

TETRA Technology Advantages & Benefits

***TETRA Association
Association House
South Park Road
Macclesfield
Sk11 6SH
England***

www.tetramou.com

January 2006

TETRA Technology Advantages & Benefits

The core technologies used in the TETRA standard provide a number of inherent advantages and benefits. These core technologies are:

- *Digital*
- *Trunking*
- *Time Division Multiple Access (TDMA)*

In the following text a description of each technology along with their respective advantages and benefits is provided.

Digital

Nowadays, practically everything electronic uses digital technology and wireless communications are no exception. Even though analogue FM PMR communications will remain a viable option for several years, the move towards digital PMR started over a decade ago and the trend is still rapidly increasing. So why is the world of PMR communications moving from analogue to digital?

The way to answer this question is to compare the relative advantages and disadvantages of analogue and digital in the important performance areas of:

- *Voice Quality*
- *RF Coverage*
- *Non-Voice Services*
- *Security*
- *Cost*
- *Other*

Comparing each of these areas will enable an overall assessment of advantages and disadvantages.

Voice Quality

The characteristics of voice quality are clarity, distortion, noise and end to end transmission delay. Because PMR is a narrow band wireless technology, low bit rate voice coder/decoders (Codecs) operating around 4 kbits/s are used to convert voice signals into a digital code for transmission and then convert the digital code at the receiving end into a representation of the original voice signal. Depending on the type of codec used, the individual characteristics of voice quality can vary.

As a general rule, all codecs will provide constant good quality voice communications throughout the coverage area independent of RF signal strength, simply because digital either works or it doesn't work. As soon as a digital signal is corrupted, such as that caused by severe RF fading conditions, voice quality drops rapidly.

However, analogue will provide high quality voice communication in high signal strength areas but this will gradually degrade down to poor voice quality in low RF signal strength areas.

RF Coverage

The extent of RF coverage is mainly determined by transmitted RF power and receiver sensitivity, combined with the propagation characteristics of the radio frequency being used. Assuming these determining factors are the same between analogue and digital the difference in RF coverage performance should be minimal.

However, the way in which receiver sensitivity is specified in analogue is different than that with digital. For example, the accepted method of specifying analogue receiver sensitivity is the RF signal level required to produce a 20 dB signal to noise ratio, whereas with digital it is the RF signal level at which a particular Bit Error Rate (BER) is exhibited.

The relationship between BER and minimum acceptable voice quality (the receiver sensitivity) is a function of the forward error correction and detection algorithm used to protect the integrity of the voice codec. A pictorial representation of analogue and digital RF coverage performance as well as voice quality performance can be seen in Chart 1.

