Technical White Paper

Long Range Digital Radio (LRDR)

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RADIO COMMUNICATIONS

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1. Introduction

Commercial High Frequency (HF) radio communications in Australia has been around since the 1960's and gained an immediate following as a means to communicate with lone or remote workers over vast distances. Every decade or so, HF Radio manufacturers release unique features that reinvigorates the market interest in the communications medium. Whilst the 1970's were reasonably subdued for HF radio, the 1980's brought about multi-channel 'computer controller' radios, the 1990's Automatic Tuning antennas and the 2000's with Automatic Link Establishment (ALE), where users no longer need to perform channel tests or have an in-depth knowledge of HF propagation. Unfortunately for HF radio, the current millennium also introduced inexpensive satellite communications which has since reduced the uptake of HF radio terminals.

In 2013, Codan Radio Communications, a division of Codan Limited, began working on the next evolution for commercial HF Radio – Long Range Digital Radio (LRDR). Although Codan had developed and was already selling an early generation of Digital Voice for its NGT™ HF radio series, the cost, performance and voice quality limited it's uptake to certain 'secretive' organisations and para-military groups. In July 2014, Codan released its Second Generation Digital Voice solution offering affordable, encrypted (optional), clear and 'better than analogue' performance with their Envoy™ series of Software Defined Radios, hence the birth of LRDR. Since its introduction, several organisations and agencies have begun upgrading their entire fleet of analogue HF radios.

It needs to be highlighted that reliable remote-area communications is only as good as the infrastructure that supports it. Without a properly designed, implemented and maintained network, the maximum benefits of an LRDR network will never be realised.

1. What is LRDR?

LRDR represents the evolution of HF long distance communications from Analogue based to Digital for voice, messaging and data communications. LRDR is a long distance communications medium utilising the HF spectrum to provide a voice quality and data transmission experience similar to cellular and P25 communications, while also providing the capability for encryption, IP and Ethernet connectivity and all standard HF capabilities, including ALE and Selcall.

2. Design considerations when establishing a reliable Long Range Digital Radio system

2.1 Location

Site location for any Analogue HF or LRDR system is critical and having a suitably located 'RF quiet' environment with enough land to deploy an appropriate base antenna is the first step to a high performing network.

Where possible choose a location, where essential services such as mains power and IP connectivity are readily available, typically located on the outskirts of a remote or rural township. Where possible, avoid locating the LRDR site near noisy SWER (Single Wire Earth Return) lines or feeding the LRDR site with AC Mains from an SWER line. Ensure that site access is possible in all circumstances and the site is physically unaffected during times of natural disaster (e.g. floods and bushfires).

2.2 The base antenna

Antennas are a critical system component that is quite often overlooked in favour of cost and as a by-product, system performance. High Frequency suppliers agree that a properly selected antenna is at times favourable over a high power transmitter. Obviously the combination of a High-Power Transmitter and a High-Performance Antenna will provide the ultimate in Quality of Service (QoS) for any Long-Distance Communications System.

In all cases, a proper base antenna such as a Full Delta, Tandem Delta or a Bi-Conical antenna (see right) will always out-perform any building-mounted vertical antenna with tuner or broadband travelling wave horizontally mounted antenna. The Bi-Conical for example has been specifically designed to promote short to medium communications distances, help reject over-seas interference due to its radiating angles and provide a reasonable amount of gain.

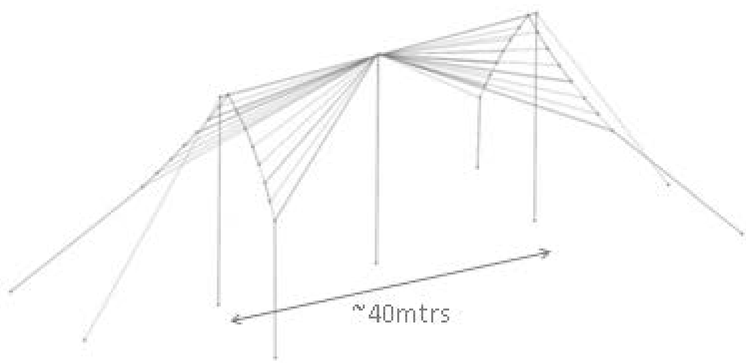

Figure 1 - Bi-Conical antenna

2.3 The base transmitter power

When we analyse High Frequency propagation there is a clear link between higher transmit powers and successful communication between stations. This is particularly noticeable when the communication is between a base station and a mobile station. A base station usually consists of a large antenna that is often placed in a RF quiet environment; these antenna types offer good efficiency due to the physical size of the radiating element.

