CHAPTER TWO

LITERATURE REVIEW

2.1 Background

2.1.1 Radio Frequency Spectrum

The complete range of possible frequencies that are now or could be used for radio communications is called the spectrum. The audible frequency range is usually considered to range from 20 to 18,000 cycles per second or Hertz. For practical purposes, the useful radio spectrum ranges from approximately 30 KHz up to more than 300 GHz. Electromagnetic waves in this frequency range, called radio waves, are extremely widely used in modern technology, particularly in telecommunication. To prevent interference between different users, the generation and transmission of radio waves is strictly regulated by national laws, coordinated by an international body, the International Telecommunication Union (ITU).

Different parts of the radio spectrum are appointed by the ITU for different radio transmission technologies and applications; some 40 radio communication services are defined in the ITU's Radio Regulations (RR). In some cases, parts of the radio spectrum are sold or licensed to operators of private radio transmission services (for example, cellular telephone operators or broadcast television stations). Ranges of allocated frequencies are often referred to by their provisioned use (for example, cellular spectrum or television spectrum) [2].

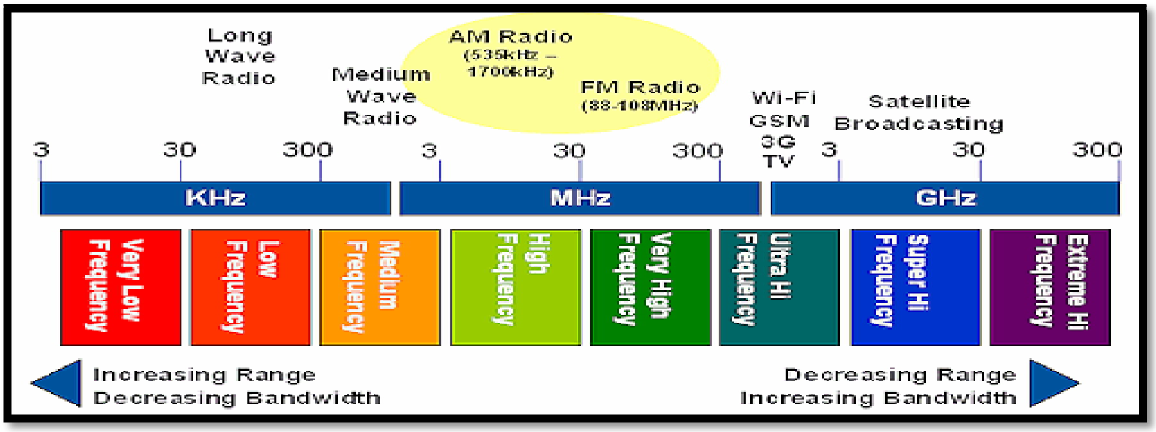


Figure 2.1: shows the radio spectrum

The radio frequency can be approached by frequency and by application.

2.1.2 Frequency

A band is a small section of the spectrum of radio communication frequencies, in which channels are usually used or set aside for the same purpose. Above 300 GHz, the absorption of electromagnetic radiation by Earth's atmosphere is so great that the atmosphere is effectively opaque, until it becomes transparent again in the near-infrared and optical window frequency ranges. To prevent interference and allow for efficient use of the radio spectrum, similar services are allocated in bands. For example, broadcasting, mobile radio, or navigation devices, will be allocated in non-overlapping ranges of frequencies. Each of these bands has a basic band plan which dictates how it is to be used and shared, to avoid interference and to set protocol for the compatibility of transmitters and receivers [3]

Table 2.1:freqeuncy bands

Frequency	Wavelength	Designation	Abbreviation
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF
30–300 Hz	10^4–10^3 km	Super low frequency	SLF
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF
3–30 kHz	100–10 km	Very low frequency	VLF
30–300 kHz	10–1 km	Low frequency	LF
300 kHz – 3 MHz	1 km -100 m	Medium frequency	MF
3–30 MHz	100–10 m	High frequency	HF
30–300 MHz	10–1 m	Very high frequency	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF
3–30 GHz	10–1 cm	Super high frequency	SHF
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF
300 GHz – 3 THz	1 mm -0.1 mm	Tremendously high frequency	THF

And for Public safety bands, two of the radio frequency bands are of particular interest to law enforcement agencies installing their own mobile radio systems. These are the VHF and UHF bands, whose ranges are designated as VHF 30 - 300 MHz and UHF 300 - 3,000 MHz [3].

Classification of frequency spectrum by:

Application

- **Broadcasting**

Broadcast frequencies:

1. Long wave AM Radio = 148.5 kHz – 283.5 kHz (LF)
2. Medium wave AM Radio = 530 kHz – 1710 kHz (MF)
3. Shortwave AM Radio = 3 MHz – 30 MHz (HF)

Designations for television and FM radio broadcast frequencies vary between countries, Since VHF and UHF frequencies are desirable for many uses in urban areas, in North America some parts of the former television broadcasting band have been reassigned to cellular phone and various land mobile communications systems.

- **Air band**

Air band refers to VHF frequencies 118 to 137 MHz, used for navigation and voice communication with aircraft. Trans-oceanic aircraft also carry HF radio and satellite transceivers.

- **Marine band**

The greatest incentive for development of radio was the need to communicate with ships out of visual range of shore. From the very early days of radio, large oceangoing vessels carried powerful long-wave and medium-wave transmitters. High-frequency allocations are still designated for ships, although satellite systems have taken over some of the safety applications previously served by 500 kHz and other frequencies. 2182 kHz is a medium-wave frequency still used for marine emergency communication.

