Technician Mini-Course

Home Study
Student Guide

10-2003-Rev-07-2012

Welcome

Welcome to Verizon's home study program. We are glad you chose our program for your career and/or personal development. We hope that you will find this course to be both interesting and worthwhile, and that you will complete it successfully.

The purpose of this course is to help you improve your ability to read technical material and give you the telecommunications background that you need in order to learn more about the technical side of the business and move into technical jobs within the company. It is our desire to help you learn new information.

This course was developed in the self-study format to allow you to progress through it at a pace suitable to your individual rate. Home study can be as effective a learning method as the traditional classroom. The key to your success will be your ability to study on your own. For the best results when studying this course, schedule study time at regular intervals. For example, it may be two hours every other day. The important thing is that a specific time for the course is set-aside on a regular basis. Set an objective before you begin each study session. Your objective may be to complete one lesson. If a lesson contains several sections, it may be better to concentrate on a part of the lesson rather than attempting the entire lesson in one session. Finally, before going on to the next lesson or section, take a couple of minutes to quiz yourself on what you have already learned.

Upon completion of the course, you will take the Posttest enclosed in the back of this manual. The test can then be self-scored. The main reason you are taking this test is to show yourself that you have learned the material presented in this course.

We wish you success with your course!

Introduction

Course Overview

The Technician Mini-Course (TMC) provides for a review of basic telecommunications theory and operations. It is designed to give students a basic understanding of the various types of technical documents and provides basic troubleshooting approaches.

Audience

This course is intended for audiences with some prior technical telecommunications knowledge.

Course Objectives

- Explain basic concepts of telecommunications
- Understand technical documentation
- Identify basic steps for troubleshooting circuits

Table of Contents

Lesson 1: Telecommunications Review

Lesson Overview

This lesson provides an overview of basic electrical theory and transmission technology and covers topics including power, AC and DC circuits, transmission principles, copper media, and fiber optics.

Lesson Objectives

Upon completion of this lesson, you will be able to:

- Describe electron theory
- Define basic electrical concepts
- Explain sound waves and how telephone services work
- Contrast analog and digital transmission
- Describe the media commonly used for voice and data networks
- Explain the effect on the signal resulting from resistance, capacitance, and inductance in the transmission line
- Describe optical fiber construction, classifications, and the advantages over copper systems

Power

Introduction

In this section you will learn about power, AC and DC current, circuits and other elements of power that are related to telecommunications systems. A basic understanding of the different aspects of the power system will give you a better overall understanding of telecommunications technology.

History of Electricity

Although the practical use of electricity has become common within the last hundred years, it has been known as a force for much longer. The Greeks discovered electricity about 2,500 years ago. They noticed that when amber was rubbed with other materials, it became charged with an unknown force. The force had the power to attract other objects, such as dried leaves, feathers, or other lightweight materials. The Greeks called amber *elektron*. The word electric was derived from this word because like amber, it had the ability to attract other objects. It was not until the early 1600's that William Gilbert discovered that materials other than amber could be charged to attract other materials. He called materials that could be charged *electriks* and materials that could not be charged *nonelektriks*.

In 1733, a Frenchman named Charles DuFay found that a piece of charged glass would repel some charged objects and attract others. These men soon learned that the force of *repulsion* was just as important as the force of *attraction*. Benjamin Franklin later made lists of materials that attracted and repulsed other objects.

Positives	Negatives
Glass rubbed on silk	Hard rubber rubbed on wool
Glass rubbed on wool or cotton	Block or sulfur rubbed on fur
Mica rubbed on cloth	Mica rubbed on dry wool
Asbestos rubbed on paper	Sealing wax rubbed on silk
Sealing wax rubbed on wool	Amber rubbed on cloth

Franklin called objects that attracted *positives* and objects that repulsed *negatives*. Any object attracted by a piece of glass rubbed on silk had a positive charge. Any object repelled by hard rubber rubbed on wool had a negative charge. The table above lists more examples.

History of Electricity (cont.)

Today we understand that electricity is the flow of electrons produced by knocking the electrons of an atom out of orbit by another electron.

There are two basic types of electric current:

- Direct Current (DC)
- Alternating Current (AC)

Next, we will review both types of electric current.

Direct Current (DC)

Electric current has been described as a flow of free electrons in a conductor connected to a source of electric potential. As long as that potential is applied with the same polarity, the electric current will flow in one direction. This type of current is *direct current (DC)*.

A *DC circuit* is one in which the electric current flow is always in one direction, from the negative pole to the positive pole. All electric circuits consist of three basic parts: a power source, conductors, and a load device.

In telecommunications, the primary type of power for all equipment is direct current. DC power sources are: generators, rectifiers, converters, and batteries. Conductors are usually copper, but can be aluminum or any precious metals.

The basic operation of an electrical circuit is best illustrated by an example. An ordinary flashlight is a good example of a simple electrical circuit. A flashlight is powered by direct current.

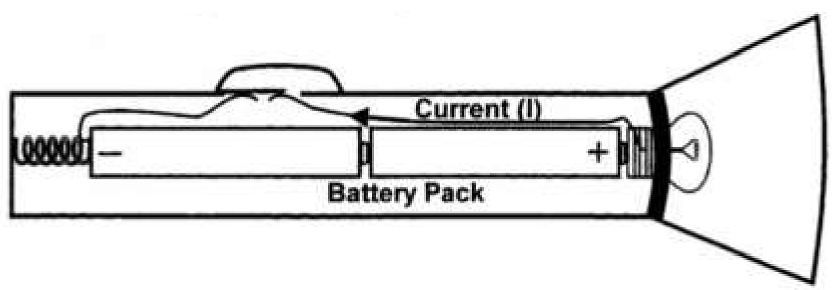


Figure 1.1

Figure 1.1 illustrates the main components of a flashlight.

- The wire (conducting material) connects the battery pack to the bulb.
- The bulb is referred to as the load.
- A complete “go and return” path (also known as a circuit) is required for electricity to flow between the battery pack (source) and the bulb (load).
- The switch is located in the circuit that connects the battery pack to the load. When the switch is open, the circuit from the battery to the load is broken, and electricity cannot flow. When the switch is closed, the circuit is no longer broken, which enables electricity to reach the load, illuminating the light bulb.

Direct Current (cont.)

To simplify the discussion of the various parts of the flashlight circuit, it is helpful to work with a circuit diagram, rather than a sketch.

Figure 1.2 is a diagram of the flashlight circuit.

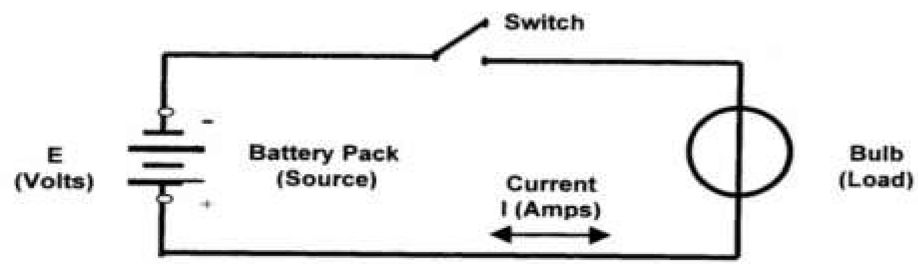


Figure 1.2

As you look at the circuit diagram, you can see that the circuit is composed of one wire that connects the positive (lower) terminal of the battery pack to the bulb. Another wire connects the opposite side of the bulb through the switch to the negative (upper) battery terminal. The wires are the conductors, which conduct the electricity from the battery (source) to the light bulb (load).

When the switch is open, the flow of electricity along the circuit path is interrupted and the light bulb receives no electricity. When the switch is closed, a closed path is formed for electricity to flow from the battery through the wire to the light bulb and back to the battery—then the bulb is illuminated.

The battery pack provides the electricity needed to activate the circuit. It is connected to the circuit at two different points called terminals. These are shown as hollow circles on the diagram. Chemical action within the battery pack creates a surplus of electrons at the negative terminal. Therefore, when a closed circuit is connected from the negative terminal to the positive terminal (by closing the switch, in this case), the electrons flow from the negative terminal to the positive terminal through the circuit. (By convention, the flow of current in a circuit is always shown in the direction from the positive terminal of the battery to the negative terminal, which is opposite to the flow of electrons.)

The wire, or filament, in the light bulb produces a high resistance, or opposition, to the flow of electrical current. This opposition allows the electrical energy of the battery pack to be converted into other forms of energy, such as heat and light.

DC Distribution System

The function of the DC distribution system is to safely deliver adequate DC power from the rectifiers and batteries to the loads. This is the final link in the flow of power to the telephone equipment. The DC distribution includes three major components.

Component	Description
Conductors	Connects the power plant voltage to the load.
Main Power Board	Provides the protection, control functions, and distributes DC power.
Battery Distribution Fuse Board (BDFB)	Used when multiple loads are being served by one feeder circuit from the Main Power Board. This allows for fewer cable runs throughout the building, thus lowering operating expenses.

Alternating Current (AC)

In the very early days of electric power generation, Thomas Edison, proposed powering the country with low-voltage direct current. His reasons were that low voltage current was safer for people to use than higher voltage alternating current. Nicola Tesla, a physicist, argued that direct current was impractical to use for large-scale operations. Tesla, with his friend George Westinghouse, was able to prove that alternating current was both feasible and inexpensive by winning a competition with Edison to provide electricity for the 1904 World's Fair. Alternating current thus became the standard type of electricity generated and distributed by electric power companies.

Alternating current (AC) is a current flow that increases in magnitude from zero to a maximum, decreases back to zero, increases to a maximum in the opposite direction, decreases to zero, and then repeats this process periodically. One significant advantage of AC power is that it is easier to distribute to the customer. Alternating currents flow because the source of potential reverses itself. The alternation occurs when the source decreases to zero either uniformly or abruptly, and then changes polarity so that the current flow changes direction. The period in which current flows first in one direction and then in the other is called a *cycle*. One cycle of AC is completed when the source voltage rises to a maximum in one direction and falls to zero, then reverses itself to rise and fall in the other direction.

Alternating current differs from direct current in that AC current reverses its direction of flow at periodic intervals. In addition to being cheaper to produce, alternating current had another major advantage over direct current: it is easier to transform alternating current in comparison to direct current. AC current can be stepped up or stepped down depending upon the need.

AC Distribution System

This system serves a dual purpose:

- It distributes the incoming AC power to various loads in the building.
- It protects cables and conductors from overload. This is possible because the system contains fuses and circuit breakers to protect from overload.

Circuit Fundamentals

For current to flow in a circuit, there must be a complete path from the negative side of the power source, through the conductor and load, and back to the positive side of the source. If there is no complete path, current cannot flow and the circuit is said to be open. An uninterrupted path is needed for electricity to flow in a circuit. A closed switch provides an uninterrupted path; an open switch interrupts the path.

An electrical circuit with a single path for electron flow from source to load and back is called a *series circuit*. Its components connected end to end so that the same electric current flows through each component.

In Figure 1.3, current will flow from the negative pole of the source, through the lamps and resistors, then back to the positive pole.

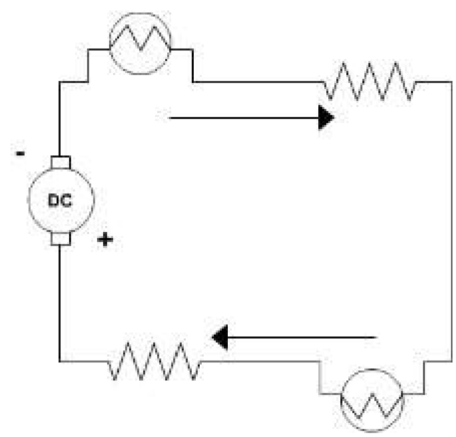


Figure 1.3

An electrical circuit that contains one or more points where the current divides and follows different paths is called a *parallel circuit*.

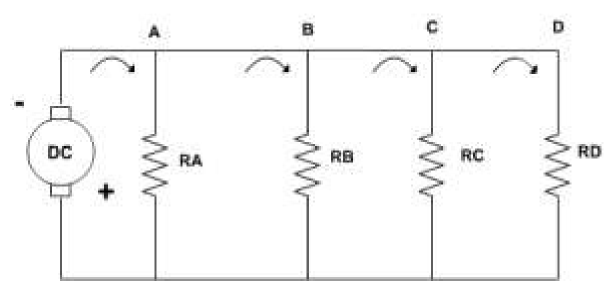


Figure 1.4

In a parallel circuit, as shown in Figure 1.4, current will flow from the negative pole of the source and will divide when it reaches Point A. Some of the current will flow down through resister A, and the remainder will flow to Point B and divide again. A portion of the current will flow down through resister B, and the remainder will flow to Point C, and so on.

In a DC circuit, the current flows in only one direction. In an AC circuit, the flow alternates.

Summary

- There are two types of electric current: Direct Current (DC) and Alternating Current (AC).
- Direct current occurs in circuits in which the electric current flow is always in one direction, from the negative pole to the positive pole.
- The telephone transmitter is powered by a direct current source.
- Alternating current reverses its direction of flow at periodic intervals.
- Alternating current is cheaper to produce and easier to transform up or down.
- All electric circuits consist of three parts: a power source, conductors and a load device.
- An electrical circuit with a single path for electron flow from source to load and back is called a series circuit.
- An electrical circuit that contains one or more points where the current divides and follows different path is called a parallel circuit.

Sound

Introduction

When a stone is dropped into a quiet pond, a set of waves spreads outward from the point of impact in ever-widening circles. The size of each circular ripple grows at a constant rate. A floating chip of wood does not move forward with the waves that strike it but merely bobs up and down, scarcely moving from its place. Besides waves on water, there are other types: light, X-rays, and radio are also forms of wave motion as are sound waves. In this section, we will discuss types of sound waves, how sound waves are measured, and an overview of telephone service.

Sound Waves

Suppose that instead of tossing a stone into a pound we explode a firecracker outdoors. The sudden explosion compresses the air nearby. Air, being highly elastic, expands outward and in doing so, compresses the layer of air just beyond. The state of compression is handed on and spread rapidly outward in much the same way as the ripples spread out over the surface of the pond. Here, however, we have a wave of compression, for that is exactly what a sound wave is. As it passes, the molecules of the air crowd together, then draw apart—the sensation of hearing results when such waves strike the ear.

Compression waves (or sound waves) can travel through solids and liquids as well as through gases such as air, since all substances are elastic to some extent; but some material is always needed as a carrier. This is because sound is a mechanical process that actually moves molecules of whatever substance is carrying the sound. Experiments have shown that sound cannot not travel in a vacuum because there are no molecules to move.

Continuous Waves

The disturbance produced by dropping a stone into water consists of only a few crests and hollows. If continuous waves are to be formed, a steadily oscillating or vibrating body must be allowed to dip into the water. The exact same thing is true of sound waves. Sustained sound comes from sources such as vibrating bells, violin strings, or drumheads.

Suppose a small rubber balloon is partly inflated and attached to a hand pump. If the handle is quickly pushed down a short distance, the balloon expands and the outside air in contact with it is suddenly compressed. This layer of air will, in turn, compress the layer beyond it, and so on. The compression that was started by the swelling of the balloon will thus travel away from the balloon in all directions. Similarly, if the handle is quickly pulled up a short distance the balloon contracts and the adjoining air suddenly expands. (See Figure 1.5.)

