BENEFITS AND FEATURES OF DMR

White Paper

Executive Summary

DMR products have many advantages over other digital public or land mobile radio technologies (PMR/LMR) targeted at the business critical and commercial sectors. As well as being able to match or better the existing features of analogue radios, the use of a two slot TDMA (Time Division Multiple Access) protocol results in DMR giving simple and effective scalability, energy efficiency, cost efficiency and a rich new set of features. DMR also brings the range and audio clarity benefits of digital radio communication.

DMR is particularly well suited to the addition of new voice or data services because it doubles capacity in existing licensed channels. In particular, when new business-enhancing data applications are introduced, with DMR there is no impact on existing voice quality of service - a well known issue due to the “chatty” spectrum hungry nature of many data applications. Moreover, DMR systems add this extra capacity at no cost to the user.

Other commercial digital systems bring benefits but not the full range of advantages of DMR. Moreover DMR is an open European Telecommunications Standards Institute (ETSI) standard backed by many leading radio manufacturers, component suppliers and others. As a result buyers can have confidence in long term supply and the benefits of competition-driven feature development, supplier responsiveness and market pricing.

DMR is the smart long-term choice for radio professionals.

Table of Contents

Executive Summary 2
Introduction 4
History and Design of DMR 4
Benefits of DMR 5
1. Predictable doubling of capacity in existing 12.5 kHz licensed channels 5
2. DMR delivers backwards spectrum compatibility with legacy analogue systems 09
3. Efficient use of infrastructure equipment 10
4. Longer battery life and greater power efficiency 11
5. Ease of use of and creation of data applications 12
6. System flexibility through simultaneous use of TDMA channels 13
7. Advanced control features 13
8. Superior audio performance 13
9. Security of supply through a fully open, well established, widely backed standard 15
The DMR Standard and Services 15
1. ETSI DMR standard 15
2. Three tiers in the DMR standard 15
3. DMR services 16
Key Technical Parameters 17
1. TDMA 17
2. Modulation 17
3. TDMA structure 18
4. Basic channel types 19
5. Packet data protocol (PDP) 20
6. Vocoder 21
Conclusion 21

Introduction

The introduction of digital PMR products is bringing great benefits to the users of professional radio. It is however, bringing a degree of complexity in that there are many different types of digital radio protocols now on offer – DMR, dPMR, NXDN, TETRA, P25 – some standardised and some proprietary. None of these protocols are compatible with each other and all bring different attributes to the table. All, however, are more efficient in terms of use of spectrum and also improve voice quality at the edges of a coverage area, when compared to analogue systems due to the efficiencies of digital processing.

It is important that the user understands some basic differences in systems technology in order to make the right choice. Some differences in specific products are the result of the way different vendors have implemented features. Other differences are due to fundamental differences in the underlying technology used by the protocol. These underlying differences impact system scalability, power efficiency, feature possibilities and both access to and use of spectrum.

Broadly speaking there are two underlying technologies to the various protocols; TDMA - used by DMR, TETRA and P25 Phase 2 - and 6.25 kHz FDMA (Frequency Division Multiple Access) - used by NXDN and dPMR. TDMA divides up spectrum using timeslots; user A gets a few milliseconds of access to the bandwidth, then its user B’s turn. FDMA, in contrast divides spectrum into discreet channels; user A has 100% use of a small slice of spectrum and user B has 100% use of another small slice of spectrum. There are a number of consequences of these two approaches.

DMR uses TDMA and many of its advantages come from this choice. The advantages of DMR are discussed in more detail in this paper.

History and Design of DMR

Compared to other radio technologies such as those used in cellular phone systems, public mobile radio has been very late coming to the digital table. This has had pros and cons for the PMR user community. One of the pros is that those involved in developing digital PMR standards were able to look at the technical developments and deployments that had taken place in other fields and to work out which best suited the needs of the PMR community.

The DMR standard was ratified in 2005 and has many benefits in comparison to legacy analogue systems and to other digital approaches. The designers of DMR looked at the market requirements and opted to use TDMA as the underlying technology for the standard as it delivers some very clear benefits.

In outline these are:

• Predictable doubling of capacity in existing 12.5 kHz licensed channels
• Backwards spectrum compatibility with legacy analogue systems
• Efficient use of infrastructure equipment
• Longer battery life and greater power efficiency
• Ease of use and creation of data applications
• System flexibility through simultaneous voice and data calls
• Advanced control features
• Superior audio performance compared to analogue (also applies to dPMR)

In addition, through following an open standardisation process with a globally recognised standards body, ETSI, the backers of DMR chose to create a standard open to any organisation to give users the best chance of long term security of equipment supply and other open standard benefits derived from open competition. The rapid user uptake and expanding number of suppliers of DMR products has vindicated the early decisions of the community behind DMR.

This paper looks at the benefits of DMR, summarises the services available and gives a brief description of the main technical parameters.

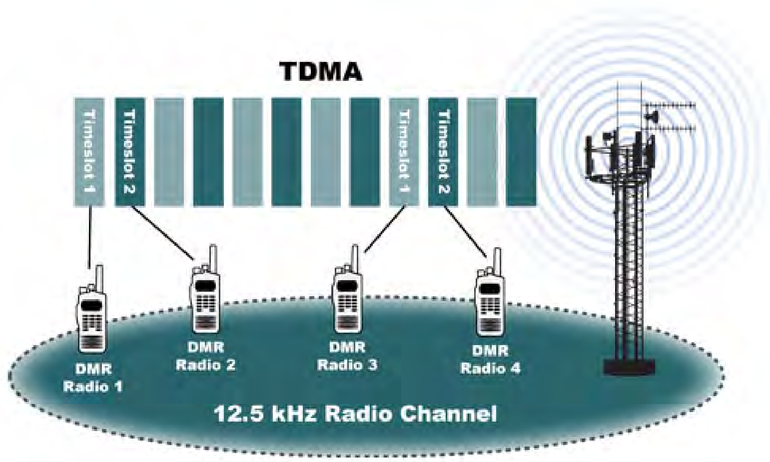
Benefits of DMR

1. Predictable doubling of capacity in existing 12.5 kHz licensed channels

One of the principle benefits of DMR is that it enables a single 12.5 kHz channel to support two simultaneous and independent calls, achieved using TDMA.

Under the DMR standard, TDMA retains the 12.5 kHz channel width and divides it into two alternating timeslots A and B (illustrated in Diagram 1 below) where each timeslot acts as a separate communication path. In Diagram 1 Radios 1 and 3 are talking on timeslot 1 and Radios 2 and 4 are talking on timeslot 2.

