IWCE 2017 – The Advantages of Digital Mobile Radio

Installing a DMR network. Avoid the pitfalls. Optimize. Listen to this first.

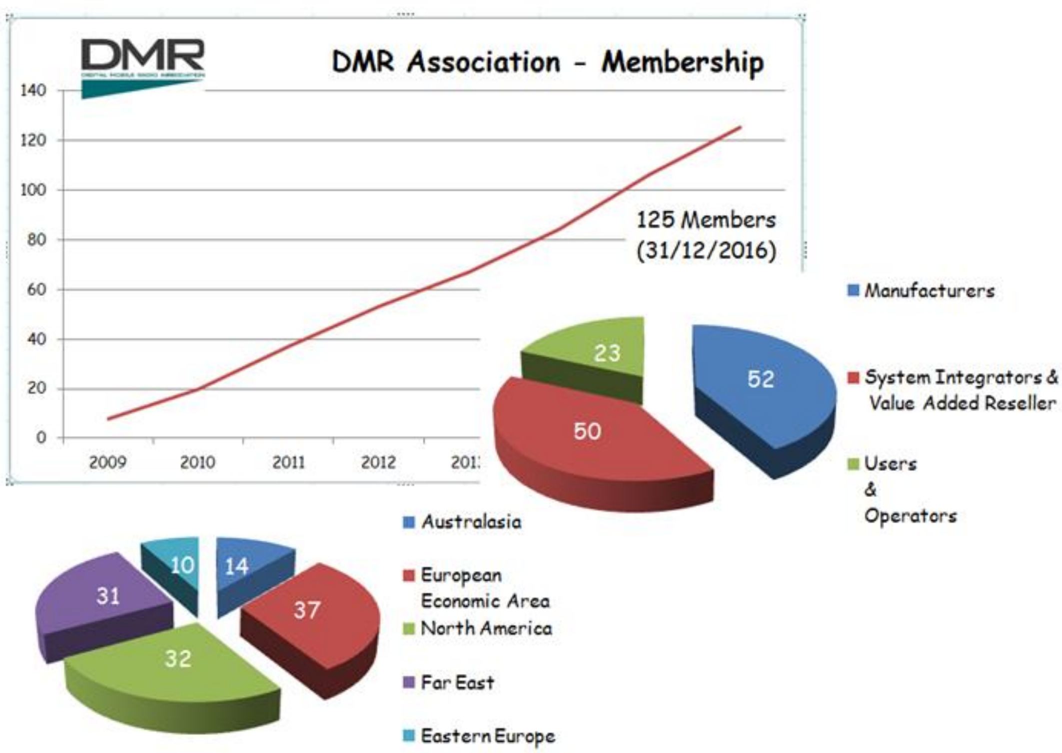
A presentation by The DMR Association

DMR is a digital protocol that has been designed to operate in our SMR $6\frac{1}{4}$Khz equivalent channels, and can share narrow band channels with analog systems.

Network Operators and users need to be confident that –

1. There is a good business case in the price of the equipment and operating costs.
2. It must have clear advantages over what it might replace
3. It must offer interoperable radio terminals
4. There must be a critical mass of manufacturers in the market to ensure competition, and therefore quality.

Do we have this critical mass?



Critical Mass of Particpants in the DMR Technology

The figure illustrates from just six manufacturers in 2009, the steady growth has accumulated 128 commercial companies supporting DMR. The geographic split PI chart shows a spread of stakeholders that is truly global. There are now over 50 active manufacturers competing in this market.

The DMR characteristics were developed with migration from analog in mind –

- Fits in a 6¼kHz equivalent channel. Fits into an analog transmitter envelope therefore is able to replace analog in existing SMR spectrum.
- A range of SMR like features, peer to peer, repeater and trunking
- Two for one. Existing 12½kHz licence holders can double their capacity
- Range same or better than 12½kHz analogue
- Good battery endurance for hand portables (goes with range)
- Speech and data services as standard.
- Low cost, low complexity

Many have found the migration to the new digital radios highly successful but others have been disappointed. Some say the range is great. Others say it is the same as analogue. Some say there are interference issues. This paper analyzes these issues.

