Basic Radio Awareness

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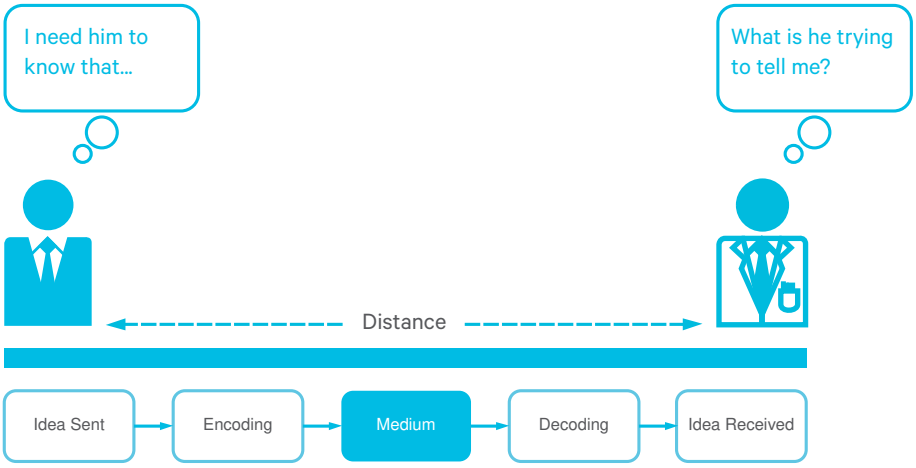
1 Introduction to Radio Communications Principals

1.1 The Process of Communication

Communication relies on transfer of information via a medium.

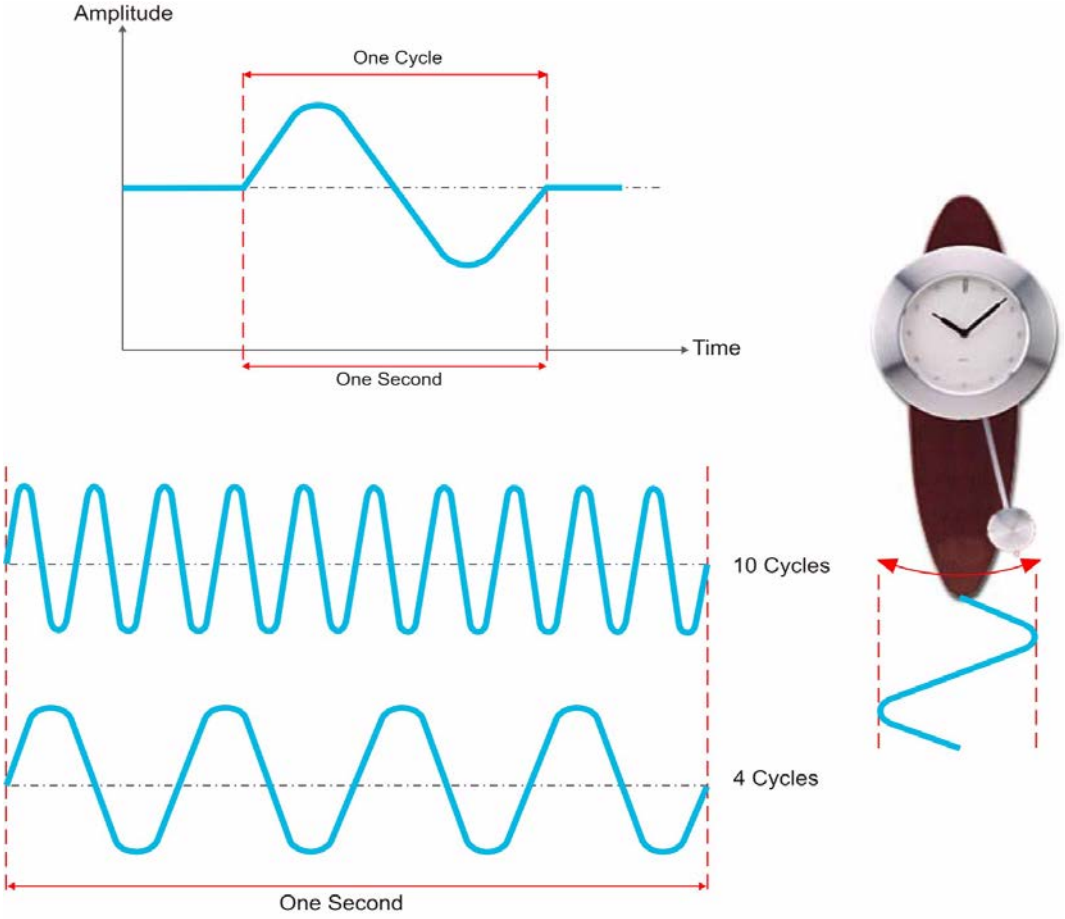


Ideas are usually encoded upon a carrier in some form, for transfer across the medium. Speech, indian drums and smoke signals all use coding of ideas or intentions upon a carrier.

Verbal and visual methods of idea transfer suffer from range and obstruction limitations.

The use of radio waves to transfer ideas allows most obstacles to be overcome, therefore providing long distance communication.

1.2 The Principle of Frequency



Frequency is a rate of activity, measured over a given time.

Examples are:

- A factory that manufactures 200 radios per day.
- A pendulum in a clock is an example of a repeating slow frequency of 1 cycle of swing occurring per second.

A typical sound wave could be 1,000 cycles or air movements per second. Radio frequencies are produced by electrical oscillators, but at a very high rate of millions of cycles per second.

Radio waves can be called electromagnetic waves and as the name implies the wave is made up of two components - magnetic wave combined with the electrical wave.

- The unit for radio frequency (cycles per second) is Hertz (Hz).
- Frequency is inversly related to wave length e.g. the higher the frequency the less the wave length.

1.3 Understanding Radio Frequencies

Because radio frequencies are so fast, special terms are used to indicate large values as a smaller number.

- The term for 1 thousand cycles per second is 1 kilo-Hertz (1kHz).
- The term for 1 million cycles per second is 1 Mega-Hertz (1MHz).
- The term for 1000 million cycles per second is 1 Giga-Hertz (1GHz).
- Other terms are used to categorise frequency bands, namely:
  - VHF (very high frequency) 30 - 300MHz.
  - UHF (ultra high frequency) 300MHz – 3GHz.

