

SIMULATIONS OF NETWORKS IN OPNET AND IMPLEMENTATION OF OFDM IN ADS

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF**

Bachelor of Technology

In

Electronics and Communication Engineering

By

SWAVAB SOURAV MOHARANA(10509027)

And

PRATEEK KUMAR PATRO(10507019)

Under the guidance of

Prof S.K.PATRA



Department of Electronics and Communication Engineering

National Institute of Technology

Rourkela-769008



National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled, “SIMULATIONS OF NETWORKS IN OPNET AND IMPLEMENTATION OF OFDM IN ADS” submitted by SWAVAB SOURAV MOHARANA and PRATEEK KUMAR PATRO in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Electronics & Communication Engineering and Electronics & Instrumentation Engineering, respectively at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

Prof S.K.PATRA

Dept. of Electronics & Communication Engineering

National Institute of Technology

Rourkela-769008

ACKNOWLEDGEMENT

We are thankful to all individuals who have lent us support and guidance without which we could not have completed our project in the stipulated period of time. First and foremost we would like to express our deepest gratitude to our project supervisor, **Prof. S.K.Patra, Department of Electronics and Communication Engineering**, for his invaluable support, guidance, motivation and encouragement throughout the period. His incisive inputs, his concern and assistance even during simulation have been extremely helpful. It was his enthusiastic and progressive outlook towards the project which inspired us throughout our work during this period? He closely followed the progress of the project and was always available for guidance. We are grateful to staff members of Computer Centre, for their valued suggestions and inputs during the course of the project work. We also extend our thanks to our fellow students for their friendly co-operation.

Prateek Ku. Patro
Roll. No. 10507019
Department of E.C.E.
NIT Rourkela

Swavab Sourav Moharana
Roll No. 10509027
Department of E.C.E.
NIT Rourkela

ABSTRACT

The OPNET software was used to simulate the different scenarios of the networks which clearly explain the way the data is transmitted and received. We also find a lot about different topologies and how subnets can be used to effectively connect nodes in a network. The easy-to-use and drag-and-drop nature of OPNET helped a lot in simulating networks in star topology, creating different types of servers for each department of a campus network. The papers on wireless networks were very enlightening, awakening us to different standards presently in use, like, 802.11, 802.16, etc.

The second half of the project included simulating ofdm in ADS. It is a case in point of the use of communication systems in present day technologies. We came to know of the use of ofdm in present wireless technologies. The advantages and disadvantages of ofdm also came to the fore. The ADS software's user-friendly interface was very helpful in simulating the transmitter and receiver.

CONTENTS

| <u>Sl.no.</u> | <u>Title</u> | <u>Page no.</u> |
|---------------|----------------------------------|-----------------|
| 1 | Simulations in OPNET | 6-17 |
| 2 | Simulations in ADS | |
| A | Chapter-1 (Introduction) | 19-21 |
| B | Chapter-2 (ADS) | 22-29 |
| C | Chapter-3 (OFDM) | 30-34 |
| D | Chapter-4 (Transmitter/Receiver) | 35-37 |
| E | Chapter-5 (Simulations) | 38-47 |
| 3 | Conclusion | 48 |
| | References | 49 |

SIMULATIONS OF NETWORKS IN OPNET

NETWORKING-A CONCEPT

Networking basically refers to the technology which strives to connect two or more computers into a cohesive network in which transfer of data can take place mutually. It is quintessential to a horde of technologies which are based on networking as the backbone. Some of the initial ideas in this topic deal with the issue of understanding the different kinds of topologies that can be implemented like:

1. Bus topology
2. Ring topology
3. Star topology
4. Mesh topology

Each of these topologies is implemented in a unique way. In bus topology, a common cable connects all the nodes and provides for the backbone of a network essentially. In star topology, each node is connected to a central hub. In ring topology, data moves around in a single direction around the ring from one node to another. Each node acts as a repeater as well. In mesh topology, each node is connected to all other nodes. The Network operating system (NOS) monitors the exchange and flow of files and other information. There are two types of NOS: peer-to-peer or client-server NOS's.

- Server-based or centralized: A centralized server serves the clients
- Peer-to-peer: Clients share the resources among themselves

A peer-to-peer network is economical and easy to setup. But on the flip side, it doesn't provide enough security and there is no central backup system as well.

The International Standards Organization (ISO) formulated the OSI model for standardizing the network architectures and enabling easy interconnectivity. The OSI model defines seven layers of network services. Each layer wraps the

preceding layer's data and header with its own header. On the receiving end, each layer strips off the header that corresponds to its respective level. The different layers corresponding to the OSI model are:

- I. Physical Layer: This layer handles the electrical/light communication across the network media. This deals with the mechanical, electrical, functional, and procedural aspects. It also defines the hardware characteristics such as voltage/current levels, signal strength, connector, and media.
- II. Data link Layer: It takes care of reliable delivery of data across a physical network by packaging, addressing and transmitting. It ensures that the information has been delivered. Ethernet, Token ring, PPP and SLIP are examples of protocols followed by this layer.
- III. Network Layer: It takes care of the routing of data (packets) to a system on the network and handles the addressing and delivery of data.
- IV. Transport Layer: It contains protocols and takes care of reliable transmission of data. Two major transport protocols are the TCP (Transmission Control Protocol) and the UDP (User Datagram Protocol).
- V. Session Layer: There are about 22 services provided by this layer. The main services are dialogue control and dialog separation.
- VI. Presentation Layer: This layer's main function is translation of the syntax and semantics of the data transmission. On the sending side, it converts computer's data representations into a standard network format. On the receiving side, it translates the network format into the receiving end computer's format.
- VII. Application Layer: This layer provides an entrance point for the application software to access network. Examples include File Transfer Protocol (FTP), Dynamic Host Configuration Protocol (DHCP), Telnet, and Simple Mail Transfer Protocol (SMTP).

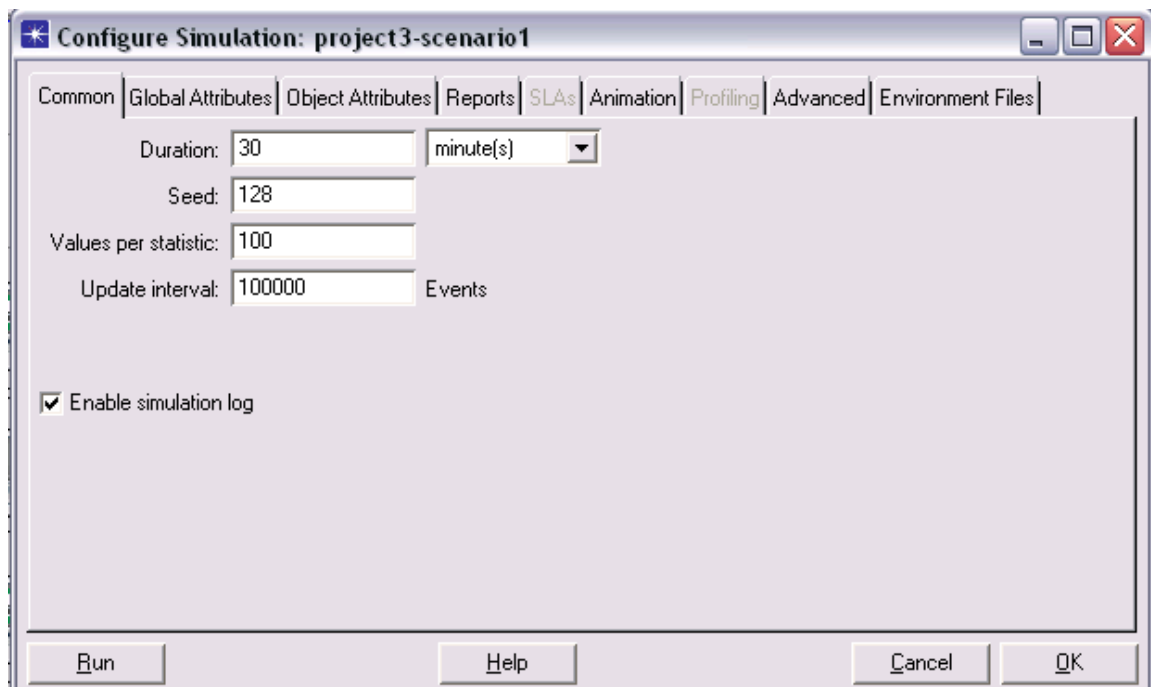
The OPNET Software For Simulations

The OPNET modeler is a sophisticated work-station based environment for the modeling and simulation of communication systems, protocols and networks. It has a hierarchical, object-based modeling structure. It also has a graphical interface which displays the characteristics of different individual parameters in comparison with the other parameters.

This software is relatively easy to use; a prognosis of the network can be performed. But the time for simulation of big networks can be cumbersome.

It has a drag-and-drop scheme for setting up networks. A network editor provides us with the workspace to work with. The network is subdivided into subnets. It consists of graphical representation of network topology. It also consists of global, node and link models.

The time of simulation can be set during the run of the simulation. The following figures show the run window.



Wireless LAN- An Introduction

A **local area network (LAN)** is a computer network covering a small physical area, like a home, office, or small group of buildings, such as a school, or an airport. It has a lot of techniques through which networks can be implemented. For example: VLAN, Spanning Tree, LAN sizing. Wireless technology is one of its more illustrious and efficient counterparts.

Wireless computing is a rapidly emerging technology providing users with network connectivity without being tethered to a wired network. Wireless local area networks (WLANs), like their wired counterparts, are being developed to provide high bandwidth to users in a limited geographical area. WLANs are being studied as an alternative to the high cost traditional additions, deletions, and changes experienced in wired LAN infrastructures. Physical and environmental necessity is another driving factor in favor of WLANs. Typically, new building architectures are being planned with network connectivity as one of the key features of the building. However, users in existing buildings may find it impractical to incorporate existing structures with wired network access. Examples of structures that are very difficult to wire include concrete buildings, trading floors, manufacturing facilities, warehouses, and historical monuments. Lastly, the operational environment may not accommodate a wired network, or the network may be temporary and operational for a very short time, making the installation of a wired network impractical. Examples where this is true include ad hoc networking needs such as conference registration centers, campus classrooms, emergency relief centers, and tactical military environments.

It has ensured the setting up of a hassle-free network at minimal cost. With an enviable bandwidth and easy access this technology is here to stay. Due to the robust nature of this kind of networks, it is possible to reach out to the remotest parts of a place with consummate ease.