Simple Repeater Site

The figure represents a repeater site and the concentric circles the notional coverage area. The radius of the circle is dependant on the frequency band, the transmit power, the receiver sensitivity, antenna gain, the modulation, the bandwidth and the protocol. Take for example the yellow circle. All subscribing radio terminals are inside this circle (coverage area). The operator must find enough subscribing users inside this circle to pay for the repeater site and produce a margin. The users are generally thought to be inside this circle - BUT, what does the circle represent? From the perspective of the user - *Coverage is the area in which the user will find the grade of service acceptable*

For administrations allocating spectrum using a spectrum assignment tool, coverage is defined by signal strength. For the user however it may be something more subtle. They do not understand radio. They just want to talk and be understood. For instance the yellow circle could be the signal for a particular signal/noise performance and the white, the same transmission with a lesser signal/noise performance.

It is how the DMR transmitters and receivers behave in a real environment that this paper will explore

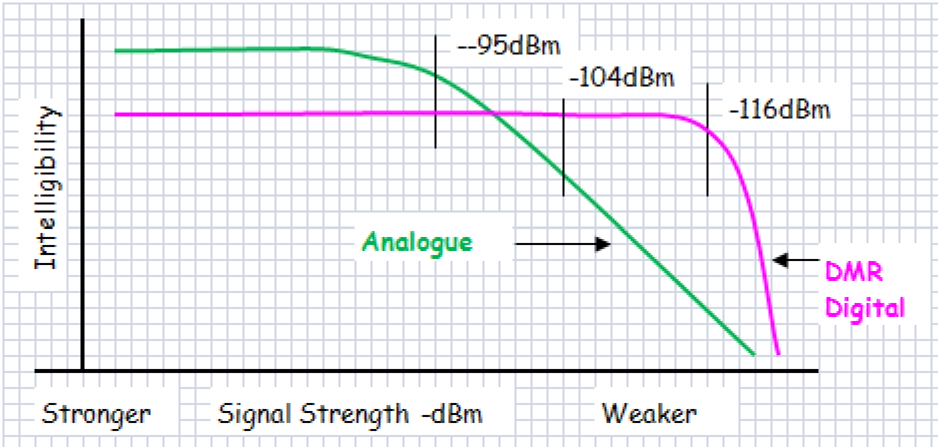
To extend the range by 20% requires 2 x the transmit power; to double the range requires 16 x transmit power. Doubling the power is 3dB but improve the receiver by 3dB gives the same result. Is that possible?

To determine the radio performance of the DMR digital protocol, there are many choices –

1. Construct a mathematical model and conduct a computer simulation
2. Erect a DMR system, take some DMR radios and conduct a field trial
3. Build a test system in the lab. In this case the environment is well controlled and accurate measurements can be taken

When the DMR protocol was being developed, the most modern techniques were used to maximise the radio performance in weak signal conditions. Anyone with an interest in astronomy will be aware of the fabulous pictures from remote probes such as the Mars-Lander. These pictures would just not have been possible without a new technique to extract the data from the noise called Turbo Coding. DMR uses this same coding technique.

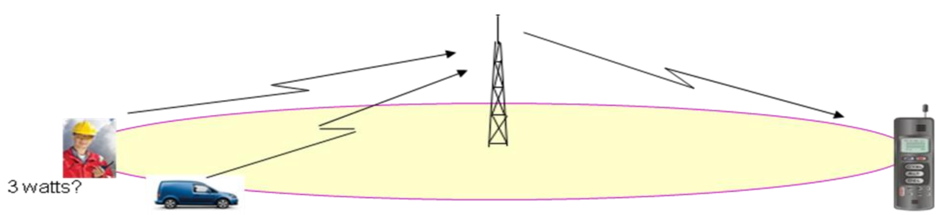
Both the mathematical model and the lab test system produced a very similar result illustrated below. This is a single radio path from transmitter to receiver.