Band	Frequency range	Use
ULF	300Hz - 3kHz	Audio range
VLF	3kHz - 30kHz	Under-sea communications
LF	30kHz - 300kHz	Navigational & broadcasting - long wave
MF	300kHz - 3MHz	Local broadcasting - medium wave
HF	3MHz - 30MHz	World-wide broadcasting - short wave
VHF	30MHz- 300MHz	See below
UHF	300MHz - 3GHz	See below

Below is a product chart showing approximate frequency ranges of some of the Tait variants manufactured.

Band	Approx Frequency range	Digital Base Stations	Base Stations	Analog Portables	Digital Portables	Mobiles
		TB9300 TB9400	TB81XX TB9100	TP8100	TP9100 TP9300 TP9400	TM81XX TM9100
VHF	66 - 88MHz	-			-	■
VHF	136 - 174MHz	■	■	■	■	■
VHF	175 - 225MHz	-	■	■	■	■
UHF	340 - 380MHz	-	-	■	-	■
UHF	400 - 520MHz	■	■	■	■	■
UHF	762 - 870MHz 870 - 940MHz	■	■	■	■	■

1.4 Use of Repeaters

As Tait radios are made for VHF or UHF bands, the radio energy travels in nearly straight lines between parties.

Figure 1.1 Simplex

If a large hill is between A and B, communications are disrupted.

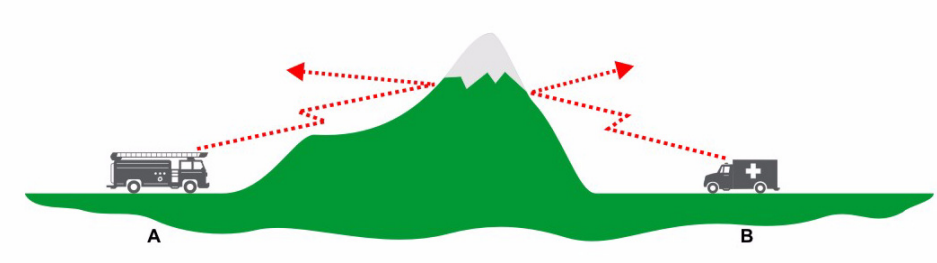


Figure 1.2 Limitation of Simplex

A hilltop repeater system can restore communications by relaying radio traffic between A and B on different frequencies. The site contains a base station receiver, transmitter and aerial system.

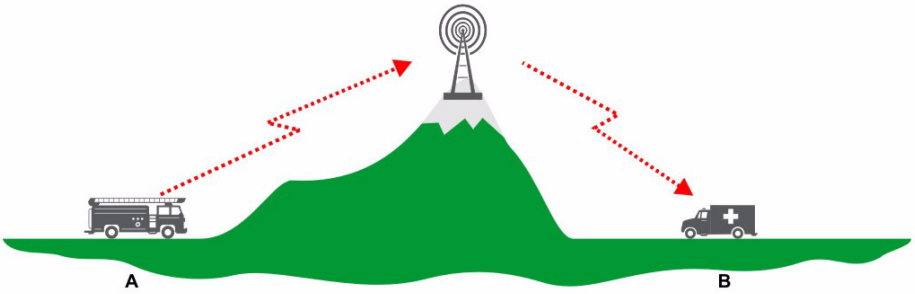
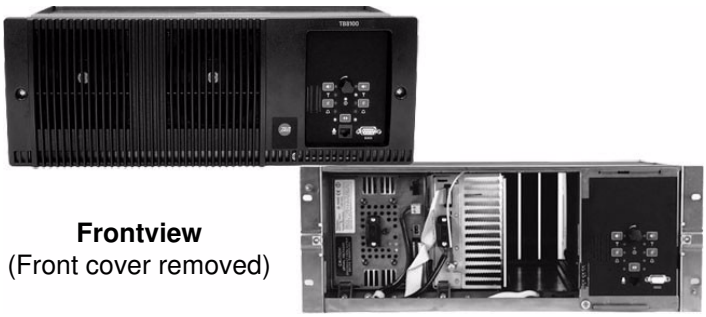


Figure 1.3 Repeaters

Front view



Frontview
(Front cover removed)

Figure 1.4 TB8100 Base Station

1.5 Radio Propagation

At VHF and UHF and above, propagation is line of sight. The transmit frequency of A travels out in a straight line, and out into space if powerful enough.

- To link mobiles A & B beyond the horizon, a satellite could be used, acting much like an overhead repeater system.
- Satellites can use VHF and above, up to about 30GHz.

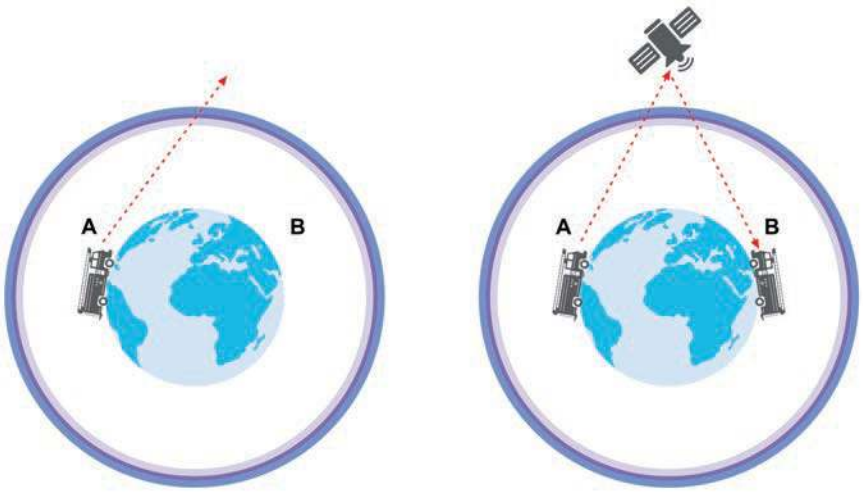


Figure 1.5 Space wave

At lower frequencies, radio waves travel in different ways.

- At MF (300kHz to 3MHz), the wave travels along the surface of the ground from the Transmitter to the Receiver.
- At short-wave frequencies or HF (3 - 30MHz), the wave takes a bouncing path between the earth and the layers of ionised upper-air particles called the Ionosphere.

