Delhi Technological University

Department of Electronics and Communication Engineering

B. Tech – 6th Semester

EC-304 Digital Signal Processing

Project Report

"Cognitive Radio Implementation by using MATLAB."

Submitted To:

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DECLARATION

We **Lokesh and Mohammad Sameer** solemnly declares that the project report "**Cognitive Radio Implementation by using MATLAB**" is based on my own work carried out during the course of our study under the supervision of **Prof. Avinash Ratre**.

I assert the statements made and conclusions drawn are an outcome of my research work.

We further certify that

I. The work contained in the report is original and has been done by me under the general supervision of my supervisor.

II. The work has not been submitted to any other Institution for any other degree/diploma/certificate in this university or any other University of India or abroad.

III. We have followed the guidelines provided by the university in writing the report.

IV. Whenever we have used materials (data, theoretical analysis, and text) from other sources, we have given due credit to them in the text of the report and giving their details in the references.

Supervisor	Made By
Prof. Avinash Ratre	Lokesh (2K19/EC/101)
	Mohammad Sameer (2K19/EC/110)

CERTIFICATE

This is to certify that the project report entitled "**Cognitive Radio Implementation by using MATLAB**", submitted to the Department of Electronics and Communication Engineering, Delhi Technological University, in partial fulfilment for the award of the degree of Bachelor of Technology is a record of work carried out by **Lokesh and Mohammad Sameer.**

No part of this report has been submitted elsewhere for award of any other degree.

Supervisor	Made By
Prof. Avinash Ratre	Lokesh (2K19/EC/101)
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Once again, we would like to thank Avinash Ratre Sir for always being so supportive and helpful. None of this would have been possible without his guidance.

A special thanks to all our colleagues who have been so supportive during this time. We feel that words will fall short in expressing how grateful we that we got to perform this project and that we were given the chance to explore and expand my horizons.

Thank you everyone.

Regards

Lokesh (2K19/EC/101)

Mohammad Sameer (2K19/EC/110)

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Objectives of our Project

- In order to simulate *Cognitive Radio System by using MATLAB*.
- To ensure maximum utilization of the frequency spectrum.
- To increase the efficiency of a frequency spectrum by decreasing spectrum holes.
- Attenuation of the noisy signal.

Cognitive Radio

Cognitive Radio and Dynamic Spectrum Access represent two complementary developments that will refashion the world of wireless communication. In order to investigate the roles of knowledge representation and reasoning technologies in this domain, we have developed an experimental cognitive radio simulation environment.

A *Cognitive Radio*(dynamic spectrum management) is a transceiver which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so more wireless communications may run concurrently in a given spectrum band at a place.

Given the demand for more bandwidth and the amount of underutilized spectrum, DSA (*Dynamic Spectrum Access*) networks employing cognitive radios are a solution that can revolutionize the telecommunications industry, significantly changing the way we use spectrum resources , and design wireless systems and services.

Spectrum is a natural resource and we have a limited availibilty of spectrum. FCC has reported that some frequency bands like Radio and TV are underutilized. While mobile bands are overutilized . This shows that there is inefficiency in utilization of spectrum. Therefore we need todynamically use the spectrum called as dynamic spectrum access. The solution is we need a clever cognitive radio system.

The important challenge is to share the licensed spectrum without interfering with the transmission of other licensed users. The cognitive radio enables the usage of temporarily unused spectrum, which is refered to spectrum hole or white space.

Possible Applications of Cognitive Radio System

Cognitive Radio techniques which allow spectrum sharing with other spectrum users are ideal for non-time critical applications. Four applications were considered to be the most promising:

- Mobile multimedia downloads (for example, download of music/video files to portable players) which require moderate data rates and near-ubiquitous coverage.
- Emergency communications services that require a moderate data rate and localized coverage (for example, video transmission from firemen's' helmets).
- Broadband wireless networking (for example, using nomadic laptops), which needs high data rates, but where users may be satisfied with localized "hot spot" services.
- Multimedia wireless networking services (e.g. audio/video distribution within homes) requiring high data rates.

The main specific benefit of full *Cognitive Radio* is that it would allow systems to use their spectrum sensing capabilities to optimize their access to and use of the spectrum. From a regulator's perspective, dynamic spectrum access techniques using *Cognitive Radio* could minimize the burden of spectrum management whilst maximizing spectrum efficiency

Background Study

Most of today's radio systems are not aware of their radio spectrum environment and operate in a specific frequency band using a specific spectrum access system. Investigations of spectrum utilization indicate that not all the spectrum is used in space (geographic location) or time. A radio, therefore, that can sense and understand its local radio spectrum environment, to identify temporarily vacant spectrum and use it, has the potential to provide higher bandwidth services, increase spectrum efficiency and minimize the need for centralized spectrum management. This could be achieved by a radio that can make autonomous (and rapid) decisions about how it accesses spectrum.
Cognitive radios have the potential to do this. Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase spectrum efficiency and provide wideband services.

Spectrum Holes

A spectrum hole in frequency is technically defined as a frequency band in which a secondarycan transmit without interfering with any primary receivers (across all frequencies).

A frequency band that is momentarily unoccupied by a primary user. Secondary usersuse spectrum sensing to find spectrum holes.

The vacant spectrum band which is not in use by any user.

FCC has recently recommended that significantly greater spectral efficiency could be realized bydeploying wireless devices that can coexist with the licensed users.