Marine VHF radio is used in coastal waters and relatively short-range communication between vessels and to shore stations. Radios are channelized, with different channels used for different purposes; marine Channel 16 is used for calling and emergencies.[3]

- **Amateur radio frequencies**

Amateur radio frequency allocation SUB – SONIC s varies around the world. Several bands are common for amateurs world-wide, usually in the shortwave part of the spectrum. Other bands are national or regional allocations only due to differing allocations for other services, especially in the VHF and UHF parts of the radio spectrum.

- **Citizens' band and personal radio services**

Citizens' band radio is allocated in many countries, using channelized radios in the upper HF part of the spectrum (around 27 MHz). It is used for personal, small business and hobby purposes. Other frequency allocations are used for similar services in different jurisdictions. A wide range of personal radio services exist around the world, usually emphasizing short-range communication between individuals or for small businesses, simplified or no license requirements, and usually FM transceivers use around 1 watt or less.

- **Industrial, scientific, medical**

The ISM bands were initially reserved for non-communications uses of RF energy, such as microwave ovens, radio-frequency heating, and similar purposes. However, in recent years the largest use of these bands has been by short-range low-power communications systems, since users do not have to hold a radio operator's license. Cordless telephones, wireless computer networks, Bluetooth devices, and garage door openers all use the ISM bands. ISM devices do not have regulatory protection against interference from other users of the band.

- **Land mobile bands**

Bands of frequencies, especially in the VHF and UHF parts of the spectrum, are allocated for communication between fixed base stations and land mobile vehicle-mounted or portable transceivers.

Police radio and other public safety services such as fire departments and ambulances are generally found in the VHF and UHF parts of the spectrum. Trucking systems are often used to make most efficient use of the limited number of frequencies available.

The demand for mobile telephone service has led to large blocks of radio spectrum allocated to cellular frequencies.

- **Radio control**

Reliable radio control uses bands dedicated to the purpose. Radio-controlled toys may use portions of unlicensed spectrum in the 27 MHz or 49 MHz bands, but more costly aircraft, boat, or land vehicle models use dedicated radio control frequencies near 72 MHz to avoid interference by unlicensed uses. Licensed amateur radio operators use portions of the 6-meter band in North America. Industrial remote control of cranes or railway locomotives use assigned frequencies that vary by area [3].

- **Radar**

Radar applications use relatively high power pulse transmitters and sensitive receivers, so radar is operated on bands not used for other purposes. Most radar bands are in the microwave part of the spectrum, although certain important applications for meteorology make use of powerful transmitters in the UHF band [4].

2.1.3 Audio Spectrum

An audio frequency (abbreviation: AF) or audible frequency is characterized as a periodic vibration whose frequency is audible to the average human. The SI unit of audio frequency is the hertz (Hz). It is the property of sound that most determines pitch.

The generally accepted standard range of audible frequencies is 20 to 20,000 Hz, although the range of frequencies individuals hear is greatly influenced by environmental factors. Frequencies below 20 Hz are generally felt rather than heard, assuming the amplitude of the vibration is great enough. Frequencies above 20,000 Hz can sometimes be sensed by young people. High frequencies are the first to be affected by hearing loss due to age and/or prolonged exposure to very loud noises. [5]

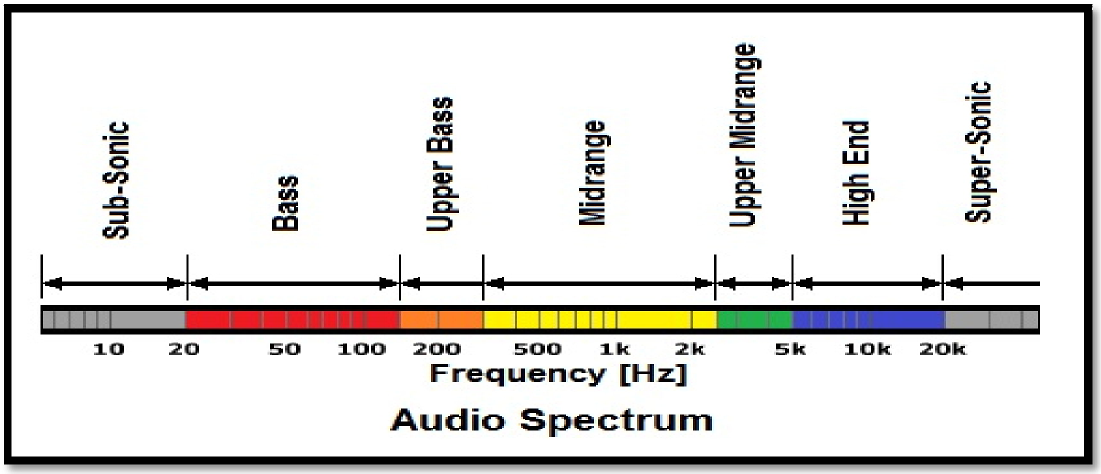


Figure 2.2 shows the audio spectrum

2.1.4 Two-way Radio

A two-way radio is basically a radio that is structured to transmit and receive. In general, most voice-wireless communications technology, counting cellular systems, is categorized by two-way radio definition. Usually, a two way radio refers to a radio system primarily utilized for group call communications. This two-way system is also called PAMR Public Access-Mobile Radio, PMR Private-Mobile Radio, LMR Land-Mobile Radio, and PMR Professional-Mobile Radio. Portable 2 way radios are frequently called "walkie-talkies" or "handie-talkies." Not much different from "handie," the term sometimes used to describe mobile phones. While we're on the subject, it's probably best to get something out in the open right now. People often interchange the terms two-way radio and walkie-talkie. However, walkie-talkie is chiefly a generic or slang-term for hand portable two way radios. Moreover, the term usually implies non-professional, license free, consumer type, or "toy" equipment. When referring to two way radios, people are basically talking about professional licensed equipment. A walkie-talkie is generally a hand-held CB radio. A 2 way radio is of superior quality and utilizes much higher frequencies. Two-way radios can also be found in mobile and base-configurations in addition to using radio network-infrastructure. In addition, two-way radios are usually decked out with a PTT or “Push-to-Talk” key to trigger the transmitter. Users simply press the PTT key and quickly begin a conversation. The user lets go of the PTT key in order to hear others. A two-way radio user can talk immediately with other radio users or utilize radio network-infrastructure. A direct-talk amongst radios, normally referred to as direct more operation/talk-around mode, has restricted reach because of limited radio power. To defeat this restriction, a radio network-infrastructure can be used to expand the communication range [6].

