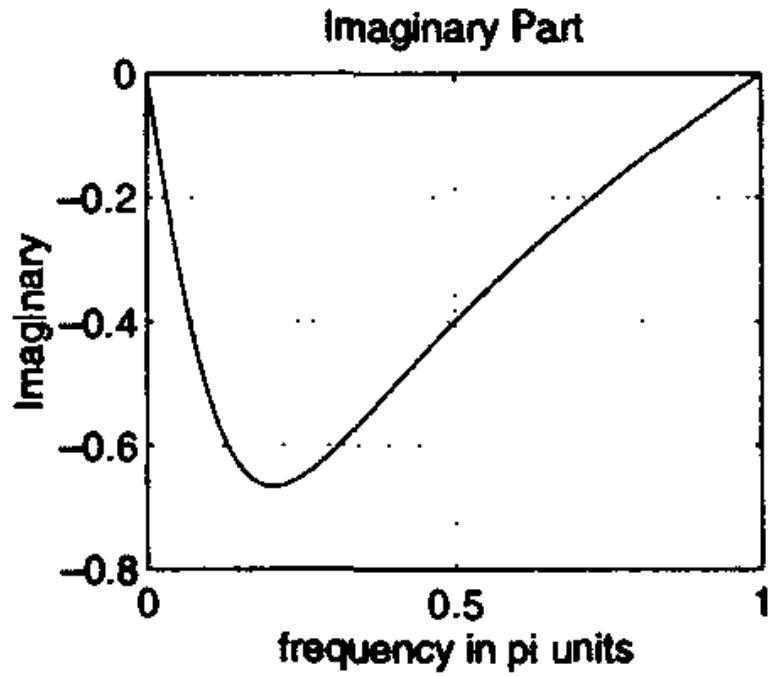
$$= \sum_{0}^{\infty} \left(0.5e^{-j\omega}\right)^n = \frac{1}{1 - 0.5e^{-j\omega}} = \frac{e^{j\omega}}{e^{j\omega} - 0.5}$$

```
>> w = [0:1:500]*pi/500;  % [0, pi] axis divided into 501 points.
>> X = exp(j*w) ./ (exp(j*w) - 0.5*ones(1,501));
>> magX = abs(X); angX = angle(X);
>> realX = real(X); imagX = imag(X);
>> subplot(2,2,1); plot(w/pi,magX); grid
>> xlabel('frequency in pi units'); title('Magnitude Part'); ylabel('Magnitude')
>> subplot(2,2,3); plot(w/pi,angX); grid
>> xlabel('frequency in pi units'); title('Angle Part'); ylabel('Radians')
>> subplot(2,2,2); plot(w/pi,realX); grid
>> xlabel('frequency in pi units'); title('Real Part'); ylabel('Real')
>> subplot(2,2,4); plot(w/pi,imagX); grid
>> xlabel('frequency in pi units'); title('Imaginary Part'); ylabel('Imaginary')
```