In comparison a mobile station is a naturally noisy RF environment due to the internal electronics of the vehicle itself (alternators, engine management systems, etc.) plus its frequent proximity to manmade RF noise such as high voltage power lines. The relatively small size of the mobile radiating element (compared to the base antenna) also introduces a high degree of inefficiency to the transmitters and receivers performance.

In essence we could say this is an asymmetrical transmission path with the odds heavily stacked against the mobile installation. We can however re-balance it by increasing the transmit power of the base station to significantly improve the receive signal level at the vehicle. This approach also counters fluctuating RF conditions which are inherent to HF propagation and provides a more stable platform for reliable voice communications.

Figure 2 - Codan HF High Power Amplifier

Where emergency service organisations are deployed during times of natural disasters we not only need to deal with the vehicle's natural noise, but the noise and less-than-ideal conditions that are presented by the disaster itself. In these circumstances, if we are to assume the worst, high-power base transmitters overcome the majority of these interference conditions to the point where an excellent QoS can be maintained, reliable communications can be attained and lives can be saved.

3. Multiple LRDR Super-Sites

For communications over large areas, one site can be established with the correct selection of frequencies permitting wide-area communications, however in this situation the single site would only permit one conversation to occur at any one time and would be prone to overseas interference due to frequency selection and antenna design. HF propagation (i.e. the communications distance) is generally based on the time of day, frequency selection and antenna design, where the lower the operational frequency the shorter the communications distance and the higher the frequency the longer communications range possible.

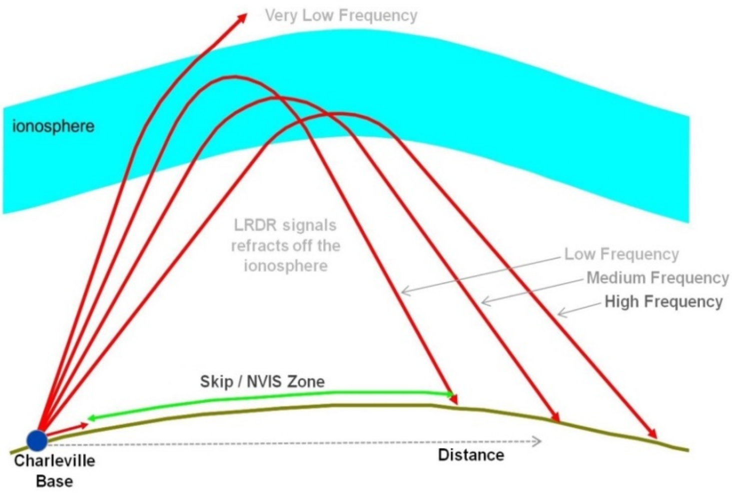

Figure 3 - HF propagation

For a deployment of a LRDR system over a large site location, such as the State of Queensland in Australia (1,852,642 km²/ 715,309.1mi²), it is recommended a minimum of three to four Super Sites be established, and limit the highest frequency to one that can communicate with the neighbouring Super Site 24/7 should there be site failure (consider this as form of Disaster Recovery). Furthermore by having multiple sites and limiting the highest frequency, we can improve the QoS considerably, promote some frequency re-use with neighbouring Australian States, minimise the chances of overseas interference and increase the signal delivered to mobile units operating in less than ideal conditions.

Figure 4 - LRDR Super Site locations in Queensland

4. ACMA and ITU Frequency Considerations for LRDR systems

Australia belongs to what is known as the International Telecommunication Union (ITU) Region 3. As HF frequencies can travel many thousands of kilometres, the ITU sets out rules and regulations governing the global issuance of radio spectrum, of which ACMA follows (Search '*ACMA Spectrum Chart 2013*').

Figure 5 - International Telecommunication Union (ITU) Region 3

With the advent of LRDR we are aware that we cannot co-share frequencies with HF Analogue (3K00J3E) users, but equally so we cannot co-share with co-state digital (3K00J2D) users on the same frequency without some form of careful planning, smart use of frequency and correct antenna selection.

