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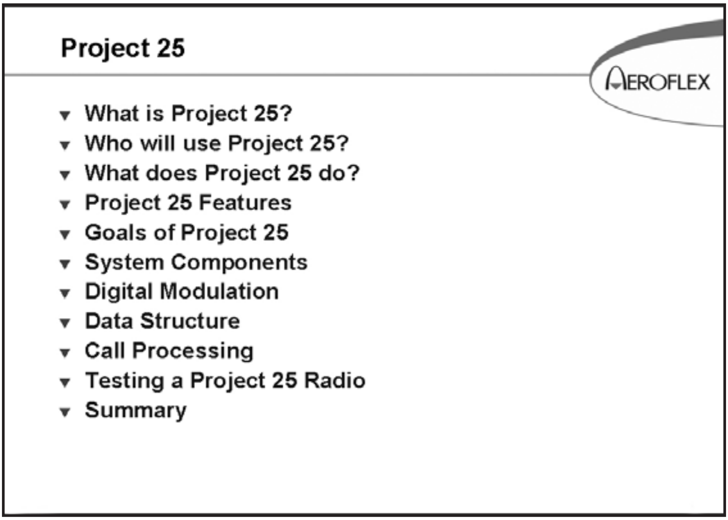
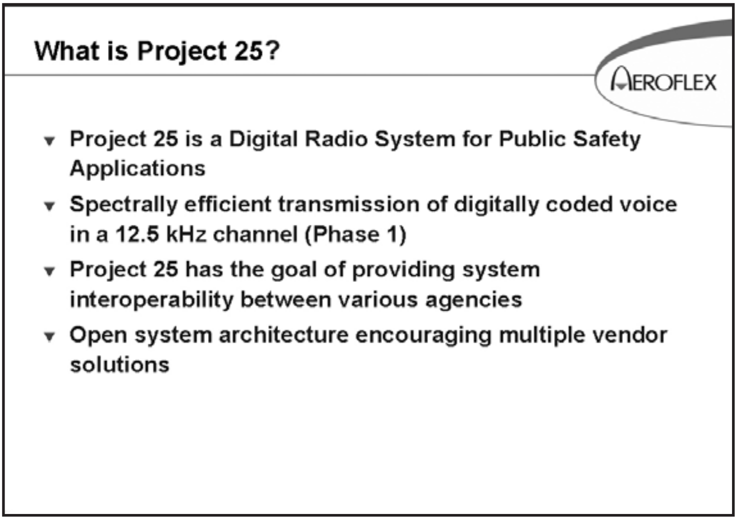
Introduction to Project 25



Introduction

This booklet is designed to give an introduction to the Project 25 radio standard and its technology.

Like most digital radio standards it raises some new test requirements and the solution to some of these tests is considered using the IFR 2975 Project 25 Radio Test Set.

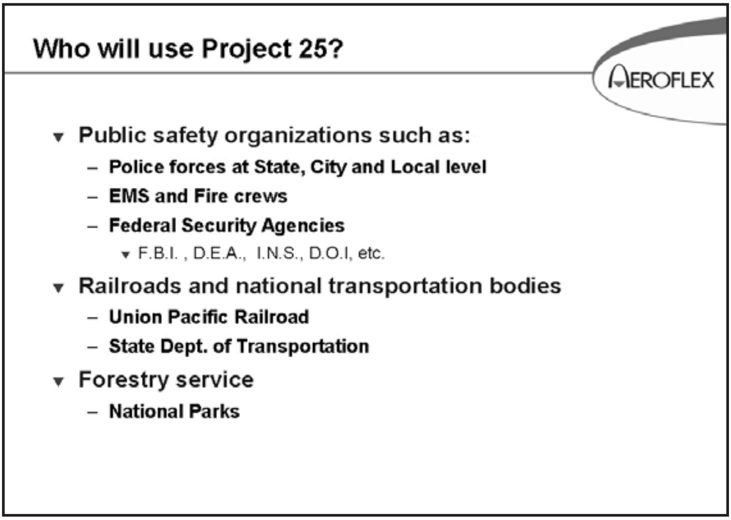


What is Project 25?

