Project 25 Home Page

APCO Project 25
STANDARDS FOR PUBLIC SAFETY DIGITAL RADIO

- USER-DEFINED STANDARDS
- PROVEN INTEROPERABILITY
- MULTI-SOURCE PROCUREMENT

Key to this page:

PROVEN INTEROPERABILITY

The final documents establishing the APCO 25 Standard were approved and signed in August 1995 at the APCO International Conference and Exposition in Detroit, Michigan.

At this event, Motorola Inc., Stanilite Pacific Ltd, E.F. Johnson Co., BK Radio Inc., and Transcrypt International participated in a history-making interoperability demonstration of APCO 25-compliant equipment utilizing a Stanilite base station and portables from BK Radio, Motorola, E.F. Johnson, Transcrypt International on the exhibition floor. Feedback from the thousands of attendees who examined the systems indicates that the test was an overwhelming success. Even those who doubted the concept of multi-vendor participation were impressed and convinced of the viability of APCO 25 as a voluntary standard.

Return to top of document

APCO INTERNATIONAL'S COMMITMENT TO ADVANCED TECHNOLOGY

As public safety agencies evaluate their two-way radio needs for the future, many are reaching some similar conclusions:

- radio spectrum is becoming more congested

- the demand for data transmission is more pronounced
- systems need increased functionality
- secure communication is a growing necessity
- improved voice quality is essential over more of the coverage area.

Of course, upgrading a communications network is a major undertaking in terms of time, energy and expense. A number of possible solutions are available, including the digital technologies that will become, and are now becoming, available. They offer the potential to address many or all major concerns, and they can provide a true platform for the future.

However, the decision to go digital is only the first step. There are several different digital technologies on the market, making the selection difficult. Each one has its own set of features thatmay or may not suit public safety organizations.

The Association of Public-Safety Communications Officials - International, Inc. (APCO International) is committed to making the selection process easier through APCO 25, an industry-wide effort to set the recommended voluntary standards of uniform digital two-way radio technology for public safety organizations. By working together with APCO International, public safety agencies can take this opportunity to move technology along a common path that benefits the greatest number of users.

Return to top of document

WHAT IS APCO 25?

APCO 25 brings together representatives from many local, state and federal government agencies who evaluate basic technologies in advanced land mobile radio. The objective is to find solutions that best serve the needs of the public safety marketplace. In addition, the committee has encouraged the participation of numerous international public safety organizations, making this a truly worldwide recommended standard-setting initiative.

Specifically, APCO 25 is co-chaired by APCO International and the National Association of State Telecommunications Directors (NASTD). The steering committee, which makes the decisions, consists of APCO International and NASTD representatives, along with federal representatives from the National Telecommunications and Information Administration (NTIA), National Communications System (NCS), and the Department of Defense (DoD). The steering committee is supported by several subcommittees that research specialized areas. A list of participating agencies is attached to this document.

OPEN REVIEW PROCESS

This team has been conducting a fully open process to seek out new two-way digital radio technologies from a large number of industry-leading private sector developers. A set of basic requirements was established to evaluate each proposed technology, with prospective vendors invited to participate in open and independent evaluation tests.

The steering committee sought to establish open system standards so multiple vendors could make competing products that are compatible. Many of the important technologies considered have been privately owned or proprietary. However, APCO 25 selected proprietary technologies as a recommended standard when the owners agreed to share the technology with other competing vendors. A list of participating companies is attached to this document.

Return to top of document

THE BENEFITS OF APCO 25

Every aspect of APCO 25 is designed to benefit public safety professionals who seek a new level of performance, efficiency, capabilities, and quality in two-way radio communications. Four key objectives guided the steering committee through this open process:

- provide enhanced functionality with equipment and capabilities focused on public safety needs.
- improve spectrum efficiency.
- ensure competition among multiple vendors through Open Systems Architecture.
- allow effective, efficient, and reliable intra-agency and inter-agency communications.

By adhering to these objectives, APCO 25 makes it easier for users to make the most informed decision possible when planning to convert existing system to digital. Each vendor's system will begin on a level playing field determined by an agreed upon base line set of specifications. This allows users to more accurately compare the direct features and benefits of both entire systems and individual radio products. This will make bidding processes more competitive among prospective vendors. Plus, users have the opportunity to mix and match equipment among APCO 25-compliant suppliers since their equipment will follow all basic standards.

Return to top of document

ORDERLY MIGRATION TO DIGITAL

APCO 25 is committed to protecting the current investment in equipment by public safety agencies. A basic requirement for new digital radio equipment is backward compatibility with standard analog FM radios. This supports an orderly migration into mixed analog and digital systems, enabling users to gradually trade out radios and infrastructure equipment. By selecting products and systems that comply with APCO 25 recommended standards, agencies are assured that the investment in the latest technology has a clear migration path for the future.

