BENEFITS OF DMR

White Paper

Executive Summary

Digital Mobile Radio (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 licenced 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. More over, 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.

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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 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 spectrum use 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 variations 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 II - 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 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 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

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 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.

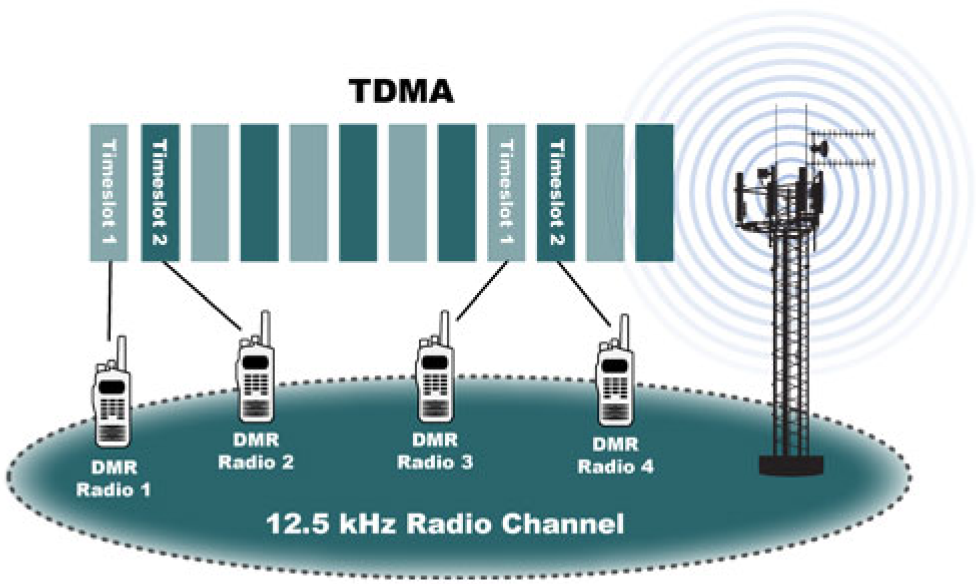
This paper looks at all the benefits of DMR in turn.

1. Predictable doubling of capacity in existing 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

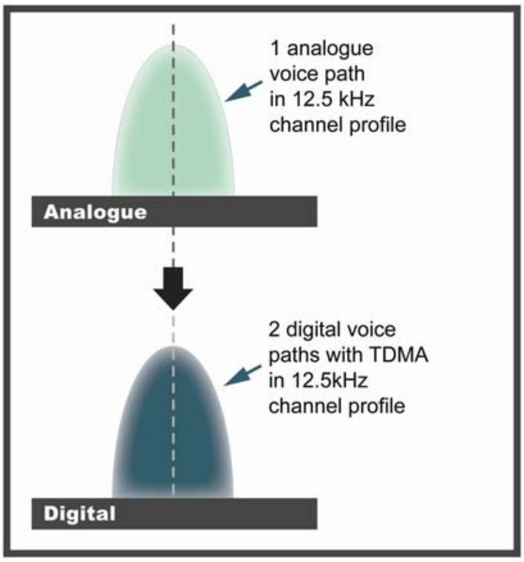


In this arrangement each communication path is active for half of the time in 12.5 kHz of bandwidth and so each uses an equivalent bandwidth of half x 12.5 kHz or 6.25 kHz . This is known as having an efficiency of one talk path per 6.25 kHz of spectrum, but with DMR the channel as a whole maintains 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 II 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 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 licenses exist and the regulatory regime does not permit a license 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 license but no increase in capacity is achieved for the user. This situation is illustrated in diagram 3 below.

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 licenses 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].