Project 25 is a digital radio system designed specifically for public safety applications by police, fire and medical services. It will also find applications with utility operators and other government agencies.

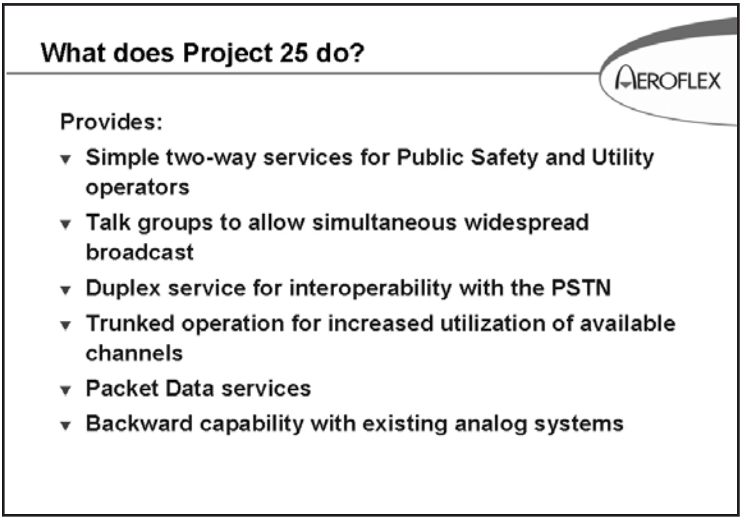
With interoperability and maximizing radio spectrum efficiency as fundamental requirements, Project 25 Phase I uses digital voice encoding to reduce the required bandwidth for speech transmission to 12.5 kHz, while simultaneously maintaining backward compatibility and interoperation with the existing 25 kHz analog FM systems. A further development of the specification will reduce the required transmission bandwidth for voice down to 6.25 kHz, thus freeing up more spectrum for future use.

The Project 25 specifications are available in the public domain, enabling multiple equipment vendors to compete for this market with the objective of reducing end user costs and providing interoperability both within and between user communities.



Who will use Project 25?

Project 25 has a considerable amount of flexibility so that it can be tailored to specific user requirements allowing it to appeal to a broad range of users. While designed with public safety applications in mind, it will also appeal to the security services who are able to use a higher level of encryption to reduce the chance of interception. As a general purpose trunked radio system, it is capable of serving the wider need of communications for transport operators and the forest service.



What does Project 25 do?

The services provided by the Project 25 system encompass a wide cross section of user needs.

Where spectrum and traffic densities are low, basic two way services provide adequate support for the Public's safety user. These are characterized as the "Push To Talk" services.

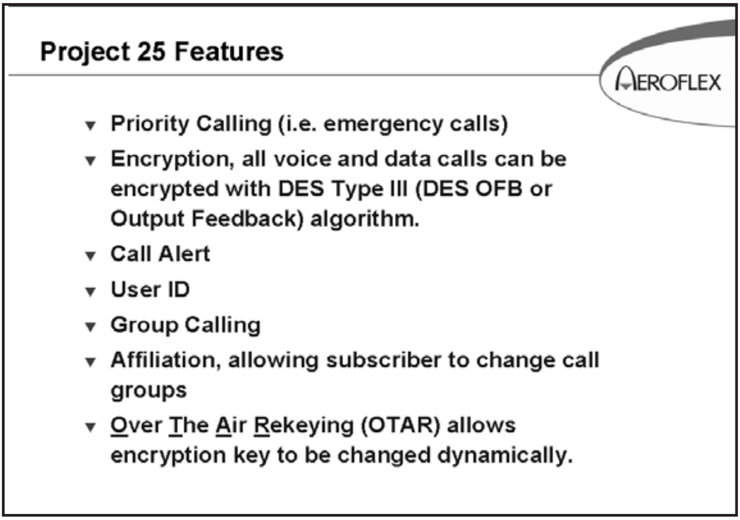
Another feature of the system is the ability to talk to a group of people with a simultaneous transmission. Users are arranged into groupings called "Talk Groups" where each member of the group receives all of the transmissions from members of the same group but not from other users outside of the group. This feature is a way of ensuring that all group members are kept informed and updated of any communication within the group.

