Unit 3: Radio Frequency and Light Signal Fundamentals

Notes

CONTENTS

Objectives

After studying this unit, you will be able to:

- Describe the Radio frequency and radio frequency receiver
- Discuss the working of light signals
- Explain about wireless transceiver
- Discuss the modulation and amplification

Introduction

Radio frequency (RF) is a rate of oscillation in the range of about 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio

Notes

signals. RF usually refers to electrical rather than mechanical oscillations; however, mechanical RF systems do exist.

Although radio frequency is a rate of oscillation, the term "radio frequency" or its abbreviation "RF" are also used as a synonym for radio – i.e. to describe the use of wireless communication, as opposed to communication via electric wires.

Example: Radio-frequency identification and ISO/IEC 14443-2 Radio frequency power and signal interface.

To receive radio signals an antenna must be used. However, since the antenna will pick up thousands of radio signals at a time, a radio tuner is necessary to tune in to a particular frequency (or frequency range). This is typically done via a resonator – in its simplest form, a circuit with a capacitor and an inductor forming a tuned circuit. The resonator amplifies oscillations within a particular frequency band, while reducing oscillations at other frequencies outside the band.

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. First developed in the 1970s, fiber-optic communication systems have revolutionized the telecommunications industry and have played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world.

The process of communicating using fiber-optics involves the following basic steps: Creating the optical signal involving the use of a transmitter, relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak, receiving the optical signal, and converting it into an electrical signal.

Fiber optics is a medium for carrying information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics is not electrical in nature. A basic fiber optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fiber cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal. The complexity of a fiber optic system can range from very simple (i.e., local area network) to extremely sophisticated and expensive (i.e., longdistance telephone or cable television trunking).

Example: The system shown in Figure below could be built very inexpensively using a visible LED, plastic fiber, a silicon photodetector, and some simple electronic circuitry. The overall cost could be less than $20.

On the other hand, a typical system used for long-distance, high-bandwidth telecommunication could cost tens or even hundreds of thousands of dollars.

3.1 Wireless Transceivers

An infrared transceiver, or IR transceiver, is capable of both sending and receiving infrared data. In other words an IR transceiver is a transmitter and a receiver housed together in one single unit and having circuitry in common. IR transceivers are often used for portable or mobile use. Some transceivers can do both functions at the same time, while other transceivers can only do one function at a time. The device may either have a focused beam, thus requiring it to be in a precise position in order to function properly, or it may be a broader beam, depending on the applications that it is designed for.

There are many different kinds of infrared transceivers. The most common types categorized by speed, size, supply voltage, link, data rate, packaging type and maximum idle current.

Notes

The most common link size is 1m. There are also infrared transceivers with link size as low as 875 nm or as high as 6.5m. The maximum idle current available is 10A, with the most common infrared transceiver chips having a maximum idle current of 10 mA.

IR transceivers are generally used in communications applications, although they also have other applications as well. In communications, infrared transceivers can often be used in order to synch devices.

Example: A PDA can be synched with a PC through the use of infrared transceivers in both devices. The systems can send data back and forth to synchronize their contents.

IR transceivers can also be used for entering and collecting data in the field. By using a handheld IR transceiver, a researcher can collect data on his portable device and then send it to a PC by using an infrared transceiver. The transceiver can also receive software upgrades, therefore keeping it up to date with the rest of the equipment in the laboratory or the plant.

3.1.1 Digi Wireless Transceiver Modules

The TRX900 is an encrypted digital wireless transmitter with optional internal backup recording and IFB. By incorporating an IFB receiver into the body of a traditional wireless transmitter, both functions are now combined in a package smaller than most transmitters on the market today.

- Fully encrypted audio transmission
- Built-in 2.4 GHz receiver to receive timecode and remote control signals from ZaxNet and/ or IFB100
- Digital modulation wireless transmitter
- Superb audio quality that rivals a mic cable
- Digital drop-out protection
- 5 hour run time on single CR123 battery
- Graphic LCD display
- Integrated timecode reception
- Small and lightweight
- No inter-modulation – up to 50 transmitters, in the same frequency block, can be used together.
- Built-in IFB audio receiver
- 96 hour internal backup recording with timecode stamp

The TRX900AA's 96 hour, 24 bit internal loop-recording option is perfect for those times when there's a lack of available frequencies or when drop-outs cannot be tolerated. The audio is timecode referenced, recorded on and played back from a removable MicroSD memory card that can be used in any standard SD card reader.

Audio can be recorded, played back and timecode referenced either manually or through remote control commands from the IFB100 transmitter.

The audio is automatically recorded full bandwidth as a .ZAX file. The included ZaxConvert file transfer software (available for both MAC and PC) utilizes sample rate conversion to obtain the sample rate and bit depth of choice when files are imported to your computer. There are two timecode stamped file types to choose from: BWF (Broadcast Wave Format) or MP3 (MPEG-1 Audio Layer 3). MP3 files are great for quickly transferring files over the internet to a transcription house. Any number of versions of the same recording can be made from a single file.

