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Part 1 – About DMR

"DMR, or Digital Mobile Radio, is a standard developed by the European Telecommunications Standards Institute. It's digital, obviously, but what exactly is DMR, and what are the benefits of the mode?

In the commercial world, DMR was born from the need to fit more data into a smaller amount of radio bandwidth. Bandwidth costs money, and DMR channels are only 12.5 kHz wide, the same as narrow FM. However, with DMR, you can have three channels within the same spectrum bandwidth. In most cases, two of the channels are used to send digital voice, while the third channel is used for signaling and clocking, which are key components in digital communications.

This feat of technology squeezes a clear voice channel into just 6.25 kHz of bandwidth, effectively doubling, and in the case of the amateur world of 25 kHz FM, tripling the capacity.

Let me explain.

DMR uses a modulation of 4-state Frequency shift keying or FSK. In simple terms, this means that the data - the digital ones and zeros - are converted into a mathematical code which is transmitted using four frequency's or tones.

These freqnecys are transmitted via a modulator, which in many ways is very similar to how a modem transmitted data over phone lines in the days of analog telephone lines. At the receiving end, the demodulator converts the tones back into digital data. 4FSK can send data over the air at a rate that corresponds to 9,600 bits per second. Sounds easy, right? But DMR has another trick up its sleeve: it uses TDMA, or Time Division Multiple Access. With TDMA, it can send two FSK data streams together.

Notice that I did not say 'at the same time.' It splits the DMR channel into 30-millisecond cycles.

Think of it like a lighthouse on the east coast of Australia. A ship down south can see the light as it points in their direction, but a ship to the north sees nothing until the light rotates northward. This is how TDMA works. The receiving station, with its accurate clock, knows when the 'light' should be facing north and when it should be facing south. With that information, it can determine its location relative to the lighthouse.

In DMR, there is a single 4FSK data stream, but during the first 15 ms, bits are allocated to the first time slot, and during the second 15 ms, they are allocated to the second time slot. This leaves 2450 bits per second after overhead for each voice channel. The explanation I've given here is intentionally simplistic; there's quite a bit more going on. But the foundation is all there. What we are left with is a type of modulation that gives us two 2.45k data channels. That's just enough to encode high-quality voice using a mathematical model called a codec.

More about that next time till then this has been Matt VK2FLY for the VKDMR network and ARNSW Radnet.

Part 2 Codecs

"Codecs are a wonderful things. But before we delve into that, let’s take a detour through AM, FM, and SSB modulation. In these modes, the loudness of your voice directly influences how you sound on the receiver's set. In cases like SSB, the received signal may even increase. As radio amateurs, we're familiar with this. You might even notice people on the street yelling into their mobile phones, blissfully unaware of their automatic gain control and noise cancellation. This is where DMR, much like your mobile phone, comes into play. And this brings us back to codecs.

In the early days of digital voice, such as with ISDN telephones, a codec's task was straightforward. It sampled the incoming voice, converted the exact frequency and amplitude into numbers, and sent it over the wire. On the receiving end, it was converted back to analog, allowing people to communicate. These systems used a voice bandwidth of 0.3 to 3.4 kHz, and with this type of codec and sampling rate, a good quality voice call required a bandwidth of 64 Kbit/sec.

However, today's codecs operate differently. They listen to the sounds of the human voice and recreate them. Human speech, from an auditory standpoint, is quite repetitive. Most words and sounds we make are derived from a small subset of other sounds. Advanced codecs break down our speech into these typical sounds, assign a value to them, called symbols, along with a pitch and amplitude, and transmit them over the air. At the receiving end, these numbers are converted back into sounds and played through the speaker.

Many say DMR and other digital modes sound robotic, and they're not wrong. Early synthesized voices, like Stephen Hawking’s famous DECtalk, used pre-recorded sounds to form words. Computers arranged these sounds to mimic speech. In a similar fashion, advanced codecs, like the one used in DMR (specifically AMBE+2), do the same, but they're better at mimicking the original speaker's voice.