With various wireless technology options and two-way radio being one of the “earliest” wireless technologies, one may question whether two-way radio is still a viable technology today. The answer is yes and the following are the 2 key points that uniquely differentiate two-way radio to other wireless technology:

- **Instant communication**

Two-way radio provides instant communication. User just needs to press the “Push-To-Talk” (PTT) button and within fraction of a second, this user can immediately talk to convey his/her messages. This is due to a quick call set-up time imbedded in the technology. This instant communication capability is one of key factors of why many organizations rely on two-way radio for their tactical or operational communications [6].

- **Group communication**

Another distinct feature of two-way radio is its capability to facilitate “one-to-many” group communication (also known as "group call") very efficiently. By efficient means that one user can talk to one, five, tens, hundreds, thousands of users at the same time. Users don’t need to repeat the same message over and over again if he/she needs to convey to more than one user. In addition, two-way radio performs the group communication using minimum RF channel resources. If all of users reside in the same area, most of the time, you only need one channel resources to talk to these hundreds of users [6].

Advantages over other wireless systems

Every wireless technology has their advantages and disadvantages. The choice of which technology is the most suitable for one’s organization depends on whether that particular technology can meet the user requirement.

For those users who need to:

- Work in a group
- Communicate instantly, and
- Mobile

Two-way radio can be considered as appropriate solution compared to other wireless technologies.

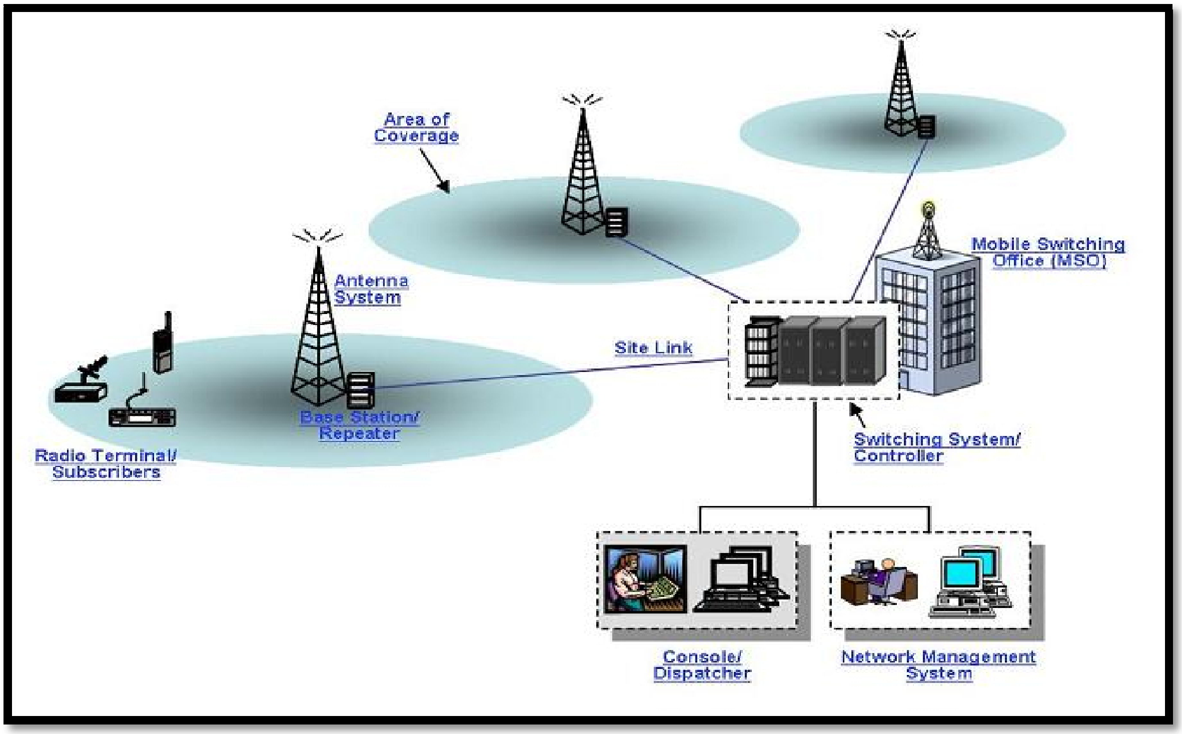


Figure 2.3 shows a radio network

Users of the two-way radio

Two-way radio has been used for many years by various organizations and industries. Due to the nature of their operational needs, they have to utilize two-way radio to address their communication needs. Examples of organizations and industries that rely on two-way radio are:

- **Public Safety organization**: Police, Fire Brigade, Emergency Medical Services / Ambulance, Disaster Recovery agency
- **Security**: Military, Intelligence agencies
- **Transportation**: Railway, Airport, Seaport, Light Rail, Subway
- **Utility companies**: Electricity, Gas, Water, Telephone, Cable TV
- **Transport Service** companies: Taxi, Limos, Trucking

- **Construction** companies: Commercial, Residential, Road and Bridge
- **Hospitality** industries: Hotel, Resort, Restaurant, Tourism
- **Government agencies**: Ministries, Local government, Municipal, Embassies, Public Works
- **Manufacturing**
- **Contractors:** Electrical, Excavating, Plumbing, Roofing
- And many others...