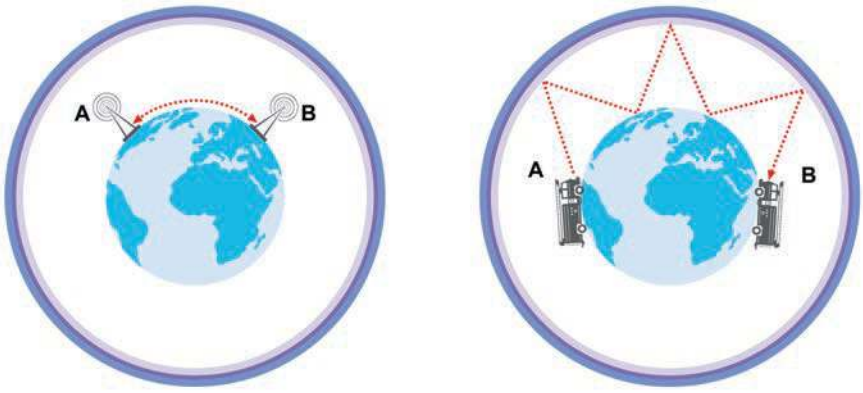


Figure 1.6 Ground and Sky wave

2 Modulation and Radio Building Blocks

2.1 Channel Spacing

Generally, most modern countries conform to a narrow band channel spacing structure for their radio spectrum. This means the channels are spaced 12.5kHz apart.

To operate on a narrow band system, the max deviation of radios is 2.5kHz, so as to not create interference in the adjacent channels of the users.

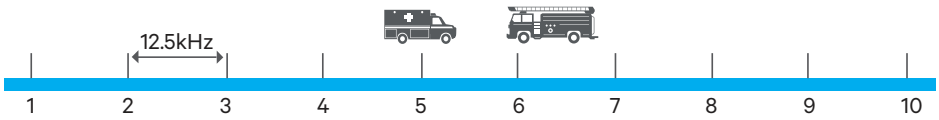


Figure 2.1 Narrow band channel spacing

In less developed countries, the radio spectrum may conform to wide band structure. This means the channels are 25kHz apart, being only half as many channels per kHz as narrow band.

For wide band operation, the maximum deviation is 5kHz to take advantage of the higher deviation before adjacent channel interference.

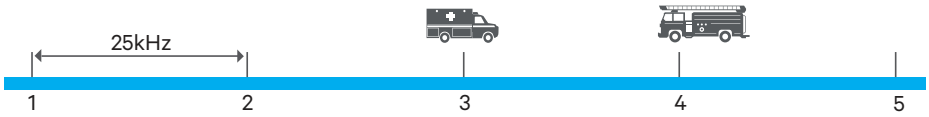


Figure 2.2 Wide band channel spacing

A higher deviation setting can provide an improvement in signal reception in marginal conditions.

For comparison, commercial FM radio stations use 75kHz deviation to ensure the greatest fidelity of the transmitted music and advertisements (this uses 200kHz channel spacing).

2.2 Understanding Modulation

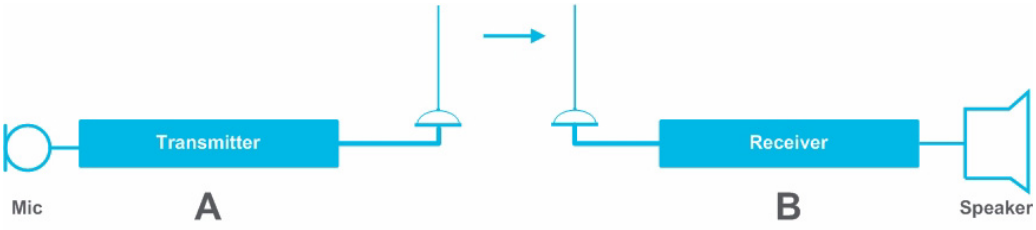


Figure 2.3 Radio frequencies are produced so as to carry speech or data to the recipient's radio.

The process of adding speech or data onto to a radio frequency carrier is called modulation.

The type of modulation used for Tait analog and some digital products is called Frequency Modulation (FM). In FM, the speech or data is carried as cyclic variations in the produced radio frequency, called deviation. Another older modulation system is called Amplitude Modulation (AM), where the output power varies with speech.

Some newer Tait equipment uses a combination of amplitude and frequency modulation. This is called Quadrature Amplitude Modulation (QAM). Digital modulation is used more and more these days. Tait use Time Division Multiple Access (TDMA) for digital communication.

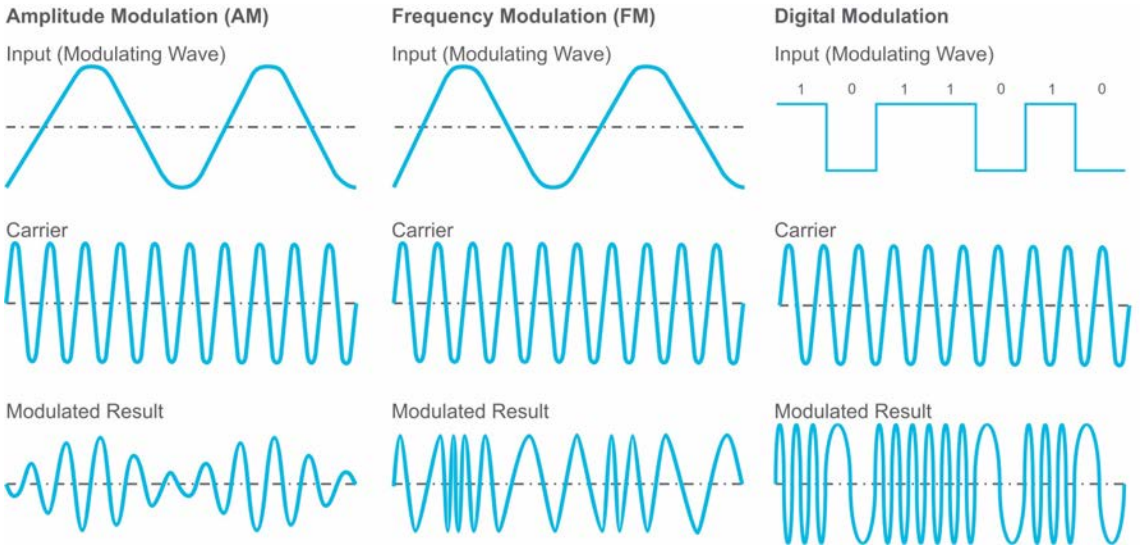


Figure 2.4 AM, FM and Digital modulation

2.3 Generating Frequency Modulation

In Tait radios, the radio frequency is generated by a circuit called a Voltage Controlled Oscillator (VCO). The VCO is made to vary its centre frequency, (deviate) according to the speech or data fed into it. The VCO has only limited tuning range, therefore there is a different model of VCO fitted for each band of radio produced.