This is why music sounds terrible over DMR. The codec is designed for voice, not other sounds. It also explains why background noise isn't transmitted. The codec is engineered to send voice and nothing else.

So, what's the key takeaway? It's all about the level. The codec recreates your voice; it doesn't transmit it. Yelling into the mic will result in a loud output at the other end. Turning the mic gain to maximum means the receiving radio will be loud, too. But this doesn't improve transmission quality. Instead, it might startle the receiving operator, who will likely turn the volume down.

What goes in comes out. On DMR and almost all digital modes, a poor signal doesn't mean low volume. It relates to packet loss, which is information sent but not received. The receiving radio can only reconstruct the sounds it successfully receives. Lost data is either replaced with silence or by repeating the last valid sound. Your dont report R2D2 you report packet loss.

So, the next time you give a signal report on DMR, it’s essentially an audio report. Rate readability from 0 to 5, and if necessary, suggest they turn down the mic gain.

Next time, I'll discuss the coverage and range of DMR. Until then, this has been Matt VK2FLY for the VKDMR network and ARNSW Radnet."

Part 3 – DMR Range & Power

Someone told me DMR has a range limit. What about ducting. That’s crazy talk.

Ok Let me explain. Hopefully, you remember from part one where I talked about TDMA, or Time Division Multiple Access. This is the DMR feature that allows us to have two conversations simultaneously on the same repeater and frequency. However, there is a downside to this, and that's range. Now, don't tune out just yet! We, as radio amateurs, are some of the first citizen scientists, so let’s honour our forebears with a brief physics discussion.

The maximum coverage of TDMA systems is indeed influenced by range, which is dependent on the speed of light and the accuracy of the clock in the receiving radio. Remember the lighthouse analogy?

You need to know when to watch for the light to determine your location. Radios use a bit of a trick for this. When you first key up a repeater, the radio sends a transmission to the repeater, which receives the signal and then sends a signal back to the remote radio. This is called a handshake. Some radios will give a series of chirps at the completion of the hand shake. This tells the users they are ok to begin talking. Like waiting for dial tone before dialling on an old phone. But I digress.

Upon receiving this signal, the remote radio synchronises its internal clock to the repeater's very accurate clock. From that point on, the remote radio knows when time slot 1 and time slot 2 and when it should transmit and when it should be silent. It doesn’t need an extremely accurate clock; it just needs to maintain synchronization for the duration of the transmission.

You might be surprised to hear that this synchronisation happens every time you transmit from a remote radio into the repeater. On FM, you key up, your radio transmits, and keeps transmitting until you release the button. But this is not what happens with DMR. When you key a DMR radio, the radio does a few things in those miliseconds between when you key up and when you speak.

Firstly, the radio sends a signal to the repeater, initiating the handshake. It essentially says, 'Hello, I’m a radio, this is my ID, can you hear me?' The repeater responds with crucial information. The first part of the handshake involves the clock, setting off the timer in your radio. From that point on, it can distinguish between time slot one and time slot two, as long as its clock remains in sync with the repeater’s clock. This allows you transmit on one time slot while someone else is transmitting on the other time slot two radios transmitting in turn without stepping on each others transmission all within a gap of 30millieseconds. Remember that during the next callback if only we had DMR’s clock.

The second part of the handshake involves negotiating other details like the repeater's radio ID. Smart radios also listen to the RSSI, or the received signal strength indicator. At this point, some radios may even decide to switch to another repeater with better RSSI, all while you're pressing the button.

But back to the physics of DMR's range limit. When the handshake occurs, the remote radio starts its timer. But as the radio wave moves out from the repeater, time also ticks away. To us, it's negligible, but it affects when the radio perceives the end of time slot one and the start of time slot two. The longer it takes for the handshake to be received the closer it is to the window where the radio thinks it’s clock is just not accurate enough. This perception is proportional to how well the

remote radio maintains accurate time from the initial synchronization pulse. For commercial radios, that's about 0.5ppm. Without delving into complex math, this essentially means the maximum range for DMR is around 100 km. Within the protocol there is a method of detecting this clock skew and when it does the radio ceases transmitting so as to not step on any other station. It will then typically send a channel unavailable signal (a beep) to the user.