In other words, users of two-way radio are any agencies or businesses with multiple staff or workers who work in group and mobile [6].

Analog over digital two-way radio:

It's believed that current state of the digital modulation leaves a lot to be desired, and that digital modulation is a huge compromise in reliable and effective communication for first responders. Technology will improve with time, but the users of critical public safety communications systems will be handicapped by digital modulation until significant advances are made in the software that converts voice to and from a compressed digital format [7].

Digital modulation has one fundamental advantage over traditional analog modulation. It conveys information with mathematical precision. It can even correct minor imperfections through mathematics. Unfortunately, the benefits end there, and come at the cost of some important advantages of traditional analog modulation. Digital modulation precludes the ability of the human brain to decipher speech that has been corrupted by noise and interference. Audio recovery is impossible when the (SNR) signal-to-noise ratio of a digitally modulated signal falls below a certain threshold. With analog modulation, the human ear and brain can “decode” speech that is buried beneath noise levels that digital circuits and algorithms cannot contend with. While analog and digital transmissions are both subject to dead spots and interference, digital modulation reduces human communication by eliminating the “gray area” afforded by analog equipment. Digital equipment will not recover any audio in cases where an analog signal will be quite understandable, especially in cases where significant multipath interference is present [7].

Industry-standard codec's (or vocoder software) that converts spoken voice to digital data cannot adequately distinguish between voice and background noise. For example, a firefighter using a digital portable radio while standing next to a fire engine that is pumping water will probably not be understandable over the radio because the codec cannot isolate the voice from the pump noise. Another example is a police officer who is trying to announce his or her location during a pursuit. The officer’s digitized voice may be unintelligible because of the siren. A canine officer with a dog that is barking loudly may not be heard because of the competing noise from the dog. In all of these examples, it is likely that analog modulation would provide reliable communication. Therefore unless a digital modulation scheme is invented that is as robust and as tolerant of low signals as the human ear, means that there is only one advantageous use for digital modulation in public-safety communication. Technology exists to encrypt digital signals. For special kinds of communication, like surveillance operations, the encryption afforded by digital outweighs the disadvantages of the medium itself. Otherwise, analog offers greater reliability through simplicity of design and robustness [7].

There are many two-way radio technologies available today. The following lists the most well-known radio technology. The table shows each of technology in terms of whether it is analog or digital, and whether it is conventional or trunked. Note that the analog conventional is the most basic and well known technology [7]

Table 2.2: analog and digital technology

Conventional	Trunked	
Analog	Analog conventional radio	APCO16,1EDACS LTR ,MPT 1327
Digital	DMR,APCO-25	APCO-25,DMR EDACS,iDEN,OpenSky TETRA,Tetrapol

2.1.5 RF Repeaters

A repeater is a network hardware device that receives a signal and retransmits it at a higher level or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances. It is a generic term that refers to several different types of devices.

The repeater makes use of two frequencies, the repeater radio functions as an

amplified relay station receiving high- or low-power base stations, low-level mobile, and handheld radio signals, changing their frequency, amplifying the signals, and re-transmitting them on the repeater output frequency [8]

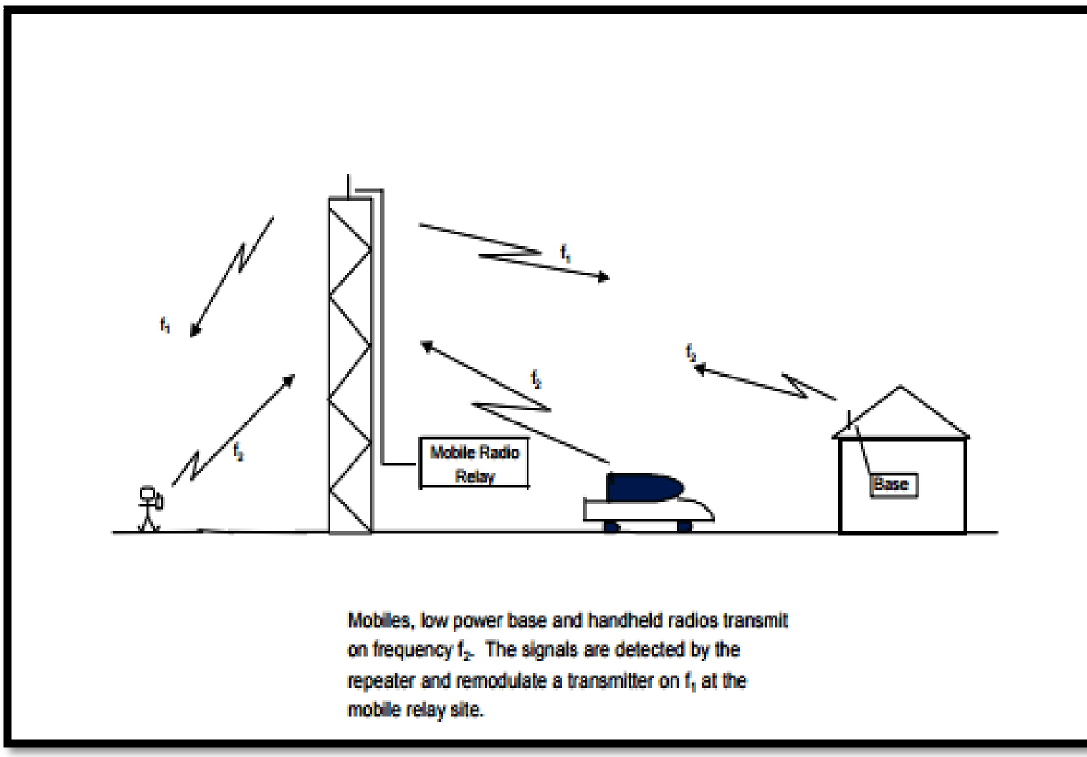
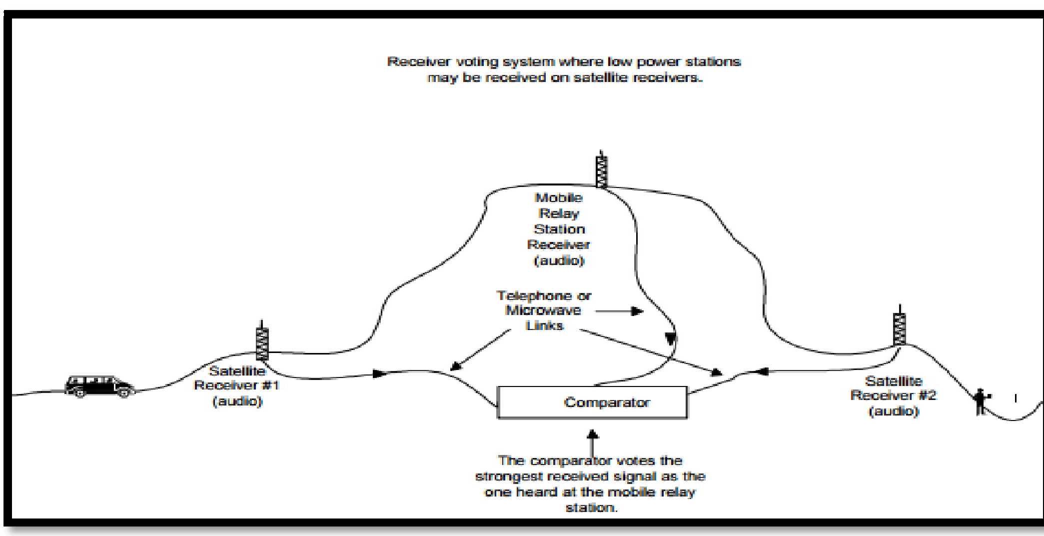