Diagram 1: Showing Two Timeslot TDMA structure of DMR

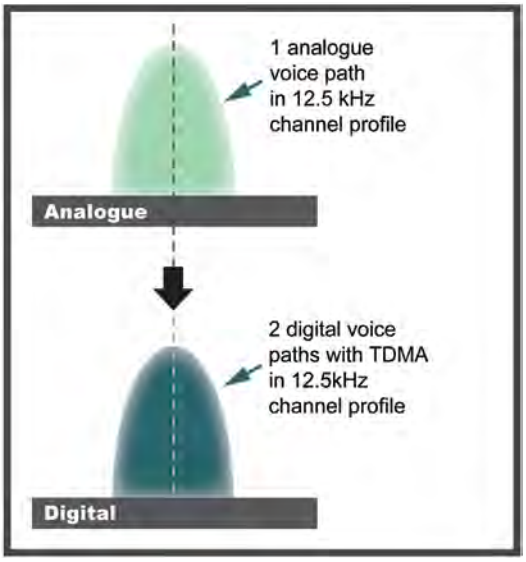


In this arrangement each communication path is active for half of the time in 12.5 kHz of bandwidth and so each uses an equivalent bandwidth of half x 12.5 kHz or 6.25 kHz . This is known as having an efficiency of one talk path per 6.25 kHz of spectrum, but with DMR the channel as a whole maintains the same profile as an analogue 12.5 kHz signal.

This enables DMR radios to operate in a licence holder's existing 12.5 kHz or 25 kHz channels meaning there is no need for re-banding or re-licensing but at the same time doubling the capacity of the channel. This is illustrated in Diagram 2 below.

This TDMA approach to increasing call capacity in a given bandwidth is very well tried and tested. TETRA and GSM cellular mobile – two of the world's most widely adopted two-way radio communication technologies - are TDMA systems. The US public safety radio standard, P25, is also currently evolving its Phase 2 specifications to two-timeslot TDMA.

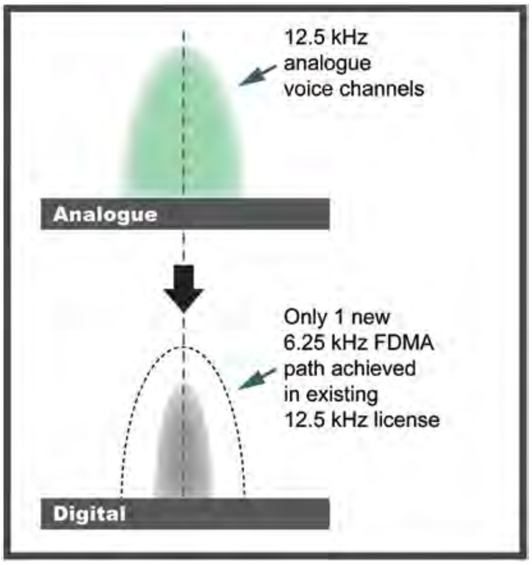
Diagram 2: Analogue to digital migration with DMR systems



The alternative approach to increasing capacity is to split 12.5 kHz or 25 kHz channels into two or more discreet 6.25 kHz channels, known as FDMA. Radios that are able to able to talk in 6.25 kHz FDMA are then theoretically able to squeeze two new channels side by side in an old 12.5 kHz channel.

The practical reality is different. In many countries no specific 6.25 kHz licences exist and the regulatory regime does not permit a licence holder to operate two 6.25 kHz channels in an existing 12.5 kHz licence. It is usually, however, possible to operate with a single 6.25 kHz radio channel within a 12.5 kHz licence but no increase in capacity is achieved for the user. This situation is illustrated in Diagram 3 below.

Diagram 3: Analogue to digital migration using 6.25 kHz digital FDMA channel



In the United States, where licensed 6.25 kHz channels are available, licence holders have not been permitted to sub-divide existing 12.5 kHz licences into multiple 6.25 kHz channels. So to increase capacity for 6.25 kHz FDMA systems, users have to seek new 6.25 kHz licences in other areas of the spectrum[1]. Even in jurisdictions where a user is allowed to squeeze two 6.25 kHz paths into an existing 12.5 kHz licensed channel, this may cause problems. Operating a system at one site using two channels that are adjacent to each other in the spectrum is well known to create a risk of interference[2]. One issue is that of "near-far interference" where the wanted signal received at a base station repeater from a "far" subscriber near the limit of its range is made unintelligible by interference from a "near" subscriber in the adjacent channel.

This near-far problem can be particularly significant in deployments where portables at the edges of their coverage area need to communicate to a base station/repeater on one frequency (f1) when higher power mobiles are transmitting close to the base/repeater station on the adjacent channel (f2). In these cases the weak inbound communications from the far portables on f1 are likely to be subject to interference from the near mobiles operating at a higher power on f2. This is shown in Diagram 4 Scenario 1 below.
Where adjacent channels are used by two base stations close to each other, but not at the same site, a similar problem can arise. In Diagram 4 Scenario 2 below, a remote portable receiving on f1 from the blue base station is subject to interference while in the proximity of the red base station transmitting on the adjacent channel, f2.

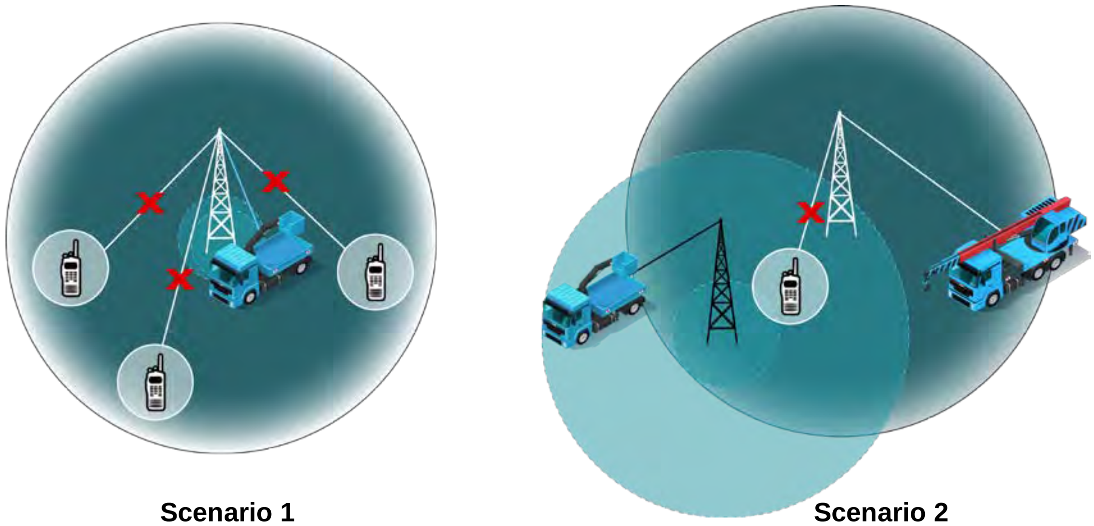
These types of near-far interference will be determined by a number of factors that will change dynamically but the overall impact is to bring engineering complexity to a deployment with such an adjacent channel configuration.

