Module III : **Wireless Technologies**

Syllabus

Module III: Wireless Technologies

Wireless LAN, PANs and Bluetooth, ZigBee and Mesh Wireless Networks, WiMAX and Wireless Metropolitan-Area Networks, Infrared Wireless, Radio-Frequency Identification and Near-Field Communications, Ultrawideband Wireless, Additional Wireless Applications.

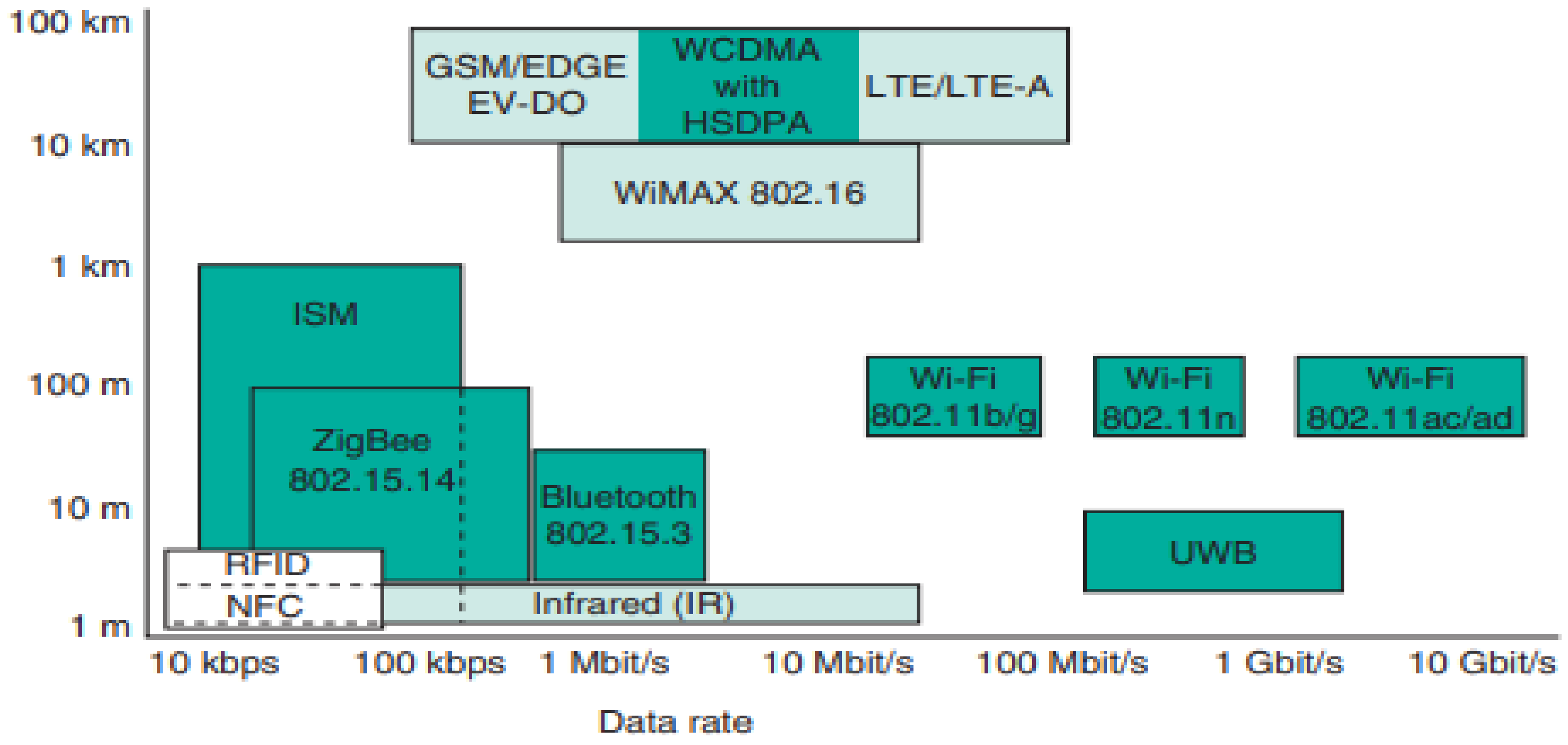
Contents

- Wireless LAN
- PANs and Bluetooth
- ZigBee and Mesh Wireless Networks
- WiMAX and Wireless Metropolitan-Area Networks
- Infrared Wireless
- Radio-Frequency Identification and Near-Field Communications
- Ultrawideband Wireless
- Additional Wireless Applications.

Wireless LAN

- Popular technologies and their main applications are summarized in the table below. Note that **each technology** is identified by its trade name or standard designation, common name or an IEEE standard number. In Fig. 21-1

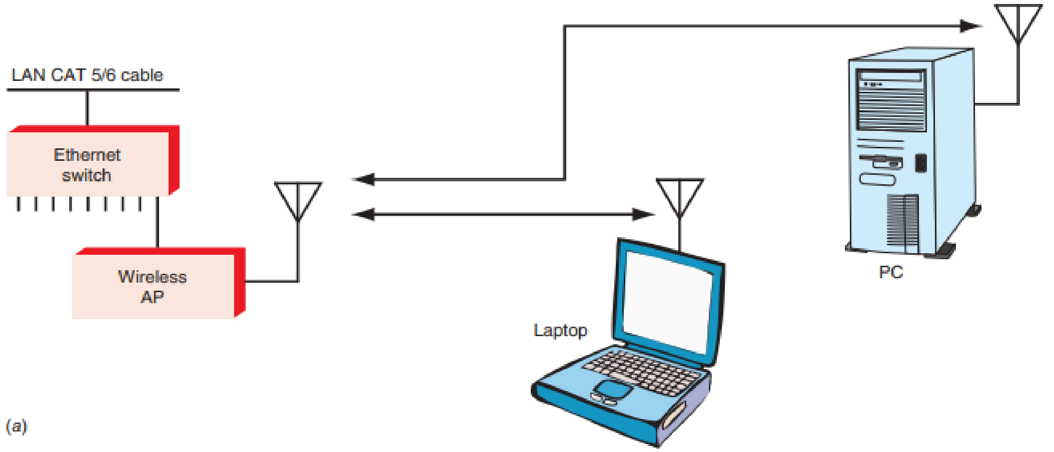
Figure 21-1 Range versus data rate: common wireless technologies.

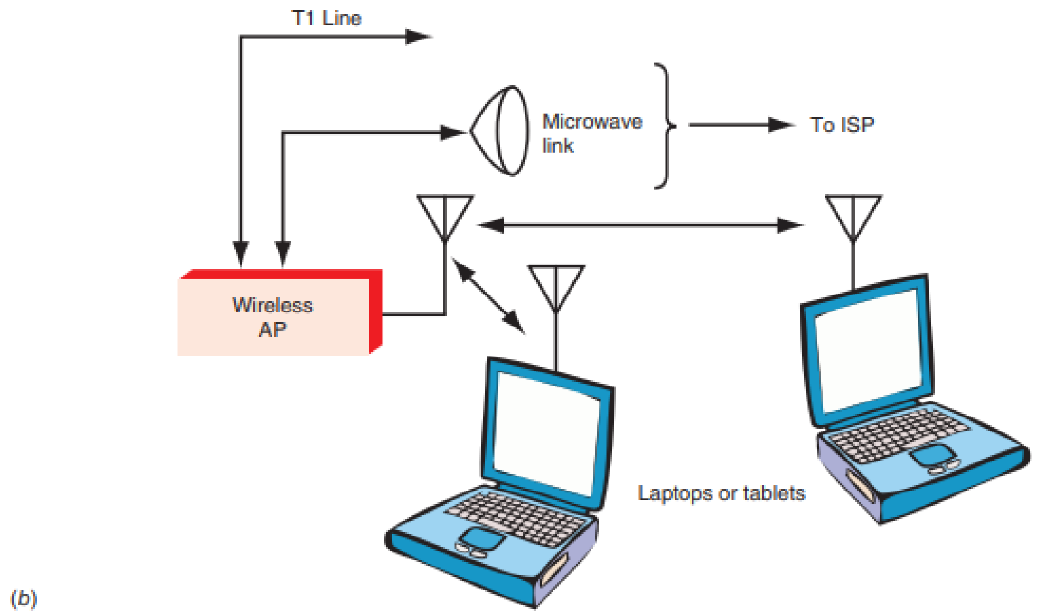


- Wireless LANs are more commonly referred to by their trade name **Wi-Fi.**
- The terms Wi-Fi, WLAN, and 802.11 are used interchangeability in this text.
- Local-area networks (**LANs**) within
- **A company,**
- **Government agency**,
- **Hospital,** or other organization typically use **CAT5e or CAT6** unshielded twisted pair as the transport medium.
- However, more and more, wireless extensions to these LANs are becoming popular as are entirely wireless LANs. Low-cost wireless modems installed in personal computers and laptops make this possible.
- Three common configurations are shown in Fig. 21-2. Fig. 21-2(a) shows a wireless access point (AP) is connected to an existing wired LAN, usually through an Ethernet switch. This AP contains a transceiver that can cover a specific geographic area, usually **inside a building**.
- This area usually extends out to no more than about 100 m, but generally the range is less due to the great signal attenuation of the walls, ceilings, floors, and other obstructions. PCs or laptops within that range and containing a radio modem can link up with the AP, which in turn connects the PC or laptop to the main LAN and any services generally available via that LAN such as e-mail and Internet access

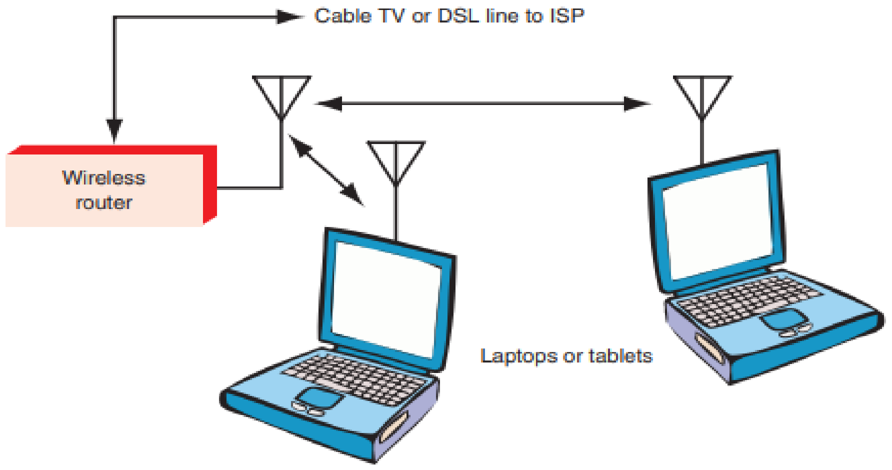
- Another popular configuration is shown in Fig. 21-2(b).
- Here the AP is connected to the main LAN or more commonly to an Internet service provider (ISP) by way of a long-range interconnection such as a hardwired T1 or T3 line, fiber connection, or a microwave relay link such as WiMAX, as described later in this chapter.
- The **AP** is usually **installed in a restaurant**, coffee shop, airport, hotel, convention center, or other public place. It is more commonly known as a "hot spot."
- **Some cities** are also installing municipal hot spots. Anyone with a laptop equipped with a LAN modem interface can link up to the AP and access his or her e-mail or the Internet.
- There are hundreds of thousands of hot spots around the world.

Figure 21-2 Types of WLANs. (*a*) Access point extension to a wired LAN. (*b*) Public access point via an Internet service provider (ISP), and (*c*) home router for Internet access.