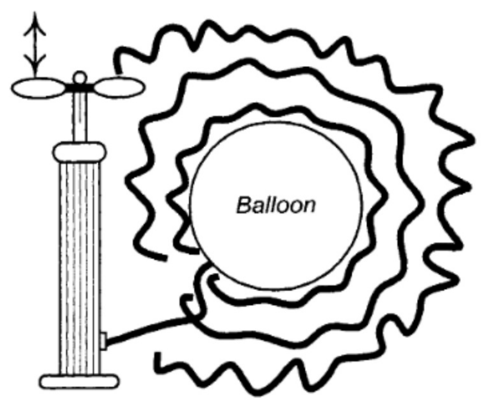


Figure 1.5

This time, a region of low pressure spreads outward in all directions. Moving the handle up and down in regular intervals makes a succession of compressions and expansions travel from the source. Such a regular train of disturbance constitutes continuous wave motion. If the up-and-down motion of the handle could be made rapid enough, a nearby observer would hear sound as these compression waves reach the ear. Vibrating violin strings, a guitar, or the human voice produces similar effects.

In any wave motion, no particle of the material that is carrying the waves ever moves very far from its normal place, but is merely displaced a short distance, first one way and then the other. In sound waves, the particles oscillate along the line in which the waves are moving. When waves are sent out by a vibrating body, the number of waves produced in one second is the same as the number of vibrations per second, or *frequency* of vibration of the source.

Continuous Waves (cont.)

The *wavelength* is defined as the distance between two successive places in the wave train that are in the same state of compression. In Figure 1.6, the wavy line is a graph of the way the pressure in the wave changes.

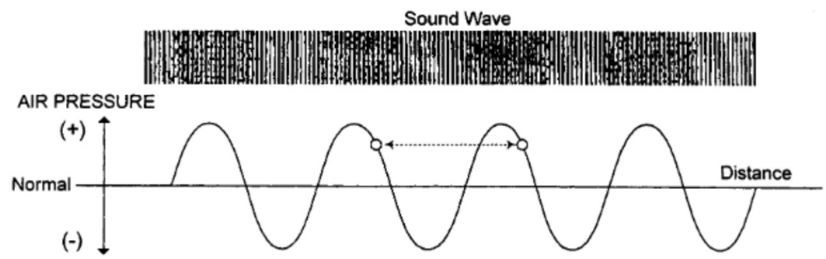


Figure 1.6

The height of the curve at any point gives the pressure, above or below, normal air pressure, at the place in the wave train. The distance between any two crests (or troughs) is one wavelength.

Telephone Service

Although much of this lesson will discuss transmission principles, it is useful to begin with a review of how telephone service actually works. Figure 1.7 shows the path that telephone service takes from the central office to the customer.

- Telephone service begins in the *central office*, where there is a power source and where all the connections that allow telephone calls to be made are housed.
- Note that there are two "wires" that go from the central office to the customer premise. These two wires are called the *tip* (the send line) and the *ring* (the receive line). The wires are housed in cables that go from the central office to the customer premise. The cables may be aerial cables strung on poles, as shown in Figure 1.7, or they may be underground cables.
- From the cable, wires are connected to the telephone handset on the customer premises. This entire system is sometimes referred to as the *local loop*.

The remainder of this lesson will discuss the principles by which voice and data are transmitted throughout the entire system.

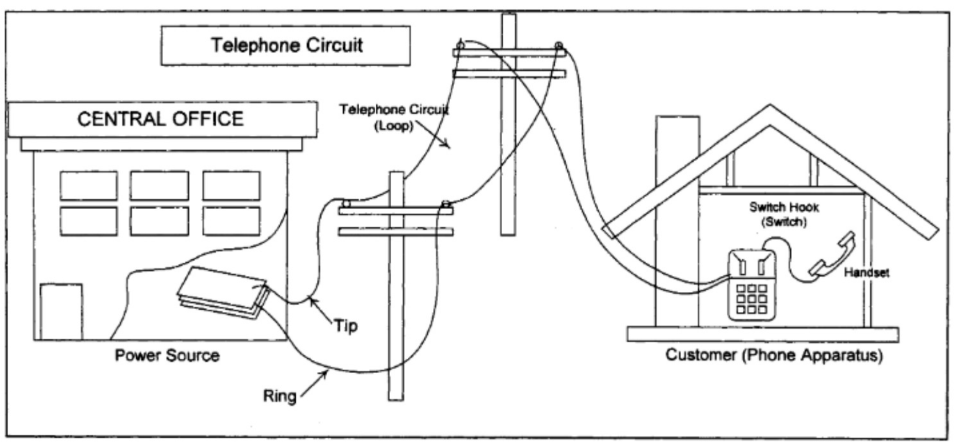


Figure 1.7

Summary

- Sound waves are continuous waves that can be measured with frequency and wavelength.
- The number of waves produced in one-second measures frequency.
- The wavelength is defined as the distance between two successive places in the wave train that are in the same state of compression.
- Telephone service begins in the central office where all telephone calls are connected.
- The tip and ring are two wires that go from the central office to the customer premise and are part of the system known as the local loop.

Transmission Principles

Introduction

The transmission line or transmission medium is used to carry information in the form of voice, music, pictures, and the like from one location to another. The transmission line can be as short as a few feet or as long as several thousand miles, and can be made of paired cable, coaxial cable, microwave radio, or optical glass fiber. The purpose of any transmission line is to act as a conducting path for an electronic signal. This section describes some of the characteristics of signals and transmission lines.

Analog Transmission

The purpose of the ideal transmission path is to deliver an accurate reproduction of the original signal to the receiving terminal. Electronic signals are generated in a variety of forms such as sine waves and voice waves. These waveforms are called analog waveforms. An *analog signal* is a continuous waveform with ever-changing frequency and amplitude (Figure 1.8).

The analog waveform is an electrical signal that represents electrically some other form of change or movement. That change could be sound pressure, light intensity, heat change, pressure change, or physical movement.

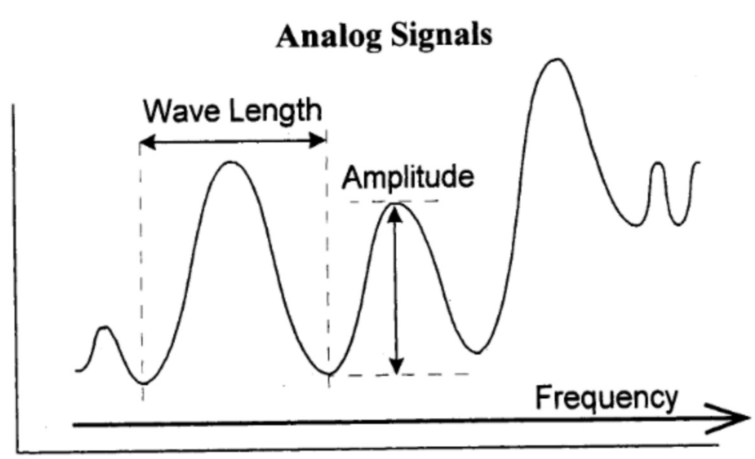


Figure 1.8

In telecommunications, the analog signal usually starts with the human voice spoken into a transmitter.

How does the transmitter actually change your voice into an analog signal?

Analog Transmission (cont.)

Speech, like any sound, is created by something vibrating. In the case of speech, your vocal cords push air molecules together as they move one way and increase the distance between these molecules as they move in the other way. These compressed and expanded segments of air moving away from the vibrating object are called sound waves.

The sound waves strike a diaphragm in the mouthpiece of the telephone, making the diaphragm move in and out with the same frequency as the sound waves hitting it. Behind the diaphragm are tiny carbon granules, which are alternately compressed and released. Since compressing carbon molecules decreases their resistance to electric current, the movement of the diaphragm is directly translated into alternately increased and decreased flow of electricity. In the receiver, this electricity is translated by an electromagnet back into sound waves (Figure 1.9).

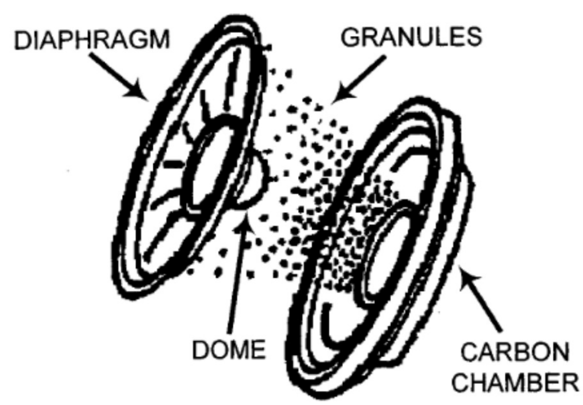


Figure 1.9

From the transmitter, this analog signal may go through many changes as it passes down the transmission line. These changes can be imposed by amplifiers, carrier systems, and radio systems, but in the end, under ideal conditions, an exact reproduction of the original signal enters the telephone receiver and converts to air pressure in the ear of the listener.

Disadvantages of Analog Signals

Aside from loss (or attenuation), analog signals are impaired by noise and distortion. Amplifiers and other apparatus used for analog signals are complex because of the need to control noise and distortion.

Term	Description
Noise	A term for unwanted electrical signals that interfere with the information signal. In transmission lines, noise comes from electrical influences such as power lines, lightning, commercial radio transmitters, and cross talk between lines.
Distortion	An unwanted change in the information signal waveform. Distortion of analog signals occurs because amplifiers and other apparatus, as well as the cable pair, do not reproduce all frequencies equally well, resulting in changes in the waveform.
Loss	The effect of a signal getting weaker the further it travels. Loss can be overcome by using an amplifier to restore the signal to its original amplitude. However, since the amplifier cannot differentiate between signal and noise, it amplifies the noise as well as any distortion in the signal. The amplified noise and distortion then becomes part of the input signal for the next leg of the transmission.

As we increase the length of the analog transmission line, we must use more amplifiers, and the effect of noise and distortion accumulates. The cumulative effect can be minimized by proper system design, but it cannot be eliminated. Noise and distortion generally limit the maximum length of an analog transmission system.

Frequency Division Multiplexing (FDM)

Analog signals can be mixed together using *frequency division multiplexing (FDM)*, although this process is not often used any more as digital transmission becomes more common. In FDM, multiple voice channels are combined into a single signal, which is carried over a link thus making the most efficient use of that link. Each low-speed voice channel is modulated on a separate frequency within the bandwidth of the line—keeping the channels apart and preventing crosstalk. At the remote end, the channels are demultiplexed or separated again.

Digital Transmission

Digital transmission is a means to transmit analog signals (voice) by converting the signals into a series of electrical pulses. The pulses are transmitted to a distant point, which are then converted back to the original analog signal.

What is a digital signal? It is simply a series of square wave pulses sent at a very high speed down a transmission line. The pulses are identical in shape with alternate pulses reversed in direction. These pulses represent pieces of information called *bits*. This word comes from the letters of the two words binary digit. A pulse or no pulse condition is known as a bit. In digital signals, a one is normally a pulse and a zero means no pulse (in some applications, these are reversed).

Digital signals or pulses are subject to the same loss, noise, and distortion problems as analog signals. Attenuation losses, however, are corrected by the use of regenerative repeaters instead of amplifiers. Noise and distortion are not a problem because when each distorted pulse arrives at the regenerator, it is reconstructed into a distinct pulse and sent on its way to the next regenerator or to the termination point, as shown in Figure 1.10.

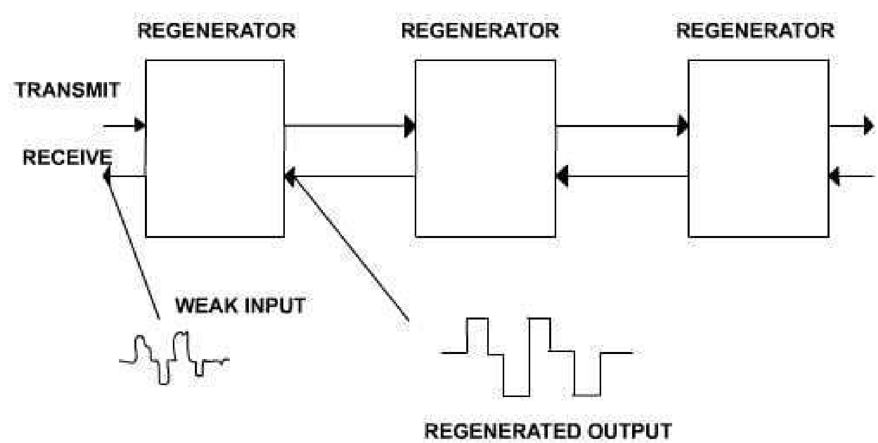


Figure 1.10

The pulse is therefore regenerated (rather than amplified) at the repeater, and the effects of transmission impairments (noise and distortion) and eliminated.

Why Digital Transmission?

There are several very important reasons for using digital transmission. They are:

- Lower cost than analog
- Free from distortion and noise
- Easier to multiplex (mix) with other signals

Analog transmission has existed since the invention of the telephone and will continue for some time in the future, but digital will eventually replace all analog systems.

Digital signals are used in T-Carrier, Subscriber Loop Carrier (SLC) systems and fiber optic systems. In the T-Carrier systems with 24 channels, 1,544,000 bits per second are sent over the line. This is a 1.544-megabit rate.

Summary

- A transmission line is a conducting path for electronic signals.
- Transmission lines are made of paired cable, coaxial cable, microwave radio, and fiber optical glass.
- Analog signals are electric signals that closely reproduce changes in sound pressure on telephone transmitters and other mechanical movement.
- Analog signals are subject to noise, distortion and loss.
- Digital signals are high-speed square wave pulses that can be derived from sampling analog signals.
- Digital pulses are regenerated rather than amplified.

Copper Media

Introduction

What do we mean when we talk about media? Media is a generic word meaning paths or ways to get from here to there. The word media is actually plural; the singular form is “medium”. When we talk about transmitting signals, the media are the physical paths that the signals follow between transmitter and receiver.

The media that have commonly been used for voice and data networks are twisted pair, coaxial cable, and optical fiber. Each type serves some applications better than the others. Twisted pair and coaxial cable are based on copper wire and are the media we are most familiar with. Optical fiber (also known as fiber-optic cable or just fiber) will be covered in the next section. In this section, you will learn about copper wire—once the only transmission medium—and the effect of the line on the quality of the transmitted signal.

Twisted Pair Wire

Twisted pair wire consists of two insulated copper wires arranged in a regular spiral pattern. The two wires are twisted together to reduce capacitance that can build up between the wires and weaken the signal. Capacitance is an object’s ability to store electrical charge. The signal in twisted pair wire can also be weakened by electrical interference (noise) from outside sources. Putting a shield around the twisted pair can prevent noise, but shielding increases the cost of the wire. Therefore, *unshielded twisted pair (UTP)* is commonly used for telephone sets.

Typically, a number of wire pairs are bundled together into a cable. A *cable* is a group of insulated wires formed into a compact core and covered with a flexible, protective, waterproof sheath or covering. The number of wires in a cable can vary from 25 to over 2000. Cables are described by pairs rather than individual wires, so a cable with 50 wires would be called a 25-pair cable. The number of pairs is important because most telephone equipment requires at least two wires for operation.

The two wires are the *tip and ring*. The tip and ring are the transmit and receive lines for the signal. Together with the Central Office (CO) and the customer premises, they make up the *local loop*.

Twisted Pair Wire (cont.)

Twisted pair wire can also be used for Local Area Networks (LANs). It is the least expensive medium for LAN installations and also the most available. Twisted pair wire is best for low-cost, short distance LANs, especially for small networks linking personal computers. It can effectively carry data at rates up to 16 megabits per second (Mbps) over distances up to several hundred feet without repeaters.