The specification allows for full duplex operation enabling the mobile user to connect into the Public Switched Telephone Network (PSTN), giving mobile access into the international network.

Trunked operation allows much more efficient use of the channels available to the operator. A channel is selected as a control channel and all calls are routed through the control channel towards unused channels thus maximizing use of available channels.

Packet data services allow efficient data transfer across the network enabling data services to be utilized as well as voice transmission.

Project 25 Phase 1 services are required to be backward compatible with existing FM based services to provide an easily managed migration to digital service.



Project 25 features

Some of the features that make Project 25 suitable for public safety use are given here.

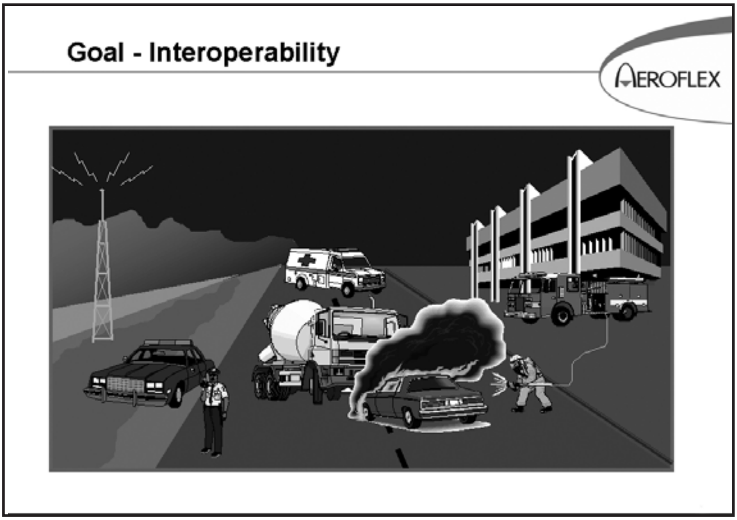
Priority calling enables calls to be ranked in importance so that the system is always available for high priority traffic such as emergency calls. These are usually accessed from a single key push on the terminal.

Encryption prevents call interception and ensures that the communication is kept secure.

Call Alert and User ID are used to keep the user fully informed of the status of the communication channel in use.

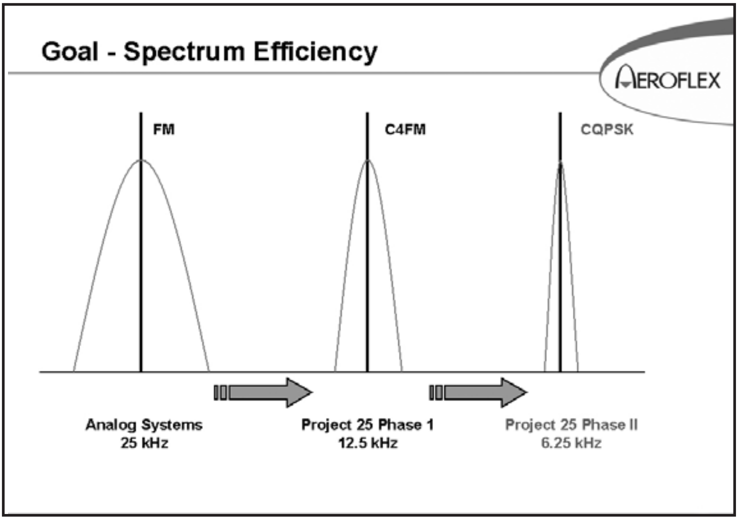
Group Calling allows a message to be broadcast to all other members of a specific group.

Affiliation enables the members of the group to change to meet operational requirements. This can be done over the air allowing dynamic reconfiguration of talk groups. Encryption keys can also be changed in this way to retain security within the talk groups.