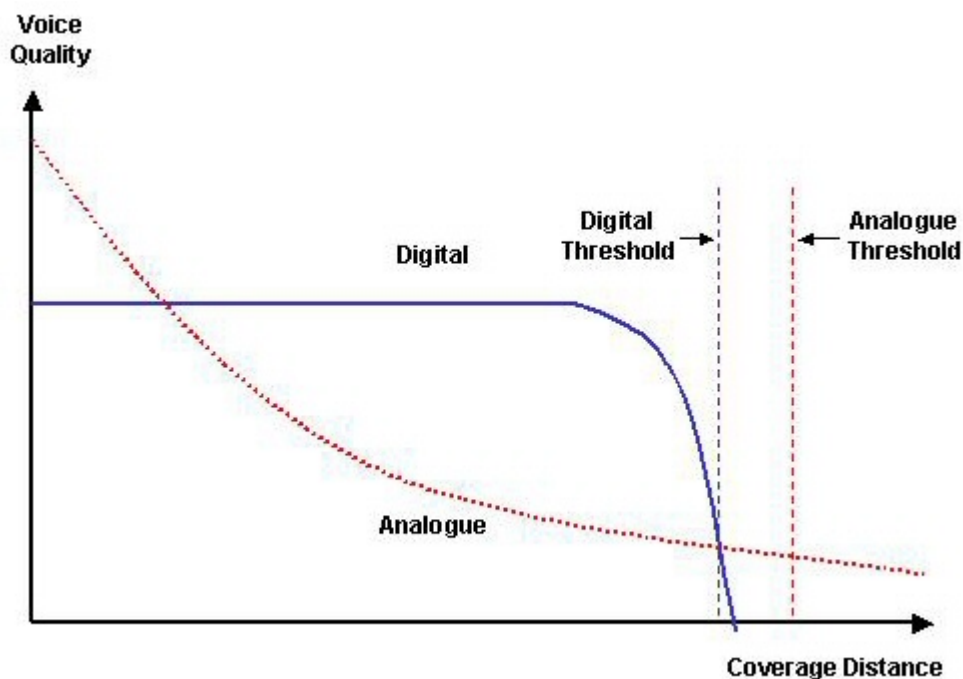


Chart 1: Analogue and Digital RF coverage and Voice Quality Performance

Note: The differences shown in chart 1 are not representative of any particular digital technology and have been provided for general illustration purposes only.

Another factor that affects voice quality is bearer circuits. In a large nation-wide system several hundred km of bearer circuits could be used to connect base stations to switches as well as switches to switches. In some countries analogue bearer circuits are still used which means that communications between users located a large distance apart could experience poor voice quality caused by added noise, variations in signal amplitude and frequency response distortion.

In a digital system all bearer circuits are digital, which means users communicating with each other from opposite ends of the system will experience the same perceived voice quality as users communicating with each other on the same local base station site.

Non-Voice Services

The transmission of digital information in analogue systems is normally carried out using sub-carrier modulation. For example, in MPT1327 Fast Frequency Shift Keying (FFSK) is used to provide a gross data rate of 1200 bits/s resulting in a net data rate of around 600 bits/s after error correction and detection. A typical digital system has a gross data rate of around 8,000 bits/s and a net user rate of around 4,800 bits/s after forward error correction and detection.

Overall, for the same occupied channel bandwidth, digital systems offer a higher data throughput than analogue systems that are primarily designed to carry voice communications. This is mainly because digital systems are designed only for the transmission of digital information, which could be voice and/or data, with no differentiation.

Security

The best form of voice security against eavesdropping is that provided by using digitally encoded voice encryption algorithms, which by nature of being digital make them difficult to employ in analogue systems. As digital systems are designed only for the transmission of digital information, the voice information elements of these transmissions can be digitally encrypted more easily.

Cost

The component cost to build an analogue radio and a digital radio are approximately the same. The main differences affecting cost, which are not technology related, are:

- *Economies of Scale*
- *Competition*
- *Technology Maturity*
- *Life Cycle Cost*
- *Other*

Economies of Scale:

The main factors affecting economies of scale are the size of the market and how well that market is harmonised in both technology and frequency bands. For example, if there was a very large market for one type of technology operating in one globally harmonised frequency band, the economies of scale would be very high. If however, the market was still very large but there were several technology options and several frequency bands to be supported, the economies of scale would be relatively low.

In the case of analogue PMR the market is declining in size but is still relatively large. However, the number of analogue technology options available and the number of frequency bands to be supported are numerous resulting in lower economies of scale compared with digital PMR which is experiencing rapid market growth towards an equally large market but with fewer technology choices and frequency bands.

This means that the size of the digital market will soon exceed that of the analogue market. Also, a large digital market served by only a few different technologies operating in the same harmonised frequency bands will provide greater economies of scale than those being experienced in the analogue market.

Competition:

The larger the market the more suppliers you have competing for business, which results in lower costs to the user. In the case of digital, there are many competing manufacturers looking for business, which has already resulted in a significant drop in terminal prices over the last few years, a trend that is likely to continue as the market grows.

In the case of analogue, particularly technologies such as MPT1327, the number of competing manufacturers is getting less as the market starts to decline. Another factor is that several manufacturers are no longer developing new analogue products because development resources are required for digital technologies.

