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Information Paper

FDMA and TDMA Narrowband Digital Systems

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It is assumed that the reader of this paper knows what FDMA and TDMA digital narrowband radio systems are currently available in the Land Mobile Radio (LMR) market.

Icom Inc. does not represent that the content of this paper is a detailed comparison of each system, or that the content should be used for comparison purposes.

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Introduction:

Three business and industry orientated narrowband digital systems are now widely available. Two of them are based on 6.25 kHz FDMA technology (One system also offers 12.5 kHz FDMA capability), and one system is based on a 2-slot TDMA modulation scheme operating in a 12.5 kHz channel bandwidth. The debate over the merits and demerits of each system has been well versed, but Icom would like to again put forward our thoughts on the matter.

Initial Conclusion: Which System is Better?

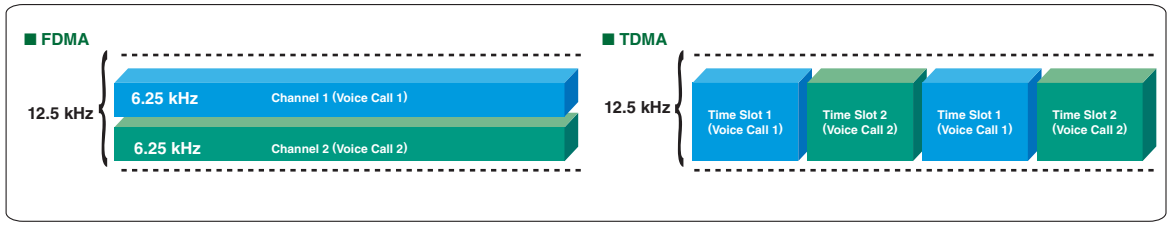
This cannot be answered as each system has its merits and demerits. We leave it up to the reader to make any necessary comparisons of each system separately based on publically available information, to make their own decision as to which system best suits their needs.

Clarifying the Facts from the Fiction:

The following is an attempt to give a non-biased explanation about the 6.25 kHz FDMA and 12.5 kHz TDMA systems. Many of the explanations listed below are clarifications of items relating to the two systems that have appeared in the public domain to date.

The Technology:

Without getting too technical, the basic difference between FDMA (Frequency Divided Multiple Access) and TDMA (Time Divided Multiple Access) is the definition of a channel and how it is used (accessed). In FDMA a particular bandwidth (E.g. 6.25 kHz) at a particular frequency (E.g. 150.000 MHz) is used to define a channel. Basically, the way channels have been allocated for over six decades.



In TDMA, the same principle applies regarding bandwidth and frequency, but the signal is divided into time slots that allow the channel to have 'extra' capacity in the same bandwidth E.g. Two 6.25 kHz 'equivalent' channels in a 12.5 kHz channel. See the diagram above for a graphical explanation.

Until now, TDMA was more spectrum efficient at wider channel spacing's like 25 kHz, as for example, two or three users could access the same bandwidth as one FDMA channel user. However, in the case of narrowband 6.25 kHz FDMA technology, both this and 2-slot 12.5 kHz TDMA technology achieve the same result as far as spectrum efficiency is concerned.

Proprietary or Open Protocols:

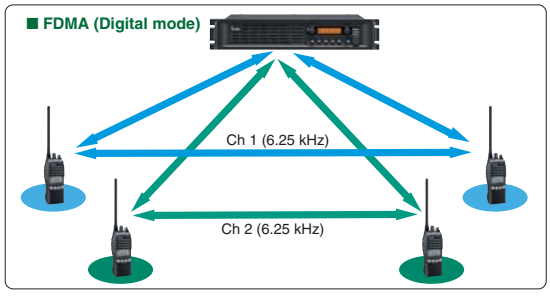
The TDMA system protocol is compliant to the open European Telecommunications Standards Institute (ETSI) technical standard TS102 361, commonly known as DMR (Digital Mobile Radio). A license and royalties to use the protocol in product development is required, but in essence, any manufacturer can develop DMR compliant products.

Again, in Europe a license-free version of the 6.25 kHz FDMA protocol is available as the ETSI technical standard TS102 490, commonly known as dPMR 446. No license or royalties are required to use this protocol, and any manufacturer is free to develop compliant products. The licensed (Tier 2) version of the dPMR standard is TS 102 658.