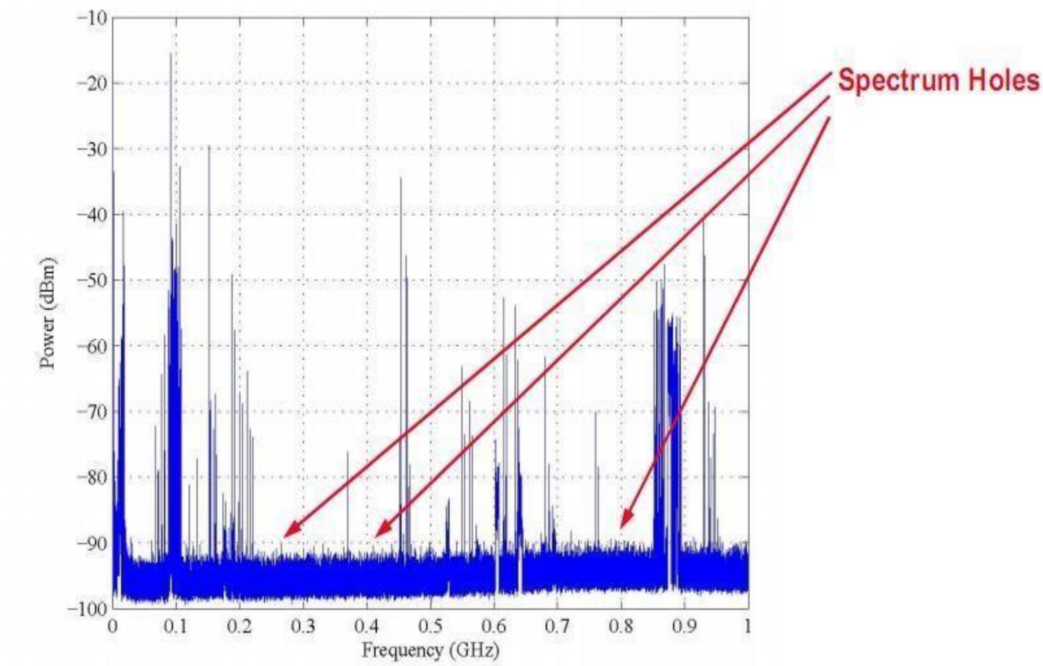
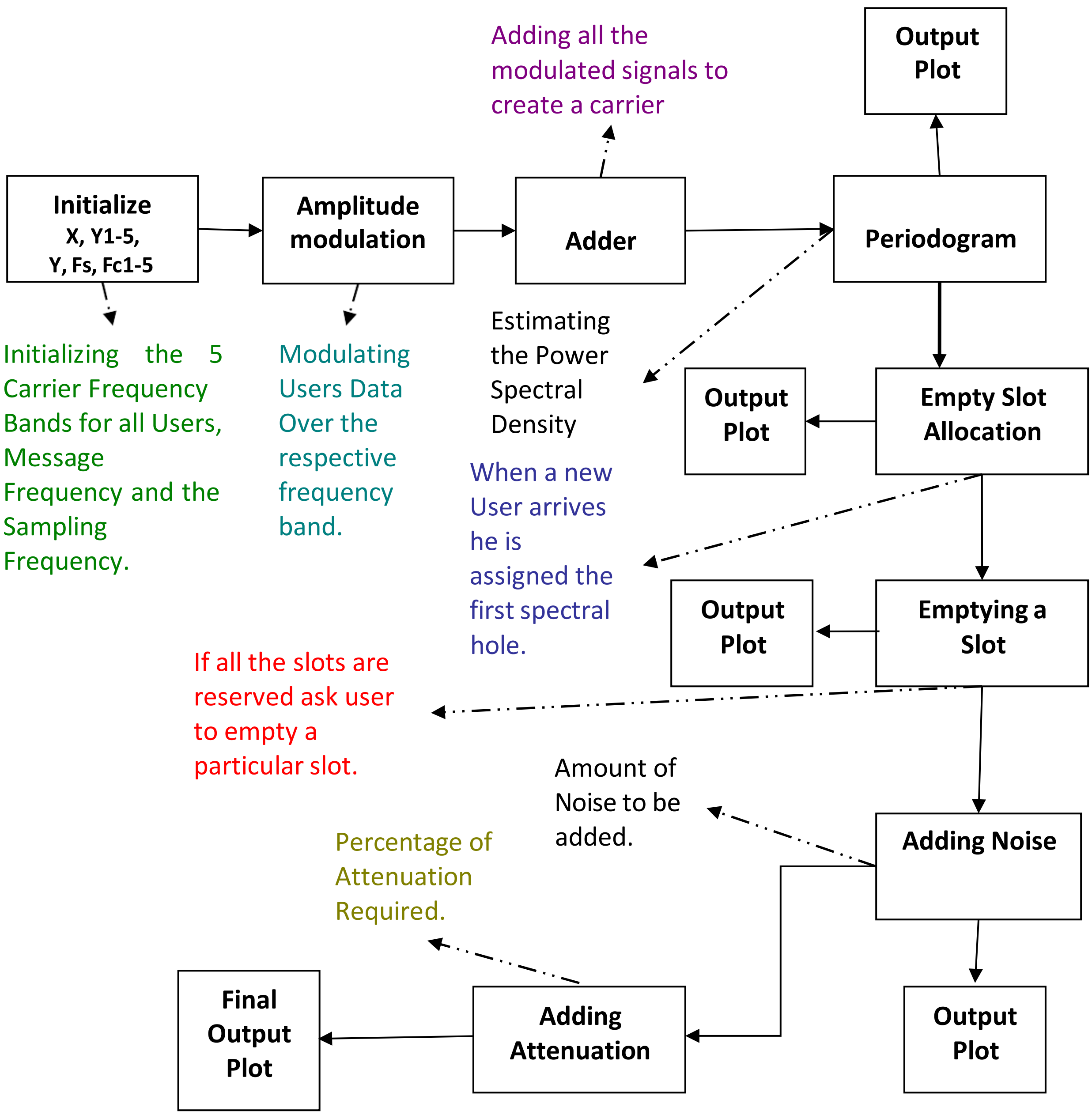


Fig 01: Spectrum measurement across the 900 kHz –1 GHz band (Lawrence, KS, USA)

Solution Technique

We've investigated the idea of simulating a cognitive radio system to reuse locally unused spectrum to increase the total system capacity. We have simulated the basics of a simple *cognitive radio system* in MATLAB R2009a. We've tried our best to make our codes and findings as simple as possible, so that they're easily understandable by anyone who has even a little ideaabout the basic communication systems.