As a consequence the number of manufacturers serving the analogue market will decrease resulting in price increases until only one remains, at which point the last manufacturer has a small captive market and can demand what price they like for products until the analogue market virtually disappears.

Technology Maturity:

As mentioned previously, most manufacturers are no longer developing new analogue products and the sales revenues they have already obtained from existing analogue products has already covered their development investment. This means that analogue product sales no longer need to consider investment recovery and can therefore be offered at lower prices and still make an acceptable profit.

In the case of digital, product developments are still continuing and are likely to continue for at least another few years until the full portfolio of facilities and services are available. This means that product sales prices need to include a significant portion for investment cost recovery, even though the total investment cost is usually amortised over the projected sales volume for products. As a result, digital products are usually more expensive than analogue products.

However, it is important to note that this only holds true if the sales volumes are the same for both analogue and digital. As sales volumes decline the actual manufacturing cost per product will increase because the fixed manufacturing overhead cost will need to be apportioned against actual product volumes.

Life Cycle Cost:

Typically, a PMR network is expected to have a life cycle of around 15 to 20 years before replacement. Therefore, investing in a technology that has good longevity will minimise the cost of product replacement and/or expansion.

Other:

Because voice signals in digital systems are translated into a digitally coded signal that best represent the voice sample in the codec's reference table, background noises with no recognisable voice characteristics are not usually encoded. This voice codec characteristic means that digital transmissions using low bit rate voice codecs are often immune to background noise. In some cases this can be advantageous such as when operating high noise environments. However, in some operational scenarios the ability for a receiving radio user to hear background sounds that are not voice is considered advantageous.

As this is a general codec characteristic the actual background noise rejection will vary depending on the type of codec used. Also, the actual acoustic design of radio terminals, as well as accessories, will cause differences in performance independent of the codec type employed.

Trunking

Trunking techniques have been used for many years in switched telephone networks. The first trunked mobile radio communication systems were deployed as early the 70s' in North America with proprietary signalling protocols and shortly afterwards in Europe using analogue MPT1327 technology.

The main benefit of trunking is normally seen as spectrum efficiency, or more radio users per RF channel for a given Grade of Service (GoS), brought about by the automatic and dynamic assignment of a small number of communication channels shared amongst a relatively large number of users.

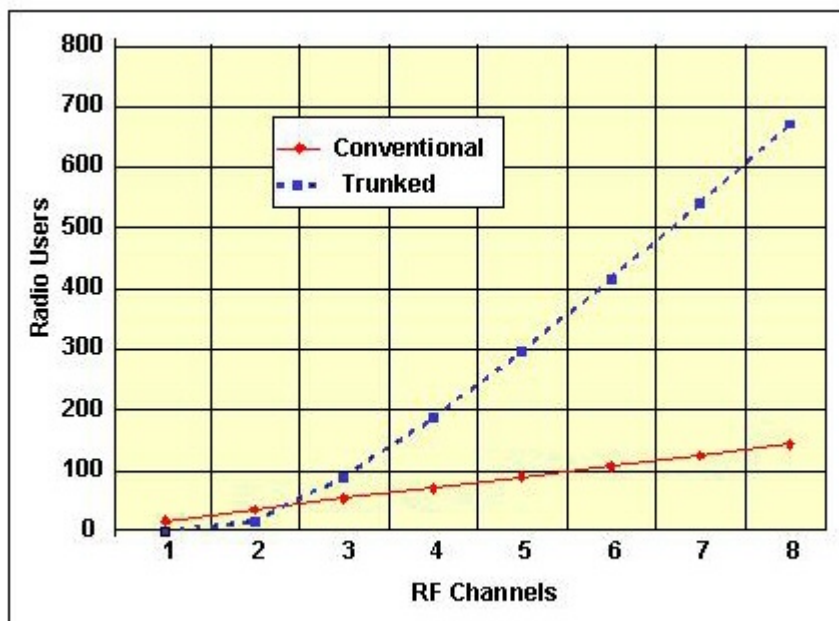


Chart1: Conventional and Trunked Radio User Loading Comparison

Chart 1 compares the number of radio users that can be supported on conventional (non-trunked) and trunked systems using the same numbers of RF channels. The figures indicated are based on 1 call per radio user each of 20 seconds duration during the busy period and a 10% GoS using Erlang C traffic theory.

