Scilab Manual for Mobile Communication by Prof Hetal Shah Others Dharmsinh Desai University[1]

Solutions provided by
Prof Hetal Shah
Others
Dharmsinh Desai

November 22, 2026

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Scilab Manual and Scilab codes written in it can be downloaded from the "Migrated Labs" section at the website http://scilab.in

Contents

List of Scilab Solutions 3

1 Digital Modulation Functions: ASK, FSK, PSK generation. 4

2 Constellation diagram and Error Rate performance of different modulation techniques with AWGN channel. 7

3 Effect of various channel on transmitted data using different modulation techniques. 13

4 Trunking Theory for Probability of blocking(Erlang B) and probability of delay(Erlang C). 23

5 Walsh Code generation 27

6 PN sequence generation. 31

7 Equalization. 35

8 Channel Coding using Linear Block Code 38

9 Transmit and receive diversity 43

10 Speech coding 47

List of Experiments

Solution 1.1	1	4
Solution 2.1	Sigal space diagram of different modulation	7
Solution 2.2	BER of BPSK and QPSK over AWGN Channel	9
Solution 3.1	BER BPSK Rayleigh fading channel	13
Solution 3.2	BER QPSK Rayleigh channel	16
Solution 3.3	1	20
Solution 4.1	Traffic calculation inErlang B and Erlang C system	23
Solution 5.1	Walsh code generation and spreading and despreading using Walsh code	27
Solution 6.1	3 bit PN sequence generation and spreading and despreading using PN sequence and shifted PN sequence	31
Solution 7.1	Adaptive equalization using LMS filter	35
Solution 8.1	Linear Block Coding over AWGN channel	38
Solution 9.1	Selection Diversity over AWGN channel	43
Solution 9.2	Maximal Ratio Combining over AWGN and Rayleigh fading Channel	44
Solution 10.1	speech coding and Decoding using LPC	47

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);
```

```
    end
    c_ask=sin(f1*t);
    cp=[cp die];
    mod_ask=[mod_ask c_ask];
    end
ask=cp.*mod_ask;//ASK modulated signal

//FSK
for n=1:length(g);
    if g(n)==0;
        die=ones(1,100);
        c_fsk=sin(f1*t);
    else g(n)==1;
        die=ones(1,100);
        c_fsk=sin(f2*t);
    end
    cp1=[cp1 die];
    mod_fsk=[mod_fsk c_fsk];
end
fsk=cp1.*mod_fsk;//FSK molated signal

//PSK
for n=1:length(g);
    if g(n)==0;
        die=ones(1,100);
        c_psk=sin(f1*t);
    else g(n)==1;
        die=ones(1,100);
        c_psk=-sin(f1*t);
    end
    cp2=[cp2 die];
    mod_psk=[mod_psk c_psk];
end
psk=cp2.*mod_psk;//PSK modulated signal
subplot(4,1,1);plot(cp,'LineWidth',1.5);//plot
   binary signal
xgrid;
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
    Theoritical 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
                 demod_out_q];//QPSK Demodulated signal
41              end
42           for i=1:1:length(data1)//BPSK Demodulation
43              if real(rec1_bpsk(i))>=0
44                   demod_out_bpsk=1;
45              else real(rec1_bpsk(i))<0
46                  demod_out_bpsk=0;
47              end
48              rec_data_bpsk=[rec_data_bpsk
                   demod_out_bpsk];//BPSK Demodulated
                   signal
49          end
50
51          errA=0;errB=0;
52      for i=1:sym
53          if rec_data_qpsk(i)==data1(i)
54              errA=errA;
55          else
56              errA=errA+1;
57          end
58      end
59          BER_qpsk(k)=errA/sym;// BER of QPSK
60
61           for i=1:sym
62          if rec_data_bpsk(i)==data1(i)
63              errB=errB;
64          else
65              errB=errB+1;
66          end
```

```
67
68          BER_bpsk(k)=errB/sym;//BER of BPSK
69      end
70      theoryBer = 0.5*erfc(sqrt(10.^(snr/10))); //
           Theoritical 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
      theoritical 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
      theoritical 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
    Symbolsfrom 0 to 1with 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
                   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.
```

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
                demod_out_q];//QPSK Demodulated signal
56            rec_data_qpsk_ray=[rec_data_qpsk_ray
                demod_out_i_ray demod_out_q_ray];//
                QPSK Demodulated signal
57            end
58
59        errA=0;errB=0;
60    for i=1:sym
61        if rec_data_qpsk(i)==data1(i)
62            errA=errA;
63        else
64            errA=errA+1;
65        end
66    end
67        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))); //
           Theoritical 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
       theoritical 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
    Symbolsfrom 0 to 1with 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
                    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 inErlang 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 perticular
      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'
            );//display blocking probability
41        disp(A-1,'Maximum traffic intensity is');//
            display max. traffic intensity
42         u=(A-1)/Au;//no. of users calculation
43        disp(u,"no .of users are accomodated");//
            display maximum no.of users accomodated in
            Erlang B system
44        break;
45    end//
46    p=0;
47        for A=1:1:100
48        while(p<pr_delay)//Find maximum traffic
            intensity for entered blocking probability
            pr_blocking
49          [p]=erlangC(A,c)//calling funtion to
              calculate erlang C probability
50          A=A+1;
51      end
52        disp(pr_delay,'for block call delay
            probability of');//display blocking
            probability
53        disp(A-1,'Maximum traffic intensity is');//
            display max. traffic intensity
54        u=(A-1)/Au;
55        disp(u,"no.of users are accomodated");//
            display maximum no.of users accomodated in
            Erlang C system
56        break;
57    end
58  //Enter blocking probability pr_blocking=0.01
59  //Enter probabolity of block call delay pr_delay
      =0.1
60  //Enter call rate= 3/60
61  //enter call duration= 2(in minute)
62  //Enter no of channels 50
63
```

```
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 despreading 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 detection code
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('transmited 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 despreading using PN sequence and shifted PN sequence