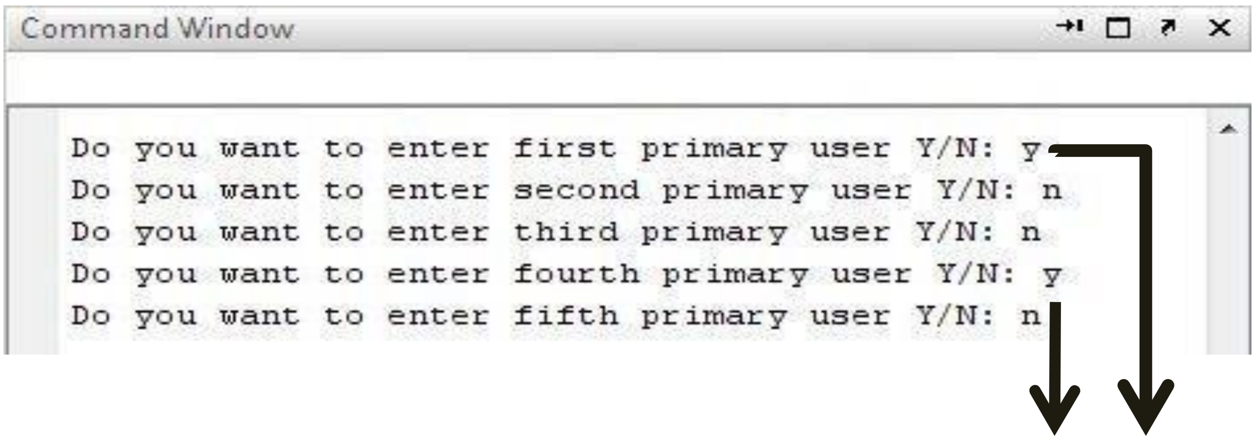
Block Diagram of Simulation



Experimental Analysis :

I. Assigning Primary User to the Frequency Spectrum

We've designed our system to have 5 different frequency channels and each User is assigned a particular frequency band. Once we run our program it'll ask to add a User and assign it a particular band in ascending order.



Data assigned for primary user 4 & 1

Fig 02: Addition of primary user in the frequency spectrum in Command Window

Here we haven't entered User 2, 3 & 5, thus their respective bands are still un-allocated. We can see them below in the power spectral density graph of our carrier signal.