From chart 1 it can be seen that trunked PMR begins to support more radio users than conventional PMR when three or more RF channels are used (inclusive of a dedicated control channel). Because trunking systems support more radio users than conventional systems, national administrations actively support the deployment of trunking systems as this helps reduce pressure on meeting PMR spectrum demands.

However, from a radio users point of view, spectrum efficiency does not mean anything. What users want is to solve all the operational problems associated with conventional PMR, yet still retain the simplicity of conventional open channel 'all informed net' operation. The fundamental element of trunking that solves these

conventional PMR problems is the use of a control channel to enable the automatic and dynamic assignment of voice traffic channels amongst mobile radio users.

Table 1 below lists the operational problems of conventional PMR and also lists how trunking solves these problems.

Conventional PMR Problem	Trunking Solution
Contention	All call requests are handled on the control channel for immediate call processing or in order of queue priority if the system is busy.
Manual Switching of Channels	Automatic cell handover takes away the need for manual channel selection
Inefficient Channel Utilisation	The automatic and dynamic assignment of a small number of communication channels shared amongst a relatively large number of users ensures an equal grade of service for all radio users on the system.
Lack of Privacy	The dynamic and random allocation of channels makes it more difficult for a casual eavesdropper to monitor conversations.
Radio User Abuse	Abuse is minimised as the identity of all radio users and the time and duration of messages are known and can therefore be easily traced to the abuser.

Table 1: Conventional PMR problems solved by Trunking

It is important to note that the operational simplicity of conventional PMR ‘all informed net’ talk group communications is still retained by employing fast call set-up “Push To Talk” (PTT) operation on radio terminals.

Additional Services and Facilities

As the control channel acts as a signalling communications link between the Trunking Controller and all mobile radio terminals operating on the system, the Trunking Controller knows the status of the system at any moment in time as well as its historic usage, which is stored in its memory. For example, the Trunking Controller knows:

- *The individual and group identity of all radio units registered on the system*
- *The individual identity and time radio units registered on the system*
- *The individual identity and time radio units de-registered from the system*
- *The individual and group identity, time and duration of all messages*

With additional intelligence in both the radio terminals and the trunking controller the advantages and benefits of trunking can be increased. For example, the length

of the control channel signalling messages can be increased by a set amount to accommodate a variety of new services and facilities. Also, the trunking controller can be programmed to handle calls in a variety of ways as required by the operator of the system.

Trunking Disadvantages

So far, only the numerous advantages and benefits of trunking have been highlighted compared with conventional PMR. To ensure an overall and balanced assessment it would be beneficial to also understand the main disadvantages of trunking.

Relatively Expensive

The most significant disadvantage of trunking is that it is more expensive than a conventional system using an equivalent number of RF channels and base station sites. This is because the intelligence needed in a trunking system requires the additional use of microprocessors in terminals as well as computers in both trunking controllers and system controllers. Also, the software programmes needed to operate a trunking system require extensive development effort, a cost that needs to be recovered in the sale of equipment.

Not Cost Effective for Low Capacity

Since trunking uses the automatic and dynamic assignment of a small number of communication channels shared amongst a relatively large number of users, trunking is only suitable for relatively large capacity networks requiring on average three or more channels at each base station site. This means that trunking is not cost effective, and is also wasteful of frequency spectrum, for systems supporting a relatively low number of radio users.

Increased Complexity

Because microprocessors and computers are used in trunking systems, the rich portfolio of facilities and services that can be made available often increase the operational complexity of terminals compared with conventional PMR, even though the operational disadvantages of conventional PMR have been solved.

Time Division Multiple Access (TDMA)

Four time slot TDMA technology was adopted in TETRA as it offered the optimum solution to balance the cost of equipment with that of supporting the services and facilities required by user organisations for a medium to high capacity network providing single site local RF coverage and/or multiple site wide area RF coverage. A diagrammatic representation of the TDMA time slot structure used in TETRA is shown in figure 1.