So, when people ask why high-power DMR radios or repeaters with hundreds of watts aren’t common well it’s because high power radios and repeaters would be useless with a 100km limit. 20 watt will easily traverse 100km in most conditions.

Next week it’s back to operation with more about talk groups and how they work.

This has been Matt VK2FLY for VKDMR and ARNSW Radnet."

Part 4 Talk groups.

Talk groups are much more than just a fancy type of CTCSS Squelch; they are an integral part of the DMR protocol. When voice packets are transmitted over the air, each packet contains not only the voice data but also several other signaling parameters. Two of the most important ones for us are the talk group and call type.

In DMR, there are two types of calls: Group Calls and Private Calls. Group calls, which we are most familiar with, are assigned a number based on the talk group your radio is configured for when you key up. A common example on the VKDMR network is 505. When you are on talk group 505, every voice packet your radio sends has this talk group attached, indicating that it is a group call.

These voice packets are received by the repeater, which then passes them to a special server on the network called an IPSC Server. 'IPSC' stands for 'IP Site Connect', a Motorola proprietary protocol that allows Motorola DMR repeaters to communicate with each other. Once your packets reach the IPSC Server, the server's logic examines the type of call - in this case, a group call on 505 - and searches its database to determine the next steps. For 505, this means routing the call to every repeater in Australia. Your voice packet is duplicated and sent to all sixty-plus repeaters, which then transmit them over the air, maintaining the information that it is a group call on talk group 505. Only radios configured to listen on 505 will decode the packet back to voice and play your call through their speakers. For instance, if a listener's radio is set for talk group 3801, it will ignore the group call to 505 as it is not set to decode group calls on that channel. You can think of the talk group like a channel: you only receive broadcasts on the channel you are tuned into.

On the VKDMR network, if you transmit using talk group 3801, the IPSC server will only send that audio to repeaters with users listening to that talk group. It knows which repeaters have active users on talk group 3801 by consulting its internal database. Repeaters without active users for a particular talk group do not receive the call and remain available for other users on other talk groups. It's important to note that I am discussing the VKDMR network's operations, as different networks behave in different ways.

DMR also facilitates private calls, which are different. Instead of broadcasting to all radios on a talk group, private calls are directed to a specific radio ID, enabling person-to-person communication. These calls are typically private, but since it's still a broadcast radio signal, if your radio is set to decode all received calls (a mode known as 'promiscuous mode'), the call might still be heard. For truly private conversations, it's better to use your mobile phone.

DMR radios are also capable of sending other types of calls, such as text messages, GPS positions, and even IP data. These calls are handled differently on various networks, which leads us to next week's topic: Why are there so many DMR networks anyway?

For now, this has been Matt VK2FLY for the VKDMR Network and ARNSW Radnet.

Part 5 – DMR Networks Used in Amateur Radio

As we have learned, DMR is a type of modulation used to send digital audio over VHF or UHF, but there seems to be different networks. You might ask, "Isn't DMR all the same?" Well, while DMR is all the same, the repeaters used are often connected to each other via the internet. These connections are through a central server or, in some cases, groups of networked servers, which allow users of one repeater to talk to people within the range of another. These networks can be run by a wide range of people, and as you can imagine, they don't always see eye to eye. As a result, these networks can sometimes be disparate and not connect to each other. A good example of this is BrandMeister and DMR-MARC. Both have an international English calling talk group. However, if you call CQ on a repeater connected to the BrandMeister network and call CQ on that talk group, someone on the international talk group on the DMR-MARC network won't hear you.

