

Scilab Manual for
Mobile Communication
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Solutions provided by
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Experiment: 1

Digital Modulation Functions: ASK, FSK, PSK generation.

Scilab code Solution 1.1 1

```
1 //Amplitude Shift Keying, Frequency Shift Keying And
   Phase Shift keying waveform generation
2 clc;
3 clear;
4 xdel(winsid());
5 sym=10; //no. of symbols
6 g=[1 1 0 1 0 0 1 1 1 0] //binary data
7 f1=1;f2=2; //frequencies of carrier
8 t=0:2*%pi/99:2*%pi; //range of time
9 //ASK
10 cp=[];bit=[];mod_ask=[];mod_fsk=[];mod_psk=[];cp1
   =[];cp2=[];
11 for n=1:length(g); //ASK modulation // Zeros and
   ones are inserted for proper plot of message
   signal
12     if g(n)==0;
13         die=zeros(1,100);
14     else g(n)==1;
15         die=ones(1,100);
```

```

16     end
17     c_ask=sin(f1*t);
18     cp=[cp die];
19     mod_ask=[mod_ask c_ask];
20     end
21 ask=cp.*mod_ask; //ASK modulated signal
22
23 //FSK
24 for n=1:length(g);
25     if g(n)==0;
26         die=ones(1,100);
27         c_fsk=sin(f1*t);
28     else g(n)==1;
29         die=ones(1,100);
30         c_fsk=sin(f2*t);
31     end
32     cp1=[cp1 die];
33     mod_fsk=[mod_fsk c_fsk];
34 end
35 fsk=cp1.*mod_fsk; //FSK modulated signal
36
37 //PSK
38 for n=1:length(g);
39     if g(n)==0;
40         die=ones(1,100);
41         c_psk=sin(f1*t);
42     else g(n)==1;
43         die=ones(1,100);
44         c_psk=-sin(f1*t);
45     end
46     cp2=[cp2 die];
47     mod_psk=[mod_psk c_psk];
48 end
49 psk=cp2.*mod_psk; //PSK modulated signal
50 subplot(4,1,1); plot(cp, 'LineWidth', 1.5); //plot
    binary signal
51 xgrid;
52 title('Binary Signal'); //title

```

```
53 mtlb_axis([0 100*length(g) -2.5 2.5]); //axis range
54 subplot(4,1,2);plot(ask,'LineWidth',1.5);//plot of
    ASK modulated signal
55 xgrid;
56 title('ASK modulation');//title of plot
57 mtlb_axis([0 100*length(g) -2.5 2.5]);//axis range
58 subplot(4,1,3);plot(fsk,'LineWidth',1.5);//plot of
    FSK modulated signal
59 xgrid;
60 title('FSK modulation');//title of plot
61 mtlb_axis([0 100*length(g) -2.5 2.5]);//axis range
62 subplot(4,1,4);plot(psk,'LineWidth',1.5);//plot of
    PSK modulated signal
63 xgrid;
64 title('PSK modulation');//title of plot
65 mtlb_axis([0 100*length(g) -2.5 2.5]);//range of
    axis
66 //Result: This experiment results plots of binary
    data, ASK modulation,FSK modulation and PSK
    modulation
```

Experiment: 2

Constellation diagram and Error Rate performance of different modulation techniques with AWGN channel.

Scilab code Solution 2.1 Sigal space diagram of different modulation

```
1 // Constellation diagram of BPSK and QPSK modulation
   and BPSK and QPSK modulation over AWGN channel
2 clc;
3 clear;
4 xdel(winsid());
5 sym=20; //No .of symbols
6 data1=grand(1,sym,"uin",0,1); //Random symbol
   generation from 0 to 1 with uniform distribution
7 snr=10; // Signal to Noise Ratio
8 qpsk_mod=[];
9 bpsk_mod=2*data1-1; //BPSK Modulation
10 for j=1:2:length(data1) // Seperation of I & Q
   component for QPSK modulation
11     i_phase=2*data1(j)-1; //BPSK modulation of I phase
   component
```



```

12     q_phase=2*data1(j+1)-1; //BPSK modulation of Q
        phase component
13     temp=i_phase+%i*q_phase; //Combinibg I phase and Q
        phase component for QPSK modulation
14     qpsk_mod=[qpsk_mod temp]; //QPSK modulated signal
15 end
16
17     noise=1/sqrt(2)*(10^(-(snr/20)))*(rand(1,length(
        bpsk_mod), 'normal')+%i*(rand(1,length(bpsk_mod)
        , 'normal'))); //White gaussian noise generation
        for bpsk
18     noise1=1/sqrt(2)*(10^(-(snr/20)))*(rand(1,length(
        qpsk_mod), 'normal')+%i*(rand(1,length(qpsk_mod)
        , 'normal'))); //White gaussian noise generation
        for qpsk
19     bpsk_awgn=bpsk_mod+noise; //BPSK Modulated signal
        passed over AWGN channel
20     qpsk_awgn=qpsk_mod+noise1; //QPSK Modulated signal
        passed over AWGN channel
21
22     figure //constellation diagram of ideal BPSK
        modulated signal and BPSK modulated signal with
        White Gaussian Noise
23 a = gca(); //to handle various object
24 a.data_bounds = [ -1 , -1;1 ,1];
25 a.x_location = "origin";
26 a.y_location = "origin";
27 plot2d ( real(bpsk_mod), imag(bpsk_mod), -2);
28 plot2d ( real(bpsk_awgn), imag(bpsk_awgn), -5);
29 xlabel( 'In phase' ); //X-axis label
30 ylabel( 'Quadrature phase' ); //Y-axis label
31 title( 'Constellation for BPSK with AWGN' ); //title
        of plot
32 legend(['Ideal message point'; 'message point with
        noise']); //legend
33 mtlb_axis([-2 2 -2 2]); //range of axis
34 figure //constellation diagram of ideal QPSK
        modulated signal and QPSK modulated signal with

```

```

    White Gaussian Noise
35 a = gca();//to handle various object
36 a.data_bounds = [ -1 , -1;1 ,1];
37 a.x_location = "origin";
38 a.y_location = "origin";
39 plot2d ( real(qpsk_mod),imag(qpsk_mod),-2);
40 plot2d ( real(qpsk_awgn),imag(qpsk_awgn),-5);
41 xlabel( 'In phase' );//X-axis label
42 ylabel( 'Quadrature phase' );//Y-axis label
43 title( 'Constellation for QPSK with AWGN' );//title
    of plot
44 legend(['Ideal message point';'message point with
    noise']);//legend
45 mtlb_axis([-2 2 -2 2]);//range of axis
46 //Result:Generates two plots: BPSK modulated signal
    with and without noise-figure-0
47 //QPSK modulated signal with
    and without noise-figure-1

```

Scilab code Solution 2.2 BER of BPSK and QPSK over AWGN Channel

```

1 //Performance comparison of Simulated BER and
    Theoretical BER of BPSK and QPSK modulation over
    AWGN channel
2 clc;
3 clear;
4 xdel(winsid());
5 sym=10000;//No .of symbols
6 M=4;
7 qpsk_mod=[];i_phase=[];
8 data1=grand(1,sym,"uin",0,1);//Random Symbol
    generation from 0 to 1 with uniform distribution
9 for j=1:2:length(data1)// Seperation of I & Q
    component
10     i_phase=2*data1(j)-1;// BPSK modulation of I