SIMULATION 1

AIM: To simulate a network using a simple star topology
Create a New Project

In this first phase a project will be opened and named and the first simulation scenario named. The first simulation scenario will consist of 16 networked stations (PCs) and one hub. In this first phase the geographic size of the network is small.

1. Start the OPNET IT Guru Academic Edition. Choose New from the File menu.
2. Select Project and click OK. Name the project. Name the scenario.
3. In the Startup Wizard, initial Topology dialog box, make sure that Create Empty Scenario is selected and click next. Choose Office from the Network Scale List. Click Finish.
4. Close the Object Palette dialog box.

Create the Network

To create our switched LAN:

1. Select Topology Rapid Configuration. From the drop-down menu choose Star and click OK.
2. Click the Select Models button in the Rapid Configuration dialog box. From the Mod List drop-down menu choose Ethernet and click OK.
3. In the Rapid Configuration dialog box, set the following six values: Center Node Mod= ethernet16_hub, Periphery Node Model = Ethernet station, Link Model = 10BaseT, Number =16, Y=50, and Radius = 42 Click OK.

The 10BaseT link represents an Ethernet connection operating at 10Mbps.

4. Now that the network has been created, it should look like the network on Figure below.

Choose Statistics

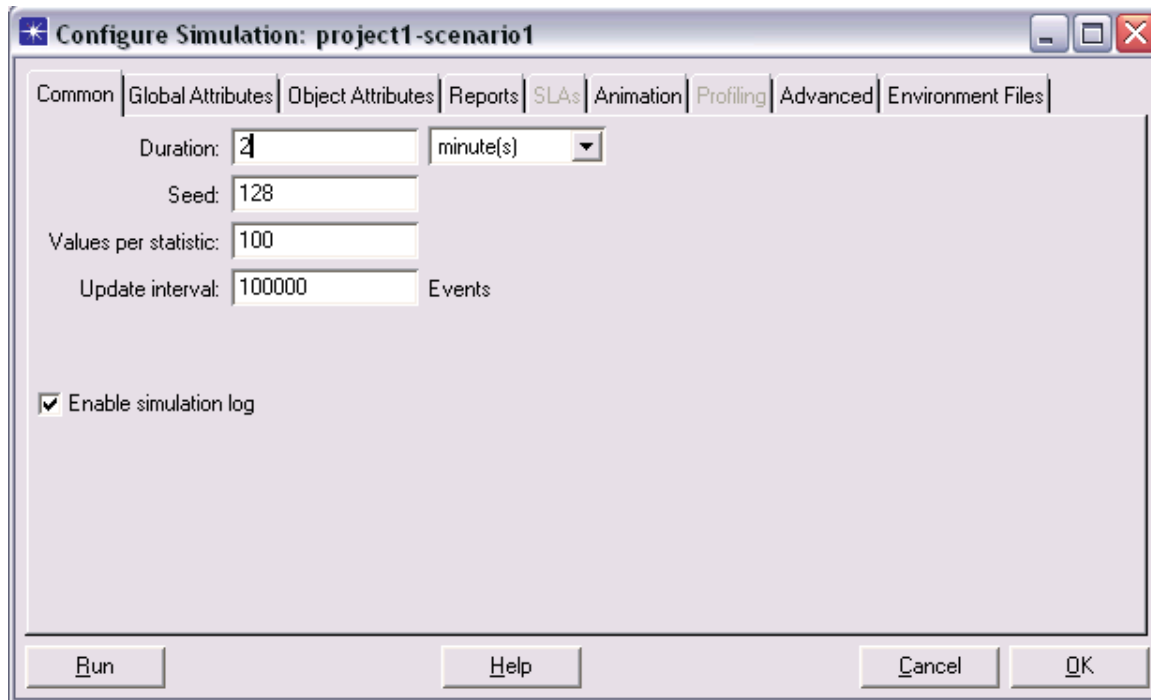
To choose the statistics to be collected during the simulation:

1. Right-click anywhere in the project workspace and select Choose Individual Statistics DES from the pop-up menu.
2. In the Choose Results dialog box, choose the following 4 statistics:

A. Ethernet Delay – this represents the end-to-end delay of all packets received

by all the stations.

B. Traffic Received (in packets/sec) by the traffic sinks across all nodes



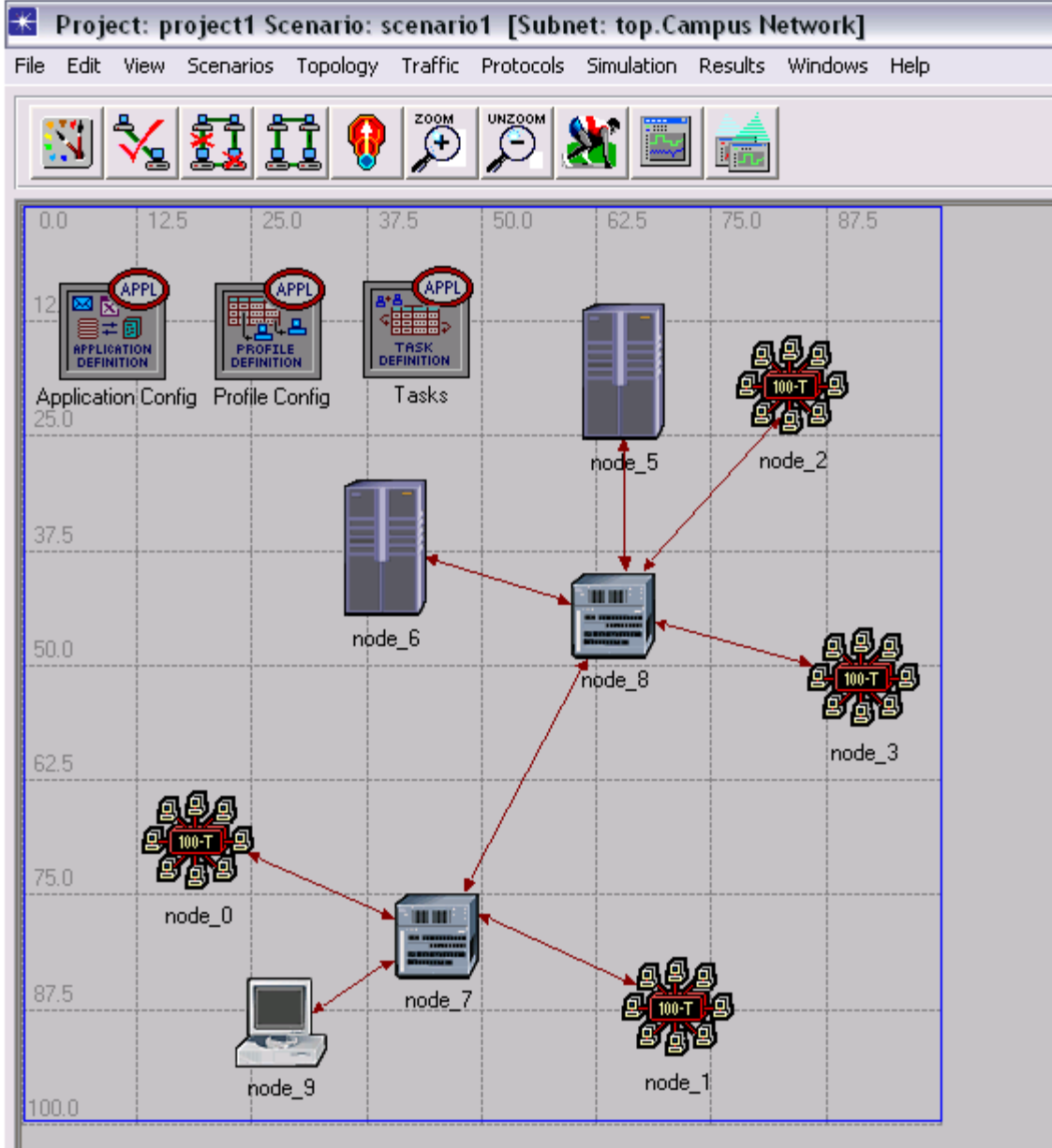
C. Traffic Sent (in packets/sec) by the traffic sources across all nodes

D. Collision count is the total number of collisions encountered by the hub during packet transmissions.

Configure the Simulation

Here we need to configure the duration of the simulation:

1. Click on the Configure / Run Simulation button.
2. Set the duration to be 2.0 minutes.



SIMULATION 2

AIM: To simulate different subnets for different departments of a campus and connect them together.

The Description:

1. Add to the project workspace the following objects from the palette: Application Config, Profile Config, and a subnet. Application Config is used to specify applications that will be used to configure users profiles. Profile Config describes the activity patterns of a user or group in terms of the applications used over a period of time.
2. Right-click on the subnet node, edit attributes, change the name attribute to Engineering and click OK.
3. Double-click on the Engineering node. You get an empty workspace, indicating that the subnet contains no objects.
4. Open the Object Palette and make sure it is still set to internet toolbox.
5. Add the following items to the subnet workspace: 10BaseT LAN, ethernet16Switch, and a 10BaseT link to connect the LAN with the Switch. Close the palette.
6. Right-click on the 10BaseT LAN node. Edit attributes and change the name of attribute to LAN and observe that the Number of Workstations attribute has a value of 10.
7. Click in the Value column for the Application: Supported Profiles attribute, and select Edit. You should get a table in which you should do the following:
 - a. Set the number of rows to 1
 - b. Set the Profile Name to Engineer. (Engineer is one of the “sample” profiles provided within the Profile Config object.)
8. The object we just created is equivalent to a 10-workstation Star topology. The traffic generated from the users of this LAN resembles that generated by “engineers”.
9. Make three copies of the Engineering subnet we just created. Click on the Engineering node. From the Edit menu, select Copy and then Paste three times, placing the subnet in the workspace after each, to create the new subnets.
10. **Configure the Servers:**
Now we need to implement a subnet that contains the servers. The servers have to support the applications defined in the profiles we deployed. You can double-check these applications by editing the attributes of our Profile node. Inspect each row under the Applications hierarchy, which in turn, is under the Profile Configuration hierarchy. You will see that we need servers that support the following applications: Web browsing, Email, Telnet, File Transfer,

Database, and File Print.