---

1 See DMR Association White Paper on US Narrowbanding

2 See ITU-R Recommendation SM.337-6 for the recommended method for calculating frequency and distance separations of radio equipment

Diagram 4: Near far interference with adjacent channels



Additionally, where two 6.25 kHz channels are created by splitting an existing 12.5 kHz channel into two, there is a risk that intermodulation products produced by two 6.25 kHz transmitters (e.g. base stations at a fixed site) operating simultaneously in the new channels will cause interference to the surrounding channels.

Let's look into a practical example of two 6.25 kHz transmitters co-sited using a 12.5 kHz channel:

- f1= frequency of the first transmitter
- f2= frequency of the second transmitter
- f2=f1+6.25 kHz

The third order intermodulation products generated by this arrangement are the following:

- IM31 = 2f1 +/- f2 and IM32 = 2f2 +/- f1

We are interested only to know the IM products that are close to the channel and can simplify the calculation to:

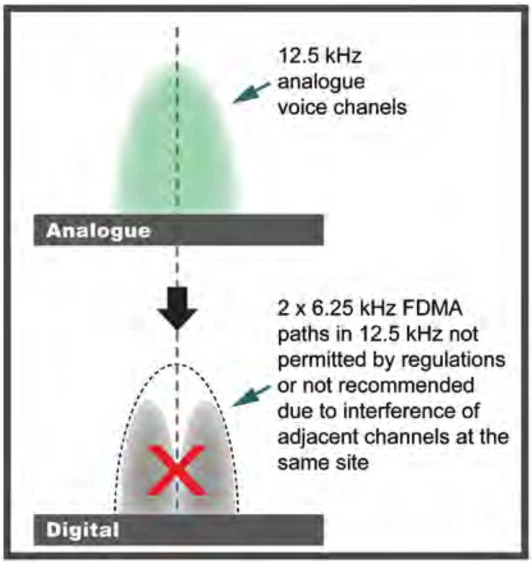
- IM31 = 2f1 – f2 = 2f1 – (f1 + 6.25 kHz) = f1 – 6.25 kHz
- IM32 = 2f2 – f1 = 2(f1 + 6.25 kHz) – f1 = f1 + 12.5 kHz = f2 + 6.25 kHz

The intermodulation products IM31 and IM32 fall exactly in the channels above and below the split 12.5 kHz channel. Therefore those products may need to be attenuated at the base station site in order to ensure compliance with regulatory limits for adjacent channel power or to meet required emission masks.
Extra engineering measures at the base station site will give higher costs.

Similarly intermodulation interference will occur when two mobile stations transmit in adjacent 6.25 kHz channels created from splitting a 12.5 kHz channel, near a base station receiver using a channel directly above or below the split channel. The two mobile stations generate intermodulation products which fall in the channels above and below the split channel, as shown above, causing additional interference over and above any adjacent channel interference, as receivers do not provide infinite attenuation of signals at unwanted frequencies.

For all these reasons many users would want to obtain a new licence in another area of the spectrum to increase capacity with a 6.25 kHz FDMA solution rather than split a 12.5 kHz channel where this is permitted (see Diagram 5 below). In contrast, because DMR's two TDMA paths fit neatly into the existing channel structure, no new interference issues will be encountered when DMR systems are installed.

Diagram 5: Analogue to digital migration using adjacent with 6.25 kHz digital FDMA channels



In summary both FDMA and TDMA systems used in digital PMR/LMR protocols are, in theory, equally spectrum efficient in that they can provide two talk paths in 12.5 kHz of spectrum but the TDMA approach used by DMR brings the advantages of compatibility with the existing licence regimes in place around the world and does not introduce new interference issues.

One potential advantage of the FDMA 6.25 kHz approach is that there is no need to co-ordinate the timing of the two independent timeslots that are used in TDMA to deliver two communications paths in a 12.5 kHz channel. However, in current DMR systems, repeaters are used to co-ordinate timeslots seamlessly to the users. Ongoing enhancements to the ETSI DMR standard[3] will specify how radios will co-ordinate timeslot timing when no repeater is present – i.e. in direct mode operation, so in reality neither TDMA nor FDMA systems have any inherent advantage when it comes to spectrum efficiency in direct or repeater mode, but TDMA systems have the advantage of predictably doubling capacity in existing 12.5 kHz licensed channels.

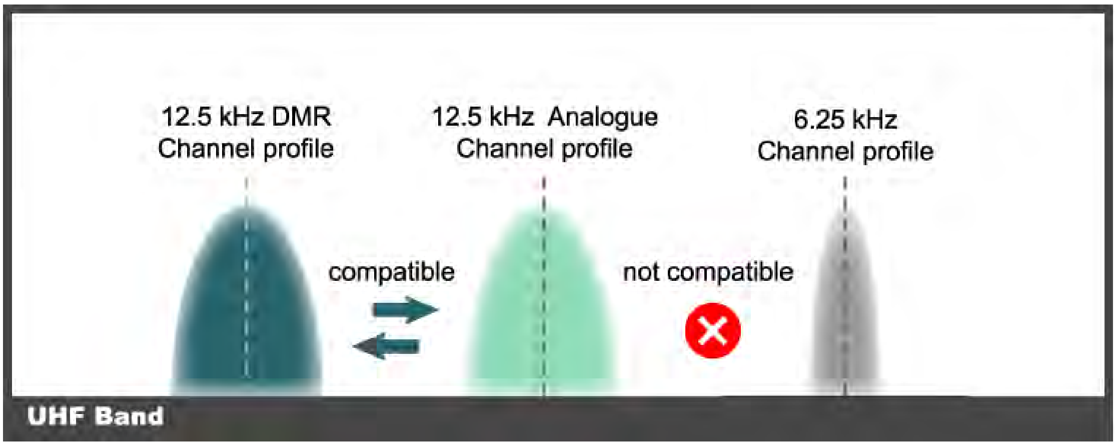
2. DMR delivers backwards spectrum compatibility with legacy analogue systems

It may also be important for license holders to keep hold of existing licences to ensure backwards compatibility with their own legacy radios or with an external organisation's analogue system (for example an

[3] TGDMR – the ETSI committee with responsibility for the DMR standard is currently reviewing proposed modifications to the standard covering direct mode operations. It is expected that modifications to the standard will be completed in Q1 2012

onsite contractor). As DMR uses 12.5 kHz channels the required spectrum compatibility is built in. This is illustrated in Diagram 6 below.