Magnitude Part
Magnitude
2
1.5
1
0.5
0
0.5
1
frequency in pi units


Real Part
Real
2
1.5
1
0.5
0
0.5
1
frequency in pi units

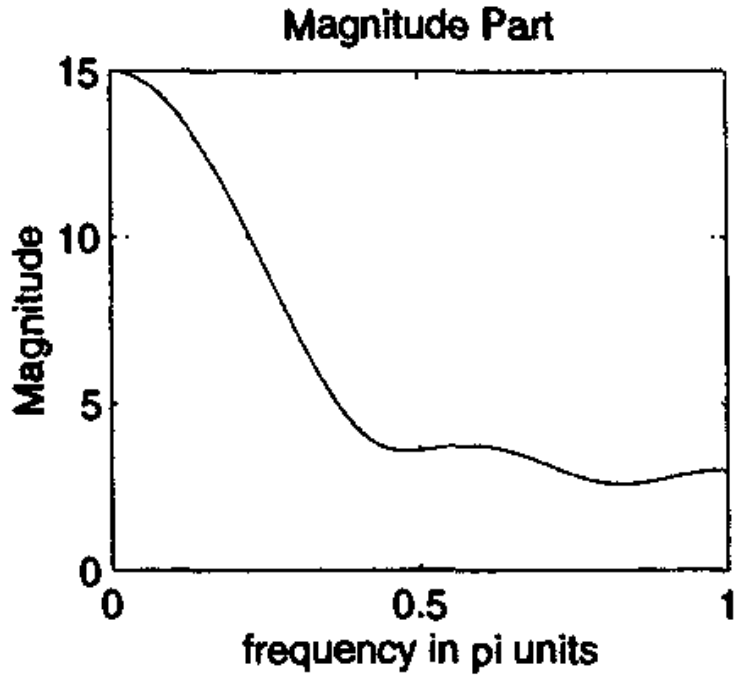

Angle Part
Radians
0
−0.2
−0.4
−0.6
0
0.5
1
frequency in pi units

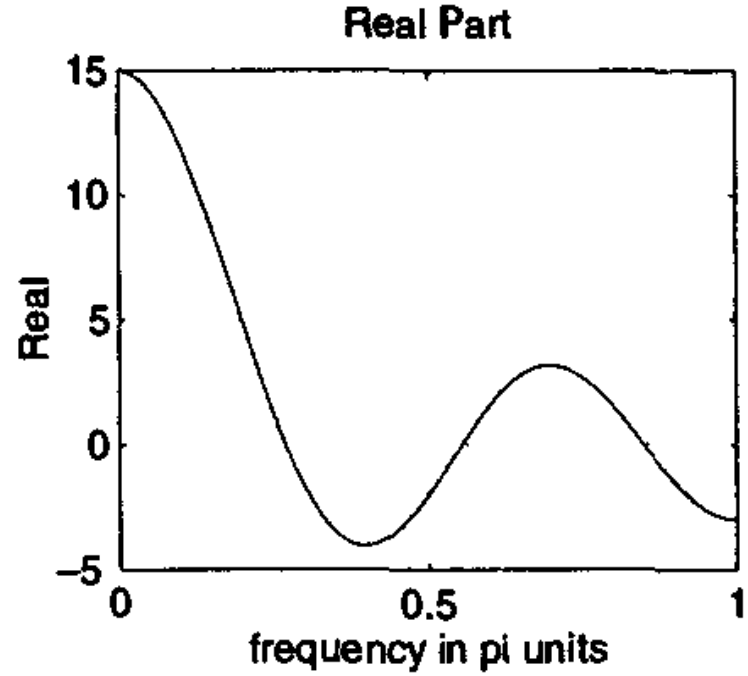

Imaginary Part
Imaginary
0
−0.2
−0.4
−0.6
−0.8
0
0.5
1
frequency in pi units

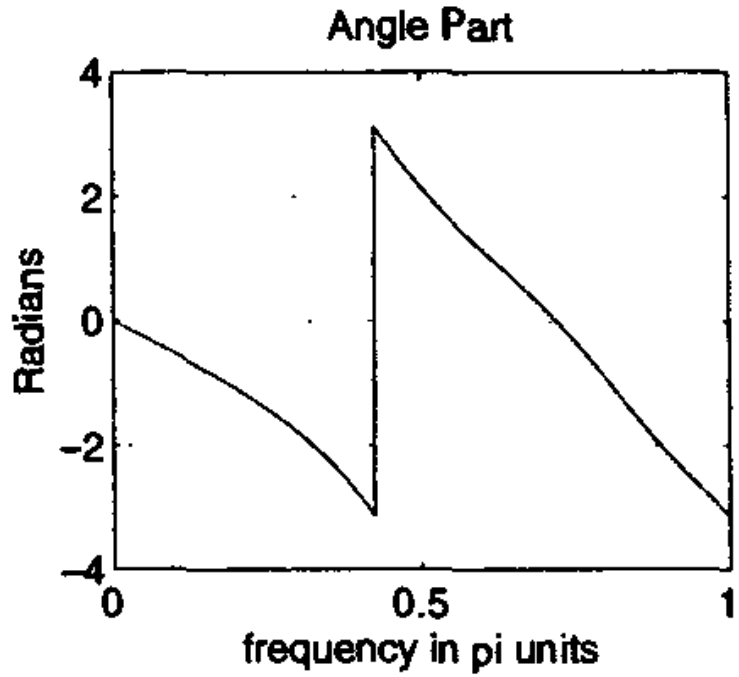
$$x(n) = \{1, \underset{\uparrow}{2}, 3, 4, 5\}$$