Standard twisted wire has, however, several significant disadvantages for data transmission. First, it is extremely susceptible to electric interference (noise) from outside sources. Second, it limits the distance that a signal can travel. A signal will grow weaker, or attenuate, as it travels further from its source. Signals attenuate on all media, but twisted pair wire acts as an antenna: the longer it gets, the more noise it gathers. After a finite distance, the increased noise obliterates the attenuated signal.

Two techniques can reduce the vulnerability of twisted pair to noise: shielding and repeating. Shielding makes the medium less vulnerable to electrical noise, but adds to the cost of the wire. Active repeaters, devices that receive a signal and retransmit it to another length of wire or cable, increase the distance a signal can travel. Repeaters are expensive and add to the cost of running twisted pair wire.

Coaxial Cable

Generally used in voce networks for inter-office trunks, *coaxial* cable (also called *coax*) comes in may forms and each is suited to a different kind of application. All forms of coaxial cable are comprised of a center conductor made of copper that carries the signal, the surrounding dielectric (a non-conducting insulator), a solid woven metal shielding layer, and protective plastic outer coating. All these layers are concentric around a common axis, thus the term “coaxial”. Coaxial cable is immune to electrical noise and can carry data at higher rates over longer distances than twisted pair wire, but is more expensive.

Coaxial cable is the most versatile transmission medium. There are two types of coaxial cable currently in use for LAN applications: 75-ohm cable, which is the standard used in community antenna television (CATV) systems, and 50-ohm cable. Typically, 50-ohm cable is used for digital signaling, called baseband; 75-ohm cable is used for analog signaling, called broadband. The term “ohm” refers to a standard unit of measurement of an object’s resistance to the flow of a steady electric current.

Transmission Loss

A transmission line is like an obstacle course in that it hinders the flow of electronic signals. The greatest effect on the signal is the loss of intensity as it travels down the line.

This loss of intensity is the result of three factors involved in basic electricity:

- Resistance
- Capacitance
- Inductance

Impedance

Cable pair transmission lines come in a variety of forms depending on the size of the conductors and the internal structure of the cable. All transmission lines have measurable impedance called *characteristic impedance*. Impedance, which is the total opposition to current flow, is made up of resistance, capacitance, and inductance.

In telecommunications, several characteristic impedances are used depending on the type of line. For example:

Characteristic Impedance	Type of Line
600 ohms	Interoffice trunk
900 ohms	Subscriber cable
1200 ohms	Carrier systems

The important thing with the characteristic impedance of cables is that you never switch to a cable with differing impedance. In a 600-ohm transmission line, the measurement is the same in either direction in order to obtain the most efficient transfer of power (least resistance) down the line. The input and output devices must also be 600 ohms. This is called *impedance matching* and is very important when a transmission system is installed or when a transmission measurement is to be made. If mismatched components are connected together, a reflection or echo will occur and customers will sound as if they were speaking into a barrel. Impedances must be matched to assure quality of transmission.

What is a Decibel?

Transmission line losses and gains are measured in units of power. Power is the product of current and voltage and the unit used is the watt or, more appropriately for telecommunications, the *milliwatt*, which equals one-thousandth of a watt.

Decibel (dB) is the name used to define the amount of power in transmission lines. The decibel, in relationship to transmission lines, refers to the amount of loss or gain in the line from the input end to the output end. In normal practice, gains are shown as +dB, but losses do not use the negative sign (-).

Summary

- Twisted pair wire consists of the two insulated copper wires arranged in regular spiral pattern.
- The cable pair (tip and ring), the Central Office (CO), and the customer premises make up the local telephone loop.
- The disadvantages of twisted pair are susceptibility to noise and limited distance. Shielding and the use of repeaters compensate for these disadvantages.
- Coaxial cable is made up of a central copper conductor that carries the signal, the surrounding dielectric (a non-conducting insulator), a solid woven metal shielding layer, and a protective plastic outer coating.
- Coaxial cable is immune to electrical noise and can carry data at higher rates over longer distances than twisted pair wire, but is more expensive.
- Resistance, capacitance, and inductance cause transmission line loss.
- Transmission lines have a fixed impedance depending on their usage.
- Failure to match impedance in transmission lines will result in echo and distortion.

Fiber Optics

Introduction

Optical fiber is the newest and most expensive transmission medium, but it has the greatest potential. As the cost comes down, fiber will become the primary medium for telephone systems. Its greatest advantage is that fiber is immune to both physical and electrical interference. Fiber is more fragile than copper wire, but recent advances in technology have made optical fiber sturdier that it used to be. You can actually tie it in a knot without damaging it.

History of Optical Communications

The concept of using light for communications is not new. In 1880, Alexander Graham Bell demonstrated a system he called a “photophone”. It focused sunlight as a source and sent a beam of light through the air to a detector. Bell’s invention was not practical because the source and medium were not reliable on foggy or rainy days or (of course) at night. It wasn’t until the 1950’s and 60’ that the concept of practical optical communications became feasible. Bell Laboratories invented the laser in 1958. Corning Glass Company produced the first practical low-loss fiber in 1970. The first continuously operating semiconductor laser operating at room temperature was also demonstrated at Bell Laboratories in 1970.

Through the early seventies, more strides were made and more processes developed for the making of practical, low-loss fibers. In 1976, an experimental fiber optic communication system was developed in Atlanta. A trial system was deployed in Chicago in 1977. The first Bell System standard 45 Mbps (million bits per second) system was put into service in Atlanta in 1980. As you can see, significant strides in several areas have been taken to produce practical fiber optic communications systems over the past 20 years. Advances in technology are being made every day and will affect this mode of communication for many years to come.

How Fiber Optics Work

Optical fiber transmits a signal-encoded beam of light by means of total internal reflection. If you shine a flashlight in one end of a piece of optical fiber, you can see the light come out at the other end. To send information over fiber, we convert the pulses of electricity to pulses of light, using the same on/off pattern we used for digital data. The optical fiber acts as a waveguide for frequencies in the visible spectrum and part of the *infrared spectrum*. The advantages of optical fiber are greater bandwidth, smaller size, lighter weight, lower attenuation, electromagnetic isolation, and greater repeater spacing.

Fiber Construction

An optical fiber is a thin, flexible medium capable of conducting an optical ray. Various glasses and plastics can be used to make optical fibers. An optical fiber cable has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the jacket (Figure 1.11).

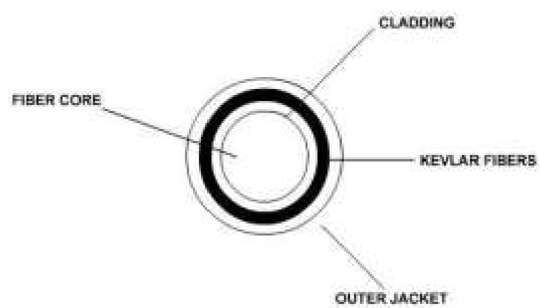


Figure 1.11

- The core is the innermost section and consists of a very thin glass or plastic strand (or fiber). The core is typically from about 8 to 62.5 µm (micrometer) in diameter.
- The core is surrounded by the cladding, a glass or plastic coating with a typical outside diameter of 125 µm.
- The outermost layer, surrounding one or a bundle of cladded fibers, is the jacket giving a total fiber diameter of 229 µm or more (almost one hundredth of an inch). The jacket is composed of plastic and other materials layered to protect against moisture, abrasion, crushing, and other environmental dangers.
- Sometimes a layer of Kevlar fibers is included between the cladding and the jacket for additional protection. Kevlar is the material used to make bulletproof vests.

Fiber Construction (cont.)

Light propagates (travels) along an optical fiber in the form of light rays. Each light ray (mode) that enters the core of an optical fiber will propagate along a path determined by the angle at which it enters the fiber and the characteristics of the fiber itself. Each mode carries an individual (but not equal) portion of the total light energy, and each mode follows an individual path. The light rays or modes stay within the core because the core is very transparent while the cladding is reflective. The cladding acts like a mirror around the core, creating a channel that keeps the light energy concentrated in the core (Figure 1.12).

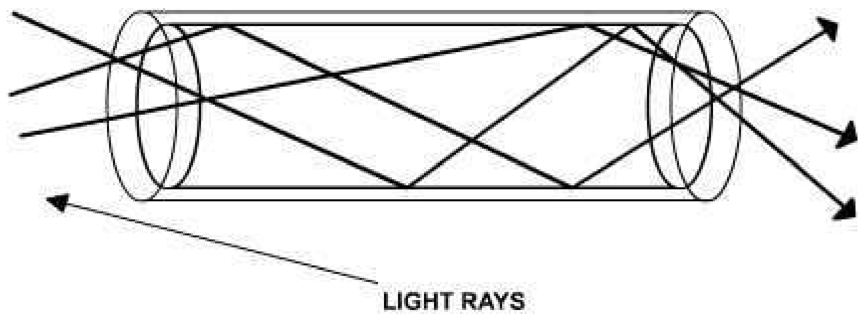


Figure 1.12

There are two basic types of optical fiber used in the telephone business today: multimode fibers (including enhanced multimode fibers) and single-mode fibers.

Multimode Optical Fiber

Multimode fibers have a cladding of 125 µm and a core of either 50 µm or 62.5 µm. This type of fiber can accommodate transmission at 825, 875, and 1300 nanometer (one billionth of a meter) wavelengths. The common bit-rate for a multimode fiber is usually either 45 Mbps or 90 Mbps.

The larger core (62. 5 µm) is used in *enhanced multimode fiber* (also known as "fat fiber"), which was developed for use in the loop plant, specifically for Pair Gain fiber optic systems. The larger diameter core permits more light to be coupled into the fiber, thus reducing the need for regenerator stations in the loop plant.

Multimode Step-Index Fiber

When these fibers were originally manufactured, a *step-index process* was used in which all of the layers of the core refracted light the same way. Each mode followed a separate propagation path and some had further to go than others, so all of the modes did not arrive at the receiving end at the same time. The longer the fiber, the longer it took these modes to reach the receiving end, causing the output pulse to widen as multiple pulses overlapped. This condition, called *modal dispersion*, shortens the required distance between regeneration points and limits the bandwidth potential. For this reason, step-index fiber is not suitable for use in multimode communications circuits.

Multimode Graded Fiber

Multimode fibers are now manufactured as *graded-index fibers*, which improve the poor transmission characteristics of the step index fibers.
The *index of refraction* is lower in the outer rings and becomes progressively higher toward the center. The center of the core will possess the highest refractive index. This will cause those modes that propagate down the center (shorter path) of the fiber core to travel at slightly lower speeds than those that take the longer paths. This controls the propagation velocity so that all modes arrive at the receive end of the fiber at virtually the same time, thus allowing regenerators to be spaced further apart.

Single-Mode Optical Fiber

The core diameter of *single-mode optical fiber* is no larger than 10 µm (or four ten-thousandths of an inch). The extremely small core diameter helps keep light scattering at a minimum; therefore, regeneration of the signal is not required as often as with multimode fiber designs. As in multimode and enhanced multimode fibers, the single-mode fiber also has a 125-µm-diameter cladding.

Single-mode fiber is intended for use in very high capacity systems such as 432 Mbps and higher. Single-mode systems are capable of transmitting more than 6048 channels simultaneously over each optical fiber pair with regenerator spacing up to twenty-five miles or more.

The extremely small single-mode core diameter cuts off all modes except the one that travels down the axis of the fiber core. Therefore, single-mode operation avoids the problem of unequal mode path lengths that cause pulse spreading in multimode operation. The achievement of less pulse spreading in single-mode fiber allows for very long regeneration spacing and a higher bandwidth range than is possible with multimode fiber.

Typical Fiber Optic System

A basic communications system consists of:

- An electrical *input signal*, which contains the information that is to be transmitted over the system.
- A *transmitter* that converts the signal into a suitable format for transfer. In a fiber optic system, the transmitter is an electrical-to-optical transducer or light source, which converts electrical energy to optical energy. A transmitter is a component that converts one form of input into another form of output energy.
- A *transmission medium*. In a fiber optic system, this medium must be suitable for the transmission of optical energy (such as a glass fiber.
- A *receiver* that extracts the message from the medium and formats it. In a fiber optic system, the receiver is an optical-to-electric transducer or *photodetector*, which converts the light energy back to electrical energy.
- An electrical *output signal*, which is ideally a replica of the original input signal.

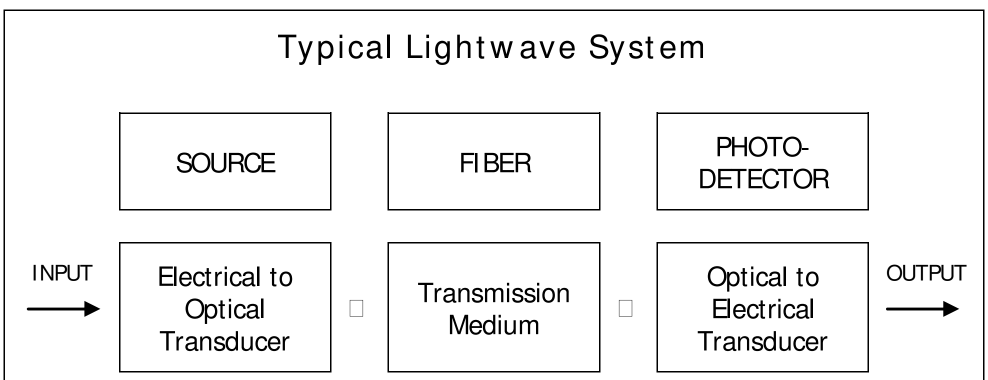


Figure 1.13

Typical Fiber Optic System (cont.)

A fiber optic communications system is designed so that its source, fiber, and photodetector are compatible. The source and photodetector must emit and collect light at the wavelengths that are most suitable for optical transmission. The input signal can be either analog or digital. Most fiber optic systems, however, are designed to transmit digital signals.

The input signal (electrical energy) is changed to optical energy by the electrical-to-optical transducer, referred to as the optical source. The most common optical sources used in telecommunications systems are semiconductor lasers and light emitting diodes (LEDs).

Any medium that transmits light signals could be used. One such medium is air. Air is suitable for applications such as ship-to-ship blinker communication. However, digital transmission of voice and data require a more dependable, high capacity transmission medium. Low loss optical fiber has been developed for this purpose.

The average amount of information sent by a ship's blinker light is about 12 words per minute, or one character per second. In digital technology we refer to the speed of transmission in terms of bits per second. Thus, a ship's blinker would transmit at about 1 bit per second. In contrast, optical fiber systems can transmit information at the rate of millions of bits per second. This is abbreviated as Mbps. For example, 500 million bits per second would be transmitted as 500 Mbps. We also use the term megabit to refer to the speed of transmission. Thus, 500 million bits per second could also be referred to as a rate of 500 megabits.

Advantages of Fiber Optic Systems

Fiber optic transmission systems are superior to copper systems in many ways, such as:

- They can carry large amounts of data, so they can support high capacity systems. Copper cable has a very limited capacity compared to fiber.
- Cables are of a small size and lightweight. Fiber optic cables are about one-half inch in diameter (regardless of the number of fibers) and weigh about 82 lbs. per 1000 feet. This factor in itself lowers transportation and handling costs.
- They provide service at a low cost per channel. Long-term cost benefits associated with fiber optic systems are outlined in the table below.

Benefit	Description
Lower construction costs	Lower construction costs due to tremendous saving in duct space. Three fiber optic cables can be placed in a four-inch duct that formerly could support only one copper cable.
High bandwidth capacity	The high bandwidth capacity of fiber optic cable reduces the need for placing additional cables in the future.
Fewer repeater sites	Fewer repeater sites are required. A typical fiber optic system requires one repeater every twenty-five miles while twenty-two repeaters are required for copper systems over the same distance.

Advantages Of Fiber Optic Systems (cont.)