A radio may have a centre frequency of 100MHz, with excursions from this value of +/- 4kHz. This means the 100MHz changes from 99.996MHz to 100.004MHz at a rate equal to the speech frequencies.

- +/- 5kHz deviation is called wide band, +/-2.5kHz is narrow band.

The actual speech frequencies fed to the VCO are limited in range to 300Hz – 3kHz, so as to conserve transmitted bandwidth. This is also the same bandwidth as used in a phone system.

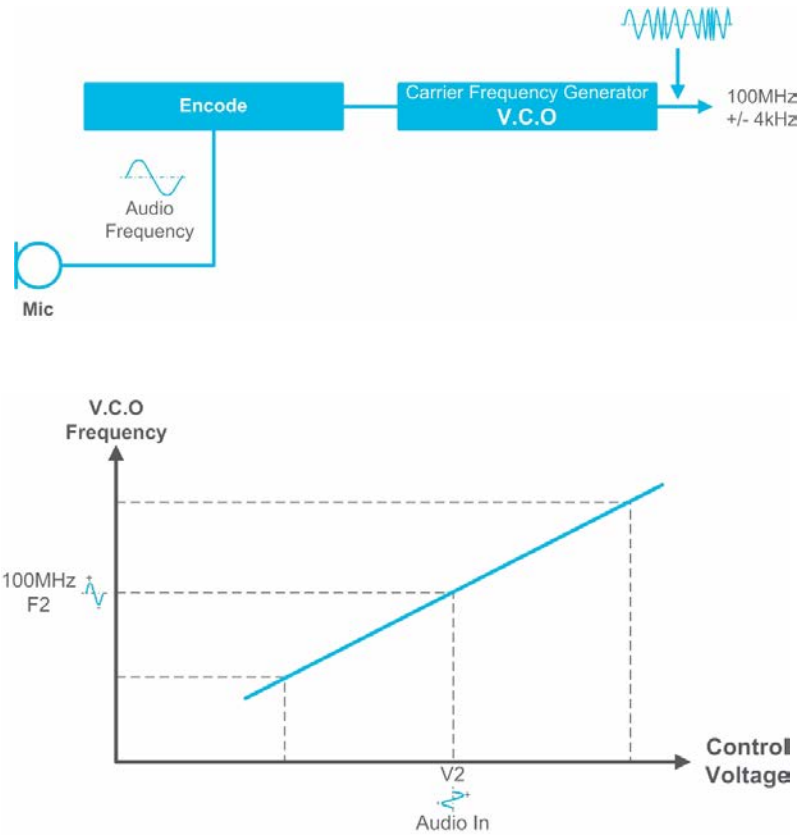


Figure 2.5 Voltage Controlled Oscillator (VCO)

2.4 The FM Transmitter Process

- Generate the selected radio frequency with the VCO.
- Frequency modulate the selected VCO frequency with speech.
- Amplify the VCO power output...
  - In Exciter
  - In Power Amplifier
- Deliver power to aerial.

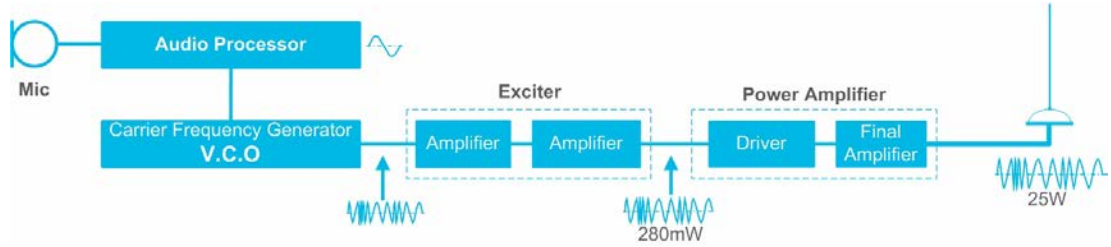


Figure 2.6 FM Transmitter

2.5 The FM Receiver Process

- VCO set to the correct frequency.
- Correct signal frequency is selected.
- Signal is mixed down to a lower frequency, to simplify filtering.
- Signal is further filtered and amplified.
- FM signal is demodulated to extract the speech information.
- Speech audio is amplified to feed a speaker.

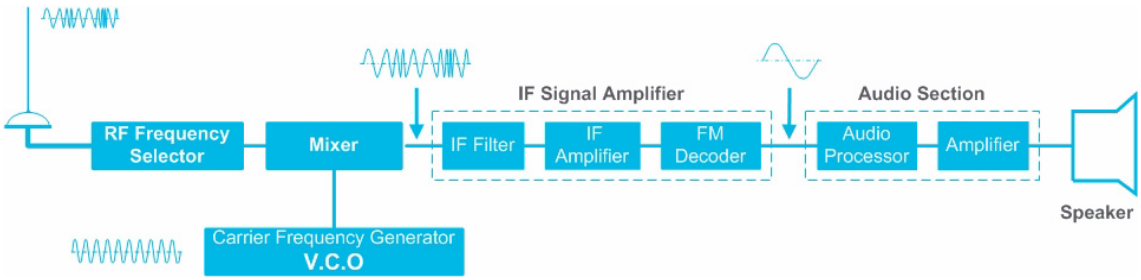


Figure 2.7 FM Receiver

2.6 The FM Transceiver - overview

The radio is essentially a combined Receiver and Transmitter, with frequency control, microprocessor, memory, and a user interface (keypad). This radio can either receive or transmit, but not both at the same time.

The VCO frequency is controlled and stabilised by a synthesiser, which is instructed to operate according to the digital output commands of the microprocessor. The microprocessor is instructed to operate according to the commands of the user, via the radio's control keypad. Frequency information for appropriate channels is stored in memory.

The VCO timeshares between receive and transmit frequency generating duties. The VCO is frequency modulated on transmit, but not on Receive. The antenna also has timeshared duties, via the antenna changeover switch.

