

# Digital Radio Standards

Advantages and  
Disadvantages of Current  
Digital Radio Standards

---

White Paper

**CONTENTS**

**Introduction** .....03

**Why Digital Radio?**.....03

**Technology Comparison** ..... 04

    DMR ..... 04

    P25.....05

    dPMR..... 06

    TETRA .....07

    OpenSky..... 08

    TETRAPOL..... 09

    NXDN ..... 10

**Other Considerations** ..... 10

    IP-based backbone..... 10

    Interoperability .....11

**Conclusion**.....11

**Further Reading**.....11

    Associations .....11

**General terms of use for Tait technical documentation.** While Tait has taken every care to ensure that the information and contents are correct and up-to-date at the time of printing, the information may contain technical inaccuracies and/or printing errors. Tait does not guarantee the accuracy or correctness of the information. Tait cannot be held liable or responsible for errors or omissions in the contents of the technical documentation. All information contained in the technical documentation is given without warranties or representations, expressed or implied.

**Disclaimer.** Tait Limited marketed under the Tait Communications brand. Tait Limited expressly disclaims all warranties, expressed or implied, including but not limited to implied warranties as to the accuracy of the contents of this document. In no event shall Tait Limited be liable for any injury, expenses, profits, loss or damage, direct, incidental, or consequential, or any other pecuniary loss arising out of the use of or reliance on the information described in this document.

**Copyright © 2012 Tait Limited.**

## INTRODUCTION

The need to transfer ever more voice and data services over the available PMR 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 digital technologies outlining the advantages and disadvantages for each of them. The technologies compared are DMR, dPMR, Tetra, TETRAPOL, P25, NXDN and Opensky. This paper will not provide the technical details behind the standards or formats used. If this is of interest, please refer to the Tait paper “Digital Radio Standards Uncovered”<sup>1</sup>.

## 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**<sup>2</sup>. 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.

---

### Footnotes:

1. <http://www.taitradio.com/industries-and-solutions/papers>
2. 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

- ▶ Lower data throughput than TETRA
  - 9600bps (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 12.5kHz 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 TETRA and P25 for those who do not need a high-end system.
- ▶ Gives 6.25kHz channel efficiency, four times that of legacy 25kHz Analog channels, which complies with all current and likely future FCC mandates.
- ▶ Doubles network call capacity when replacing an analog network with 12.5kHz bandwidth.
- ▶ TDMA extends radio battery charge duration, when compared with P25 or 12.5kHz analog FM radios.
- ▶ 12.5kHz channel size allows re-use of existing frequency licenses and site infrastructure (combiners, antennas).

### Disadvantages of DMR

- ▶ Does not provide full duplex

## P25

### Phase 1

- ▶ Lower data throughput than TETRA
- ▶ 9600bps (Symbol rate of 4800 symbols/sec)
- ▶ C4FM Modulation
- ▶ No need for linear transmitters
  - ◆ Cost and size about same as analog FM transmitter
- ▶ Transmitter output spectrum fits in to existing 12.5kHz 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
  - 12000bps (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 12.5kHz 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.
- ▶ Fully featured.
- ▶ 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.
- ▶ Very secure end-to-end encryption.

### **Disadvantages of P25**

- ▶ Only 12.5kHz channel efficiency (FDMA). However, Phase 2 of the P25 standard provides an upgrade path to 6.25kHz 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
- ▶ Lower data throughput than TETRA, same as DMR
  - 4800bps (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 12.5kHz narrowband FM Analog channel
  - No need for re-banding or re-licensing but may only get 1 channel in 12.5kHz
  - 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.

#### **TETRA**

- ▶ Higher data throughput than DMR, P25 or dPMR
  - ▀ Bit Rate 36000bps (18000 symbols/sec)
  - ▀ 4-slot TDMA
- ▶  $\pi/4$  DQPSK modulation
  - ▀ Requires linear transmitter in base station and terminals, which is more expensive, requires a higher current and is physically larger
- ▶ Requires wideband 25kHz channel
  - ▀ Few areas of spectrum where wideband channels licensed, e.g. only 380-430MHz in Europe.
  - ▀ Needs minimum transmit/receive frequency separation.
  - ▀ Cannot operate next to narrowband channels.
- ▶ No upgrade path from analog
- ▶ Poorer coverage
  - ▀ Coverage roughly half that of DMR for same frequency and transmit power, thus need 4 times amount of sites.