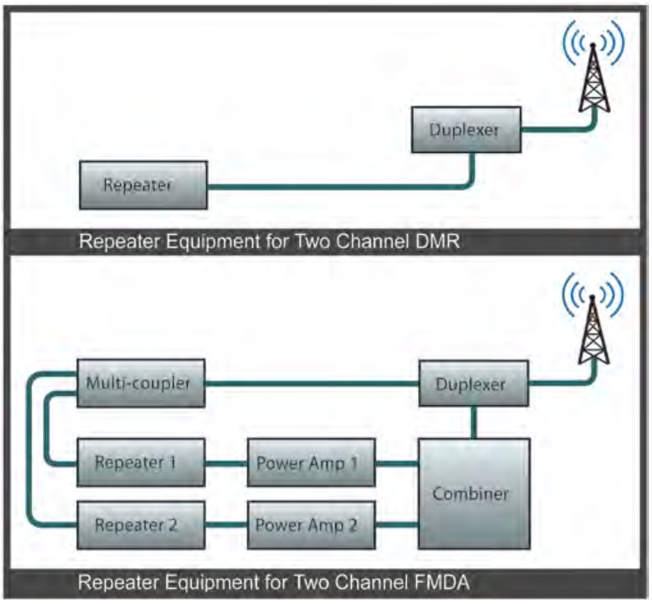
Diagram 6: Compatibility of DMR spectrum channels with legacy analogue systems



3. Efficient use of infrastructure equipment

Another advantage of the DMR TDMA approach is that you get two communications channels with one repeater, one antenna and a simple duplexer. Compared to FDMA solutions, two-slot TDMA allows you to achieve 6.25 kHz efficiency while minimising investments in repeaters and combining equipment. The required equipment of the two approaches for a simple system is shown in Diagram 7 below.

Diagram 7: Equipment required for two channel FDMA and TDMA systems



So, where users are migrating from an existing analogue 12.5 kHz system to TDMA much of the existing infrastructure equipment can be re-used whereas FDMA requires a dedicated repeater for each channel, plus a transmitter combiner and a multi-coupler (for the receive path) to enable multiple frequencies to share a single base station antenna. It can be particularly expensive (typically many thousand US$) to make combining equipment work with 6.25 kHz signals due to the narrower filters needed compared to 12.5 kHz.

There is also a loss in signal quality and range when combining equipment is introduced, hence the need for the power amplifiers shown in Diagram 7. Apart from the additional cost for the infrastructure, it should also be borne in mind that additional equipment needs additional rack space, larger power supplies and additional ventilation and air conditioning.

With FDMA 6.25 kHz systems there is also lower tolerance for errors introduced by the phenomenon of oscillator ageing and resulting signal drift away from the desired centre frequency by the transmitting radio. This results in less robust adjacent channel protection, making the system vulnerable to interference. This can be offset using a specialised piece of equipment, called a high stability oscillator, but at a cost.

In contrast, two-slot TDMA achieves stable two-channel equivalency using single-channel equipment. No extra repeaters or combining equipment are required which means lower costs and simpler site planning for DMR users.

4. Longer battery life and greater power efficiency

One of the biggest challenges with mobile devices has always been battery life. In the past, there have been limited options for increasing the talk time on a single battery charge.

Two-slot TDMA, however, offers a good way forward. Since an individual call uses only one of the two timeslots, it requires only half of the transmitter's capacity. The transmitter is idle for half of the time — that is, whenever it's the unused timeslot's "turn".

For example, in a typical duty cycle of 5 percent transmit, 5 percent receive, and 90 percent idle, the transmit time accounts for a high proportion of the drain on the radio's battery. By cutting the effective transmit time in half, two-slot TDMA can enable up to 40 percent improvement in talk time in comparison with analogue radios. (One manufacturer's published product literature gives a talk time of 9 hours operation for analogue mode but 13 hours for digital mode on the same radio). With overall battery consumption per call dramatically reduced, longer usage time in the field between recharges is enabled. DMR digital devices can also include sleep and power-management technologies that increase battery life even further.

Even though many factors affect power consumption in an individual device, comparing published battery life figures for widely marketed DMR and FDMA digital radios shows the benefit of the TDMA approach over FDMA. For each hour of usage the TDMA radios show between 19% and 34% less battery capacity is required than for the FDMA models.

Apart from the environmental reasons for not wasting energy, choosing a technology with lower energy use gives more flexibility in the future. As communications needs grow for users (for example greater data requirements) more battery capacity is needed and it is better to bet on the technology which it is inherently more efficient and therefore has more room to play with.

As discussed above, DMR infrastructure is also simpler than that required for FDMA systems. This means that the energy requirements to run a site are lower for TDMA than for FDMA

These power efficient features give DMR users a leaner and greener radio network as well as one with the benefit of long battery life on the radios themselves.

5. Ease of use of and creation of data applications

The end-to-end digital nature of DMR enables applications such as text messaging, GPS and telemetry to be easily added onto radio devices and systems. As the DMR standard also supports the transmission of IP data over the air, this enables the easy development of standard applications. In a world which increasingly relies on data as well as voice communication, this ability to add a wide range of data applications to your system results in the greatest possible return on your investment. In fact, one of the key drivers for users switching to digital is to add business enhancing data services and applications to radio systems.

The doubling of channel capacity that DMR implementations achieve is also key to adding data applications. In order to maintain the existing voice service at the same level of quality it is necessary to have extra capacity for data traffic. This can be particularly important for applications such as Automatic Vehicle Location, where a very large number of messages can be generated by the system to keep locations continually updated. Although this can be a highly valuable tool to the business user, extra capacity will be needed if voice services are not to be negatively impacted. DMR implementations deliver the extra capacity required simply and cleanly.