```

```

    phase component
11     q_phase=2*data1(j+1)-1; //BPSK modulation of Q
        phase component
12     temp=i_phase+%i*q_phase; //combining of I phase
        and Q phase component for QPSK modulation
13     qpsk_mod=[qpsk_mod temp]; //QPSK modulated signal
14     end
15     bpsk_mod=2*data1-1; //BPSK Modulated signal
16
17     snr=1:10; //Signal to Noise Ratio
18     for k=1:1:length(snr)
19         H=1/sqrt(2)*(rand(1,length(qpsk_mod),'normal
                ')+%i*(rand(1,length(qpsk_mod),'normal'))
                );
20         noise1=1/sqrt(2)*(10^(-(k/20)))*(rand(1,
                length(qpsk_mod),'normal')+%i*(rand(1,
                length(qpsk_mod),'normal'))); //White
                Gaussian Noise generation for QPSK
21         noise=1/sqrt(2)*(10^(-(k/20)))*(rand(1,
                length(bpsk_mod),'normal')+%i*(rand(1,
                length(bpsk_mod),'normal'))); //White
                Gaussian Noise generation for QPSK
22         rec1_qpsk=qpsk_mod+noise1; //QPSK
                modulated signal over AWGN channel
23         rec1_bpsk= bpsk_mod+noise; //BPSK
                modulated signal over AWGN channel
24
25         rec_data_qpsk=[]; rec_data_bpsk=[];
26         rec1_i=real(rec1_qpsk); //Seperation
                of I phase and Q phase comopnent
                of received QPSK modulated signal
27         rec1_q=imag(rec1_qpsk);
28         //
29         for i=1:length(rec1_i) //QPSK Demodulation:
                BPSK demodulation of I phase and Q phase
                components
30             if rec1_i(i)>=0
31                 demod_out_i=1;

```

```

32         else rec1_i(i)<0
33             demod_out_i=0;
34         end
35         if rec1_q(i)>=0
36             demod_out_q=1;
37         else rec1_q(i)<0
38             demod_out_q=0;
39         end
40         rec_data_qpsk=[rec_data_qpsk demod_out_i
41             demod_out_q]; //QPSK Demodulated signal
42         end
43         for i=1:length(data1) //BPSK Demodulation
44             if real(rec1_bpsk(i))>=0
45                 demod_out_bpsk=1;
46             else real(rec1_bpsk(i))<0
47                 demod_out_bpsk=0;
48             end
49             rec_data_bpsk=[rec_data_bpsk
50                 demod_out_bpsk]; //BPSK Demodulated
51                 signal
52         end
53         errA=0;errB=0;
54         for i=1:sym
55             if rec_data_qpsk(i)==data1(i)
56                 errA=errA;
57             else
58                 errA=errA+1;
59             end
60         end
61         BER_qpsk(k)=errA/sym; // BER of QPSK
62         for i=1:sym
63             if rec_data_bpsk(i)==data1(i)
64                 errB=errB;
65             else
66                 errB=errB+1;
67             end

```

```

67
68     BER_bpsk(k)=errB/sym; //BER of BPSK
69     end
70     theoryBer = 0.5*erfc(sqrt(10.^(snr/10))); //
        Theoretical BER of BPSK & QPSK
71     end
72
73     // end
74 snr=1:1:10;
75 plot2d(snr, BER_bpsk, 5, logflag="nl"); //plot simulated
        BER of BPSK over AWGN channel
76 plot2d(snr, BER_qpsk, 2, logflag="nl"); //plot simulated
        BER of QPSK over AWGN channel
77 plot2d(snr, theoryBer, 3, logflag="nl"); //Plot
        theoretical BER of QPSK and BPSK over AWGN
        channel
78 mtlb_axis([0 20 10^-5 0.5]); // axis
79 xgrid(10);
80 xtitle( 'Bit Error Rate plot for BPSK & QPSK
        Modulation', 'SNR', 'BER') ; //title of plot
81
82
83 legend(['BER_sim_BPSK'; 'BER_sim_QPSK'; 'BER_Theory'])
        ; //legend
84 //This experiments results plot of bit error rate(
        BER) comparison of simulated BPSK over AWGN
        channel, simulated QPSK over AWGN channel and
        theoretical BER of BPSK and QPSK
85 // It will take few minutes to get plots as 100000
        bits are applied as an input to get better plots

```

Experiment: 3

Effect of various channel on transmitted data using different modulation techniques.

Scilab code Solution 3.1 BER BPSK Rayleigh fading channel

```
1 //Error rate performance of BPSK modulated signal
   over only AWGN channel and AWGN and Rayleigh
   channel both
2 clc;
3 clear;
4 xdel(winsid());
5 sym=10000; //No .of symbols
6 data1=grand(1,sym,"uin",0,1); //Randomly generated
   Symbols from 0 to 1 with uniform distribution
7
8 bpsk_mod=2*data1-1; //BPSK Modulation
9 snr=1:20; //signal to Noise Ratio
10    for k=1:1:length(snr)
11
12        H1=1/sqrt(2)*(rand(1,length(bpsk_mod),'
           normal')+%i*(rand(1,length(bpsk_mod),'
           normal'))); //Rayleigh fading generation
```

```

13
14     noise=1/sqrt(2)*(10^(-(k/20)))*(rand(1,
        length(bpsk_mod), 'normal')+%i*(rand(1,
        length(bpsk_mod), 'normal'))); // White
        Gaussian Noise generation
15
16         rec1_bpsk=bpsk_mod+noise; //BPSK
            modulated signal over AWGN channel
17     rec1_bpsk_ray1= H1.*bpsk_mod+noise; //
        BPSK modulated signal over AWGN
        channel and Rayleigh Fading
        channel
18     rec1_bpsk_ray=conj(H1).*rec1_bpsk_ray1
        ; //multiplication with conjugate of
        rayleigh fading to nullify phase
        because of Rayleigh Fading
19     // rec1_bpsk_ray=rec1_bpsk_ray1./(H1.*
        conj(H1));
20
21     rec_data_bpsk=[]; rec_ray_bpsk=[];
22
23     for i=1:1:length(data1) //BPSK Demodulation
        of received signal over AWGN channel
24         if real(rec1_bpsk(i))>=0
25             demod_out_bpsk=1;
26         else real(rec1_bpsk(i))<0
27             demod_out_bpsk=0;
28         end
29     rec_data_bpsk=[rec_data_bpsk
        demod_out_bpsk]; //Received signal
30
31     if real(rec1_bpsk_ray(i))>=0 //BPSK
        Demodulation of received signal over
        AWGN channel and Rayleigh channel
32         demod_ray_bpsk=1;
33     else real(rec1_bpsk_ray(i))<0
34         demod_ray_bpsk=0;
35     end

```

```

36         rec_ray_bpsk=[rec_ray_bpsk
37                     demod_ray_bpsk];/////Received signal
38     end
39     errB=0;errC=0;
40     for i=1:sym
41
42         if rec_data_bpsk(i)==data1(i)//Error rate
43             calculation of received signal by
44             considering only AWGN Channel
45             errB=errB;
46         else
47             errB=errB+1;
48         end
49
50         BER_bpsk(k)=errB/sym;//BER at receiver by
51         considering only AWGN Channel
52
53         if rec_ray_bpsk(i)==data1(i)//Error rate
54             calculation of received signal by
55             considering AWGN Channel and Rayleigh
56             channel
57             errC=errC;
58         else
59             errC=errC+1;
60         end
61
62         BER_bpsk_ray(k)=errC/sym;//BER at receiver
63         by considering AWGN Channel and rayleigh
64         channel
65     end end
66
67     // end
68     snr=1:1:20;
69     plot2d(snr, BER_bpsk,5,logflag="nl");
70     plot2d(snr, BER_bpsk_ray,3,logflag="nl");
71     mtlb_axis([0 20 10^-5 0.5]);
72     xgrid(10);

```



```

65 xtitle( 'Bit Error Rate plot for BPSK modulated
    signal over AWGN channel and AWGN and Rayleigh
    channel both', 'SNR', 'BER') ;
66 legend(['BER_BPSK_AWGN'; 'BER_BPSK_AWGN & Rayleigh'])
    ;
67 //This experiment results plot of error rate
    performance of BPSK modulated signal over AWGN
    channe and AWGN and Rayleigh channel both.
68 //This experiment will take some time to display
    plot as higher no. of bits entered as an input to
    get better plots.