Of the many problems facing the ACMA is the desire to satisfy Australian users whilst maintain their obligations to the ITU and neighbouring countries – even though vacant frequencies exist in the ACMA 2-18MHz spectrum database, this doesn't mean they are available for use. For example, Papua New Guinea (PNG) Air Services (PNG-AS) have numerous frequencies used for Air-Ground communications within PNG and surrounding areas, yet it is possible to receive PNG-AS HF traffic in various parts of Australia. Therefore the ITU coordinates with member nations to provide exclusivity for critical services; such is the case for PNG-AS and the reason why their frequencies appear to be available in the ACMA's database.

If you combine the above HF frequency allocation dilemmas with organisations desire for High-Power licences (typically 400 watts) and the ACMA has additional concerns and rules when assigning frequencies to Australian clients.

Bottom-Line: Act early, be prepared to wait for your 3K00J2D frequencies and similarly be prepared to reject frequency allocations where it is obvious interference will occur with co-state users

5. LRDR optional features

5.1 GPS Positioning

Besides the plethora of digital advantages for clear and reliable communications, we can also make use of smart frequency allocation dedicated to GPS positioning of fielded mobiles. Using intelligent GPS controller options for the Envoy transceiver, we can now manage the transmission of GPS coordinates to a central location without fear of interference to voice services using additional receivers at the LRDR Voting sites.

Other advances include the possibility of connecting an inexpensive Garmin® Nuvi™ to the same GPS intelligent controller to permit short SMS style messaging to/from mobiles, using the display of the Nuvi as a Mobile Data Terminal.

5.2 LRDR Voting

Until now, any type of signal measurement / reporting using Analogue HF transceiver was quite 'hit and miss', due to the transceiver not knowing what was considered Voice and what was considered interference. One of the very elegant features of available on Digital Radio is the ability to measure the Bit Error Rate (BER) and obtain a useful measurement of signal quality. With a reasonable amount of licence-free LRDR receivers scattered throughout the state, all joined to form an intelligent network, we can now use a form of Transmission Voting to measure the BER and use the appropriate audio with the greatest signal quality.

Earlier in this document, it was specified the LRDR base to be located in an RF quiet environment (to assist with mobile reception), with an appropriate base antenna for short to medium range communications and to increase the base transmitter to 400 watts to overcome the inherent noise found within modern-day vehicles. With LRDR Voting the mobile now has the ability to have its transmitted signal (using its very inefficient antenna) received by multiple licence-free stations geographically spaced apart so that any natural events (cyclones, electrical storms, etc.) do not affect the QoS expected by organisations. LRDR Voting will be an optional feature available 2015.

5.3 Disaster Recovery

As part of any large-scale critical communications deployment, Disaster Recovery (DR) techniques must be considered early in the design phase. These can take the form of component redundancy, network duplication or the use of satellite back-haul when ground infrastructure has failed.

6. Analogue vs Digital radio

Whilst Digital communications over HF has been around for many years, it is generally been restricted to military or para-military organisations due to the inherent cost and 'robotic' nature of the recovered audio (generally reserved for highly trained individuals).

In July, 2014 Codan introduced a commercially available and affordable Digital Voice (DV) system offering vastly superior recovered voice performance, comparable to P25 audio. The standard 2400bps and optional 1200bps vocoder rates not only offered vastly superior recovered audio, but totally eliminated any traditional 'pops', whistles and crackles often associated with HF communications.

Furthermore ,the analogue HF transmitter power is linear to the amount of voice energy at the microphone. Where a soft-spoken or untrained individual is using the Analogue transceiver, you will often find the average transmitter power to be less than 50 watts (from 100 watts maximum) – In an environment where 'power is king', this is undesirable. However in DV mode, the average transmitter power is closer to 90+ watts regardless of the soft spoken or untrained individual. This higher than average transmitter power helps overcome interference and combined with the excellent recovery properties of the digital signal (5dB or better over Analogue) provides a compelling case for a digital upgrade.

6.1 Analogue vs Digital - Fact 1

Based on trials, an Adelaide Envoy base communicating to a mobile 360Km away with the vehicle travelling at 100Km/h, with ignition noise and some other interference present in Analogue Mode, by switching to DV Mode, it eliminated all noise and interference to allow clear communications to take place (see Codan White Paper - Government Public Safety).

6.2 Analogue vs Digital - Fact 2

Over a communications distance of 290Km, an Envoy base to stationery vehicle, a user experienced significant overseas Radio-Teletype interference at 5pm making Analogue communications virtually impossible. Switching to DV Mode, the locally transmitted digital signal coupled with the Envoy's excellent DV performance allowed crystal-clear communications to take place (Test performed by the Ambulance Service of NSW Radio Technicians).