Diagram 8: Location based services being used with a DMR system for tracking user locations

6. System flexibility through simultaneous use of TDMA channels

While voice is utilising the first time slot the second time-slot can, in a TDMA system, be used for transmitting application data such as text messaging or location data in parallel with call activity — useful, for example, in dispatch systems that provide both verbal and visual dispatch instructions. In an increasingly data rich world this enhanced data capability is becoming more important. The future roadmap for two-slot TDMA applications includes the ability to temporarily combine both slots to effectively double the data rate to 9.6 Kbit/s, or to use both slots together to enable full-duplex (phone call like) private calls. FDMA radios cannot deliver these capabilities (without the expense of adding extra transceivers and using additional licensed channels) because in a single 6.25 kHz FDMA channel there is only one communication path, meaning one person can talk or you can transmit voice or data, but not both and the data rate is limited to the 4.8 Kbit/s that can be squeezed down a single 6.25 kHz channel.

7. Advanced control features

The DMR standard allows for the ability to use the second time-slot for reverse-channel signalling – that is, instructions in the form of signalling being sent to the radio on the second timeslot channel while the first channel is in a call. This capability can be used for priority call control, remote control of the transmitting radio or emergency call pre-emption and gives precise control and flexibility to the operator of a radio system. FDMA systems cannot deliver similar functionality because they are limited to one path only per spectrum channel.

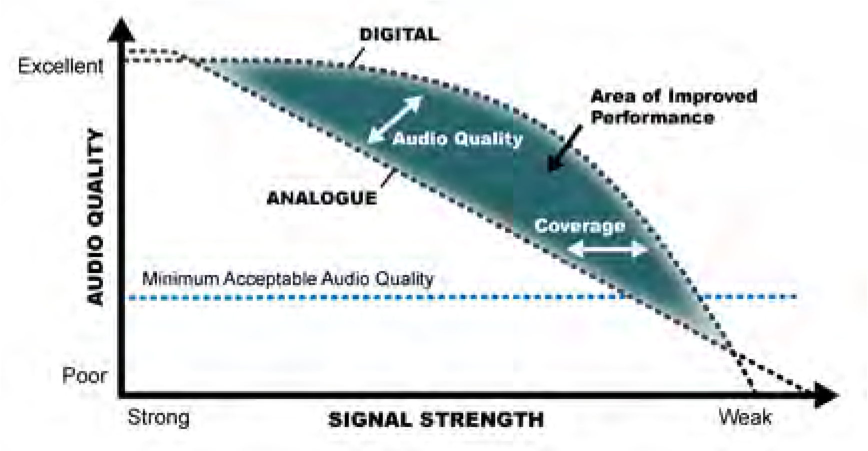
8. Superior audio performance

DMR digital technology provides better noise rejection and preserves voice quality over a greater range than analogue, especially at the farthest edges of the transmission range.

One of the reasons that DMR has an excellent range performance is that a great deal of effort was put into selecting Forward Error Correction (FEC) and Cyclic Redundancy Check (CRC) coders when developing the standard. These coders enable receiving radios to detect and automatically correct transmission errors by analysing bits inserted into messages that enable the receiving radio to tell if there is an error. The DMR standard specifies over 14 different coders to be used, each matched to different types of traffic that is being transmitted.

Through the use of coders and other techniques, digital processing is able to screen out noise and re-construct signals from degraded transmissions. Users can hear everything being said much more clearly — increasing the effective range of the radio solution and keeping users responsive to changing situations in the field.

Diagram 9: Range improvement with DMR compared to analogue



There is some discussion about which digital system gives the best coverage, a 12.5 kHz or a 6.25 kHz channel based system. Both have advantages and disadvantages.

- Some regulators will limit the power of repeaters used in 6.25 kHz FDMA systems to 50% of that available to a 12.5 kHz DMR system, where a user wishes to operate two 6.25 kHz repeaters in a given 12.5 kHz of spectrum. This is to ensure that overall power levels are maintained per unit of spectrum. Such restrictions impact range.
- FDMA systems do, however, benefit from the fact that with a 6.25 kHz channel there is a lower noise floor than with a wider 12.5 kHz channel. This is because the noise floor of any receiver is proportional to the filter bandwidth and so in theory with a smaller bandwidth weaker signals can be received. Therefore for the same RF power output FDMA receivers have in theory better coverage or it gives users the ability to reduce the power which will extend the battery life of handheld units. However this consideration is limited to an ideal environment in which the sensitivity is noise limited; in real conditions most of the today's systems are interference limited.
- Because of practical filter-implementation problems, narrower channel allocations are not able to maintain the same channel selectivity as wider channels and are more susceptible to adjacent-channel interference - another example of the near-far problem, where a strong nearby transmitter in an adjacent channel desensitizes a receiver trying to capture a weak signal from a distant user.
- The mobile radio employs a crystal oscillator that serves as the frequency reference for the receiver's local oscillator. As the crystal ages, its frequency drifts. Periodic frequency alignments can correct for this drift, but a narrower channel filter is more sensitive to this problem.
- When the mobile station is travelling at speed, the Doppler Effect shift of the carrier frequency will have twice the effect on the bit error rate in a 6.25 kHz channel as compared to a 12.5 kHz channel.

Adding all this together no system can properly claim a significant advantage over the other.

9. Security of supply through a fully open, well established, widely backed standard

As DMR is a fully public open standard backed by a wide variety of vendors, buyers can be assured of continuity of supply. There are many examples of the success of technologies incorporated into open standards because standards encourage wide ranging supplier participation. More suppliers results in more choice for users, more rapid product development and lower prices from competitive pressures.

Today DMR is the most widely adopted digital two way radio system, is in active use in over 100 countries and is the market leading digital PMR technology in the business sector. Most importantly it is backed by a very wide range of radio manufacturers and ancillary equipment suppliers. More details of these suppliers are available on the DMR Association web site.