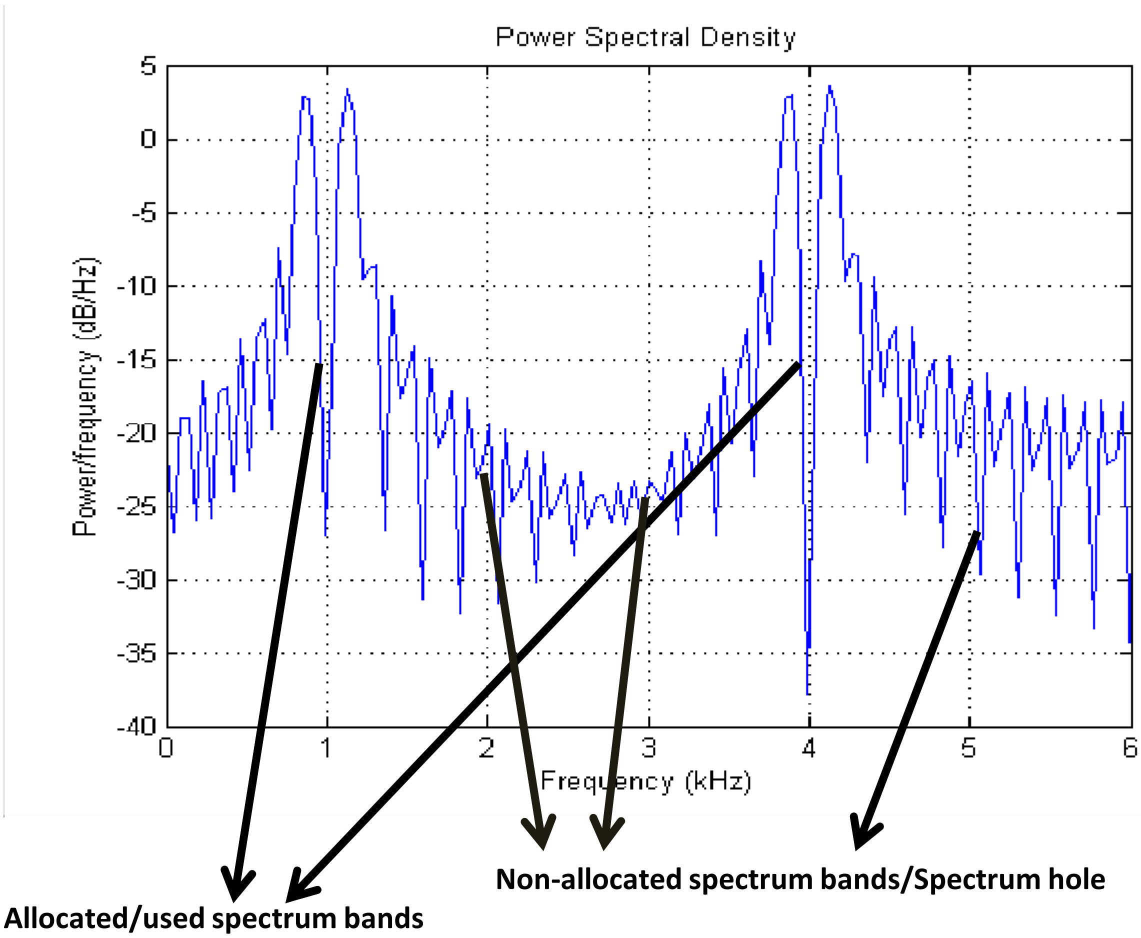


Fig 03: Power spectral density curve

II. Assigning new user to the Spectrum Holes

Now we’re adding another User, the system will search the first available gap in the spectrum and automatically assign it to the new user. As the first available gap was after User-1 as User-2 was not sending any data so the band reserved for User-2 at start is now assigned to this new User.

```
Command Window

Do you want to enter first primary user Y/N:  y
Do you want to enter second primary user Y/N:  n
Do you want to enter third primary user Y/N:  n
Do you want to enter fourth primary user Y/N:  y
Do you want to enter fifth primary user Y/N:  n

Do you want to enter another primary user Y/N:  y
Assigned to User 2 as it was not present.

Do you want to enter another primary user Y/N:  y
Assigned to User 3 as it was not present.
```

Fig 04: Assigning new user to the Spectrum Holes in Command window

Here we can see that the first spectral gap has been filled by assigning the new incoming User'sdata. The first spectral gap belonged was that of User-2.

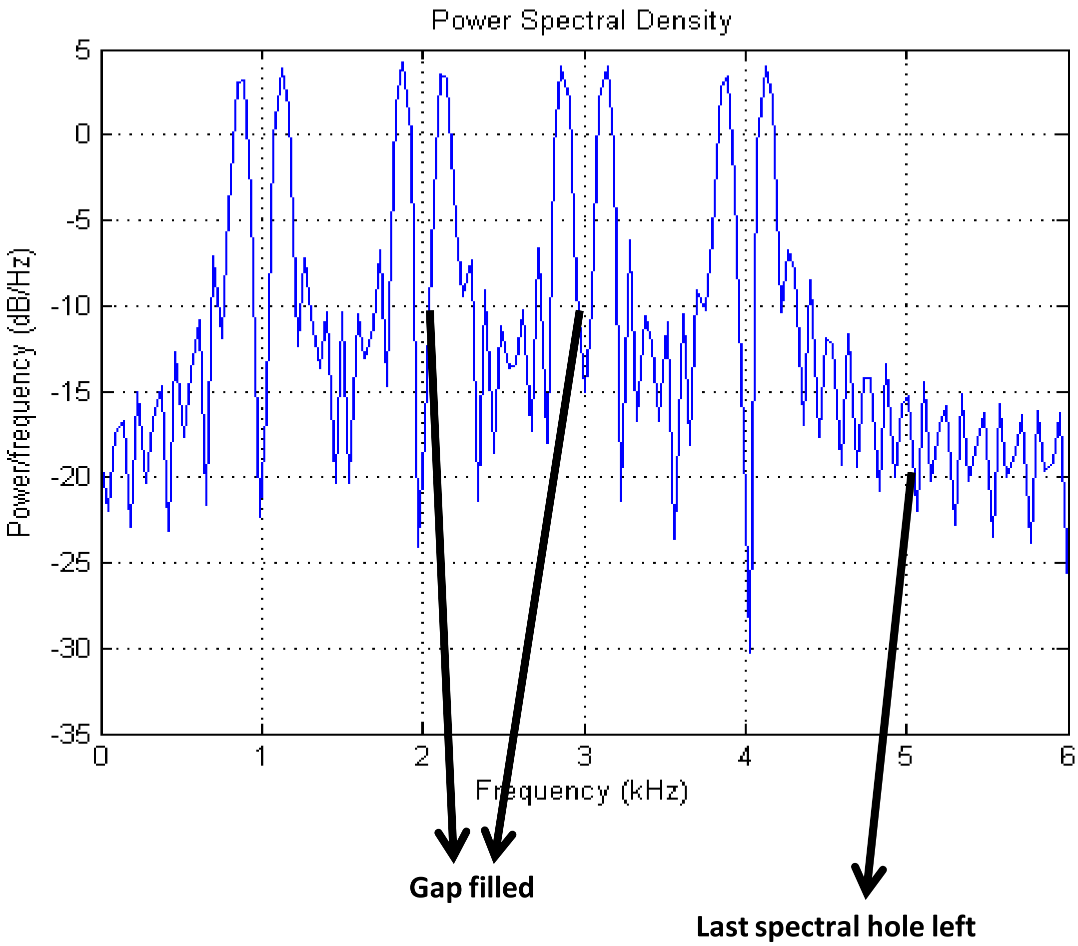


Fig 05: Power spectral density curve: one slot remaining in the frequency spectrum

III. Efficient frequency Band width

Now we've just one empty slot left which will get filled by addition of another Primary User.

The power spectral density curve of the signal shows us that all of the frequency bands areefficiently in use after the addition of the last incoming user.