Figure 2.4: shows the use of frequencies in a repeater configuration

In the figure, f1 is the output frequency of the repeater and the input frequency to all bases, mobile, and handheld radios and f2 is the output frequency of the base, mobile, and handheld radios and the input frequency of the repeater. Repeaters are generally installed on the highest points within the coverage areas, including high buildings and mountaintops where the topography allows for maximum coverage and penetration. Thus, regardless of the output or the antenna heights on handheld, mobile, and base radios, the repeater signal is always the same strength at any receiving site [8].Repeater stations are usually high-power stations, 600 to 3,500 watts ERP, and cover a large area. Handheld radios, with their low output power of 0.5 to 3 watts ERP, are often unable to be heard at the repeater site, particularly in hilly or mountainous terrain or in urban areas having numerous tall buildings. To correct this power imbalance, one or more satellite receiving sites may be set up in these coverage areas close to the

Figure 2.5: voting system



Low-power radios to receive the low-power signals. Each satellite receiver’s output is sent via telephone line or microwave radio transmission to a signal comparator at a central site, where the strongest signal is selected through “voting” and utilized to drive the repeater [9] . Another scheme used where there are problems transmitting to and receiving from mobiles and handheld radios due to large changes in topography requires several repeaters at different locations that may be switched at a central position,

usually at the police communications dispatch center, to the repeater receiving the highest signal level. In this way the signal is “steered” toward the station, as shown in figure 2.5. Where very large areas are to be covered, for example several counties, simulcast systems using multiple repeaters operating on the same frequency may be employed. In this case, all transmitters operate simultaneously and send a composite signal to receivers in the field. Special emphasis must be placed on frequency stability of the carriers, for they must be within a few Hertz at all stations; the modulation must be transmitted at exactly the same time, or there will be interference in the overlap zones of the repeaters [10].