Notes

Did u know? The TRX900 internal IFB audio option adds the ability to receive IFB (confidence) audio directly on the bodypack via the built-in 2.4 GHz receiver. To monitor audio an EA100 or Stereo Adapter is required.

3.2 Understanding RF Signals

A frequency of electromagnetic radiation in the range at which radio signals are transmitted, ranging from approximately 3 kilohertz to 300 gigahertz. Many astronomical bodies, such as pulsars, quasars, and possibly black holes, emit radio frequency radiation is called radio frequency.

3.2.1 RF Signal Attributes

All RF waves have characteristics that vary to define the wave. Some of these properties can be modified to modulate information onto the wave. These properties are wavelength, frequency, amplitude, and phase.

- ***Wavelength:*** The wavelength of an RF wave is calculated as the distance between two adjacent identical points on the wave. For example, Figure 2.3 shows a standard sine wave. Point A and Point B mark two identical points on the wave, and the distance between them is defined as the wavelength. The wavelength is frequently measured as the distance from one crest of the wave to the next.
- ***Frequency:*** Frequency refers to the number of wave cycles that occur in a given window of time. Usually measured in second intervals, a frequency of 1 kilohertz (KHz) would represent 1000 cycles of the wave in 1 second. To remember this, just keep in mind that a wave cycles frequently and just how frequently it cycles determines its frequency.
- ***Amplitude:*** You might wonder that the volume of sound waves is dependent on the frequency, since lower-frequency waves are heard at a greater distance; however, there is actually another characteristic of waves that impacts the volume. Remember, at greater distances, shorter-wavelength waves are more difficult to detect as the waveform spreads ever wider (though this may be more a factor of the antenna used than of the waveform itself). The characteristic that defines the volume is known as amplitude. In sound wave engineering, an increase in amplitude is equivalent to an increase in volume; hence, an amplifier adds to the volume, or makes the sound louder. While the frequency affects the distance a sound wave can travel, the amplitude affects the ability to detect (hear) the sound wave at that distance. RF waves are similar.
- ***Phase:*** Unlike wavelength, frequency, and amplitude, phase is not a characteristic of a single RF wave but is instead a comparison between two RF waves. If two copies of the same RF wave arrive at a receiving antenna at the same time, their phase state will impact how the composite wave is able to be used. When the waves are in phase, they strengthen each other, and when the waves are out of phase, they sometimes strengthen and sometimes cancel each other. In specific out-of-phase cases, they only cancel each other. Phase is measured in degrees, though real-world analysis usually benefits only from the knowledge of whether the waves are in phase or out of phase. Two waves that are completely out of phase would be 180 degrees out of phase, while two waves that are completely in phase would be 0 degrees out of phase. Figure 2.6 shows a main wave signal, another in-phase signal, and an out-of-phase signal.

Caution When troubleshooting wireless networks, the phase of duplicate RF signals is mostly an implication of reflection or scattering in an area that may cause dead zones due to the out-of-phase signals.

3.2.2 RF Signal Pros and Cons

Advantages of RF include:

- ***Efficiency:*** RFID tags do not require line-of-sight to be deciphered They can be read through cardboard, plastic, wood and even the human body. RFID tags can easily track moving objects and send the required information back to the reader. This eliminates human errors, reduces labor and provides quick access to a wealth of information.
- ***Return on Investment (ROI):*** RFID costs more to implement than a barcode system, but provides a good return on investment in the long run, since RFID is significantly more efficient.
- ***Less Vulnerable to Damage:*** RFID tags are less susceptible to damage. An RFID tag is securely placed within an object or embedded in plastic, enabling the system to be used in a variety of harsh environments, such as areas of high temperature or moisture, or with exposure to chemicals or the outdoors.

Disadvantages of RF include:

- ***Expense:*** RFID systems are typically more expensive than alternatives such as barcode systems. While passive tag reading is similar to (and generally less expensive than) barcode reading, active tags are costly due to their complexity. Active tags consist of an antenna, radio transceiver and microchip, increasing the overall cost of an RFID system.
- ***Collision:*** Tag collision and reader collision are common problems with RFID. Tag collision occurs when numerous tags are present in a confined area. The RFID tag reader energizes multiple tags simultaneously, all of which reflect their signals back to the reader. This results in tag collision, and the RFID reader fails to differentiate between incoming data. RFID reader collision results when the coverage area managed by one RFID reader overlaps with the coverage area of another reader. This causes signal interference and multiple reads of the same tag.
- ***Security:*** RFID technology gives rise to numerous security concerns. Since the system is not limited to line-of-sight, external (and malicious) high-intensity directional antennas could be used to scan sensitive tags. Fraud is always a possibility when the technology is used for high-security operations, such as payment verification.