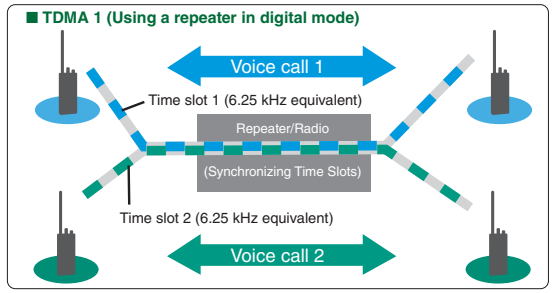
The NXDN™ standard is also an open protocol, and is a royalty free standard for manufacturers. A derivative of the DMR standard is found in China, known as CDMR. It is royalty free for use in China only. Similarly, the ARIB standards body in Japan has used a derivative of NXDN™ for a radio category called DCR (Digital Commercial Radio). In conclusion, all available protocols are open standards.

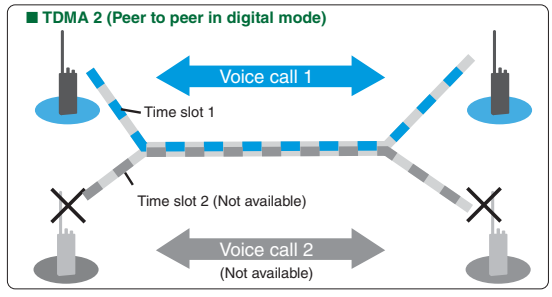
Spectrum Efficiency and "Double Capacity":

As explained above, both technologies achieve the same 6.25 kHz narrowband capability via different methods. The difference is that the FDMA system is a 'true' 6.25 kHz channel and the TDMA system provides 6.25kHz channel 'equivalence' via the time slots in 12.5 kHz bandwidth. From the perspective that 12.5 kHz is considered the current narrowband standard channel spacing, then both systems achieve so called "double capacity". The difference is that the FDMA system is ALWAYS double capacity whether it is used with or without infrastructure. For TDMA, double capacity is ONLY achieved when a repeater or "Master" radio is synchronizing the time slots, and that two users are in the same geographical area, accessing the same repeater at the same time. See the diagram below.



• The FDMA is always double capacity, whether in peer to peer or via a repeater.





• Voice call 1 (Time slot 1) occupies whole channel, so time slot 2 stations cannot communicate.

Audio Quality:

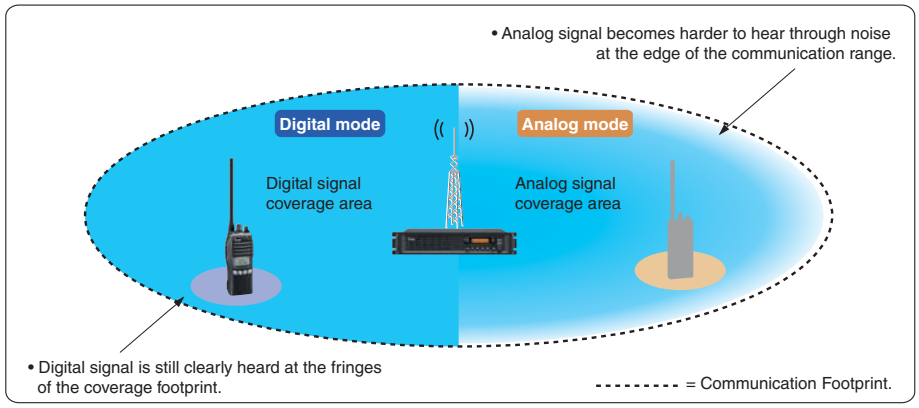
Much has been said about the improvements in audio quality of digital LMR radios compared to analog FM. Currently, both the FDMA and TDMA systems are utilizing the same vocoder, so apart from any differences in the speaker design or output; both systems' audio quality would be of a similar level.

Coverage:

In theory, in identical conditions, the narrower channel width of the FDMA system would allow the signal to achieve better coverage than the 12.5 kHz TDMA (or FDMA) system when transmitted at the same output power. This is because the noise floor of any receiver is proportional to the filter bandwidth, therefore the smaller the bandwidth the smaller the signals that can be received.

In real world use, various factors such as topography, antenna height of base stations and surrounding buildings etc. all affect coverage, so without specific comparison tests, either system cannot claim to be better than the other.

What can be said is that when compared to an analog FM signal, digital easily out-performs analog in audio clarity at the fringes of the communication range, thus providing more reliable audio over a greater total area, even if the coverage footprint is the same as analog FM. See the diagram below for an image.



Battery Life:

The manufacturer of the TDMA system claims 40% improved battery life in digital mode as the radio is transmitting only half the time (I.e. one time slot). In actual use, FDMA and TDMA radios both provide anywhere from 10–18 hours of operation. Therefore no real advantage as spelled out in the "40%" claim is gained in TDMA.