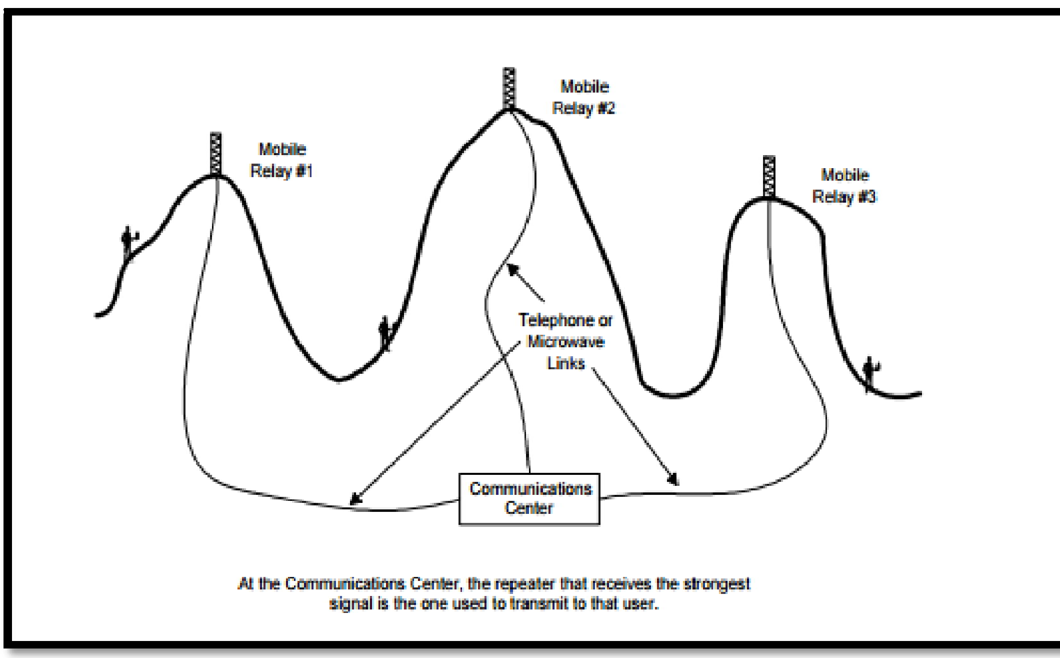


Figure 2.6 shows repeater steering

2.1.6 Relay

A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current. The heart of a relay is an electromagnet (a coil of wire that becomes a temporary magnet when electricity flows through it). A relay may seem as an electric lever: switch it on with a small current and it switches on ("leverages") another appliance using a much bigger current. It is useful because many sensors are incredibly sensitive pieces of electronic equipment and produce only small electric currents. But often these sensors are needed to drive bigger pieces of apparatus that use bigger currents. Relays bridge the gap, making it possible for small currents to activate larger ones. That means relays can work either as switches (turning things on and off) or as amplifiers (converting small currents into larger ones). Here is a figure illustrating how relays use one circuit to switch on a second circuit [11].

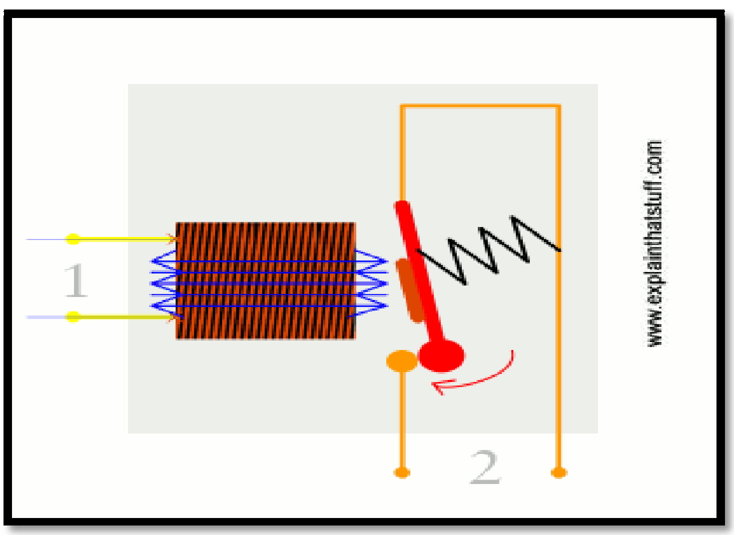


Figure 2.7: Relay circuit 1

When power flows through the first circuit (1), it activates the electromagnet (brown), generating a magnetic field (blue) that attracts a contact (red) and activates the second circuit (2). When the power is switched off, a spring pulls the contact back up to its original position, switching the second circuit off again. This is an example of a "normally open" (NO) relay: the contacts in the second circuit are not connected by default, and switch on only when a current flows through the magnet. Other relays are "normally closed" (NC; the contacts are connected so a current flows through them by default) and switch off only when the magnet is activated, pulling or pushing the contacts apart. Normally open relays are the most common [11].

Here's another animation showing how a relay links two circuits together. It's essentially the same thing drawn in a slightly different way. On the left side, there's an input circuit powered by a switch or a sensor of some kind. When this circuit is activated, it feeds current to an electromagnet that pulls a metal switch closed and activates the second, output circuit (on the right side). The relatively small current in the input circuit thus activates the larger current in the output circuit:

1. The input circuit (black loop) is switched off and no current flows through it until something (either a sensor or a switch closing) turns it on. The output circuit (blue loop) is also switched off.
2. When a small current flows in the input circuit, it activates the electromagnet (shown here as a red coil), which produces a magnetic field all around it.

3. The energized electromagnet pulls the metal bar in the output circuit toward it, closing the switch and allowing a much bigger current to flow through the output circuit.
4. The output circuit operates a high-current appliance such as a lamp or an electric motor [11].

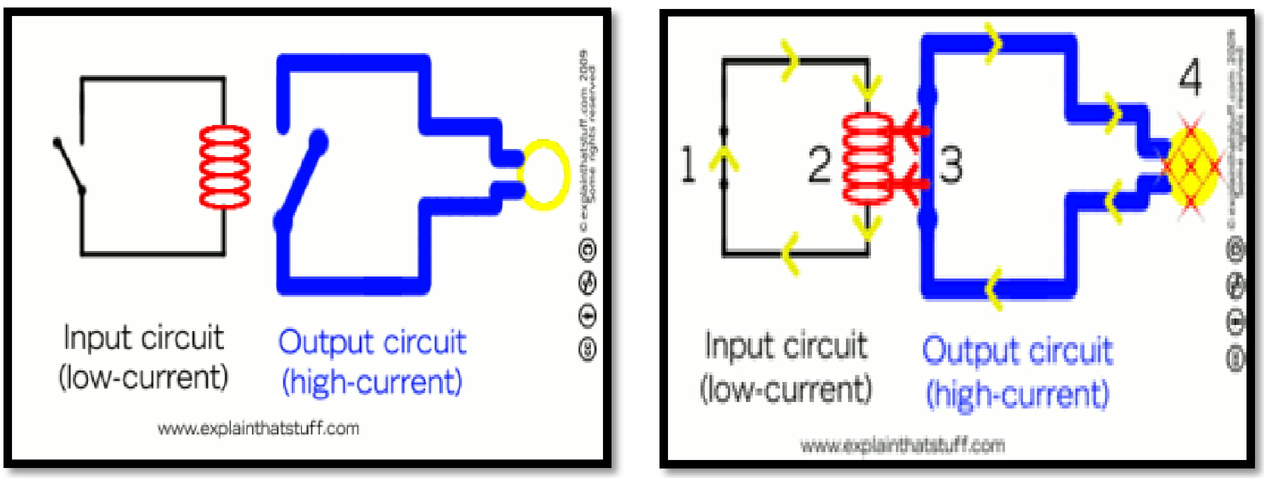


Figure 2.8: Relay switch

2.2 Literature Review

2.2.1 methods of interconnection

Shared channels can provide an improved level of communication interoperability by using existing systems and resources. Each agency and community has unique communications resources, needs, and requirements. However, no "one size fits all" technical solution exists that can adequately provide voice and/or data interoperability for every scenario. As a result agencies must typically employ a number of solutions to meet their interoperability requirements [12].