3.2.3 RF Signal Impairments

Interference and multipath propagation causes lower performance in the communication between the sender and receiver.

3.2.4 Interference

Electromagnetic radiation which is emitted by electrical circuits carrying rapidly changing signals, as a by-product of their normal operation, and which causes unwanted signals (interference or noise) to be induced in other circuits. The most important means of reducing RFI are: use of bypass or "decoupling" capacitors on each active device (connected across the power supply, as close to the device as possible), rise time control of high speed signals using series resistors and VCC filtering. Shielding is usually a last resort after other techniques have failed because of the added expense of RF gaskets and the like.

The efficiency of the radiation is dependant on the height above the ground or power plane (at RF one is as good as the other) and the length of the conductor in relationship to the wavelength of the signal component (fundamental, harmonic or transient (overshoot, undershoot or ringing)). At lower frequencies, such as 133 MHz, radiation is almost exclusively via I/O cables; RF noise

Notes

gets onto the power planes and is coupled to the line drivers via the VCC and ground pins. The Rf is then coupled to the cable through the line driver as common node noise. Since the noise is common mode, shielding has very little effect, even with differential pairs. The RF energy is capacitively coupled from the signal pair to the shield and the shield itself does the radiating.

At higher frequencies, usually above 500 Mhz, traces get electrically longer and higher above the plane. Two techniques are used at these frequencies: wave shaping with series resistors and embedding the traces between the two planes. If all these measures still leave too much RFI, sheilding such as RF gaskets and copper tape can be used. Most digital equipment is designed with metal, or coated plastic, cases.

Switching power supplies can be a source of RFI, but have become less of a problem as design techniques have improved.

Most countries have legal requirements that electronic and electrical hardware must still work correctly when subjected to certain amounts of RFI, and should not emit RFI which could interfere with other equipment (such as radios).

3.2.5 Multipath

In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings.

The effects of multipath include constructive and destructive interference, and phase shifting of the signal. Destructive interference causes fading. Where the magnitudes of the signals arriving by the various paths have a distribution known as the Rayleigh distribution, this is known as Rayleigh fading. Where one component (often, but not necessarily, a line of sight component) dominates, a Rician distribution provides a more accurate model, and this is known as Rician fading.

In facsimile and television transmission, multipath causes jitter and ghosting, seen as a faded duplicate image to the right of the main image. Ghosts occur when transmissions bounce off a mountain or other large object, while also arriving at the antenna by a shorter, direct route, with the receiver picking up two signals separated by a delay.

In radar processing, multipath causes ghost targets to appear, deceiving the radar receiver. These ghosts are particularly bothersome since they move and behave like the normal targets (which they echo), and so the receiver has difficulty in isolating the correct target echo. These problems can be overcome by incorporating a ground map of the radar's surroundings and eliminating all echoes which appear to originate below ground or above a certain height.

In digital radio communications (such as GSM) multipath can cause errors and affect the quality of communications. The errors are due to intersymbol interference (ISI). Equalisers are often used to correct the ISI. Alternatively, techniques such as orthogonal frequency division modulation and rake receivers may be used.

Notes In a Global Positioning System receiver, Multipath Effect can cause a stationary receiver's output to indicate as if it were randomly jumping about or creeping. When the unit is moving the jumping or creeping is hidden, but it still degrades the displayed accuracy.

Self-Assessment

Fill in the blanks:

1. .... communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber.
2. Fiber optics is a medium for carrying information from one point to another in the form of ....
3. .... transceivers are often used for portable or mobile use.
4. A frequency of electromagnetic radiation in the range at which radio signals are transmitted, ranging from approximately 3 kilohertz to .... gigahertz.
5. The .... is frequently measured as the distance from one crest of the wave to the next.
6. .... is used for many modern RF modulation algorithms
7. Tag collision and reader collision are common problems with ....
8. .... collision occurs when numerous tags are present in a confined area
9. RFID .... collision results when the coverage area managed by one RFID reader overlaps with the coverage area of another reader
10. .... are often used to correct the ISI.

3.3 Working of Light Signals

Light signals have been in use with communications systems for even longer than RF systems. Lanterns would provide a source of light to use with sending codes between ships at sea hundreds of years ago. Light guns are still in use today at many airports as a backup communication with aircraft having malfunctioning radio gear.

Wireless networks that utilize light signals, however, are not as common as these that use radio signals. Light signals generally satisfy needs for special applications, such as building-to-building links and short-range personal-area networks. Some wireless LANs and inter-building products use laser light to carry information between computers.

A light signal is analog in form and has a very high frequency that's not regulated by the FCC. Most wireless networks that use light for wireless signaling purposes utilize infrared light, which has a wavelength of approximately 900 nanometers. This equates to 333,333 GHz, which is quite a bit higher than RF signals and falls just below the visual range of humans.