FIG-1

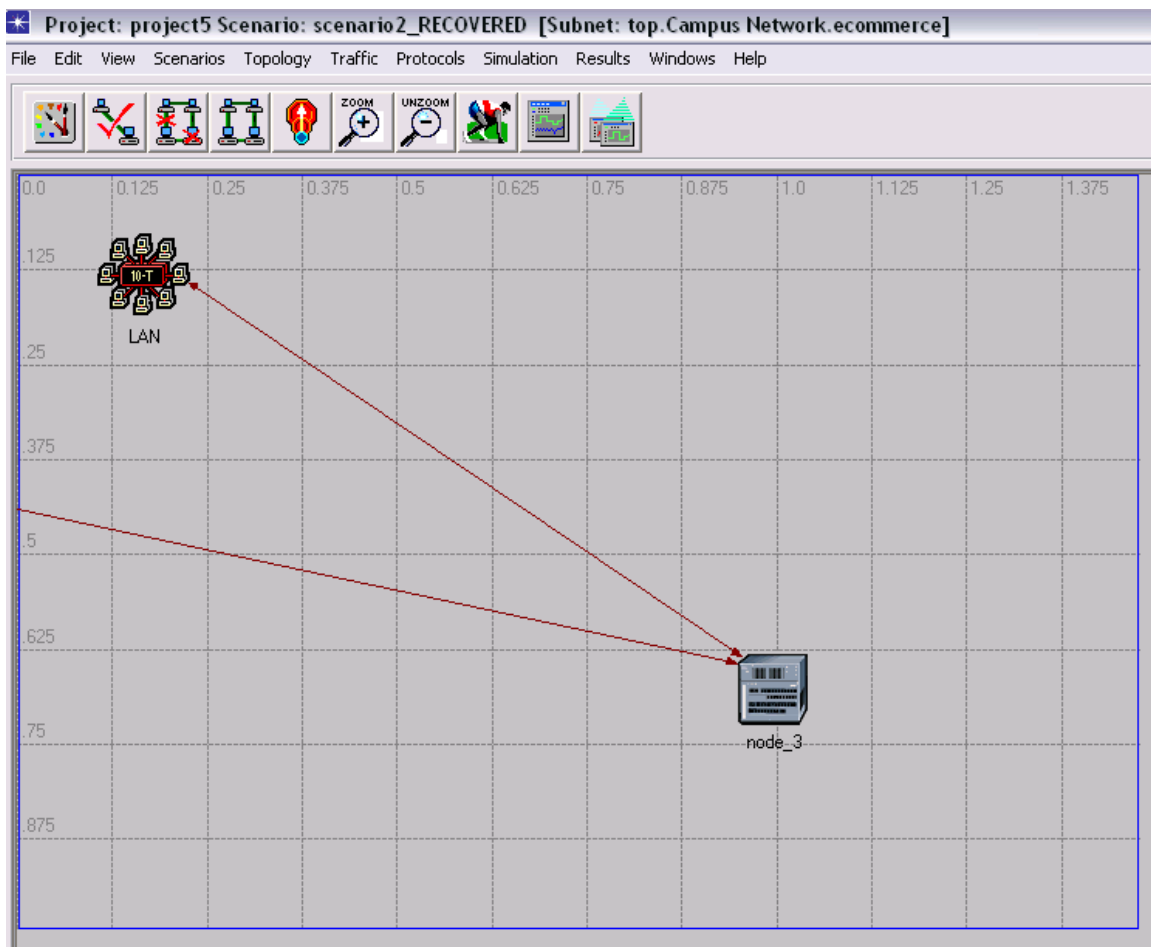
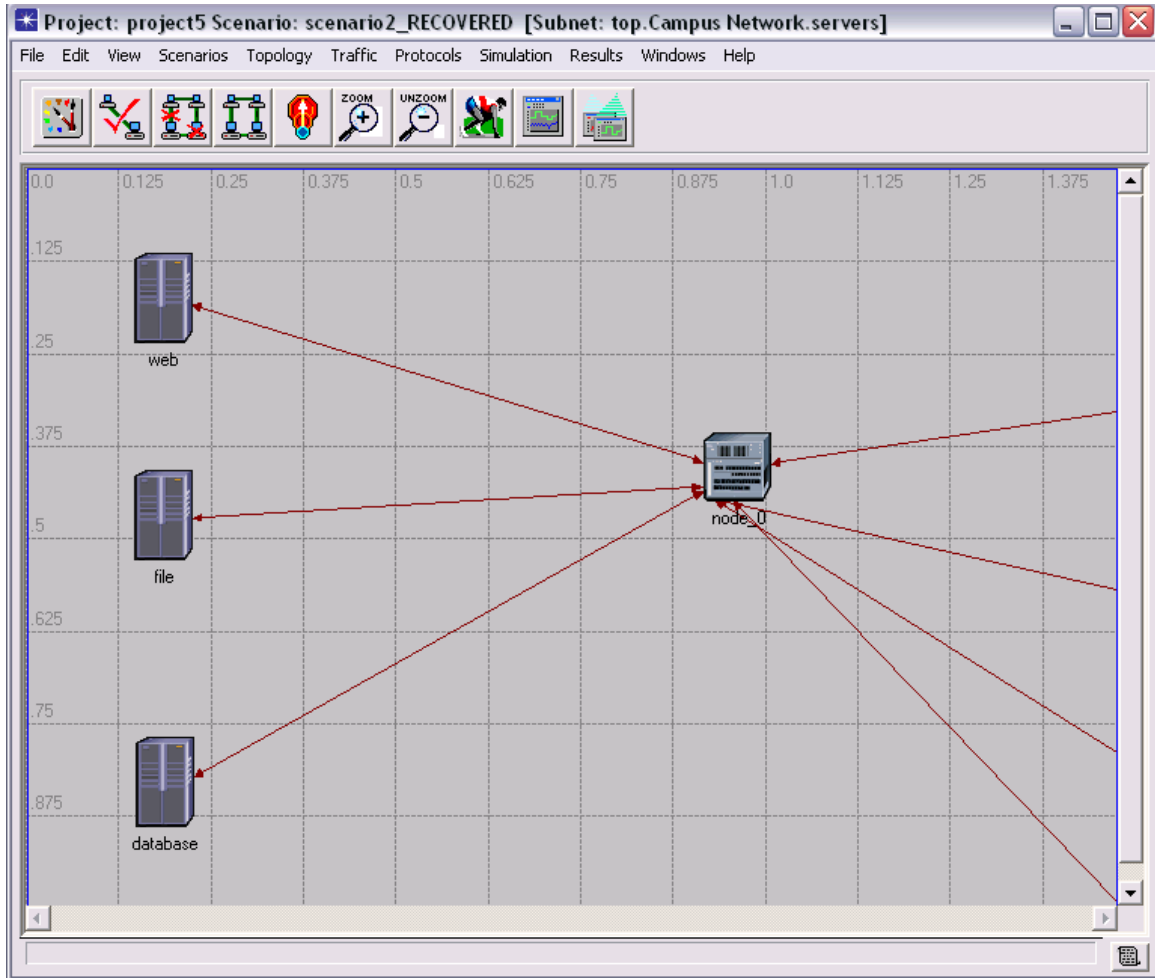


FIG-2

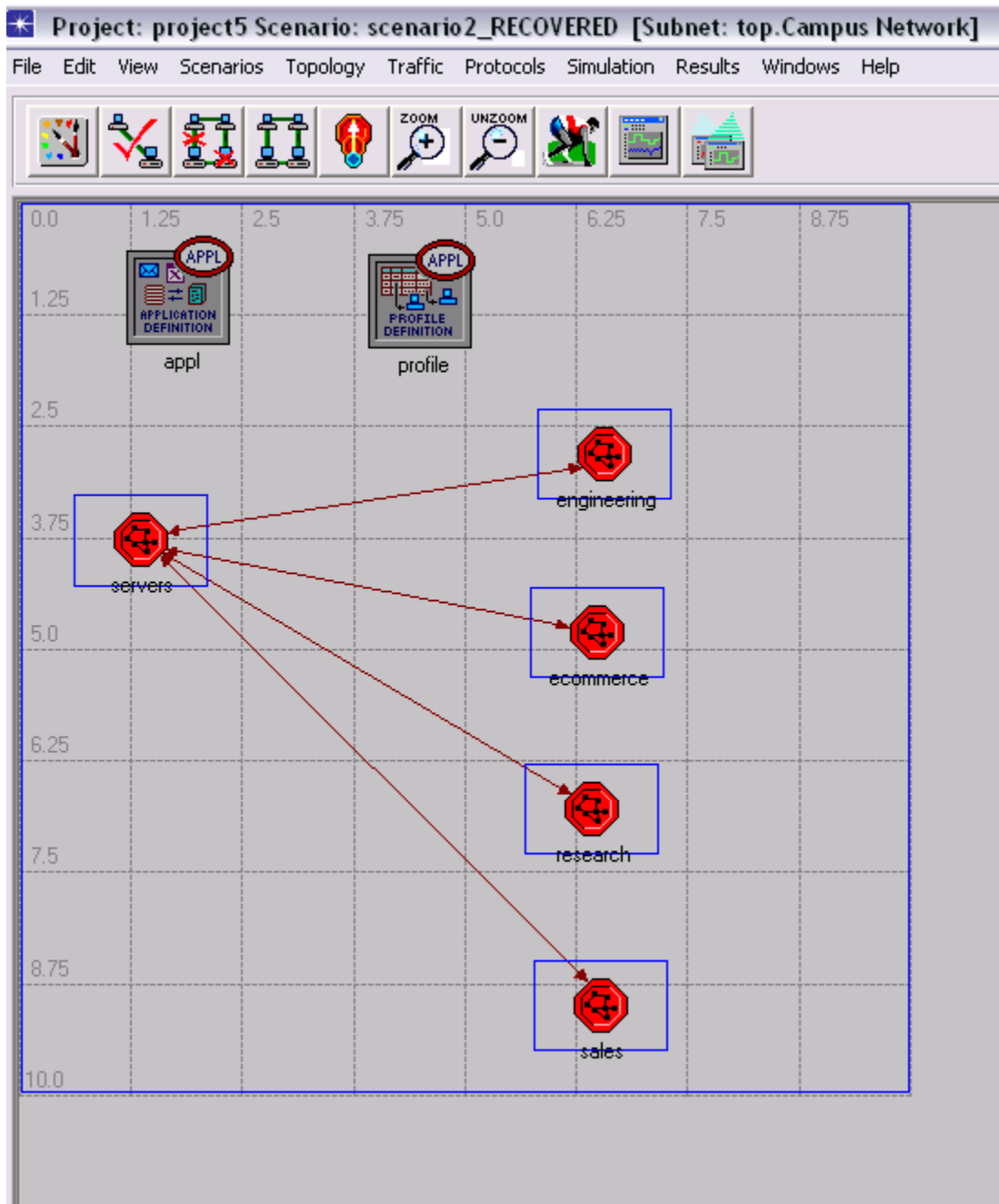


The figure-1 shows the servers subnet inside which there are individual servers for different purposes and are interconnected.