Return to top of document

FEATURES OF APCO 25

6.25 kHz Bandwidth (CQPSK) Modulation

The CQPSK modulator consists of a table look-up, the two outputs of which (I and Q) are Nyquist filtered and then amplitude modulated, in phase and quadrature phase, before summing. The information bits are processed by the look-up table to yield a 5-level I signal and a 5-level Q signal. The I and Q signals are filtered with the Nyquist Raised Cosine Filter previously described. The I signal is then multiplied by the carrier and the Q signal is multiplied by the carrier after it has been delayed by 90 degrees. The modulated I and Q carriers are then summed together to yield the modulator output.

12.5kHz Bandwidth (C4FM) Modulation

The C4FM modulator consists of a Nyquist Raised Cosine Filter, cascaded with a shaping filter, cascaded with a frequency modulator.

Addressing

A very large number of radio addresses are provided, both for individual radios and talk-groups.

Aggregate Bit Rate

The aggregate bit rate is 9600 bits/s. In the case of data transmission, data packets basically consist of a header, containing overhead information, followed by data. In the case of digitized voice transmission, after the transmission of a header containing error protected overheadinformation, 2400 bits/s is devoted to periodically repeating the overheadinformation needed to allow for late entry (or the missed reception of the header).

C4FM Frequency Modulator

The deviation is +1.8 kHz for dibit 01, +0.6 kHz for dibit 00, -0.6 kHz for dibit 10, and -1.8 kHzfor dibit 11.

C4FM Nyquist Filter

The dibits of information (i.e., 4800 symbols) are filtered with a raised cosine filter which satisfies the Nyquist criterion minimizing inter-symbol interference. The group delay of the filter is flat over the pass-band for |f| < 2880 Hz. The magnitude response of the filter is approximately 1 for |f| < 1920 Hz, 0.5 + 0.5 cos (2(f/1920) for 1920 Hz < |f| < 2880 Hz, and 0 for |f| > 2880 Hz.

C4FM Shaping Filter

The shaping filter has a flat group delay over the band-pass for |f| < 2880Hz. The magnitude response of the filter for |f| < 2880 Hz is sin(pif/4800)/(pif/4800).

Data Packet Data Blocks

Confirmed Data Blocks contain a 7-bit serial number (to allow for selective transmission), 9 bits of error detection on the entire block, and 14 octets of data. Unconfirmed Data Blocks contain 12 octets of data (note: a 32-bit error detection code is appended to the end of all data packets).

Data Packet Error Correction

Header Blocks normally use a rate 1/2 trellis coder for error correction. Unconfirmed data packets normally use a rate 1/2 trellis coder, while confirmed data packets normally use a rate 3/4 trellis coder. Interleaving is applied over Data Blocks.

Data Packet Header

The Header Block used for communications between a radio and a packet data node (i.e., switch) contains 10 octets of address and control information, followed by 2 octets of error detectioncoding. Information contained in the header includes: the identity of the Service Access Point to which the data is being directed, a manufacturers identification (to allow for non-standard functions), a logical link identifier to identify the sending radio of an inbound packet to a node and the receiving radio of a packet outbound from a node, the number of blocks to follow in the packet, the number of pad octets to fill out the last block, the sequence number of the packet, and the Fragment sequence number. For packet data communications directly between two radios, essentially two 12-octet Header Blocks are used at the beginning of each packet in order to convey the necessary address and control information. The header is preceded by 48 bits of synchronization and 64 bits of network identifier (to prevent confusion between radios in different networks).

Data Packet Structure

Data messages are divided into Fragments of less than 512 octets. Fragments are, in turn, divided into Blocks of M octets, where M=12 for unconfirmed messages and M=16 for confirmed messages (except Header Blocks are 12 octets in length). Note: a Fragment, preceded by header information, is defined as a Data Packet.

Demodulator

The demodulator is capable of receiving both the C4FM and the CQPSK signals. It consists of a frequency modulation detector, followed by an Integrate and Dump Filter and then a stochastic gradient clock recovery device. The Integrate and Dump Filter has a flat group delay over the band-pass for |f| < 2880 Hz. The magnitude response of the Integrate and Dump Filter, for |f| < 2880Hz, is approximately sin (pif/4800)/(pif/4800).

Digitized Voice Coder Method

After evaluating several candidates, APCO 25 selected IMBE (Improved MultiBand Excitation)vocoder, operating at 4400 bits/s. An additional 2800 bits/s of forward error correction is added, for error correction of the digitized voice. IMBE has also been selected by INMARSAT, for use in digital voice maritime satellite communications.