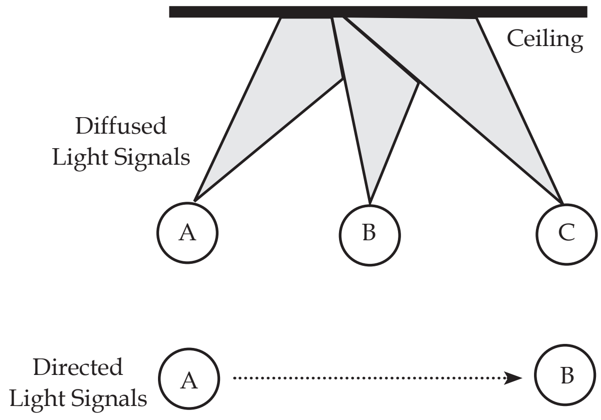
Diffused and direct infrared are two main types of light transmission. Figure 3.1 illustrates these two concepts. Diffused laser light is normally reflected off a wall or ceiling, and direct laser is directly focused in a line-of-sight fashion. Most laser LANs utilize diffused infrared; inter-building modems and PDAs use the direct infrared technique.

Infrared light has very high bandwidth; however, the diffusing technique severely attenuates the signal and requires slow data transmissions (less than 1 Mbps) to avoid significant transmission errors. In addition, this technique limits wireless component spacing to around 40 feet, mainly because of the lower ceilings indoors and resulting signal path geometry. The advantage is relatively easy installation with inexpensive components.

The direct infrared approach, commonly referred to as free-space optics, intensifies the light signal power similarly to a directive radio signal antenna. This increases the range of low-power laser systems to a mile or so at data rates up in the Gbps range.

Notes

Figure 3.1: Both Diffused and Directed Light Signals Offer a Basis for Wireless Networks



Source: http://etutorials.org/Networking/wn/Chapter+3.+Radio+Frequency+and+Light+Signal+Fundamentals+The+Invisible+Medium/Understanding+Light+Signals/

As with RF signals, the amplitude of light also decreases as distance between the sending and receiving stations increase. The range of an infrared light system can vary from a few feet with PDA applications to 1 mile with direct infrared systems. This is significantly less range than with RF systems.

As compared to RF signals, light signals have the characteristics defined in Table 3-2.

Table 3 2: Comparing the Pros and Cons of Light Signals

Light Signal Pros	Light Signal Cons
Extremely high throughput, up to the Gbps range	Variable, unreliable performance in the presence of significant smog, fog, rain, snow, and other airborne particulate matter
High inherent security because of narrow laser beam	Relatively short-range (1 mile) capability
License-free operation	Requirement for line-of-sight operation, free from obstructions such as buildings, trees, and telephone poles
Extremely low potential for RF interference from external systems	Issues dealing with alignment because of building swaying

Source: http://etutorials.org/Networking/wn/Chapter+3.+Radio+Frequency+and+Light+Signal+Fundamentals+The+Invisible+Medium/Understanding+Light+Signals/

These characteristics make the use of light signals most effective for specialized applications where extremely high performance is necessary. For example, a company can install an infrared communications link between two nearby buildings in order to facilitate high-speed server backups over a wireless network.

Light signal propagation is not free from difficulties. Impairments, such as interference and obstructions, limit the performance of the wireless network that uses light signals.

Light signals are free from RF sources of interference such as cordless phones, and microwave ovens. In fact, the FCC doesn't regulate light signals because of extremely limited potential interference among systems. Light signals have such a high frequency that their emissions are well outside the spectrum of RF systems, which means that the FCC doesn't regulate light signals.

Interference from other sources of light, however, can still be a problem for systems that use light signals. For example, the installation of a point-to-point infrared transmission system aimed in an easterly or westerly direction can receive substantial interference from infrared light found within sunlight because the sun is low to the horizon. This interference can be high enough in some cases to completely disrupt transmission of data on the infrared link. When installing these types of systems, be certain to follow the manufacturer's recommendations when orienting the antennae.

Obstructions such as buildings, mountains, and trees offer substantial amounts of attenuation to light signals as they propagate through the air. Most of these objects are composed of materials that readily absorb and scatter the light. As a result, be sure that the path between the end points of a light-based communications system are completely clear of obstacles.

Even if the communications path is open, weather can still impress large amounts of attenuation to light signals. The problem with weather is that it varies. For example, heavy fog might be present, and then the skies might be completely clear the following hour. This makes planning link budgets for light-based systems, especially those operating near the range limits, extremely difficult. Planners must be certain that the attenuation imposed by weather will not disrupt communications.