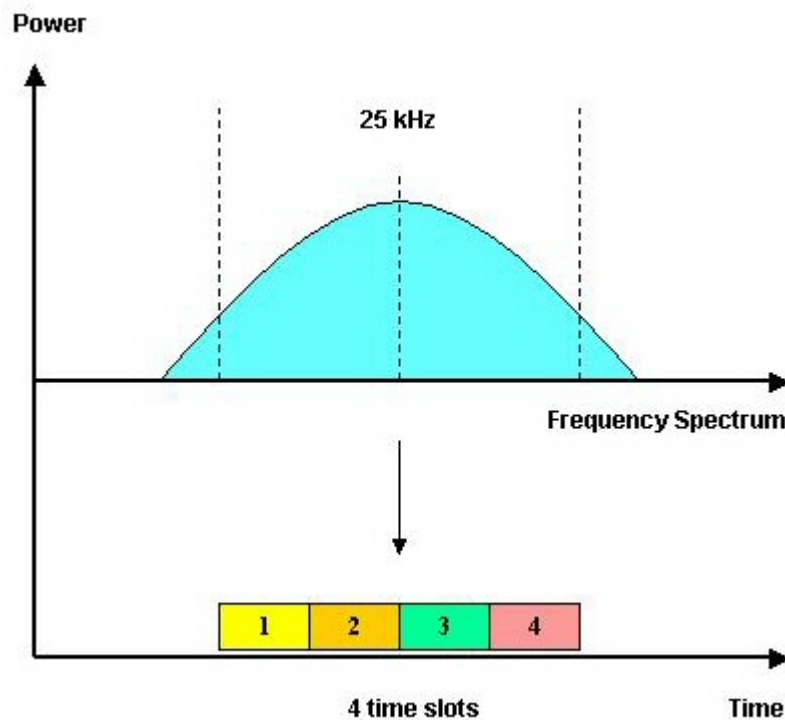


Figure 1: TETRA TDMA Time Slot Structure

RF Spectrum efficiency is a combination of three main factors being the occupied bandwidth per communication channel, the frequency re-use factor determined by the Carrier to Interference protection ratio C/I in dB's and the trunking technology used. As previously mentioned TETRA utilises the latest in trunking technology. Also, as can be seen in the diagram, the TDMA technology used in TETRA provides 4 independent communications channels in a 25 kHz RF bandwidth Channel, making it twice as efficient in occupied bandwidth terms as a traditional 12.5 kHz RF bandwidth FDMA channel. Although FDMA technologies tend to have a better C/I performance than TDMA TETRA, the overall spectrum efficiency advantage lies with TETRA, especially for medium to high capacity networks.

Because trunking is employed to increase network capacity and/or RF spectrum efficiency (for a given Grade of Service) the cost and equipment space at base station site can be significantly reduced compared with traditional FDMA technology trunking solutions. For example, the diagram in figure 2 clearly shows how these space and cost benefits can be achieved by comparing the base station equipment requirement for a TDMA and FDMA 4 channel trunked Community Repeater (COMREP).