```

Scilab code Solution 3.2 BER QPSK Rayleigh channel

```

1 //Error rate performance of QPSK modulated signal
    over only AWGN channel and AWGN and Rayleigh
    channel both
2 clc;
3 clear;
4 xdel(winsid());
5 sym=10000;//No .of symbols
6 M=4;
7 qpsk_mod=[]; i_phase=[];
8 data1=grand(1, sym, "uin", 0, 1); //Random Symbol
    generation from 0 to 1 with uniform distribution
9 for j=1:2:length(data1) // Seperation of I & Q
    component
10     i_phase=2*data1(j)-1; // BPSK modulation of I
        phase component
11     q_phase=2*data1(j+1)-1; //BPSK modulation of Q
        phase component
12     temp=i_phase+%i*q_phase; //combining of I phase
        and Q phase component for QPSK modulation
13     qpsk_mod=[qpsk_mod temp]; //QPSK modulated signal
14 end

```

```

15
16 snr=1:5:41; //Signal to Noise Ratio
17 for k=1:length(snr)
18     H=1/sqrt(2)*(rand(1,length(qpsk_mod),'normal
        ')+%i*(rand(1,length(qpsk_mod),'normal')))
        ); //Rayleigh fading generation
19
20     noise1=1/sqrt(2)*(10^(-(k/20)))*(rand(1,
        length(qpsk_mod),'normal')+%i*(rand(1,
        length(qpsk_mod),'normal'))); //White
        Gaussian Noise generation for QPSK
21
22         rec1_qpsk=qpsk_mod+noise1; //QPSK
        modulated signal over AWGN channel
23         rec1_qpsk_ray1= H.*qpsk_mod+noise1;
        //BPSK modulated signal over AWGN
        channel and Rayleigh Fading
        channel
24         rec1_qpsk_ray=conj(H).*rec1_qpsk_ray1
        ; //multiplication with conjugate
        of rayleigh fading to nullify
        phase because of Rayleigh Fading
25
26         rec_data_qpsk=[]; rec_data_qpsk_ray
        =[];
27
28         rec1_i=real(rec1_qpsk); //Seperation
        of I phase and Q phase comopnent
        of received QPSK modulated signal
29         rec1_q=imag(rec1_qpsk);
30
31         rec1_i_ray=real(rec1_qpsk_ray); //
        Seperation of I phase and Q phase
        comopnent of received QPSK
        modulated signal
32         rec1_q_ray=imag(rec1_qpsk_ray);
33         //
34         for i=1:length(rec1_i) //QPSK Demodulation:

```

BPSK demodulation of I phase and Q phase components

```
35     if rec1_i(i)>=0
36         demod_out_i=1;
37     else rec1_i(i)<0
38         demod_out_i=0;
39     end
40     if rec1_q(i)>=0
41         demod_out_q=1;
42     else rec1_q(i)<0
43         demod_out_q=0;
44     end
45     if rec1_i_ray(i)>=0
46         demod_out_i_ray=1;
47     else rec1_i(i)<0
48         demod_out_i_ray=0;
49     end
50     if rec1_q_ray(i)>=0
51         demod_out_q_ray=1;
52     else rec1_q_ray(i)<0
53         demod_out_q_ray=0;
54     end
55     rec_data_qpsk=[rec_data_qpsk demod_out_i
56                 demod_out_q]; //QPSK Demodulated signal
57     rec_data_qpsk_ray=[rec_data_qpsk_ray
58                     demod_out_i_ray demod_out_q_ray]; //
59     QPSK Demodulated signal
60     end
61     errA=0; errB=0;
62     for i=1:sym
63         if rec_data_qpsk(i)==data1(i)
64             errA=errA;
65         else
66             errA=errA+1;
67         end
68     end
69     BER_qpsk(k)=errA/sym; // BER of QPSK
```

```

68
69         for i=1:sym
70             if rec_data_qpsk_ray(i)==data1(i)
71                 errB=errB;
72             else
73                 errB=errB+1;
74             end
75
76             BER_qpsk_ray(k)=errB/sym; //BER of BPSK
77         end
78         //theoryBer = 0.5*erfc(sqrt(10.^(snr/10))); //
           Theoretical BER of BPSK & QPSK
79     end
80
81         // end
82     snr=1:5:41;
83     plot2d(snr, BER_qpsk, 5, logflag="nl"); //plot simulated
           BER of BPSK over AWGN channel
84     plot2d(snr, BER_qpsk_ray, 2, logflag="nl"); //plot
           simulated BER of QPSK over AWGN channel
85     //plot2d(snr, theoryBer, 3, logflag="nl"); //Plot
           theoretical BER of QPSK and BPSK over AWGN
           channel
86     mtlb_axis([0 40 10^-5 0.5]); //axis
87     xgrid(10);
88     xtitle('Bit Error Rate plot for QPSK over AWGN
           channel & AWGN and Rayleigh channel both', 'SNR',
           'BER') ; //title of plot
89
90     legend(['BER_QPSK_AWGN'; 'BER_QPSK_AWGN & Rayleigh'])
           ; //legend
91     //This experiments results plot of bit error rate(
           BER) comparison of simulated QPSK over AWGN
           channel, simulated QPSK over AWGN channel and
           Rayleigh fading channel.
92     // It will take few minutes to get plots as 10000
           bits are applied as an input to get better plots