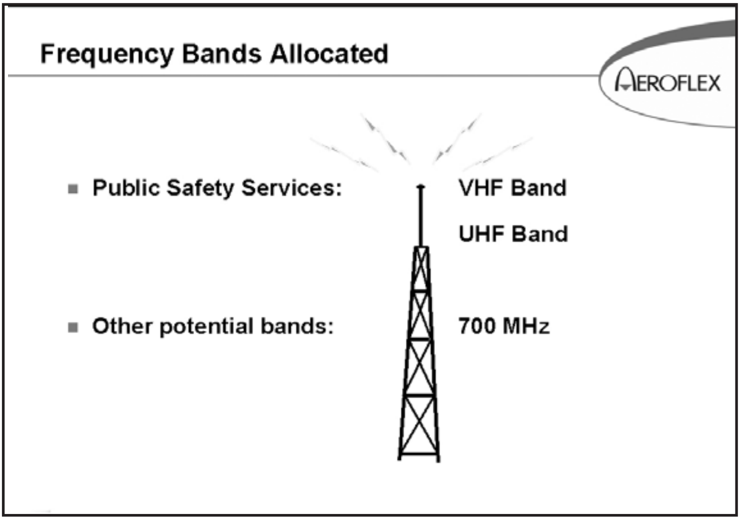
Goal - Interoperability

User groups can be dynamically reconfigured over the air so that communications can be maintained between all those required to be in attendance. Cross-Band Repeaters can also be used when agencies are allocated different frequency plans.



Goal - Spectrum Efficiency

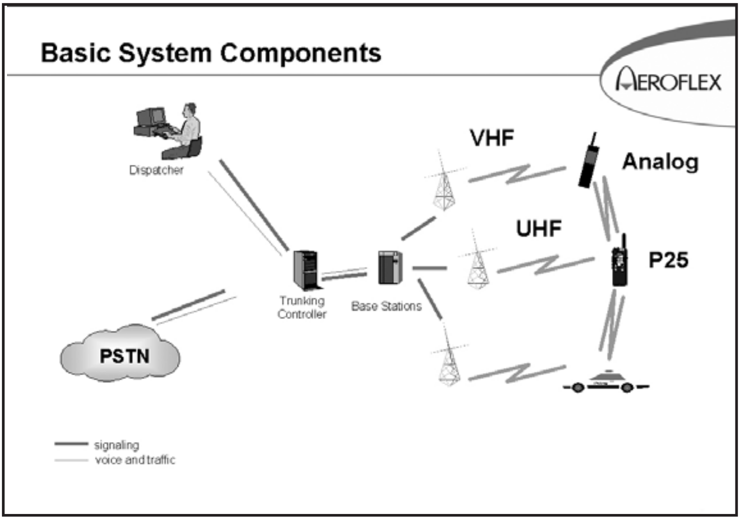
Existing analog technology supports voice traffic in a bandwidth of 25 kHz. The use of digital technology allows the same voice quality to be transmitted in a 12.5 kHz bandwidth for Project 25 Phase 1. In the future a more complex modulation will allow the same voice information to be transmitted in a 6.25 kHz bandwidth.



Frequency Bands Allocated

Although designed for application across a broad frequency range, Project 25 is regulated to the above frequencies for public safety applications within the USA. The 800 MHz frequencies provide a full duplex channel if required with an offset of 45 MHz.

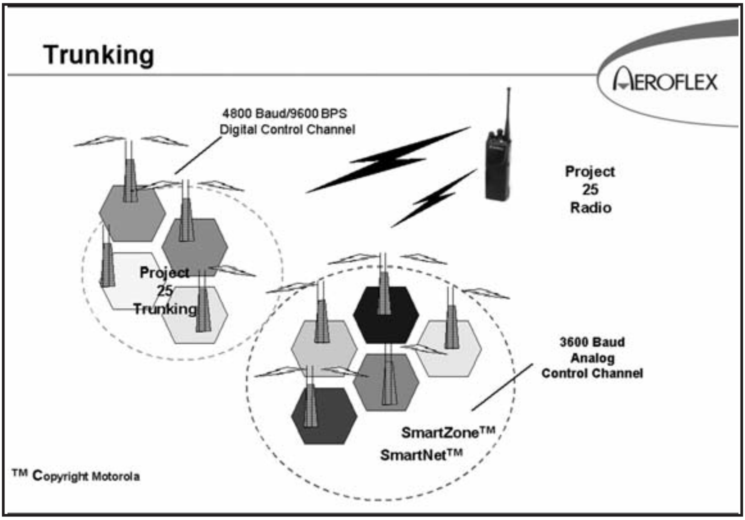
More spectrum may become available in the 700 MHz frequency range as the analog TV channels are taken out of service. Currently the allocation of this additional spectrum is the subject of much debate.