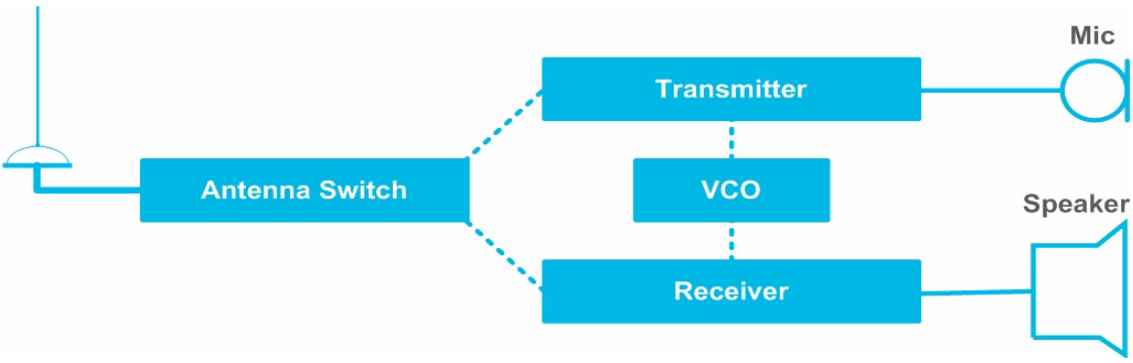


Figure 2.8 Simplified FM Transceiver

2.7 The Digital Transmitter Process

- Analog audio signals are detected by the microphone.
- Audio signals are then digitised by an analog to digital convertor.
- The digitised audio is compressed and encoded to meet the necessary digital radio transmission standards.
- RF carrier is modulated with the digital information.

Figure 2.9 Digital Transmitter

2.8 The Digital Receiver Process

- RF Signal is received and demodulated.
- Digital information is decoded and processed in the vocoder.
- Digital information is converted back to analog audio by a digital to analog converter.
- Speech is amplified to feed a speaker.

Figure 2.10 Digital Receiver

2.9 Access Methods: FDMA or TDMA

With the large-scale migration to digital radio in professional applications well underway regulatory pressures combined with real-world operating needs are driving radio manufacturers and users to communicate more information in a given slice of RF spectrum, in other words, to increase spectrum efficiency.

Two current techniques that are used to achieve this are:

- Dividing the time that each signal occupies the channel using Time-Division Multiple-Access (TDMA)
- Dividing the existing channel bandwidth yet further using FDMA.

FDMA and TDMA are different ways of enabling multiple users access to communication channels. FDMA does this by dividing the available bandwidth into separate RF frequency channels. TDMA subdivides each RF frequency channel into a number of timeslots.

FDMA

Analog and some digital radio standards only carry one conversation per radio frequency. To overcome this limitation of handling one call at a time it is necessary to add additional radio channels at a site to be able to handle multiple simultaneous calls.

This method of allowing a number of simultaneous conversations to take place on different radio frequencies is known as Frequency-Division Multiple-Access (FDMA), and is utilized in most radio communications.

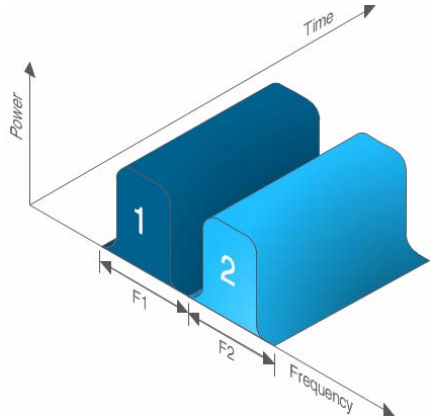


Figure 2.11 Two Channels of FDMA

With FDMA each conversation occupies a specified bandwidth continuously whilst a radio unit is transmitting, for example 12.5kHz narrowband or 25kHz wideband analog FM. In practice it is undesirable (but not impossible) to use adjacent channels at the same base station site.

2.10 TDMA

Time division multiple access (TDMA) is digital transmission technology that allows a number of users "simultaneous" access to a single radio-frequency channel without interference. The TDMA digital transmission scheme allows a number of voice or data signals to be sent over a single radio channel by allocating each user a specific time slot for transmission and reception.
Therefore "simultaneous" access in the case of TDMA is not strictly simultaneous but is actually rapid and repetitive sequential access to a single radio-frequency.

The images below shows a single radio frequency F1 with 2 time slot TDMA. This could represent for example, 2 Mobiles that are all transmitting to a base station on frequency F1, with each user assigned a specific time slot to transmit. Each separate transmission can be "re-assembled" by the base station receiver to recover the two mobiles transmissions as 2 separate conversations.

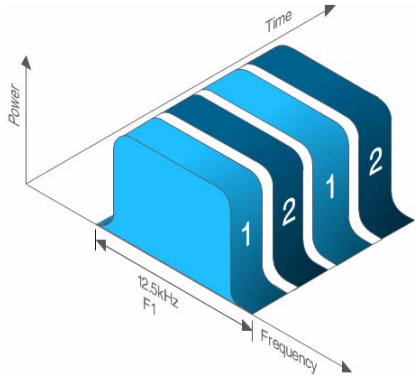


Figure 2.12 Two time slot TDMA

With two time slots as shown in the image above, it is clear that there is still a very limited call capacity. All Digital TDMA radio systems increase call handling capacity by making use of traditional FDMA techniques as shown in the following image. Maximum simultaneous call handling capacity for this scenario is 4.

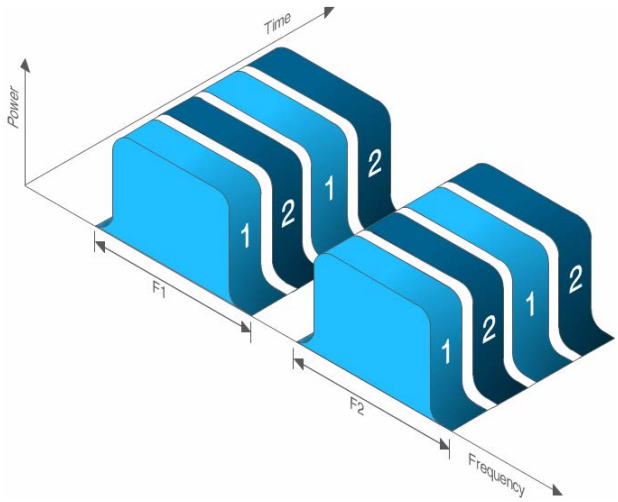


Figure 2.13 2 x Frequencies and 2 x Timeslot = 4 conversations

2.11 Principles of Range and Power

The output power and frequency of a radio affects how far the signal will travel before becoming unusable. Radios convert battery power to radio frequency power.

A TM9000 requires a car battery or desktop power supply in order to operate, as it is a high-powered radio drawing substantial battery power. It has a metal body in order to radiate excess heat generated as a by-product of radio power amplification.

A TP9300 and TP9400 Portables have a small battery, as power drain is lower for the lower power transmitted (5 W). The Portables PA generates little excess heat, so a plastic outer case is used. The aerial can be made physically shorter than the equivalent mobile, which detracts from its radiating performance but is easier to carry.