[1] See DMR Association White Paper on US Narrowbanding

Even in jurisdictions where a user is allowed to squeeze two 6.25 kHz paths into an existing licence, 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]. So, for this reason users would still most likely want to obtain a new licence in another area of the spectrum to increase capacity with a 6.25 kHz FDMA solution (see diagram 4 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 3: Analogue to digital migration with 6.25 kHz digital FDMA systems

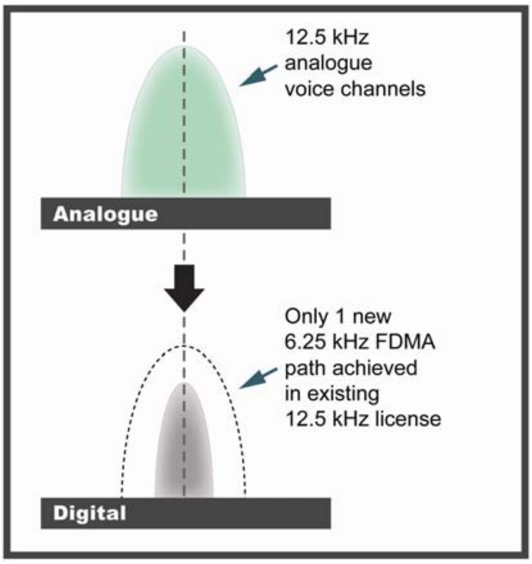
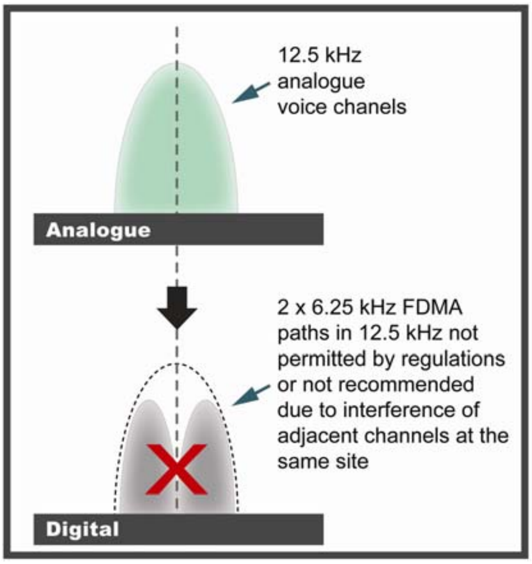


Diagram 4: Analogue to digital migration with 6.25 kHz



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.

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[2] See ITU-R SM.337-6 Frequency and distance separations

One potential advantage of the FDMA 6.25 kHz approach is that you do not need a repeater to co-ordinate TDMA timeslots to deliver two independent talk paths as is necessary for DMR. (DMR systems do work well without repeaters and still deliver the many benefits inherent in DMR systems such as reverse channel signalling, but not two fully independent channels per 12.5 kHz of spectrum.) Without a repeater, however, all radios need to be in range of each other at all times to get a predictable doubling of capacity with FDMA. So if the system needs a repeater for extra range, or to cover a problem area, now or in the future (e.g. with a site move or the opening of a new location) this benefit of FDMA is of limited value.

So the non-repeater advantage of 6.25 kHz FDMA systems for capacity increase is only beneficial if:
a) You only have a small site where at all times for the lifetime of the system all radio users will be in direct range of all other users they might need to communicate with.

b) You have been able to obtain the frequencies required, as splitting an existing license into multiple 6.25 kHz channels will not be an option for regulatory or interference reasons.