- Another **growing** use of wireless LANs is in the implementation of home networks. See Fig. 21-2(c).
- As more and more families become users of multiple PCs, tablets, and smart phones, there is a need to interconnect each device to a broadband Internet connection such as a DSL or cable TV line.
- It allows each user to access e-mail or the Internet or to share a common peripheral such as a printer.
- Most homeowners do not want to wire their homes with CAT5/6 cable at great expense. Installing a wireless LAN is fast, easy, and very inexpensive these days.
- A special box called a residential gateway or wireless router connects to the cable TV or DSL and serves as the access point(AP).
- This gateway or router uses a software approach called network address translation (NAT) to make it appear as if each networked PC has its own Internet address, when in reality only the one associated with the incoming broadband line is used



(c)

Hardware of Wireless LANs:

- The hardware devices in a wireless LAN are the access point or the gateway/router and the radio modems in the PCs.
- The access point is just a box containing a transceiver that Wireless Technologies 819 interfaces to an existing LAN by way of CAT5/6 wiring.
- It typically gets its **dc operating power** via the twisted-pair cabling, because the dc supply voltage is superimposed on the data.

Wireless LAN Standards:

- Over the years, a number of wireless LAN methods have been developed, tested, and abandoned.
- One standard has emerged as the most flexible, affordable, and reliable Known as the IEEE 802.11 standard, it is available in multiple forms for different needs.
- The table shows the different versions of the IEEE standard and some technical details

IEEE Standard	Frequency, GHz	Access	Max. Data Rate, Mbps	Max. Range, m
802.11a	5	OFDM	54	50
802.11b	2.4	DSSS	11	100
802.11g	2.4	OFDM	54	100
802.11n	2.4/5	OFDM/MIMO	600	100
802.11ac	5	OFDM/MIMO	1.3	50–100
802.11ad	60	OFDM/beamforming	7	10

Wireless LAN Standards:

IEEE 802.11b.

- The earliest useful and most widely adopted version of the 802.11 standard is 802.11b.
- It operates in 11 channels in the 2.4-GHz unlicensed ISM band
- The access method is direct sequence spread spectrum (DSSS) so that multiple signals may share the same band.
- The 802.11b standard specifies a maximum data rate to 11 Mbps.
- To achieve its faster rates of 5.5 and 11 Mbps, a different form of coding called complementary code keying (CCK) is used.
- The modulation is differential quadrature phase-shift keying (DQPSK).
- The maximum allowed equivalent isotropic radiated power (EIRP) is 1 W.
- Most IC transceivers produce an output of 100 mW.

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

Wireless LAN Standards:

IEEE 802.11a

- The 802.11a standard was developed next. It uses the unlicensed 5-GHz band. There are three authorized segments: 5.15 to 5.25 GHz with 50-mW maximum power, 5.25 to 5.35 GHz with 250-mW maximum power, and 5.725 to 5.825 GHz at a maximum of 1 W of power.
- Each of these bands is divided into multiple nonoverlapping 20-MHz-wide channels.
- Each channel is designed to carry an OFDM signal made up of 52 subcarriers, 48 for data and the other 4 for error correction codes. Each of the subcarriers is about 300 kHz wide. As with the 802.11b standard, the 802.11a version supports a wide range of data rates. The fastest is 54 Mbps
- For 6 Mbps-BPSK is used. For 12 Mbps-QPSK is used. For the higher rates-QAM is used; 16-QAM gives 24 Mbps, while 64-QAM is used to achieve 54 Mbps.

Wireless LAN Standards:

IEEE 802.11g

- The 802.11g standard was an attempt **to extend the data rate** within the popular 2.4-GHz band. Using OFDM, this standard provides for a maximum data rate of 54 Mbps at 100m indoors.
- The 802.11g standard also accommodates the 802.11b standards and so is fully backward-compatible.
- An 802.11b transceiver can talk to an 802.11g **AP** but at the lower data rate. An 802.11g transceiver can also talk to an 802.11b **AP** but also at the **lower data rate.**

IEEE 802.11n

- The 802.11n version was developed to further increase the data rate. It uses both the 2.4-GHz and 5-GHz bands and OFDM.
- A primary feature of this standard is the use of multiple-input multiple-output (MIMO) antenna systems to improve reliability of the link.
- APs for 802.11n use two or more transmit antennas and three or more receive antennas. The wireless nodes use a similar arrangement. In each case, multiple transceivers are required for the AP and the node. This arrangement permits a data rate in the 100- to 600-Mbps range at a distance up to 100 m

Wireless LAN Standards:

Table 21-1 Summary of the Most Current Active Wi-Fi Standards

IEEE std.	Band	Technology	Modulation	Channel BW	MIMO (antennas)	Range (meters)	Max. Speed
802.11n	2.4 & 5 GHz	OFDM	Up to 64QAM	20, 40 MHz	Up to 4×4	100	600 Mbps
802.11ac	5 GHz	OFDM	Up to 256QAM	40, 80, 160 MHz	Up to 8×8	100	3 Gbps
802.11ad	60 GHz	OFDM	Up to 64QAM	2.16 GHz	Beamforming	10	7 Gbps

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

Related Wi-Fi Standards:

- **802.11e** Provides Quality of Service (QoS) features that allow VoIP and other critical services to be carried over Wi-Fi.
- **802.11i** Provides full security for Wi-Fi in the form of **WEP, WPA, and WPA2**.
- **802.11s** Brings automatic adhoc mesh networking to Wi-Fi.
- **802.11u** Provides a protocol between **access points and clients** that permits inter-networking with support for authentication, authorization, and accounting with network selection, encryption policy enforcement, and resource management. Facilitates automatic connections and network handoffs. Allows Wi-Fi to be used for cellular handoff in small cells.
- **802.11y** Brings Wi-Fi to the 3650–3700 MHz band.
- One of the most interesting versions of Wi-Fi is the **802.11p** standard that is to be deployed in V2x or **vehicle-to-vehicle (V2V)**
- The Dedicated Short-Range Communications (**DSRC**) system uses the **IEEE 802.11p** standard and a **protocol** referred to as Wireless Access in Vehicular Environments (**WAVE**).

The Wi-Fi Alliance:

- What makes Wi-Fi so good is the support, promotion, and development of the Wi-Fi Alliance (WFA), a trade association of companies developing and using the standard.
- Its key function is testing and certifying all chips and products to ensure full compatibility and interoperability.
- The **WFA also develops** its own standards and some excellent enhancements to the standards.

Some examples are

- Wi-Fi Direct,
- HotSpot 2.0 and Passpoint, and Miracast
- Wi-Fi Direct is a modification of the basic standard to permit Wi-Fi-enabled devices to connect with one another without going through a traditional hotSpot or router.
- **This lets** smart phones, laptops and tablets, cameras, printers, and other Wi-Fi-equipped devices to automatically develop one-to-one communications
- The enabler of HotSpot 2.0 is the 802.11u standard. It allows devices and networks to negotiate and connect automatically.

Wi-Fi Future:

- Even though Wi-Fi appears to be everywhere now, soon it will be even more widespread.
- It is already available in many airliners so that passengers can connect to the Internet in flight.
- It is used in printers and cameras. But that's not all. Another Wi-Fi target is the machine-to machine (**M2M**) field and the Internet of Things (IoT).
- For example, Wi-Fi appears to be emerging as the wireless of choice in home networks and even appliances. Both ZigBee and Z-Wave wireless devices are already in the home, but they require some kind of gateway to make an Internet connection.
- Because many homes already have a Wi-Fi network, it is a natural choice for home networks. Whirlpool, LG, and others use Wi-Fi to collect usage data on their refrigerators, washers, and other appliances.
- Some appliance makers offer a **smart phone app** that lets the owner **see energy consumption**, **usage,** maintenance, and other data on each connected appliance.

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

Wi-Fi Future:

Wireless Security:

- The 802.11 standard also includes provision for encryption to protect the privacy of wireless users.
- Because radio signals can literally be picked up by anyone with an appropriate receiver, those concerned about privacy and security should use the encryption feature built into the system.
- The basic security protocol is called Wired Equivalent Privacy (WEP) and uses the RC4 encryption standard and authentication.
- WEP may be turned off or on by the user. It does provide a basic level of security; however, WEP has been cracked by hackers and is not totally secure from the most high-tech data thieves.
- Two stronger encryption standards called Wi-Fi Protected Access (**WPA**) and WPA2 are also available in several forms to further **boost the encryption process**.

PANs and Bluetooth

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

- A personal-area network (**PAN**) is a very small wireless network that is created informally or on an **ad hoc** basis.
- It typically involves only two or three nodes, but some systems permit many nodes to be connected in a small area. The most popular wireless PAN system is Bluetooth, a standard developed by the cell phone company Ericsson for use as a cable replacement.
- The objective was to provide hands-free cell phone operation by eliminating the cable connecting a cell phone to a headset.
- Today, this is one of the main applications of Bluetooth, but it also has other cable replacement applications.
- Bluetooth is a digital radio standard that uses frequency-hopping spread spectrum (FHSS) in the unlicensed 2.4-GHz ISM band. It hops over 79 frequencies spaced 1 MHz apart from 2.402 to 2.480 GHz.
- The hop rate is 1600 hops per second. The dwell time on each frequency, therefore, is 1y1600 5 625 μs. During this time, digital data is transmitted. The total data rate is 1 Mbps, but some of that is overhead (headers, error detection and correction, etc.). The actual data rate is 723.2 kbps simplex or 433.9 kbps

PANs and Bluetooth

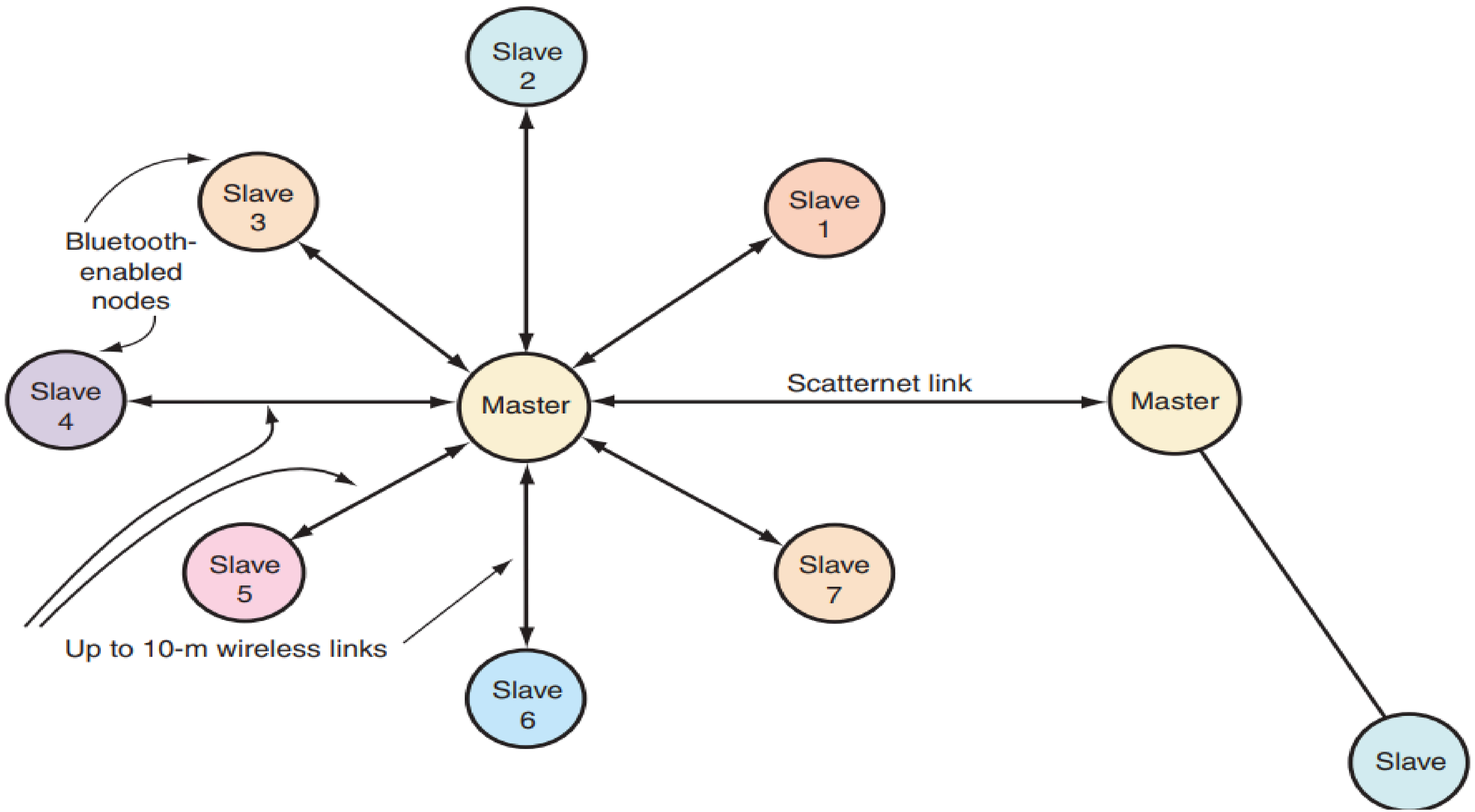
GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