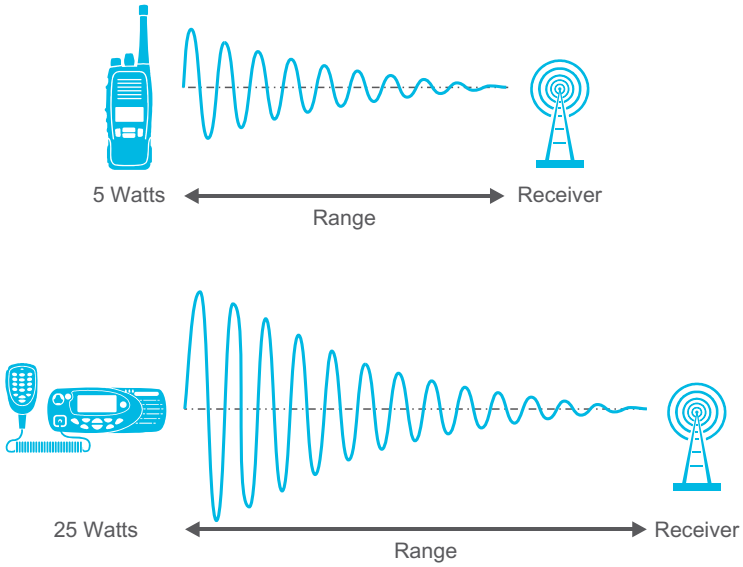


Figure 2.14 Portable and Mobile radio range and power

3 Communications Systems and Tait Offerings

3.1 Conventional Analog System Types

- Base Station TB8100,
- Mobile Terminal TM8000,
- Portable Terminal TP8100

Before modern advances in microprocessor technology, subscribers had to manually select a radio channel to communicate on.

Tait offers a range of conventional system types, from a single repeater to wide-area simulcast / multi-cast networks with similar functionality to older generation solutions. With the addition of advanced features such as scanning and voting, Tait are able to improve and simplify the functionality of these systems for the end users.

3.1.1 Call Screening and Signalling Methods

There are several methods that can be used to identify who is talking or provide privacy between groups or fleets of users sharing a common repeater system. Some examples are given below.

CTCSS

CTCSS (Continuous Tone Controlled Squelch System) uses transmitted sub-audible tones to allow call access to radios tuned to the particular tone transmitted. The CTCSS frequency band is between 67 - 250 Hz. One tone is allocated to a group. It is transmitted during the call but is below the transmitted speech frequency range so is not heard by the radio users.

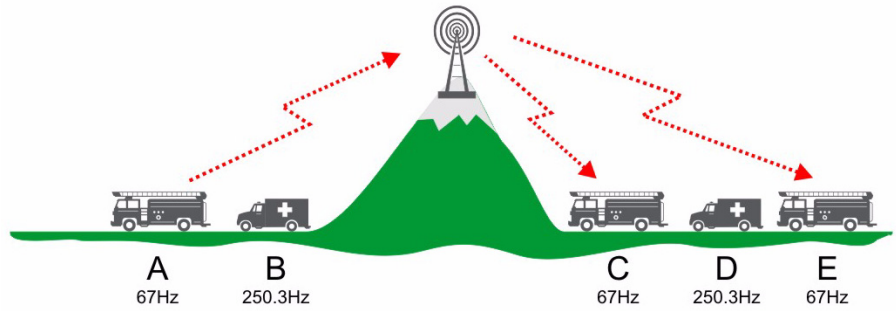


Figure 3.1 Continuous Tone Controlled Squelch System

DCS

DCS (Digital Coded Squelch) is similar to CTCSS but a digital code is transmitted instead of a tone.

SELCALL

SELCALL (Selective calling) uses an audible tone sequence to allow individual access to a particular radio. Each SELCALL tone corresponds to a number, thereby forming a five-digit code. As SELCALL tones are within the audio band, they cannot be transmitted during speech, they are sent either at the start or the end of the call. SELCALL provides the user with facility to dial another specific user of a fleet.

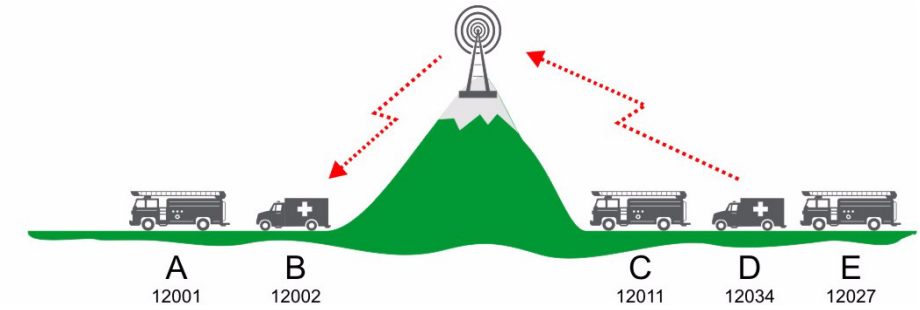


Figure 3.2 Each user has a five-digit selcall code

MDC 1200

MDC1200 offers similar features to SELCALL but uses a short burst of data rather than audio tones to transmit and receive unit identification numbers.

3.1.2 Scanning

If a user has to operate on a number of different repeaters, scanning means they do not have to manually change channel when they enter a new area. Alternativly, scanning allows a user to monitor other channels in addition to the one they are using for communication. When scanning, all channels in the scan group are sampled sequentially and continuously until one is found to contain valid traffic, that channel is then captured and the audio is heard. That channel is held until the conditions are satisfied for scanning to resume. The radio could be configured to allow a PTT to occur on the captured channel or to return to a defaut channel for transmissions.

Priority Scanning:

Allows up to two priority channels to be checked more frequently by scanning them out of sequence on a timed basis. While the scanning has captured a non-priority channel, the priority channels are still regularly tested for activity to ensure that no vital information is lost.

Nuisance Delete:

Allows the user to temporarily remove an undesired channel from the scan group. The removal shall only persist while the scan group remains active.

Scan Group Editing:

Allows the user to edit the members of the scan group from the radio front panel. This is a non-volatile action, and the changes will be saved.

