PABNA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Department of Information & Communication Engineering

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Lab Report

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Experiment 01: A spectrum of 30 MHz is allocated to a wireless FDD cellular system which uses two 25 KHz simplex channels to provide full duplex voice and control channels. Compute the number of channels available per cell if a system uses a) Four cell reuse (b) Seven cell reuse and (c) 12 - cell reuse If 1MHz of the allocated spectrum is dedicated to control channel determine the equitable distribution of control channels and voice channels in each cell of each of the three systems.

Solution:

Given: Total bandwidth = 30 MHz

Channel bandwidth = 25 KHz × 2 simplex channels

= 50 KHz / duplex channel

Total available channels = 30,000/50 = 600 channels.

a) For N=4

total number of channels available per cell = 600/4

= 150 channels

b) for N=7,

total number of channels available per cell = 600/7 = 85 channels

c) For N= 12

total number of channels available per cell = 600/12

= 50 channels

A 1 MHz spectrum for control channels implies that there are 1000/50 = 20 control channels out of the 600 channels available.

(a) For N = 4, we can have 5 control channels and 145 voice channels per cell.

(b) Total number of voice channels for N = 7, (600 − 20)/7 = 82 voice channels are to be assigned to each cell approximately, 4 cells with 3 control channels and 82 voice channels, and 3 cell with 2 control channels are to be assigned along with 83 voice channels.

(c) for N = 12 we can have eight cells with two control channels and 48 voice channels, and four cells with one control channels and 49 voice channels each.

Matlab code for Experiment 01:

```
clc
clear all;
close all;
BW = 30000; %Total Bandwidth (KHz)
CBW = (25*2); % Channel Bandwidth (KHz / duplex channel)
TAC = BW/CBW; % Total available channel
As = 1000 ; % Allocated spectrum
```

```
ACch = AS/CBW; Available control channel

% (a) For N=4
N=4;
ch=TAC/N; %total number of "channel" available per cell
vch=(TAC-ACch)/N; %Voice channel per cell.
cch=ch-vch % control channel per cell
fprintf('(a) for N=4\n');
fprintf('Total number of channel available per cell = %d\n',ch);
fprintf('voice channel per cell = %d\n',vch);
fprintf('control channel per cell = %d\n',cch);

% (b) for N=7

N=7;
ch=floor(TAC/N);
vch=floor((TAC-ACch)/N);
cch=ch-vch;
fprintf('(b) for N=7\n');
fprintf('Total number of channel available per cell = %d\n',ch);
fprintf('Voice channel per cell =%d\n',vch);
fprintf('controlchannel per cell= %d\n',cch);

%(C) For N=12

N=12;
Ch=floor(TAC/N);
vch= floor((TAC-ACch)/N);
cch=ch-Vch;
fprintf('(c) For N=12\n');
fprintf('Total number of channel available per cell = %d\n',ch);
fprintf('Voice channel per cell = %d\n', Vch);
```

```
fprintf('control channel per cell = %d\n', cch);
```

Input & Output:

(a) For $N=4$

Total Number of channel available per cell = 150
voice channel per cell = 145
control channel per cell = 5

(b) for $N=7$

Total number of channel available per cell = 85
voice channel per cell = 82
control channel per cell = 3

(c) For $N=12$

Total number of channel available per cell = 50
voice channel per cell = 48
control channel per cell = 2

Experiment 02: For given path loss exponent (a) $n=4$ and (b) $n=3$ find the frequency reuse factor and the cluster size that should be used for maximum capacity. The signal to interference ratio of 15 dB is minimum required for satisfactory forward channel performance of a cellular system. There are six co channel cells in the first tier, and all of them are at the same distance from the mobile. use suitable approximation.

Solution:

(a) $n=4$

first, let us consider a seven cell reuse pattern

using Equation $Q = \frac{D}{R} = \sqrt{3N}$, Frequency reuse factor $= \sqrt{21}$
$= 4.583$

using equation $\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0}$

$= (1/6) \times (4.583)^4 = 75.3 = 18.66$ dB

since this is greater than the minimum required S/I, $N=7$ can be used.

(b) $n=3$

First, Let us consider a seven cell reuse pattern

using equation $\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0}$, the signal to interference ratio is given by

$S/I = (1/6) \times (4.583)^3 = 16.04 = 12.05$ dB

since this is less than the minimum required S/I, we need to use a larger N.

using equation $N = i^2 + ij + j^2$ the next possible values of N is 12 $(i = j = 2)$.