3.4 Modulation

In electronics and telecommunications, modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted. This is done in a similar fashion to a musician modulating a tone (a periodic waveform) from a musical instrument by varying its volume, timing and pitch. The three key parameters of a periodic waveform are its amplitude ("volume"), its phase ("timing") and its frequency ("pitch"). Any of these properties can be modified in accordance with a low frequency signal to obtain the modulated signal. Typically a high-frequency sinusoid waveform is used as carrier signal, but a square wave pulse train may also be used.

In telecommunications, modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform is used to transform a baseband message signal into a passband signal, for example low-frequency audio signal into a radio-frequency signal (RF signal). In radio communications, cable TV systems or the public switched telephone network for instance, electrical signals can only be transferred over a limited passband frequency spectrum, with specific (non-zero) lower and upper cutoff frequencies. Modulating a sine-wave carrier makes it possible to keep the frequency content of the transferred signal as close as possible to the centre frequency (typically the carrier frequency) of the passband.

A device that performs modulation is known as a modulator and a device that performs the inverse operation of modulation is known as a demodulator (sometimes detector or demod). A device that can do both operations is a modem (from "modulator–demodulator").

The aim of digital modulation is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network (where a bandpass filter limits the frequency range to between 300 and 3400 Hz), or over a limited radio frequency band.

The aim of analog modulation is to transfer an analog baseband (or lowpass) signal, for example an audio signal or TV signal, over an analog bandpass channel at a different frequency, for example over a limited radio frequency band or a cable TV network channel.

Analog and digital modulation facilitate frequency division multiplexing (FDM), where several low pass information signals are transferred simultaneously over the same shared physical medium, using separate passband channels (several different carrier frequencies).

Notes

The aim of digital baseband modulation methods, also known as line coding, is to transfer a digital bit stream over a baseband channel, typically a non-filtered copper wire such as a serial bus or a wired local area network.

The aim of pulse modulation methods is to transfer a narrowband analog signal, for example a phone call over a wideband baseband channel or, in some of the schemes, as a bit stream over another digital transmission system.

In music synthesizers, modulation may be used to synthesise waveforms with an extensive overtone spectrum using a small number of oscillators. In this case the carrier frequency is typically in the same order or much lower than the modulating waveform.

3.4.1 Frequency Shift-Keying (FSK)

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is binary FSK (BFSK). BFSK literally implies using a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency. The time domain of an FSK modulated carrier is illustrated in the figures to the right.

3.4.2 Phase Shift-Keying (PSK)

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).

Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal — such a system is termed coherent (and referred to as CPSK).

Alternatively, instead of operating with respect to a constant reference wave, the broadcast can operate with respect to itself. Changes in phase of a single broadcast waveform can be considered the significant items. In this system, the demodulator determines the changes in the phase of the received signal rather than the phase (relative to a reference wave) itself. Since this scheme depends on the difference between successive phases, it is termed differential phase-shift keying (DPSK). DPSK can be significantly simpler to implement than ordinary PSK since there is no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal (it is a non-coherent scheme). In exchange, it produces more erroneous demodulation.

3.4.3 Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components — hence the name of the scheme. The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or (in the analog case) of phase modulation (PM) and amplitude modulation. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are

Notes

used. PSK modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the modulated carrier signal is constant. QAM is used extensively as a modulation scheme for digital telecommunication systems. Arbitrarily high spectral efficiencies can be achieved with QAM by setting a suitable constellation size, limited only by the noise level and linearity of the communications channel.

QAM modulation is being used in optical fiber systems as bit rates increase; QAM16 and QAM64 can be optically emulated with a 3-path interferometer.

3.4.4 Spread Spectrum

Spread-spectrum communications technology was first described on paper by an actress and a musician! In 1941 Hollywood actress Hedy Lamarr and pianist George Antheil described a secure radio link to control torpedos. They received U.S. Patent #2.292.387. The technology was not taken seriously at that time by the U.S. Army and was forgotten until the 1980s, when it became active. Since then the technology has become increasingly popular for applications that involve radio links in hostile environments.

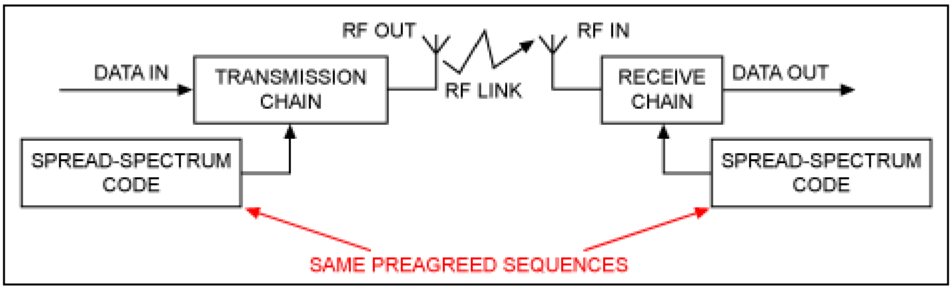
Typical applications for the resulting short-range data transceivers include satellite-positioning systems (GPS), 3G mobile telecommunications, W-LAN (IEEE® 802.11a, IEEE 802.11b, IEEE 802.11g), and Bluetooth. Spread-spectrum techniques also aid in the endless race between communication needs and radio-frequency availability—situations where the radio spectrum is limited and is, therefore, an expensive resource.

