White Paper

Comparison of DMR and TETRA

Current and predicted future functionality

This paper provides a comparison between two European Telecommunications Standards Institute (ETSI) open standards for digital radio: Digital Mobile Radio (DMR) and Terrestrial Trunked Radio (TETRA).

The paper examines the features and functionality of each of the technologies, as they exist in the drafted standards. It will also compare what products are available in the marketplace, and what products and developments are expected in the future.

TETRA is already a mature and well supported standard that is well suited to the needs of the emergency services and other 'mission critical' purposes, as well as professional users. DMR, on the other hand, is still developing, and it remains to be seen whether manufacturers will support the variety of modes that are likely to emerge. What DMR does provide today is a solution for the consumer and commercial user starting from the lower end of the scale.

The middle ground – business critical and general business use in the lower categories – is where both standards are vying for customers. And although this means more choice for users, it may also mean more confusion about the options available.

The DMR standard

History

The work on DMR in ETSI started in 2003, and replaced the Digital Information Interchange Signalling (DIIS) work. The aim of DIIS was a new digital radio standard for professional business radio users, providing low-complexity two-way radios with mobiles, portables and base stations. This work stalled in 2003/2004, and did not come to fruition due to IPR problems and commercial deadlock. The DMR standard has been developed within Task Group (TG) DMR, which is under the Technical Body EMC and Radio Spectrum Matters (ERM). Its target was the 'licence-exempt' and 'licensed' professional mobile radio (PMR) market. There are a number of PMR manufacturers involved in the standards activity.

DMR is intended to be a digital replacement for conventional analogue PMR radios, as well as shared repeater systems and MPT 1327 trunked radio systems. The DMR standard was first published in 2005, and has had a number of maintenance updates. Equipment became available in the marketplace from mid 2007 onwards.

DMR characteristics

There are several levels of the DMR standard. DMR is divided into three tiers.

Tier	Description
Tier I: Unlicensed	DMR equipment having an integral antenna and working in direct mode (communication without infrastructure)
Tier II: Licensed, Conventional	DMR systems operating under individual spectrum licences working in direct mode or using a base station (BS) as a repeater
Tier III: Licensed, Trunked	DMR trunking systems under individual spectrum licences operating with a controller function that automatically regulates the communications

Figure 1: Overview of DMR tiers [Source: Analysys Mason]

In practice, the DMR standard currently covers Tiers I, II and III. A separate standard, created by the same group, and known as dPMR, provides, at the moment, only a Tier I solution. Both Tier I DMR and dPMR standards, which are for unlicensed use, operate with a maximum power of 500mW, and use frequency division multiple access (FDMA), with respectively a 12.5KHz and 6.25KHz channel. They are intended as a replacement for PMR 446. PMR 446 is a part of the UHF radio frequency range that is open without licensing for personal usage in most countries of the European Union.

All DMR tiers have a channel bandwidth of 12.5kHz, and two-slot time-division multiple access (TDMA) is used. The standard is designed so that DMR channels can directly replace existing 12.5kHz channels, and fit within the existing emission mask. This provides a capability to migrate from 12.5kHz analogue channels to DMR, with a two-fold improvement in channel efficiency, within a user's existing channel assignments.

For readers interested in the technical characteristics, the air interface operates at a transmission rate of 9,600bps (4,800 symbols/s), with a 4FSK constant envelope modulation, which gives two bits per symbol. Each voice burst in the two-slot TDMA carrier provides a 'vocoder socket' for 2 × 108 bits vocoder payload to carry 60 ms of compressed speech The constant envelope modulation makes the design of the radio r.f. components easier.

DMR is expected to operate on any frequency between 30MHz and 1GHz, but will mainly be used in 68MHz to 87.5MHz, 146MHz to 174MHz and 400MHz to 470MHz. These are the traditional PMR bands.

The 4FSK modulation used is designed to meet both European and Federal Communications Commission (FCC) emission masks.

DMR services

DMR is capable of carrying both voice and packet data protocol services; earlier analogue solutions, such as MPT 1327, have support for voice and circuit mode data, but not packet data.

Voice services include:

- Individual Call (point to point)
- Group Call (point to multipoint)
- All Call (one-way voice call to all users)
- Broadcast (one-way group call).