```

Scilab code Solution 3.3 1

```
1 //Error rate performance of BPSK modulated signal
   over only AWGN channel and AWGN and Rayleigh
   channel both
2 clc;
3 clear;
4 xdel(winsid());
5 sym=10000; //No .of symbols
6 data1=grand(1, sym, "uin", 0, 1); //Randomly generated
   Symbols from 0 to 1 with uniform distribution
7
8 bpsk_mod=2*data1-1; //BPSK Modulation
9 snr=1:20; //signal to Noise Ratio
10 for k=1:1:length(snr)
11
12     H1=1/sqrt(2)*(rand(1, length(bpsk_mod), '
        normal')+%i*(rand(1, length(bpsk_mod), '
        normal'))); //Rayleigh fading generation
13
14     noise=1/sqrt(2)*(10^(-(k/20)))*(rand(1,
        length(bpsk_mod), 'normal')+%i*(rand(1,
        length(bpsk_mod), 'normal'))); // White
        Gaussian Noise generation
15
16     rec1_bpsk=bpsk_mod+noise; //BPSK
        modulated signal over AWGN channel
17     rec1_bpsk_ray1= H1.*bpsk_mod+noise; //
        BPSK modulated signal over AWGN
        channel and Rayleigh Fading
        channel
18     rec1_bpsk_ray=conj(H1).*rec1_bpsk_ray1
        ; //multiplication with conjugate of
        rayleigh fading to nullify phase
```

```

19         because of Rayleigh Fading
           // rec1_bpsk_ray=rec1_bpsk_ray1./(H1.*
           conj(H1));
20
21         rec_data_bpsk=[];rec_ray_bpsk=[];
22
23         for i=1:1:length(data1)//BPSK Demodulation
           of received signal over AWGN channel
24             if real(rec1_bpsk(i))>=0
25                 demod_out_bpsk=1;
26             else real(rec1_bpsk(i))<0
27                 demod_out_bpsk=0;
28             end
29         rec_data_bpsk=[rec_data_bpsk
           demod_out_bpsk];//Received signal
30
31         if real(rec1_bpsk_ray(i))>=0 //BPSK
           Demodulation of received signal over
           AWGN channel and Rayleigh channel
32             demod_ray_bpsk=1;
33         else real(rec1_bpsk_ray(i))<0
34             demod_ray_bpsk=0;
35         end
36         rec_ray_bpsk=[rec_ray_bpsk
           demod_ray_bpsk];////Received signal
37     end
38
39     errB=0;errC=0;
40     for i=1:sym
41
42         if rec_data_bpsk(i)==data1(i)//Error rate
           calculation of received signal by
           considering only AWGN Channel
43             errB=errB;
44         else
45             errB=errB+1;
46         end
47

```

```

48         BER_bpsk(k)=errB/sym; //BER at receiver by
           considering only AWGN Channel
49
50         if rec_ray_bpsk(i)==data1(i) //Error rate
           calculation of received signal by
           considering AWGN Channel and Rayleigh
           channel
51             errC=errC;
52         else
53             errC=errC+1;
54         end
55
56         BER_bpsk_ray(k)=errC/sym; //BER at receiver
           by considering AWGN Channel and rayleigh
           channel
57     end end
58
59     // end
60 snr=1:1:20;
61 plot2d(snr, BER_bpsk, 5, logflag="nl");
62 plot2d(snr, BER_bpsk_ray, 3, logflag="nl");
63 mtlb_axis([0 20 10^-5 0.5]);
64 xgrid(10);
65 xtitle('Bit Error Rate plot for BPSK modulated
           signal over AWGN channel and AWGN and Rayleigh
           channel both', 'SNR', 'BER') ;
66 legend(['BER_BPSK_AWGN'; 'BER_BPSK_AWGN & Rayleigh'])
        ;
67 //This experiment results plot of error rate
           performance of BPSK modulated signal over AWGN
           channe and AWGN and Rayleigh channel both.
68 //This experiment will take some time to display
           plot as higher no. of bits entered as an input to
           get better plots.

```

Experiment: 4

Trunking Theory for Probability of blocking(Erlang B) and probability of delay(Erlang C).

Scilab code Solution 4.1 Traffic calculation in Erlang B and Erlang C system

```
1 //Exp-4 Calculates maximum traffic intensity and
   maximum no. of users accomodated in Erlang B and
   Erlang C system for given no of channels
2 clc;
3 clear;
4 xdel(winsid());
5
6 function [p1]=erlangB(A1,c1)// calculate blocking
   probability for Erlang B system
7     pr2=0;
8     pr1=A1^c1/factorial(c1);
9     for k=1:c1
10        pr2=pr2+(A1^k/factorial(k));
11    end
```



```

12     // A1=A1+1;
13     p1=pr1/pr2;
14 endfunction
15
16 function [p2]=erlangC(A2,c2)// calculate
    probability of blocked call delayed in Erlang C
    system
17     temp_1=0;
18 for k=0:c2-1
19     temp_1=temp_1+A2^k/factorial(k);
20 end
21 denominator=A^c2+(factorial(c2)*(1-(A2/c))*temp_1);
22 p2=A2^c2/denominator;
23 endfunction
24
25 pr_blocking=input('enter probability of blocking');
    //enter probability of blocking for particular
    system
26 pr_delay=input('enter probability of block call
    delay ');//enter probability of blocked call
    delayed for particular system
27 y=input('enter call rate');// Average no .of calls
    per minute
28 H=input('enter the average call duration');//
    Average call duration in minute
29 c=input("enter no.of channels");//Enter no. of
    channels
30 disp("no. of channel=");
31 disp(c);
32 Au=y*H;//Traffic intensity per user
33
34 p=0;
35 for A=1:1:100
36     while(p<pr_blocking)//Find maximum traffic
        intensity for entered blocking
        probability pr_blocking
37     [p]=erlangB(A,c)//calling function erlangB
38     A=A+1;

```

```

39         end
40         disp(pr_blocking, 'for blocking probability of '
41             '); //display blocking probability
42         disp(A-1, 'Maximum traffic intensity is '); //
43             display max. traffic intensity
44         u=(A-1)/Au; //no. of users calculation
45         disp(u, "no .of users are accomodated"); //
46             display maximum no.of users accomodated in
47             Erlang B system
48     break;
49 end //
50 p=0;
51 for A=1:1:100
52     while(p<pr_delay) //Find maximum traffic
53         intensity for entered blocking probability
54         pr_blocking
55         [p]=erlangC(A,c) //calling funtion to
56         calculate erlang C probability
57         A=A+1;
58     end
59     disp(pr_delay, 'for block call delay
60         probability of '); //display blocking
61         probability
62     disp(A-1, 'Maximum traffic intensity is '); //
63         display max. traffic intensity
64     u=(A-1)/Au;
65     disp(u, "no.of users are accomodated"); //
66         display maximum no.of users accomodated in
67         Erlang C system
68     break;
69 end
70 //Enter blocking probability pr_blocking=0.01
71 //Enter probaboly of block call delay pr_delay
72     =0.1
73 //Enter call rate= 3/60
74 //enter call duration= 2(in minute)
75 //Enter no of channels 50
76

```

```
64 //Output:
65 //no.of channel= 50.
66
67 // for blocking probability of 0.01
68 // Maximum traffic intensity is 38.
69 // no .of users are accomodated 380.
70
71 // for block call delay probability of 0.1
72 // Maximum traffic intensity is 41.
73 //no.of users are accomodated 410.
```