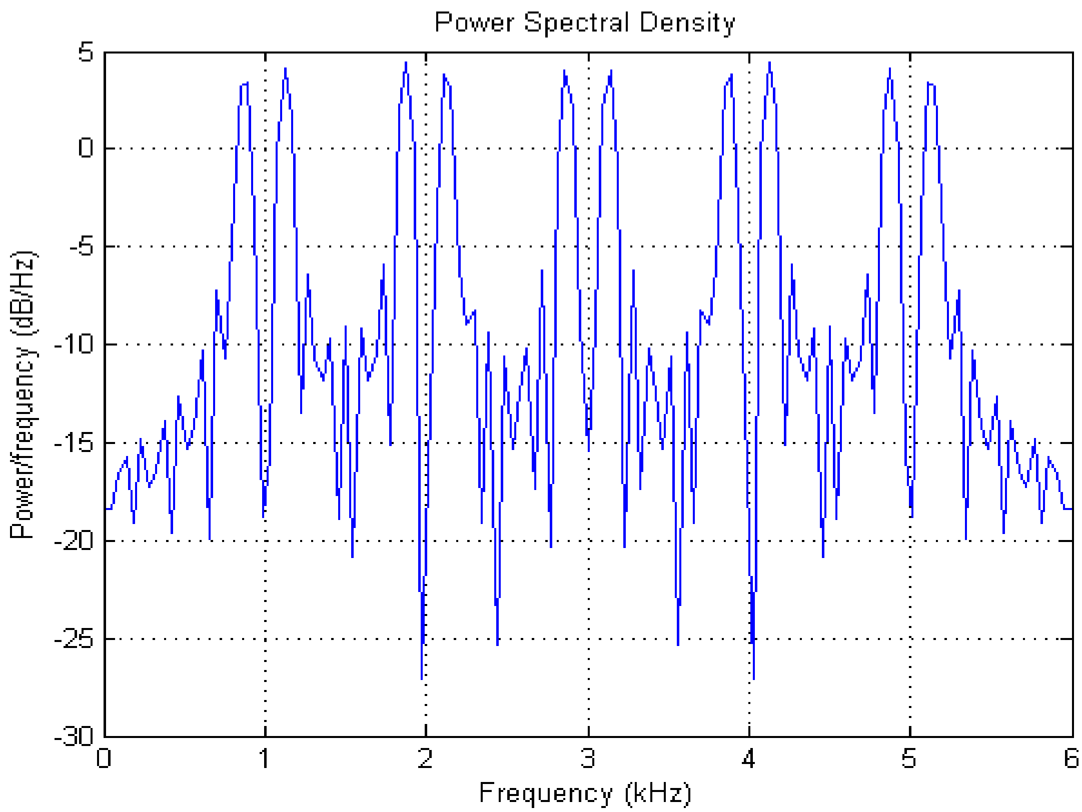


Fig 06: Power spectral density curve: All of the frequency bands are efficiently in use

IV. Elimination of a Slot

Once all the slots are being assigned, our system will entertain no other User and will be able tofree up the slots one by one as shown below.

If we ask it to empty a slot, it will remove the data of that slot and make it ready for the nextassignment.

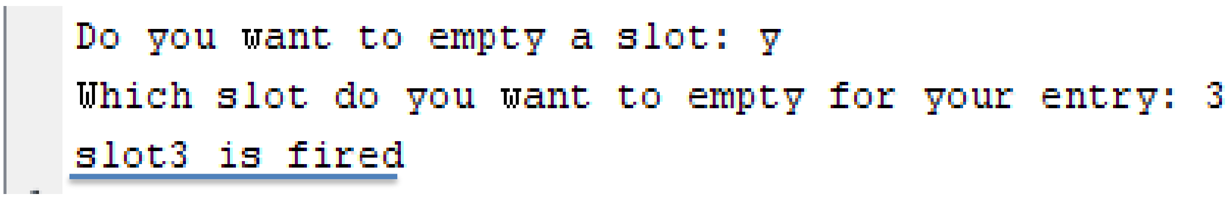


Fig 07: Elimination of a slot in Command Window

Following graph is shown below.