- Bluetooth transceivers are available as single-chip transceivers that interface to the device to be part of a PAN. These devices invariably contain some kind of embedded controller that handles the application. If voice is used, a vocoder is needed
- Bluetooth is set up so that the wireless transceiver constantly sends out a search signal and then **listens for other nearby,** similarly equipped Bluetooth devices.
- If another device comes into range, the two Bluetooth devices automatically interconnect and exchange data.
- These devices form what is called a **piconet,** the linking of one Bluetooth device that serves as a master controller to up to 7 other Bluetooth slave devices.
- Once the PAN has been established, the nodes can exchange information with one another. Bluetooth devices can also link to other piconets to establish larger **scatternets.**
- Another version **2.0 of Bluetooth** is called Enhanced Data Rate (**EDR**). It has all the features described earlier but increases the **overall data rate to 3 Mbps**

PANs and Bluetooth

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

Figure 21-3 Bluetooth piconet with scatternet link. Up to seven devices can be actively connected.



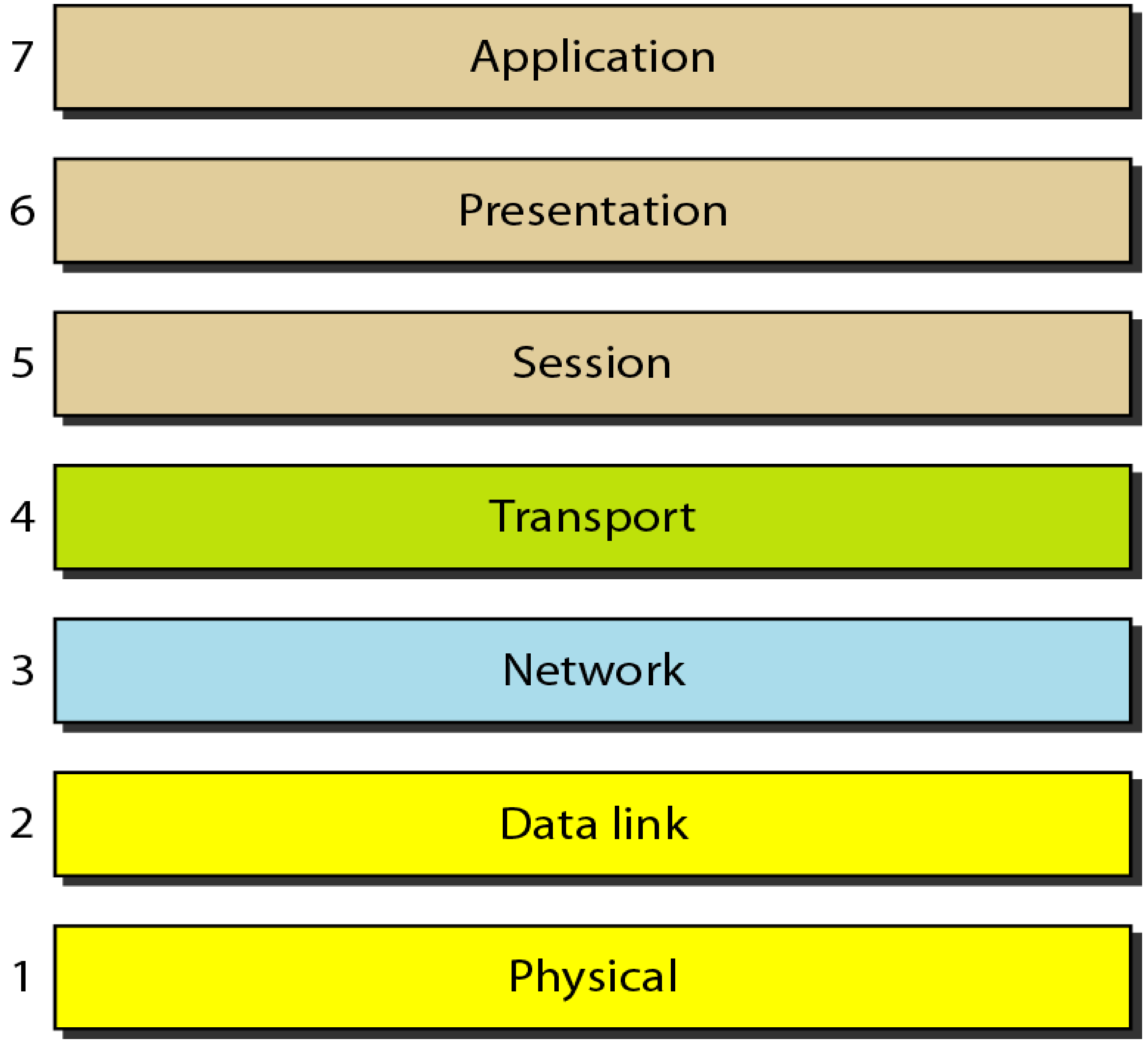
ZigBee and Mesh Wireless Networks

- **ZigBee** is the commercial name for another **PAN network technology** based on the IEEE 802.15.4 wireless standard.
- Like Bluetooth, it is a **short-range technology** with networking capability.
- It was designed primarily for **commercial, industrial, and home monitoring** and control applications.
- The 802.15.4 standard defines the so-called air interface, which is the physical layer (PHY or layer 1 of the OSI standard) and the media access control (MAC or layer 2) of the system.
- The ZigBee Alliance, an organization of chip, software, and equipment vendors of ZigBee products, **specifies** additional higher levels of layers including networking and security.

ZigBee and Mesh Wireless Networks

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

- OSI standard

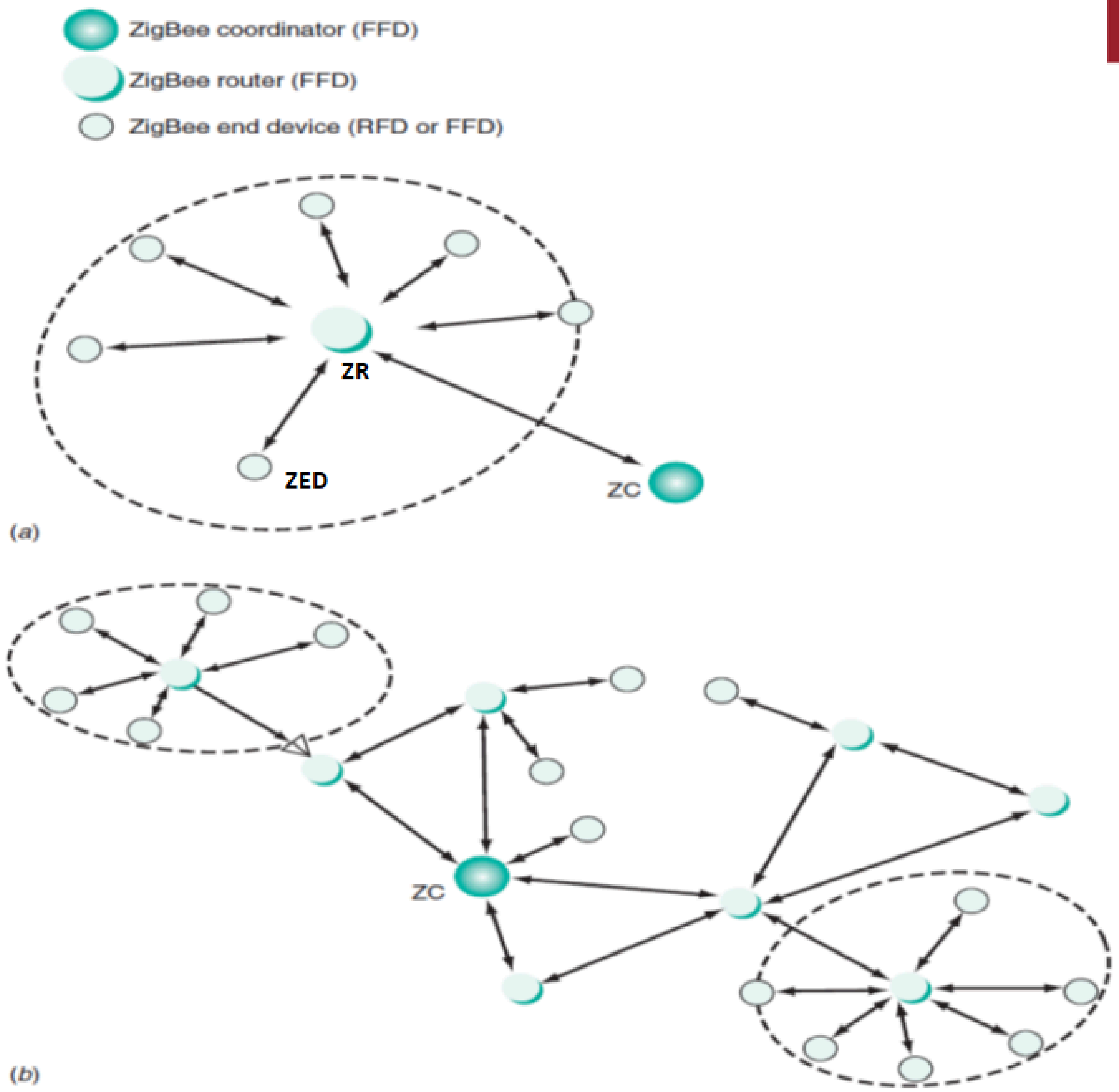


- ZigBee is designed to operate in the license-free spectrum available in the world.
- This is defined **by** the Federal Communications Commission(FCC) Part 15 in the United States.
- There are **three basic bands and versions**.

Frequency Band	Number of Channels	Modulation	Max. Data Rate, Kbps
868 MHz (Europe)	1	DSSS/BPSK	20
915 MHz	1	DSSS/BPSK	40
2.4 GHz	16	DSSS/O-QPSK	250

- ZigBee's virtue is its versatile networking capability.
- The standard supports three topologies: star, mesh, and cluster tree.
- The most commonly used are the star and mesh, illustrated in Fig. 21-4.
- These network topologies are made up of three types of ZigBee nodes: a ZigBee coordinator (ZC), a ZigBee router (ZR), and ZigBee end device (ZED).
- The ZC initiates a network formation.
- There is only one ZC per network.
- The ZR serves as monitor or **control device** that observes a sensor or initiates off/on operations on some end device.
- It also serves as a router as it can receive data from other nodes and retransmit it to other nodes.
- The ZED is simply an end monitor or control device that only receives data or transmits it.
- It does not repeat or route.
- The ZC and ZR nodes are called full-function devices (FFDs), and the ZED is known as a reduced-function device (RFD).

Figure 21-4 Most common ZigBee network topologies. (*a*) Star. (*b*) Mesh.



GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

WiMAX and Wireless Metropolitan-Area Networks

- Metropolitan-area networks (**MAN**s) are primarily fiber-optic networks, most often SONET rings, that connect enterprise LANs to WANs or the Internet backbone.
- Another typical MAN is a local cable TV network.
- Now there is wireless contender for metropolitan-area networking(MAN). Known as WiMAX, it is the wireless system defined by the IEEE 802.16 standard.
- It was developed to provide a wireless alternative to consumers for broadband Internet connections.
- These connections are now dominated by cable TV and DSL, but with the new WiMAX standard, wireless Internet service providers (WISPs) may soon be offering wireless broadband connections.

- The primary standard is known as IEEE **802.16**-2004 or **802.16d.**
- Its primary applications will fit into two basic categories: point-to-point (**P2P**) or point-to-multipoint (PMP).
- The P2P mode is for applications requiring the transfer of data between two points.
- Common examples are cell site backhaul from a base station to the switching office or Wi-Fi hot spot interconnections to the ISP.
- Both of these applications typically rely on hardwired T1 or T3 connections, which are very expensive.
- A wireless backhaul link is **far less expensive**, not to mention easier to install.

Infrared Wireless

- The most widespread wireless system uses infrared light for short- distance data communication.
- The most existing example is the wireless remote control on virtually all TV sets, DVD players, and on most audio CD stereo systems.
- **Infrared** has also been used **for** wireless PANs.

- Because light travels in straight lines, there must be a clear path from transmitter to receiver for the system to work.
- Furthermore, light does not penetrate walls, floors, and ceilings, as wireless radio does, so IR LANs are not practical.
- Wireless PANs, however, are widely used to link nearby laptops, PCs, and PDAs such as **Palm Pilots**.

Infrared Wireless

TV Remote Control :

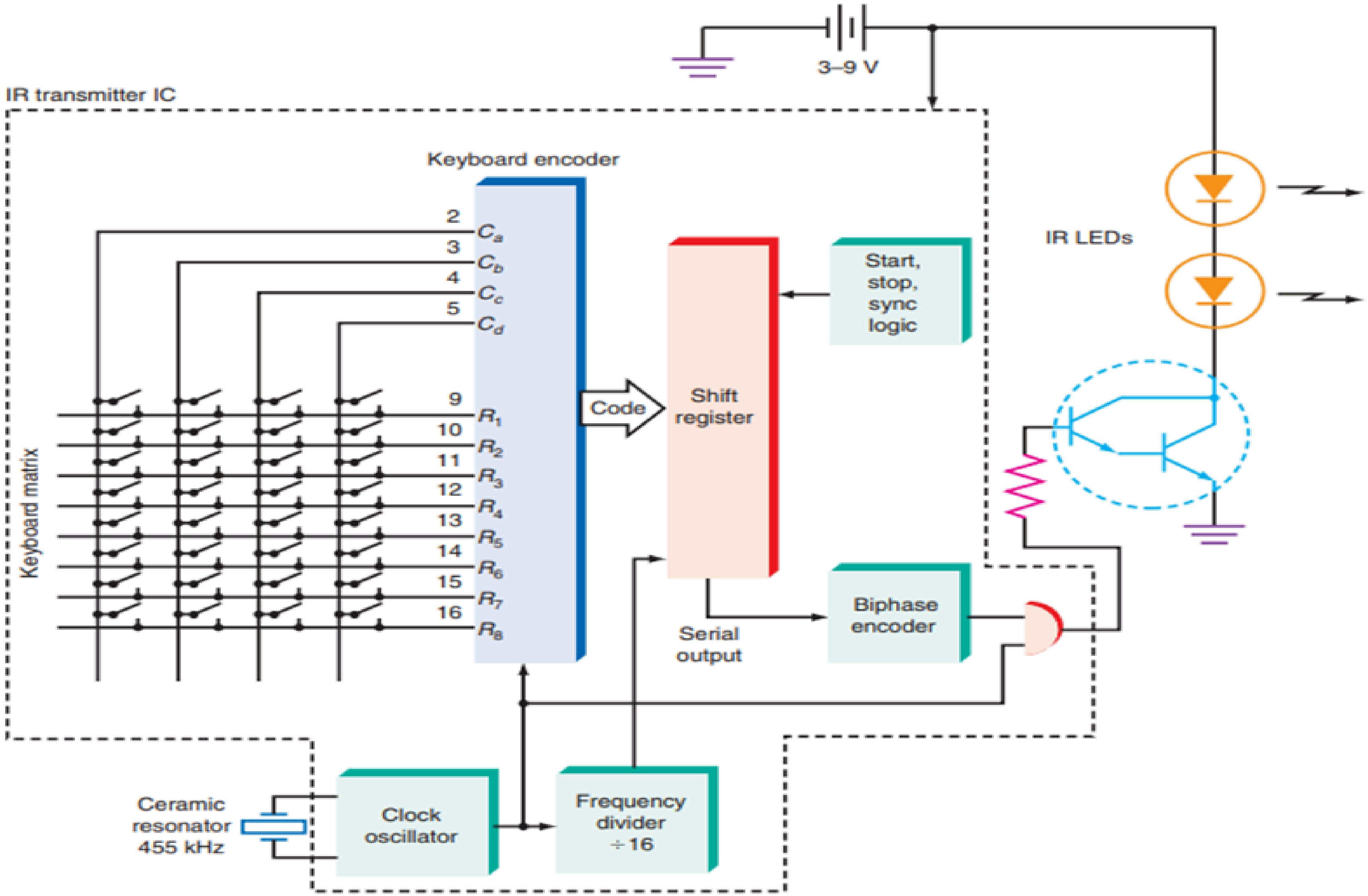
- Almost every TV set has a wireless remote control, regardless of size or cost,
- Other consumer electronic products have **remote controls** including VCRs, cable TV converters, CD and DVD players, stereo audio systems, and some ordinary radios.
- Generic remote controls are available to hook up to any device that you wish to control remotely.
- All these devices work on the same basic principle.
- A small handheld battery powered unit transmits a serial digital code via an IR beam to a receiver that decodes it and carries out the specific action defined by the code.
- A TV remote control is one of the more sophisticated of these controls, for it requires many codes to perform volume control, channel selection, and other functions.

Infrared Wireless

- Fig. 21-5 is a general block diagram of a remote control transmitter.
- In most modern units, all the circuitry, except for the IR LED driver transistors, is contained within a single IC.
- The purpose of the transmitter is to convert a keyboard entry to a serial binary code that is transmitted by **IR to the receiver**.
- The keyboard is a matrix of momentary-contact single-pole single-throw (SPST) pushbuttons.
- The arrangement shown is organized as **8** rows and **4** columns.
- The **row** and **column** connections are made to a keyboard encoder circuit inside the IC.

Infrared Wireless

Figure 21-5 IR TV remote control transmitter.



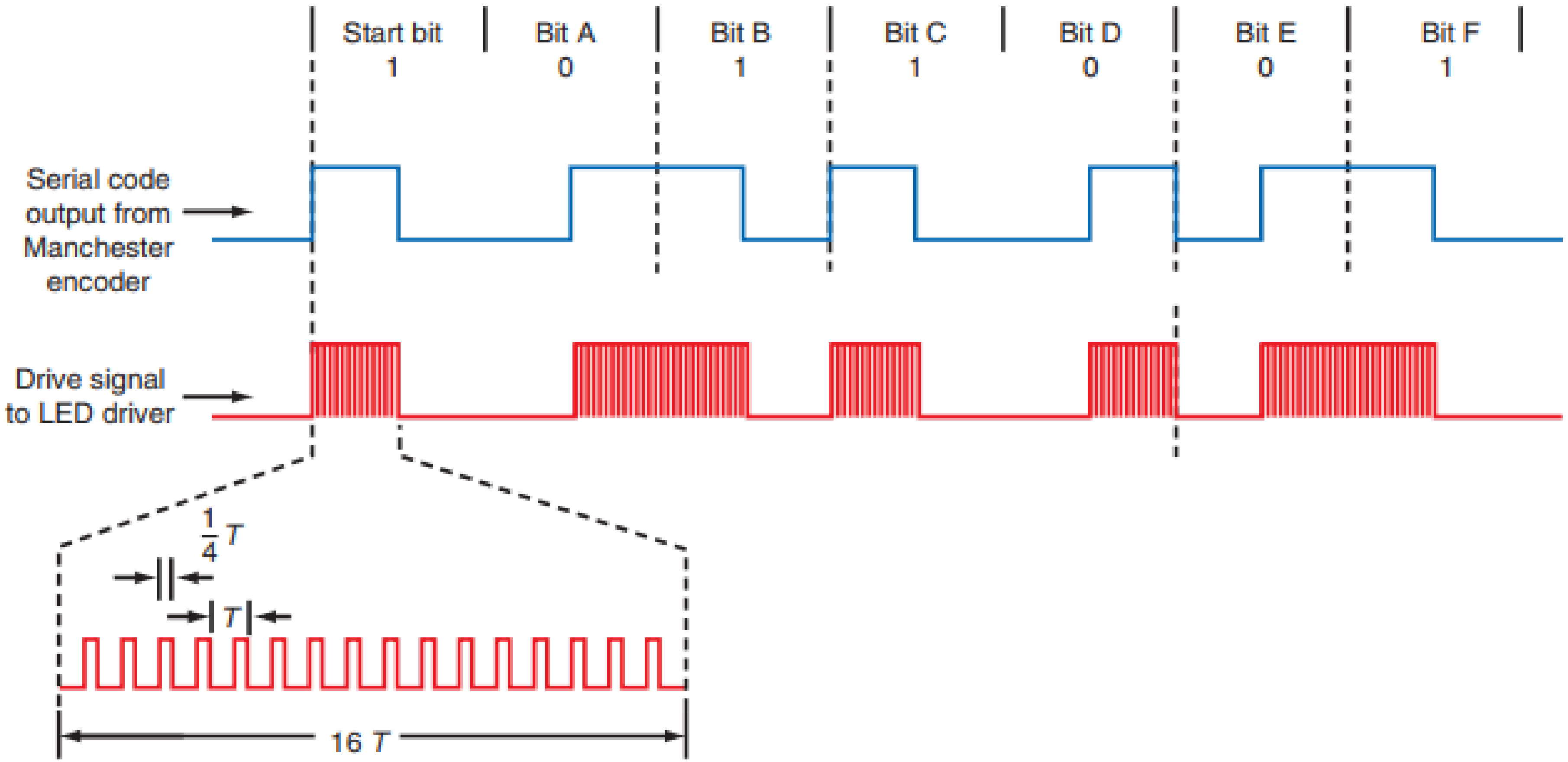
GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

Infrared Wireless

- Pulses generated internally are applied to the column lines.
- When a key is depressed, the pulses from one of the column outputs are connected to one of the row inputs.
- The encoder circuit converts this input to a unique binary code representing a **number** for channel selection or some function such as volume control.
- Some encoders generate as few as 6 bits, and others generate up to 32-bit codes.
- Also 9- and 10-bit codes are very common. The serial output is generated by the shift register as data is shifted out.
- A standard nonreturn to zero (NRZ) serial code is generated.
- This is usually applied to a serial encoder to generate a standard biphase or Manchester code.
- Recall that the biphase code provides more reliable transmission and reception because there is a signal change for every 0-to-1 or 1-to-0 transition.
- The actual bit rate is usually in the 30- to 70-kbps range.
- The serial bit stream turns a higher-frequency pulse source off and on according to the code's binary 1s and 0s.
- The transmitter IC contains a clock oscillator that runs at a frequency in the 445- to 510-kHz range.
- A typical unit runs at 455 kHz, using an external ceramic resonator to set the frequency.
- The serial data turns the 455-kHz pulses off and on.
- **For example**, a binary 1 generates a burst of 16 pulses of 455 kHz, as shown in Fig. 21-6.
- When a binary 0 occurs in the data train, no pulses are transmitted.
- The figure shows a **6-bit code (011001) with a start pulse**.
- The period T of the 455-kHz pulses is 2.2 μs. The pulse width is set for a duty cycle of about 25 percent, or T/4.