```
1  // Spreading  of sequence using PN sequence and
       despreading 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=1:1: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 sequnce
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(l);
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 despreded 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 guassian
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(
      in)) );
40
41 kk=kk+1;
42 aa(kk,:)=w';
43 end
44
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 =
      0.01']);
50 xlabel('Iteration Number');
51 ylabel('Output Estimation Error in dB');
52 figure;
53 plot3d(abs(aa(:,1)),abs(aa(:,2)),abs(e));
54 title('LMS adaption curve with weight factors');
55 xlabel('adaptive weight factor1');
56 ylabel('adaptive weight factor2');
```

```
57 zlabel('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 receved.
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))));
              //decoded signal
64     end
65 end
66
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]
```

```
    e=[0 0 0 0 0 1 0];
     z=bitxor(y,e);
end
if S==[1 0 0]
    e=[0 0 0 0 1 0 0];
     z=bitxor(y,e);
end
if S==[1 1 1]
    e=[0 0 0 1 0 0 0];
     z=bitxor(y,e);
end
if S==[1 0 1]
    e=[0 0 1 0 0 0 0];
     z=bitxor(y,e);
end
if S==[0 1 1]
    e=[0 1 0 0 0 0 0];
     z=bitxor(y,e);
end
if S==[1 1 0]
    e=[1 0 0 0 0 0 0];
     z=bitxor(y,e);
end
//disp('error');
//disp(e);
x1=z(1,1:k);
endfunction
snr_dB=2;

x=[1 0 0 1];   //                input bits to the
   encoder of size 1* k
y1=linblkcode(x);//            //   y1 is the output
   of linear block encoder
n1 = 1/sqrt(2)*[rand(1,length(y1),'normal') + %i*
   rand(1,length(y1),'normal')];//white gaussian
   noise generation
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 receivivng
       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
               ayleigh 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'
     );
```

Experiment: 10

Speech coding

Scilab code Solution 10.1 speech coding and Decoding using LPC

```
1 //Exp-10 Speech coding using Long Term Predictive
    coder
2 //This code read wav file and play original signal
    and compressed signal
3 // It also plots original signal as well as
    compressed signal
4
5 function [aCoeff, tcount_of_aCoeff, e] =
    func_lev_durb(y, M);
6 //M=order and y is array of the data point  of the
    current frame
7 sk=0;        //initializing summartion term "sk"
8 a=[zeros(M+1);zeros(M+1)]; //defining a matrix of
    zeros for "a" for init.
9 //MAIN BODY OF THIS PROGRAM STARTS FROM HERE
    >>>>>>>>>>>>>>>
10 z=xcorr(y);
11
12 //finding array of R[l]
13 R=z( ( (length(z)+1) ./2 ) : length(z)); //R=array
    of "R[l]", where l=0,1,...(b+N)-1  %R(1)=R[lag
```

```
    =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; //
                               trancation
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)
               ];      //as it says z^-T in page 121
106          e_s_padded_for_delay_r = [e_s(c1:c1+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
107         e_with_dummy_pad = filter([1 LT_gain], 1,
               e_s_padded_for_delay_r);    // = 1 + 0*z
               ^-1 + 0*z^-2 + ... + b*z^-T
108          e_LT(bs:bs+39,1) = e_with_dummy_pad(Topt(bs
               )+1 : Topt(bs)+1+39);    //LT predicted "
               e"
109         e(bs:bs+39, 1) = e_s(c1 : c1+39) - e_LT(bs :
               bs+39);
110
111         //WEIGHTING FILTER:
112         w = [-0.0004;
               -0.0156;-0.0677;0.0545;0.6069;1.0000;0.6069;0.0545;-0.0677
                //11 point flattop window is
               temporarily chosen
113         wndd = conv(w, e(bs:bs+39));      //outputs
               total 50 samples
114         x_n(bs:bs+39) = wndd(6:45);  //middle 40
               samples are taken
115
116         //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 + ... + 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-proprocessing):
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;
```

```
xdel(winsid());
inpfilenm = "SCI/modules/sound/demos/s1ofwb.wav";
[x,fs,bits] =wavread(inpfilenm);

t=length(x)./fs;// total time t seconds
//COMPRESSION STARTS HERE,
disp('original signal');
sound(x, fs);
[aCoeff, b_LTopt, Topt, e_prime] = f_ENCODER_relp(x,
    fs);

        // e_prime is instead of position,
           peak_magitude_index and
           sample_amplitude_index. (temporarily)
//halt()
//halt('Press a key to play the original sound!')

[synth_speech] = f_DECODER_relp(aCoeff, b_LTopt,
   Topt, e_prime);

//RESULTS,


disp('compressed signal');
sound(synth_speech, fs);

figure;
subplot(211),
plot(x); title(['Original signal = "', inpfilenm, '"
   ']);
subplot(212), plot(synth_speech); title('RELP
   compressed output');
//Output plays original signal and after
   approximately 5 minutes it plays compressed sound
    and plot the original signal and compressed
   signal.
```