Experiment: 5

Walsh Code generation

Scilab code Solution 5.1 Walsh code generation and spreading and de-spreading using Walsh code

```
1 // Walsh Code generation
2 //Spreading and despreading of information for three
   users using Walsh code
3 clc;
4 clear;
5 xdel(winsid());
6 a=input('enter the number order of 2:'); //input
   required length of Walsh Code which is always
   order of 2
7 c1=[1 -1 -1]; //information of user 1
8 c2=[-1 1 -1]; //information of user 2
9 c3=[1 -1 1]; //information of user 3
10 W=[0 0;0 1]; // Basic Walsh code Matrix
11 m=2;
12 %n=2^m;
13 for m =2:1:a
14 for i = 1:1:a //genration of walsh code matrix of
   entered length
15     if i==2^m
16         Winv=bitcmp(W,1);
```

```

17         W=[W W;W Winv];
18         end
19
20     end
21 end
22 temp=0;
23 W1=[];
24 disp(W)
25 for i=1:1:length(W(1,:))//0 replaced by -1 in walsh
    code matrix
26     for j=1:1:length(W(1,:))
27         if W(i,j)==0 then
28             W(i,j)=W(i,j)-1;
29         else W(i,j)=W(i,j)+0;
30
31         end
32
33     end
34
35 end
36 //disp(W)
37 //spreading using Walsh code
38 tans_c1=[c1(1,1).*W(1,:) c1(1,2).*W(1,:) c1(1,3).*W
    (1,:)];//spreading of user 1 information using
    first row of Walsh Matrix
39 tans_c2=[c2(1,1).*W(2,:) c2(1,2).*W(2,:) c2(1,3).*W
    (2,:)];//spreading of user 2 information using
    second row of Walsh Matrix
40 tans_c3=[c3(1,1).*W(3,:) c3(1,2).*W(3,:) c3(1,3).*W
    (3,:)];//spreading of user 3 information using
    third row of Walsh Matrix
41 aa1=tans_c1(1,1:a)+tans_c2(1,1:a)+tans_c3(1,1:a);
42 aa2=tans_c1(1,(a+1):(2*a))+tans_c2(1,(a+1):(2*a))+
    tans_c3(1,(a+1):(2*a));
43 aa3=tans_c1(1,((2*a))+1:(3*a))+tans_c2(1,((2*a))
    +1:(3*a))+tans_c3(1,((2*a))+1:(3*a));
44 tans_sig=[aa1 aa2 aa3];//transmission of spreaded
    signal

```

```

45 det_code1=input('enter detection code');//Enter any
    integer no. ranging up to no. of rows of walsh
    matrix
46
47     select det_code1//select case to get information
        of entered user
48     case 1
49         det_code=W(1,:);
50     case 2
51         det_code=W(2,:);
52     case 3
53         det_code=W(3,:);
54     else
55         det_code=W(4,:);
56         disp('invalid detection code');//display
            message for input of invalid detection
            code
57     end
58
59
60 rec_sig =[det_code(1,:).*aa1 det_code(1,:).*aa2
    det_code(1,:).*aa3];//received signal multiplied
    with dete
61 det_sig=[rec_sig(1,1)+rec_sig(1,2)+rec_sig(1,3)+
    rec_sig(1,4) rec_sig(1,5)+rec_sig(1,6)+rec_sig
    (1,7)+rec_sig(1,8) rec_sig(1,9)+rec_sig(1,10)+
    rec_sig(1,11)+rec_sig(1,12)];//detection of
    information from received signal
62 final_sig=(1/4)*det_sig;
63 disp('transmitted information is ');
64 disp(final_sig)//information transmmited using
    selected valid detection code
65 //input a=4
66 //W=[0 0 0 0 ;0 1 0 1;0 0 1 1 ;0 1 1 0]
67 //detection code=2, output=-1 1-1(information of
    user 2 spreaded with second row of Walsh Matrix)
68 //detection code > 3 , results : code not available
    0 0 0

```


Experiment: 6

PN sequence generation.

Scilab code Solution 6.1 3 bit PN sequence generation and spreading and despread using PN sequence and shifted PN sequence

```
1 // Spreading of sequence using PN sequence and
   despreding of sequence using PN sequence and
   shifted PN sequence
2 clc;
3 clear;
4 xdel(winsid());
5 // Generation of 7 bit PN sequence
6 // Coefficient of polynomial
7 a1=1;
8 a2=1;
9 a3=1;
10 // Initial states of flip flop
11 R(1)=1;
12 R(2)=0;
13 R(3)=0;
14 m=3;
15 disp('output after every clock pulse');
16 for i=1:((2^m)-1)//shift of bit in each register for
   every clock pulse
17     r1=R(1);
```



```

18     r2=R(2);
19     r3=R(3);
20     PN(i)=R(3);
21     // if(a1==0)
22 R1=bitxor(r2,r3); //input of register is modulo2
    addition of R2 and R3
23 R(3)=R(2);
24 R(2)=R(1);
25 R(1)=R1;
26
27 disp(R);
28 end
29 disp('PN sequence is ');
30 disp(PN); //Display 7 bit PN sequence
31 c1=[1 -1 -1]; //information of user 1
32 for j=1:length(PN) //0 replaced with -1 in PN
    sequence
33     if PN(j)==0 then
34         PN(j)=PN(j)-1;
35     else PN(j)=PN(j)+0;
36     end
37
38     end
39     disp(PN);
40 spreaded_sig=[c1(1).*PN' c1(2).*PN' c1(3).*PN'] //
    Spreading of data of user 1 using PN sequence
41 detect_code=[spreaded_sig(1:7).*PN' spreaded_sig
    (8:14).*PN' spreaded_sig(15:21).*PN']; //at
    receiver, recieved spreaded signal multiplied
    with PN seunqce
42 corr_code=[sum(detect_code(1:7)) sum(detect_code
    (8:14)) sum(detect_code(15:21))];
43 rec_sig=(1/7).*corr_code; //get information form
    received signal
44 disp('received signal with correct PN sequence is ');
45 disp(rec_sig); //received data of user 1 at receiver
    :1 -1 -1
46 //Despreading with shifted PN sequence

```

```

47 shift_fact=input('enter the shifting factor');
48 l=1;
49     k=shift_fact-1;
50 for i=1:1:length(PN)    //generation of shifted PN
    sequence as per entered shifting factor
51     if i<=shift_fact
52         shift_seq(i)=PN(length(PN)-k);
53         k=k-1;
54     else i>shift_fact
55         shift_seq(i)=PN(1);
56         l=l+1;
57     end
58 end
59 disp('shifted sequence is');
60 disp(shift_seq'); //display shifted sequence
61 //despreading using shifted PN sequence
62 detect_shift_code=[spreaded_sig(1:7).*shift_seq'
    spreaded_sig(8:14).*shift_seq' spreaded_sig
    (15:21).*shift_seq'];
63 corr_shift_code=[sum(detect_shift_code(1:7)) sum(
    detect_shift_code(8:14)) sum(detect_shift_code
    (15:21))];
64 rec_shift_sig=(1/7).*corr_shift_code;
65 disp("recieved signal with shifted PN sequence is
    ");
66 disp(rec_shift_sig); //Invalid data received
    beacuse signal was despreading with shifted PN
    sequence
67 disp('which is not valid transmitted signal');
68 //Result:
69 //output of PN sequence generator after each
    clock pulse
70 // PN =0 0 1 0 1 1 1 replace 0 with -1,PN=-1 -1 1
    -1 1 1 1
71 //entered shifting factor =3, shifted PN sequence=
    1 1 1 -1 -1 1 -1
72 //Invalid signal is received when despreading is
    with shifted version of PN

```

```
73 //rec_shift_sig= 0.1428571    0.1428571  
    0.1428571
```

Experiment: 7

Equalization.