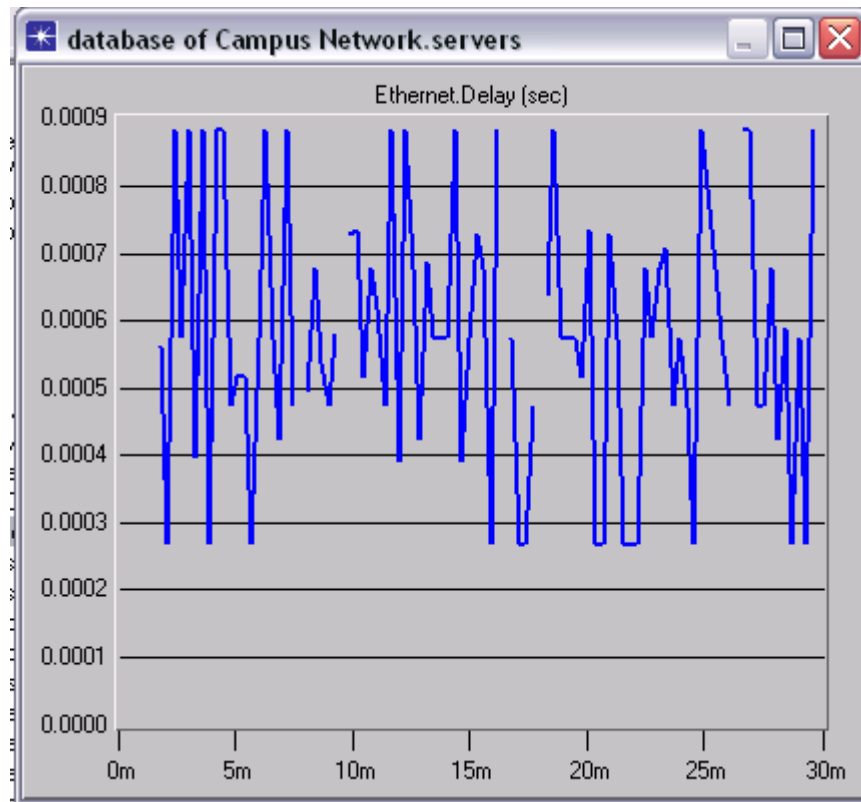
The figure-2 shows each of the different departments' subnets.

The figure-3 shows the overview of the entire network.

FIG-3



OUTPUT



IMPLEMENTATION OF OFDM IN ADS

CHAPTER-1

Introduction

Advanced Design System (ADS)

Advanced Design System (ADS) is an electronic design automation software system produced by Agilent EEs of EDA, a unit of Agilent Technologies. It provides an integrated design environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, radar systems, and high-speed data links.

Agilent ADS supports every step of the design process -- schematic capture, layout, frequency-domain and time-domain circuit simulation, and electromagnetic field simulation -- allowing the engineer to fully characterize and optimize an RF design without changing tools.

Agilent EEs of EDA has donated copies of the ADS software to the electrical engineering departments at many universities and a large percentage of new graduates are experienced in its use. As a result, the system has found wide acceptance in industry.

Use ADS and its highly integrated links and support as a basis for your design verification solution. ADS can be used for virtual prototyping, debugging, or as an aid in manufacturing test. To enhance engineering productivity and shorten time-to-market, ADS software offers a high level of design automation and applications intelligence. This proven software environment is easily extensible: you can customize ADS by adding features focused on your particular application needs. ADS run on PCs and workstations, with complete file compatibility between platforms and across networks.

With a complete set of simulation technologies ranging from frequency-, time-, numeric and physical domain simulation to electromagnetic field simulation, ADS lets designers fully characterize and optimize designs. The single, integrated design environment provides system, circuit, and electromagnetic simulators, along with schematic capture, layout, and verification capability -- eliminating the stops and starts associated with changing design tools in mid-cycle.

Orthogonal frequency-division multiplexing (OFDM)

It is essentially identical to Coded OFDM (COFDM) and discrete multi-tone modulation (DMT). It is a frequency-division multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. The separation of the subcarriers is theoretically minimal such that there is a very compact spectral utilization. The attraction of OFDM is mainly due to how the system handles the multipath interference at the receiver. Multipath generates

two effects: frequency selective fading and intersymbol interference (ISI). The "flatness" perceived by a narrow-band channel overcomes the former, and modulating at a very low symbol rate, which makes the symbols much longer than the channel impulse response, diminishes the latter. Using powerful error correcting codes together with time and frequency interleaving yields even more robustness against frequency selective fading, and the insertion of an extra guard interval

between consecutive OFDM symbols can reduce the effects of ISI even more. Thus, an equalizer in the receiver is not necessary.

CHAPTER-2

Getting Started with ADS **(ADVANCED DESIGN SYSTEM)**

Opening a Data Display Window

To open a Data Display window:

- Choose **Window > New Data Display** or click the **New Data Display Window** button on the toolbar from the Main or Schematic window.

To open additional windows from a Data Display window:

- Choose **File > New** or click the **New** button to open a window for a new dataset.
- Choose **View > New Window** to open a window for the same dataset.

To open an existing data display:

- Choose **Window > Open Data Display** from the Main or Schematic window, select the dataset, and click **OK**.

To close a data display:

- Choose **File > Close Window** in the window you want to close. This closes only the active window and does not affect the rest of the data display. If the contents of the display have been modified and it is the only window displaying data from that dataset, you are prompted to save any changes.

The following form the basic elements of a data display window:

- The *Menu bar* displays the menus that are available in a Data Display window.

- The *Dataset List* displays the datasets that are available in a Data Display window.

- The *Title bar* displays the window type, filename, and a number for identifying which data display window it is.

- The *Toolbar* contains buttons for frequently used commands. • The

Display Area is where you create your data presentations.

Inserting Pages

The Data Display allows the user to add multiple pages to the display area. Multiple pages provide the user with additional display area that can be used to display and organize large amounts of data. To insert a new page

1. Choose **Insert > Page**.
2. The New Page dialog box appears. Type a new name for the page.
3. Click the **OK** button to close the dialog box and insert the page

Creating a Data Display

The basic process of creating a data display consists of:

- Choosing a dataset (by name) to display
- Choosing a plot type for the display (Rectangular, Polar, etc.)
- Specifying the data variable to be displayed
- Choosing a trace type (Linear, Scatter, Histogram, etc.)

The various plot and trace types enable you to display data in different formats. Equations enable you to perform complex mathematical operations on data for further analysis.

Optionally, you can enhance your data display by adding:

- Markers identifying specific data points
- Text for clarification
- Graphical objects, such as lines and circles

Choosing a Dataset

When you open a Data Display window, all datasets defined for the current project are available for display. One dataset is selected as the default; it will

be used as the source of data unless a different dataset is chosen. If no datasets have been defined for the current project, the label on the drop-down menu reads *dataset*.



Default Dataset

You can also view datasets that are stored under other projects or are not part of a project, such as a dataset that contains measured instrument data. This can be useful for comparing simulated versus actual results or comparing results between projects.

The data display does not store any data, it only retrieves and displays the data within a dataset. Thus, if the data in the dataset changes (for example, if you alter a design and resimulate), the data display will be updated to reflect the most current information in the dataset.

To choose a dataset:

1. Click the arrow to view the drop-down list of currently defined datasets.
2. Choose the name of the desired dataset. The Datasets and Equations list box is updated to reflect the data variables contained in the selected dataset.

Choosing a Plot Type

A variety of plot types are available so that you can view data in different ways. The available plot types are shown in the following illustration.



Rectangular Plot—displays scalar data in a linear or logarithmic format

Polar Plot—displays real and imaginary components of complex data on a polar plot

Smith Chart—displays real and imaginary components of complex data on a Smith chart

Stacked Plot—displays multiple rectangular plots

List—displays data in tabular format

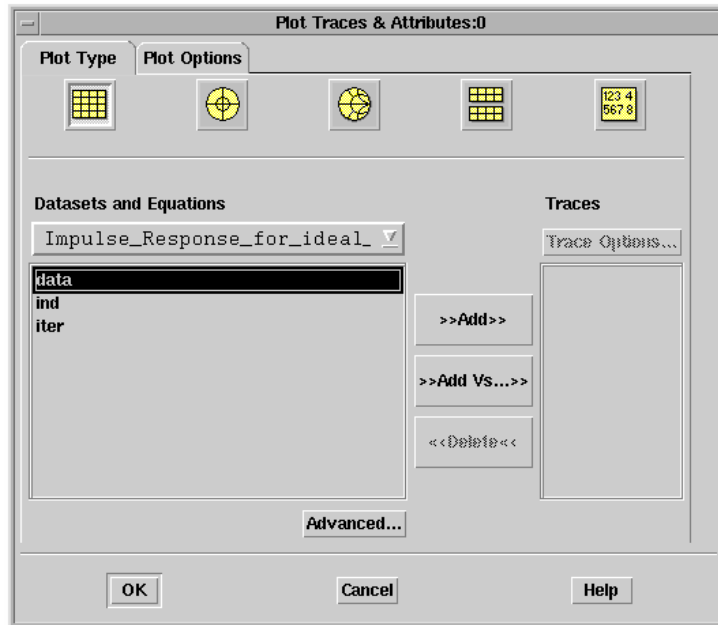
Equation—displays equation created to generate data for display

To specify a plot type:

1. Choose **Insert** > **Plot** or click one of the plot type buttons on the palette.
2. As you move the pointer into the display area, an outline of the shape and size of the current plot type appears.
 - If you are satisfied with the size, position the image as desired and click to place it.
 - If you want to change the size of the plot, position the image as desired (the upper-left corner is the reference point), press the left mouse button, and drag the pointer to the opposite corner. When the shape is the desired size, release the mouse button.
3. Use the Plot Traces & Attributes dialog box to add the desired traces to the plot.

Plot
Types

Data you
can plot



4. Click **OK**.

Selecting a Data Variable

By default, selected data is plotted as the dependent variable, and the independent variable is a logical default, such as frequency or time. For a rectangular plot or a listing, you can also choose the independent variable.