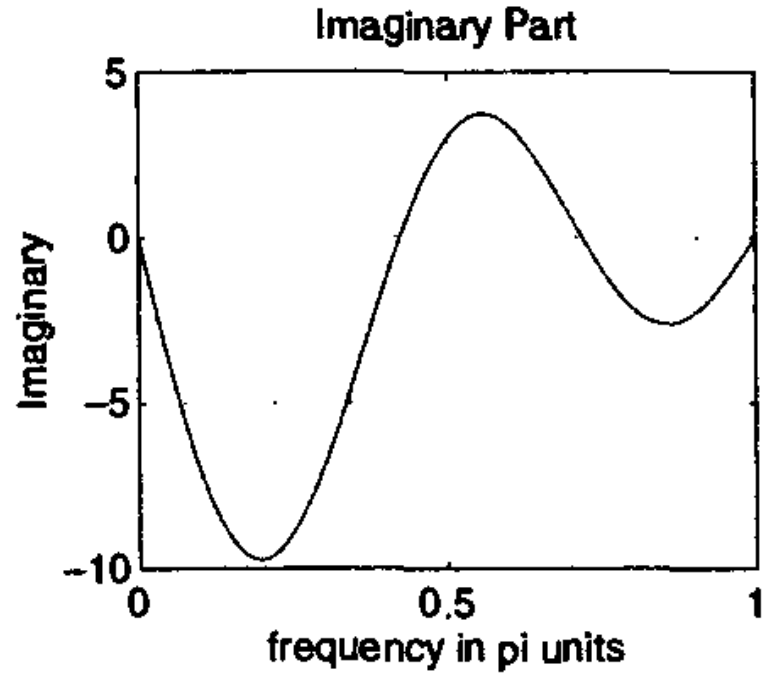
$$X(e^{j\omega}) = \sum_{-\infty}^{\infty} x(n)e^{-j\omega n} = e^{j\omega} + 2 + 3e^{-j\omega} + 4e^{-j2\omega} + 5e^{-j3\omega}$$

```
>> n = -1:3; x = 1:5;
>> k = 0:500; w = (pi/500)*k;
>> X = x * (exp(-j*pi/500)) .^ (n'*k);
>> magX = abs(X); angX = angle(X);
>> realX = real(X); imagX = imag(X);
>> subplot(2,2,1); plot(k/500,magX);grid
>> xlabel('frequency in pi units'); title('Magnitude Part')
>> subplot(2,2,3); plot(k/500,angX/pi);grid
>> xlabel('frequency in pi units'); title('Angle Part')
>> subplot(2,2,2); plot(k/500,realX);grid
>> xlabel('frequency in pi units'); title('Real Part')
>> subplot(2,2,4); plot(k/500,imagX);grid
>> xlabel('frequency in pi units'); title('Imaginary Part')
```