Individual and Group Calls can operate in Open Voice Channel Mode (this replicates the conventional open channel mode users are familiar with, and allows them to monitor and participate in voice channel activity). They can also have talking party identification and late entry. Individual calls can be Press and Talk Call Set Up (PATCS) and Off Air Call Set Up (OACSU), which checks the called party's radio is available before allocating a channel.

Individual calls can be duplex, using the two-slot TDMA mechanism. This gives the user the appearance of a full duplex call without the radio having to transmit and receive at the same time, which increases complexity. This feature is also available in the four-slot TETRA TDMA system, but is more challenging in a two-slot TDMA system and is not commonly implemented in current DMR terminals.

Data services include:

- IP Packet Data (confirmed and unconfirmed – also known as acknowledged/unacknowledged), IPv4
- short data services carried over Packet Data Protocol (PDP) – these can be Free text, Status/Pre-coded (which are coded messages), pre-defined data types, such as ASCII, or raw data (unformatted).

Data services can be either single or dual slot. The data rates when using two slots will be double the rates when using only one slot. With an air interface data rate of 9,600 bits/second for both channels, protected data rates per slot will be no greater than 2,400 bits/second, and is typically 1,800 bits/second.

The DMR Tier III trunking standard aims to provide a low-complexity trunked solution for voice and data applications. The use of two-slot TDMA means the minimum can be a single site with one r.f. channel carrying two logical channels (for example, one control and one traffic). Control channels can be dedicated or composite (shared between control and traffic), and use a slotted aloha random access mechanism.

The codec is not standardised within the ETSI standard, but the 'vocoder socket' (format of vocoder payload) is, so any vocoder has to be compatible with the air interface. However, the advanced multi-band excitation (AMBE) vocoder from Digital Voice Systems, Inc. (DVSI) has been selected by the DMR MoU group as the preferred vocoder for interoperability. Since there are other codecs being advertised as suitable for DMR – especially the Robust Advanced Low Complexity Waveform Interpolation (RALCWI) CML Microcircuits codec – this weakens the interoperability position. At the moment, equipment on the marketplace uses only the DVSI AMBE vocoder.

Encryption is not part of the standard. The use of TDMA and a digital codec will make monitoring of the signal more difficult than analogue, and encryption could be added as an external/terminal application. Again, this may result in interoperability issues. A fixed key version of encryption is today available in equipment on the marketplace.

The TETRA standard

History

TETRA is an open digital trunked radio standard defined by ETSI to meet the needs of the PMR user. The standard was defined during the 1990s and equipment became available in the marketplace from 1997 onwards, with many contracts delivered from 2000. Since 2000 there have been updates to the standard, which have increased the functionality, in particular the TETRA Enhanced Data Services (TEDS) work.

Early TETRA committees had both manufacturers and potential users, including a strong contingent of public safety users, who drove the specification to provide a standard that was suitable for the marketplace. This included testing the codec for high noise environments, ensuring the encryption was suitable for the range of public safety users, and the features developed by suppliers were those needed by the users. The Working Group WG1 is led by users, and continues to examine requirements before they are passed to the other technical working groups.

An important part of TETRA is the Interoperability Process (IOP), which is managed by the TETRA Association, and provides test sessions where suppliers check terminals against infrastructure, so that users can be sure there is genuine interoperability. This interoperability testing also applies to Direct Mode, where terminals from one supplier are tested for compatibility with terminals from another supplier.

TETRA characteristics

TETRA is a TDMA technology with four timeslots in a 25kHz bandwidth. There are preferred bands where equipment is available: 380–400MHz, 410–430MHz and 450–470MHz. However, equipment is available for other bands, including the 300–344MHz band in Russia, the 350–370MHz band in China, and the 805–870MHz band, which is often available for users outside the EU.

TETRA uses a pi/4 Differential Quadrature Phase Shift Keying (DQPSK) modulation, with a bit rate of 36kbit/s. pi/4 DQPSK is a four-level modulation scheme, which means that the data rate on the r.f. channel is 18 ksymbol/s (2 bits per symbol). The modulation signal does not go through the zero crossing point, making it a robust modulation. This assists in the reduction of out of band emissions, and the design of the linear power amplifier.