Basic System Components

This graphic shows the basic system components. Mobile terminals, either vehicular mounted or portable, communicate in normal mode to the Base repeaters. These are interconnected with a land line or microwave link to the main switch in the base station. Depending on system complexity, a Trunking controller may be included to provide more efficient use of spectrum if the traffic level demands it. Interfaces to a dispatch console complete the basic system and a PSTN interconnect can also be provided.

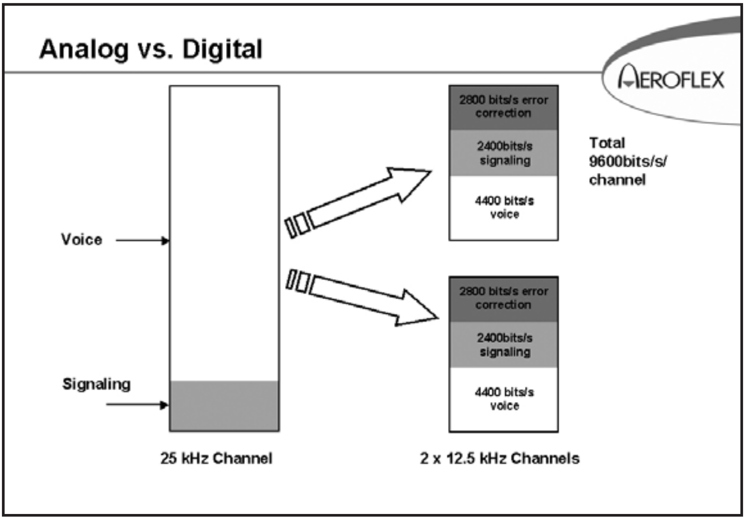
Additionally, the terminals have a talk around facility which allows direct communication between mobiles without the need for the infrastructure.



Trunking

Trunking gives a significant increase in capacity as well as having the capability to build a geographically larger network. Backwards compatibility with the existing analog systems enables Project 25 to use existing trunked infrastructure such as the Smartnet™ and Smartzone™ systems from Motorola.

The Project 25 standard also has its own defined trunked mode for implementation of a totally digital network.

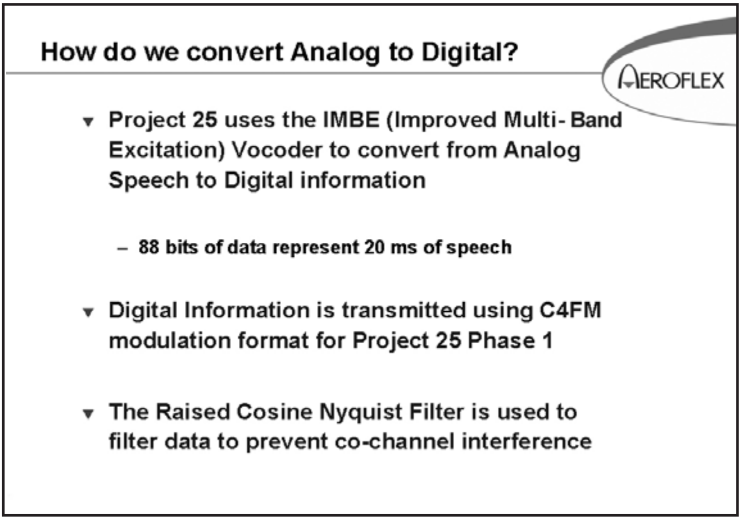


Analog vs. Digital

In order to obtain an acceptable voice quality using analog FM modulation, a channel bandwidth approaching 25 kHz is required. Additionally, signaling to maintain the radio link and provide call management occupies some of the available resource.

The use of a high level modulation called Continuous 4 level FM (C4FM) enables 9600 bits to be transmitted in a 12.5 kHz channel. This enables error correction information to be transmitted along with the voice signal and signaling information. The error correction is able to correct for small errors in the received signal thus providing a more robust service without any of the background hiss that you hear on analog systems as they get near the edge of range.