Digitized Voice Frame Structure

The Header Word, transmitted at the start of every transmission, contains 120 bits of information and 528 bits of error correction. Voice Frames are 180 ms in length and pairs of Voice frames compose a 360 ms Superframe. The first of a pair of voice frames transmits, in addition to digitized voice and its error corrective coding, 72 bits of link control information, 168 bits of error corrective coding on the link control information, and 16 bits of embedded low-speed data signaling with 16 bits of error corrective coding. The second of the pair of voice frames transmits an additional 16 bits of low-speed data signaling with 16 bits of error corrective coding, 96 bits of encipherment information, and 144 bits of error protective coding on the encipherment information.

Digitized Voice Header Word

The header is preceded by 48 bits of synchronization signal and a 64-bit network identifier (to prevent confusion between radios in different networks). The 120 bits of information in the Header Word consists of 72 bits for the encipherment initialization vector, 8 bits for a manufacturer identifier, 8 bits to identify the encipherment algorithm, 16 bits to identify which encipherment key variable is being employed (in systems with multiple encipherment key variables), and 16 bits for the talkgroup address. Including error corrective coding, status symbols (22 bits) not described in this brief contribution, and preceding signaling, the header requires 82.5 ms for transmission.

Digitized Voice Encryption Information

The 96 bits of encipherment information consist of the three encipherment-related fields in the header: the 72-bit encipherment initialization vector, the 8-bit encipherment algorithm identifier, and the 16-bit encipherment key variable identifier. The encipherment information is protected by 144 bits of error corrective coding. Note: the encipherment process does not change during a transmission. The repeating of this information every 360 ms is primarily for late-entry by receiving radios.

Digitized Voice Link Control Information

As previously stated, 72 bits of link control information is contained in the first of each pair of Voice Frames. If the addressee is a talk-group, the link control information consists of 1 octet describing the type of information (e.g., talk-group type of transmission), 1 octet containing the manufacturer identifier, 1 bit indicating whether or not the transmission is of an emergency nature, 15 bits reserved for future use, 2 octets for the talk-group address, and 3 octets for the transmitting radio's identifier. If the addressee is another radio, the last 7 of the 9 octets consist of : 1 octet reserved for future use, 3 octets for the destination radio's identifier, and 3 octets for the transmitting radio's identifier. This information is protected with 168 bits of error corrective coding.

Encryption

Information required for decoding to take place (including the encoding initialization vector) is transmitted at the beginning of all transmissions, and is embedded in the signaling overhead throughout all digitized voice transmissions. This allows for the use of multiple encoding algorithms and "key variables". An adequate number of bits have been assigned to allow for even the highest (i.e., most secure) levels of encoding.

Error Protection

To provide for the maximum possible coverage (i.e., range of operation), a high degree of forward error correction and interleaving has been provided for. The mobile environment is subject to severe Rayleigh fading and the APCO 25 techniques have been designed to operate in bit error rate environments of up to 7 percent.

Flexible Modulation Method

A pair of modulation methods have been selected that utilize a common receiver. The first, which utilizes a constant-envelope 4-level Frequency Modulation (FM) variant, can utilize simple, high-efficiency amplifiers and has emissions that fit within a 12.5 kHz bandwidth. This method will be fielded in most equipment initially. The second, which utilizes a CQPSK variant with amplitude components, requires the use of highly linear or linearized amplifiers and has emissions that fit within a 6.25 kHz bandwidth. (The receiver, common to both, has a 6.25 kHz bandwidth.)

Low-Speed Data With Digitized Voice

An 88.9 bit/s low-speed data channel is provided in the digitized voice frame structure. No application is currently defined. One application under discussion is to use the low-speed data channel for the transmission of accurate geographic location information.

Talk-Group Operation

Unlike normal telephone operation, all members of a talkgroup can receive the transmissions of all other members of that talk-group. Members of a talk-group do not have to receive the beginning of a digitized voice transmission (i.e., late entry is provided for).

Return to top of document

HISTORY AND CURRENT STATUS OF APCO 25

In January 1993, APCO Project 25 moved forward by adopting a proposed system architecture through six interface standards that will determine the future of digital technology for use in public safety markets. The first of these interfaces to be defined was the critically important Common Air Interface (CAI). CAI sets the recommended standards for radio-to-radio digital signal compatibility and interoperation. This means that in an APCO Project 25-compliant system, mobile and portable equipment from any manufacturer is designed to be freely combined.

In November 1993, the APCO Project 25 Steering Committee accepted the TIA-recommended Common Air Interface Standard document, which specifies

- the FDMA access method
- QPSK-C modulation
- 9.6 data rate
- the DVSI vocoder, using a 12.5 KHZ channel.

The other five interfaces that were defined are

- data port
- data host
- inter-connect
- network management
- inter-system interfaces

Return to top of document

U.S. GOVERNMENT AND ITU STANDARDS

The APCO 25 Standards are in the process of being approved by the International Telecommunications Union (ITU).

The United States Government is in the process of accepting and approving the APCO 25 Standardsfor its agencies.