The corresponding co-channel ratio is given by Equation (Eq-4)

$Q = \frac{D}{R} = \sqrt{3N}$ as $D/R = 6.0$

the signal to interference ratio is given by $S/I = (1/6) \times (6)^3$

$= 36$

$= 15.56$ dB

since this is greater than the minimum required S/I, N=12 is used.

Matlab code for Experiment 02:

```
clc;
clear all;
close all;
% Given that
min_SNIdB = 15; % minimum required signal to interference ratio
% (a) n=4
n=4
fprintf('(a) n=4\n'
N=7;
[SNIdB, N] = SNratiofunction(N,n,min_SNIdB);
fprintf('signal-to-noise interference ratio is %f and N= %d can be used\n'
,SNIdB,N);
% (b) n=3
n=3
fprintf('(b) n=3\n');
N=7;
```

```
[SNIdB, N] = SNratioFunction (N, n, min_SNIdB);
fprintf ('signal-to-noise intefenence ratio is %f and N = %d can be used \n',
                                                              SNIdB, N);
```

Input & Output:

(a) n=4

signal-to-noise interference ratio is 18.662873 and N =7 can be used

(b) n=3

signal-to-noise interference ratio is 15.563025 and N =12 can be used

Experiment 03: How many users can be supported for 0.5% blocking probability for the following number of trunked channel in a blocked calls cleared system? (a) 1 (b) 5. (c) 10 (d) 20 (e) 100. Assume each user generates 0.1 Erlangs of traffic.

solution: From the capacity of an Erlang B system table ~~ea~~ we can find the total capacity in Erlangs for the 0.5% GOS for different numbers of channels. By using the relation $A = UA_u$, we can obtain the total number of user that can be supported in the system.

(a) Given $C=1$, $A_u = 0.1$, GOS $= 0.005$

From figure we obtain $A = 0.005$

~~(b)~~ Therefore, total number of users $U = A/A_u = 0.005/0.1$

$= 0.05$ users

But, actually one user could be supported on one channel so, $U = 1$

(b) Given $C = 5$, $A_u = 0.1$ GOS $= 0.005$

From Figure we obtain $A = 1.13$

Therefore, total number of users $U = A/A_u = 1.13/0.1 = 11$ users

(c) Given $C = 10$, $A_u = 0.1$ and GOS $= 0.005$

From figure: we obtain $A = 3.96$

Therefore total number of users $U = A/A_u = 3.96/0.1 \approx 39$ users

(d) Given $c = 20$, $A_u = 0.1$ $GOS = 0.005$

From figure we obtain $A = 11.10$

Therefore, total number of users $U = A/A_u = 11.1/0.1$

$= 110$ users.

(e) Given $c = 100$, $A_u = 0.1$, $GOS = 0.005$

From figure we obtain $A = 80.9$

Therefore, total number of users $U = A/A_u = 80.9/0.1$

$= 809$ users.

Source Code for Experiment 03:

```
clc
close all;
clear all;
Au = 0.1;
GOS = 0.005;
fprintf('(a)\n');
c = 1
A = 0.005;
U= ceil(A/Au)
fprintf('(b)\n');
c=5;
A=1.13;
U=floor(A/Au)
fprintf('(c)\n');
c=10;
```

```
A=3.96;
U=floor(A/Au)
fprintf('(d)'\n');
c=20;
A=11.10;
U=floor(A/Au);
fprintf('(e)\n');
c=100;
A=80.9;
U=floor(A/Au);
```

Input & Output:

~~(a) n=4~~
~~signal to noise~~

(a) U = 1 (d) U = 3110

(b) U = 11 (e) U = 809

(c) U = 39

Experiment 04: An urban area has a population of two million residents. Three competing trunked mobile networks provide cellular service in this area. System A has 394 cells with 19 channel each system B has 98 cells with 57 channel each and system C has 49 cells, each with 100 channels. Find the number of users that can be supported at 2% blocking ~~channel~~ ~~find the number of users~~ if each user averages two calls per hour at an average call duration of three minutes Assuming that all three trunked systems are operated at maximum capacity, compute the percentage market penetration of each cellular provider.