To select the variable whose data you wish to plot for analysis:

1. Select a dataset from the Datasets and Equations list box. Variables in the dataset appear in the list below.
2. Select a variable and click **Add**. The selected data is added to the Traces list box.
3. Repeat as needed to display the desired data on the current plot.
4. Click **OK**.

To plot one variable against another:

1. Double-click on the plot or select the plot and choose **Edit > Item Options**.
2. The Plot Traces & Attributes dialog box appears.
3. Select a variable from the Datasets and Equations list box. This variable will be plotted along the Y-axis.

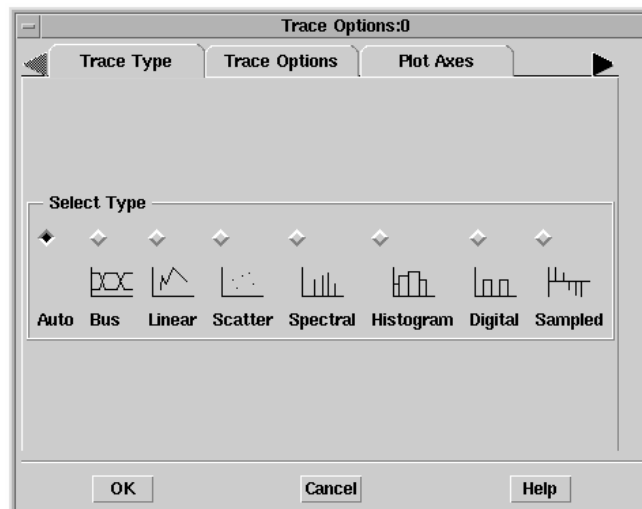
4. Click the **Add vs.** button. From the dialog box that appears, select a second variable. (It can be from a different dataset or equation.) This one will be plotted along the x-axis and is considered the independent variable.
5. Click **OK** to accept the variable.
6. Click **OK** to display the trace on the plot.

Selecting a Trace Type

A trace type is assigned to the data during simulation to simplify viewing results. The trace type can be changed. A variety of trace types are available so that you can view data in different ways.

To select a trace type:

1. Double-click on the plot or select the plot and choose **Edit > Menu Items**.
2. Select at least one variable from the Traces list box.
3. Click **Trace Options** to display the Trace Options dialog box.
4. Click the **Trace Type** tab and select the desired trace type.
5. Click **OK**.



Saving a Data Display

There are two commands for saving a data display: Save and Save As.

- Choose *File > Save* to save changes to an existing file. A file suffix of *.dds* is automatically appended to a data display file.
- Choose *File > Save As* to save the Data Display window as a new file or to save a copy of the open file using a new name.

CHAPTER-3

Orthogonal Frequency Division Multiplexing (OFDM)

OFDM

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions — for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath — without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate inter-symbol interference (ISI). This mechanism also facilitates the design of single-frequency networks, where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

Advantages:-

- Can easily adapt to severe channel conditions without complex equalization
- Robust against narrow-band co-channel interference
- Robust against Inter-symbol interference (ISI) and fading caused by multipath propagation
- High spectral efficiency
- Efficient implementation using FFT
- Low sensitivity to time synchronization errors
- Tuned sub-channel receiver filters are not required (unlike conventional FDM).
- Facilitates Single Frequency Networks, *i.e.* transmitter macro diversity.

Disadvantages:-

- Sensitive to Doppler shift.
- Sensitive to frequency synchronization problems.
- High peak-to-average-power ratio (PAPR), requiring linear transmitter circuitry, which suffers from poor power efficiency.
- Loss of efficiency caused by Cyclic prefix/Guard interval.

In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub-channel is not required.

The orthogonality requires that the sub-carrier spacing is

$$\Delta f = k/(T_U) \text{ Hertz,}$$

where T_U seconds is the useful symbol duration (the receiver side window size), and k is a positive integer, typically equal to 1. Therefore, with N sub-carriers, the total passband bandwidth will be

$$B \approx N \cdot \Delta f \text{ (Hz).}$$

The orthogonality also allows high spectral efficiency, with a total symbol rate near the Nyquist rate. Almost the whole available frequency band can be utilized. OFDM generally has a nearly 'white' spectrum, giving it benign electromagnetic interference properties with respect to other co-channel users.

OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation the sub-carriers will no longer be orthogonal, causing *inter-carrier interference* (ICI), *i.e.* cross-talk between the sub-carriers. Frequency offsets are typically caused by mismatched transmitter and receiver oscillators, or by Doppler shift due to movement. While Doppler shift alone may be compensated for by the receiver, the situation is worsened when combined with multipath, as reflections will appear at various frequency offsets, which is much harder to correct. This effect typically worsens as speed increases, and is an important factor limiting the use of OFDM in high-speed vehicles. Several techniques for ICI suppression are suggested, but they may increase the receiver complexity.

Elimination of ISI (Inter-Symbol Interference):-

One key principle of OFDM is that since low symbol rate modulation schemes (*i.e.* where the symbols are relatively long compared to the channel time characteristics) suffer less from inter-symbol interference caused by multipath propagation, it is advantageous to transmit a number of low-rate streams in parallel instead of a single high-rate stream. Since the duration of each symbol is long, it is feasible to insert a guard interval between the OFDM symbols, thus eliminating the inter-symbol interference.

The guard interval also eliminates the need for a pulse-shaping filter, and it reduces the sensitivity to time synchronization problems.

A simple example: If one sends a million symbols per second using conventional single-carrier modulation over a wireless channel, then the duration of each symbol would be one microsecond or less. This imposes severe constraints on synchronization and necessitates the removal of multipath interference. If the same million symbols per second are spread among one thousand sub-channels, the duration of each symbol can be longer by a factor of a thousand, *i.e.* one millisecond, for orthogonality with approximately the same bandwidth. Assume that a guard interval of 1/8 of the symbol length is inserted between each symbol. Inter-symbol interference can be avoided if the multipath time-spreading (the time between the reception of the first and the last echo) is shorter than the guard interval, *i.e.* 125 microseconds. This corresponds to a maximum difference of 37.5 kilometers between the lengths of the paths.

The cyclic prefix, which is transmitted during the guard interval, consists of the end of the OFDM symbol copied into the guard interval, and the guard interval is transmitted followed by the OFDM symbol. The reason that the guard interval consists of a copy of the end of the OFDM symbol is so that the receiver will

integrate over an integer number of sinusoid cycles for each of the multi-paths when it performs OFDM demodulation with the FFT.

Inter Carrier Interference(ICI) in OFDM:-

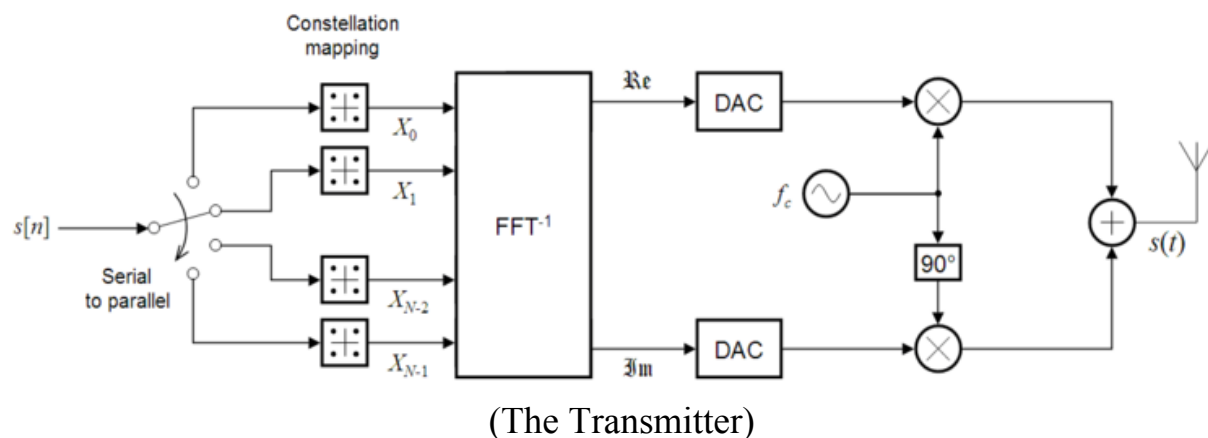
Multi Carrier systems like OFDM has the problem of Inter Carrier Interference (ICI), which results from the loss of Orthogonality between the sub carriers. This happens when the FFT is considered over duration where the subcarrier is non integer number of cycles, which would be the case when multipath is present and the guard time has amplitude is zero. This is reduced by use of cyclic prefix, where we transmit a copy the last part of the symbol followed by the symbol itself. This ensures Orthogonality over the FFT period in case of delayed multipath.

CHAPTER – 4

OFDM Transmitter & Receiver

OFDM Transmitter :-

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier.



$s[n]$ is a serial stream of binary digits. By inverse multiplexing, these are first demultiplexed into N parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, so some streams may carry a higher bit-rate than others.

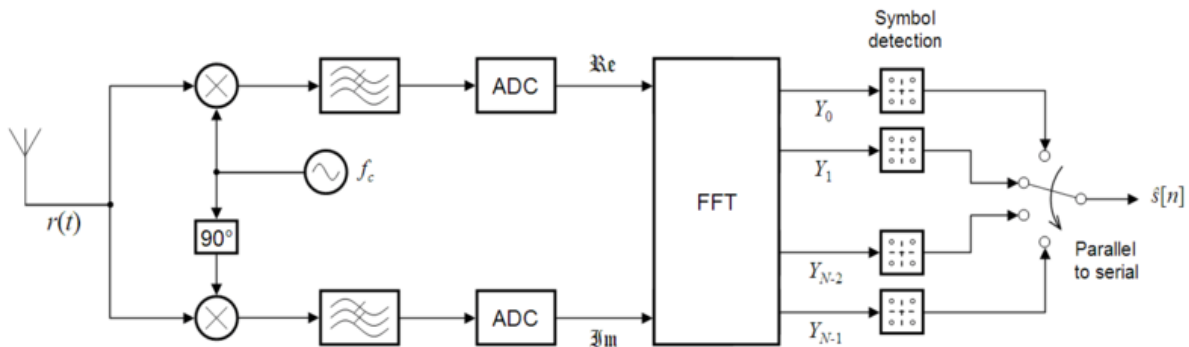
An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs) ; the analogue

signals are then used to modulate cosine and sine waves at the carrier frequency, f_c , respectively. These signals are then summed to give the transmission signal, $s(t)$.