6.3 Analogue vs Digital - Fact 3

With a 'virtual carrier' now present on every Digital HF transmission, we gain a few very important features, including:

a) Recovered voice clarity comparable to P25;
b) Vastly improved signal performance over Analogue with Digital performance close to 0dB S/N;
c) Secure communications using AES256bit encryption. Law enforcement issues and patient history can be discussed in total privacy;
d) We can mimic a standard VHF/UHF transceiver as we gain a 'Busy Line' from the Envoy that allows the audio to be routed just like a standard FM transceiver.

Acknowledgements

Codan Radio Communications acknowledges the significant contribution of Nick Stefanou of Mobile Communications QLD for the content and development of this white paper.

Digital Voice Field Trial

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Long Range Digital Radio: 2nd General DV

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Codan Long Range Digital Radio (LRDR): Second Generation Digital Voice Trial Field Report – June 2014

Scope

In June 2014, a local government public safety department kindly agreed to a request from Codan Radio to participate in a live field trial to validate the performance of our second (2nd) Generation Digital Voice on the Envoy Software Defined Radio (SDR) platform. This coincided with a pre-planned equipment maintenance inspection which took them into the far north of South Australia and outside of SAGRN (South Australia Government Radio Network) coverage with total distances up to 1250 km (see Figure 1).

All communications were between a static base station in Renmark, SA and a mobile vehicle. Equipment configurations were as follows:

	Radio	Transmit Power	Antenna
Base	Codan Envoy X2	100W	Full Delta
Vehicle	Codan Envoy X2	100W	9350 tuner with 1.6m whip

The trial ran for a total of 7 days and mainly focused upon digital voice testing but also included secure messaging and GPS vehicle monitoring where all co-ordinates were obtained over the air.

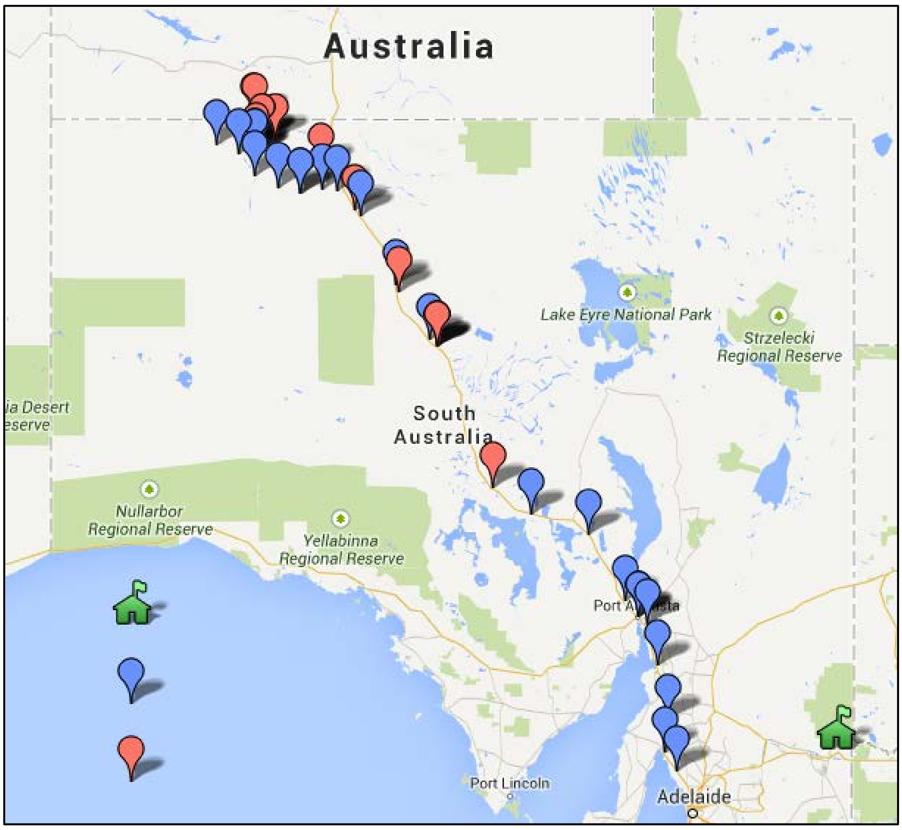

Figure 1 – Map of testing distances and locations

Historical Background

The local government public safety department have long been Codan customers however had concerns during a review about whether to continue with high frequency (HF) radios as a part of their total communication strategy. The issues were centred on three core concerns:

1. High Frequency radios are viewed as hard to operate and required significant operator training to use effectively
2. Analogue SSB radio lacked voice clarity and needed the operator to "listen hard" to transmissions due the inherent "hiss and crackle", this is often impractical in noisy and stressful operations which is common in government public safety
3. As a long range broadcast medium without encryption, high importance/sensitive information could not be passed securely

However there is a clear operational need for a mobile and robust long range communications strategy to talk when outside of SAGRN coverage or in times of natural disaster when internal infrastructure is affected.