Fiber optic systems are immune to the following electrical problems.

- Crosstalk
- Safety problems like electrical sparking or shock.
- Fiber optic systems are reliable. They can tolerate higher temperatures than copper and do not rust. The jacket prevents water from contacting the core and interfering with the signal.
- Radio frequency interference (RFI) is emissions from electronic equipment, while electromagnetic interference (EMI) is emissions from natural phenomena like thunderstorm or unintentional causes like static.
- They are more secure than copper systems. Copper systems allow signal emissions, which can be picked up "bugs", but very little light energy radiates out of the fiber core, making interception of the signal virtually impossible.

There are a few disadvantages of fiber. It is still somewhat more expensive than cable, though prices are changing. The optical connector is expensive and is the main cause of signal loss. Also, it is more difficult to tap in to a fiber than a copper cable.

Optical transmission systems can be considered for any application where data, video, voice, or control communications are required. Fiber optic systems are particularly advantageous when high capacity, room for growth, security, and immunity to outside interference are needed.

Summary

- Light propagates along an electrical fiber in the form of light rays or modes.
- The fiber used in fiber optics consists of a core, cladding, and a plastic coating or jacket. Sometimes a layer of kevlar fibers is included between the cladding and the jacket.
- Fiber optic cable can be classified as multimode, enhanced multimode, and single-mode. Enhanced multimode has a larger core and is used in Pair Gain systems. Single-mode is used in very high capacity systems.
- Multimode fiber was originally step-indexed fiber, but is now usually graded-index fiber. Graded-index is preferred because it allows longer regenerator spacing and higher bandwidth, because the output signal is less affected by modal dispersion (pulse spreading).
- A typical fiber optic system consists of an electrical input signal, an electrical-to-optical transducer (light source), a transmission medium (fiber), an optical-to-electrical transducer (photodetector), and an electrical output signal.
- Fiber optic media are superior fro transmission because of the high capacity, low cost per channel, immunity to electrical problems, and security.

Lesson 1: Review Questions

This test consists of 25 questions. To get the most out of this practice, limit yourself to 15 minutes to answer these questions. Answers are provided at the end of this book. Fill in your answers to all the questions and then turn to the answer key.

Circle the letter of the correct answer. Choose only one answer.

1. Which of the following are DC power sources?
   a. Generators
   b. Batteries
   c. Converters
   d. All of the above
2. Which of the following describe advantages of alternating current over direct current?
   a. AC travels more rapidly than DC
   b. AC travels in only one direction, while DC reverses its direction
   c. It is easier to transform AC in comparison to DC
   d. All of the above
3. The device that translates electricity into sound waves in a telephone receiver is which of the following:
   a. Electromagnet
   b. Carbon granules
   c. Diaphragm
   d. Photodetector
4. Amplifiers are used to control which of the following problems?
   a. Noise
   b. Distortion
   c. Interference
   d. Attenuation

5. Which of the following is a source of noise in an analog transmission line?
   a. Lighting
   b. Power lines
   c. Radio transmitters
   d. All of the above
6. Digital transmission converts signals into:
   a. Analog wave forms
   b. Sine waves
   c. A series of electrical pulses
   d. Air pressure
7. Which of the following is TRUE of digital signals?
   a. They are easier to multiplex with other signals
   b. They cost more than analog
   c. They carry more noise than analog
   d. All of the above
8. Which of the following media does not use copper wire?
   a. Twisted Pair
   b. Coax
   c. Fiber Optic Cable
   d. Shielded Twisted Pair
9. This wire consists of two insulated copper wires arranged in a regular spiral pattern.
   a. Coax
   b. Coil
   c. Twisted Pair
   d. Fiber

10. Which of the following is a basic part of a transmission system?

    a. LED

    b. Pulse regenerator

    c. Analog waveform

    d. Source of energy

11. Which of the following is considered a transmission medium?

    a. Paired cable

    b. Optical glass fiber

    c. Coaxial cable

    d. All of the above

12. An exact reproduction of the voice signal enters the telephone receiver and converts to _____ in the ear of the listener.

    a. Electromagnetic waves

    b. Air pressure

    c. Electrical signals

    d. Modulated pulses

13. Which of the following is a method for preventing crosstalk?

    a. Frequency Division Multiplexing

    b. Amplification

    c. Regeneration

    d. Longer transmission systems

14. Which of the following is part of the local loop?

    a. Tip and ring

    b. Customer premises

    c. Central Office

    d. All of the above

15. What is the best transmission medium for small networks linking personal computers?

    a. Untwisted pair

    b. Fiber optic cable

    c. Coaxial cable

    d. Twisted pair

16. Two techniques that reduce the vulnerability of twisted pair to noise are:

    a. Multiplexing and demultiplexing

    b. Shielding and repeating

    c. Regeneration and dispersion

    d. Amplification and de-amplification

17. The center conductor in a coaxial cable is made of which of the following?

    a. Kevlar fibers

    b. Copper

    c. Glass

    d. Optical fiber

18. Which of the following constitutes the innermost layer of optical fiber cable?

    a. Glass

    b. Copper

    c. Dielectric

    d. Kevlar fibers

19. Modal dispersion:

    a. Increases noise in the system

    b. Shortens the required distance between regeneration points

    c. Lengthens the required distance between regeneration points

    d. Speeds up the signal

20. Which of the following is a type of optical fiber?

    a. Single-mode fibers

    b. Graded-index fibers

    c. Enhanced multimode fibers

    d. All of the above

21. The cladding is the:

    a. Innermost layer of optical fiber cable

    b. Very thin glass or plastic strand of optical fiber cable

    c. Middle layer of optical fiber cable surrounding the core

    d. Material used to make bullet-proof vests added to fiber for additional protection

22. Which of the following is a disadvantage of fiber optic cable?

    a. Fiber is more susceptible to interference than copper cable

    b. Fiber is more expensive than copper

    c. Construction costs for fiber are higher

    d. All of the above

23. The outermost layer of optical fiber cable is the:

    a. Cladding

    b. Copper

    c. Jacket

    d. Kevlar fibers

24. The _____ refers to the amount of loss or gain in the transmission line from the input end to the output end.

    a. Bit rate

    b. Decibel

    c. Frequency

    d. Bandwidth

25. What problems are analog signals subject to?

    a. Loss

    b. Noise

    c. Distortion

    d. All of the above

Lesson 2: Understanding Technical Documents

Lesson Overview

This lesson is designed to familiarize you with some of the basic concepts and functions involving technical documentation that are used in the work of technicians. The Work Order Referral Document (WORK) Request as it is used in this lesson is a generic document that combines elements of some of the existing systems used to communicate information to telecommunications technicians.

Lesson Objectives

Upon completion of this lesson, you will be able to:

- Explain the purpose of a WORK Request
- Identify the three sections of a WORK Request and explain the functions of each section
- Locate information found in a the WORK Request to complete work assignments

Work Order Referral Document (WORK)

Introduction

The installation and maintenance of circuits begins with the receipt of an official authorization document. Over the years, a variety of documents were used for this purpose. Even though they had different names and looked different, these documents all served the same purpose. One such document is the Work Order Referral Document (WORK) Request. In the near future, almost all circuit work orders will be computer generated and distributed automatically using a WORK Request.

The WORK Request as it is used in this lesson is a generic document that combines elements of some of the existing systems used to communicate information to telecommunications technicians. The material and the references in this lesson are not actually used in any of the systems currently in place at Verizon, so you should not assume that the material that you might have learned in the past will apply. Therefore, in reading this lesson, you should rely only on the material provided in this book.

The material in this lesson is designed to familiarize you with some of the basic concepts and functions involving technical documentation that are used in the work of technicians. Documents, such as the WORK Requests, described in this lesson are valuable tools that contain all the important source information necessary to enable you to complete and record your work assignments. This lesson will acquaint you with the more significant information found in a WORK Request.

The WORK Request is composed of three distinct sections, each with a specific purpose:

- Customer Information (CI)
- Circuit Specifications (CS)
- Work Authorization (WA)

Customer Information (CI)

The first section of the WORK Request is the customer information section (shaded area shown in Figure 2.1). This section provides the technician with necessary information about the customer, type of available service options, and other customer information depending on the document. A Code List is provided in the Appendix to assist you in interpreting the request.

WORK Request

	C.I.	
CN Boone	CL south cen	APC 578-0596
ATM – NO	BOSS – 11	CAP SP
PTN 788-5902	BTN 204-532-5672	TC - 762-9804
	C.S.	
WTL east cen	LCL 203	WDN 219
ORd – 9/21/xx	WLO west cen	SST 102
ACS 245	LSP CO-2	WSN - 197
	W.A.	
RN – 2162	ONA NO	NPO 1520
CCSA YES	GTI 160	LFACS 121
WRD 915	POP 15	WB 2220

Figure 2.1

Each code (shown in bold print) represents a specific type of information. Using the Code List in the appendix, you can identify the type of information represented by each code.

For example, in the WORK Request above, the "CN" represents "Customer Name" and the "BTN" represents the "Billing Telephone Number". Therefore, the information associated with the code CN (customer name) is Boone and the BTN (billing telephone number) is 204-532-5672.

Circuit Specifications (CS)

The second section of the WORK Request contains information on circuit specifications. This information is useful when you need to install, test, and troubleshoot a telephone circuit. The circuit specifications section includes codes such as wire design number (WDN), wire specification number (WSN), and other information depending on the document. In Figure 2.2, the circuit specifications section is the shaded area.

WORK Request

	C.I.	
CN Boone	CL south cen	APC 578-0596
ATM – NO	BOSS – 11	CAP SP
PTN 788-5902	BTN 204-532-5672	TC - 762-9804
	C.S.	
WTL east cen	LCL 203	WDN 219
ORd – 9/21/xx	WLO west cen	SST 102
ACS 245	LSP CO-2	WSN - 197
	W.A.	
RN – 2162	ONA NO	NPO 1520
CCSA YES	GTI 160	LFACS 121
WRD 915	POP 15	WB 2220

Figure 2.2

Work Authorization (WA)

The third section of the WORK Request provides information on work authorization. The WA section contains information regarding the type of work to be performed for the customer. It also provides the purchase order number, LFACS number, and other information depending on the document. Refer to Figure 2.3. The work authorization section is the shaded area.

WORK Request

	C.I.	
CN Boone	CL south cen	APC 578-0596
ATM – NO	BOSS – 11	CAP SP
PTN 788-5902	BTN 204-532-5672	TC - 762-9804
	C.S.	
WTL east cen	LCL 203	WDN 219
ORd – 9/21/xx	WLO west cen	SST 102
ACS 245	LSP CO-2	WSN - 197
	W.A.	
RN – 2162	ONA NO	NPO 1520
CCSA YES	GTI 160	LFACS 121
WRD 915	POP 15	WB 2220

Figure 2.3

Figuring out the codes to identify work authorization information follows the same straightforward method used for the CI section, discussed earlier.

Step	Action
1.	Look up the desired listing in the Code List.
2.	Identify the corresponding code.
3.	Refer to the WORK Request for the desired information.

Lesson 2: Review Questions

Refer to the WORK document below to answer the following questions. Circle the letter of the correct answer. Choose only one answer.

WORK Request

C.I.

CN McCann	CL west cen	APC 434-3325
WATS – YES		ATM - YES
BTN 312-4453		TC - 988-2311
PTN 881-7911		

C.S.

WLO south cen	LCL west	WDN 121
ORd – 11/24/xx	WTL west cen	SST 1128
WSN - 321	LSP 101	ACS - 244

W.A.

RN – 1016	TCP/IP NOT IN USE	NPO 2002
POP 1	GTI 122	WB 2012
WRD 1119	CWS - NO	LFACS 122

Figure 2.4

1. This section of the WORK Request contains information regarding the type of work to be performed for the customer.
   a. Section 1
   b. Section 2
   c. Section 3
   d. All three sections

2. The Customer Information section of the WORK Request provides the technician with which of the following pieces of information?

   a. Customer name

   b. Prior telephone number

   c. Type of available service options

   d. All of the above

3. What is the customer's telephone number in the WORK Request?

   a. 312-4453

   b. 434-3325

   c. 881-7911

   d. 988-2311

4. The Wire Design Number is:

   a. 321

   b. 121

   c. 1119

   d. 2012

5. Which code has the value of 122?

   a. Loop Customer Line

   b. Services Switching Point

   c. Loop Fiber Area Circuit System

   d. Loop Facility Assignment and Control System

Lesson 3: Troubleshooting Circuits

Lesson Overview

Troubleshooting introduces a process for locating and eliminating sources of problems in a logical and prescribed manner. Problems can be located and resolved much more quickly if a logical troubleshooting process is followed. In this lesson, you will learn some general concepts of troubleshooting and then learn to apply a specific series of troubleshooting steps to a set of problems for transmission circuits using WORK documents.

Lesson Objectives

Upon completion of this lesson, you will be able to:

- Explain the importance of troubleshooting techniques
- Read a flowchart
- Describe the steps for troubleshooting transmission circuits
- Use WORK documents and troubleshooting flowcharts to determine corrective action to trouble situations

What is Troubleshooting?

Introduction

The word "troubleshooting" literally means aiming at a trouble or a problem and firing away until you hit the bulls-eye. In a more practical sense, the term refers to a process for locating and eliminating sources of problems in a logical and prescribed manner. It is a process that lets you approach a problem from all angles and zero in on the cause in a way that involves the least amount of time and energy.

The need for a thorough grasp of troubleshooting techniques and procedures in today's high-tech world is underscored by the fact that troubleshooting is the basis of all electronic and mechanical repairs. Most industrial and consumer electronic devices today come with manuals that contain a troubleshooting guide.

Mapping Out the Process

An analysis of the troubleshooting process reveals that it is possible to break the process down into three distinct phases or steps:

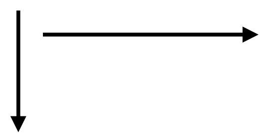
1. Analysis of symptoms and generation of possible causes.
2. Arrangement of the list of causes in a logical order, with the most probable at the top.
3. Using the process to rule out possibilities, test each probable cause until the problem is identified.

The troubleshooting process can be mapped to show steps in sequence along with key questions involved in identifying the problem. To map the process, we can use a flowchart.

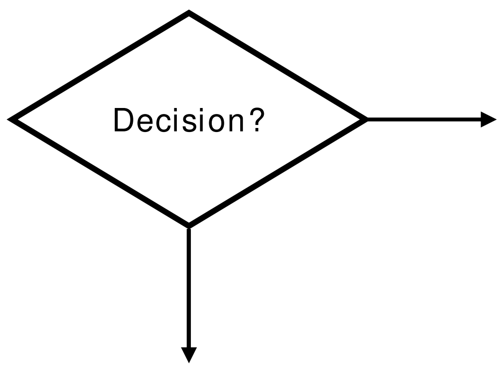
How to Read a Flowchart

A *flowchart* is a graphic representation of the steps that should be followed in troubleshooting a problem. Flowcharts use symbols connected by arrows. Tasks are shown as rectangles. Processes are made up of a sequence of tasks. Usually the tasks are listed from top to bottom.

Arrows show the direction of the action. Arrows flow from top to bottom and left to right.



Flowcharts show decision points as diamonds.



These decision points generally ask a question. Depending on the answer to the question, the arrows may send you on different paths.

In this lesson, we will use flowcharts, decision tables, and other graphic tools to show the steps and possible routes of the troubleshooting process.

Example #1

Consider the following example. In the table shown below, an error message code indicates that there is a problem and provides some information about what the problem is. In this case, the problem is improper or no power being supplied to a circuit.