Different spread-spectrum techniques are available, but all have one idea in common: the key (also called the code or sequence) attached to the communication channel. The manner of inserting this code defines precisely the spread-spectrum technique. The term "spread spectrum" refers to the expansion of signal bandwidth, by several orders of magnitude in some cases, which occurs when a key is attached to the communication channel.

The formal definition of spread spectrum is more precise: an RF communications system in which the baseband signal bandwidth is intentionally spread over a larger bandwidth by injecting a higher frequency signal (Figure 1). As a direct consequence, energy used in transmitting the signal is spread over a wider bandwidth, and appears as noise. The ratio (in dB) between the spread baseband and the original signal is called processing gain. Typical spread-spectrum processing gains run from 10dB to 60dB.

To apply a spread-spectrum technique, simply inject the corresponding spread-spectrum code somewhere in the transmitting chain before the antenna (receiver). (That injection is called the spreading operation.) The effect is to diffuse the information in a larger bandwidth. Conversely, you can remove the spread-spectrum code (called a despreading operation) at a point in the receive chain before data retrieval. A despreading operation reconstitutes the information into its original bandwidth. Obviously, the same code must be known in advance at both ends of the transmission channel. (In some circumstances, the code should be known only by those two parties.)

Figure 3.2. Spread-spectrum Communication System



Source: http://www.maximintegrated.com/app-notes/index.mvp/id/1890

Notes

3.4.5 Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications.

OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. The word "coded" comes from the use of forward error correction (FEC). A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

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

3.4.6 Ultra Wideband Modulation (UWB)

Ultra-wideband (UWB) signals are generally defined as signals with fractional bandwidth greater then twenty percent of their central frequency or as signals with bandwidth more than 500MHz, whichever is less. The bandwith is specified by 10dB decrease of the signal power spectral density. Many different generation techniques may be used to satisfy these requirements. The principal group of generation techniques is based on spectral characteristics of very short pulses and we can denominate these techniques as Impulse Radio concepts. These very short duration pulses (hundreds of picoseconds) have very wide spectrum, which must adhere to the spectral mask requirements. Very low power levels are permitted for typical UWB transmission because of the compatibility with other radiocommunication services. Many pulses are typically combined to carry the information for one bit and to separate individual transmissions of several users. For the same purposes, a variety of pulse shapes, wavelets and waveforms can be used. Pulses can be sent individually, in bursts, or in near-continuous streams, and they can encode information in pulse amplitude, polarity, shape, and position.

3.5 Sending Data Packets in the Air

A central problem for business individuals on the move, concerns the ability to communicate data between the work base and remote locations. A new technology has evolved over the past few years which allows the transmission of digital data across existing air link analogue cellular voice channels as well as across existing Circuit Switched telephone networks. This technology is known as Cellular Digital Packet Data (CDPD).

Notes

This technology allows data from a portable computer or a Personal Digital Assistant (PDA) to be transmitted to Wide Area Computer Networks (WAN) and Public Switched Telephone Networks (PSTN) as well as other mobile units ie: mobile phones or portable computers. This allows individuals total freedom to transmit data back to the office from remote locations.

Self-Assessment

Fill in the blanks:

11. The three key parameters of a periodic waveform are its............................., its phase ("timing") and its frequency ("pitch").
12. The aim of digital baseband modulation methods, also known as line coding, is to transfer a digital bit stream over a ....channel
13. .... is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).
14. .... technology allows data from a portable computer) to be transmitted to Wide Area Computer Networks (WAN) and Public Switched Telephone Networks (PSTN) as well as other mobile units
15. .... is used extensively as a modulation scheme for digital telecommunication systems.

Case Study

Stark RFID-Enabled System Helps Brick And Ceramic Product Manufacturers Improve Inventory Control And Delivery Accuracy

The growing acceptance and reliability of RFID technology for supply chain management and asset tracking is spurring software companies to develop RFID solutions that will help them penetrate new markets.

One such example is Stark RFID, based in Greenville, South Carolina, a systems integrator and provider of turnkey RFID solutions designed to transform supply chain efficiency for brick and refractory products manufacturers. The company's innovative StarkFG™ RFID application delivers an accurate, real-time asset tracking solution that greatly improves inventory visibility, management and control.

According to Lance Burnett, the company's co-founder and president, although this market sector has adopted technology-based enterprise solutions for running business processes efficiently, a large majority of companies still rely heavily on manual processes for managing inventory and fulfilling orders.