LRDR Technology

Recent developments in software defined radio (SDR) and HF optimised digital voice needed to be field trialled to re-establish confidence at both the operator and management level. In essence to ascertain the operational validity of what is now being referred to as Long Range Digital Radio (LRDR). This technology needed to be stressed to its limits to prove itself as a wholly modern, secure and effective tool that complements the radio suite that the public safety department vehicles currently carry.

The competing adjacent technology for HF radios is satellite phones. Their differentiator has always been one of voice quality over traditional analogue HF radio. However with the introduction of the latest generation digital voice technology the gap has closed up significantly. Digital voice over HF has no crackle or hiss just high clarity audio, meaning that inexperienced operators can clearly hear what is being said and it can be digitally encrypted to ensure the highest level of operational security. Vocoding rates, hence voice quality, are equivalent to satellite communications and at 2400 bps the difference is indiscernible. For the first time satellite communications can be directly compared with a LRDR network in terms of voice quality and security. Another attractive aspect is that LRDR offers OH&S safety compliance using GPS location services for deployed personnel operating in remote areas, this is a clear benefit over satellite services as an equivalent satellite phone GPS Polling system would require a large amount of additional data at a significant extra cost to the business. LRDR in comparison has no ongoing costs, all data is free.

Another point for consideration is one of network ownership. With an LRDR network the owner has full sight of every aspect and is not dependent upon third party infrastructure as with satellite communication. This level of control is key when mission critical communications are involved.

In addition to the from the audio clarity that LRDR provides, all voice traffic can be fully AES 256 encrypted and therefore an operator can freely discuss any operational matter without fear of breaching communications security (COMSEC).

Trial Results

Over the course of the 7 days the results of the digital voice trial were overwhelmingly positive so much so that in Codan Limited's 2014 Annual Report the local government public safety department granted permission for one of the trialling personnel to be quoted as saying:

> *"The latest generation digital voice over HF gives us the ability to talk securely, and the digital quality of the audio enables easy and clear communications. This makes HF a much more operator-friendly option than ever before."*
>
> http://bit.ly/1yz1YYW (page 13)

The department has also made direct requests for added capabilities which they deemed essential to fit with their operational requirements. One of note (that is now fully implemented in our latest firmware release) is a feature that allows seamless switching between secure and non-secure networks that is entirely automated and is transparent to the operator.

Envoy was also commented upon favourably and often these were based around its "Smartphone" feel. This is a result of many interactions directly with customers who wanted the product to be "intuitive" and to "make sense".

Envoy (as an IP addressable radio) can be placed wherever is suitable and be operated, via a console, anywhere globally. This has a tremendous impact when considering a multi-site complex communication environment.

Trial Outcomes

The local government public safety department decided to add Codan Envoy's to their future remote communication strategy and did subsequently purchase a large number of Envoy radios with secure digital voice capabilities and are project scoping a gradual upgrade from analogue to LRDR across their entire fleet.

The department's progressive stance on LRDR technology is being echoed across Australia by a number of other Government Departments, Police and Emergency Services. Notably, there have been recent sales in NSW into the Ambulance Service, SES and Police.

Thanks

Codan would like to thank the local government public safety department both for their technical expertise and product reviews; these were directly fed into our radio engineering teams as part of our continual improvement processes. Partnering with our customers to make our products better is something Codan sees true value in.

If you would like to discuss further directly with the end user or Codan Radio, please contact Daniel Scalzi, Regional Sales Director on +61 8 8305 0385 or daniel.scalzi@codanradio.com

Supporting Information

1. Web article - Brisbane Times, Tropical Cyclone Ita: April 12, 2014 – Hope Vale, QLD
   - 300 in the Hope Vale Event Centre
   - 949 without power and no restoration timeframe
   - No mobile or internet. Police codan radio only.

2. Codan Envoy & Digital Voice Demo Web Link

   http://www.codanradio.com/envoy