Infrared Wireless

Figure 21-6 Pulse waveforms in the IR remote control transmitter.



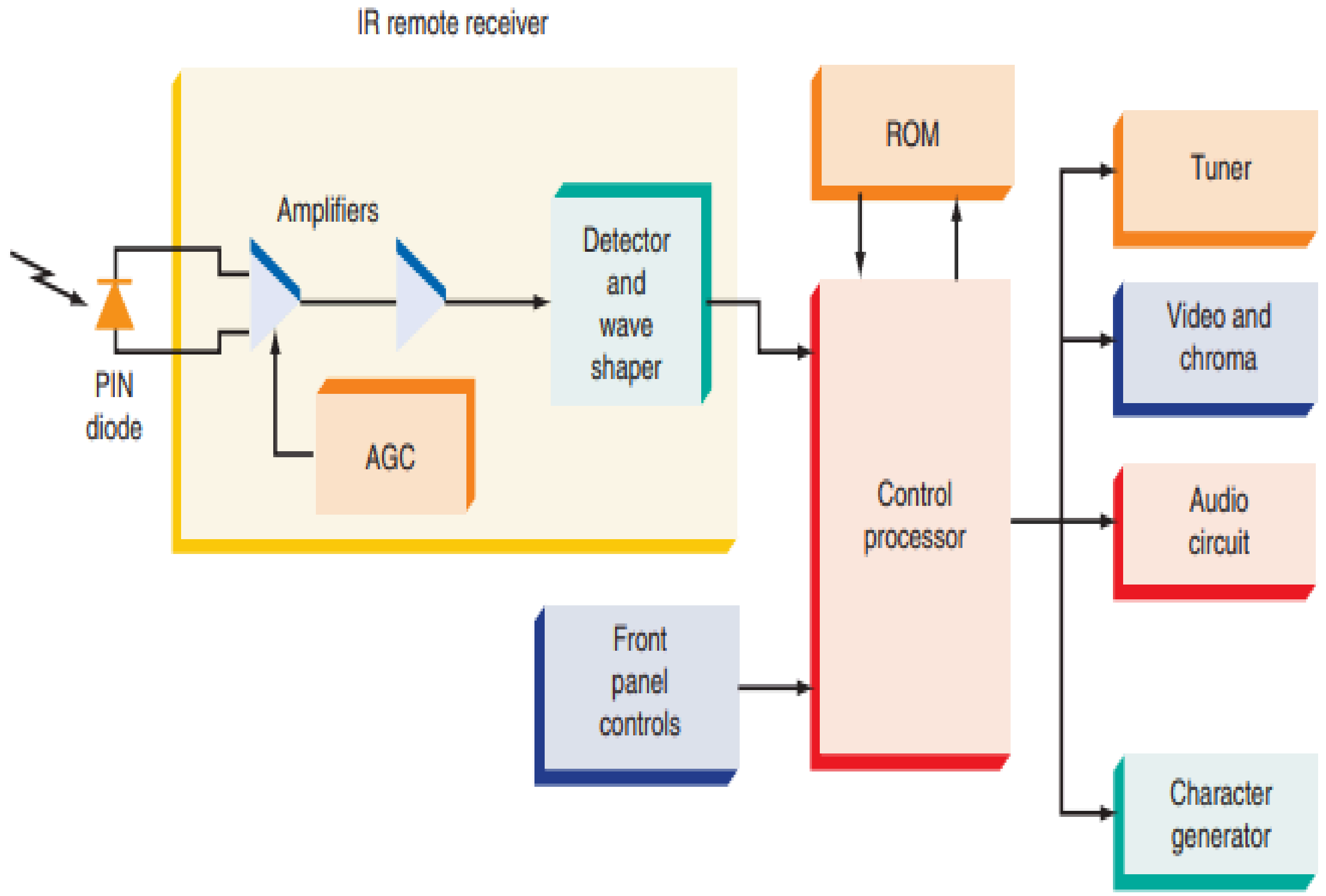
GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

Infrared Wireless

- An IR receiver is shown in Fig. 21-7.
- The PIN IR photodiode is mounted on the front of the TV set, where it picks up the IR signal from the transmitter.
- The received signal is very small despite the fact that the distance between the transmitter and receiver is only 6 to 15 ft on average.
- Two or more high-gain amplifiers **boost the signal level**.
- Most circuits have some form of **automatic gain control** (AGC).
- The incoming pulses are detected, shaped, and converted to the original serial data train. This serial data is then read by the control microcomputer that is usually part of the TV receiver.
- The microcontroller is a dedicated microcomputer built into every TV set.
- A master control program is stored in a ROM. The microcomputer converts inputs from the remote control and front panel controls to output signals that control the various functions in a TV set, such as channel selection and volume control.

Infrared Wireless

Figure 21-7 The IR receiver and control microprocessor.



Infrared Wireless

- The microcontroller inputs and decodes the incoming signal and then issues output control signals to all other circuits: the PLL frequency synthesizer that controls the TV tuner, the volume control circuits in the audio section, and in the more advanced receivers, chroma and video such as hue, saturation, brightness, and contrast.
- The microcontroller also generates, sometimes with the help of an external IC, the characters and simple graphics that can be displayed on the screen.
- Most microcontrollers also contain a built-in clock.
- IR controls are still widely used and will continue to be.
- However, they are gradually being replaced by a radio version based on ZigBee called **RF4CE** or radio frequency for consumer electronics.
- RF4CE remotes have a longer range and do not require line-of sight orientation.
- In addition they add the ability of two-way communications with the controlled device.
- Some products will use **both RF4CE and IR.**

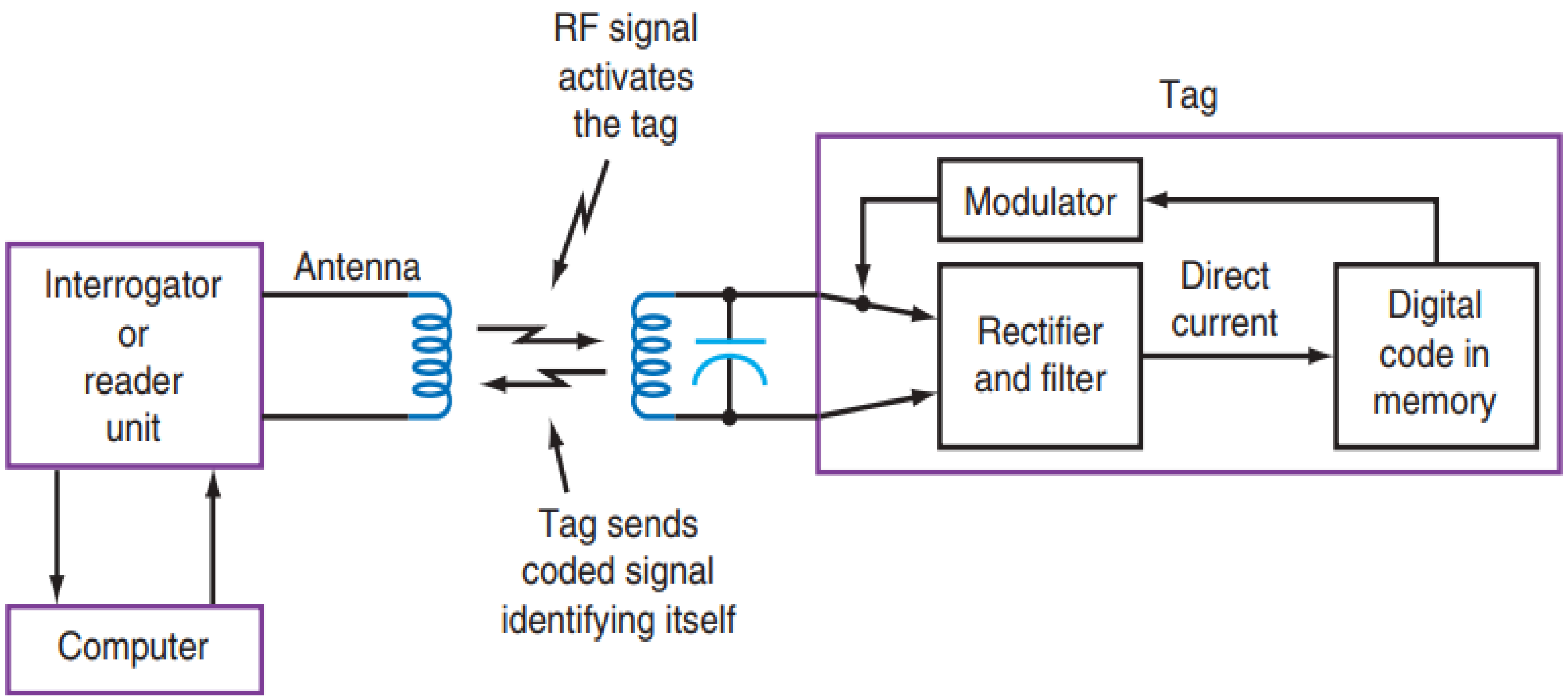
Radio-Frequency Identification(RFID) and Near-Field Communications(NFC)

GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

- Another growing wireless technique is radio-frequency identification (RFID). You can think of it as the wireless version of bar codes.
- This technology uses thin, inexpensive tags or labels containing passive radio circuits that can be queried by a remote wireless **interrogation unit.**
- The tags are attached to any item that is to be monitored, tracked, accessed, located, or otherwise identified.
- RFID tags are widely used in inventory control, container and parcel shipping, capital equipment and other asset management, baggage handling, and manufacturing and production line tracking.
- They are also widely used for automatic toll collection and parking access for vehicles. Other applications for RFID tags are personnel security checking and access, animal tracking, and **theft prevention.**

The basic concept of RFID is illustrated in Fig. 21-10. The tag is a very thin label like device into which is embedded a simple passive single-chip radio transceiver and antenna.

Figure 21-10 Basic concept and components of an RFID system.