Return to top of document

YOUR ROLE IN THE FUTURE OF DIGITAL TECHNOLOGY

Adhering to these recommended standards is voluntary on your part as you evaluate your own system needs for the future. By specifying and purchasing digital radios and systems that are fully APCO 25-compliant, you will help all public safety agencies better communicate their needs to manufacturers who can respond with digital technology to meet your needs now and in the future.

APCO International stands behind you with a strong, unified voice for performance, interoperability, and value in recommending the best in digital two-way radio communications for the public safety user of today and tomorrow.

Return to top of document

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Return to top of document

APCO 25 PARTICIPANTS - PUBLIC SECTOR

(Note: the following lists do not indicate endorsement of P25, but are a reference to those entities that have provided input on the develeopment of the standard.)

- American Association of Railroads (AAR)
- APCO Canada
- APCO International
- British APCO (BAPCO)
- British Home Office
- Defence Research Agency (UK)
- State of California Division of Telecommunications
- State of Colorado Communications
- State of Delaware
- Federal Bureau of Investigation (U.S.)
- Federal Communications Commission (U.S.)
- State of Florida Division of Telecommunications
- State of Georgia Division of Communications
- Houston (Texas) Police Department
- Illinois State Toll Highway Authority
- Indiana State Police
- International Association of Chiefs of Police (IACP)
- State of Kentucky Telecommunications
- Lower Merion (Ardmore, Pennsylvania) Township Police
- City of Minneapolis
- State of Minnesota Department of Transportation
- State of Montana
- City of Montreal
- National Association of State Telecommunications Directors (NASTD)
- National Communications System (U.S.)
- National Institute of Justice
- National Security Agency (U.S.)

- National Telecommunications and Information Administration (NTIA)
- State of Nebraska
- State of Nevada Department of Public Safety
- New York State Police
- New Jersey State Police Communications
- State of Oklahoma
- Orange County (California) Division of Communiciations
- Peel Regional Police Systems (Canada)
- San Bernardino County (California)
- Suffolk County (New York) Police Department
- State of Utah
- Commonwealth of Virginia EMS
- Commonwealth of Virginia State Police
- State of Wyoming Division of Telecommunications
- Telecommunications Industry Association (TIA)
- University of California - Berkeley
- U.S. Air Force - Hanscom Air Force Base
- U.S. Army - Fort Monmouth
- U.S. Coast Guard
- U.S. Department of Defense
- U.S. Defense Information Systems Agency
- U.S. Department of Energy
- U.S. Department of Treasury
- U.S. Drug Enforcement Administration
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Immigration and Naturalization Service
- U.S. Marshall Service
- U.S. Park Police
- U.S. Secret Service

Return to top of document

APCO 25 PARTICIPANTS - PRIVATE SECTOR

- ARCON Corporation
- AT&T Bell Labs
- Automated Monitoring & Control Int'l
- Aware Inc.
- BK Radio
- Bosch Telecommunications
- Cable & Wireless Ltd.
- Clearsoft Inc.
- Comarco Corp.
- Communication Technical Asssociations
- CSX Transportation
- Cycomm Corp.
- Dataradio Inc.
- Digital Voice Systems Inc. (DVSI)
- DRA Malvern
- E. F. Johnson Co.

- Ericsson
- Garmin International
- GEC-Marconi
- Glenayre Electronics
- GTE Inc.
- Harris Corp.
- Hewlett Packard Corp.
- Hitachi Telecommunications Inc.
- Hughes Aircraft Company
- IFR Corp.
- ITT Research Institute
- IVHS America
- Japan Radio Company
- Kokusai
- Kustom Electronics Inc.
- MATRA Corp.
- Maxon
- Midland International
- MITRE Corp.
- Motorola Inc.
- MX COM
- National Communications Systems (NCS)
- NTT America
- OCS Technologies
- Phillips Communications
- Quantum Telecommunications
- Racal Communications
- RAM Communications
- Raytheon Service
- RI/ERT
- SafeTran Systems Inc.
- SCC Corp.
- SEA Inc.
- Securicor
- Stanilite Pacific Ltd
- Swan & Associates
- Tait Electronics
- Tektronix Corp.
- TeleResources PIC
- TeleTec Corp.
- Top Tech Group
- Transcrypt International Inc.
- Union Pacific Railroad
- Wilkes, Artis, Hedrick & Lane
- Zetron, Inc.

APCO 25 DOCUMENTS

Copies of a CD-ROM containing the 30 published documents are available to all federal, state and local government personnel free of charge by contacting the TIA Standards Coordinator at 703.907.7961. Others may purchase the 30 documents, all in TIA's 102-series, from TIA's document agent, Global

Engineering Documents. Global Engineering Documents has sales offices in several countries.

Return to top of document

Project 25 Home Page