Magnitude Part
Magnitude
15
10
5
0
0
0.5
1
frequency in pi units

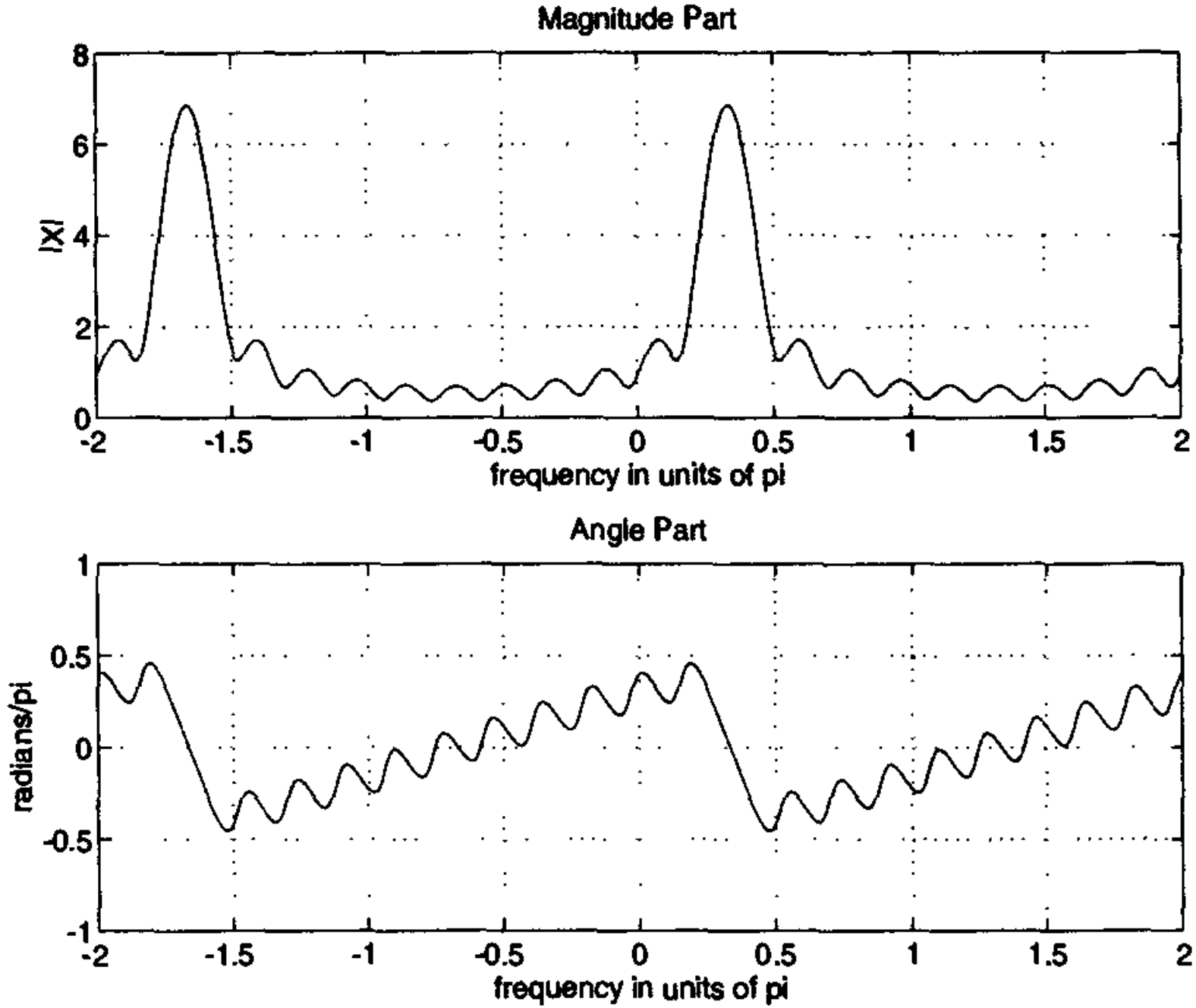

Real Part
Real
15
10
5
0
−5
0
0.5
1
frequency in pi units


Angle Part
Radians
4
2
0
−2