ERROR MESSAGE CODE	PROBLEM
	IMPROPER OR NO POWER BEING SUPPLIED TO THE CIRCUIT

In order to troubleshoot this problem a technician would follow a logical sequence.

The proper sequence of procedures for troubleshooting the power problem would involve the following five steps.

Step	Action
1.	Check for power.
2.	Check for a blown fuse.
3.	Is the appropriate level of voltage being generated?
4.	Is the power supply correctly installed?
5.	Are the connections to the power supply plugged in?

The five steps and the logical sequence in which they are followed can be represented in a flowchart. Refer to the troubleshooting flowchart on the next page.

Figure 3.1 shows the flowchart for troubleshooting the power problem.

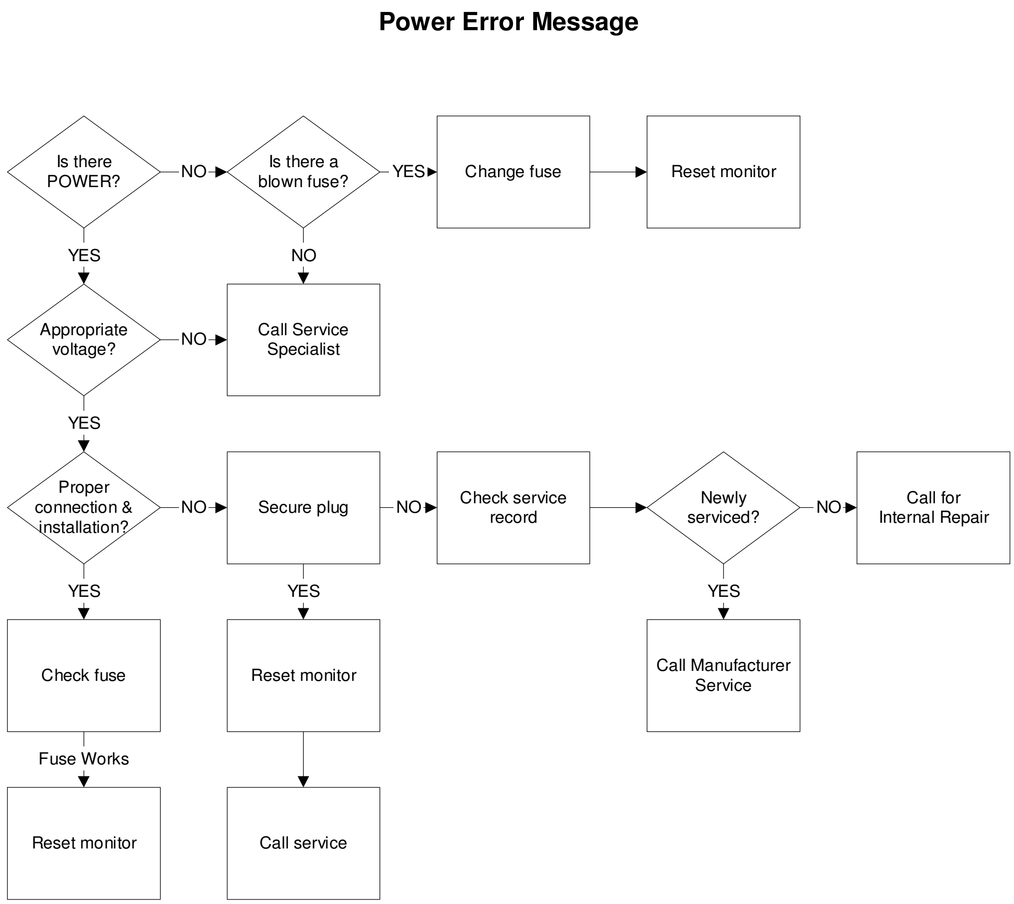


Figure 3.1

Notice that at each step of the troubleshooting flowchart a check or test is done. Depending upon the outcome or results of the test a different path is followed. This sequence of activities is followed until the problem is resolved.

- In Step 1 a check for power is made. If power is not present, the technician checks for a blown fuse. The fuse should then be changed and the monitor should be reset. If power is present, then Step 2 is carried out.
- In Step 2, the voltage should be checked to make sure that it is at the right level. If it is not, then a service specialist should be called.
- If voltage is appropriate then Step 3 should be performed.
- Note that each step is dependent upon the outcome of a previous step. By following the flowchart sequence, an individual with limited knowledge of the system can solve troubleshooting problems.

Example #2

A second example is shown below. The problem or "trouble" is a communication error resulting from a poor quality phone line.

ERROR MESSAGE CODE	PROBLEM
COMM.ERROR	YOU HAVE ENCOUNTERED A COMMUNICATION ERROR THAT RESULTED FROM A POOR QUALITY PHONE LINE

In order to solve this problem a technician would follow a sequence of the following five steps.

Step	Action
1.	Try call again.
2.	Check sending unit for dial indicator for send position.
3.	Check sending unit for clean contacts and connections.
4.	Turn ignition switch on to sending unit, hold send button for two seconds, observe the red LED on panel for system okay message.
5.	Call for service.

Each of these steps is represented in the flowchart on the following page.

Figure 3.2 shows the flowchart for troubleshooting the communication problem.

Communication Error Message

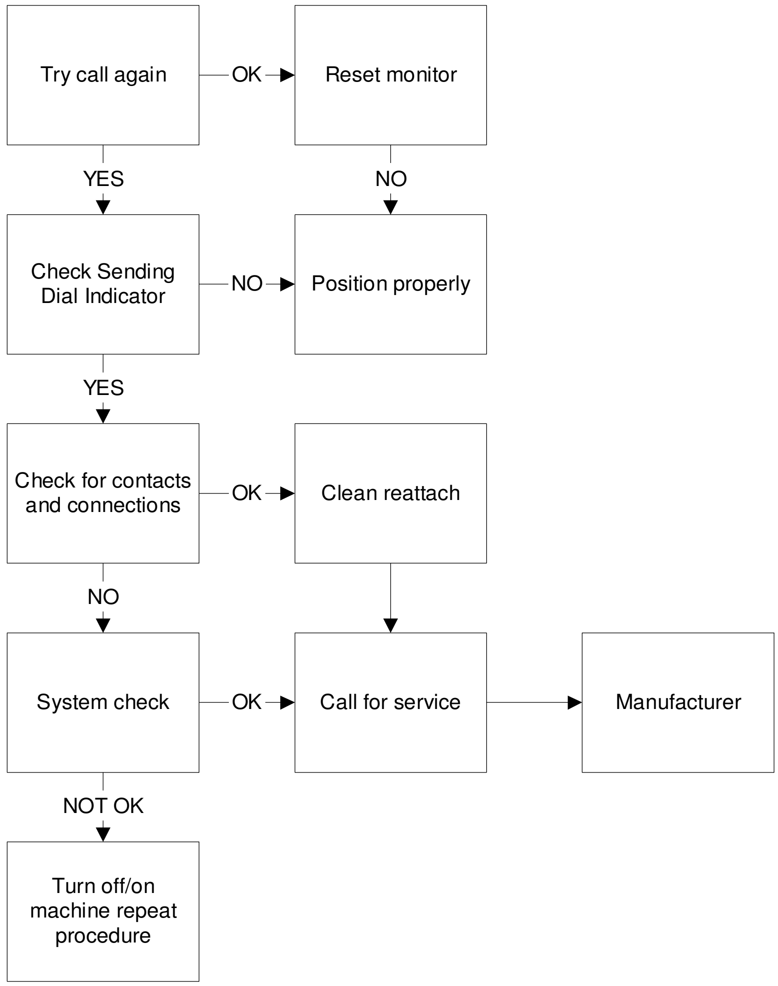


Figure 3.2

Steps for Troubleshooting Circuits

The remainder of this lesson is designed to familiarize you with a generic troubleshooting process for transmission circuits. The WORK Request described earlier will serve as a starting point for the troubleshooting steps. Each time a trouble report is received, specific steps should be taken. The order of the steps remains the same from one trouble situation to the next. These steps reduce the time it takes to find and correct the trouble.

This table summarizes the steps for troubleshooting circuits.

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1.</td><td>Locate the Loop Facility Assignment and Control Number (LFACS) and the Wire Specification Number (WSN).</td></tr>
<tr><td>2.</td><td>Compare the two numbers.
<table>
<tr><th>If…</th><th>Then…</th></tr>
<tr><td>LFACS is higher than the WSN</td><td>Find the Wideband (WB) to get the diagnostic test results.</td></tr>
<tr><td>WSN is higher than the LFACS</td><td>Find the Purchase Order Number (NPO) to get the diagnostic test results.</td></tr>
</table></td></tr>
<tr><td>3.</td><td>Identify the appropriate troubleshooting flowchart.</td></tr>
<tr><td>4.</td><td>Determine which path on the flowchart to follow.</td></tr>
<tr><td>5.</td><td>Identify the appropriate corrective action flowchart.</td></tr>
<tr><td>6.</td><td>Find the Wire Location (WLO).</td></tr>
<tr><td>7.</td><td>Determine which path on the corrective action flowchart to follow.</td></tr>
<tr><td>8.</td><td>Obtain the Wire Design Number (WDN).</td></tr>
<tr><td>9.</td><td>Determine which sub-path to follow.
<table>
<tr><th>If…</th><th>Then…</th></tr>
<tr><td>WDN is 199 and below</td><td>Follow the upper route of the path</td></tr>
<tr><td>WDN is 200 and above</td><td>Follow the lower route of the path</td></tr>
</table></td></tr>
<tr><td>10.</td><td>Identify the appropriate corrective action to take.</td></tr>
</table>

Example: Troubleshooting Circuits

Let's practice the troubleshooting steps by walking through an example. Refer to the WORK Request in Figure 3.3.

WORK Request

	C.I.	
CN Smith	CL north cen	APC 337-3358
WATS – NO	BTN 201-231-2332	ATM YES
PTN 691-7575	CALL C - NO	C - 210-5969
	C.S.	
WLO east cen	LCL East	WDN 209
ORd – 11/23/xx	WTL west cen	SST 1129
WSN - 201	NOS - 2278	ACS - 464
	W.A.	
RN – 1009	TCP/IP – IN USE	NPO 1160
POP NONE	GTI 160	WB 2026
WRD 1129	WATS South	LFACS 649

Figure 3.3

Step 1

Locate the Loop Facility Assignment and Control Number and the Wire Specification Number.

- Using the Code List in the Appendix, we determine the Loop Facility Assignment and Control Number uses the "LFACS" designation and the Wire Specification Number uses the "WSN" designation.
- Now that we have identified the code, we can locate the desired information on the WORK Request. The LFACS number is 649 and the WSN is 201.

Step 2

Compare the two numbers.

- Since the LFACS number is higher than the WSN, we refer to the Wideband number to get the diagnostic test results.
- According to the Code List, the designation for Wideband is "WB".
- Therefore, the test results indicate a value of 2026.

Step 3

Identify the appropriate troubleshooting flowchart.

- We determined in Step 2 that the Wideband is the appropriate test results. We can use this number to find the correct troubleshooting flowchart.
- The Wideband (and Purchase Order Number) range of values is listed in the top right hand side of the flowchart pages in the Appendix.
- Flowchart 4 is the correct flowchart to follow because the Wideband test results in this example (2026) fall between 2021-2030.

Step 4

Determine which path on the flowchart to follow.

- Next we must consider another range of values to determine the path.
- Since the Wideband results are 2026, the correct path in Flowchart 4 is Path 2.

Step 5

Identify the appropriate corrective action flowchart.

- Follow the arrows of Path 2 to identify the corrective action.
- In this example, Flowchart 7 is the right corrective action flowchart.

Step 6

Find the Wire Location.

- To find the appropriate corrective action in Flowchart 7, we must determine the Wire Location.
- Using the Code List, we determine the Wire Location uses the "WLO" designation. Now, we can locate the desired information on the WORK Request.
- The WLO is East Central.

Step 7

Determine which path on the corrective action flowchart to follow.

- Now that we have obtained the needed Wire Location (East Central), we can read the corrective action flowchart (Flowchart 7) to identify the correct path to follow.
- Since East Central is the Wire Location, we follow Path 3.

Step 8

Obtain the wire design number.

- In order to use Flowchart 7, we must also have the Wire Design Number. The designation for Wire Design Number is WDN.
- Referring to the WORK Request, the WDN is 209.

Step 9

Determine which sub-path to follow.

- The Wire Design Number is 209, which directs us to follow the "200 and above" sub-path.
- In this example, we follow the lower route of Path 3.

Step 10

Identify the appropriate corrective action to take.

- Finally, we simply follow the lower route of Path 3 to the appropriate corrective action.
- The corrective action reads: Select Cable Config. B.

Now that the corrective action has been found, the troubleshooting process is complete.

Lesson 3: Review Questions

Refer to the WORK document below to answer the following questions. Circle the letter of the correct answer. Choose only one answer.

WORK Request

C.I.

CN McCann	CL west cen	APC 434-3325
WATS – YES		ATM - YES
BTN 775-312-4453		TC - 988-2311
PTN 881-7911		

C.S.

WLO south cen	LCL west	WDN 121
ORd – 11/24/xx	WTL west cen	SST 1128
WSN - 321	LSP 101	ACS - 244

W.A.

RN – 1016	TCP/IP NOT IN USE	NPO 2002
POP 1	GTI 122	WB 2012
WRD 1119	CWS - NO	LFACS 122

Figure 3.4

1. Which is the correct initial flowchart you should use to determine this problem?

   a. Flowchart 1

   b. Flowchart 2

   c. Flowchart 3

   d. Flowchart 4

   e. Flowchart 5

2. Which is the correct Path on the initial flowchart you should follow in this problem?

   a. Path 1

   b. Path 2

   c. Path 3

   d. Path 4

3. Which is the corrective action you should take to fix this problem?

   a. Use Suppressor C

   b. Use Suppressor D

   c. Redesign Circuit to Type A

   d. Redesign Circuit to Type B

Appendix

Appendix

Code List

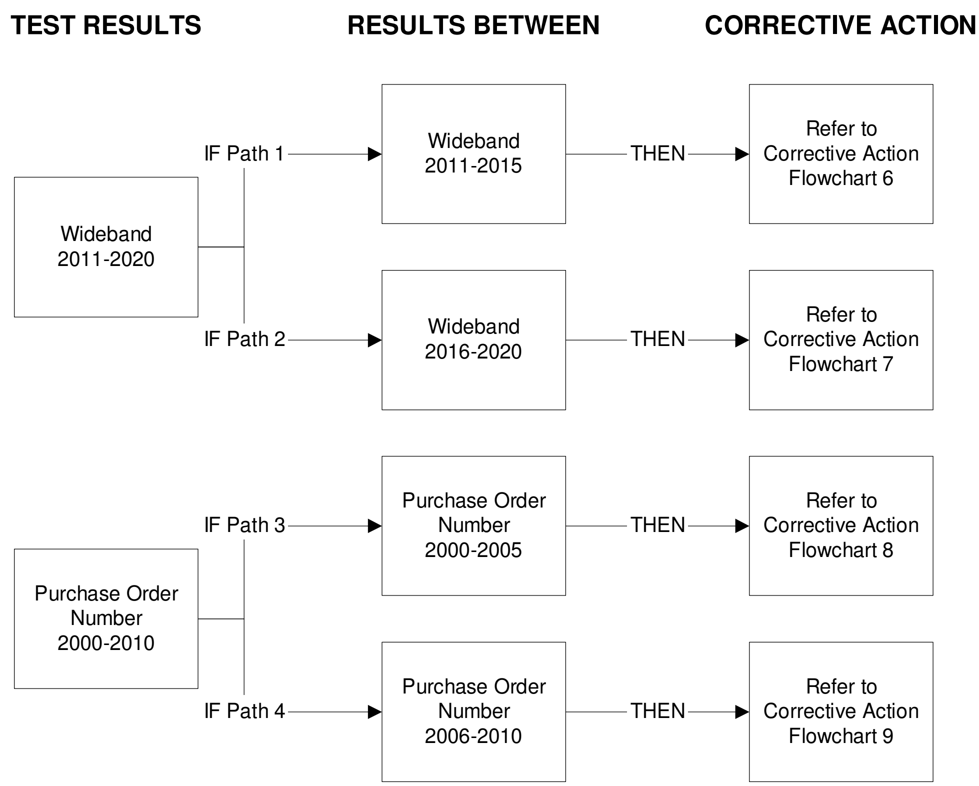
Name	Code
1. Alarm Protection Code	APC
2. Area Code	AC
3. Asynchronous Transfer Mode	ATM
4. Band Rate	BR
5. Bell Operating Company	BOC
6. Billing and Order System Support	BOSS
7. Billing Telephone Number	BTN
8. Business Process Reengineering	BPR
9. Call Collection	CALL C
10. Cellular Wireless Services	CWS
11. Circuit Switching Access	ACS
12. Common Control Switching Arrangement	CCSA
13. Competitive Access Provider	CAP
14. Customer Location	CL
15. Customer Name	CN
16. Data Terminal Equipment	CTE
17. Digital Access and Cross-Connect	DACS
18. Digital Channel Service	DCS
19. Electronic Switching Systems	ESS
20. Fiber Distributed Data Interface	FDDI
21. Frame Relay	FR
22. Geographic test Index	GTI
23. Integrated Services Digital Network	ISDN
24. Loop Customer Line	LCL
25. Loop Facility Assignment and Control System Number	LFACS
26. Message Rate Service	MRS
27. Network Operating System	NOS