The gross bit rate is 36kbit/s, with 7.2kbit/s per TDMA channel (the difference between 28.8kbit/s (4*7.2) and 36kbit/s is an overhead of the TDMA structure). Speech uses an ACELP codec with a data rate of 4.4kbit/s and protection of 2.8kbit/s, while data rates for a timeslot are 7.2kbit/s unprotected, 4.8kbit/s medium protection and 2.4kbit/s high protection. Timeslots can be concatenated to allow higher data rates, up to 28.8kbit/s unprotected, 19.2kbit/s with medium protection or 9.6kbit/s with high protection. In practice, most systems do not use the unprotected data rate, but instead use 4.8kbit/s medium protection.

The ACELP codec was optimised for use in a high noise environment, and evaluated with sirens and gunshots, to ensure it would be suitable for typical public safety usage. The codec is standardised, and is part of the TETRA standard.

Services

TETRA has a wide range of services, including the services essential for public safety, such as:

- Individual (point to point) with hook or direct call signalling
- Group (point to multipoint)
- Pre-emptive Priority
- Late Entry
- Wide-area Group Call, with restriction on coverage of a group
- Dynamic Group Number Assignment
- Ambience Listening
- Discreet Listening
- Air Interface Encryption, and provision for end-to-end encryption.

It also has a number of services important to the public access mobile radio (PAMR) user:

- call forwarding
- call barring.

Other features which are common to both public safety and PAMR users are:

- full duplex voice calls (without any r.f. duplexer in the radio terminal and inherent in the TDMA protocol)
- direct mode unit to unit calls
- mobile equipments used as Repeaters (Direct Mode to Direct Mode) or Gateways (Direct Mode to Trunked Mode)
- fast call set up (sub 300-500ms)
- status, short data and IP packet data services (single and multi-slot)
- data call concurrent with a voice call.

Comparison and products available

Comparison of the standards

TETRA is recognised to be primarily for 'mission critical' applications, and an increasing number of 'business critical' applications. The term 'mission critical' is used rather than 'public safety', since there is an increasing number of users – transportation and utilities, for example – where a highly resilient system is required, although there may not be a direct impact on traditional public safety. There are also now a number of users who are commercial users.

DMR is targeted to be for 'business critical' applications. This is a level below 'mission critical', and is for users who need reliable communications, but do not need, or want to pay for, very high levels of availability.

While TETRA is a trunked radio system, DMR has a number of tiers (or flavours). This extends the number of applications where the standard can be used from consumer and commercial uses, through to different professional modes, from the construction and haulage industry, through to more critical and complex uses in public safety. This can be seen in Figure 2 below.

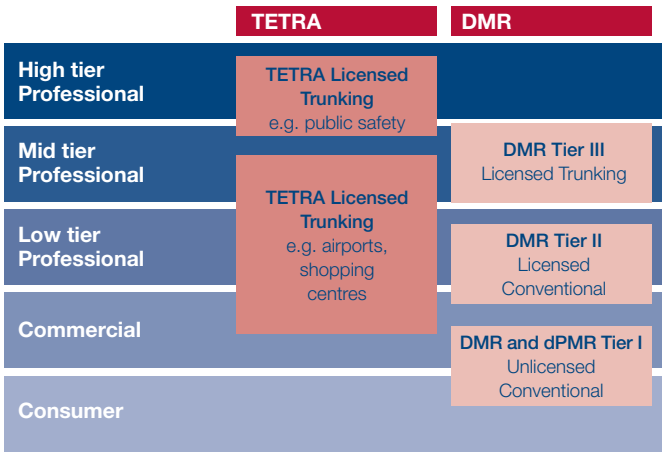

Figure 2: There is significant overlap between TETRA and DMR in the lower to mid professional tiers [Source: Analysys Mason]

TETRA is not suitable for the consumer, and early systems did not appeal to the commercial and lower tier professional users mainly because of the high cost of the early systems which were targeted at large regional/national public safety systems. There are now smaller capacity systems, and systems with distributed processing, as opposed to systems with a large central switch, which are selling into markets such as shopping centres and airports. There are single site system requirements which need a full feature set including data, and TETRA is positioned to compete here with DMT Tier II. TETRA has generally not been successful in providing PAMR services

Figure 2 shows that the standards are complementary for the lower tiers of DMR, but that there is overlap and competition between TETRA and the higher tiers of DMR. For example, a TETRA solution for a shopping centre would be in direct competition with a Tier III DMR solution. Such competition that gives end users choice is healthy.