The specific technical solutions for voice interoperability that the Interoperability Continuum identifies are outlined below:

- **Swap Radios**

Swapping radios may consist of emergency response agencies trading radio equipment for the duration of an event or issuing radios to emergency responders from a compatible set of radios known as a radio cache. This solution achieves a basic level of interoperability; however, swapping radios as an event occurs can be time-consuming, management-intensive, and may only provide limited results. Swap Radios is a solution that is often best suited for communications at the command and control level. However, large tactical radio caches may provide interoperability for nearly all emergency responders on the scene of a prolonged incident [12].

- **Gateways**

A gateway is one type of interconnect system. Most gateways are typically dedicated stand-alone devices that allow users to connect multiple HF, VHF low band, and VHF high band, UHF, and 700 and 800 MHz radios. They can also connect trunked talk groups, encrypted networks, public telephone systems, and cellular or satellite phone connections [13]. Most gateway devices are mobile and portable, but many are used in permanent configurations. Gateways transmit and receive audio among multiple externally connected communications devices, as illustrated in figure 1.

Gateway solutions can provide interoperability by allowing users to connect incompatible radio systems or frequency bands to provide a common talk path for voice communications. Gateways available today include portable, mobile, and fixed devices that can provide connectivity for the duration of an event or incident. However, gateway solutions do have limitations: 1) gateways inefficiently use radio spectrum because each gateway talk path requires a separate channel or talk group for each incompatible radio system and frequency band; 2) a gateway's effective geographic coverage at an incident is limited by the range of the systems and radios used for the talk path; 3) complex gateways may require trained staff to set up and operate, and the incident may be over before a common talk path can be established [13].

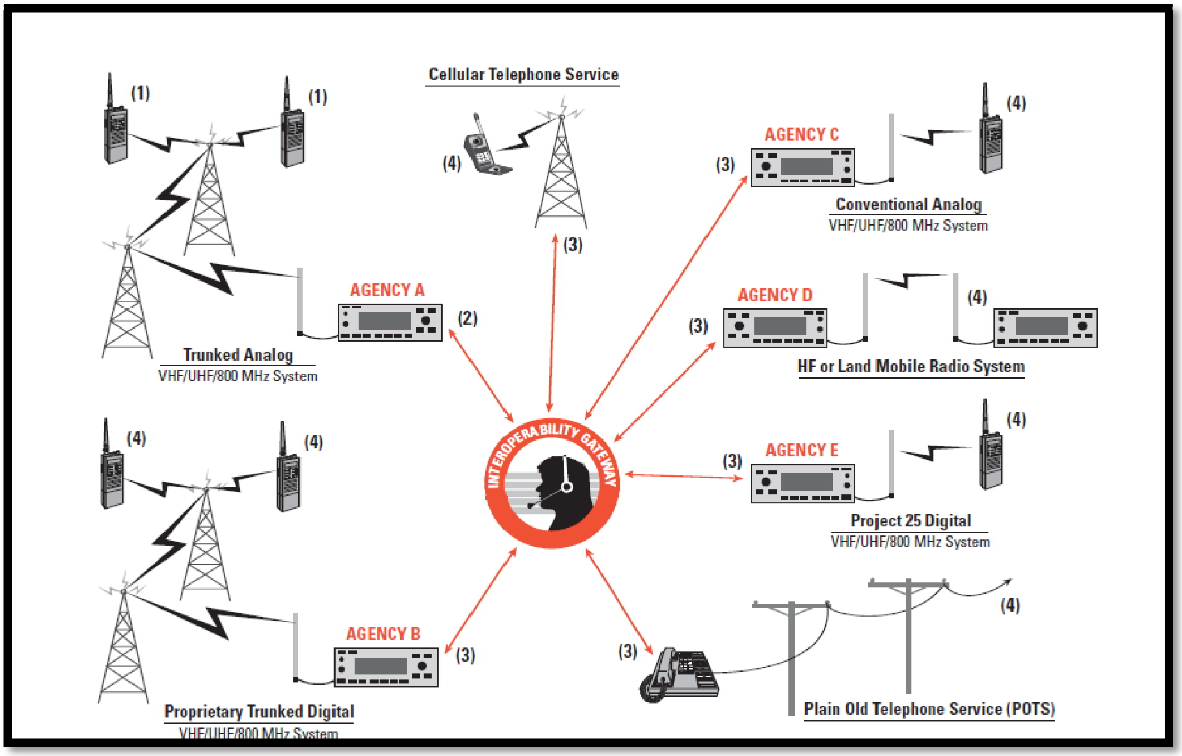


Figure 2.9 Gateway interconnect system

- **Shared Channels**

Shared channels consist of frequencies licensed to individual agencies by the Federal Communications Commission (FCC) and allocated by the licensee for use by other agencies for the purpose of interoperability. The use of shared channels can improve interoperability by establishing a common frequency over which multiple jurisdictions or disciplines can communicate. This solution can be achieved using existing systems and resources as long as the shared channels are pre-programmed into each piece of equipment, and the radios operate in the same frequency band. Similarly, shared talk groups are specific radio resources that are shared with other agencies and disciplines throughout a trunked radio system [14]. The use of shared channels improves the efficient use of spectrum; however, the limited availability of frequencies and the potential for radio communications congestion can limit the effectiveness of this solution [14].