So, here is a quick rundown of the major networks worldwide, in no particular order:

BrandMeister is the biggest network. It consists of a group of networked servers, typically geographically based. It has both connected hotspot users and repeaters; however, the largest group of connected users are hotspot users. International calling is popular, especially on the international talk group 91. There are a lot of short, sharp DX-type contacts and often a lot of doubling and confusion. There are many new users and often users experimenting on the network; as a result, it can be unreliable at times. The BrandMeister network supports DMR APRS, SMS messaging, and has gateways to some other types of networks. SMS messaging can be unreliable due to compatibility issues between brands of radios.

TGIF (Thank God It's Friday Network) is mostly about chat. They have a large net that operates on a Friday evening (US time). The TGIF network uses a central server, so connection is easy and generally fairly reliable. The network has well over 6,000 users, and you will usually find someone to chat with. The network also tends to be fairly reliable, being a central server under the control of a small group of admins. Users are friendly, and minimal experimentation is permitted.

FreeDMR/HBLink is a bit of a wild west. Mostly operating out of the UK, it’s a loose amalgamation of DMR networks that all run the open-source DMR code based on HBLink. Experimentation is encouraged, and most of the users operate on hotspots. These servers could run at home on Raspberry Pis right up to data centre-based servers, so your mileage will definitely vary. It’s a great network, however, if you want to play around with code, experiment with linking, and generally do the things that amateur radio is famous for.

DMR-MARC Worldwide Network incorporating DMRPlus is the original amateur DMR network. Originally initiated by the Motorola Amateur Radio Club, the DMR-MARC network concentrates on simple programming and reliable communications. To that end, the network administrators do not endorse experimentation, and things like linking other networks or connecting analog

gateways are prohibited. In general, the DMR-MARC Network is a network that consists of a number of regional bodies running their own servers that are linked together for global communications. But generally, the local groups make their own rules and configure the local network to suit local operators. In Australia, the VKDMR Network, of which Amateur Radio New South Wales's RadNET repeaters form a part, belongs to the DMR-MARC network group. In Australia, that is around 60 repeaters and growing, and almost 1,000 repeaters worldwide. At any one time in Australia,

more than 270 hotspots are connected, with tens of thousands of users worldwide. The size of this amateur network is truly staggering.

Now, that is just a quick rundown of some of the different options available for connecting to DMR networks, and it is by no means complete. These networks are so large and their user base so vast, some of the information I have discussed here might have even changed by the time you're hearing this. So, it’s always best to check your local group's website for more information. If you're interested in Australia's biggest network, check out VKDMR.net or ARNSW.net, which has much more information than I can relay here.

Next week I will give more information on how to operate on the VKDMR network until then this has been Matt VK2FLY.

Part 6 – How to use the VKDMR network and ARNSW Radnet

The VKDMR Network is the most prevalent DMR Network in Australia, so I thought I would discuss some of the on-air operating procedures and protocols. In a further episode, I will discuss the dreaded code plug and how to configure your radio. But for now, let's concentrate on how the talk groups and time slots work and how to operate on air.

The easiest way to get on air is by using a local repeater, and there is no shortage of them in VK. In NSW alone, there are 24. You can find the frequencies on the VKDMR website. We are going to assume your radio is configured for your local repeater and is in range. You can easily tell if a repeater is in range of your radio, as I'm sure you remember from when we began this journey: there is a two-way handshake between your radio and the repeater when you key up. Most radios will give you a series of beeps when you key the button. However, these beeps are not random tones. They are a clear to transmit indication. They tell you your radio is in range of the repeater, the repeater and radio are in sync, and the repeater is waiting to retransmit your audio. Most radios will also relay an error tone if the repeater is out of range. So, it’s best to familiarise yourself with these tones depending on your radio.

On the VKDMR network, tune your radio to talk group 505, time slot 2. This is the Australia-wide calling talk group. A call on this talk group keys up every repeater and every hotspot in Australia. Every DMR radio, likely many hundreds of them, will open its squelch and relay your audio; your callsign and name will also likely appear on all radios listening. This happens even with a quick kerchunk. So, kerchunking over and over to see if you are in range is frowned upon, and in a lot of cases, it's unnecessary as a correctly configured DMR radio will usually indicate on the screen if you are in range of a repeater. So, if you're on 505 and ready to go, why not start with a CQ or requesting a radio check? Typically, someone will reply. Remember, if you are asking for or give a radio check, only your audio quality is useful. Signal strength means nothing on a digital DMR network; it either works or it doesn't. So, radio checks should be limited to audio quality and whether there is any breakup or not. I simply like to stick to a simple 1 – 5 readability scale.