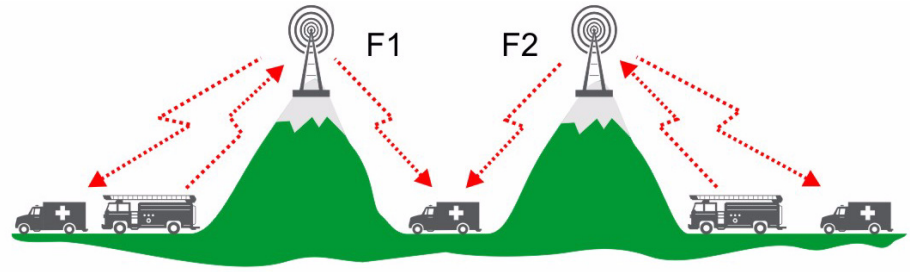


Figure 3.3 Editing scan groups

3.1.3 Voting

Voting is used where a number of different repeaters all carry the same audio. A subscriber unit near one repeater site moving towards a second site will eventually receive a better signal from the second site than from the first site.

Voting in the subscriber unit allows the radio to automatically select from a group of channels the channel that has the best quality audio at any moment so the user will always hear the best signal. In the subscriber units, voting has 3 phases:

- Searching for activity (similar to scanning)
- Measuring the signal strength of all the channels
- Go to the channel with the best signal strength and unmute.

Voting also takes place in the network. Typically in a voted network, all the repeaters receive on the same frequency. When a subscriber unit transmits, voting takes place in the network to choose the receiver that received the best audio and this is retransmitted from all sites.

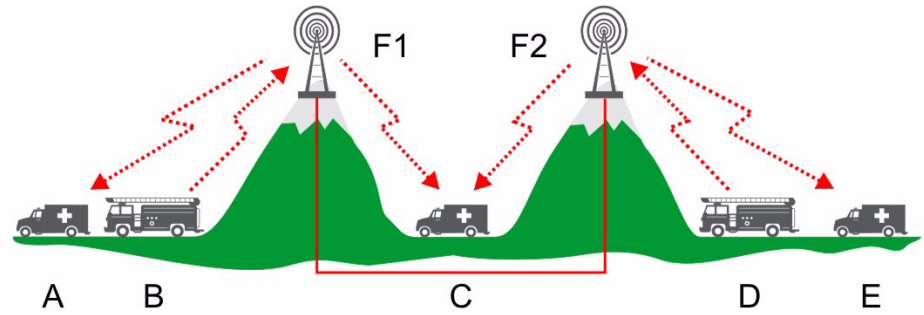


Figure 3.4 The repeaters transmit on different frequencies.

3.1.4 Simulcast

A simulcast network has several base stations transmitting on the same frequency with overlapping coverage areas. A simulcast network is designed so that the base stations time synchronize their transmissions making them all appear like one base station with a large coverage area. Simulcast is an effective way to cover a large area with only one frequency. Tait subscriber units have been designed to operate on simulcast infrastructure and can be configured to receive several non-standard modulation schemes often used on simulcast networks.

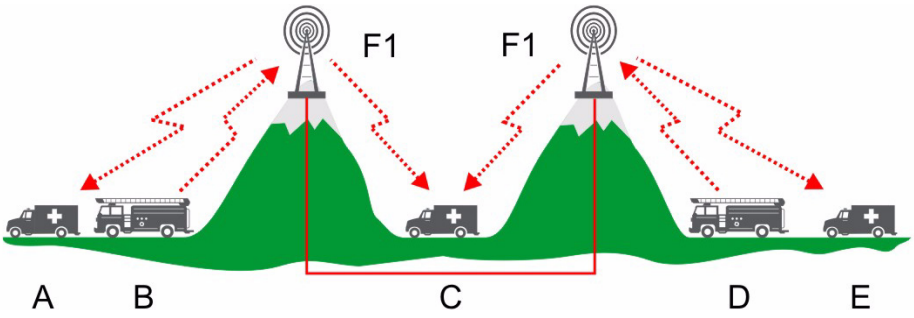


Figure 3.5 The repeaters transmit on the same frequency.

3.2 Trunked System Types

Trunking is an efficient way for a large number of subscribers to share a limited number of channels. Intelligent controllers are added to the system. Instead of selecting a channel, a subscriber simply selects a group (or individual) they wish to communicate with, and the system automatically assigns them to a free channel for each call. The idea works on the principle that not all the groups of users on a network will want to access a channel at the same time so there can be many more groups using a system that the number of repeaters in the system.

3.2.1 Bank Example

This example shows the idea of conventional and trunked operation using a bank as an example.

- The conventional bank tellers can only do one type of transaction or deal with one type of customer. The users can vary throughout the day and in this case most people want to withdraw cash. This means that 5 people are waiting for this type of transaction. There are free tellers but only for specific transactions. This is similar to a conventional radio system where users have to select channels manually.
- The trunked bank tellers can do any type of transaction. The people wanting to make a transaction are sent to the first free teller by the controller. The idea is to maximize the use of all the tellers for best efficiency. The controller in a trunked radio system knows the free channels and tells the mobile radio the frequency to use.

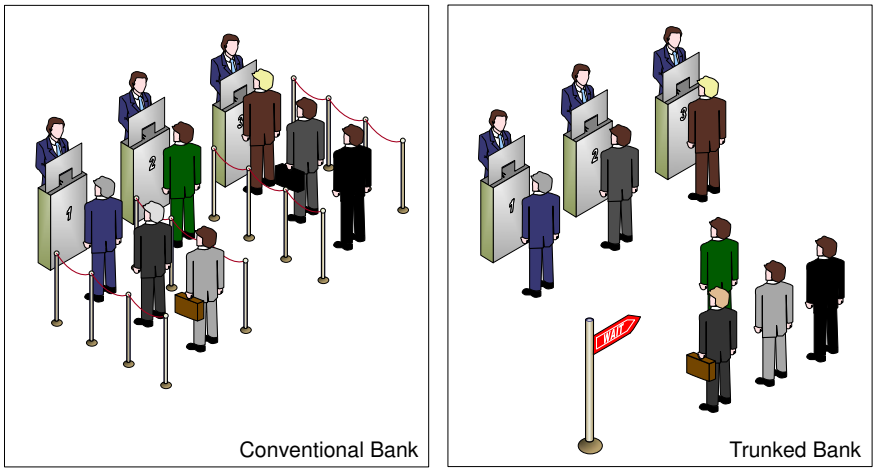


Figure 3.6 The difference between a conventional and a trunked bank

3.2.2 Trunked Radio

Advances in technology provided a break-through in the form of low cost single chip microprocessors. This allowed the concept of trunking to be applied to mobile radio systems. A better name for trunked radio would be “computer aided radio” as it is the application of microprocessors and synthesizers that enables Trunked Radio Systems to share a pool of radio channels between many groups of users. A trunked radio system has:

- A Control Channel that is used to send messages between the trunked system and the subscriber units.
- A number of Traffic Channels used for the voice calls.