Receiver performance Comparison

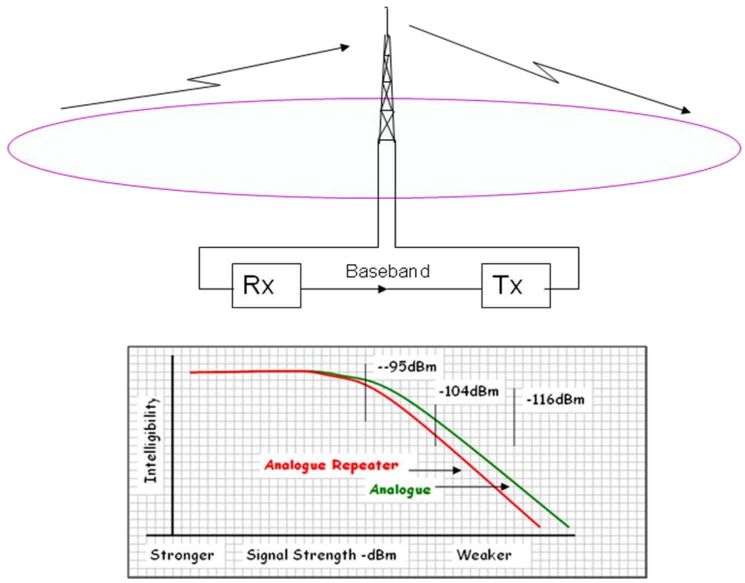
The diagram illustrates an analog 12½kHz signal in green. At a signal level of -95dBm the received signal is fully quieting. -104dBm is the limit for many administrations range limit for a technically assigned licence. -116dBm is the edge of the range used for separating systems sharing a radio channel. The band between -104dBm and -116dBm suffers degraded intelligibility as the background noise rises.

A DMR receiver has this clever Turbo Coding (Forward Error Correction). The noise in the receiver is treated as bit errors that the FEC is able to correct. The listener therefore hears only the voice with no background noise until a limit is reached at ~-119dBm. The difference between a fully quieting voice and silence is just 1 or 2 dB.



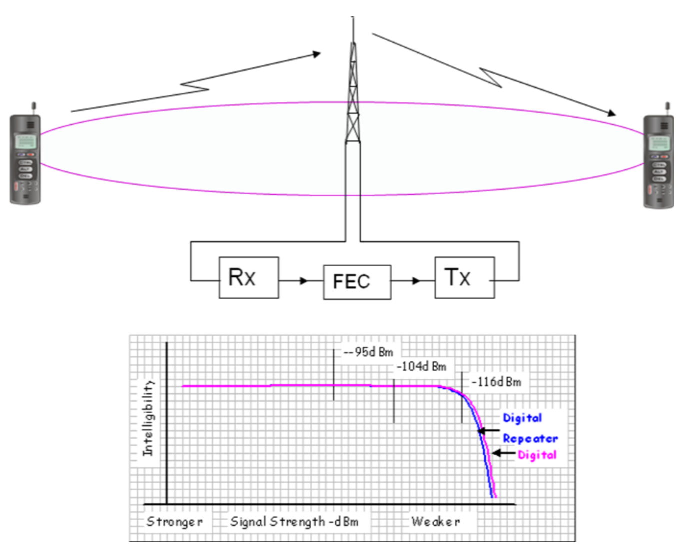
Reciprocity

Reciprocity is matching the path performance between base and radio terminals. The range is determined by the weakest link. For mobile operation it might be the path from mobile to base that has the advantage because of losses in antenna combining at the site. For hand portable operation however the limit on battery endurance and safety limits the transmit power so the path to the site is the weakest.