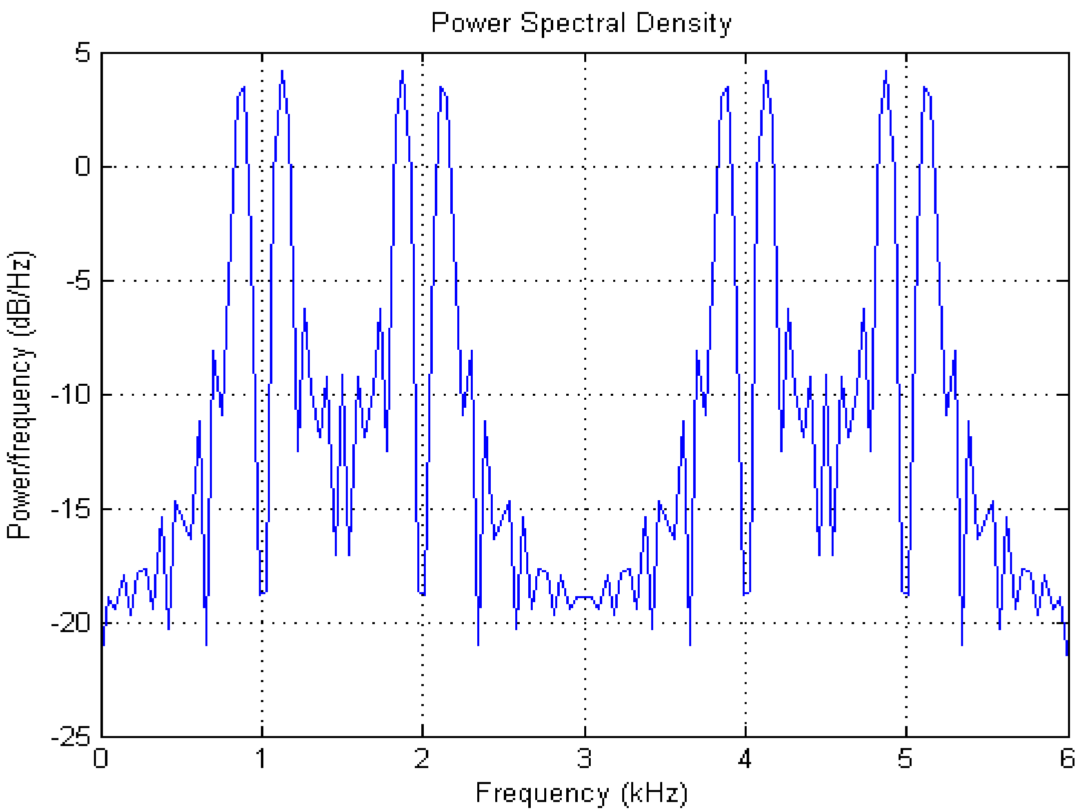
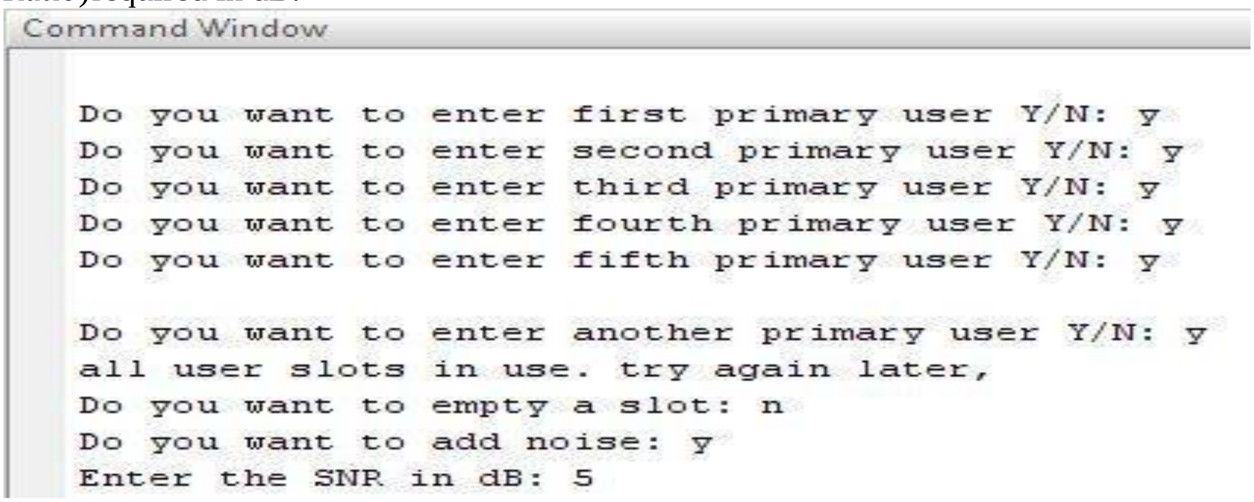


Fig 08: Power spectral density curve: From the frequency spectrum 3rd slot has been eliminated

V. Addition of Noise Parameters to Analyze the Channel Characteristics

Now we can add noise in our carrier and the system will ask for the SNR (*Signal to Noise Ratio*)required in dB.



```
Command Window

Do you want to enter first primary user Y/N: y
Do you want to enter second primary user Y/N: y
Do you want to enter third primary user Y/N: y
Do you want to enter fourth primary user Y/N: y
Do you want to enter fifth primary user Y/N: y

Do you want to enter another primary user Y/N: y
all user slots in use. try again later,
Do you want to empty a slot: n
Do you want to add noise: y
Enter the SNR in dB: 5
```

Fig 09: Addition of noise in Command Window

Here we've added noise to our signal. The resulting noisy carrier's power spectral graph is givenbelow.