−4
0
0.5
1
frequency in pi units


Imaginary Part
Imaginary
5
0
−5
−10
0
0.5
1
frequency in pi units

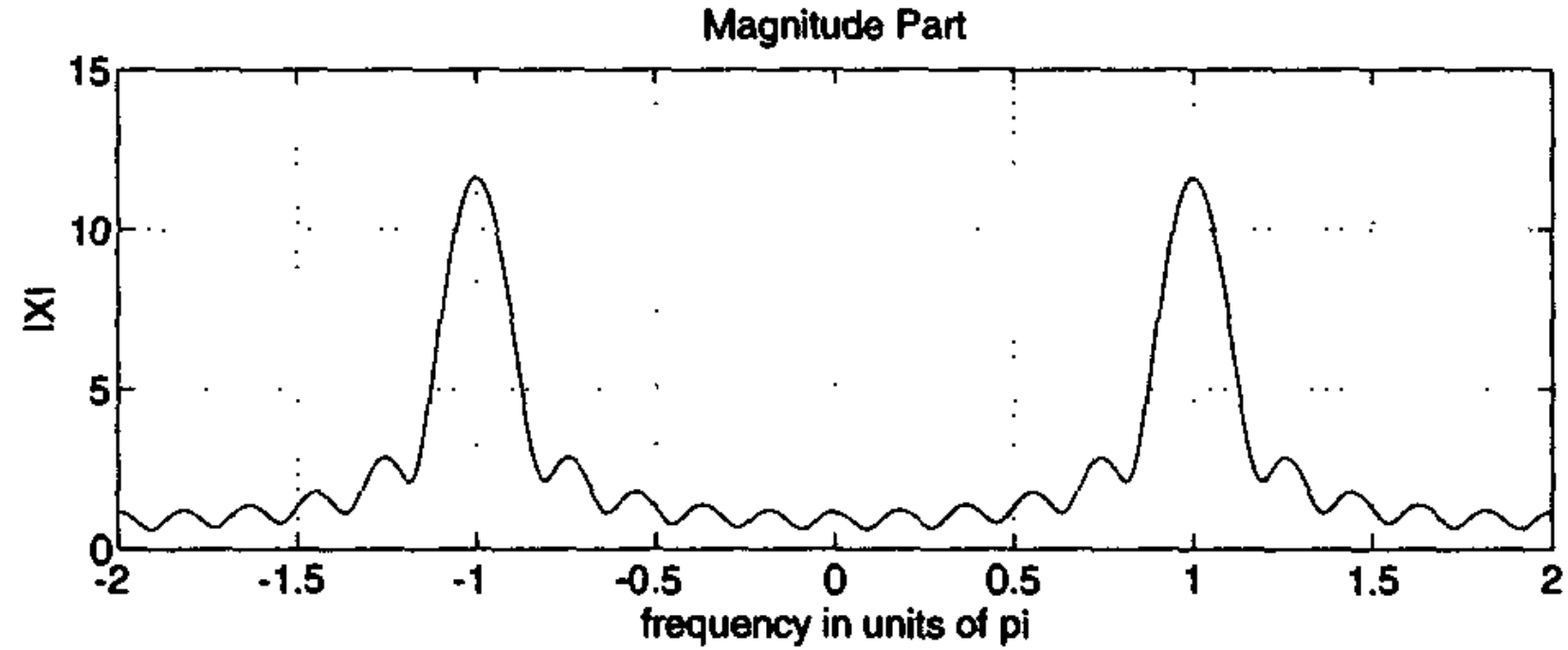
$$x(n) = (0.9\exp(j\pi/3))^n, \quad 0 \le n \le 10$$