4. The DMR Standard and Services

1. ETSI DMR standard

The standards that define DMR consist of the following four ETSI documents which are available free of charge from the ETSI website:

- **TS 102 361-1**: DMR Air Interface protocol
- **TS 102 361-2**: DMR voice and generic services and facilities
- **TS 102 361-3**: DMR data protocol
- **TS 102 361-4**: DMR trunking protocol

There is also a designers' guide encompassing elements from all parts of the standard that is an easier read:

- **TR 102 398**: DMR General System Design

2. Three tiers in the DMR standard

There are three tiers in the DMR standard:

DMR Tier I: Unlicenced

- DMR Tier I products are for licence-free use in the 446MHz band.
- Tier I provides for consumer applications and low-power commercial applications, using a maximum of 0.5Watt RF power with an integral antenna and working in direct-mode (communication without use of an infrastructure). With a limited number of channels and no use of repeaters, no use of telephone interconnects, and fixed/integrated antennas, Tier I DMR devices are best suited for personal use, recreation, small retail and other settings that do not require wide area coverage or advanced features.

DMR Tier II: Conventional DMR

- Tier II covers licensed conventional radio systems, mobiles and hand portables operating in PMR frequency bands from 66-960MHz working in direct mode or using a Base Station (BS) for repeating. The ETSI DMR Tier II standard is targeted at professional users who need spectral efficiency, advanced voice features and integrated IP data services in licensed bands for high-power communications. ETSI DMR Tier II specifies two-slot TDMA in 12.5 kHz channels.

DMR Tier III: Trunked

- DMR Tier III covers trunking operation in frequency bands 66-960MHz for professional users. The advantage of trunking is that the radio channels available are shared amongst the users whereas with a non-trunked system each user must wait for a specific channel to be free. Fewer channels are therefore needed to provide a specific grade of service but at the expense of a more complex system.
- The Tier III standard specifies two-slot TDMA in 12.5 kHz channels. Tier III supports voice and short messaging handling similar to MPT-1327 with built-in 128 character status messaging and short messaging with up to 288 bits of data in a variety of formats. It also supports packet data service in a variety of formats, including support for IPv4 and IPv6.

3. DMR services

Table 1 below shows the services that are defined by the DMR standards for Tiers I and II.

Table 1: DMR Tier I and Tier II DMR services

Services		Supplementary services
Voice	Individual Call	Late Entry
		Open Voice Channel Mode Call
		Talking Party Identification
	Group Call	Late Entry
		Unaddressed Voice Call
		Open Voice Channel Mode Call
		Talking Party Identification
	All Call	Late Entry
		Talking Party Identification
	Broadcast Call	Late Entry
		Talking Party Identification
Confirmed Packet Data Protocol (PDP)	IP over PDP	-
	Short Data over PDP	-
Unconfirmed Packet Data Protocol	IP over PDP	-
	Short Data over PDP	-

The **Individual Call** service provides a voice service between one individual user and another individual user.

The **Group Call** service provides a voice call service between one individual user and a predetermined group of users. All parties in the group can hear each other.

The **All Call** voice service provides a one-way voice call from any user to all users on a channel.

The **Broadcast Call** voice service provides a one-way voice call from any user to a predetermined large group of users.

The **Open Voice Channel Mode** (OVCM) supplementary service allows third party users to monitor and participate in an existing individual or group call.

The **Unaddressed Voice Call** supplementary service is a special type of group call which gives users the possibility to define a mobile station's behaviour which may be different from that of a normal group call, for example special alert tones, and can be used for communications between different user organizations, each of which has its own group definitions.

The **Late Entry** supplementary service provides continuous call in progress updates to allow latecomers to join an ongoing call.

The **Talking Party Identification** supplementary service displays the identity of the radio terminal transmitting in an individual or group call in all other radio terminals receiving the call.

Data services are provided using a Packet Data Protocol (PDP) which supports Internet Protocol (IP) or Short Data Service (SDS) data services. The DMR IP standard supports both IPv4 and IPv6. SDS messages can be up to between 626 and 1130 bytes long depending on the mode and protection rate.

Further details of these DMR services can be found in the ETSI DMR standards **TR 102 398** clauses 6 & 7 and **TS 102 361-2**. DMT Tier III provides additional services as described in **TR 102 398** clause 8.

5. Technical Parameters

1. TDMA

DMR employs a two-slot Time-Division Multiple Access (TDMA) system offering low cost and flexible digital voice and data solutions, and uses a well established 4FSK modulation scheme. The TDMA implementation in DMR uses a 12.5 kHz spaced radio carrier to send two simultaneous radio channels thus offering a spectrum-efficiency of 6.25 kHz per channel.

2. Modulation

In the 4-level FSK modulation employed by DMR, each set of two bits (a dibit) is represented as a symbol with a fixed deviation from the transmit frequency. With a rate of 4,800 symbols/s a data rate of 9600 bit/s is achieved (utilising both TDMA slots). The four frequency deviations from the transmit frequency and the information bit values are given in Table 2 below:

Table 2: Dibit symbol mapping to 4FSK deviation

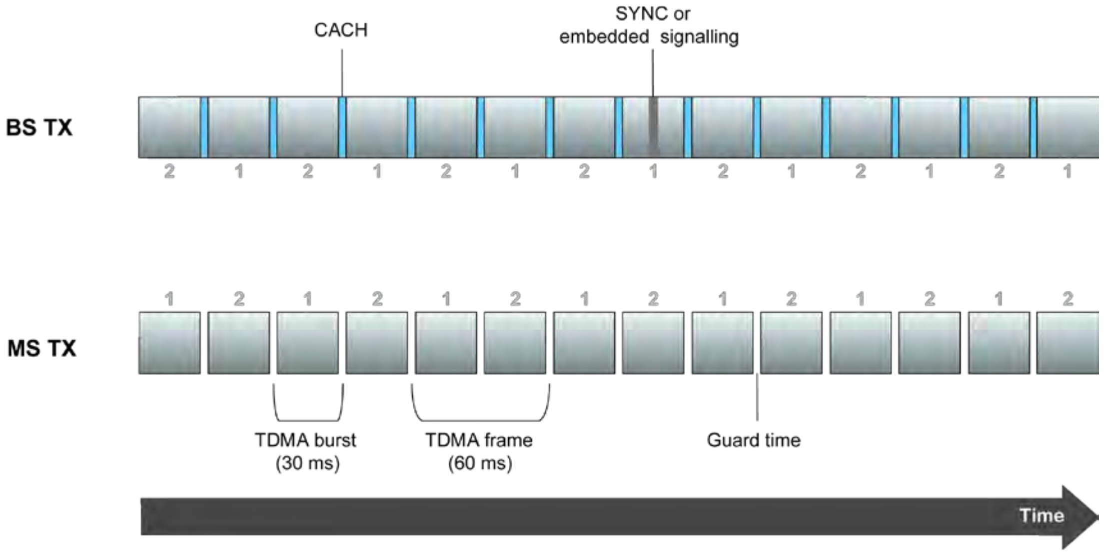
Information bits		Symbol	4FSK deviation
Bit 1	Bit 0		
0	1	+3	+1,944 kHz
0	0	+1	+0,648 kHz
1	0	-1	-0,648 kHz
1	1	-3	-1,944 kHz

3. TDMA structure

The DMR protocol is built around a 30 ms TDMA 2-slot structure. In the spaces between the transmitted blocks the protocol calls for the unit to be receiving. This therefore allows signalling and/or voice in the reverse direction, even during a conversation. The perception of the user will be that this unit is providing a full duplex conversation.