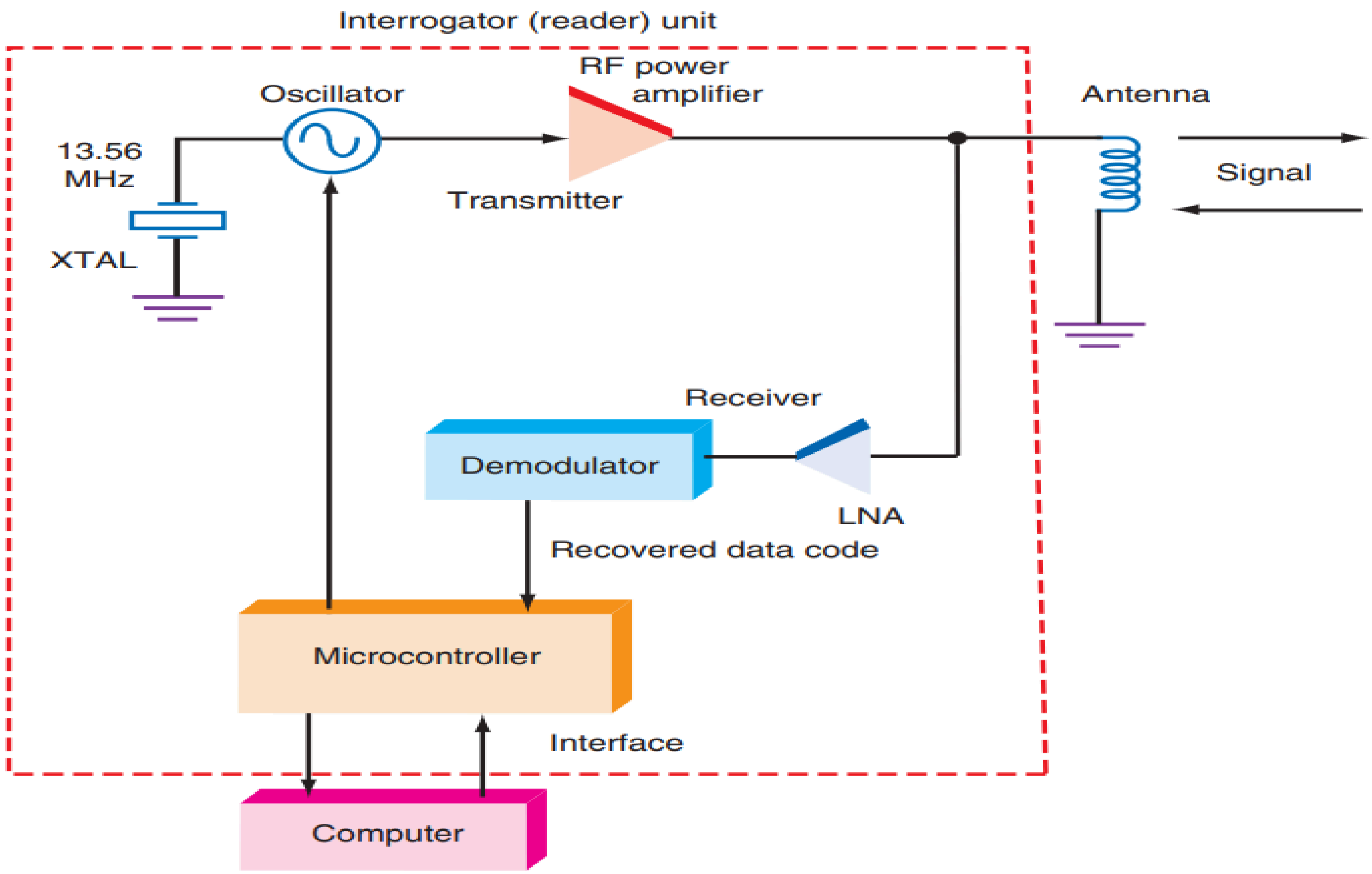


- The chip also contains a memory that **stores a digital ID code** unique to the tagged item.
- For the **item to be identified**, it must pass by the interrogation or reader unit, or the reader unit must physically go to a location near the item.
- Longer-range systems cover a complete building or area. The reader unit sends out a **radio signal** that may travel from a few inches up to no more than 100 ft or so.
- The radio signal is strong enough to activate the tag. The tag rectifies and filters the RF signal into direct current that operates the transceiver.
- This activates a low-power transmitter that sends a signal back to the interrogator unit along with its embedded **ID code**. The reader then checks its attached computer, where it notes the presence of the item and may perform other processing tasks associated with the application
- RFID systems operate over the **full radio spectrum**. Commercial systems have been built to operate from **50 kHz to 2.4 GHz.**
- The **most popular ranges** are **125 kHz, 13.56 MHz, 902 to 928 MHz, and 2.45 GHz**.

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

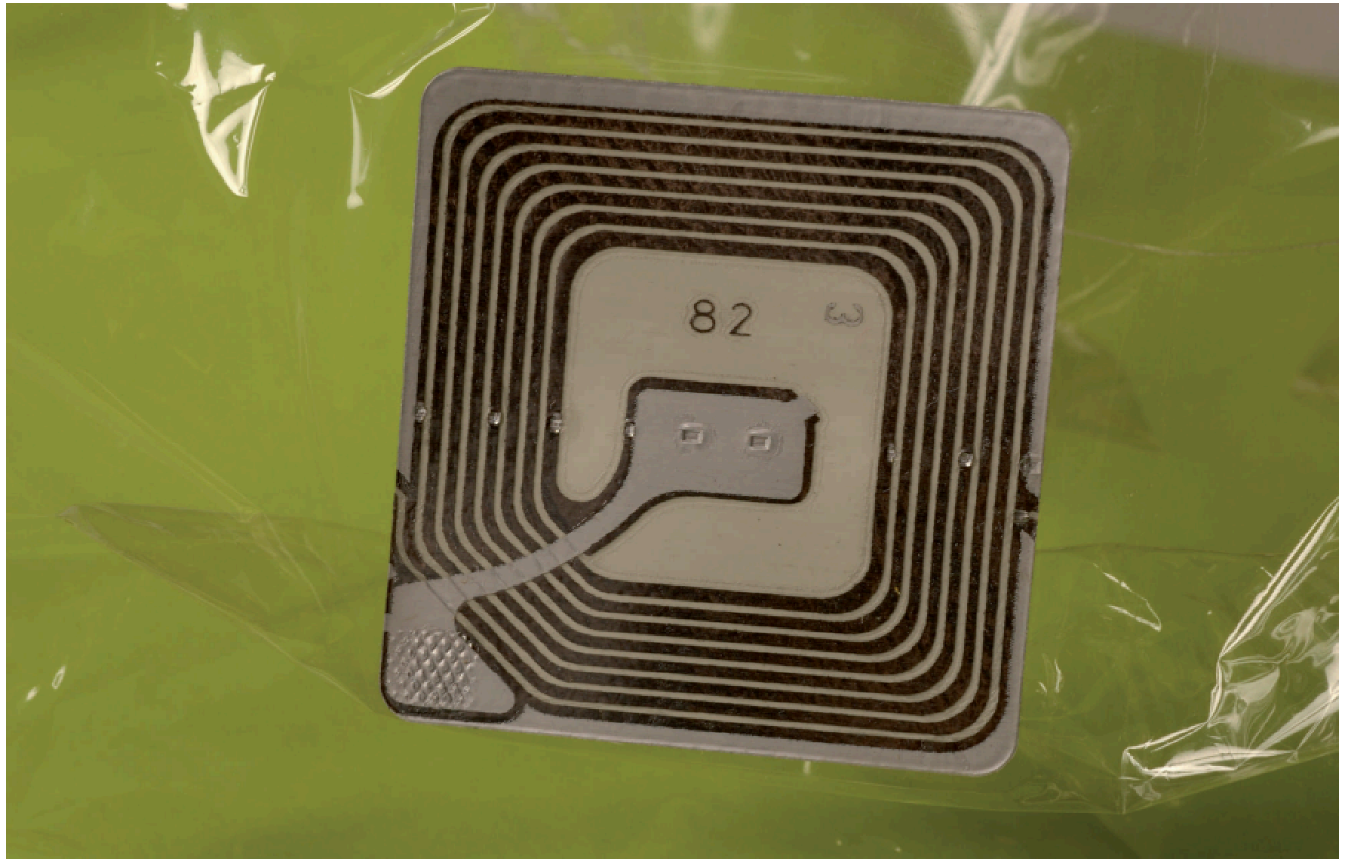
- Fig. 21-11 shows a **block diagram of a typical 13.56-MHz** RFID interrogator unit. A 13.56-MHz crystal oscillator generates the basic RF signal, which is amplified and sent to the antenna.
- A microcontroller gates the oscillator on for a short time, and then the receiver waits for a response from the tag.
- The antenna picks up the weak tag signal. The receiver amplifies and demodulates it and then recovers the serial data code.
- The microcontroller communicates with the attached computer to do whatever processing is needed in the ID process

Figure 21-11 Block diagram of RFID interrogator (reader).



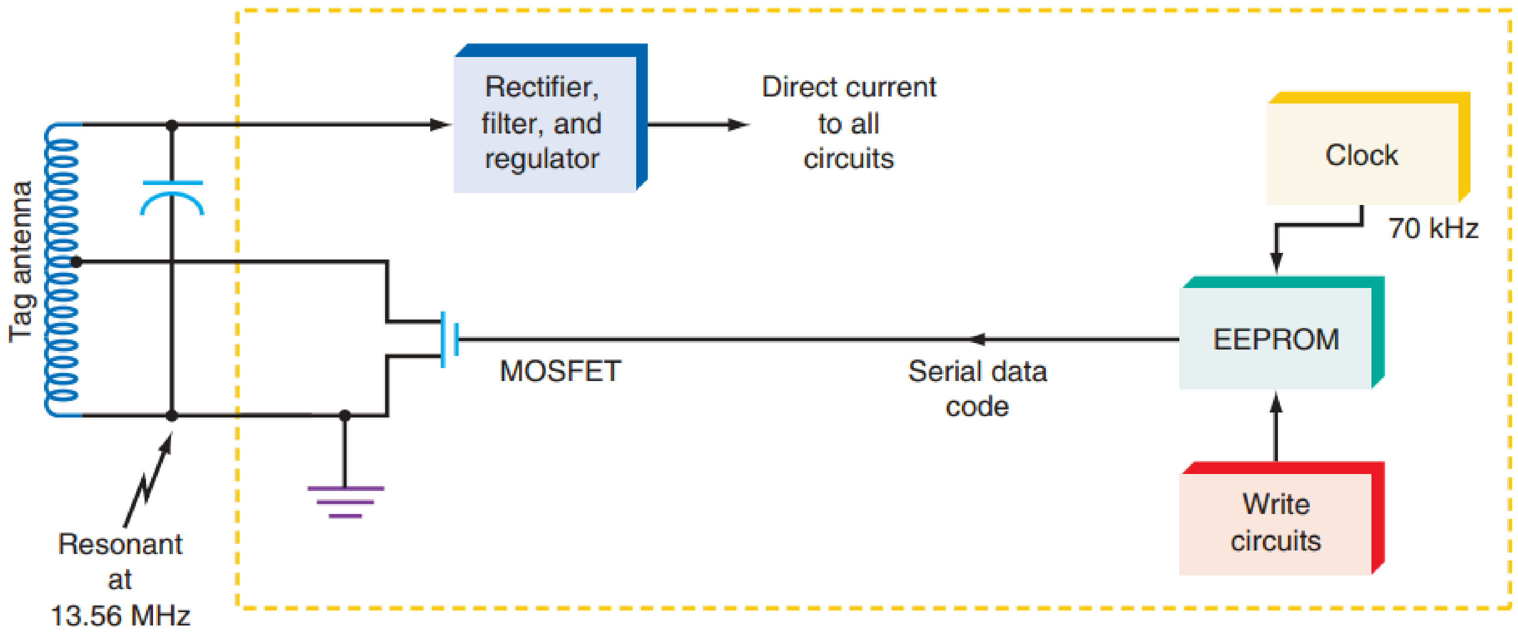
- Some **RFID tag** configurations are shown in Fig. 21-12.
- They consist of a **flat spiral inductor** and a **capacitor** that make up a **13.56MHz tuned circuit** that serves as the antenna. The **transceiver chip is contained in the black dot on the tag.**

Figure 21-12 RFID tag configurations.



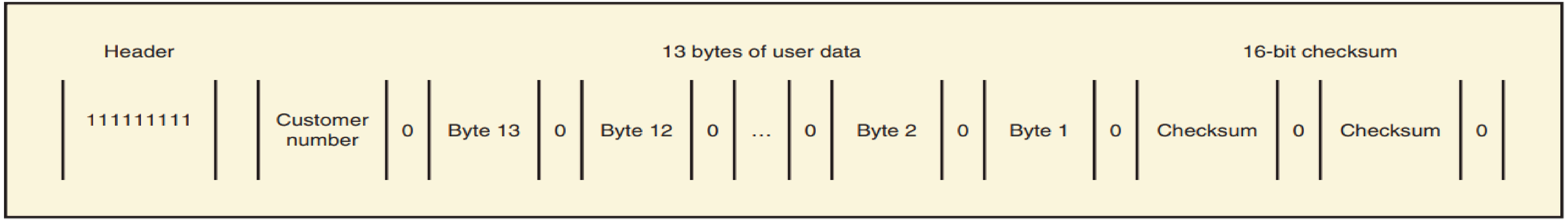
- A block diagram of the circuitry is given in Fig. 21-13. A typical tag is the model MCRF 355/360, a product of **Microchip Technology** Inc.
- The resonant circuit picks up the interrogator signal as if it were the induced signal in a transformer secondary rather than an actual received electromagnetic radio wave. When the voltage reaches about 4 Vp-p, the power circuits are activated. The RF is rectified in a voltage multiplier circuit, filtered, and regulated into the direct current that operates the remaining circuits.
- The unique ID code is stored in an electrically erasable programmable read only memory (EEPROM) in the tag chip. In this device, the code is 154 bits long

Figure 21-13 Block diagram of RFID tag.