Solution

System A

Given:

Probability of blocking $= 2\% = 0.02$

Number of channels per cell used in the system $C = 19$

Traffic intensity per user $A_u = \lambda H = 2 \times (3/60) = 0.1$ Erlangs

For GOS $= 0.02$ and $C = 19$ from the Erlang B chart, the total carried traffic A is obtained as 12 Erlangs.

Therefore, the number of users that can be supported per cell is $U = A/A_u = 12/0.1 = 120$

Since there are 394 cells, the total number of subscribers that can be supported by system A is equal to $120 \times 394 = 47280$

System B

Given:

Probability of blocking : 2% = 0.02

Number of channel per cell used in the system $c = 57$

Traffic intensity per user $= A_u = \lambda H = 2\times(3/60) = 0.1$ Erlangs

For GOS $= 0.02$ and $c = 57$ from the Erlang B chart, the total carried traffic, A is obtained as 45 Erlangs.

Therefore the number of users that can be supported per cell is $U = A/A_u = 45/0.1 = 450$

Since there are 98 cells, the total number of subscriber that can be supported by system B is equal to $450 \times 98 = 44,100$

System C

Given probability of blocking $= 2\% = 0.02$

Number of channel per cell used in the system $C = 100$

Traffic intensity per user, $A_u = \lambda H = 2\times(3\times 60) = 0.1$ Erlangs

For GOS $= 0.02$ and $c = 100$ from the Erlang B chart the total carried traffic A is obtained as 88 Erlangs.

Therefore, the number of users that can be supported per cell is $U = A/A_u = 88/0.1 = 880$.

Since there are 49 cells, the total number of subscriber that can be supported by system C is equal to $880 \times 49 = 43,120$

Therefore the total number of cellular subscriber in System A is equal to 47280 the percentage market penetration is equal to $47,280/2,000,000 = 2.36\%$

similarly, market penetration of system B is equal to

44,100/2,000,000 = ~~2.96%~~ 2.205%.

and the market penetration of system C is equal to

43,120/2,000,000 = 2.156%

The market penetration of the three system combined is equal to 134,500/2,000,000 = 6.725%.

Source code for Experiment 04:

```
clc;
clear all;
close all;
BP=(2/100);
lemda=2;
H=(3/60);
AU= lemda*H;
TR= 2000000

% System (a)
fprintf('(a)\n'
c=19;
cell=394;
GOS=BP;
A=12
U= A/AU;
fprintf('\n The Number of User that can be supported per cell is U=%d',U);
S1= U*cell;
fprintf('\n Total number of subscriber supported by system A= %d\n',S1);
```

```
clc
%system(b)
fprintf('\n(b)\n');
c=57;
cell=98;
GOS = BP;
A=45;
fprintf('\nThe Number of usere that can be supported per cell is U=%d',U);
S2=U* cell;
fprintf( '\nTotal number of subsciber supported by system B=%d\n', S2);

% system(C)
fprintf ('\n(c)\n'
C=100
cell= 49;
GOS = BP;
A = 88;
U=A/AU;
fprintf ('\nThe Number of User that can be supported per cell is U=%d',U);
S3=U* cell;
fprintf( \nTotal number of subsciber supported by System C=%d\n', S3);
S=S1+S2+S3;
fprintf ('\nTotal number of subsciber supported by Three system is=%d\n',S);
P1=(S1/TR)* 100;
fprintf('\nThe marcket penetration for system A=%.2f percent\n', P1);
P2 =(S2/TR)* 100;
fprintf('\nThe market penetration for system B=%.2f percent\n', P2);
P3=(S3/TR)* 100;
fprintf ('\nThe marcket penetration for system C = %.3f percent\n', P3);
P=P1+P2+P3;
```

```
fprintf('\n The market penetration of the three system combined is equal
        to = %.3f percent\n',P);
```

Input and Output:

(a) The Number of user that can be supported per cell is U= 120
Total Number of subscriber supported by system A= 47280

(b) The Number of user that can be supported per cell is U=450
Total Number of subscriber supported by system B = 44100

(c) The Number of user that can be supported per cell is U=880
Total Number of subscriber supported by system C = 43120

The market penetration for system A = 2.36%

The " " " " B = 2.205%

The " " " " C = 2.156%

The market penetration of the three system combined is equal to
= 6.725 percent.

Experiment 05: Find the Fraunhofer distance for an antenna with maximum dimension of 1 m and operating frequency of 900 MHz. If antennas have unity gain, calculate the path loss.