#### **Advantages of TETRA**

- ▶ Open standard.
- ▶ High level of interoperability between TETRA products from different vendors.
- ▶ Fully featured.
- ▶ TDMA gives 6.25kHz channel efficiency (four timeslots in 25kHz channels).
- ▶ Radios have a lower transmit power and therefore can be smaller, less expensive, and similar to cellphones.
- ▶ Encryption.

## **Disadvantages of TETRA**

- ▶ TETRA systems require clean blocks of contiguous spectrum, which may not be available from the relevant regulatory authority. This is in part because TETRA channels cause interference on existing analog channels and in part because the standard requires that transmit and receive frequencies of a channel are 10MHz apart. For example, if the transmit frequency is 381.0000MHz, the receive frequency must be 391.0000MHz. A “clean” block of spectrum is needed, so that no currently licensed frequencies interfere with the TETRA channel plan. TETRA requires 25kHz channels, which may conflict with narrow banding plans. Many countries are considering plans to reform their spectrum into 12.5kHz channels, to increase the number of available channels.
- ▶ TETRA is not designed for backwards compatibility or migration from legacy analog networks. Organizations that decide on a TETRA system will need to completely replace their radios because TETRA radios will not interoperate with analog FM radios. Moreover, TETRA infrastructure cannot operate in an analog FM mode to provide services to legacy radios.
- ▶ TETRA coverage is significantly less than for other PMR/LMR standards, which means that many more radio sites are required for a given service area. This is an important consideration for networks in areas with a low population density. It may also mean that more channel licenses are required.
- ▶ TETRA is not available as a conventional network.
- ▶ The lower power of TETRA radios (1W) restricts the range between peer-to-peer (direct mode) users to as little as three kilometers (two miles).
- ▶ TETRA base stations/repeaters must be linear, which adds to their cost.
- ▶ The TETRA vocoder is older than and probably not as effective as the new half-rate vocoders.

## **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.
- ▶ Encryption is available.
- ▶ Multimode terminals are available that support P25, OpenSky and EDACS, allowing for easy migration and integration.

#### **Disadvantages of OpenSky**

- ▶ Only one vendor.
- ▶ 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 25kHz channels and is available only in the 700/800MHz bands.

#### **TETRAPOL**

TETRAPOL is a trunking technology that was developed by EADS (formerly MATRA) and is mainly in use by police and military in Europe. It pre-dates TETRA, as its first implementation was for the French National Gendarmerie in 1988. The core design criteria have been trunking, encryption, and wide area coverage. TETRAPOL is well-proven having enjoyed a successful rollout over some years, and although it is a proprietary system, the system interfaces are publicly available.

TETRAPOL uses FDMA 10 or 12.5kHz channels. Future third generation TETRAPOL is expected to make provision for two 6.25kHz channels in a single 12.5kHz channel. Present TETRAPOL systems are switch-linked, however very large TETRAPOL systems may be linked via IP.

#### **Advantages of TETRAPOL**

- ▶ TETRAPOL has been well planned from the outset, with initial consensus from the users, and with all specifications available and stable for vendors to use in their product designs. Consequently there has been no uncertainty for vendors about features or operation.
- ▶ In the TETRAPOL trunking systems, a range of services are available. These include status messaging, and call types such as individual, group and emergency calls.
- ▶ TETRAPOL systems also provide a “direct” or simplex mode.
- ▶ Approximately 4.8kbit/s data speed is achieved to the limit of radio coverage.
- ▶ The available data speed does not deteriorate as the signal weakens.

### **Disadvantages of TETRAPOL**

- ▶ TETRAPOL radios themselves offer no conventional mode operation, and it is necessary to use a SCC (Single Channel Converter) to communicate with analog radios. (This interface can also provide an interface with other types of radio networks.)
- ▶ Very limited vendor support.
- ▶ Aging design with older vocoder.

### **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 6.25kHz 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 6.25kHz 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 FDMA transmission format.
- ▶ Limited vendors.

## **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.

## **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**

TETRA Association: [www.tetra-association.com/](http://www.tetra-association.com/)

DMR Association: [www.dmrassociation.org/](http://www.dmrassociation.org/)

dPMR Forum: [www.dpmr-mou.org](http://www.dpmr-mou.org)

NXDN Forum: [www.nxdn-forum.com/](http://www.nxdn-forum.com/)

Project 25 Technology Interest Group: [www.project25.org/](http://www.project25.org/)