- Fig. 21-14 shows the format of the packet sent to the reader. The 9-bit header initiates synchronization at the **reader receiver for clock recovery**.
- The customer's **unique ID number is encoded with 13 bytes**. The checksum provides for error checking at the reader. The **code is stored in the chip** by the manufacturer with a contact transmitter that activates the chip and writes the code **into memory**. **The tag chip contains the EEPROM write circuitry that stores the code.**
- The ID code in EEPROM is **read out serially** in NRZ data format, which is then **converted to a Manchester** or **biphase signal** that is used to modulate the carrier sent back to the reader

Figure 21-14 Format of coded packets transmitted to the reader by the tag. *(Courtesy Microchip Technology)*

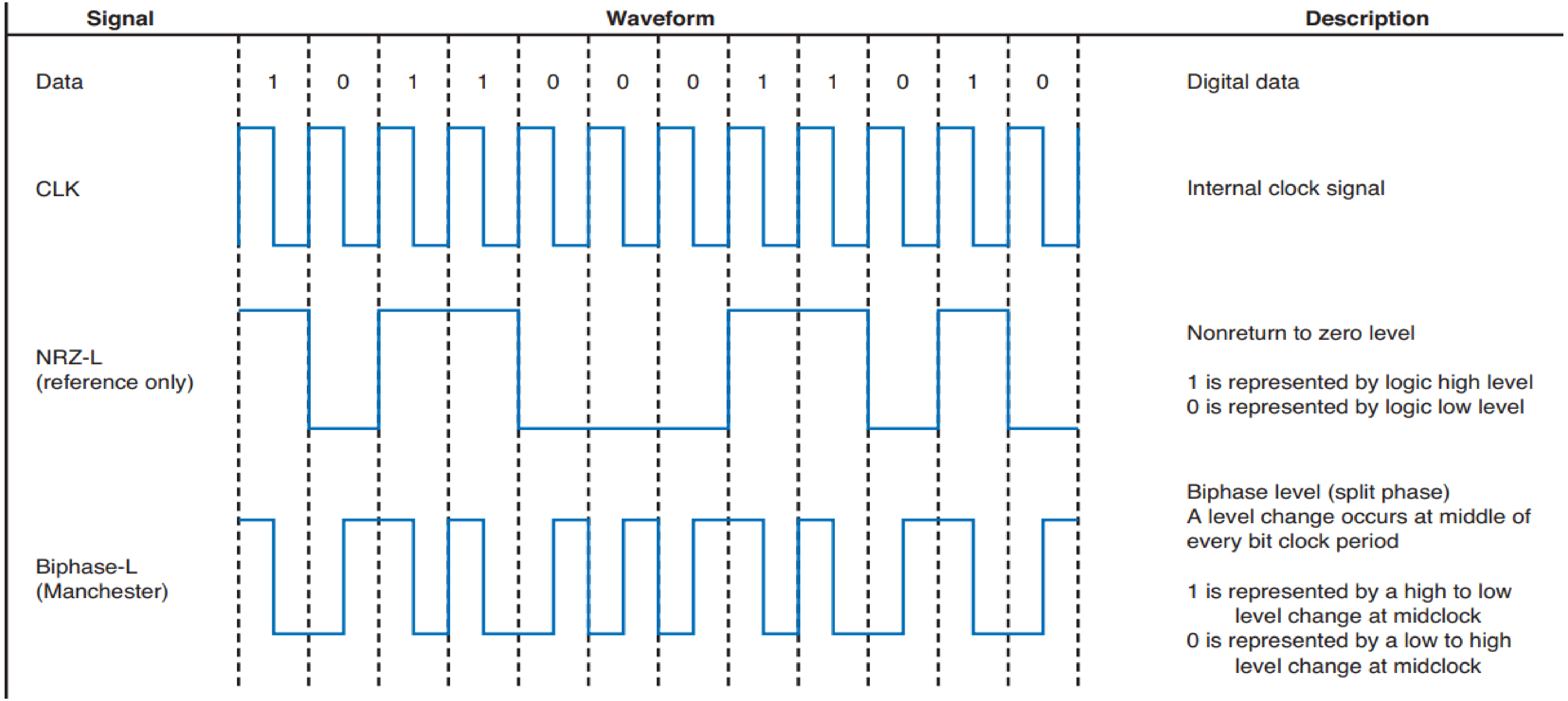


9 bit header
8 bit customer number
104 bits (13 × 8) of user data
17 bits of zeros between each byte, header, and checksum
16 bits of checksum

Total: 154 bits

- See Fig. 21-15. The Manchester code is used so that the clock can be easily recovered from the data in the reader. The data rate is typically 70 kbps. to transmit the 154-bit code

Figure 21-15 Data waveforms in the tag. The Manchester-coded signal operates the cloaking transistor. *(Courtesy Microchip Technology)*



Near-Field Communications

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

- One of the newest forms of wireless is a version of RFID called near-field communications (NFC). It is an ultrashort-range wireless whose range is rarely **more than a few inches**.
- It is a technology **used in smart cards** and cell phones to pay for purchases or gain admittance to some facilities
- Near field means the near field of **a radio wave**. As discussed earlier, a radio wave is made up of both electric and magnetic fields.
- The two fields exchange energy and reinforce each other as it passes from transmitting antenna to receiving antenna. This is the so-called far field.
- At a distance of less than 10 wavelengths from the transmitting antenna is the near field, where the individual electric and magnetic fields exist. The electric field is not useful, **but the magnetic field is used for shortrange communications.**
- The way to imagine NFC is as the magnetic field between the windings of a transformer. The coefficient of coupling is very low because of a large distance between the primary winding (the transmitting antenna) and secondary winding (the receiving antenna).
- The primary limitation of the near field is that the magnetic field strength drops off at a rate of about $1/d^6$, where d is the distance with only low power the range is very limited. The far field only drops off at a $1/d^2$ rate.

Near-Field Communications

GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

- NFC is standardized internationally. The technology is similar to that used in RFID. It is similar to and compatible with the technology used in smart cards, those credit cards with an internal chip that allow you to pay for something by just passing the card over a point-of-sale (POS) terminal reader.
- The standard specifies an operating frequency of 13.56 MHz.
- The transfer data rate is 106, 212, or 424 kbps. The speed depends upon the range, which is up to maximum of 20 cm or about 8 in. In most cases, the actual range will be only a few inches or not more than 10 cm.
- The standard also specifies an active and a passive mode of operation. In the active mode, both parties have powered transceivers. This means that each node has a battery or some other power supply. Either unit may initiate a transmission, which is half duplex with a “listen before transmit” protocol. One of the devices is the initiator, and the **other device becomes the target.**
- In the passive mode, the target is a passive device such as an RFID tag. The tag gets its operational power from the field transmitted by the initiator. It then transmits data back to the initiator by modulating the magnetic field, using backscatter AM.

Near-Field Communications

GITAM (DEEMED TO BE UNIVERSITY) (Estd. u/s 3 of the UGC Act, 1956)

1. The most frequent use is an automatic payment tool such as a smart card. But instead of using a smart card, the NFC transceiver is built into your cell phone.

- To buy something, you just tap your cell phone on the reader or pass it within an inch or so, and your credit card account is automatically billed.
- You could use it to buy movie tickets or even to pay for a plane, train, or hotel charge. Some modern smart phones have NFC built in, but payment with this technology is still not widespread.

1. The second most useful application is automatic gated entry. Passing your cell phone near the reader allows you entry into a building, parking lot, or other controlled area.

- NFC chips are also expected to be incorporated into the next-generation passports.

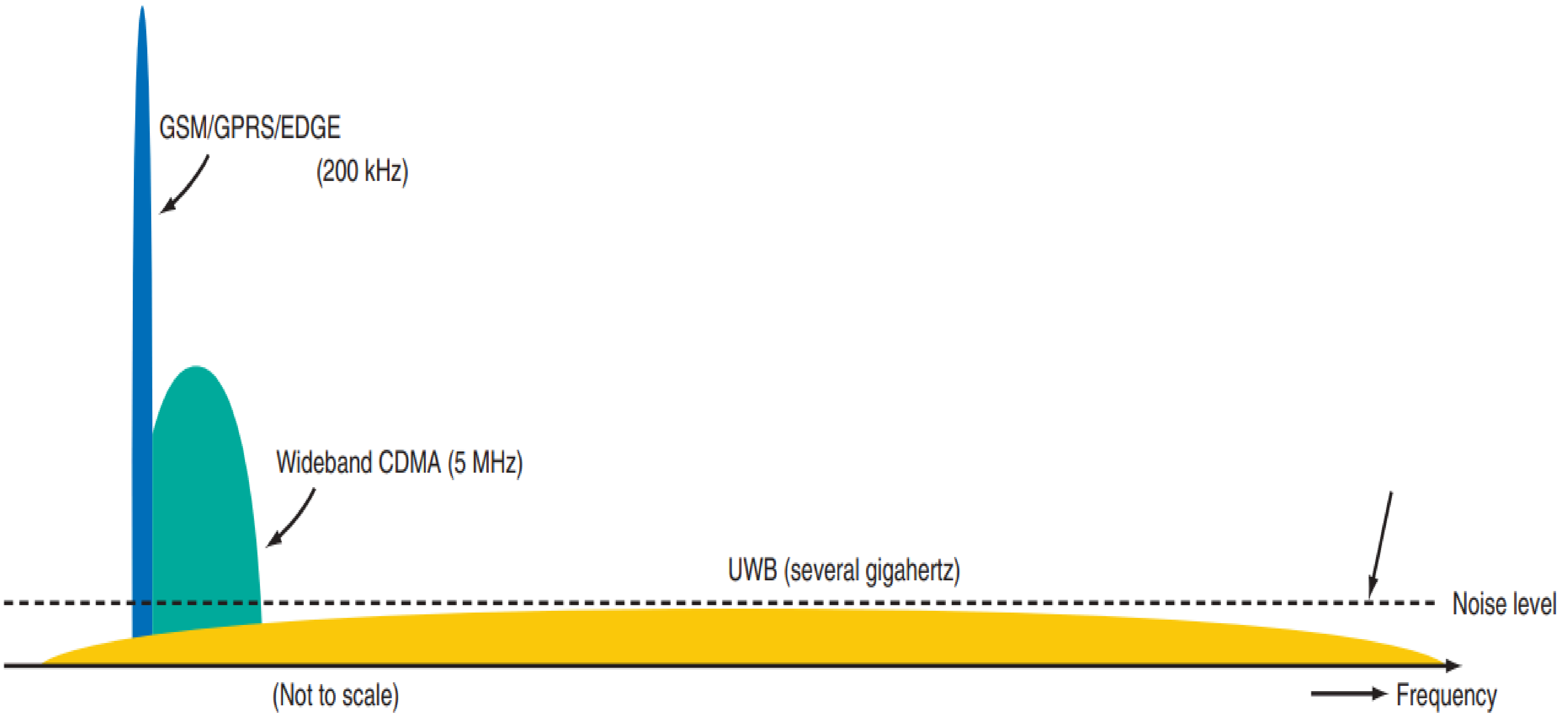
Ultrawideband Wireless

- The newest and most unusual form of wireless is known as ultrawideband (UWB) wireless. There are two basic forms of UWB, the original version based on very narrow impulses and the newer kind based on OFDM. Both spread the signal over a very widerange of spectrum but at a very low signal level, so it does not interfere with other signals operating over those frequencies. Both methods are used, but the newer OFDM version appears to have captured the greatest number of manufacturing companies and the applications.
- The original UWB discovered in the 1960s is known as impulse, baseband, or carrierless wireless. This form of UWB transmits data in the form of very short pulses, typically **less than 1 ns.**
- Another definition specifies UWB as occupying more than 500 MHz of spectrum. Fig. 21-17 shows a UWB signal spectrum compared to a standard 30-kHz cell phone channel and a 5-MHz wideband CDMA (spread spectrum) cell phone channel.
- The FCC permits UWB in the 3.1- to 10.6-GHz range. The only other services in this region are satellites, radars, broadband wireless, and wireless networks.. UWB is like spread spectrum in that many users can share a single wide bandwidth simultaneously