Solution:

Operating frequency, $f = 900\,MHz$

$$\lambda = c/f = \frac{3\times10^8 m/s}{900\times10^6 Hz} = 0.33m$$

Fraunhofer distance, $d_f = 2D^2/\lambda = 2(1)^2/0.33 = 6m$

path loss $P_L(dB) = -10\log[(\lambda)^2/(4\pi)^2 d^2]$ $\cancel{= -10\log[(0.33)^2}$

$= -10\log[(0.33)^2/(4\times3.14)^2\times36]$

$= 47\,dB$

Source code for Experiment 05:

```
clc;
clear all;
close all;

c=3*10^8;
f=900*10^6;
D=1;
lemda=c/f;
df=2*(D^2)/lemda;
pl=-10*log10((lemda^2)/(((4*pi)^2)*(df^2)));
fprintf('path Loss PL(dB)= %f\n',Pl);
```

Input & Output:

Path Loss PL (dB) = 47.089647

Experiment 06: In the US. digital cellular system, if $f_c = 900$ MHz and the mobile velocity is 70 Km/hr, calculate the received carrier frequency if the mobile (a) directly toward the transmitter (b) directly away from the transmitter (c) in a direction perpendicular to the direction of the arrival of the transmitted signal.

solution:

Given:

Carrier frequency $f_c = 900$ MHz

Therefore wavelength $\lambda = c/f_c = \frac{3\times10^8}{900\times10^6} = 1/3\,m = 0.33m$

vehicle speed $v = 70 \times 1000/60 \times 60 = 19.44$ m/s

(a) The vehicle is moving directly toward the transmitter

The received frequency is

$$f = f_c + f_d = 900\times10^6 + \frac{19.44}{0.33} = 900.0000589 \text{ MHz}$$

(b) The vehicle is moving directly away from the transmitter

The received frequency is given by

$$f = f_c - f_d = 900\times10^6 - \frac{19.44}{0.33} = 899.9999411 \text{ MHz}$$

(c) The vehicle is moving perpendicular to the angle of arrival of the transmitted signal.

In this case $\theta = 90°$, $\cos\theta = 0$ and there is no Doppler shift.

The received signal frequency is the same as the transmitted frequency of 900 MHz.

Source code for Experiment 06:

```
clc;
clear
close
carrier_frequency = 900* 10^6
wavelength = (3*10^8) / (900*10^6)
vehicle_speed = 70*(1000/(60*60))
disp('(A)');
disp( The vehicle is moving directly away from the transmitter)
The_received_frequency_of_A_is = floor (carrier_frequency)+
                                        (vehicle_speed/wavelength)

disp('B');
disp('(The vehicle is moving directly towards the transmitter)');
The_received_frequency_of_B_is = floor (carrier_frequency)_
                                        (vehicle_speed/wavelength)
disp('C');
disp('The vehicle is moving perpendicular to the angle of
      arrival of the transmitted signal)');
disp('The_received_signal_frequency_is_the_same_as_the_
      transmitted_frequency_900MHz);
```

Input & Output:

carrier_frequency = 900000000

wavelength = 0.3333

vehicle_speed = 19.4444

A

The vehicle is moving directly toward the transmitter

The received . frequency - of. A = 9.000 e +08

B

The vehicle is moving directly away from the transmitter

The - received - frequency - of - B = 9.0000 e + 08

C The vehicle is moving perpendicular to the angle of transmitted signal

so the received - frequency - of - C 900 MHz

Experiment 07: An urban RF radio channels are modelled on SIRCIM and SMRCIM statistical channel models with excess delays as large as 150 μs and microcellular channel with excess delays no larger than 4 μs. If the multiple path bin is selected at 70. calculate (a) ~~Af~~ $\Delta\tau$, (b) the maximum bandwidth which two model can accurately represent and (c) if the Indoor channel model with excess delays as large as 500 ns exists, calculate the values of (a) and (b).

solution:

The maximum excess delay of the channel model is given by $\tau_N = N\Delta\tau$.