One significant differentiator between the standards could be spectrum. If a low or mid tier professional user has existing 12.5kHz spectrum, they may struggle to obtain suitable 2 kHz spectrum allocations which are required for TETRA, but be able to deploy DMR without having to change their spectrum allocations. Note that if they have contiguous 12.5kHz spectrum they may be able to use it in 25 kHz channel assignments for TETRA.

Products available

DMR products

At the consumer end of the market there are dPMR licence-exempt handportable equipments. These operate on 6.25kHz FDMA, and often have 16 digital channels and eight analogue channels (operating in the PMR 446 band). At this time, Icom, a Japanese supplier of PMR terminals, is the only supplier with a radio on the market in Tier I, but a number of other suppliers of such products are involved in the DMR standards creation activity.

Motorola offers the MOTOTRBO product range of Tier II products, including handportables, mobiles and a repeater. Selex is offering the ECOS-D simulcast system, which includes a network of Tier II base stations, and badged Motorola equipment. Tait has said it intends to produce DMR Tier III equipment (which will also support Tier II). HYT is a new Chinese supplier of TETRA terminals, and has announced plans to have DMR terminals available during 2009. Other suppliers who are active in the DMR/dPMR standardisation activities include Fylde Microsystems, CML, CTE International, Kenwood and Vertex Standard.

DMR Tier II products have been sold in the UK to solutions such as logistics (warehousing) for Boots Ltd and a shopping centre in Cumbernauld, Scotland. There have been up to 200,000 radio terminals sold worldwide. There are a lot of application developers producing applications suitable for DMR.

TETRA products

There is a wide range of TETRA products available at the current time. These include infrastructure products, which range from small systems that can control fewer than 10 sites, to scalable systems that can cover a complete country. These systems can be centralised or distributed control. One of the largest systems to date is the Airwave system in the UK, with over 3,000 sites and over 200,000 subscribers. One of the smallest systems is North Sydney Hospital with a single base station and 12 terminals.

There are many suppliers making terminals, and these have a fast development cycle. First generation TETRA terminals were large, with short battery life. Current terminals are now third or fourth generation, and smaller, with built in GPS and colour screens, and longer battery life. More than thirty terminals have been launched in the last three years. The users being targeted are generally the professional user, who has a need for a very robust reliable radio, so while some users would like a very small terminal similar to a modern phone, with perhaps a hinged or extending unit, this market is small and not served at present. There are a number of covert radios, but these tend to be designed to be hidden, with remote controls, rather than small cellphone style. There are also a small number of Intrinsically Safe (IS) radios, for use in hazardous environments.

There is still a need for vehicular radios, although the majority of terminals sold are portable.

There is now a TETRA PDA device, and a number of people integrating the TETRA radio with a portable computer, to provide data capabilities. Some suppliers are considering developing TEDS (TETRA Enhanced Data Services is discussed in the following section) only data terminals.

Recently, a number of Far East manufacturers have either launched TETRA products, or are planning to develop TETRA products. These radios are coming from suppliers active in the PMR markets, could be lower cost compared to the professional high tier product, and better suited from a price perspective for use in the mid and low tier professional systems.

Developments and future products

DMR

There is a work item in the DMR standards committee to develop an FDMA version (based upon the FDMA modulation in the current Tier I dPMR standard TS 102 490) of the current TDMA Tier II/III standard (DMR standard specification number TS 102 361) on the basis that this can offer a less complex and hence lower cost alternative. The dPMR specification number TS 102 490 was specifically for peer-to-peer operation with a channel spacing of 6.25kHz FDMA, had an e.r.p. of 500mW, and was licence exempt. The new FDMA variant (specification number TS 102 658), will operate with a channel spacing of 6.25kHz, but will be suitable for licensed bands and provide the so-called dPMR Modes 1, 2 and 3 which provide peer-to-peer licensed, as well as repeater (simple and complex) operation. Effectively dPMR Mode 1 is equivalent to DMR Tier II (peer to peer), dPMR Mode 2 is equivalent to DMR Tier II (Low complexity repeater) and dPMR Mode 3 is equivalent to DMR Tier III (High throughput repeater/trunked).