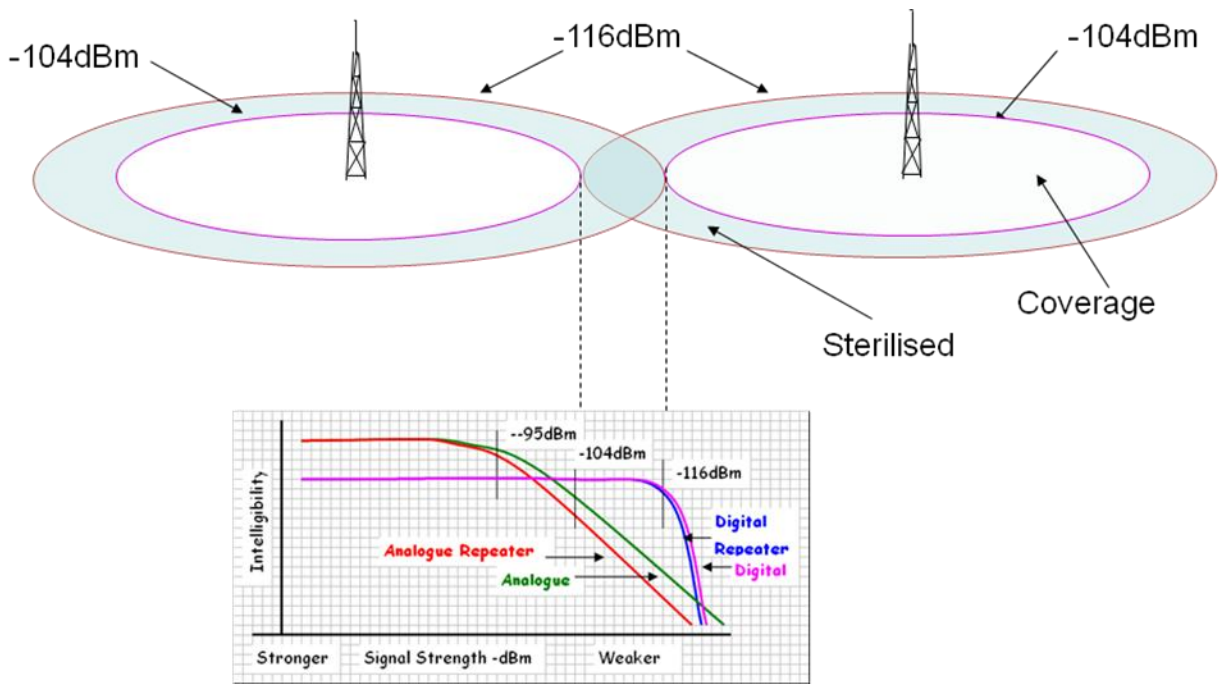
Repeater Path from Terminal to Terminal – Analog. Green is the path from terminal to base. Red is the combined paths, terminal to terminal

Many systems are repeater based. There are two paths, one inbound to the radio site followed by outbound to the listener. In the case of analog, the received speech is retransmitted. Any noise inbound is retransmitted adding to the noise on the outbound path. -95dBm is the point where an analogue FM receive will experience full quieting, -104dBm is the coverage limit of many administration license assignment tools. As the signal becomes weaker the signal/noise increases reducing the intelligibility for the listening radio terminal.



Repeater Path from Terminal to Terminal – DMR

For digital repeater networks there is an advantage that analog does not share. The digital path is a series of bits. Noise causes errors in those bits. As the signal becomes weaker the processing in the repeater is able to correct those errors before the bit-stream is retransmitted. The signal degradation is therefore less for digital. The performance in a weak signal is almost identical whether the radio path is terminal to terminal or via a repeater



Coverage Area in Shared Spectrum

A Spectrum Assignment tool will separate a shared channel into a coverage areas and a sterilisation area. The diagram illustrates an analog example (red/green). The difference between the two signal strengths ensures 'FM capture effect' will in most instances prevent interference between the different radio fleets in the shared spectrum.

It can be seen that the digital signal offers extended coverage into the sterilised area. What is also clear however is that the coverage has a cliff edge. The user will either hear perfectly clear speech or nothing at all. The digital signal does not have a sterilised area. The coverage is precisely defined.

What can possibly go wrong? There seems to be a number of dBs advantage employing digital against analogue.

The issues for the digital systems is carrier to noise (C/N). The (C/N) performance for DMR is 10 to 12dB. This means that the signal level must be 10 to 12 dB higher that the noise to successfully retrieve the data (voice). Interference also manifests itself similar to noise so C/N can also be C/I. In contrast an analog system is able to tolerate a signal/noise {S/N) of 6 to 7dB (FM capture in the demodulator)

Whether the signal is analogue or digital the signal/noise (or interference) must be better than a certain value to provide an acceptable grade of service.
If the transmission is analogue the noise will be heard above the voice.
If the transmission is digital if the carrier/noise is not high enough nothing will be heard at all.
IF THE NOISE FLOOR AT THE RECEIVER ANTENNA IS HIGH, THIS NOISE ADDS TO THE NOISE FLOOR OF THE RECEIVER.
This means that the added receiver sensitivity can only be realised if the received signal is 10dB to 12dB higher than the noise (or interference). For example a signal at -112dBm will only be successfully received if the noise floor is better than -122dBm.