Scilab code Solution 7.1 Adaptive equalization using LMS filter

```
1 // Least Mean Square adaptive equalizer
2 clc;
3 clear all;
4 xdel(winsid());
5 numPoints = 500;
6 numTaps = 1;           //channel order
7 Mu = 0.01;           //iteration step size
8
9 // input is gaussian
10 x = rand(numPoints,1,'normal') + %i*rand(numPoints
    ,1,'normal');
11 //choose channel to be random uniform
12 h = rand(numTaps,1) + %i*rand(numTaps, 1);
13
14 h = h/max(abs(h)); //normalize channel
15 // convolve channel with the input
16 d = filter(h, 1, x);
17
18 //initialize variables
19 w = [];
20 y = [];
```

```

21 in = [];
22 e = []; // error, final result to be computed
23
24 w = zeros(numTaps+1,1) + %i*zeros(numTaps+1,1);
25 kk=1;
26 aa(kk,:)=w';
27 //LMS Adaptation
28 for n = numTaps+1 : numPoints
29
30     // select part of training input
31     in = x(n : -1 : n-numTaps) ;
32     y(n) =w'* in;
33
34     // compute error
35     e(n) = d(n)-y(n);
36
37     // update taps
38
39 w = w+ Mu*( real(e(n)*conj(in)) - %i*imag(e(n)*conj(
40     in)) );
41
42 kk=kk+1;
43 aa(kk,:)=w';
44 end
45 // Plot results
46 figure;
47 iter=1:500
48 plot2d(iter,abs(e),5,logflag="nn");
49 title(['LMS Adaptation Learning Curve Using Mu =
50     0.01']);
51 xlabel('Iteration Number');
52 ylabel('Output Estimation Error in dB');
53 figure;
54 plot3d(abs(aa(:,1)),abs(aa(:,2)),abs(e));
55 title('LMS adaption curve with weight factors');
56 xlabel('adaptive weight factor1');
57 ylabel('adaptive weight factor2');

```

```
57 xlabel('mean square error');
58 // Output shows plot of MSE with no. of iterations
    in figure 1 and 3D plot of MSE with weight
    factors
```

Experiment: 8

Channel Coding using Linear Block Code

Scilab code Solution 8.1 Linear Block Coding over AWGN channel

```
1
2
3 //this is a linear block coding and decoding over
  awgn channel
4 // 4 bits input signal is coded with linear block
  code (4,7), 7 bit coded signal is transmitted
  over awgn channel and at receiver side signal is
  decoded. If there is error in one bit, li//near
  block code correct that error and original
  transmitter code is received.
5 //If error is in more than one bit, code is not
  corrected so wrong code is recieved
6 clc;
7 clear all;
8 xdel(winsid());
9 global P n k;
10
11 n=7; //length of coded input
12 k=4; //length of input
```

```

13 P=[1 1 0; 0 1 1; 1 0 1;1 1 1]; //parity matrix of
    size k*(n-k) to be
14 // selected so that
    the systematic generator
15 // matrix is linearly
    independent or full rank
16 // matrix
17
18 //(n,k) linear block code where k – no. of input
    data bits and n–no. of o/p
19 //data bits. code rate=k/n
20 // x is an input vector containing k bits
21
22 //This is an linear block encoding function
23 function y1=linblkcode(x);
24 global P n k;
25 n=7;
26 k=4;
27 P=[1 1 0; 0 1 1; 1 0 1;1 1 1];//parity matrix
28 //x=[0 1 1 0];
29
30 //G=[ ]; // % Generator matrix k*n
31 G=[eye(k,k) P];
32
33 y1=zeros(1,n);
34 for i=1:k//linear block coding
35     var(i,:)=x(1,i) & G(i,:);
36     var(i,:)=bool2s(var(i,:));
37     y1(1,:)=bitxor(var(i,:),y1(1,:));//coded signal
38 end
39
40 endfunction
41
42
43 //%This is a linear block syndrome decoding function
    file%
44
45 function x1=linblkdecoder(y)

```



```

46  %% here y is recieved vector 7 bits long
47
48  %% (7,4) linear block code
49  global P n k;
50
51
52  //H=[ ]; %% PARITY CHECK MATRIX
53
54  H=[P' eye((n-k),(n-k))];
55  Ht=H'; %%transpose of H
56
57  S=zeros(1,n-k); %%syndrome of recieved vector x
58  for i=1:n-k// decoding of linear block code
59      S(i)=y(1) & Ht(1,i);
60      S(i)=bool2s(S(i));
61      for j=2:n
62
63          S(i)=bitxor(S(i), bool2s((y(j) & Ht(j,i))));
64          //decoded signal
65      end
66  end
67
68
69  %%%***SYNDROME LOOK UP TABLE*****
70
71  %%%*****
72  %%
73  if S==[0 0 0]
74      e=[0 0 0 0 0 0 0];
75      z=bitxor(y,e);
76  end
77
78  if S==[0 0 1]
79      e=[0 0 0 0 0 0 1];
80      z=bitxor(y,e);
81  end
82  if S==[0 1 0]

```

```

83     e=[0 0 0 0 0 1 0];
84     z=bitxor(y,e);
85 end
86 if S==[1 0 0]
87     e=[0 0 0 0 1 0 0];
88     z=bitxor(y,e);
89 end
90 if S==[1 1 1]
91     e=[0 0 0 1 0 0 0];
92     z=bitxor(y,e);
93 end
94 if S==[1 0 1]
95     e=[0 0 1 0 0 0 0];
96     z=bitxor(y,e);
97 end
98 if S==[0 1 1]
99     e=[0 1 0 0 0 0 0];
100    z=bitxor(y,e);
101 end
102 if S==[1 1 0]
103    e=[1 0 0 0 0 0 0];
104    z=bitxor(y,e);
105 end
106 //disp('error ');
107 //disp(e);
108 x1=z(1,1:k);
109 endfunction
110 snr_dB=2;
111
112 x=[1 0 0 1]; //           input bits to the
           encoder of size 1* k
113 y1=linblkcode(x);//           // y1 is the output
           of linear block encoder
114 n1 = 1/sqrt(2)*[rand(1,length(y1),'normal') + %i*
           rand(1,length(y1),'normal')]; //white gaussian
           noise generation
115 r=y1+ 10^(-snr_dB/20)*n1; //received signal over awgn
           channel

```

```

116 //r1=real(r)
117 rec=real(r)>=0.5;//detection of bit 1 and 0 in
    received signal
118 rec_fin=bool2s(rec);//convert boolean matrix to zero
    one matrix
119 //rec_err=rec_fin==y1;
120 //no_err=bool2s(rec_err);
121 disp('The information signal=')//display input
122 disp(x)
123 disp('The transmitted encoded signal=')//display
    coded signal
124 disp(y1)
125 disp('The recieved signal=')//display received
    signal
126 disp(rec_fin);
127 x1=linblkdecoder(rec_fin); //           % x1 is the
    output of the linear block decoder
128 disp('The decoded signal=')//display decoded signal
129 disp(x1);
130 if x1==x then disp('one or less than one error so
    correct code is received');
131 else
132     disp('more than one error so wrong code detected
        ');
133 end
134 //Output: The information signal is : 1001
135 //transmitted code is : 1001001
136 //1. received signal is :1011001(e.g)(error in only
    one bit)
137 //decoded signal: 1001
138 //one or less than one error so correct code is
    received
139 //2. received signal is:1011011(e.g)(error in more
    than one bits)
140 //decoded signal:1010
141 //more than one error so wrong code is received