Name	Code
28. Open Network Architecture	ONA
29. Order Request Data	ORd
30. Point of Presence	POP
31. Prior Telephone Number	
32. Purchase Order Number	NPO
33. Request Number	RN
34. Special Services Test Number	SST
35. Switching Point Location	LSP
36. Terminal Code	TC
37. Terminal Service Number	TSN
38. Transmission Control Protocol/Internet Protocol	TCP/IP
39. Voice Digitization	VD
40. Wide Area Telecommunication Service	WATS
41. Wideband	WB
42. Wire Design Number	WDN
43. Wire Location	WLO
44. Wire Request Number	WRD
45. Wire Specification Number	WSN
46. Wire Termination Location	WTL

Flowchart 1

Wideband 2011 – 2020

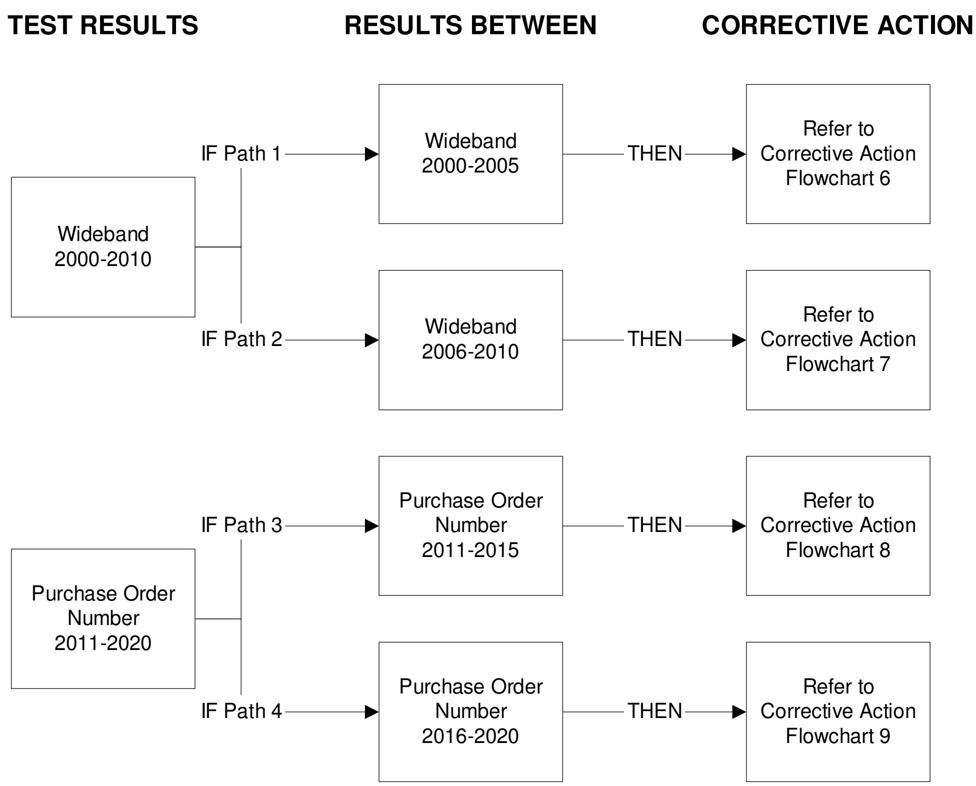
Problem: Attenuation **Purchase Order Number 2000 – 2010**



Flowchart 2

Wideband 2000 – 2010

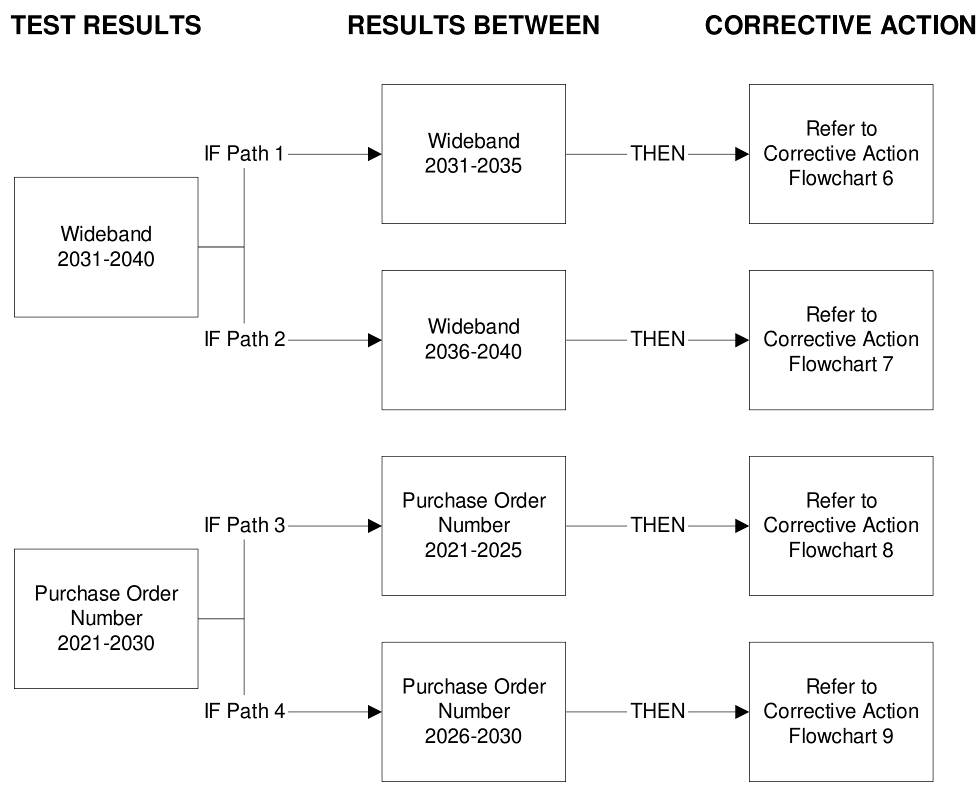
Problem: Noise **Purchase Order Number 2011 – 2020**



Flowchart 3

Wideband 2031 – 2040

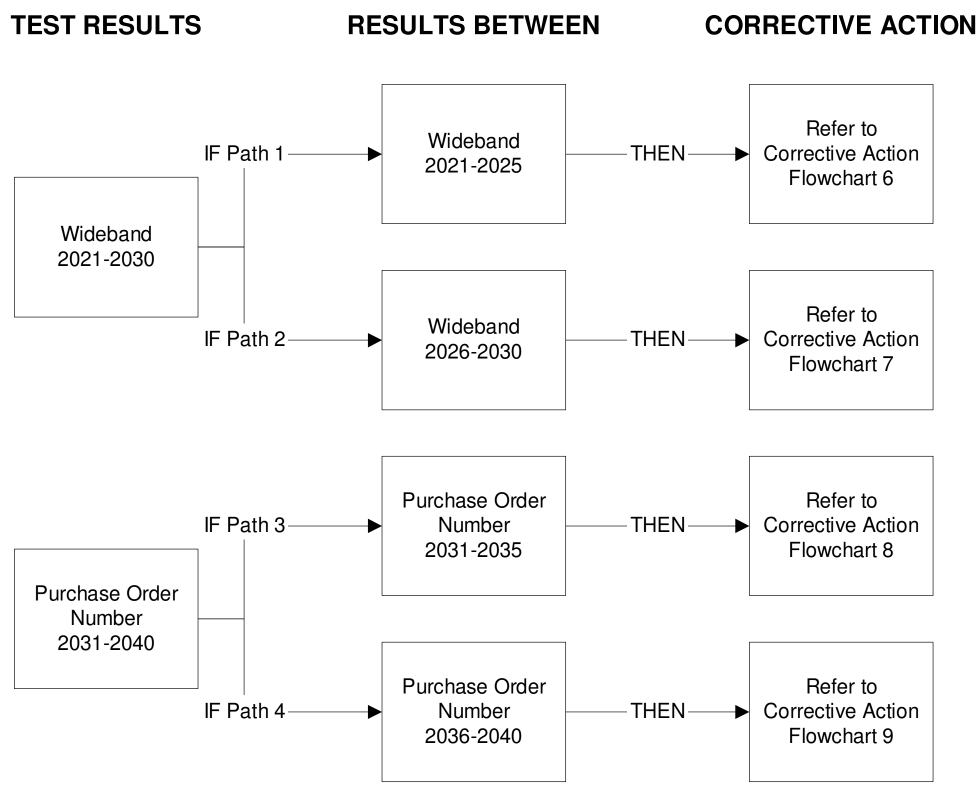
Problem: Echoes **Purchase Order Number 2021 – 2030**



Flowchart 4

Wideband 2021 – 2030

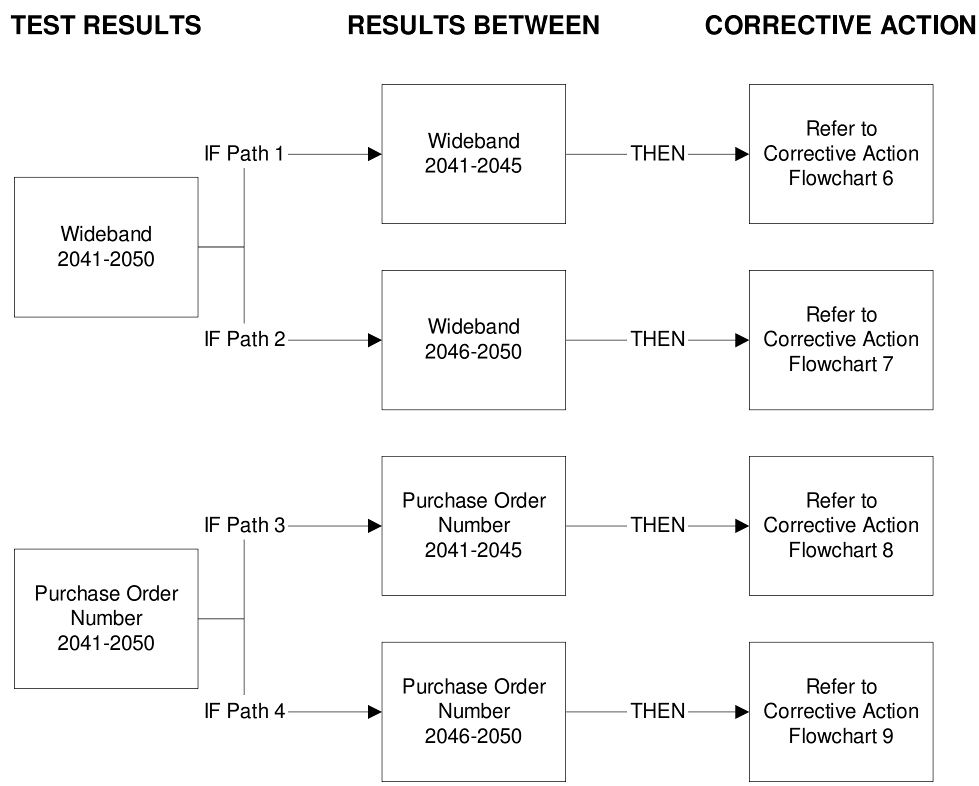
Problem: Cross Talk **Purchase Order Number 2031 – 2040**