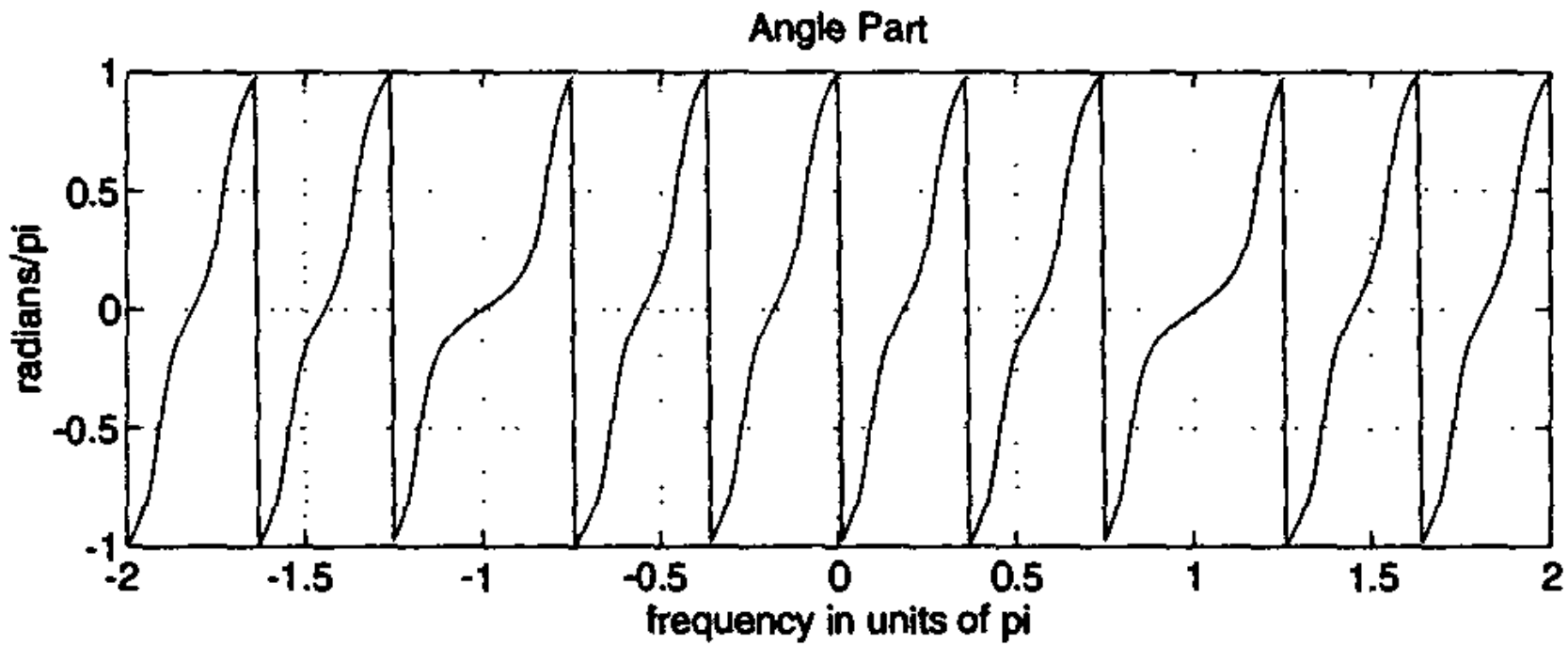
```
>> n = 0:10; x = (0.9*exp(j*pi/3)).^n;
>> k = -200:200; w = (pi/100)*k;
>> X = x * (exp(-j*pi/100)) .^ (n'*k);
>> magX = abs(X); angX =angle(X);
>> subplot(2,1,1); plot(w/pi,magX);grid
>> xlabel('frequency in units of pi'); ylabel('|X|')
>> title('Magnitude Part')
>> subplot(2,1,2); plot(w/pi,angX/pi);grid
>> xlabel('frequency in units of pi'); ylabel('radians/pi')
>> title('Angle Part')
```


Magnitude Part
|X|
8
6
4
2
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
frequency in units of pi
Angle Part
radians/pi
1
0.5
0
-0.5
-1
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
frequency in units of pi