As explained in "Coverage", in the FDMA system, reduced noise components with the narrower channel bandwidth improves receiver sensitivity. Therefore, it is possible to transmit at reduced output power, which in turn conserves battery life and thus can prolong radio use time.

System Costs:

The argument about total system set up cost depends on a number of factors and/or assumptions like;

- All systems will be new sites or systems only.
  One of the aims of Icom's system has been to allow users to migrate their existing analog system to a digital system at their pace. A completely new system is not required.

- FDMA system components are expensive.
  The cost of products is an individual business policy of each manufacturer. Manufacturers are continually reducing the cost of products and systems based on natural market competition and technical advances.

In the end individual user needs and market trends will determine the outcome of system costs, and again this applies to all available systems on offer.

Interference Issues:

Due to the narrower bandwidth, concerns about adjacent channel interference were raised regarding 6.25 kHz FDMA early on. Significant testing and presentations to U.S. frequency coordinating authorities showed that any interference issues were mute, resulting in the granting of licenses for 6.25 kHz channel use. Icom's FDMA products are also compliant with the European ETSI standard EN301 166 for analog/digital narrowband communications, at the more difficult to comply with 6.25 kHz bandwidth.

TDMA system products also comply with relevant requirements. Some interference issues have been raised on occasions, but the general rules in system separation and frequency coordination apply to all RF based solutions.

Digital Functions:

Both the FDMA and TDMA systems offer a number of functions in both analog and digital modes. A separate comparison of each system by the reader is recommended to obtain better knowledge of which system may suit your requirements, but we will list up what we see as common to both systems for digital features.

- **Dual Mode Capability**
  Both systems have analog and digital 'dual mode' capability, and compatibility with existing analog FM systems.
- **Peer to peer communication**
  Both systems can communicate peer to peer in digital mode. However, as explained, the 6.25 kHz FDMA system will always use only 6.25 kHz of bandwidth per channel in digital mode. As explained in "Spectrum Efficiency and Double Capacity", the TDMA system will occupy 12.5 kHz of bandwidth, but only use half of the channel (i.e., one time slot). From a spectrum efficiency point of view, FDMA has an advantage in peer to peer communication mode.
- **Signaling and Call type features**
  Although the naming may differ between systems, the digital equivalent of individual call, group call, selective call, data calls, status messages etc. exist in both systems to one extent or another
- **Digital trunking**
  Each system offers a variation of either central channel type trunking or distributed logic type trunking.
- **Network interfacing**
  Both systems have the capability for networking and/or IP capability.

Interoperability:

The minimum requirement for interoperability is the following:

- More than one manufacturer offering a product utilizing a common protocol.
- All manufacturers of such a protocol being compliant with the minimum feature set.

As explained in "Proprietary or Open Protocols:", open standards of both the FDMA and TDMA systems exist. Interoperability and conformance test suites also exist and many manufacturers have carried out interoperability testing.

To End:

As shown in this paper, both FDMA and TDMA offer similar advantages and features. With a total of over 3 million units currently in use, most if not all of the “Propaganda” against 6.25 kHz FDMA in particular, has been proven to be untrue. Icom continues to provide new products and solutions complying to dPMR™ and NXDN™ protocols. Icom will also continue to provide information on the advantages of 6.25 kHz FDMA as well.

Why 6.25 kHz FDMA Narrowband?

True Narrowband: Reliable Communications for Half the Spectrum!

6.25 kHz FDMA allows you to double the capacity of your valued spectrum. The choice of two independent 6.25 kHz in 12.5 kHz, or a standalone 6.25 kHz channel is yours. This double capacity/independent channel flexibility and efficiency is only possible with 6.25 kHz FDMA.

Communications Reliability When You Most Need It

No need to allow for TDMA time slot synchronization. Instant communications in emergencies and critical situations. FDMA is the fail safe mode of choice in land mobile radio. Nothing else compares.

FDMA: Proven History Like No Other Radio Technology

For over 50 years, FDMA has been the backbone of two-way radio communication. Generational enhancements have culminated in the realization of 6.25 kHz FDMA digital protocols that are literally ahead of their time, while keeping backward compatibility with analog FM.

6.25 kHz Channels: the Current and Future Trend

6.25 kHz channel plans and standards are used in North America, Europe, Japan, Oceania, and the list goes on. 6.25 kHz provides an answer to the worldwide problem of spectrum shortage and efficient use.

6.25 kHz Fundamental Excellence

Narrower bandwidth FDMA provides technical excellence in sensitivity, interference resistance, increased coverage, audio quality, spectrum efficiency and more. Why look at anything else?

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