"For these industries, the challenge of managing inventory is due in large part to the sheer volume of manufactured products in the brickyard or warehouse, which makes manual, line-of-sight inventory difficult, if not impossible," says Burnett. "As we explored the capabilities of RFID technology, we decided to be first-to-market with an inventory tracking system that would make the job faster and easier. Now, having implemented StarkFG in several customer sites, it is clearly proving to be a transformative RFID solution."

Brick Industry Challenges

Brick manufacturers serve the residential and commercial construction industries, typically selling through distribution channels to builders and contractors. In the commercial building market especially, where on-site labor costs are high and sequential workflow is

Contd...

Notes

carefully planned, the right materials must be delivered to the right place at the right time to meet construction schedules. This is essential to customer satisfaction.

Burnett explains: "If a load of bricks is not delivered on time, if a shipment is sent to the wrong location, or if the product delivered does not match the order specifications, the entire construction job can be delayed until the right materials can be obtained. This is a costly proposition for builders and, for their suppliers, it can result in punitive fines and even law suits."

Many of the problems experienced by brick manufacturers occur not in the factory, but rather in the brickyard where inventory is stored and prepared for shipment. Manufactured bricks for the construction trade are massed in strapped loads of about 500 bricks to a cube, often called a hack. The cubes are delivered to the brickyard where they sit outdoors, subject to dust, dirt, rain, sleet and snow – making it difficult to label the cubes with vital product information such as electronic product codes and lot numbers. Lot numbers are important, since the same type of bricks manufactured on one day will vary somewhat in color from bricks made the next day. Builders and contractors may refuse to accept a 'mixed run' shipment if the colors are poorly matched.

Before Stark RFID developed the StarkFG solution, entering the newly manufactured cubes of brick into inventory and deciding where it should be stored was a manual process typically performed by brickyard personnel. It was a time- and labor-intensive process, prone to human error. Similarly, when it was time to assemble and load an order for shipping, the process was reversed. This also led to frequent mistakes as workers spent a great deal of time finding, identifying and loading the right cubes of bricks to transport via forklift to waiting trucks.

"We knew these inventory management and quality control issues were the major pain points to be addressed in creating a solution that would bring a higher level of automation to brickyard management," says Burnett. "The concept of building a system for this application on RFID technology struck us as the perfect answer."

Real-Time Inventory Tracking

StarkFG is the first RFID-enabled solution designed specifically to help brick manufacturers automate their inventory management and order fulfillment processes. With this system, the company can print and encode rugged 8-inch wide labels with all the necessary product information, then fold the labels and affix them to each strapped cube of new bricks.

When the cubes are delivered to the brickyard, StarkFG's bin loading module informs the forklift operator's computer where to place the cubes in the yard, based on the type of product being unloaded. Once the bricks have been placed in the proper bin, the inventory system is automatically updated. Likewise, once they are removed from the yard for shipping, they are automatically removed from the inventory count.

More Accurate Order Fulfillment

When an order is scheduled for shipping, the enterprise system generates a pick list and bill of lading and beams them to the computer of a forklift operator, who is directed to the right product location. There the RFID reader reads the tag to verify that the product specifications match the order printed on the pick list and bill of lading before the brick cubes are lifted and loaded for transport to the assigned truck. This process of order location, product identification and verification, which could take a significant amount of time in a manual system, has now been reduced to mere minutes. And, with positive RFID tag identification, the inventory manager and brickyard personnel have the assurance that the right order has been picked.

Combining rugged hardware and weather-proof RFID tags, the StarkFG system eliminates the physical counting of and finding cubes in the brickyard by enabling the product

Contd...

identification tags to be read from virtually any angle, without a direct line of sight. "This capability alone saves significantly on inventory management time and labor and greatly improves inventory and shipping accuracy. RFID tagging could also make it easier for brick suppliers to sell their products to big box retailers with RFID compliance mandates," notes Burnett.

HackTrac System Components

The components comprising the StarkFG system include:

StarkFG proprietary software, built on a Microsoft MS.Net platform, and incorporating 802.11b wireless communication protocol to integrate with a user's centralized wireless local area network (WLAN)

Forklift-mounted computers made by Noax Technologies AG, a German producer of ruggedized, industrial touch-panel computers

RFID readers from Alien Technology, also forklift-mounted

Rugged, weather-resistant, 8-inch wide, wet inlay RFID tags (Class 1 Gen 2) incorporating Intermec antennas and Avery Dennison RFID's AD-220 Inlays

An 8-inch RFID label printer/encoder, supplied by Avery Dennison

Since each manufacturer has its own inventory management procedures, Stark RFID works closely with customers to map out their processes and configure the system to their specific requirements. The company also provides users with middleware to allow them to integrate the inventory management system with their ERP system, providing a convenient end-to-end turnkey solution.

Burnett adds that Stark RFID performed its own extensive 'guerilla' testing of the RFID tags in real-world outdoor environments to ensure their performance, durability and reliability, even under extreme weather conditions.