Once this is developed, there will be both dPMR FDMA and DMR 2-slot TDMA options for DMR, with three Modes, giving six (seven if unlicensed dPMR is included) different options for users. There will be three ETSI specifications in place. It remains to be seen if the market will support all these DMR/dPMR variations, or whether manufacturers will only develop specific pieces of the standard. It is believed that most suppliers will continue with the TDMA standard, and there will be limited supplier development of the FDMA standard.

		TDMA(DMR) (12.5kHz)	FDMA (dPMR) (6.25kHz)
Peer to peer	Tier I (Unlicensed)	TS 102 361	TS 102 490
	Mode 1		TS 102 658
	(Unlicensed)Tier II	TS 102 361	
Simple repeater	Tier II	TS 102 361	
	Mode 2		TS 102 658
Managed repeater (trunked)	Tier III	TS 102 361	
	Mode 3		TS 102 658

Figure 3: The different DMR Standard specification document numbers [Source: Analysys Mason]

It is anticipated that future DMR products will be developed at both the low end of the market, and the top end, based on developments to date.

MPT 1327 is a trunked standard which is still viable, with active developments. There are still MPT 1327 trunked systems being sold to a range of users, including the low and mid tier professional users. Tier III of DMR is a logical successor for these, although TETRA is a direct competitor here. As more spectrum becomes tradable, and the cost to the user increases, the efficiency of a 6.25 kHz equivalent technology (compared to 12.5kHz), whether it is FDMA two-slot TDMA (DMR) or four-slot TDMA (TETRA), becomes increasingly attractive.

It is difficult to predict what the impact of parallel FDMA and TDMA DMR systems will have, and whether the market will support both variants. There is a distinct risk that the parallel standards will fragment the market and cause confusion.

TETRA

The TETRA standard is mature, but continues to be maintained by the various sub groups, and to be developed with additional functionality. This has been the case with Location Information Protocol (LIP) and Net Assist Protocol (NAP), which are both air interface optimised applications for location services.

Users and suppliers identified a number of areas where the TETRA standard would benefit from enhancements, and these were given the name TETRA Release 2. Part of the work under TETRA2 has been to:

- extend the working range of the air interface, for ground air/rural telephone and linear network applications
- develop alternative codecs, for interoperability with cellular and military users (this work is suspended at this time)
- develop a wide band data solution. This is known as TETRA Enhanced Data Services (TEDS).

For Germany there have been developments in the use of a SIM card (from TETRA SIM to U-SIM).

The most significant work done under TETRA2 is TEDS. The TEDS development work to the TETRA Air Interface has provided the capability for moderate, but significant, increases in data speed. These have been achieved by increases in channel bandwidth and increased modulation complexity. Data rates achievable are up to 160kbit/s using 64QAM in a 50kHz channel, and up to 538kbit/s with 64QAM in a 150kHz channel. These data rates are not as fast as the enhanced 3G data rates, such as HSDPA, but are better than GPRS. The bonus is that TEDS is integrated into the TETRA standard, and will provide mission critical data for professional users, with wide area capabilities and encryption.

The next terminal developments in TETRA will be to incorporate the TEDS air interface. This is likely to be in stages, with support for the 50kHz channel bandwidth initially, and then data terminals supporting the full TEDS standard. There will be improvements in the hand-held terminal size and weight.

In the infrastructure products, the emphasis will be on systems that are able to meet the smaller system size requirements. There is an increase in TETRA solutions for transportation and utilities, including oil and gas production, and often these will be smaller systems.

This is where there could be an increasing overlap between TETRA and DMR. One example would be a system for the security staff in a large shopping mall, where both technologies could meet the requirement. Another would be a system for a regional bus operator or transport executive (PTE), to provide emergency voice communications and travel information for a bus fleet.

Conclusion

ETSI has developed two standards for mobile radio users, as distinct from cellular users, which cover the whole range of applications, from the PMR 446 licence-exempt use for consumers and some business users, through the general business user (such as a hotel or shopping centre), and the business critical user (such as a bus operator) to the mission critical user (such as a police force). These standards are DMR and TETRA.