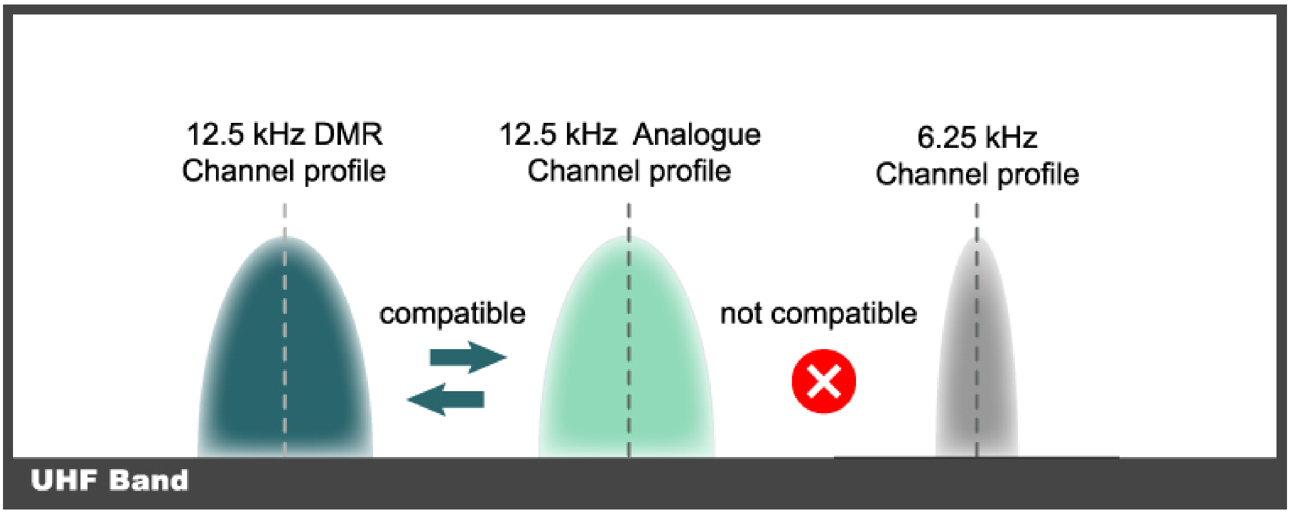
c) Availability of 12.5 kHz channel licenses is an issue.

d) There is no need to have compatibility with legacy 12.5 kHz analogue systems (see below).
DMR, which was developed from the start with long term business needs in mind, does not have these constraints.

2. DMR delivers backwards spectrum compatibility with legacy analogue systems

It also may be important for license holders to keep hold of existing licenses to ensure backwards compatibility with their own legacy radios or with an external organisation's analogue system (for example an on site contractor). As DMR uses 12.5 kHz channels the required spectrum compatibility is built in. This is illustrated in diagram 5 below.

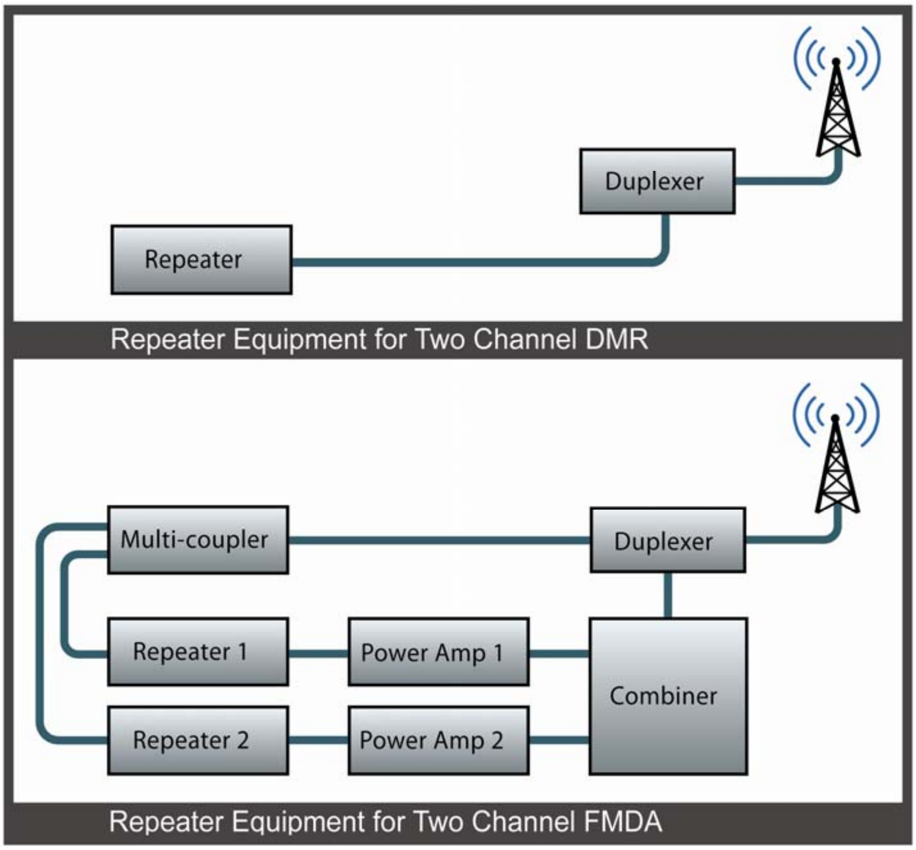
Diagram 5: Compatibility of DMR spectrum channels with legacy analogue systems