Flowchart 5

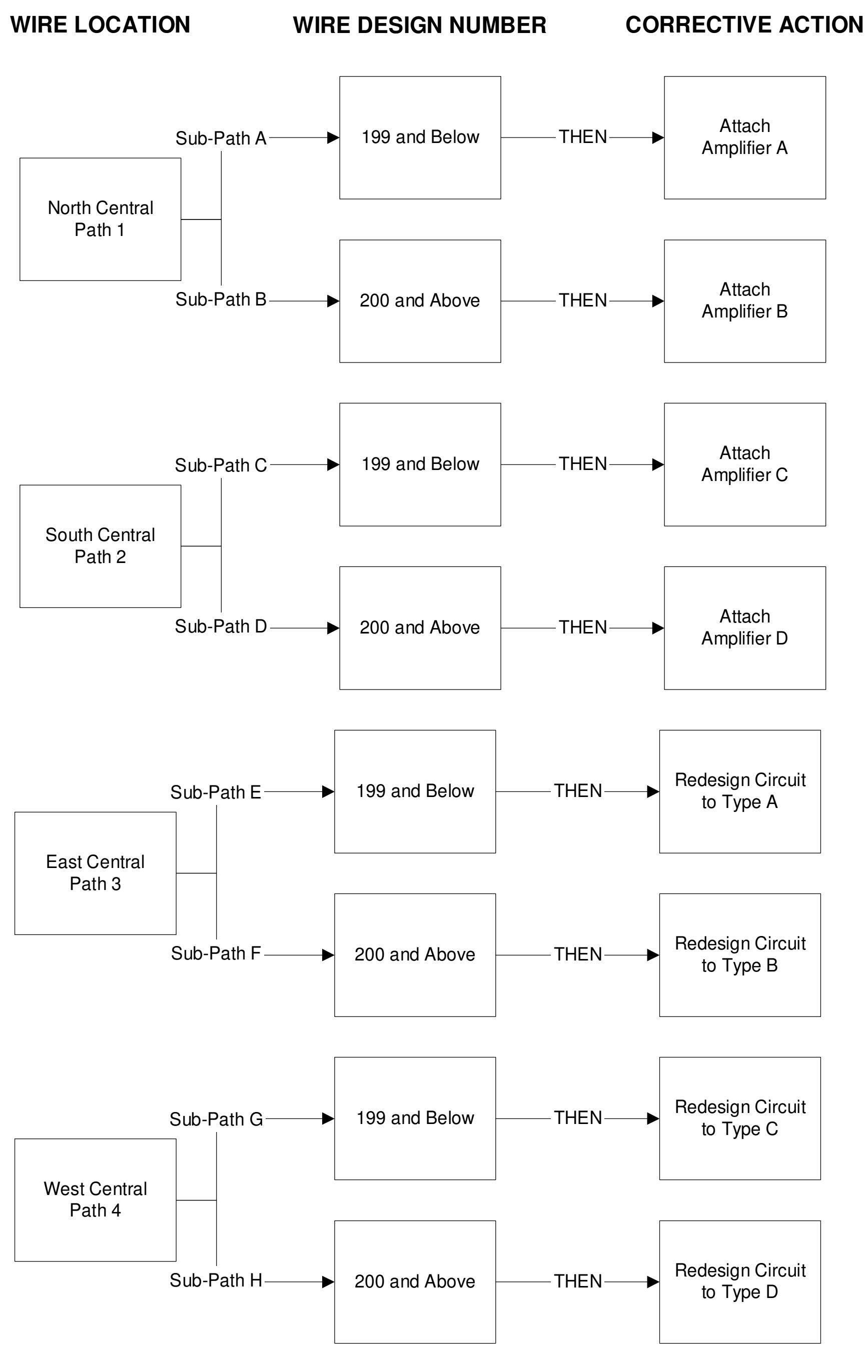
Wideband 2041 – 2050

Problem: Distortion **Purchase Order Number 2041 – 2050**



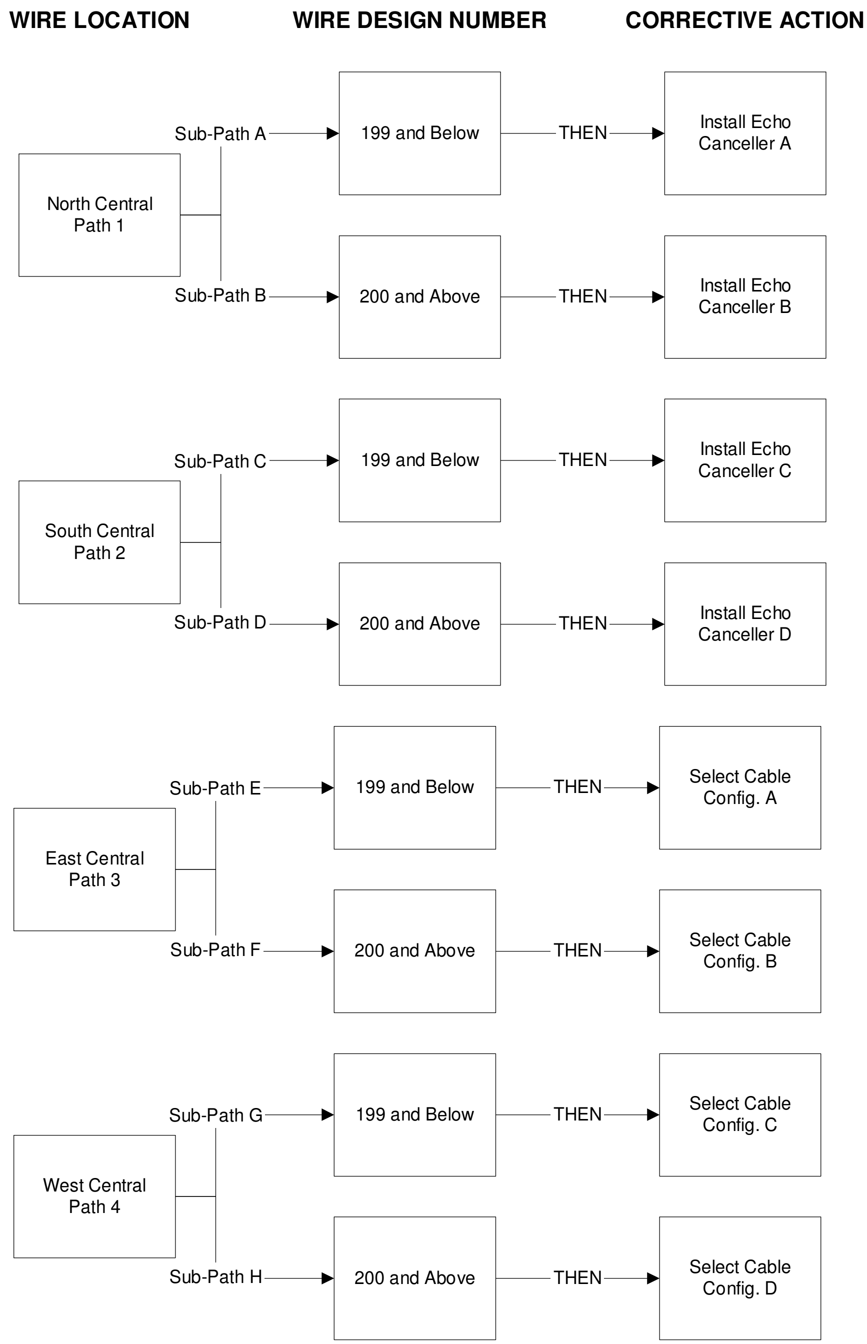
Flowchart 6

Problem: Corrective Action



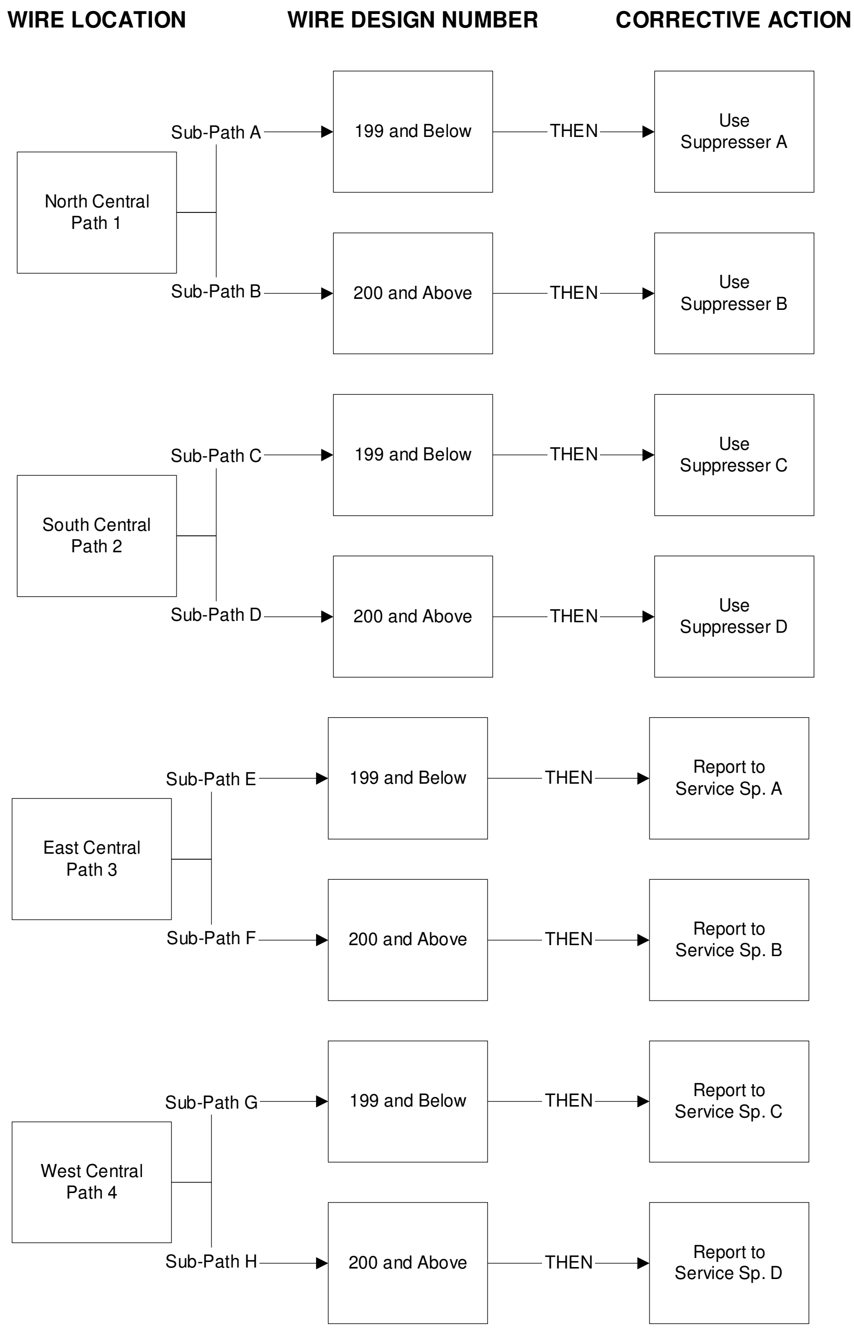
Flowchart 7

Problem: Corrective Action



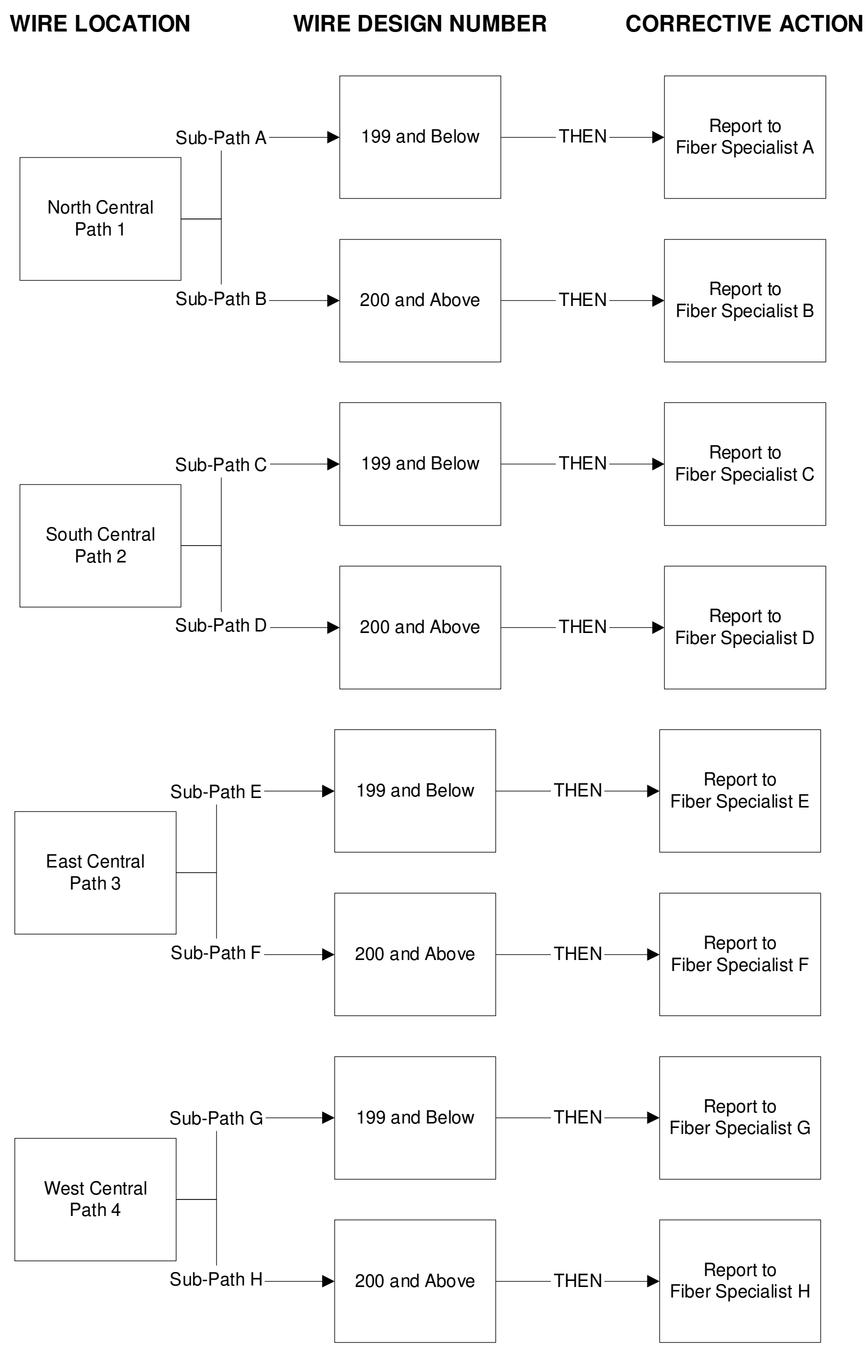
Flowchart 8

Problem: Corrective Action



Flowchart 9

Problem: Corrective Action



Procedures for the Posttest

Congratulations on completing the *Technician Mini-Course* and good luck on the Posttest. Be sure to read the following information completely before taking the test.

- If you find a question that you think has more than one answer, mark the answer that you feel is most correct.
- The main reason you are taking this test is to show yourself if you have learned the material presented in this course.
- The posttest consists of 30 questions relating to this course.
- To get the most out of this practice, limit yourself to 30 minutes to answer these questions.
- Answers are provided at the end of this book. Fill in your answers to all the questions and then turn to the answer key.

Posttest

Circle the letter of the correct answer. Choose only one answer.

1. The installation and maintenance of circuits begin with:

   a. Wire Order Reference Document

   b. Work Order Referral Document

   c. Work Operations Reference Document

   d. None of the above

2. The WORK document is composed of:

   a. Two distinct sections

   b. Three distinct sections

   c. Four distinct sections

   d. None of the above

3. In which section of the WORK document would you find customer information?

   a. First section

   b. Second section

   c. Third section

   d. All of the above

4. Competition for Verizon comes from competitive access to providers such as AT&T and Sprint. Which code in the WORK document would be most likely to provide information to competitive access providers?

   a. CAP

   b. BTN

   c. TC

   d. None of the above

5. Which of the following codes in the WORK document provides information about the Billing and Order System Support?

    a. PTN

    b. LSP

    c. NPO

    d. None of the above

6. In which section is information about the wire termination location most likely to be found?

    a. Section 1

    b. Section 2

    c. Section 3

    d. All three sections

Refer to the WORK document in Figure 1 to answer questions 7–10.

WORK Request

C.I.

CN Geary	CL north cen	APC 322-5567
ATM – NO	BOSS - 13	CAP Nt
BTN 243-981-6722		TC - 544-2323
PTN 443-7444		

C.S.

WLO south cen	LCL 333	WDN 332
ORd – 5/11/xx	WLO west cen	SST 517
WSN - 131	LSP CO-4	ACS - 944

W.A.

RN – 2022	ONA YES	NPO 1888
CCSA YES	GTI 342	WB 2117
WRD 55	POP 11	LFACS 432

Figure 1

7. Which of the following is the Billing and Order System Support code?
   a. 776-7767
   b. 13
   c. 4
   d. 332
8. The Point of Presence code is:
   a. 11
   b. 13
   c. 4 days
   d. 342

9. Which code has a value of 333?

    a. Customer Location

    b. Customer Options

    c. Services Switching Point

    d. Loop Customer Line

10. Which of the following has the highest numerical value?

    a. Wire Request Number

    b. Special Services Test Number

    c. Purchase Order Number

    d. Network Schedule Number

Refer to the WORK document in Figure 2 to answer questions 11–14.

WORK Request

C.I.

CN Karl	CL mid-atlantic	APC 322-9320
DACS – 10	BOC – YES	CALL C - NO
PTN 450-493-3269	BTN 450-339-8722	TC 450-239-5920

C.S.

WLO north atlantic	LCL 312	WDN 132
ORd – 6/21/xx	WTL west cen	SST 622
WSN - 330	LSP 16	ACS - NO

W.A.