Ultrawideband Wireless

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

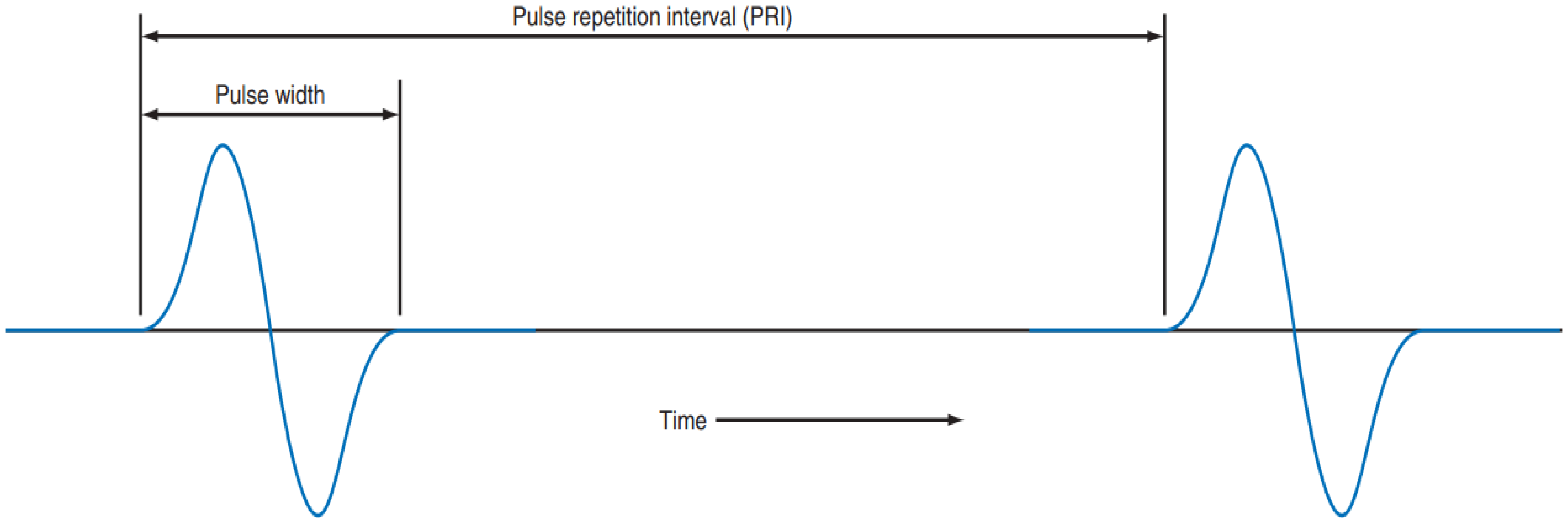
Figure 21-17 UWB signal bandwidth compared to conventional and spread spectrum signal bandwidth.



Ultrawideband Wireless

- A UWB signal starts as a very low duty cycle (< 1 percent) rectangular pulse stream at some pulse repetition interval (PRI). The pulses are then Gaussian-filtered and differentiated to produce the final pulses to be transmitted. The pulses are applied directly to the antenna (see Fig. 21-18). Known as monocycles, these pulses are not just one cycle of a sine wave. They are shaped by a Gaussian filter.

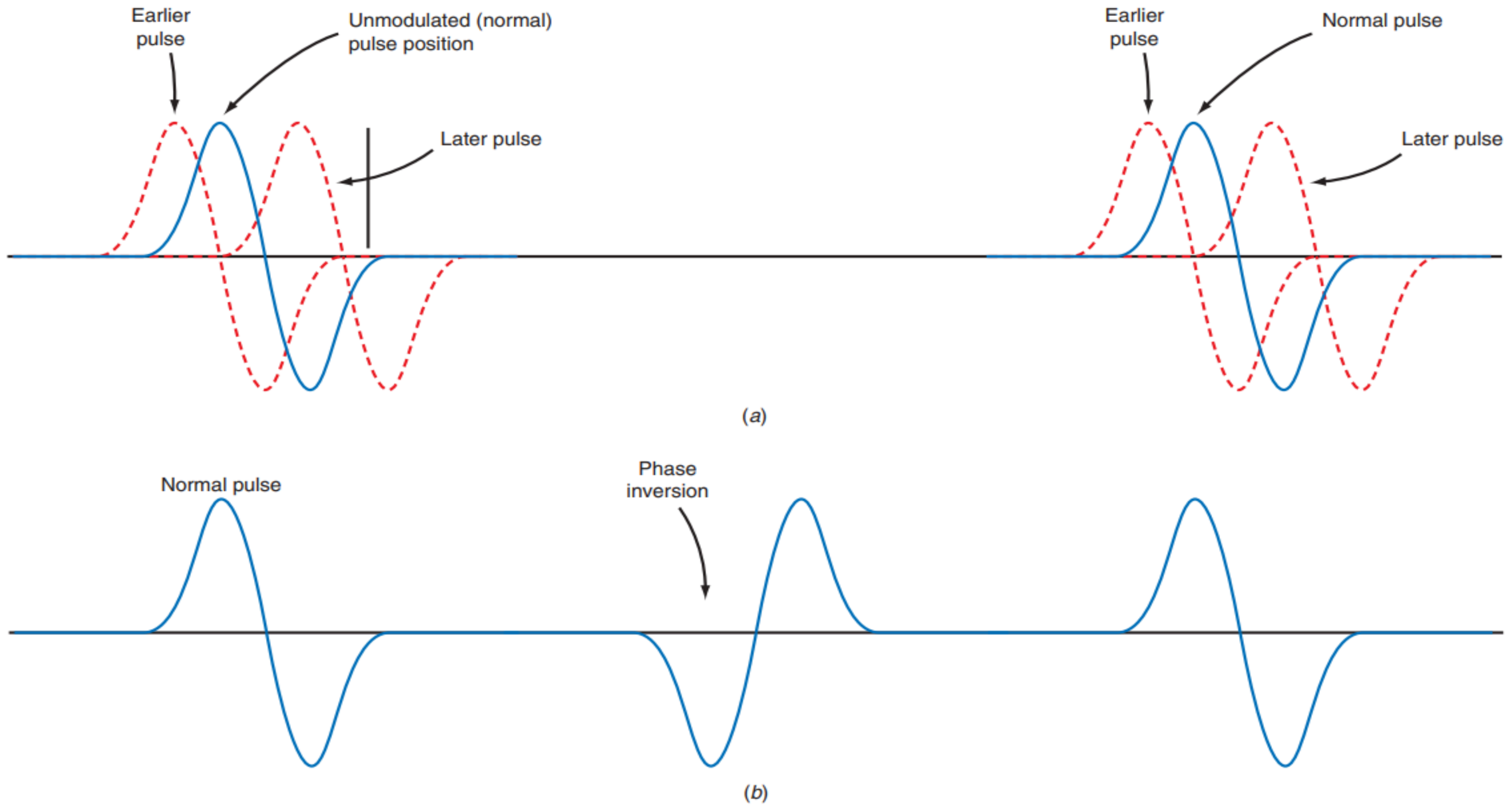
Figure 21-18 Basic UWB waveform of repetitive monocycles.



Ultrawideband Wireless

- The serial data to be transmitted is then encoded with a unique pseudorandom code like that **used in CDMA**. This method effectively "channelizes" the system so that multiple users can share the spectrum but still be individually identified. The coded signal then modulates the pulse train by either PPM or BPSK. Both methods are illustrated in Fig. 21-19. In PPM,

Fig. 21-19 Types of UWB modulation. (*a*) Pulse position modulation (PPM). (*b*) Binary phase-shift keying (BPSK).



Ultrawideband Wireless

GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC Act, 1956)

Multiband OFDM UWB

The newest form of UWB is called multiband OFDM or MB-OFDM UWB. The term multiband is derived from the fact that many OFDM carriers make up the signal.

This form of UWB divides the lower end of the assigned spectrum into three 528-MHz-wide channels, as shown in Fig. 21-20.

These bands extend from 3.168 to 4.952 GHz. Note the center frequencies of the three bands. Each band is designed to hold an OFDM data signal.

There are 128 carriers per band, and each carrier has a bandwidth of 4.125 MHz. Of the bands 100 actually carry the data while 12 are used as pilot carriers to aid in establishing communications with nearby nodes.

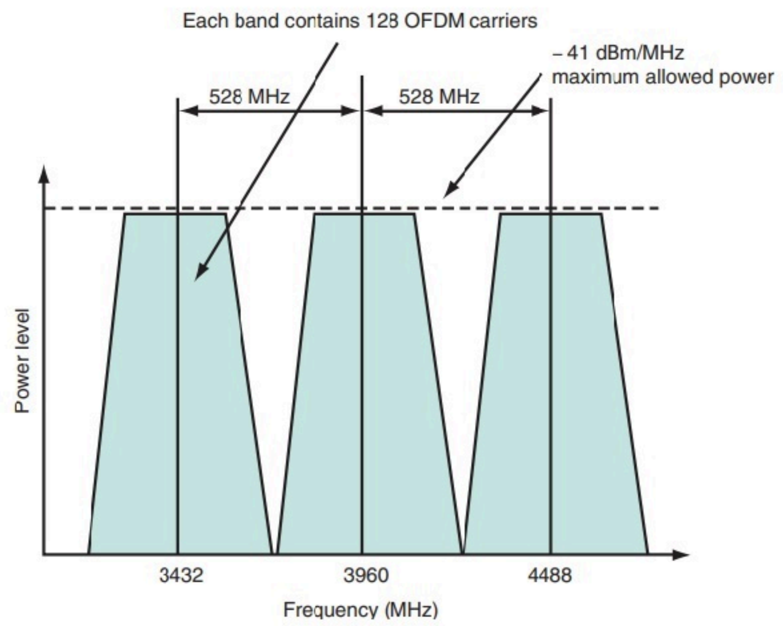
The remaining carriers serve as guard bands on either side to prevent interference between the three portions of spectrum.

Ultrawideband Wireless

Multiband OFDM UWB

There is no UWB standard. Companies worked for years in an IEEE Task Group to create a single standard to be designated 802.15.3a.

Figure 21-20 Operating spectrum for multiband OFDM UWB.



Advantages and Disadvantages of UWB

UWB offers many benefits to radar, imaging, and communication applications:

1. Superior resolution in radar and imaging.
2. Immunity to multipath propagation effects.
3. License-free operation.
4. No interference to other signals using the same frequency band. UWB signals appear as random noise to conventional radios.
5. Power-efficient, extremely low-power operation. Peak power levels are in the milliwatt region, and average power is in microwatts.
6. Simple circuitry, most of which can be integrated in standard CMOS. 7. Potentially low cost