(a) Given, for $\tau_N = 150\ \mu s$, and $N = 70$, $\Delta\tau = \tau_N/N = 2.14\ \mu s$

(b) The maximum bandwidth that the SMRCIM model can accurately represent is equal to $2/\Delta\tau = 2/2.14\ \mu s = 0.933\ MHz$

for the SMRCIM urban microcell model, $\tau_N = 4\ \mu s$, $\Delta\tau = \tau_N/N = 57.1\ ns$

The maximum RF bandwidth that can be represented ~~a~~ is

$$2/\Delta\tau = 2/57.1\ ns = 35\ MHz.$$

(c) Similarly, for indoor channel, $\Delta\tau = \dfrac{500\times10^{-9}}{70} = 7.14\ ns$.

The maximum RF bandwidth for the indoor channel model is

$$2/\Delta\tau = 2/7.14\ ns = 280\ MHz.$$

Source code for Experiment 07:

```
clc
clear all;
close all
%(a)
fprintf('(a)"\n');
Tn=150;
N=70;
delT=Tn/N;
fprintf('delT = %f ns\n', delT);
%(b)
fprintf('(b)\n'
Tn=4;
MBW=2/delT;
fprintf('The maximum bandwidth that the SMRCIM model can accurately represent = %f MHz\n',MBW);
Tn=4
delT=(Tn/N)*1000;
fprintf(' delT for SMRCIM urban microcell model is %f ns \n', RFBW)
RFBW=(2/delT)*1000;
fprintf('(c)*\n');
Exdel=500;
delT=Exdel/N;
fprintf('For indoor channel %f ns\n;delT);
RFBW=(2/delT)*1000;
fprintf('The maximum RF bandwidth for the indoor channel model is %.2f MHz\n', RFBW);
```

Input & Output:

(a) delT = 2.14 μs

(b) The maximum bandwidth that the SMRCIM model can accurately represent = 0.933MHz

delT for SMRCIM urban microcell model is 57.142857 ns

The Maximum RF bandwidth that can be represented is 35.00 MHz

(c) For indoor channel, 7.142857s

The maximum RF bandwidth for indoor channel model is 250. Hz.

Experiment 08: A zero mean sinosoidal message is applied to a ~~transformer~~ transmitter that radiates an AM signal with 400 KW power. Compute the carrier power if the signal is modulated on a depth of 0.75.

(a) what percentage of the total power is in the carrier?

(b) calculate the power in each sideband?

(c) what will be the total power saving if the carrier and one of the sidebands are now suppressed?

Solution:

using equation

$$P_{AM} = \frac{1}{2} A_c^2 [1 + P_m] = P_c \left[1 + \frac{K^2}{2}\right]$$

where $P_c = A_c^2/2$ is the power in the carrier signal

$P_m = (m^2(t))$ is the power in the modulating signal $m(t)$, and K is the modulation index.

$$P_c = \frac{P_{AM}}{1 + K^2/2} = \frac{400}{1 + 0.75^2/2} = 312.5 \text{ KW}$$

(a) Total power in the carrier is

$$\frac{P_c}{P_{AM}} \times 100 = 78.125\%$$

(b) Power in each sideband

$$\frac{1}{2}(P_{AM} - P_c) = 0.5 \times (400 - 312.5) = 87.5 \text{ Kw}$$

(c) Percentage power saving if one of the sideband and carrier is suppressed $= \left[1 - \left(\frac{87.5}{400}\right)\right] \times 100\% = 78.125\%$

sounce code for Experiment 08:

```
clc;
clear all
close all

Am signal power = 400;
modulation_depth = 0.75;
carrier_power_pc = (Am_signal_power)/(1+(0.75)^2)/2

disp('(a)');
total_power = (carrier_power_pc/Am_signal)*100;
disp('B');

Power_in_each_sideband = (Am signal_power_ carrier_power_pc)*0.5
disp('(c)');

percentage_power = (1-(Power_each_sideband)/Am side_power))*
100;
```

Output:

Carrier_power pc = 312.195;

A total_power_in_carrier = 78.0488

B power_each_sideband = 43.9024

C pertentage_power_saving = 89.0244

Experiment 09: A sinosoidal modulating signal $m(t) = 8\cos(2\pi 4 \times 10^3 t + 10)$ is applied to a modulator that has a frequency deviation constant gain of 10 KHz/V. compute

(a) the peak frequency deviation

(b) the modulating index.

(c) the phase modulating index.