Each group of users gets the exclusive use of a Traffic Channel for the duration of their call. No other groups are using the channel at the same time. A call has different meanings depending of the type of trunking:

- In Transmission Trunking a call is a single over (press of the PTT).
- Quasi-Transmission Trunking uses a “Hang Time”. A reply within the hang time is part of the same call and uses the same traffic channel.
- In Message Trunking a call may consist of several overs (a conversation) and continues until one of the users presses a button to end the call. Typically used for individual calls.

To set up a voice call on a trunking system:

- A subscriber presses the PTT and the subscriber unit transmits a call request to the system via the control channel.
- The system sends, via the control channel, a Channel Grant message to the calling subscriber unit and the subscriber unit (or group of subscriber units) that they called.
- All the subscriber units involved in the call then tune to the designated traffic channel and the call takes place.

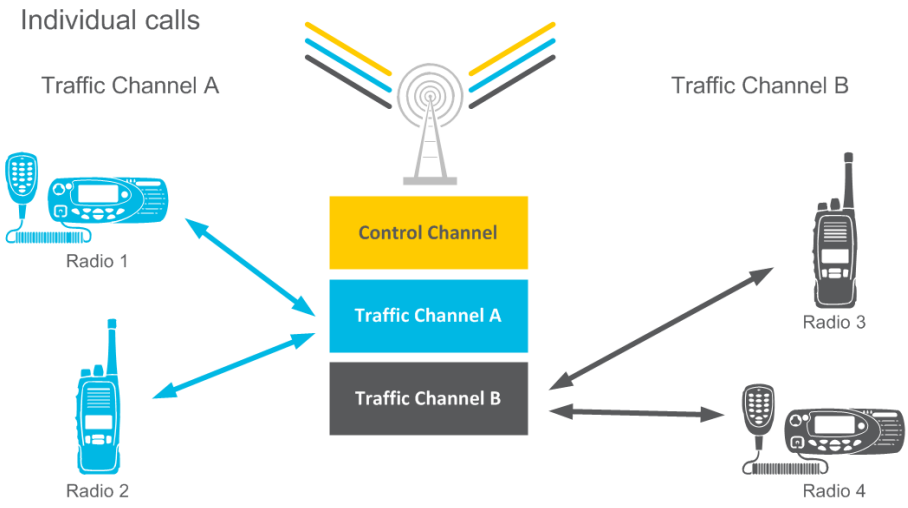


Figure 3.7 Call setup on a trunking system

Advantages of Trunking

- Better utilization of channels.
- Less waiting.
- Privacy because any channel at random can be allocated.
- Mixture of users can use the system.
- The system collates all radio activities for logging and billing purposes.

3.2.3 Single Site Trunking

A trunked site has a control channel and a number of traffic channels. When a subscriber makes a call, the control channel is used by the network to automatically send the caller and the called radio (or group of radios) to a traffic channel. The traffic channel is used for the call. At the end of the call, the subscriber units return to the control channel, and the traffic channel is available for others to use.

3.2.4 Multi-Site Trunking

A trunked system with more than one site. As a subscriber unit moves around the coverage area, it automatically roams from one site to another so it is always listening to the best control channel. If a call involves subscriber units at different sites, a traffic channel is allocated at each site.

3.2.5 Trunked Receiver - Voted System

When portables and mobiles are used on the same system, sometimes the mobiles can make calls where the portables cannot because they transmit with more power. A trunked receiver voted system is a trunked system that has extra sites with receivers only (lower cost) to balance the coverage between portables and mobiles.

3.2.6 Trunked Simulcast System

Where frequencies are scarce, trunking and simulcast can be combined to create trunked sites that cover wide areas by using multiple transmitters on the same frequency in different locations.

3.3 Digital Radio

These are available in the same system schemes as analog radio systemse.g. trunking, simulcast and conventional operation.Tait offer DMR and P25 in the following equipment.

	DMR	P25
Mobile	TM9300	TM9400
Portable	TP9300	TP9100 TP9400
Basestation	TB9300	TB9100 TB9400
Network	TN9300	TN9400

Where are our radios used?

- Public safety - Police, Fire, and Ambulance.
- Utlities - Power companies.
- Transport - Airports, Trains, Busses and Taxis.
- Other - Oil refinaries, Industrial plants, Port authorities.

3.3.1 DMR - Digital Mobile Radio

This is an open European standard adopted and used world wide. DMR uses 12.5kHz channel spacing, and 2 times slots within this 12.5kHz channel spacing, giving 6.25kHz channel equivalency.

Tait are manufacturing Tier II and III Base stations, Portables, and Mobiles. Tier II covers licensed conventional operation and Tier III covers Trunking operation.

Tier I is license free simplex hand portable, low power used in Europe and Tait are not involved with this market.

3.3.2 P25 - Project 25

This is an open standard developed in the USA and has been adopted by the rest of the world. P25 equipment is mainly used by public safety agencies, such as police, fire, and ambulance services. The P25 standard specifies that radios are to be backward compatible with analog systems, thus allowing customers to upgrade their existing analog systems over time.

P25 Phase 1 is in operation now and operates in 12.5kHz channel spacing with Frequency Division Multiple Access (FDMA) system. P25 is utilized for Trunking, Conventional, and Simulcast.

P25 Phase 2 is currently defined for trunked traffic channels only and uses Time Division Multiple Access (TDMA).

3.3.3 Advantages and Disadvantages of Digital Radio

Advantages

- Security - can have voice encryption without loss in range
- Infrastructure has built in IP linking
- Bandwidth reduction
- Background Audio noise reduction right to the end of its range
- Improved services
- Improved battery shift life (handheld portable radio)

Disadvantages

- Introduces audio delay (around 1/2 sec)
- Voice does not quite sound the same as analog and may take some time to get accustomed to
- Audio is clear to the end of range then cuts out abruptly (little warning that communications will be lost)

3.3.4 System Management

To manage and maintain the system TaitEnable offers a set of tools to manage, monitor, protect and report on a radio communications network.

- EnableMonitor: for realtime monitoring of network status, including alarms.
- EnableReport: for performance reporting, and generating reports of network usage
- EnableFleet: for managing the configuration of a fleet of radios, giving control of programming, feature licences, and radio firmware versions.
- EnableProtect:
  - Radio encryption key management and loading
  - Centralized key management
  - Provides read/write protection of radio personalities.