Digital Radio Standards
Advantages and Disadvantages of Current North American Digital Radio Standards
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INTRODUCTION

The need to transfer ever more voice and data services over the available Land Mobile Radio (LMR) radio spectrum has led many organizations to consider replacement of their existing radio networks. But, finding the right technology to meet their specific needs and use cases can be both confusing and time consuming.

This positioning paper will provide a summarized comparison of the current North American digital technologies outlining the advantages and disadvantages for each of them. The technologies compared are DMR, dPMR, P25, NXDN and Opensky®.

WHY DIGITAL RADIO?

Basically, compared to legacy analog systems, digital radio networks give:

- More capacity from the same number of frequencies; that is, they provide superior Spectral Efficiency\(^1\). This is a result of the modulation methods used, and the fact that, in many cases more than one ‘conversation’ can be accommodated within a single radio channel.

- Consistent voice clarity at low received signal levels near the edge of coverage. The general consensus is that digital radios provide better audio quality than analog ones. With analog FM radios, the audio quality steadily declines as the received signal strength gets weaker. Digital radios however, will have a consistent audio quality throughout the full service area. The edges of the coverage area in a digital radio system are similar to those experienced with cellular telephones.

- Data is defined in the standard. This means data implementations are no longer proprietary, there are a wide variety of data mechanisms and interoperability can extend into the data domain. With the accepted increase of efficiency by using data communications over voice, this will further increase the usability and effectiveness of digital radio systems.

- Secure transmissions in digital technologies, data and voice can be secured using encryption without impacting voice quality using industry standard encryption techniques.

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\(^1\) Spectral Efficiency is a term relating to the amount of information that can be conveyed in a given bandwidth.
TECHNOLOGY COMPARISON

The following section summarizes the key aspects of the current digital standards and lists some of the relative advantages and disadvantages of each.

DMR

- Similar data throughput P25 Phase 2
  - 9600 bps (symbol rate of 4800 symbols/sec)
  - 2-slot TDMA
- 4FSK Modulation
  - No need for linear transmitters
    - Cost and size about same as analog FM transmitter
- Transmitter output spectrum fits into existing 12.5 kHz narrowband FM Analog channel
  - No need for re-banding or re-licensing
  - Thus can choose best frequency for application
- Designed to make analog to digital upgrade easy
- Coverage designed to be the same as Analog FM
  - Can use existing Infrastructure sites

Advantages of DMR

- Non-proprietary open standard
- Commercially attractive alternative to P25 for those who do not need a high-end system
- Gives 6.25 kHz channel efficiency, four times that of legacy 25 kHz Analog channels, which complies with all current and likely future FCC mandates.
- Doubles network call capacity when replacing an analog network with 12.5 kHz bandwidth
- TDMA extends radio battery charge duration, when compared with P25 or 12.5 kHz analog FM radios
- 12.5 kHz channel size allows re-use of existing frequency licenses and site infrastructure (i.e., combiners, antennas)

Disadvantages of DMR

Does not provide full duplex

P25

Phase 1

- Similar data throughput to DMR
- 9600 bps (Symbol rate of 4800 symbols/sec)
- C4FM Modulation
  - No need for linear transmitters
    - Cost and size about same as analog FM transmitter
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- Transmitter output spectrum fits in to existing 12.5 kHz narrowband FM Analog channel
  - No need for re-banding or re-licensing
  - Thus can choose best frequency for application
- Designed to make analog-to-digital upgrade easy
- Coverage designed to be the same as Analog FM
  - Can use existing infrastructure sites

Phase 2

- Lower data throughput than TETRA
  - 12000 bps (Symbol Rate of 4800 symbols/sec)
  - 2-slot TDMA
- Modulation choices made to optimize performance and simplify terminal design
  - HDQPSK Modulation in downlink (base station to terminals)
    › Requires linear transmitter in base station - more expensive, needs a higher current and is physically larger
  - HCPM modulation in uplink (terminals to base station)
    › No need for linear transmitters in terminals
    › Cost and size about same as Analog FM Transmitter
- Transmitter output spectrum fits into existing 12.5 kHz narrowband FM Analog channel
  - No need for re-banding or re-licensing
  - Thus can choose best frequency for application
- Designed to make analog to digital upgrade easy
- Coverage designed to be the same as analog FM
  - Can use existing infrastructure sites

Advantages of P25

- Non-proprietary open standard
- Designed with public safety in mind
- Conventional, trunked, and simulcast options. Combinations of these options can be optimized to reflect customer requirements. For example, trunked in high-density urban areas and conventional in rural areas
- Designed for gradual, phased migration from analog FM. Equipment can operate in Analog FM mode, in digital P25 mode, or in dual mode
- Supports simplex mode (repeater talkaround) for direct communications outside network coverage
- Secure end-to-end encryption

Disadvantages of P25

- Only 12.5 kHz channel efficiency (FDMA). However, Phase 2 of the P25 standard provides an upgrade path to 6.25 kHz channel equivalence, but only for voice
- While P25 radios can be dual mode (analog FM or digital P25), trunked P25 networks cannot offer analog FM services
- High cost of systems
dPMR