OFDM Receiver:-

The receiver picks up the signal $r(t)$, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on $2f_c$, so low-pass filters are used to reject these. The baseband signals are then sampled and digitized using analogue-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain.

This returns N parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream, $\hat{s}[n]$, which is an estimate of the original binary stream at the transmitter.

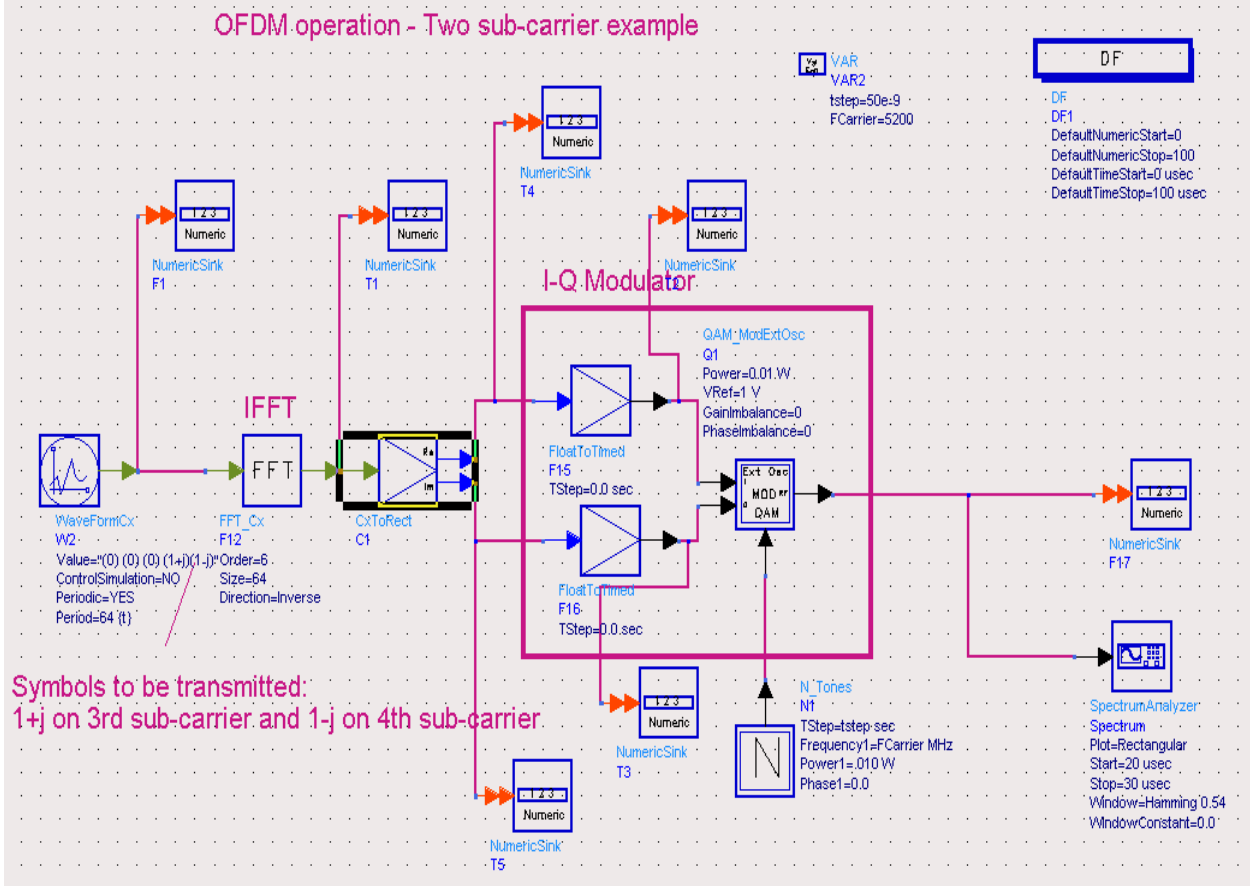


(The Receiver)