Real-World Results: Cost Savings, Improved Customer Service

The true test of an RFID-enabled solution is how well it performs in the real world. According to reports from Stark RFID's customers, the system has proven to be so reliable that not a single mis-shipment has occurred since StarkFG has been up and running. Among Stark RFID's brick manufacturing customers are Lee Brick of Sanford, North Carolina, a manufacturer of high quality residential, commercial and architectural brick, and Columbus Brick, a regional brick producer in Columbus, Mississippi.

StarkFG has proven to be a highly effective automation tool for companies in the refractory manufacturing industry as well. One StarkFG user in this market sector is a leading global provider of custom-engineered, high-temperature insulating fibers, firebrick and monolithics used in industrial furnaces and for fire protection. For all users, the primary benefits of the RFID-enabled track-and trace system include improved inventory accuracy, elimination of incorrect shipments, and increased speed and productivity in order picking, loading and shipping. In fact, the inventory manager at Lee Brick said his company was able to completely eliminate manual cycle counts due to the dead-on accuracy of the StarkFG system.

Once StarkFG is implemented and workflow becomes faster and more streamlined, manufacturers may find that fewer forklifts are required in the brickyard or warehouse. The result: more efficient asset utilization, significant cost savings, improved profitability, and higher customer satisfaction.

Burnett asserts that the toughness and durability of the system's RFID tags are key to its successful performance in these harsh industrial environments. "For a track-and-trace system like StarkFG to work effectively, you need to ensure 100 percent RFID tag read rates

Contd...

Notes

– and we have achieved that goal," he states. "Avery Dennison RFID's technical support team was extremely helpful in guiding our choice of RFID inlays, antennas and tags to be sure they would perform and hold up well over time, even in the toughest environmental conditions."

Questions:

1. Study and analyse the case.
2. Write down the case facts.
3. What do you infer from it?

Source: http://www.starkrfid.com/about/rfid-case-studies/stark-rfid-brick-case-study.php

3.6 Summary

Radio frequency (RF) is a rate of oscillation in the range of about 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals.

Electric currents that oscillate at radio frequencies have special properties not shared by direct current or alternating current of lower frequencies.

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber.

Fiber optics is a medium for carrying information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics is not electrical in nature.

All RF waves have characteristics that vary to define the wave. Some of these properties can be modified to modulate information onto the wave. These properties are wavelength, frequency, amplitude, and phase.

Wireless networks that utilize light signals, however, are not as common as these that use radio signals.

Light signals have been in use with communications systems for even longer than RF systems.

3.7 Keywords

Radio frequency (RF): is a rate of oscillation in the range of about 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals.

TRX900: is an encrypted digital wireless transmitter with optional internal backup recording and IFB.

Frequency: refers to the number of wave cycles that occur in a given window of time.

Multipath: is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths.

Modulation: is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted.

Line Coding: is to transfer a digital bit stream over a baseband channel, typically a non-filtered copper wire such as a serial bus or a wired local area network.

Frequency-shift keying (FSK): is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave.

Notes

Phase-shift keying (PSK): is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).

Orthogonal frequency-division multiplexing (OFDM): is a method of encoding digital data on multiple carrier frequencies.

Ultra-wideband (UWB) signals: are generally defined as signals with fractional bandwidth greater then twenty percent of their central frequency or as signals with bandwidth more than 500MHz, whichever is less.

3.8 Review Questions

1. Describe the process of communicating using fiber-optics
2. What are wireless transceivers?
3. Discuss the properties of RF waves
4. Discuss the RF signal pros and cons
5. Describe RF signal impairments
6. Explain the working of light signals
7. What do you mean by modulation?
8. Discuss phase shift-keying.
9. Describe quadrature amplitude modulation.
10. Explain orthogonal frequency division multiplexing.

Answers: Self-Assessment

1. Fiber-optic
2. Light
3. IR
4. 300
5. Wavelength
6. Phase
7. RFID
8. Tag
9. Reader
10. Equalisers
11. amplitude (“volume”)
12. baseband
13. Phase-shift keying (PSK)
14. Cellular Digital Packet Data
15. QAM

3.9 Further Readings

Books

802.11 Wireless Networks: The Definitive Guide, Second Edition, Matthew Gast

Introduction to wireless networks, John Ross

Wireless Communications & Networking, Vijay Garg

Wireless Communications: Principles and Practice, Theodore S. Rappaport

Notes

Online links

http://www.digi.com/technology/rf-articles/wireless-transceiver-module

http://faculty.ccri.edu/jbernardini/JB-Website/ETEK1500/1500Notes/CWNA-ed4-Chapter-2.pdf

http://www.ehow.com/list_6116737_advantages-disadvantages-rfid.html

http://www.urel.feec.vutbr.cz/ra2008/archive/ra2006/abstracts/088.pdf