It’s also useful if you have a computer or tablet handy to have the VKDMR dashboard up when you're making your first calls. The dashboard will show all the repeaters on the network and all the current transmissions. When you make your first call on 505, you will note that the dashboard will indicate green on your local repeater, indicating your call is being received, and orange on all the other repeaters to indicate they are transmitting your message across Australia.

Once you have established contact on 505 and if you want to continue the conversation longer than a quick exchange, the administrators of the VKDMR network request that you then QSY to another vacant talk group to continue the conversation. These are called the TAC talk groups and range from 3801 to 3810 on time slot 1. This frees up 505 for another user to make a call. Once

you have QSY’ed to another talk group, the network will automatically route your call between the two (or more) repeaters where that talk group is selected. So, only those repeaters with active users on that talk group will be engaged in the conversation. The rest of the network then remains free for other conversations. This is the power of the DMR network to provide massive capacity for intercommunications simultaneously. Once you have finished your QSO on one of the TAC talk groups, all you need to do is QSY back to 505. The network will automatically remove the links between repeaters when they have remained unused for longer than 15 minutes.

It's mostly just that simple. Call on the call channel, make a contact, QSY to a vacant talk group, and continue the QSO. No matter what repeater or what part of the country you are in, the network does all the heavy lifting for you. Whether you're in Port Macquarie or Port Melbourne, it's exactly the same.

A universal resource for radio amateurs in Australia to communicate at will with reliability and ease of use.

Next week, we tackle the dreaded code plug. I promise I won't mention the learning curve.

Till then, this has been VK2FLY.

Part 7 – What the hell is a code plug?

What do you think is the most common question I get asked in relation to DMR? "Do you have a code plug for XYZ Brand Radio?"

But what the hell is a code plug, and why can't people seem to make them for themselves? Well, to the first question, the term code plug is used by Motorola staff and salespeople. It's the name Motorola adopted for what simply is a configuration file for your radio. It's a callback to when you needed to make a config file for Motorola radios, burn it into an ROM, and plug it into the radio. So, the answer really is you only need a Code Plug if you happen to own a Motorola; other than that, you need a config file for your radio. Almost all DMR radios use some type of config file that is generated by some software and then uploaded to the radio. The config file simply contains the setup of the radio, information like the frequency of the repeaters, the splits, the talk group, and time slots. None of the information should be too hard to understand or configure. It might take some trial and error and even some patience, but it should not be beyond any amateur to do it unassisted.

I find the best way to start is to gather the information you need to build the radio's config. Get the frequencies for the repeaters or hotspots you want to access. I usually allocate each repeater its own zone. Then within the zone, add some channels. The channels on VKDMR are always the same for every repeater. They will include the talk group 505 time slot 2 and the talk groups 3801 – 3810 time slot 1. At its very simplest, that is all you need: a single repeater or hotspot in a zone and then 11 channels. Above that, you also need to be careful to add your radio ID, which is a unique ID you will need to apply for on the net. It's no harder than that.

Start off small with one repeater or a single hotspot. Once you have things working, you can try and add more repeaters. The other thing to remember is to not switch on any special features early on. This is where things can get confusing. If your radio has promiscuous mode, you will want to disable it. Promiscuous mode is a bit like scan; it will listen to multiple talk groups, and you will hear the audio no matter what talk group is in use. This can be useful but, in the initial stages, very confusing as some radios jump the transmit talk group to the last talk group heard when in promiscuous mode. A situation then occurs where you have no idea what talk group you are transmitting on. Not good for your first adventure into DMR. So, turn that off. You will also want to turn off any location sending or GPS features as they are not supported on the VKDMR network; again, make the configuration as simple as possible, get it working, and then work your way up.