```

Experiment: 9

Transmit and receive diversity

Scilab code Solution 9.1 Selection Diversity over AWGN channel

```
1 //ber performance with 1, 2 and 3 receiver antennas
   over awgn channel using selection diversity
2 clc;
3 clear;
4 xdel(winsid());
5 sym=10000;//no. of symbols
6 data1=grand(1,sym,"uin",0,1);//randomly generated
   input
7 s = 2*data1-1; // BPSK modulation 0 -> -1; 1 -> 1
8 nRx = [1 2 3];//no .of receiving antennas
9 snr_dB = [1:10]; // signal to noise ratio
10 for j = 1:length(nRx)
11     for i = 1:length(snr_dB)
12         n = 1/sqrt(2)*[rand(nRx(j),sym,'normal') +
   %i*rand(nRx(j),sym,'normal')]; //white
   gaussian noise
13
14         y = ones(nRx(j),1)*s + 10^(-snr_dB(i)/20)*n;
   //received signal over awgn channel
15         [yHat1 ind] = mtlb_max(y,[],1);//find
   strongest received signal from all
```

```

                                antennas
16
17     ipHat1 = real(yHat1)>0;
18     ipHat = bool2s(ipHat1); //boolean to zero one
                                matrix conversion
19     // effective SNR
20     nErr(j,i) = size(find([data1- ipHat]),2); //
                                no. of error calculation
21     end
22 end
23 simBer = nErr/sym; //BER calculation
24 // plot of ber comparison plot for 1,2 and 3
                                receiving antennas
25 snr_dB=1:10
26 plot2d(snr_dB,simBer(1,:),5,logflag="nl");
27 plot2d(snr_dB,simBer(2,:),2,logflag="nl");
28 plot2d(snr_dB,simBer(3,:),12,logflag="nl");
29 xgrid
30 legend( ['1X1'; '1X2'; '1x3' ]);
31 xlabel('Number of receive antenna');
32 ylabel('effective SNR, dB');
33 title('SNR improvement with Selection Combining');
34 //output presents BER performance comparison plots
                                with 1,2 and 3 receiving antennas over awgn
                                channels

```

Scilab code Solution 9.2 Maximal Ratio Combining over AWGN and Rayleigh fading Channel

```

1 // BER Performance coamparison with one receivng
                                atenna and two receiving antennas with Maximal
                                ratio Combining diversity technique over awgn
                                channe and rayleigh fading channel
2 clc;
3 clear;

```

```

4 xdel(winsid());
5 sym=100000; // no. of symbols
6 M=2;
7 data1=grand(1,sym,"uin",0,1); // input signal is
    randomly generated
8 //N = 10; % number of bits or symbols
9 //ip = rand(1,N)>0.5; % generating 0,1 with equal
    probability
10 s = 2*data1-1; // BPSK modulation 0 -> -1; 1 -> 1
11 nRx = [1 2]; //no of receivers
12 snr_dB = [1:20]; // signal to noise ration in dB
13 for jj = 1:length(nRx)
14     for ii = 1:length(snr_dB)
15         n = 1/sqrt(2)*[rand(nRx(jj),sym,'normal') +
            %i*rand(nRx(jj),sym,'normal')]; //white
            gaussian noise ,
16         h = 1/sqrt(2)*[rand(nRx(jj),sym,'normal') +
            %i*rand(nRx(jj),sym,'normal')]; //
            Rayleigh fading channel
17         // Channel and noise Noise addition
18         sD = kron(ones(nRx(jj),1),s);
19         y = h.*sD + 10^(-snr_dB(ii)/20)*n; //
            received signal over awgn channel and
            Rayleigh fading channel
20         // finding the power of the channel on all
            rx chain
21         yHat = sum(conj(h).*y,1)./sum(h.*conj(h)
            ,1); // maximal ratio combining
22         // hPower1 = h.*conj(h);
23
24         ipHat = real(yHat)>0;
25         // effective SNR
26         nErr(jj,ii) = size(find([data1-
            ipHat]),2); //calculate error
27         end
28     end
29 simBer = nErr/sym; //bit error rate calculation
30 // plot

```

```

31 snr_dB=1:20
32 plot2d(snr_dB,simBer(1,:),5,logflag="nl");//snr- ber
    plot with one receiving antenna
33 plot2d(snr_dB,simBer(2,:),2,logflag="nl");//snr- ber
    plot with two receiving antennas
34 //plot(nRx,10*log10(EbN0EffSim),'bp-','LineWidth',2)
    ;
35 //mtlb_axis([1 20 0 6])
36 xgrid
37 legend(['1X1';'1X2']);
38 xlabel('Number of receive antenna');
39 ylabel('effective SNR, dB');
40 title('SNR improvement with Maximal ratio Combining'
    );

```

```

    =0], R(2)=R[lag=1], %R(3)=R[lag=2]... etc
14
15 //GETTING OTHER PARAMETERS OF PREDICTOR OF ORDER
    "0":
16 s=1;           //s=step no.
17 J(1)=R(1);     //J=array of "Jl", where l
    =0,1,2...(b+N)-1, J(1)=J0, J(2)=J1, J(3)=J2 etc
18
19 //GETTING OTHER PARAMETERS OF PREDICTOR OF ORDER "(s
    -1)"
20 for s=2:M+1,
21     sk=0;           //clearing "sk" for each
        iteration
22     for i=2:(s-1),
23         sk=sk + a(i,(s-1)).*R(s-i+1);
24     end           //now we know value of "sk",
        the summation term
25                 //of formula of calculating
                    "k(l)"
26     k(s)=(R(s) + sk)./J(s-1);
27     J(s)=J(s-1).*(1-(k(s)).^2);
28
29     a(s,s)= -k(s);
30     a(1,s)=1;
31     for i=2:(s-1),
32         a(i,s)=a(i,(s-1)) - k(s).*a((s-i+1),(s-1));
33     end
34     end
35 //increment "b" and do same for next frame until end
    of frame when
36 //combining this code with other parts of LPC algo
37
38 //PREDICTION ERROR; FOR TESTING THE ABOVE PREDICTOR
39 aCoeff=a((1:s),s)'; //array of "a(i,s)", where
    , s=M+1
40 tcount_of_aCoeff = length(aCoeff);
41
42 y_padded_for_delay_r = [y'; zeros(1,1)]; //it is

```

```

        padded with zeros to remove the effect of delay
        in filter
43  est_y_with_dummy_pad = filter([0 -aCoeff(2:9)],1,
        y_padded_for_delay_r);    // = s^(n) with a cap
        on page 92 of the book
44  est_y = est_y_with_dummy_pad(2:321);
45  e = y' - est_y;    //supposed to be a white noise
46  endfunction
47
48  function [aCoeff, b_LTopt, Topt, e_prime] =
        f_ENCODER_relp(x, fs)
49  M = 8; //prediction order for LP analysis
50  //INITIALIZATION;
51  b=1;    //index no. of starting data point of
        current frame
52  fsize = 20e-3;    //frame size (in milisec)
53  frame_length = round(fs .* fsize);    //number data
        points in each framesize of "x"
54  N= frame_length - 1; //N+1 = frame length = number
        of data points in each framesize
55
56  y_proc = filter([1 -1], [1 -0.999], x); //pre-
        processing
57  //FRAME SEGMENTATION
58  for b=1 : frame_length : (length(x) - N)
59
60  y_f = y_proc(b:b+N);    //"b+N" denotes the end
        point of current frame. "y" denotes an array of
        the data points of the current frame
61  //LP ANALYSIS [lev-durb] & PREDICTION ERROR (short-
        term) FILTER;
62  [a, tcount_of_aCoeff, e_s] = func_lev_durb (y_f,
        M); //e=error signal from lev-durb proc
63  aCoeff(b: (b + tcount_of_aCoeff - 1)) = a; //
        aCoeff is array of "a" for whole "x"
64  //LONG-TERM LP ANALYSIS, FILTERING, AND CODING
        analysis:
65  T_min = round (fs .* 5e-3);    //total data