- Minimum cost digital voice standard offered by Kenwood and Icom as alternative to DMR
- Data throughput same as DMR
  - 4800 bps (symbol rate of 2400 symbols/sec)
- Uses FDMA
  - Infrastructure more complicated than DMR
  - Increased transmit power lost in combining equipment
  - Adjacent channel performance worse than DMR
  - Shorter portable battery life
- 4FSK Modulation
  - No need for linear transmitters
    › Cost and size about same as analog FM transmitter
  - Transmitter output spectrum fits into existing 12.5 kHz narrowband FM Analog channel
    - No need for re-banding or re-licensing but may only get 1 channel in 12.5 kHz
    - Thus can choose best frequency for application
- Coverage designed to be the same as Analog FM
  - Can use existing infrastructure sites

Advantages of dPMR

- Non-proprietary open standard
- Conventional and trunking options
- Simple solution to replace existing low capacity systems

Disadvantages of dPMR

- More complicated radio site engineering for larger solutions
- Limited vendor offerings
- Portable shift life less than TDMA alternatives

OpenSky®

OpenSky is a proprietary radio system used in North America which targets public safety, transport and utility customers. It uses 4-slot TDMA in 25kHz channels. It provides a data rate of 19.2kbit/s over a 25kHz channel.

Advantages of OpenSky

- OpenSky networks are IP based. Radios have IP addresses, which are used to identify the destination for a message
- These networks use interface cards to interconnect with other networks and this is how OpenSky achieves interoperability. This form of interconnection provides a customer with an easy migration path during a fleet changeover
- The technology used in OpenSky is versatile enough to be used in trunked or conventional mode. When used in the trunked mode, no control channel is needed—an advantage in site planning
- When a user switches on their radio, they are able to enter a PIN number which causes their own personalized radio profile to be downloaded onto that radio
- The advantage here is that any user, can personalize any radio very quickly in terms of channels and set ups
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Encryption is available
Multimode terminals are available that support P25, OpenSky and EDACS®, allowing for easy migration and integration

Disadvantages of OpenSky
Proprietary²
OpenSky has limited range due to the modulation scheme and slot timing. More sites are often required to achieve the same coverage as the analog systems that are being replaced
Requires 25 kHz channels and is available only in the 700/800 MHz and 900 MHz bands

NXDN™
NXDN™ (Next Generation Digital Narrowband) is a set of protocols that have been jointly developed by Icom Incorporated and Kenwood Corporation. NXDN is based on the dPMR standard but does not comply with all aspects of it. The initial driver has been to meet the requirement of 6.25 kHz channel efficiency. Both companies have released products (IDAS from Icom and Nexedge from Kenwood) based on these protocols. Each has both conventional and trunked options. It is worth noting that the trunked options are not currently compatible with each other.
The basic outline of the NXDN specifications is complete and it was anticipated that other companies would develop products based on this specification.

Advantages of NXDN
Complies with FCC requirements for 6.25 kHz channel equivalence
Low cost of ownership
Backwards compatible with analog and with LTR (Logic Trunked Radio networks

Disadvantages of NXDN
Trunked NXDN products from different manufacturers (Icom and Kenwood) are not compatible with each other
Reduced portable shift life due to FDMA transmission format
Outdated and proprietary offering with limited vendor support

OTHER CONSIDERATIONS

IP-based Backbone
Linking sites in a legacy analog network can be expensive, with a separate leased line for each voice channel and additional links for control signaling. Modern radio networks now generally use an IP-based backbone. Voice and signaling are transported as IP packets over a network that uses data-capable circuits and off-the-shelf building-blocks, such as routers and switches. This makes it possible to multiplex control signaling and multiple voice calls over the one link.
The standards may not specify line interfaces but there is an advantage to having a network that uses an IP-based backbone. Identify networks whose elements were designed to work with an IP-based backbone. Some networks can only use an IP-based backbone if they have additional equipment to carry out the necessary protocol conversions from older circuit-switched technologies.

² OpenSky® is an offering exclusively from Harris.
Interoperability
Organizations may be called on to interoperate with other organizations, especially in emergency situations. For example, an electricity utility may need to be in communication with police when dealing with storm damage. Once the procedures for dealing with such situations are clear, any interoperability needs will emerge.

Having a network based on the same standard as the organizations that you interoperate with may become important. Standards that offer an analog FM mode of operation may offer advantages. For example, direct mode may be of use to provide interoperability at the scene.

CONCLUSION
Recent years have seen an increase in the number of radio standards and proprietary options. Those who are considering investing in a new or upgraded network have the benefit of an increased range to choose from but also the risk of making an inappropriate choice. A careful analysis of actual communications requirements, followed by an exploration of the available options, hopefully assisted by this white paper, will facilitate the choice of the best fit for your organization.

FOR FURTHER READING
Associations
DMR Association
dmrassociation.org
dPMR Forum
dpmr-mou.org
NXDN™ Forum
nxdn-forum.com
Project 25 Technology Interest Group
project25.org
RadioReference.com LLC
wiki.radioreference.com