A generalised timing diagram of exchanges between the MS (mobile station) and the BS (base station) is shown in Diagram 10 below where the time slots for the two TDMA physical channels are labelled "1" and "2". The inbound transmission is labelled "MS TX" and the outbound transmission is labelled "BS TX".

Diagram 10: TDMA timing overview



- The inbound channel (MS TX) has an unused guard time between bursts to allow for Power Amplifier ramping and propagation delay.
- The outbound channel, which transmits continuously when the BS is activated, uses the equivalent of this guard time to insert a Common Announcement Channel (CACH) between bursts for traffic channel management (framing and access) and low speed signalling. If no information is available to transmit in channel 1 and/or channel 2, the BS transmits idle messages to fill out the bursts.
- All bursts have either a synchronization pattern or an embedded signalling field located in the centre of the burst.

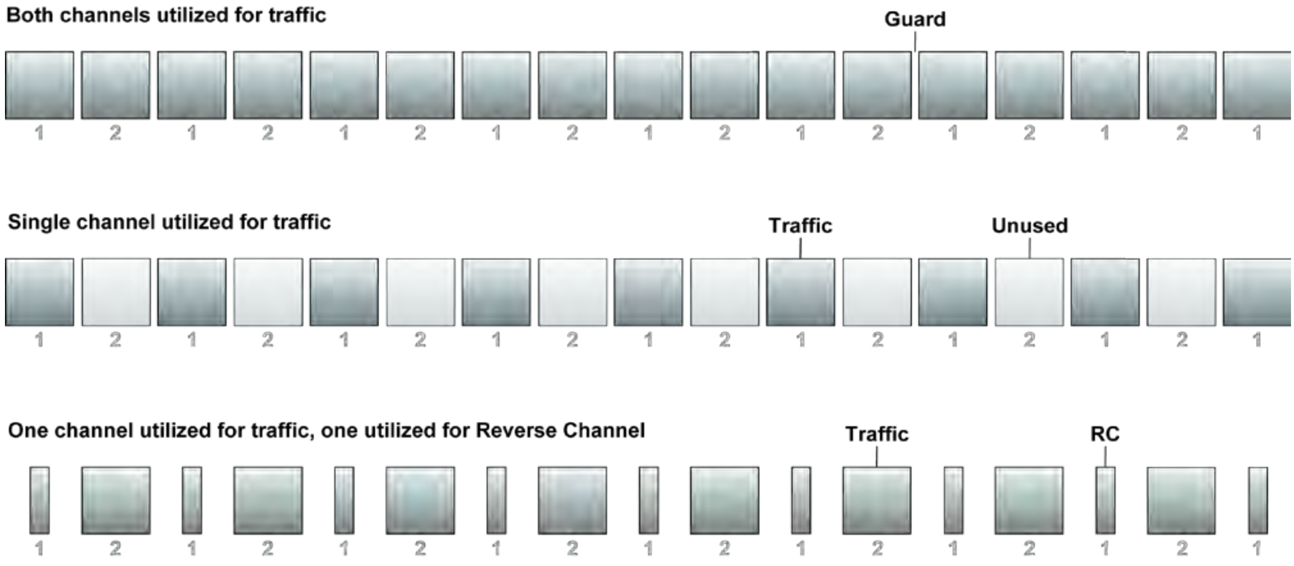
Further details of the TDMA frame structure can be found in ETSI **TS 102 361-1** clause 4.2.

4. Basic channel types

There are three main basic channel types used by DMR:

- **Traffic channel with CACH** - the same as the BS TX example in §5.3 above. This channel type is used for outbound BS transmissions but is also used for the continuous transmission mode between MS units used for Tier 1 DMR.
- **Traffic channel with guard time** - the same as the MS TX example in §5.3 above. This channel type is used for inbound transmissions from an MS to a two-frequency BS. Three use cases are available for this channel type as illustrated in Diagram 11 below:

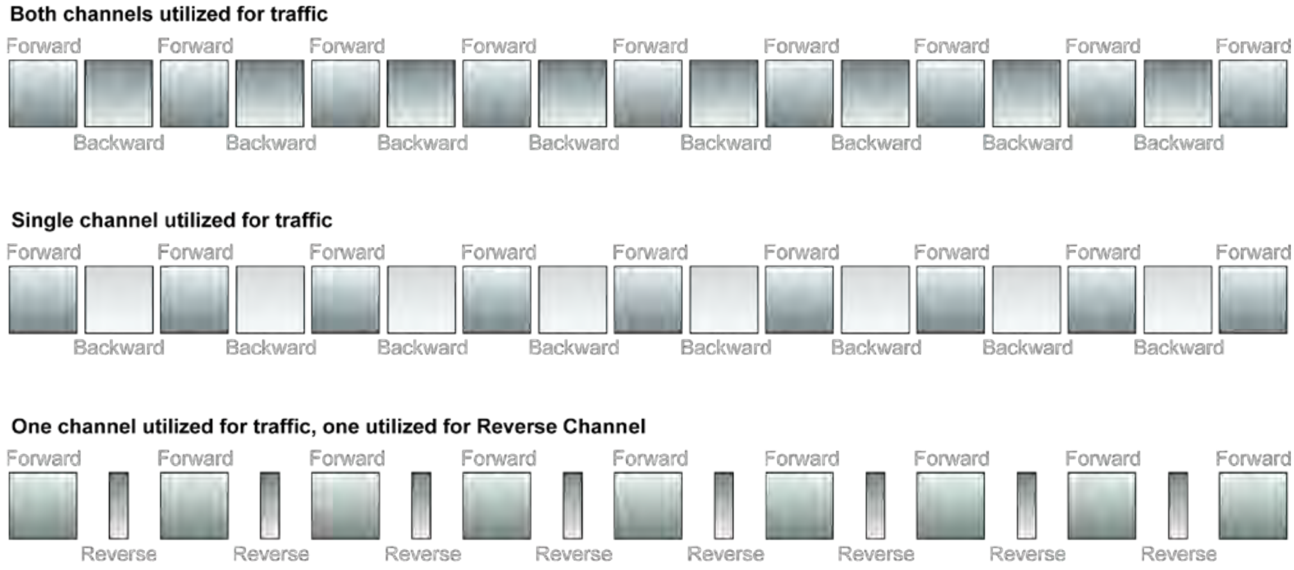
Diagram 11: Traffic channel with guard time



Transmissions on the reverse channel can be used, for example, to support the operation of applications during speech sessions, for example to tell a transmitting radio to stop, because an emergency call is waiting, or to inform it of its signal strength, so that it can adjust it's transmit power.