```

```

        points in 5ms of "x"
66     T_max = round (fs .* 15e-3);
67     c1 = 1;
68     for bs = b : 40 : b+length(y_f)-40 //subframing
        bs = 1281;
69         if bs < T_max
70             break;
71         end
72
73         Jmin(bs) = 10^9;
74
75         for T = T_min : T_max //within 1 (
            current) frame T = 40;
76             for c = 1:40 //data points of
                current subframe c=1; temporary
77                 sm1(c) = ( y_proc(bs+(c-1)) .*
                    y_proc(bs-T+(c-1))); //es(n)
78                 sm2(c) = y_proc(bs-T+(c-1)); // =
                    es(n-T)
79                 sm22(c) = sm2(c).^2;
80             end
81             q1 = sum(sm1);
82             q2 = sum(sm22);
83             b_LT(T) = -(q1./q2);
84         //J loop:
85         for c = 1:40 //data points of
            current subframe c=1; temporary
86             smJ1(c) = y_proc(bs+(c-1));
87             smJ2(c) = b_LT(T) .* y_proc(bs-T
                +(c-1));
88         end
89         smJ = smJ1 + smJ2;
90         qJ = smJ.^2;
91         J(T) = sum(qJ);
92
93         if J(T) < Jmin(bs),
94             Jmin(bs) = J(T);
95             Topt(bs) = T;

```

```

96         if b_LT(T)>=1,
97             b_LTopt(bs) = 0.9999; //
                truncation
98         else
99             b_LTopt(bs) = b_LT(T);
100        end
101        else
102        end
103    end //T loop ends
104    //predictor:
105    LT_gain = [zeros(1, Topt(bs)-1), b_LTopt(bs)
106    ]; //as it says  $z^{-T}$  in page 121
107    e_s_padded_for_delay_r = [e_s(c1:c1+39);
108    zeros(Topt(bs), 1)]; //it is padded with
109    zeros to remove the effect of delay in
110    filter. %Topt(bs) no. of 'z's and one
111    '1' results in total 'Topt(bs)' amount
112    of delay
113    e_with_dummy_pad = filter([1 LT_gain], 1,
114    e_s_padded_for_delay_r); // =  $1 + 0*z$ 
115     $^{-1} + 0*z^{-2} + \dots + b*z^{-T}$ 
116    e_LT(bs:bs+39,1) = e_with_dummy_pad(Topt(bs)
117    )+1 : Topt(bs)+1+39); //LT predicted "
118    e"
119    e(bs:bs+39, 1) = e_s(c1 : c1+39) - e_LT(bs :
120    bs+39);
121
122    //WEIGHTING FILTER:
123    w = [-0.0004;
124    -0.0156; -0.0677; 0.0545; 0.6069; 1.0000; 0.6069; 0.0545; -0.0677
125    //11 point flattop window is
126    temporarily chosen
127    wndd = conv(w, e(bs:bs+39)); //outputs
128    total 50 samples
129    x_n(bs:bs+39) = wndd(6:45); //middle 40
130    samples are taken
131
132    //POSITION SELECTION & EXCITATION GENERATOR:

```

```

117         for i1 = 0:3
118             for i = i1+bs : 3 : bs+i1+38;
119                 x_m(i1+1,i) = x_n(i);
120             end
121
122             E_m(i1+1,1) = sum((x_m(i1+1, bs:3)).^2);
123         end
124         [E_m_max, index_max] = gsort(E_m);
125         e_prime(bs : bs+39) = x_m(index_max(4), bs:
            bs+39);
126         c1 = c1 + 40;
127     end
128 end
129 endfunction
130
131 //RELP DECODER portion:
132 function [synth_speech, synth_speech1, LT_gain,
            e_prime_pad_for_d_r, e_prime_op_dummy_pad,
            e_prime_op, e_prime_op_pad_delay_r,
            synth_speech_dummy_pad] = f_DECODER_relp(aCoeff,
            b_LTopt, Topt, e_prime)
133 //re-calculating frame_length for this decoder
134 frame_length=9; //initial value for calculation
135 for i=10:length(aCoeff)
136     if aCoeff(i) == 0
137         frame_length = frame_length + 1;
138     else break;
139     end
140 end
141 e_prime = e_prime'; //making it a column matrix
            for convenience
142
143 for b=1 : frame_length : length(aCoeff) //length(
            aCoeff) should be very close (i.e less than a
            frame_length error) to length(x)
144     for bs = b : 40 : b+frame_length-40 //
            subframing
145

```

```

146 //EXCITATION GENERATOR: not done yet.
    because e_prime has been sent to this
    decoder directly. without quantization.
147 //PITCH SYNTHESIS FILTER: %has to be done
    per subframe
148 LT_gain = [zeros(1, Topt(bs)-1), b_LTopt(bs)
    ]; //as it says  $z^{-T}$ 
149 e_prime_pad_for_d_r = [e_prime(bs:bs+39);
    zeros(Topt(bs), 1)]; //it is padded with
    zeros to remove the effect of delay in
    filter. %Topt(bs) no. of 'z's and one
    '1' results in total 'Topt(bs)' amount
    of delay
150 e_prime_op_dummy_pad = filter(1, [1 LT_gain
    ], e_prime_pad_for_d_r); // =  $1 / (1 +$ 
     $0*z^{-1} + 0*z^{-2} + \dots + b*z^{-T})$ 
151 e_prime_op(bs:bs+39,1) =
    e_prime_op_dummy_pad(Topt(bs)+1 : Topt(bs)
    )+1+39); //pitch-synthesis filter
    output
152 end //FORMANT SYNTHESIS FILTER:
153 e_prime_op_pad_delay_r= [e_prime_op(b : b
    +159); zeros(1,1)]; //it is padded with
    zeros to remove the effect of delay in
    filter
154 synth_speech_dummy_pad = filter(1, [1 aCoeff
    (b+1 : b+8)], e_prime_op_pad_delay_r);
155 synth_speech1(b : b+159) =
    synth_speech_dummy_pad (2:161); //DE-
    EMPHASIS (de-processing):
156 synth_speech(b : b+159) = filter([1 -0.999],
    [1 -1], synth_speech1(b : b+159)); //De-
    -processing
157 end
158 endfunction
159
160 clc;
161 clear all;

```

```

162 xdel(winsid());
163 inpfilem = "SCI/modules/sound/demos/s1ofwb.wav";
164 [x,fs,bits] =wavread(inpfilem);
165
166 t=length(x)./fs;// total time t seconds
167 //COMPRESSION STARTS HERE,
168 disp('original signal');
169 sound(x, fs);
170 [aCoeff, b_LTopt, Topt, e_prime] = f_ENCODER_relp(x,
        fs);
171
172         // e_prime is instead of position ,
        peak_magitude_index and
        sample_amplitude_index. (temporarily)
173 //halt()
174 //halt('Press a key to play the original sound!')
175
176 [synth_speech] = f_DECODER_relp(aCoeff, b_LTopt,
        Topt, e_prime);
177
178 //RESULTS,
179
180
181 disp('compressed signal');
182 sound(synth_speech, fs);
183
184 figure;
185 subplot(211),
186 plot(x); title(['Original signal = "', inpfilem, "'
        ']);
187 subplot(212), plot(synth_speech); title('RELP
        compressed output');
188 //Output plays original signal and after
        approximately 5 minutes it plays compressed sound
        and plot the original signal and compressed
        signal.

```