$$x(n) = 2^n, \quad -10 \leq n \leq 10.$$

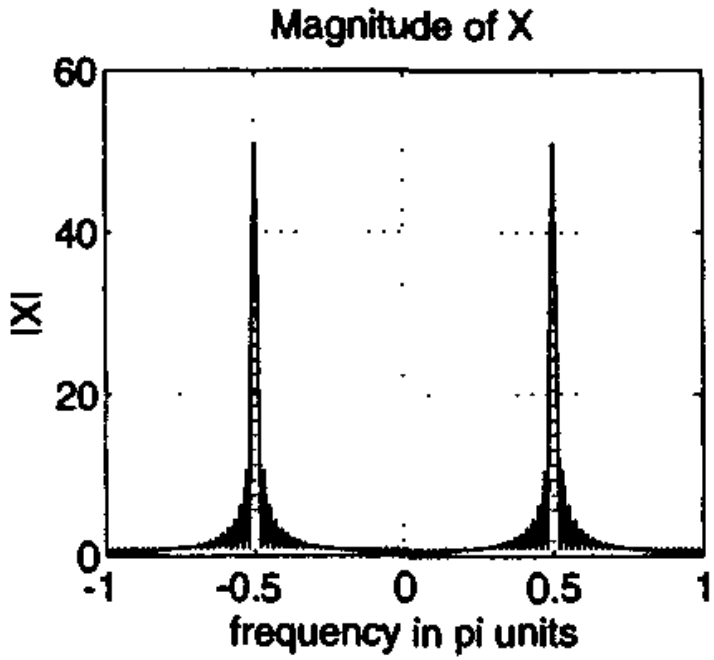
```
subplot(1,1,1)
n = -5:5; x = (-0.9).^n;
k = -200:200; w = (pi/100)*k;
X = x * (exp(-j*pi/100)) .^ (n'*k);
magX = abs(X); angX =angle(X);
subplot(2,1,1); plot(w/pi,magX);grid
axis([-2,2,0,15])
xlabel('frequency in units of pi'); ylabel('|X|')
title('Magnitude Part')
subplot(2,1,2); plot(w/pi,angX)/pi;grid
axis([-2,2,-1,1])
xlabel('frequency in units of pi'); ylabel('radians/pi')
title('Angle Part')
```

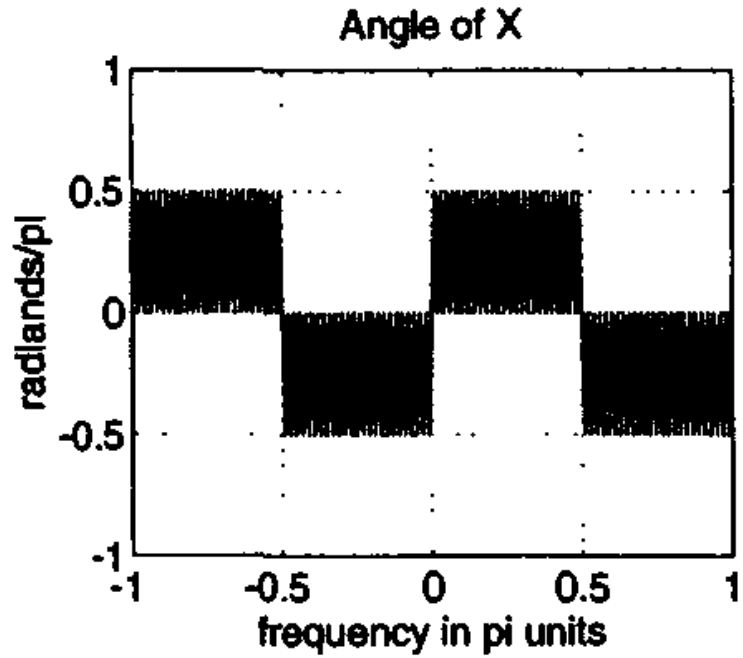

Magnitude Part
|X|
15
10
5
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
frequency in units of pi

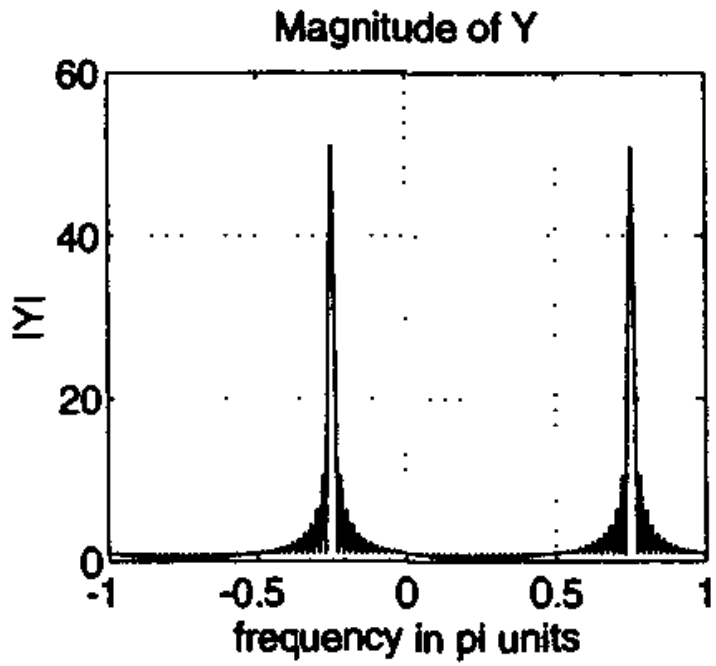

Angle Part
radians/pi
1
0.5
0
-0.5
-1
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
frequency in units of pi