- **Proprietary Shared Systems and Standards-Based Shared Systems**

Shared systems refer to the use of a single radio system infrastructure to provide service to multiple agencies within a region. A standards-based shared system promotes competitive procurement by allowing agencies to use a wide selection of products to meet specific user needs. A proprietary shared system, on the other hand, prevents open competition by forcing users to procure one manufacturer's product exclusively. With proper planning, regionally shared systems can provide optimal functionality and interoperability for users of the system in the region; however, this type of solution can be costly to construct [15].

The technical solutions outlined above each have benefits and limitations; yet, given the variety of existing systems, none can solely provide the greatest interoperability. A combination of these solutions is required to best accommodate the communications needs of a region or community [15].

2.2.2 APCO Project 16 Trunked Radio System

The Law Enforcement Assistance Administration (LEAA) in 1977 provided a grant to the Association of Public-Safety Communications Officials International (APCO) to make possible the opportunity for the public safety community to develop test beds and study various parameters associated with UHF band trunking systems [16].

APCO Project 16 members were charged with evaluating the technical, economic, and regulatory questions raised by the 800/900 MHz spectrum made available by the FCC. Studies were made on three experimental systems in Chicago, Miami, and Orange County, California.

When the study was completed, APCO published a document defining the mandatory and desirable functional capabilities for a public safety analog trunked radio system. It was issued in March 1979, and requirements were tailored for law enforcement and addressed channel access times, automated priority recognition, data systems interface, individuality of system users, command/control flexibility, systems growth capability, frequency utilization, and reliability [16].

APCO 16 trunking systems are presently being used by many large and medium-sized government agencies. To make the technology available to smaller government groups in adjoining cities, some communities are sharing systems. This has cut down on both capital investment and operating costs for any single entity [16].

The APCO 16 specification had no interoperability or encryption requirements; thus systems supplied by different manufacturers do not talk to one another. This limits competitive bidding for expansion and replacement parts. A new digital system specification, under the Project 25 Steering Committee, has been in process for years to correct some of the interoperability difficulties, improve spectrum efficiency, and take into account the changing world to more efficiently and economically manufacture digital radio systems [16].

2.2.3 Project 25 (P25)

is the standard for the design and manufacture of interoperable digital two-way wireless communications products. Developed in North America with state, local and federal representatives and Telecommunications Industry Association (TIA) governance, P25 has gained worldwide acceptance for public safety, security, public service, and commercial applications.

The published P25 standards suite is administered by the Telecommunications Industry Association (TIA Mobile and Personal Private Radio Standards Committee TR-8). Radio equipment that demonstrates compliance with P25 is able to meet a set of minimum requirements to fit the needs of public safety. The P25 standard was created by, and is intended for, public safety professionals [17].

The benefits of project 25

From the beginning, P25 has targeted four primary objectives:

- Allow effective, efficient, and reliable intra-agency and inter-agency communications so organizations can easily implement interoperable and seamless joint communication in both routine and emergency circumstances.
- Ensure competition in system life cycle procurements, so agencies can choose from multiple vendors and products, ultimately saving money and

gaining the freedom to select from the widest range of equipment and features.

- Provide user-friendly equipment, so users can take full advantage of their radios' lifesaving capabilities on the job – even under adverse conditions – with minimal training.
- Improve radio spectrum efficiency, so networks will have enough capacity to handle calls and allow room for growth, even in areas where the spectrum is crowded and it's difficult for agencies to obtain licenses for additional radio frequencies.

Therefore Project 25 enables successful fulfillment of these factors that are critical to public safety operations and the use of two-way radio communications in the field. and also it Enables ease of operation for more rapid adoption and training, planned migration of systems and equipment from old to new, Enables Interoperability essential to multiple jurisdiction and joint operations. And enables multiple vendors sourcing for cost effective and competitive procurements with no compromise in system capabilities [18].

2.2.4 Terrestrial Trunked Radio (TETRA)

TETRA (Terrestrial Trunked Radio) is a digital trunked radio standard developed by the European Telecommunications Standards Institute (ETSI). ETSI is a standardization body for Information and Communication Technology in Europe. The purpose of the TETRA standard was to meet the needs of Professional Mobile Radio (PMR) user organizations. The first version of TETRA standard was published in 1995 [19]

Because the TETRA standard has been specifically developed to meet the needs of a wide variety of PMR user organizations, it has a scalable architecture allowing network deployments ranging from single site - local area coverage to multiple site - wide area national coverage. Besides meeting the needs of PMR user organizations, the TETRA standard has also been developed to meet the needs of Public Access Mobile Radio (PAMR) operators [19]

Recognizing that important market requirements outside the responsibility of ETSI needed to be addressed to ensure the success of TETRA, a number of organizations formed the TETRA MoU (Memorandum of Understanding) Association in December 1994. The main objectives of the TETRA Association are to promote the TETRA standard and to ensure multi-vendor equipment interoperability. This forum acts on behalf of all interested parties, representing users, manufacturers, application providers, integrators, operators, test houses and telecom agencies who are involved in the development and or deployment of the TETRA standard. Today the TETRA Association represents over 135 organizations, from all continents of the world.

From end user point of view, TETRA provides the following features and services:

- Group call
- Individual call
- Telephone Interconnect Call
- Wireless data: Circuit switch and/or packet data
- Integrated Voice and Data
- Secured network with authentication and encryption

- Direct Mode Operation
- Advanced radio features and capabilities such as Dynamic Grouping, emergency call, etc

And bout Spectrum Utilization, TETRA utilizes Time Division Multiple Access (TDMA) technique to achieve spectrum efficiency. TETRA can achieve up to **4 (four)** TDMA time slots in one 25 KHz radio channel [20].