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 6 below.

Diagram 6: Equipment required for two channel FDMA and TDMA systems



FDMA requires a dedicated repeater for each channel, plus expensive combining equipment to enable multiple frequencies to share a single base-station antenna. It can be particularly expensive to make combining equipment work with 6.25 kHz signals, and there's typically a loss in signal quality and range when it's used in this way, hence the need for power amplifiers shown in diagram 6.

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 (and there is lower drain on air conditioning and less back up power supplies needed at a repeater site). This means lower cost 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 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 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 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 most probably need to be provided if voice services are not to be negatively impacted. DMR implementations deliver the extra capacity required simply and cleanly.

Diagram 7: Location based services being used with a DMR system to tracking user locations

6. System flexibility through simultaneous use of TDMA channels

While voice is utilising the first timeslot the second timeslot 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 kb/s, or to use both slots together to enable full-duplex (phone call like) private calls. FDMA radios can not 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 kb/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 timeslot 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 can not deliver similar functionality because they are limited to one path only per spectrum channel.

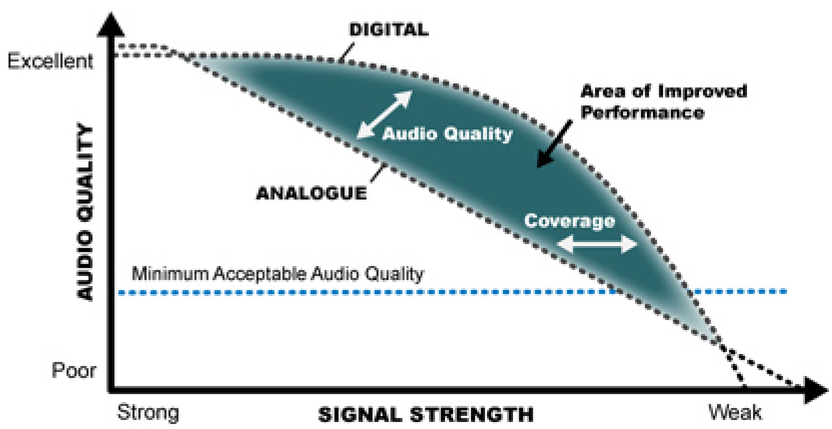
8. Superior audio performance

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 8: 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. 6.25 kHz based systems are disadvantaged because when you squeeze multiple high power transmissions in 6.25 kHz channels into the spectrum, it is necessary to limit the modulating signal of each transmission quite tightly (in technical terms reduce the signal deviation) so as not to cause interference in the next channel along in the spectrum. This limit on the signal deviation means the receiver is less able to distinguish whether it is being sent a one or a zero when the signal is weak – i.e. at the edge of the system's range. This, in theory, impacts the coverage of 6.25 kHz systems. Some regulators will also 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 may also impact range. DMR systems also benefit from the advance of implementation of Forward Error Correction techniques discussed above. 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. 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.

Conclusion

DMR has been designed from the ground up for users of professional mobile radio. It efficiently increases capacity, gives longer battery life and minimises 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 clarify 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.

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www.dmrassociation.org