- **Bi-directional channel** - This channel type is used for direct mode communication between MS units. The channel consists of a Forward and a Backward TDMA traffic channel on the same frequency separated by guard times. Three use cases are available for this channel type as illustrated in Diagram 12 below:

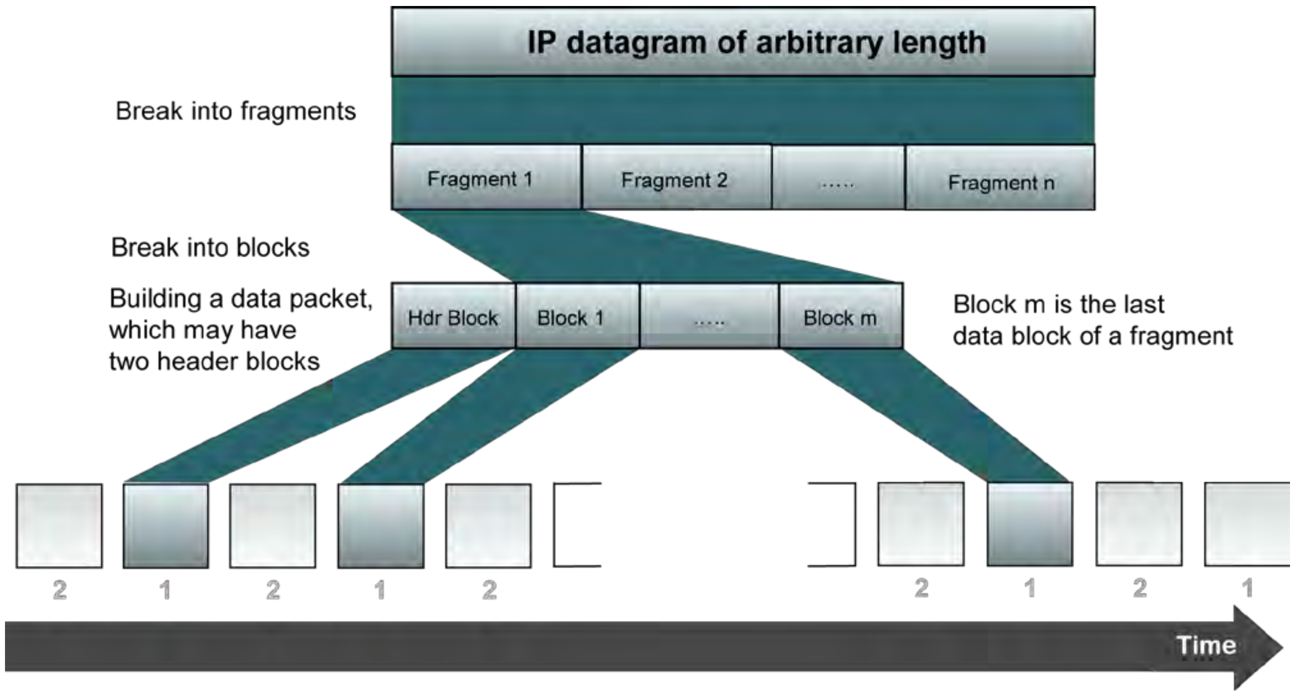
Diagram 12: Bi-directional channel



5. Packet data protocol (PDP)

If the PDP is required to transport a message whose length is bigger than a maximum length, the message is first split into fragments. Each fragment is then mapped into a single packet consisting of a sequence of data blocks 1 to m preceded by one or two header blocks. Each block is protected by its own Forward Error Correcting (FEC) code. The fragmentation and packetisation is illustrated in Diagram 13 below:

Diagram 13: Decomposition of a datagram into packets (single slot)



6. Vocoder

A vocoder (voice encoder) compresses the transmitted digital voice signal to enable it to fit into a smaller bandwidth channel and at the receiving end it uncompresses the signal. Different digital standards use different vocoder technologies. A full-rate vocoder compresses voice sufficiently for it to fit in a narrow-band (12.5 kHz) channel. A half-rate vocoder is necessary to compress it enough to fit into a 6.25 kHz channel or in one 12.5 kHz TDMA timeslot such as used by DMR.

Although the ETSI DMR standard does not specify the use of a particular vocoder, DMR Association members have agreed to use the Advanced Multi-Band Excitation (AMBE+2) half-rate vocoder to ensure compatibility between different manufacturers' equipments. This vocoder is a proprietary software device produced by Digital Voice Systems Inc. (http://www.dvsinc.com/products/software.htm).

Conclusion

DMR has been designed from the ground up for users of professional mobile radio. It efficiently increases capacity, gives longer battery life and minimizes the use of infrastructure. The standard also facilitates advanced functionality and control features and the use of business critical data applications. Finally DMR brings the range benefits and clarity of digital voice.

There are significant differences in the digital products that are currently being brought to market and users need to exercise care in choosing a solution. This is all the more the case because of the longevity of PMR products.

Buyers of PMR/LMR products need to consider a variety of higher order factors in their decision making: spectrum and licensing; system evolution potential, legacy compatibility, long term supply of compatible products and in these increasingly green times – energy use, as well as specific product features.

DMR stands up well when tested against all these criteria. This is not surprising – it is exactly what you would expect from a system designed from the outset for the professional radio user.

About the DMR Association

The DMR Association is focused on making DMR the most widely supported 21st Century digital radio standard for the business world. Through a combination of interoperability testing, certification, education, and awareness, the Association seeks to ensure that business buyers of today's digital radio technology gain ongoing value through the competition and choice derived from an open, multi-vendor value chain.

DIGITAL MOBILE RADIO ASSOCIATION

www.dmrassociation.org