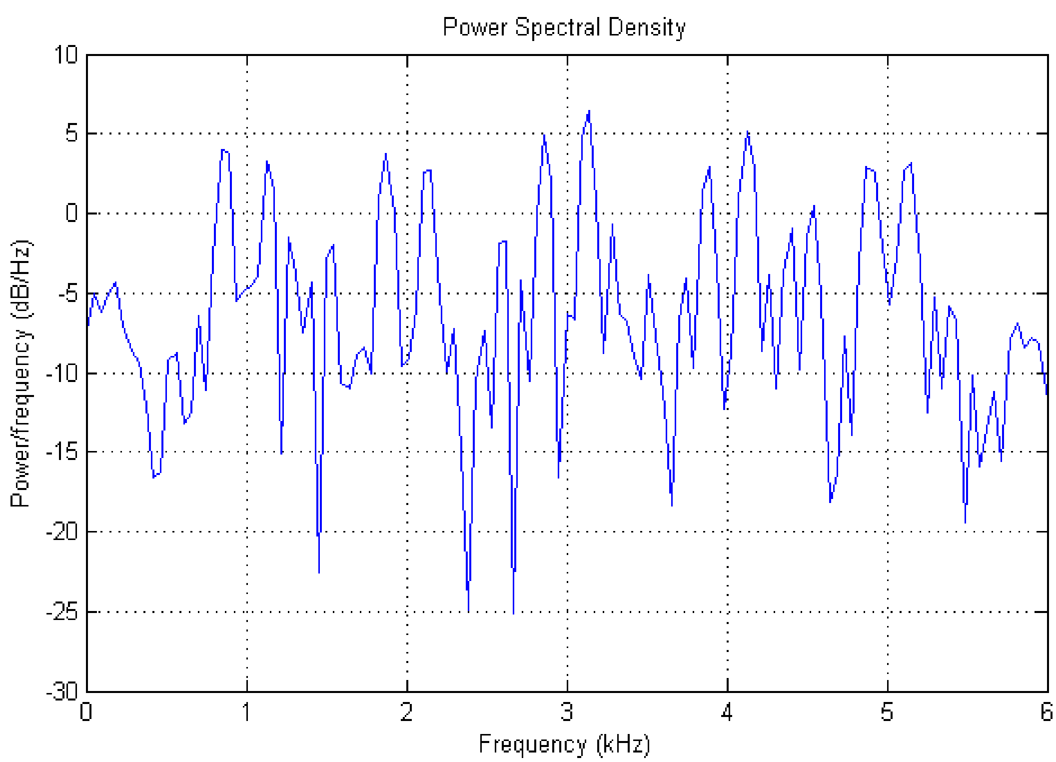


Fig 10: Power spectral density curve with a noise at 5dB

VI. Attenuation of the Signal

Now we're attenuating our carrier and the system will ask for the percentage of attenuation required.

```
Command Window

Do you want to enter first primary user Y/N: y
Do you want to enter second primary user Y/N: y
Do you want to enter third primary user Y/N: y
Do you want to enter fourth primary user Y/N: y
Do you want to enter fifth primary user Y/N: y

Do you want to enter another primary user Y/N: y
all user slots in use. try again later,
Do you want to empty a slot: n
Do you want to add noise: y
Enter the SNR in dB: 5
Do you want to attenuate the signals? [Y/N]: y
Enter the percentage to attenuate the signal: 30
```

Fig 11: Attenuation of the signal in Command Window

The attenuated signal is shown below.

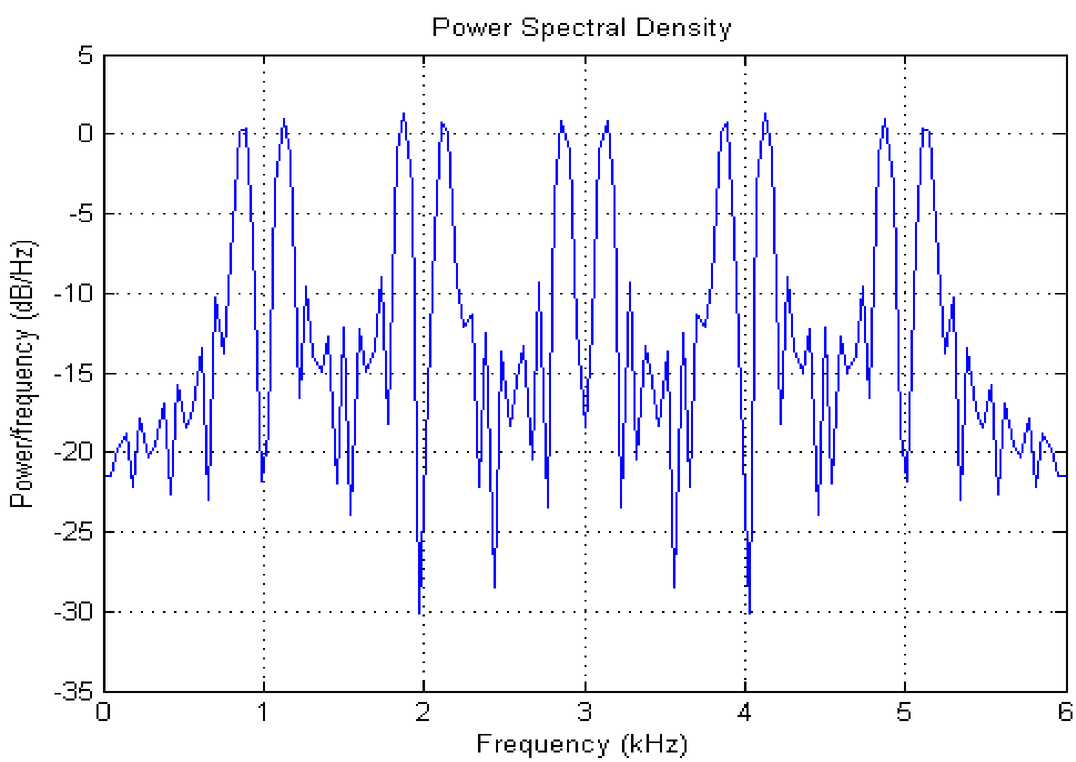


Fig 12: Power spectral density curve with a noise at 5dB and 30% attenuation

Once all the parameter have been applied to the carrier, the system will ask for re-assignments of bands by starting the whole process again infinitely so that all the incoming users at any instant of time are accommodated in the spectral holes left in the channel maximizing the overall output of the channel.