RN – 2327	TCP/IP IN USE	NPO 1230
ONA 45	GTI 128	ISDN NO
WRD 61	WATS east	LFACS 1344

Figure 2

11. Which of the following is NOT true of the WORK Request in Figure 2?
    a. The Geographic Test Index is 128
    b. The Circuit Switching Access is "YES"
    c. The Wide Area Telecommunication Service is East
    d. The Open Network Architecture is 45
12. Which of the following codes has the value of 1344?
    a. Purchase Order Number
    b. Service Order Administrative Control Number
    c. Digital Access and Cross-Connect
    d. Loop Facility Assignment and Control System Number

13. What is the Billing Telephone Number?

    a. 450-339-8722

    b. 450-493-3269

    c. 450-239-5920

    d. 322-9320

14. What is the customer location?

    a. West Central

    b. North Central

    c. Mid-Atlantic

    d. East

Refer to the WORK document in Figure 3 to answer questions 15–17.

WORK Request

C.I.

CN Adams	CL atlantic	APC 377-5358
BOSS - Atlas	DCS - NO	CTE mid-atlantic
BTN 425-3474		TC - 955-4212
PTN 396-4474		

C.S.

WLO south cen	FDDI IN USE	WDN 86
ORd – 9/29/xx	WTL north cen	SST 108
WSN - 212	TSN 331h	ACS - 208

W.A.

RN – 1014	POP NO	NPO 2044
LSP east central	GTI 245	WB 2024
WRD 925	WATS north	LFACS 1027

Figure 3

15. Which is the correct initial flowchart you should use to determine this problem?

    a. Flowchart 1

    b. Flowchart 2

    c. Flowchart 3

    d. Flowchart 4

    e. Flowchart 5

16. Which is the correct Path on the initial flowchart you should follow in this problem?

    a. Path 1

    b. Path 2

    c. Path 3

    d. Path 4

17. Which is the corrective action you should take to fix this problem?

    a. Use Suppressor A

    b. Report to Service Specialist C

    c. Use Suppressor C

    d. Attach Amplifier C

Refer to the WORK document in Figure 4 to answer questions 18–20.

WORK Request

C.I.

CN Watson	CL west cen	APC 574-8533
WATS – YES		ATM - YES
BTN 235-122-2221		TC - 622-6211
PTN 751-6511		

C.S.

WLO east cen	LCL 203	WDN 121
ORd – 11/24/xx	WTL east cen	SST 1128
WSN - 121	LSP 101	ACS - 118

W.A.

RN – 1016	TCP/IP NOT IN USE	NPO 2027
POP 1	GTI 160	WB 1001
WRD 1119	SSC - central	LFACS 112

Figure 4

18. Which is the correct initial flowchart you should use to determine this problem?
    a. Flowchart 1
    b. Flowchart 2
    c. Flowchart 3
    d. Flowchart 4
    e. Flowchart 5

19. Which is the correct Path on the initial flowchart you should follow in this problem?

    a. Path 1

    b. Path 2

    c. Path 3

    d. Path 4

20. Which is the corrective action you should take to fix this problem?

    a. Attach Amplifier A

    b. Report to Fiber Specialist E

    c. Install Echo Canceller A

    d. Attach Amplifier D

Refer to the WORK document in Figure 5 to answer questions 21–23.

WORK Request

C.I.

CN Bauer	CL atlantic	APC 737-3358
BOSS – Atlas	DCS - NO	CTE east atlantic
BTN 554-1474	PTN 956-4574	TC - 985-3212

C.S.

WLO north cen	FDDI IN USE	WDN 225
ORd – 10/29/xx	WTL south cen	SST 118
WSN - 181	TSN 212	ACS - 345

W.A.

RN – 1014	TCP/IP IN USE	NPO 8866
LSP east cen	GTI 285	WB 2049
WRD 1025	WATS - NO	LFACS 1027

Figure 5

21. Which is the correct initial flowchart you should use to determine this problem?

    a. Flowchart 1

    b. Flowchart 2

    c. Flowchart 3

    d. Flowchart 4

    e. Flowchart 5

22. Which is the correct Path on the initial flowchart you should follow in this problem?

    a. Path 1

    b. Path 2

    c. Path 3

    d. Path 4

23. Which is the corrective action you should take to fix this problem?

    a. Report to Service Specialist A

    b. Attach Amplifier A

    c. Install Echo Canceller B

    d. Report to Service Specialist B

Refer to the WORK document in Figure 6 to answer questions 24–26.

WORK Request

C.I.

CN Simmons	CL mid-atlantic	APC 567-3458
BOSS - Atlas	DCS - NO	CTE south-atlantic
BTN 534-1474		TC - 955-3212
PTN 356-4574		

C.S.

WLO east cen	FDDI IN USE	WDN 225
ORd – 10/29/xx	WTL south cen	SST 118
WSN - 2226	TSN 544	ACS - 225

W.A.

RN – 1014	POP NO	NPO 2014
LSP east cen	GTI 182	WB 2024
WRD 1025	CWS - 1200	LFACS 1027

Figure 6

24. Which is the correct initial flowchart you should use to determine this problem?
    a. Flowchart 1
    b. Flowchart 2
    c. Flowchart 3
    d. Flowchart 4
    e. Flowchart 5

25. Which is the correct Path on the initial flowchart you should follow in this problem?

    a. Path 1

    b. Path 2

    c. Path 3

    d. Path 4

26. Which is the corrective action you should take to fix this problem?

    a. Report to Service Specialist B

    b. Attach Suppressor D

    c. Report to Fiber Specialist C

    d. Report to Fiber Specialist D

Refer to the WORK document in Figure 7 to answer questions 27–30.

WORK Request

C.I.

CN Davis	CL east cen	APC 544-2533
WATS – YES		ATM - YES
BTN 235-112-1121		TC - 232-2311
PTN 751-6511		

C.S.

WLO east cen	LCL west	WDN 121
ORd – 11/24/xx	WTL west cen	SST 1128
WSN - 110	TSN 101	ACS - 111

W.A.

RN – 1016	TCP/IP NOT IN USE	NPO 2050
POP 1	GTI 282	WB 2022
WRD 1119	SSC - central	LFACS 122

Figure 7

27. The Wire Specification Number is higher than the LFACS number.
    a. True
    b. False
28. Which is the correct initial flowchart you should use to determine this problem?
    a. Flowchart 1
    b. Flowchart 2
    c. Flowchart 3
    d. Flowchart 4
    e. Flowchart 5

29. Which is the correct Path on the initial flowchart you should follow in this problem?

    a. Path 1

    b. Path 2

    c. Path 3

    d. Path 4

30. Which is the corrective action you should take to fix this problem?

    a. Attach Amplifier C

    b. Attach Amplifier D

    c. Redesign Circuit to Type A

    d. Redesign Circuit to Type B

Answers to Lesson Review Questions

Lesson 1

1. d
2. c
3. a
4. d
5. d
6. c
7. a
8. c
9. c
10. d
11. d
12. b
13. a
14. d
15. d
16. b
17. b
18. a
19. b
20. d
21. c
22. b
23. c
24. b
25. d

Lesson 2

1. c
2. d
3. a
4. b
5. d

Lesson 3

1. a
2. c
3. a

Answers to Posttest

1. b
2. b
3. a
4. a
5. d
6. b
7. b
8. a
9. d
10. c
11. b
12. d
13. a
14. c
15. d
16. a
17. d
18. c
19. d
20. b
21. e
22. b
23. c
24. b
25. c
26. a
27. b
28. d
29. a
30. c

Glossary

Alternating Current: The flow of electrons (current) back and forth along a pathway. Generators produce alternating current.

Amplifier: An electric device that strengthens a telephone signal. Amplifiers are used in telephone transmission because analog signals weaken as they travel and encounter resistance.

Analog Signal: A continuously varying signal. An analog signal can be represented as a series of sine waves.

Attenuation: The loss of signal power.

Baseband signaling: Transmission of an analog or digital signal at its original frequencies.

Bit Rate: The rate at which we are able to send binary information through a system—the number of bits we can send into the system each second.

Bit: Short for binary digit. A single binary value, either 0 or 1.

Broadband: Transmission facility that has a bandwidth (capacity) greater than that necessary for voice transmission. Coaxial cable is a broadband transmission facility with the capacity to carry numerous voice, video, and data channels simultaneously.

Byte: A byte is a unit of data that is eight binary digits long.

Cable: Refers to a group of wires capable of carrying voice or data transmissions.

Capacitance: The capacity of a medium, such as copper wire, to store an electrical charge.

Carrier system: A system where several different signals can be combined into one carrier by changing some feature of the signals, transmitting them (modulation), and then converting the signals back to their original form (demodulation).

Characteristic Impedance: Refers to the internal signal-transmission characteristics of the cable. All transmission lines have measurable impedance called characteristic impedance.

Charge: An electrical property of particles, such as electrons and protons, which causes them to attract or repel each other.

Circuit: The physical connection (or path) between two given points, through which an electric current may be established.

Cladding: Cladding is used in fiber optics where one form of fiber surrounds the center core. That surrounding is called cladding.

Coaxial Cable: A cable composed of a central copper conductor that carries the signal, the surrounding dielectric (a non-conducting insulator), a solid woven metal shielding layer, and a protective plastic outer coating.

Conductors: Any substance, usually a wire or cable, that carry an electrical current.

Core: The innermost section of the fiber cable consists of a very thin glass or plastic strand (or fibers).

Decibel (dB): Refers to the amount of loss or gain in the transmission line from the input end to the output end.

Demultiplexer: A device that pulls several streams of data out of a bigger, fatter, or faster stream of data.

Diaphragm: The thin flexible sheet that vibrates in response to sound waves (as in a microphone) or in response to electrical signals (as in a speaker or the receiver of a telephone handset).

Dielectric: A non-conducting or insulating substance which resists passage of electric current, allowing electrostatic induction to act across it, as in the insulating medium between the metal plates of a capacitor.

Digital Signal: A series of square wave pulses sent at a very high speed down a transmission line. Characterized by outputs of only two discrete levels (e.g., 0 or 1, high or low, on or off, true or false).

Direct Current: The flow of electrons (current) in a single direction. Generally produced by sources such as batteries.

Distortion: An unwanted change in the information signal waveform.

Electromagnet: A core of magnetic material surrounded by a coil of wire through which an electric current is passed to magnetize the core.

Electromagnetic Interference (EMI): The interference in signal transmission or reception caused by the radiation of electrical and magnetic fields.

Electromagnetic isolation: A characteristic of optical fiber that makes it not vulnerable to interference, impulse noise, or crosstalk.

Electron: A particle or charge of negative electricity.

Enhanced Multimode Fiber: Also known as Fat Fiber. An optical fiber with a large core designed to carry multiple signals distinguished by frequency or phase at the same time. Used in Pair Gain fiber optic systems.

Fiber Optic Cable: Consists of a center glass or plastic core surrounded by several layers of protective materials. It transmits light rather than electronic signals.

Frequency Division Multiplexing: A technique in which the available transmission bandwidth of a circuit is divided by frequency into narrower bands, each used for a separate voice or data transmission channel.

Graded-index fibers: A multimode fiber optic cable that is made with progressively lower refractive index fiber toward the outer core. This reduces dispersion, which is fiber's equivalent of fading.

Impedance Matching: The connection of an additional impedance to an existing one in order to accomplish a specific effect, such as to balance a circuit or to reduce reflection in a transmission line.

Impedance: The total opposition a circuit offers to the flow of current. Low impedance will provide reduction in the severity of noise and other problems.

Index of refraction: A ratio of the velocity of light in a vacuum to the velocity of light in another medium, like glass.

Inductance: The property of an electric force field built up around a conductor. Inductance allows a circuit to store up electrical energy in electromagnetic form.

Infrared spectrum: Lying outside the visible spectrum at its red end; thermal radiation of wavelengths longer than those of visible light.

Kevlar Fiber: Fibers included between the cladding and the jacket of the fiber cable used for additional protection. Kevlar is the material used to make bulletproof vests.

Laser: Stands for Light Amplification by Stimulated Emission of Radiation. A semiconductor device that produces a very narrow, intense beam of coherent light.

Light-Emitting Diode (LED): A special diode that emits light in the visible spectrum of light frequencies. The LED produces more unwanted wavelengths than the laser, limiting its transmission capabilities.

Local Area Network (LAN): A data communications network spanning a limited geographical area. It provides communications between computers and peripherals.

Local Loop: The physical wires (typically, twisted pair of copper wire) connecting the end user (subscriber) to the central office.

Loss: The effect of a signal getting weaker the further it travels. Also called attenuation.

Main Power Board: One of three components of the DC Distribution System. Provides protection, control functions, and distributes DC power.

Megabit: One million bits.

Micrometer (µm)**:** Used for measuring minute distances.

Microwave radio: Transmits frequencies in the electromagnetic spectrum above one billing hertz (one gigahertz).

Milliwatt: One thousandth of a watt. Used as a reference point for signal levels at a given point in a circuit.

Modal dispersion: A distortion occurring in multimode fibers, in which the signal is spread in time because the propagation of the optical signal is not the same for all modes.

Multimode Fiber: Optical fiber that is designed to carry multiple light rays or modes concurrently, each at a slightly different reflection angle within the optical fiber core. Multimode fiber transmission is used for relatively short distances. Multimode fiber has a larger core than single mode.

Nanometer (nm): One billionth of a meter.

Noise: Unwanted electrical signals that interfere with the information signal.

Parallel circuit: An electrical circuit that contains one or more points where the current divides and follows different paths.

Photodetector: In a lightwave system, a device that turns pulses of light into bursts of electricity.

Proton: The part of the atom that carries a positive charge.

Radio Frequency Interference (RFI): The disruption of radio signal reception caused by any source, which generates radio waves at the same frequency and along the same path as the desired wave.

Regenerator: A device used to restore a signal to its original shape.

Repeater: A device inserted at intervals along a circuit to boost and amplify an analog signal being transmitted.

Resistance: Generates heat and occasionally light. A property or characteristic of a conductor. The measure of opposition to the flow of electricity.

Series circuit: An electrical circuit with a single path for electron flow from source to load and back.

Shielding: The metal-backed mylar, plastic, Teflon, or PVC that protects a data-communications medium, such as coaxial cable, from Electromagnetic Interference and Radio Frequency Interference.

Sine Wave: A waveform that gradually and continuously increases and decreases in amplitude.

Single-Mode Fiber: Optical fiber that is designed for the transmission of a single ray or mode of light as a carrier and is used for long-distance signal transmission. Single mode fiber has a much smaller core than multimode fiber.

Square Wave: A waveform with only two levels (high and low).

Step-index process: A type of optical fiber with a uniform index of refraction throughout the core.

Subscriber Loop Carrier (SLC): A short haul multiplexing device, which enables up to 96 telephone customers to be served on three pairs of wires.

T-Carrier System: A time-division multiplexed, phone company supplied, digital transmission facility operating at an aggregate data rate of 1.544 Mbit/s.

Time Division Multiplexing (TDM): A process by which several digital transmission paths are combined to form a single path.

Tip and Ring: Two wires needed to set up a telephone connection. The Tip is usually connected to the positive side of a battery at the Central Office and the Ring is usually connected to the negative side.

Transducer: A device that converts one form of energy into another. The diaphragm in the telephone receiver and the carbon microphone in the transmitter are transducers.

Twisted Pair Wire: Consists of two insulated copper wires arranged in a regular spiral pattern. Twisted pair wire comes in two varieties: shielded (STP) and unshielded (UTP).

Visible spectrum: The range of colors that can be seen by the naked eye. The spectrum is basically from red to yellow and orange (roughly the 5770 to 7700 angstrom range) and from green to violet-black (approximately the 3900 to 5770 angstrom range).

Waveform: The characteristic shape of a period signal usually shown as a plot of amplitude over a period of time.