Another thing you may want to try is to load a DMR radio ID database into your radio. The database will allow your radio to display the caller's name, callsign, and perhaps even their location on the screen of your radio when you hear their transmission. As we know, there are a wide range of DMR-capable radios. Some radios allow many contacts to be loaded into their memory, other radios will only allow a limited amount. A worldwide radio ID database has hundreds of thousands of entries, and only a small number of DMR radios will accept that entire table. So, you may need to limit the amount of contacts you load into your radio to just VK, for example. There are a number of places you can download these databases from the internet so they can be imported into your radio software and in turn uploaded into your radio. A good place to start is the ARNSW config generator, which will dump a limited radio ID database that just contains VK users that are using

the VKDMR network. The database will fit into most radios, and there are a number of options on the site for different radio types.

So, really now, you have the basics for making a config file for a DMR radio. The main thing to remember is you can't really break the radio, and other than upsetting a few OMs on the air with your radio checks, you can't really go wrong by giving it a go. You will also get a kick out of having a config on your radio that is unique to you and exactly the way you want to operate rather than using a hand-me-down.

This has been Matt VK2FLY until next time.

Part 8 – Wrapping Up:

As we close this series on Digital Mobile Radio (DMR) for amateur radio in Australia, let's take a moment to reflect on the ground we've covered and the knowledge we've shared. From the basics of DMR, through codecs, range, power, talk groups, to the intricacies of DMR networks and the essential code plug, our journey has been both comprehensive and insightful.

DMR stands out in the digital landscape for its efficient use of bandwidth, offering clear voice communication and the capability to carry two conversations simultaneously over a single frequency, thanks to TDMA. We've delved into the science behind codecs, the digital alchemy that converts our voice into data packets, enabling crisp, clear communication across the airwaves. Understanding codecs was crucial, as it shed light on why DMR can sometimes sound robotic and why it excels in voice but not music transmission.

Exploring the range and power of DMR, we debunked myths and confirmed that while DMR's range is indeed influenced by physics, its operational range is more than adequate for amateur use, with the added benefit of requiring less power. Talk groups further demonstrated DMR's versatility, allowing for both broad and targeted communication, enabling users to connect with groups or individuals across the globe or just around the corner.

Our journey through DMR's diverse networks revealed the vast ecosystem of interconnected repeaters and hotspots, from BrandMeister's extensive network to the pioneering DMR-MARC, highlighting the flexibility and global reach of DMR. Each network serves a unique purpose, catering to different aspects of the amateur radio experience, from casual chats to technical experimentation.

Understanding how to navigate the VKDMR network and ARNSW Radnet was pivotal, providing practical advice on accessing and utilizing these resources to enhance your DMR experience. Whether it was mastering talk groups, optimizing time slots, or simply making your first call, these insights aimed to demystify the process and encourage active participation.

Finally, the concept of the code plug, while initially perplexing to some, was demystified. Essential for configuring your radio to your unique needs and preferences, the code plug is your key to unlocking the full potential of DMR. With patience and a bit of trial and error, anyone can create a personalised setup that enhances their amateur radio experience.

In wrapping up this series, it's clear that DMR is not just a mode of communication; it's a gateway to a vibrant, global community of amateur radio enthusiasts. The knowledge shared here is but a foundation, one upon which you can build your own journey of discovery and connection. As

technology evolves, so too will the world of DMR, offering new opportunities to learn, to experiment, and to connect.

This series may have concluded, but your adventure into the world of DMR is just beginning. Embrace the challenges, revel in the successes, and remember, the amateur radio community thrives on collaboration and shared knowledge. So, get out there and keep the airwaves alive.

If you would like to review this series again the transcript can be found on the ARNSW Radnet Microsite at arnsw.net there you will find transcripts of the series as well as links to the audio on you tube.

Until next time this has been Matt VK2FLY