While TETRA is now a mature technology, with a competitive supplier market driving more infrastructure and terminal solutions, DMR products from a similar range of suppliers are still to be developed. However, there is no reason to believe a healthy competitive supplier environment will not develop.

TTETRA does not provide a solution for the consumer and this is covered by the dPMR (license exempt) equipment. Small commercial users such as a building site or local plumbing company may not be able to justify a 25kHz TDMA solution like TETRA (on cost or spectrum grounds), and these user categories are covered by DMR.

TETRA clearly meets the requirements for the mission critical user, and DMR does not. From a standards point of view the lack of authentication/encryption, Stun/Kill, Key Management and a standardised vocoder optimised for high noise environments, and no design target of minimum call set up times in the user requirement, makes DMR unsuitable for this category of user.

However, there are a wide range of business critical and general business users, in the low and medium tier professional user category, where both standards are suitable. On a case-by-case basis, either TETRA or DMR may be the best match for the user requirements, and the costs could vary depending on the precise solution.

For example, an oil production company may not need encryption, but will need intrinsically safe radios. At the moment TETRA will meet its requirements, while DMR will not. On the other hand, a shopping centre which has only 10 or 20 security staff using a four-slot TDMA TETRA radio scheme would be very inefficient in its spectrum usage, while a single Tier II DMR repeater could easily meet the user requirements.

This means that for the professional user, there will be more choice, and a wider range of solutions which better match their requirements, in terms of features and cost. Ultimately, this is good news for these business radio users.

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Glossary	
Term	**Gloss**
bps	Bits per second – measurement of transmission rate
DIIS	Digital Information Interchange Signalling – previous standard targeting digital radio standard for professional business radio users
DMR	Digital Mobile Radio – standard targeting licence-exempt and licensed professional mobile radio market
dPMR	A standard created by the DMR working group, which details an FDMA licence exempt solution
DQPSK	Differential Quadrature Phase Shift Keying – robust modulation used by the TETRA standard
ERM	EMC and Radio Spectrum Matters – an ETSI Technical Committee (TC)
ETSI	European Telecommunications Standards Institute – a recognised European Standards Organisation, generating globally applicable standards for ICT
FCC	Federal Communications Commission – the US government agency responsible for regulating interstate and international communications (radio, television, wire, satellite and cable)
FDMA	Frequency division multiple access – a system where access to the radio channel is divided into discrete frequencies, and the user uses a specific frequency
FSK	Frequency-shift keying – type of modulation for DMR air interface that provides two bits per symbol
IOP	Interoperability Process – test sessions run by the TETRA Association for suppliers to check terminals against infrastructure
IS	Intrinsically Safe – a means of ensuring a radio terminal can be operated in a hazardous environment, where explosive vapour may be present
LIP	Location Information Protocol – air interface optimised application for location services
MPT 1327	Signalling standard for trunked private land mobile radio systems
NAP	Net Assist Protocol – air interface optimised application for location services
OACSU	Off Air Call Set Up – a call set up mechanism where the system checks for the presence of the called party radio, before allocating a channel
PAMR	Public Access Mobile Radio – a shared access radio network used for commercial purposes
PATCS	Press and Talk Call Set Up – a call set up mechanism where the user presses a button, and is then allocated a channel
PDA	Personal digital assistant – a handheld computer device
PDP	Packet Data Protocol – a means of sending data where the data to be sent is broken down into short packets
PMR	Professional mobile radio – a radio communication network used by professional or commercial users
QAM	Quadrature amplitude modulation – a modulation scheme which passes data by changing the amplitude of two signals
r.f.	Radio frequency
TDMA	Time-division multiple access – a system where access to the radio channel is divided into time slots, and users operate in specific slots
TEDS	TETRA Enhanced Data Services – this update adds a wide band data capability to TETRA
TETRA	Terrestrial Trunked Radio – an European open digital trunked radio standard defined by ETSI for the PMR market
TETRA2	Second release of TETRA (2005), incorporating a number of enhancements, including TEDS
TG	Task Group – an ETSI standards group reporting into a technical committee

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