- Digital does not fix poor Radio Site Engineering, digital does not fix a high noise floor
  - Inappropriate choice of radio site
  - Proximity of receiver antenna to other transmitter antennas (wide band and spread spectrum 3G LTE etc)
  - Incorrect or badly positioned antenna
  - Poorly designed or adjusted antenna duplexer/combiner
  - External interference

SO – Can DMR and best practice radio site engineering make a real difference in radio networks used for critical communications?

Can PMR + DMR compete in ?

- performance
- cost
- resilience in emergency conditions
  - access
  - continuation of service in power-outage

There is a small improvement in range for DMR repeater based systems. There is also a range improvement, BUT this is only possible if the noise floor of the receiver is very low. (10dB margin over the noise floor needed)

The DMR advantage is only possible by BEST PRACTICE RADIO SITE ENGINEERING
The skills needed to design and manage a SMR radio site are under-estimated and undervalued. The SMR industry has dummed down
Bad practices on shared radio sites results in high noise floor, limits receiver performance – range suffers
Digital will not fix interference. Users will just hear silence
Other wide band spread spectrum transmissions will be a threat in the future (LTE)

The ECO future.
DMR and best practice radio site engineering offers –

- Inherent privacy – encryption built in
- Greater range
- Good reciprocity for hand portables
- Half the spectrum (from a 12½kHz ch)
- Half the licence cost?
- Sixth the energy use
- Six times standby power endurance
- Electricity cost saving
- No moving parts (fans), low maintenance
- Smaller site footprint. Less site rent
- Green credentials
- **Potential Saving of 3.6 tons CO_2/year**

For further information about the ECO future, please see -

IWCE_Presentation_2017_The_ECO_Future.pps

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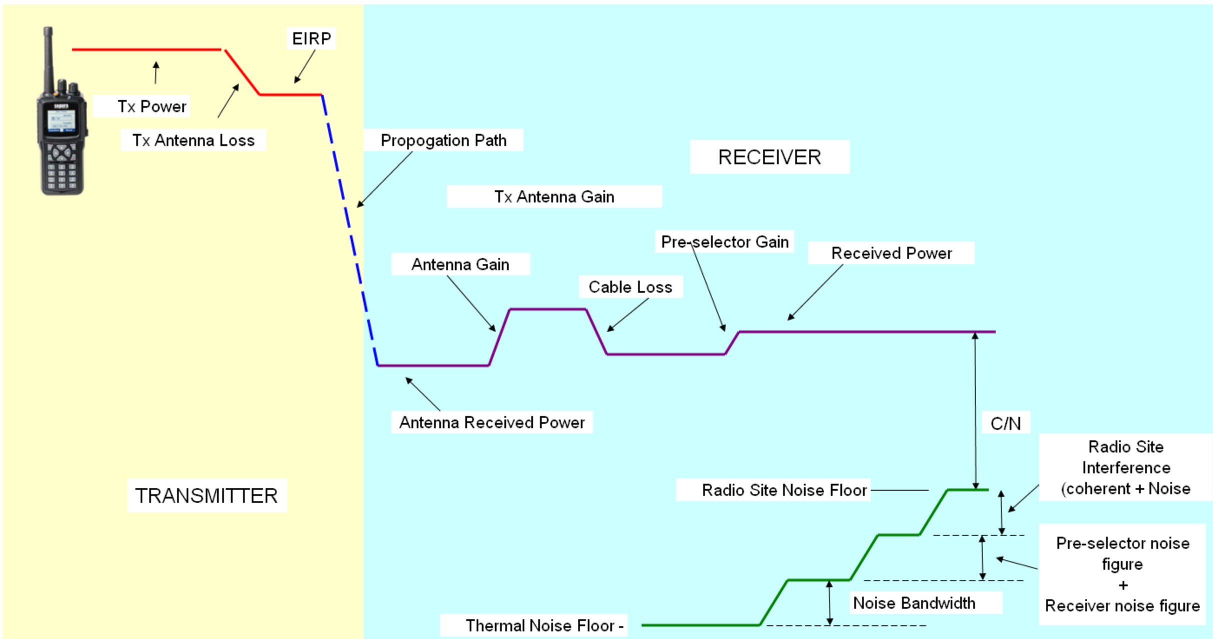
Annex – Reference diagrams

A.1 Signal and Noise Power Path - Generic



A.2 Signal and Noise power Path - DMR