Solution:

(a) For the given m(t), maximum value is 8V.

hence, the peak deviation $\Delta f = 8V \times 10\,KHz/V = 80\,KHz$

(b) Frequency modulation index, $\beta_f = \frac{\Delta f}{f_m} = \frac{80}{4} = 20$

(c) Phase modulation index, $\beta_p = K_p A_m = 10$ radians/v $\times 8v$

$= 80$ radians.

Source code for Experiment 09:

```
clc
clear all;
close all;

Fm=4;

mt_max_value=8;

womeca=10;

disp('A)');

Peak_deviation_delta_f = mt_max_value * womeca;

disp('B)');
```

```
Fre_modu_index_Bf = ( Peak_deviation_delta_f/Fm);
disp('(C)' );
phase_modulation_index = womeca * mt_max_value;
```

Output:

A
peak deviation_delta_f = 80

B
frequency_modulation_index_Bf = 20

C
phase_modulation_index = 80

Experiment 10: If GSM uses a frame structure where each frame consist of eight time slots, and each time slot contains 156.25 bits and data is transmitted at 270.833 Kbps in the channel, find (a) the time duration of a bit (b) the time duration of a slot (c) the time duration of a frame (d) how long must a user occupying a single time slot wait between two successive transmissions.

Solution:

(a) The time duration of a bit, $T_b = \frac{1}{270.833 \text{ Kbps}} = 3.692\ \mu s$.

(b) The time duration of a slot, $T_{slot} = 156.25 \times T_b = 0.577\ ms$

(c) The time duration of a frame, $T_f = 8 \times T_{slot} = 4.615\ ms$

(d) A user has to wait 4.615 ms, the arrival time of a new frame, for its next transmission.

- Source code for experiment 10:

```
clc;
clear all;
close all;
trans_data = 270.833;
Each_time_slot_bit = 156.25;
Num_time_slot = 8;
disp('(A)');
Time_duration_of_a_bit = Tb = (1/trans_data);
```

```
disp('(B)');

Time_duration_of_a_slot_Ts = (Each_time_slot_bit * Time_duration_of_a_bit_Tb);

disp('(C)');

Time_duration_of_a_frame_Tf = (Time_duration_of_a_slot_Ts * Num_time_slot);

disp('(A user has to wait 4.6.15 ms)');
```

Output:

A
$T_b = 0.0037$

B
$T_s = 0.5769$

C
$T_s = 4.6154$

D
A user has to wait 4.615 ms

Experiment 11: A normal GSM has 3 start bits, 3 stop bits 26 training bits for allowing adaptive equalization, 8.25 guard bits and 2 bursts of 58 bits of encrypted data which is transmitted at 270.833 Kbps in channel. Find

a) number of overhead bits per frame, b_{oh}
b) total number of bits/frame
c) frame rate
d) time duration of a slot
e) frame efficiency

Solution: A time slot has $6+8.25+26+2(58) = 156.25$ bits

(a) Number of overhead bits $b_{oh} = 8(6) + 8(8.25) + 8(26) = 322$ bit

(b) Number of bit/frame $= 8 \times 156.25 = 1250$ bit/frame

(c) Frame rate : 270.833 kbps / 1250 bits/frame = 216.66 frame/se

(d) Time duration of a slot $= 156.25 \times 1/270.833$ kbps

$= 576.92\ \mu s$

(e) Frame efficiency : $\eta = [1 - (322/1250)] = 74.24\%$

Source code for Experiment 11:

```
clc;
clear all;
close all;
tra_fre = 270.833;
```

```
Num_of_bits_in_each_time_slot = (6+ 8.25+26+ 2* 58);

disp('(A)');

BOH= (8*6 + 8 * 8.25 + 8*26);

disp('(B)');

Num_of_bits_per_frame = (8* Number_of_bits_in_each_time_slot);

disp('(C)');

frame_rate = (tra_fre/ Num_of_bits_per_frame)* 1000

disp('(D)');

Time_duration_of_a_slot = (Number_of_bits_in_each_time_slot)*
                                        (1/tra_free)* 1000

disp('(E)' );

Frame efficiency = (1 - (Number_of_overall_bits_BOH)/Number_
                                        of_bit_per_frame));
```

Output;

```
num_of_bits_in each_time_slot = 156.2500
num_of_overall_bit_ BOH = 322
num_of_bits per_frame = 1250
frame_rate = 216.6664
Time_duration_of_a_slot = 576.9238
Frame_efficiency = 74.2400
```