Matlab Code:

```
t = 0:0.00001:0.001;
% we've taken 5 carrier frequencies Fc1 = 1000, Fc2 = 2000, Fc3 = 3000, Fc4=4000 & Fc5 = 5000
% keeping the user message/data signal frequency as 1000.
Fc1 = 1000;
Fc2 = 2000;
Fc3 = 3000;
Fc4 = 4000;
Fc5 = 5000;
Fs = 12000;
y1 = 1; y2 = 0; y3 = 0; y4 = 0; y5 = 0; Y = 0; y = 0;
x1 = cos(2*pi*1000*t);                          % every user's base band data signal

% once user 1's data arrive, it is modulated at the first carrier Fc1, similarly as the 2nd user's
% data arrives; it is modulated at the 2nd carrier Fc2, so on till fifth user is assigned the Fc5
% band. If any user's data isn't present his frequency band remains empty which is called a
% Spectral Hole.

in_p = input('\nDo you want to enter first primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y1 = ammod(x1,Fc1,Fs);
end
in_p = input('Do you want to enter second primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y2 = ammod(x1,Fc2,Fs);
end
in_p = input('Do you want to enter third primary user Y/N: ','s');
if(in_p == 'Y' ||in_p == 'y')
y3 = ammod(x1,Fc3,Fs);
end
in_p = input('Do you want to enter fourth primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y4 = ammod(x1,Fc4,Fs);
end
in_p = input('Do you want to enter fifth primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
y5 = ammod(x1,Fc5,Fs);
```

```
end
% once all the assignment is complete we add all the signals to create a carrier signal
% which will be analyzed for empty slots as the channel.
y = y1 + y2 + y3 + y4 + y5 ;
while(1)
% Now we'll estimate the power spectral density of our carrier signal using the periodogram();
% function and the values are stored in an array Pxx. Pxx is the distribution of power per unit
% frequency. This value is then stored in a dsp data object and then plotted.
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
% psd                 - Power Spectral Density (PSD) data object
% pseudospectrum - Pseudo Spectrum data object
in_p = input('\nDo you want to enter another primary user Y/N: ','s');
if(in_p == 'Y' || in_p == 'y')
tp=0;
% we've obtained five points for all users in the array Pxx which multiplied by 10000 should be
% above 8000 if there's no spectral hole. //this just an observation which is working so far, the
% technical aspects will be addressed later in the presentation.
chek1 = Pxx(25)*10000;
chek2  =  Pxx(46)*10000;
chek3  =  Pxx(62)*10000;
chek4  =  Pxx(89)*10000;
chek5 = Pxx(105)*10000;
% now if there is a new user entering the channel, we'll check the array Pxx, at certain location
% and assign user the first spectral gap as coded below
if(chek1 < 8000)
disp('Assigned to User 1 as it was not present.');
y1 = ammod(x1,Fc1,Fs);
elseif (chek2 < 8000)
disp('Assigned to User 2 as it was not present.');
y2 = ammod(x1,Fc2,Fs);
elseif(chek3 < 8000)
disp('Assigned to User 3 as it was not present.');
y3 = ammod(x1,Fc3,Fs);
elseif(chek4 < 8000)
disp('Assigned to User 4 as it was not present.');
y4 = ammod(x1,Fc4,Fs);
elseif(chek5 < 8000)
disp('Assigned to User 5 as it was not present.');
y5 = ammod(x1,Fc5,Fs);
else
```

```
disp('all user slots in use. try again later,');
tp=1;
end
figure
y = y1 + y2 + y3 + y4 + y5 ;
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
if(tp==1)
% then we've the slot emptying algorithm which will empty the already occupied bands by
% asking user to choose a slot and executing the following code.
inp_t=input('Do you want to empty a slot: ','s');
if(inp_t=='Y'||inp_t=='y')
inp_t=input('Which slot do you want to empty for your entry: ','s');
switch(inp_t)
case ('1')
y1=0;
disp('slot1 is fired');
y = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
case('2')
y2=0;
disp('slot2 is fired');
y = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
case('3')
y3=0;
disp('slot3 is fired');
% then we repeat the above plotting procedure that was done after the assignments.
% To add noise to our signal I've used the simpler awgn(); function.
y = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
case('4')
y4=0;
disp('slot4 is fired');
y = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
```

```
plot(Hpsd);
case('5')
y5=0;
disp('slot5 is fired');
y = y1 + y2 + y3 + y4 + y5;
Pxx = periodogram(y);
Hpsd = dspdata.psd(Pxx,'Fs',Fs);
plot(Hpsd);
otherwise disp('Invalid slot entered');
end
end
end
inp_t=input('Do you want to add noise: ','s');
if(inp_t=='y'||inp_t=='Y')
d = input('Enter the SNR in dB: ');
figure
Y = awgn(y,d);
Pxx1 = periodogram(Y);
Hpsd = dspdata.psd(Pxx1,'Fs',Fs);
plot(Hpsd);
End

% to attenuate our signal the system asks for the percentage of attenuation required followed
% by the plot of the attenuated carrier signal. The percentage divided by hundred is subtracted
% from 1 and the remaining number is multiplied with the signal.
temp = input('Do you want to attenuate the signals? [Y/N]: ','s');
if(temp == 'Y' || temp == 'y')
aF = input('Enter the percentage to attenuate the signal: ');
figure
tem = aF/100;
tm = 1-tem;
Z = y.*tm;
disp('attenuating');
grid;
plot(Z);
Pxx4 = periodogram(Z);
Hpsd = dspdata.psd(Pxx4,'Fs',Fs);
plot(Hpsd);
end
end
temp = input('Do you want to re-run the program? [Y/N]: ','s');
if(temp == 'Y' || temp == 'y')
disp('\n\nEnter the users again.\n\n');
else
```

```
break;
end
end
```

Conclusion

We’ve simulated the basics of a cognitive radio systems enabling dynamic spectrum access at run time. Mobile multimedia downloads emergency communications services, broadband wireless networking, “hot spot” services; multimedia wireless networking services are the best applications of Cognitive radio system. Cognitive radios are still in research pipelines as cognitive science is in its infancy. By using MATLAB, we intend to come out with a simpler and efficient simulating technique. The consequences on the basis of power spectral density of the channel which can be used cognitively to find out the available gaps those can be assigned to new incoming users thus improving the overall channel’s output.

Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase spectrum efficiency and provide wideband services. We’ve shown the simulation of a *Cognitive Radio System by using MATLAB* where maximum utilization and efficiency of the frequency spectrum have been ensured and the noisy signal has also been attenuated.

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