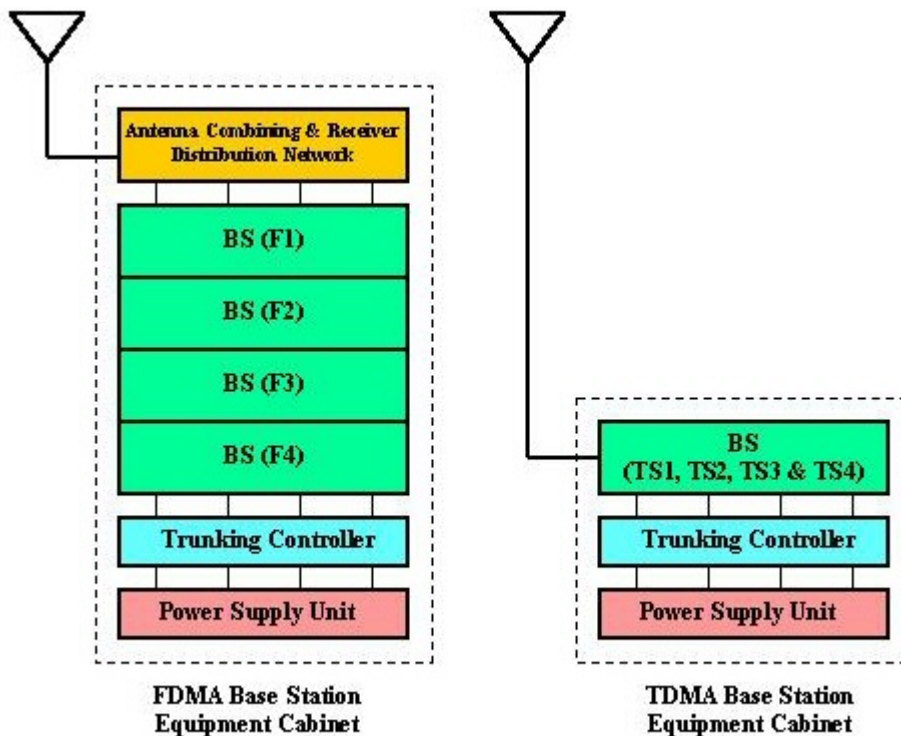


Figure 2: Typical FDMA and TDMA 4 Channel COMPREP Configuration

From the base station equipment configuration in figure 2 it can be seen that the FDMA solution requires 4 separate transceivers where as the TDMA solution only requires 1 transceiver. As a consequence, the FDMA solution requires a transmitter antenna combining and receiver splitting network to enable single transmit and receive antenna working. Also, the RF power output of the FDMA transmitters will need to be higher in order to compensate for transmission losses in the transmit antenna combining network. Because 4 slot TDMA already supports four independent communication paths, no antenna combining equipment is required, thereby saving space as well as cost.

Another advantage of TDMA technology is that it enables new services and facilities to be supported with minimum cost. Some examples are:

Higher Data Rates

The 'laws of physics' limits the maximum data rate in a given RF channel bandwidth. Assuming the same modulation scheme, the wider the channel bandwidth the higher the data rate. Because TDMA uses wider channels than FDMA, the combined data rate on a single RF carrier is greater.

Improved Data Throughput in Poor RF Signal Conditions

The net data rate in TDMA is better than FDMA in poor RF propagation conditions. This is because Automatic Repeat Requests (ARQ's) are required when received data is corrupted as a result of RF fading. As TDMA terminal devices effectively

operate in full duplex ARQ's can be sent efficiently after each time slot transmission if required. As FDMA terminals operate mainly in simplex (either transmit or receive), any ARQ scheme employed will require a transmission interrupt to allow ARQ's to be received, which dependent on the number of interrupts employed can be very inefficient.

Bandwidth on Demand

In TDMA any number of time slots up to the maximum limit of the technology being employed can be combined to increase data throughput as required for specific applications.

Concurrent Voice and Data

Because of the TDMA time slot structure it is possible to assign one time slot to support voice and the next time slot to support data in a two slot transmission from radio terminals. This capability effectively allows a single radio terminal to concurrently transmit or receiver voice and data at the same time.

Full duplex Voice Communications

TDMA technology inherently supports full duplex communications. Although full duplex voice communications can be supported on FDMA systems the need for duplex operation requires RF screening between the transmitter and receiver and also a duplexer to allow single antenna working. Because of this, duplex FDMA radio terminals are usually bulkier and more costly to produce than TDMA terminals, which do not need RF screening or antenna duplexers.

In summary, TETRA's 4 time slot TDMA technology offers the optimum solution, which balances the cost of equipment with that of supporting the services and facilities required by user organisations for a medium to high capacity network providing single site local RF coverage and/or multiple site wide area RF coverage.