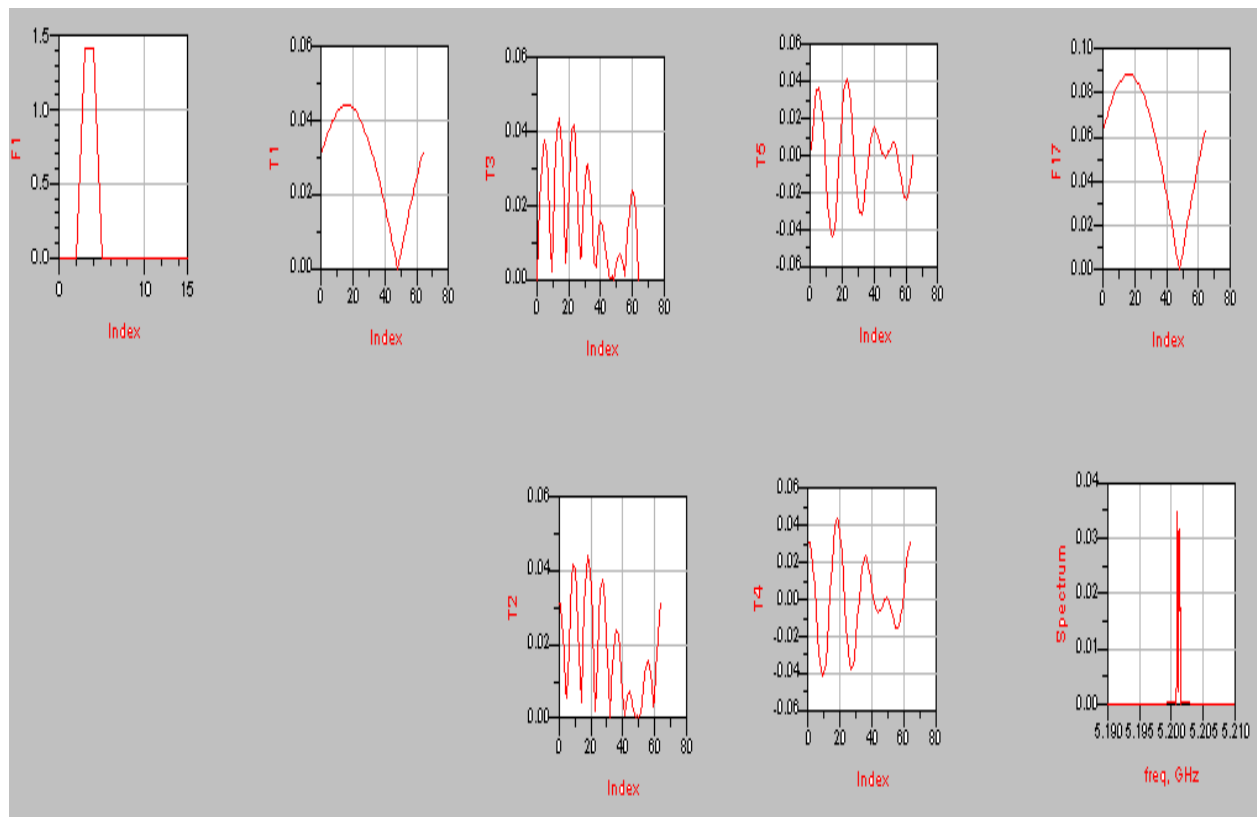
CHAPTER – 5

Simulations

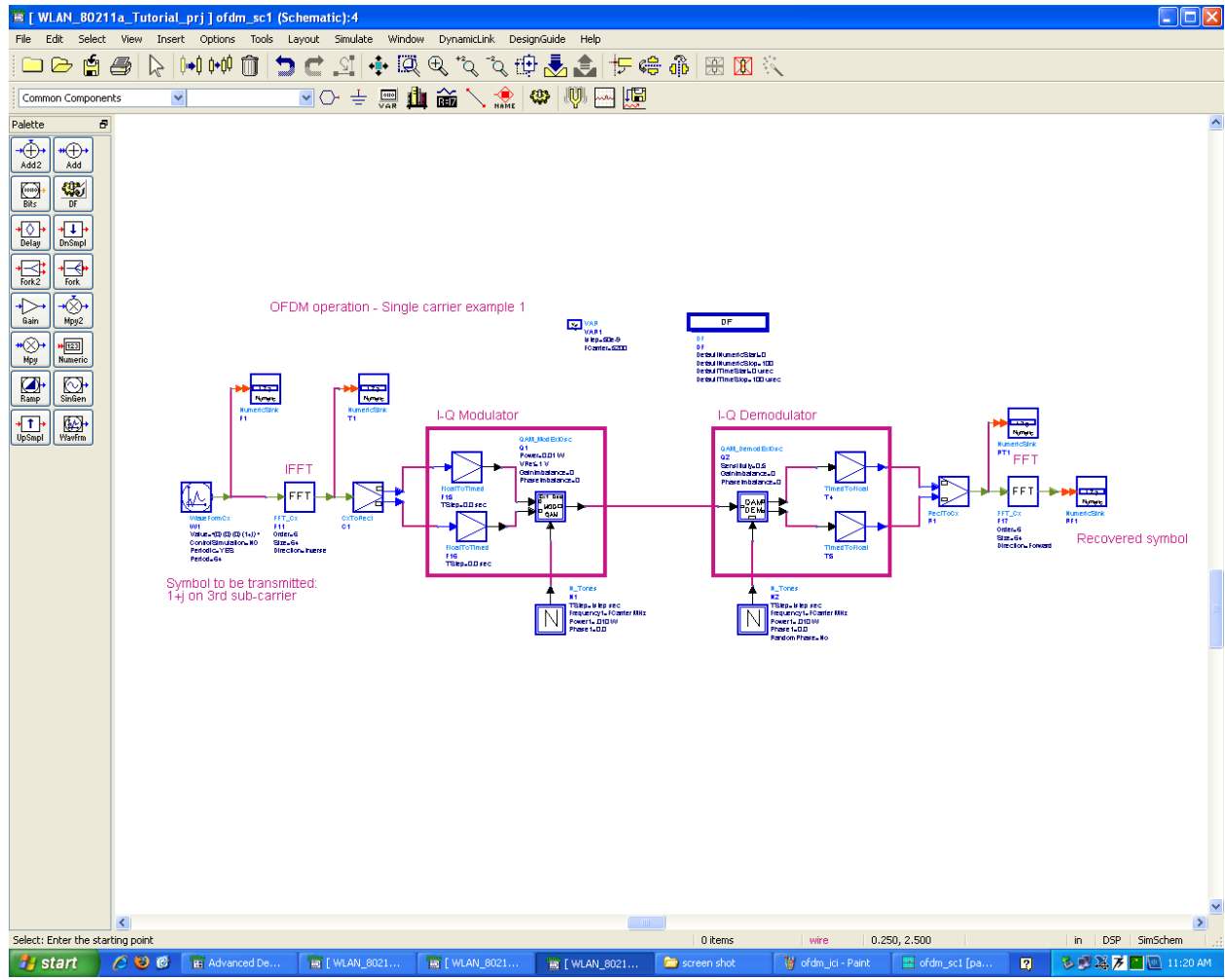
OFDM Transmitter



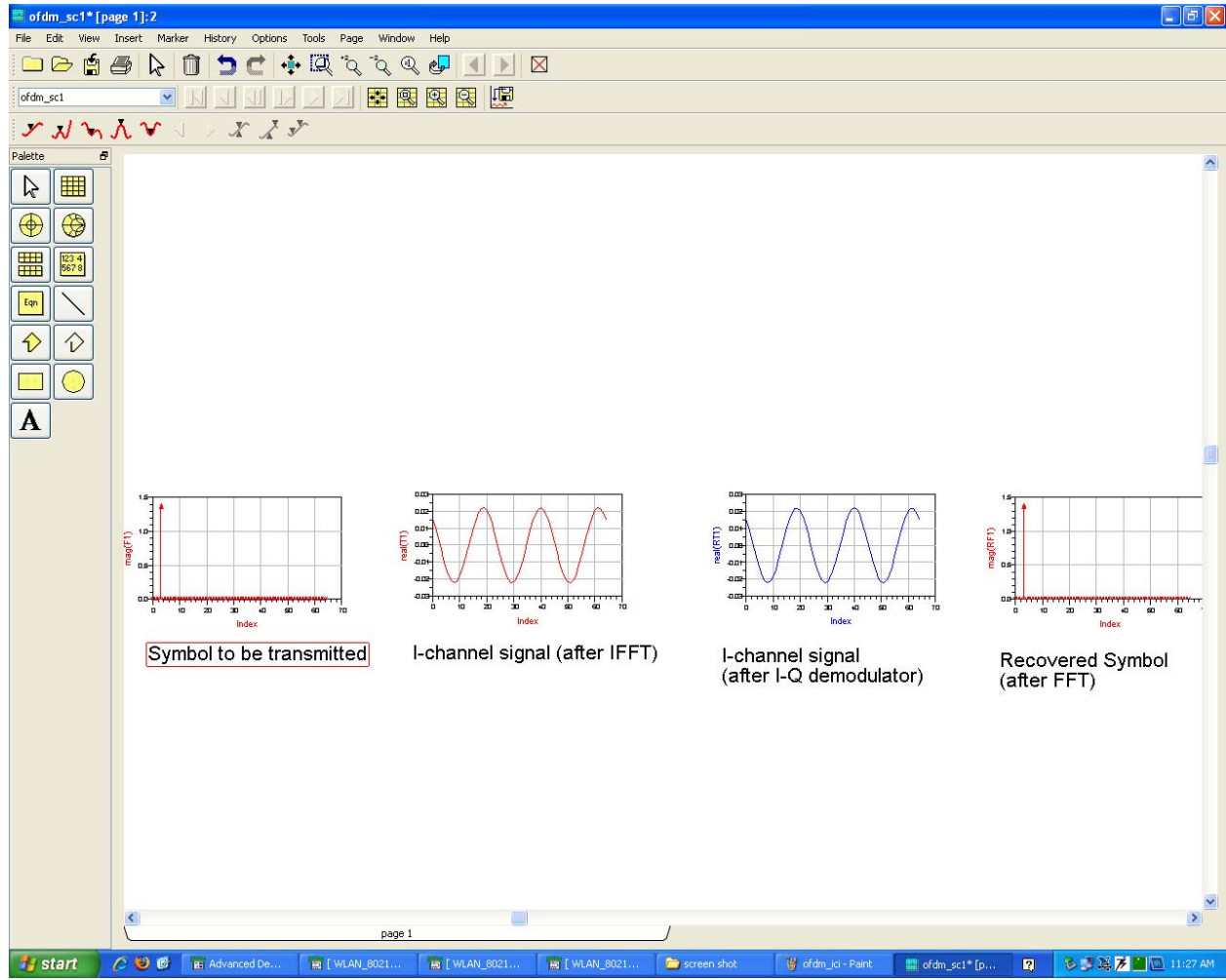
Results



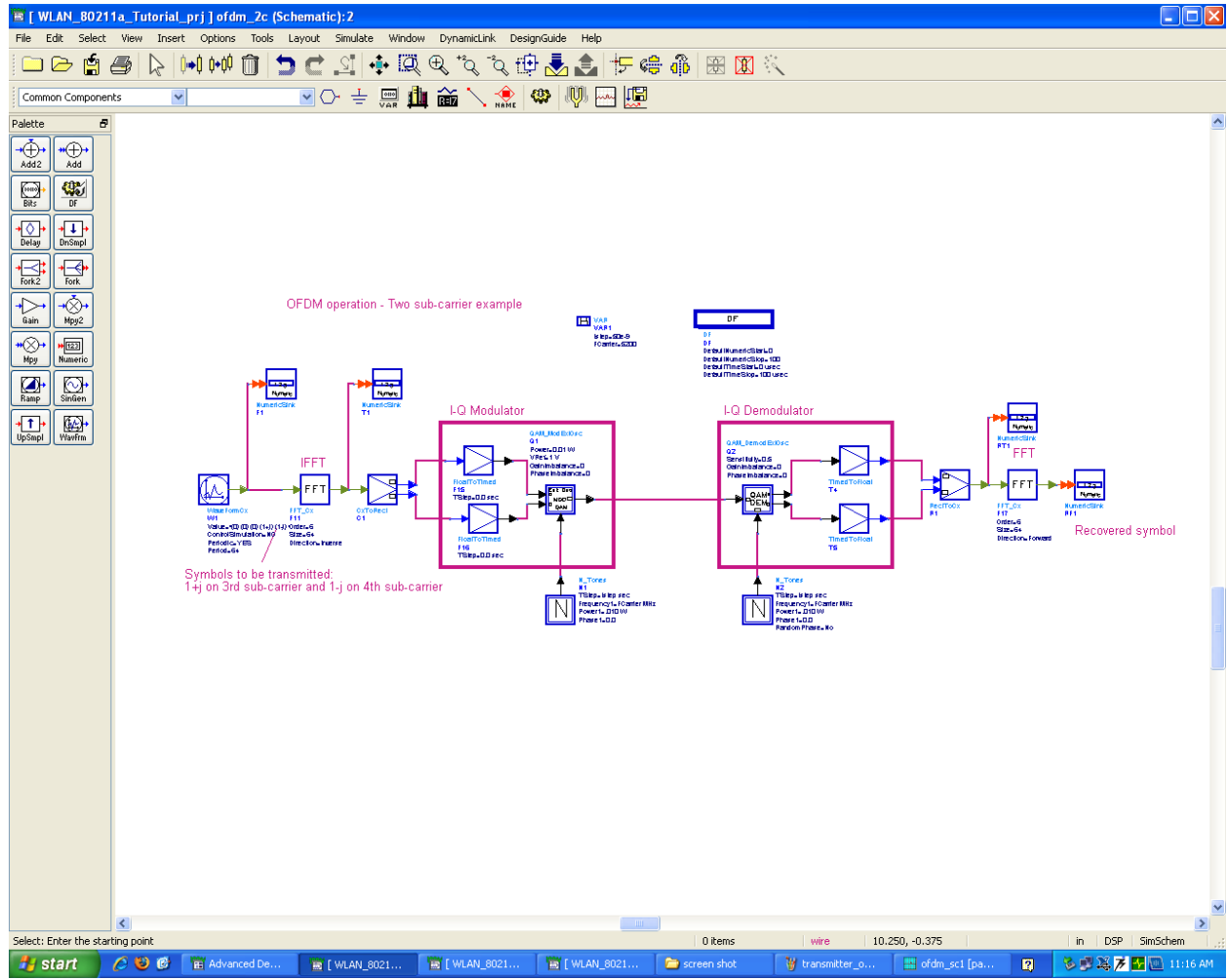
Single Carrier OFDM



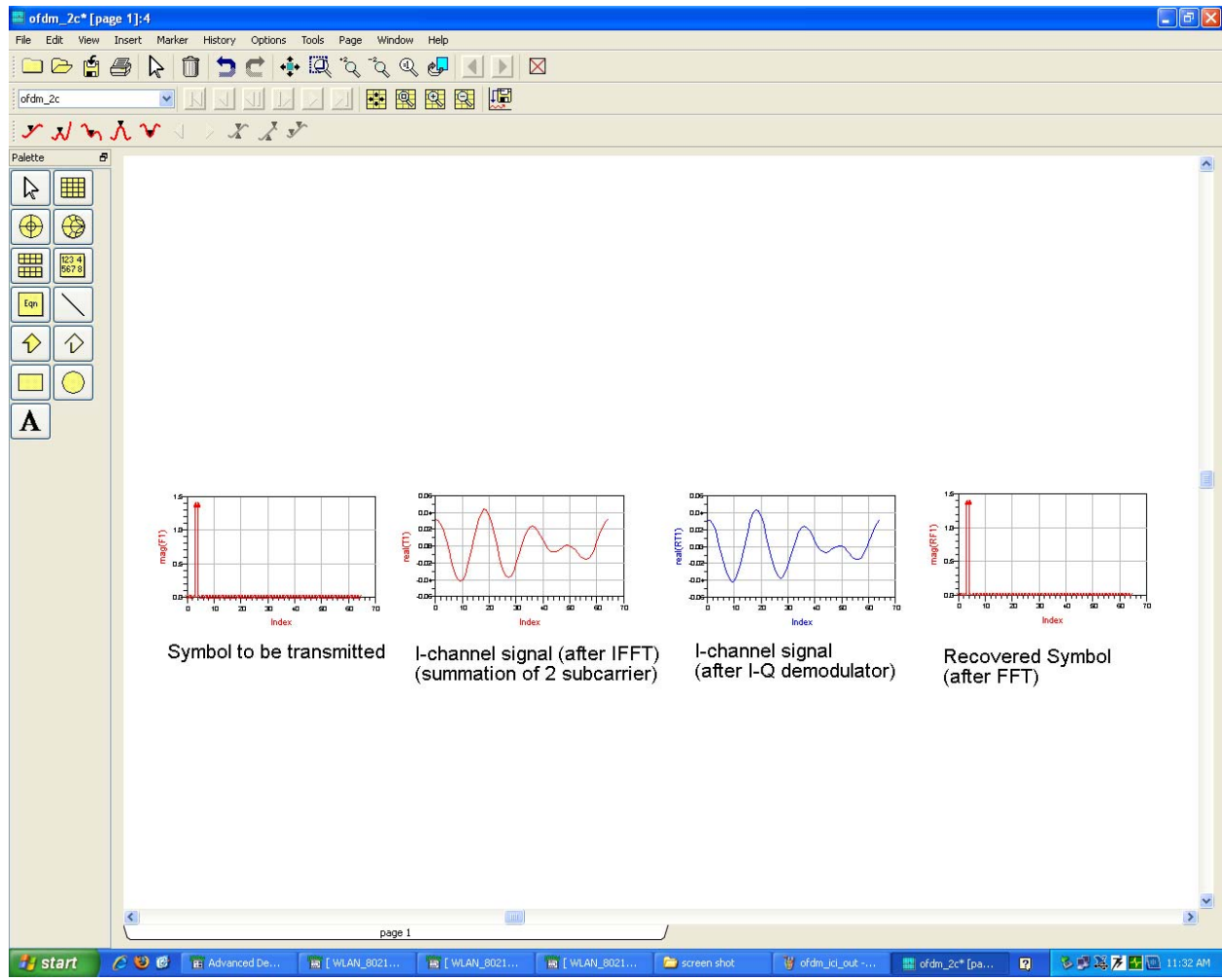
Results



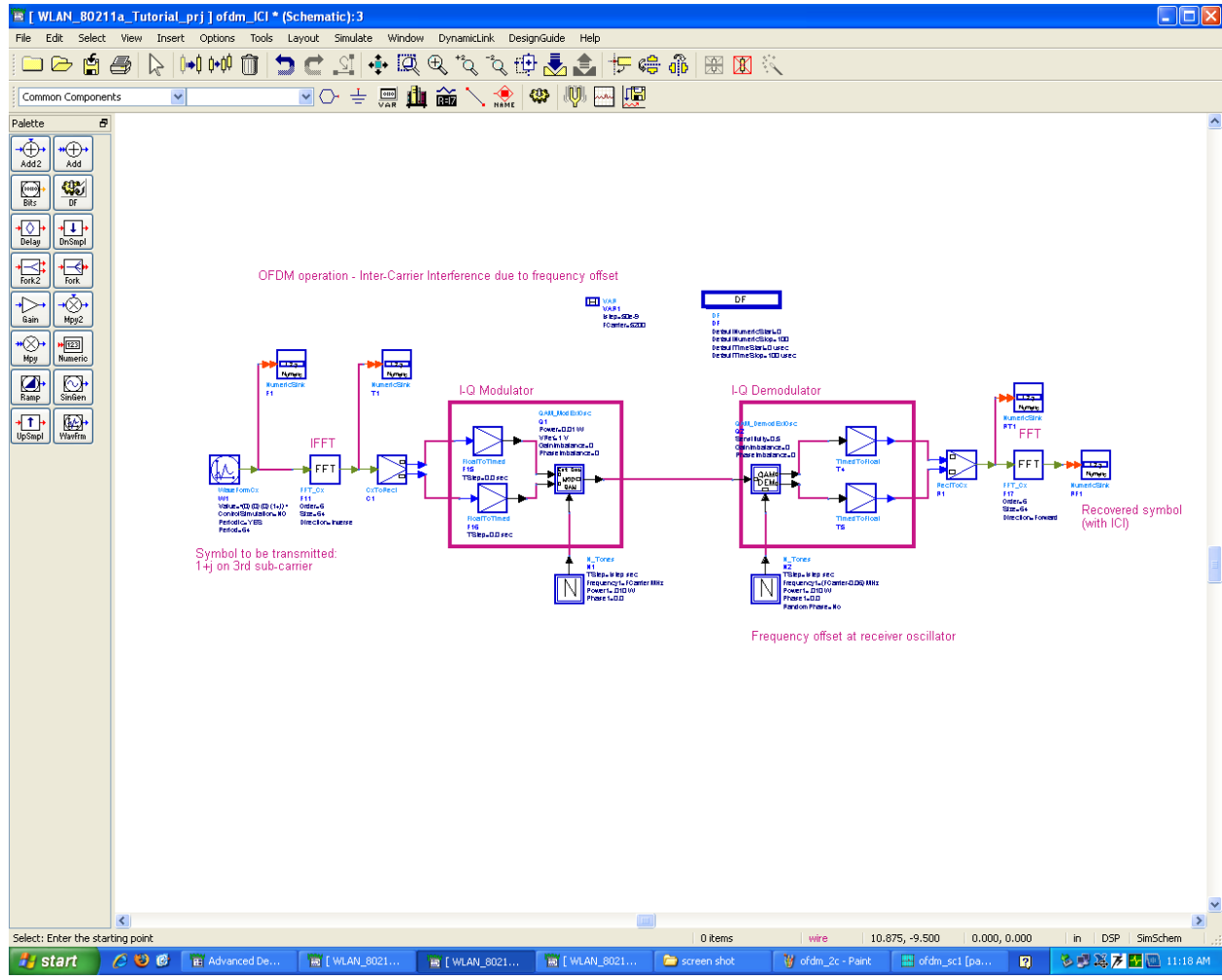
Two-Carrier OFDM



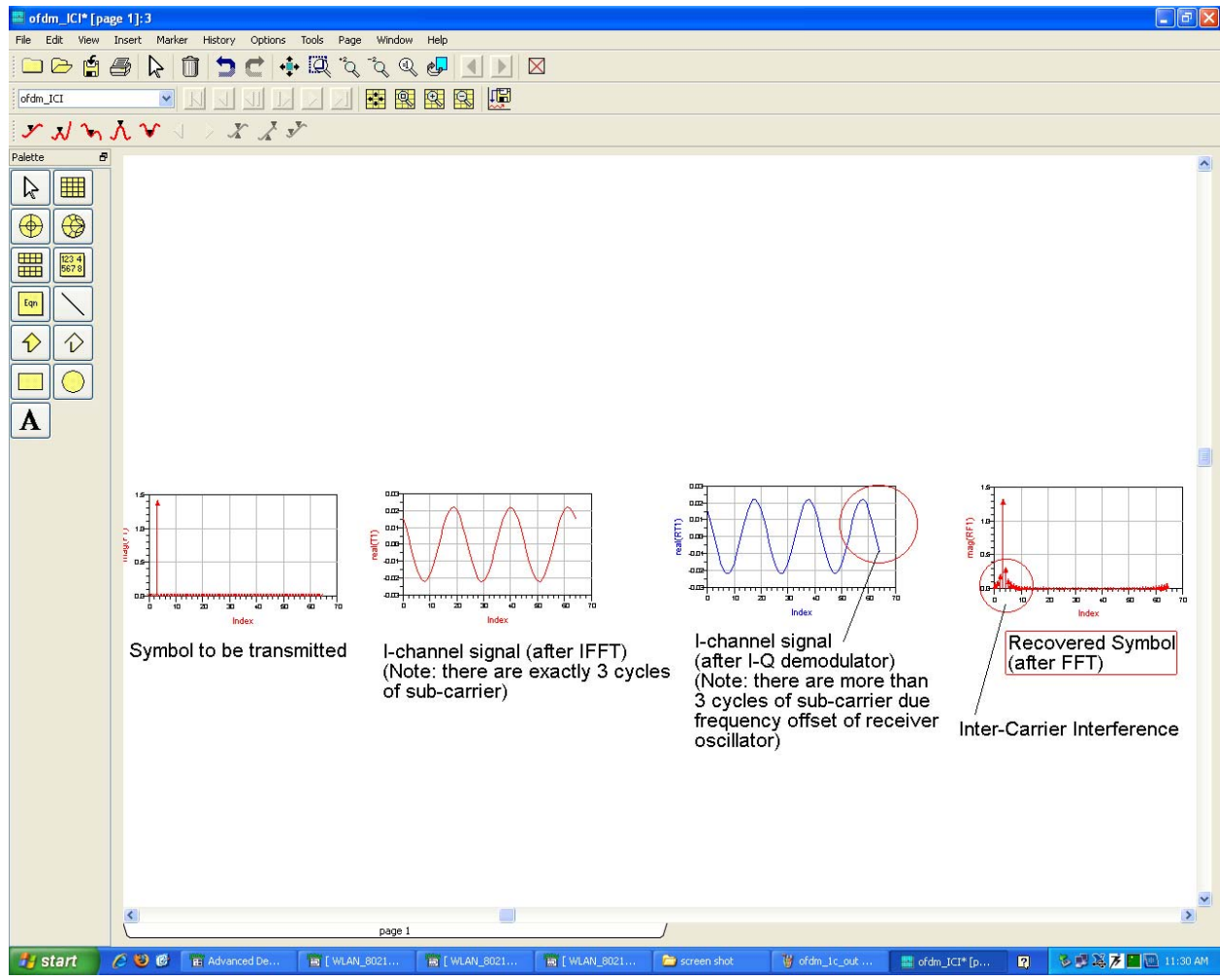
Results



ICI in OFDM



Results



CONCLUSION

The OPNET software was of great help during the simulations of different scenarios of the networks clearly explain the way the data is transmitted and received. We also learnt about different topologies and how subnets can be used to effectively connect nodes in a network. The easy-to-use and drag-and-drop nature of OPNET helped a lot in simulating networks in star topology, creating different types of servers for each department of a campus network. The papers on wireless networks were very enlightening, awakening us to different standards presently in use, like, 802.11, 802.16, etc.

The second half of the project included simulating ofdm in ADS. It was a great learning experience in communication systems. We came to know of the use of ofdm in present wireless technologies. The advantages and disadvantages of ofdm also came to the fore. The ADS software's user-friendly interface was very helpful in simulating the transmitter and receiver.

REFERENCES

1. A survey on emerging broadband wireless access technologies
Mehmet S. Kuran, Tuna Tugcu

2. Reinforce Networking Theory with OPNET Simulation
Jinhua Guo, Weidong Xiang, and Shengquan Wang
University of Michigan-Dearborn, MI, USA

3. Performance Evaluation of Wireless IEEE 802.11b used for ELearning Classroom Network
Salam A. Najim, Ibrahiem M. M. El Emary, and Samir M. Saied
Faculty of Engineering, Al Ahliyya Amman University
Amman, Jordan