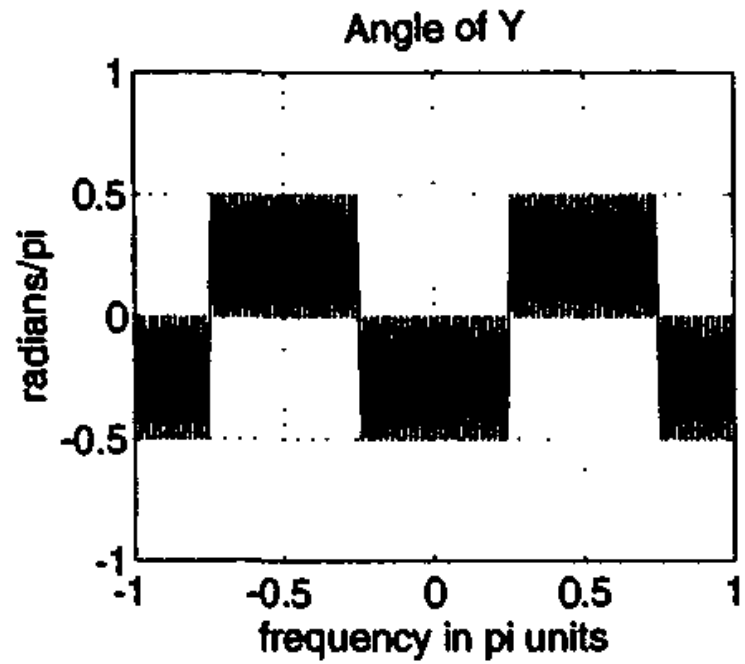
$$x(n) = \cos(\pi n/2), \quad 0 \le n \le 100 \qquad \text{and} \qquad y(n) = e^{j\pi n/4} x(n)$$

```
>> n = 0:100; x = cos(pi*n/2);
>> k = -100:100; w = (pi/100)*k;          % frequency between -pi and +pi
>> X = x * (exp(-j*pi/100)).^(n'*k);      % DTFT of x
%
>> y = exp(j*pi*n/4).*x;                  % signal multiplied by exp(j*pi*n/4)
>> Y = y * (exp(-j*pi/100)).^(n'*k);      % DTFT of y
% Graphical verification
>> subplot(1,1,1)
>> subplot(2,2,1); plot(w/pi,abs(X)); grid; axis([-1,1,0,60])
>> xlabel('frequency in pi units'); ylabel('|X|')
>> title('Magnitude of X')
>> subplot(2,2,2); plot(w/pi,angle(X)/pi); grid; axis([-1,1,-1,1])
>> xlabel('frequency in pi units'); ylabel('radiands/pi')
>> title('Angle of X')
>> subplot(2,2,3); plot(w/pi,abs(Y)); grid; axis([-1,1,0,60])
>> xlabel('frequency in pi units'); ylabel('|Y|')
>> title('Magnitude of Y')
>> subplot(2,2,4); plot(w/pi,angle(Y)/pi); grid; axis([-1,1,-1,1])
>> xlabel('frequency in pi units'); ylabel('radians/pi')
>> title('Angle of Y')
```


Magnitude of X
|X|
60
40
20
0
-1
-0.5
0
0.5
1
frequency in pi units


Angle of X
radiands/pi
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
frequency in pi units


Magnitude of Y
|Y|
60
40
20
0
-1
-0.5
0
0.5
1
frequency in pi units


Angle of Y
radians/pi
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
frequency in pi units