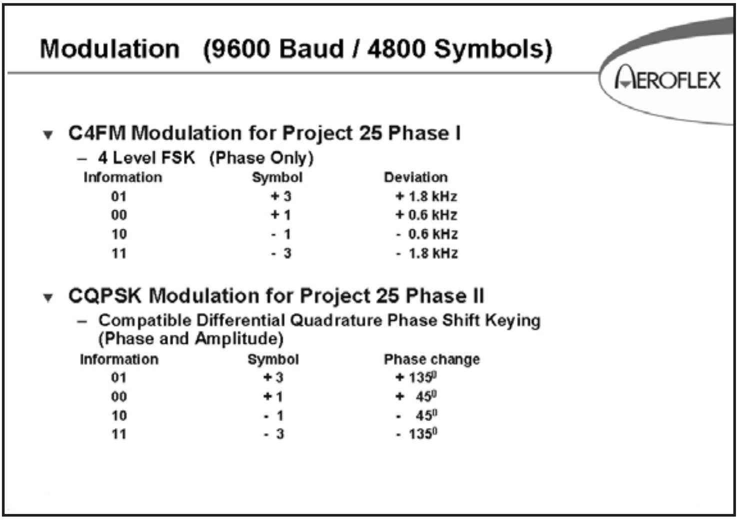
The Phase II implementation will use a further increase in modulation complexity to support the same 9600 bits in a 6.25 kHz channel.



How do we convert Analog to Digital?

In a digital system the voice is encoded into a bit stream by a device called a Vocoder. Various techniques are used to do this and the one selected for use in Project 25 is called an Improved Multi-Band Excitation (IMBE) Vocoder. This uses complex algorithms to reduce each 20ms of speech to 88 bits of information to be transmitted over the radio link. The receiving device reverses the process to produce 20ms of analog speech signal.

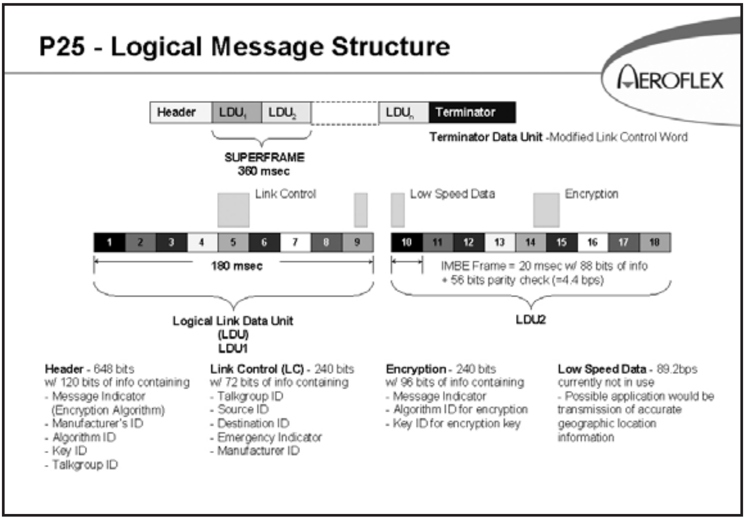
The IMBE Vocoder converts a 3100 Hz audio band (300-3400 Hz) to a 4400 bps digital signal.



Modulation

The Phase I implementation of Project 25 uses a modified form of four level FM as its modulation technique. The information is transmitted in the form of a digital data stream and is modulated as symbols. Each symbol type is determined by two bits of data giving four symbol types in total. The symbol types are represented by a particular FM deviation applied to the carrier. The modulation is characterized as being complex because the deviation is not symmetrical about the carrier as you would expect in a conventional FM system although it is of fixed amplitude.

Compatible Quadrature Phase Shift Keying (CQPSK) has been considered as a possibility for Phase II modulation. With CQPSK, each symbol is identified by the phase change from the previous symbol. This is one of a family of modulations generally grouped under the term of linear modulation in which both the phase and the amplitude of the signal vary from symbol to symbol.

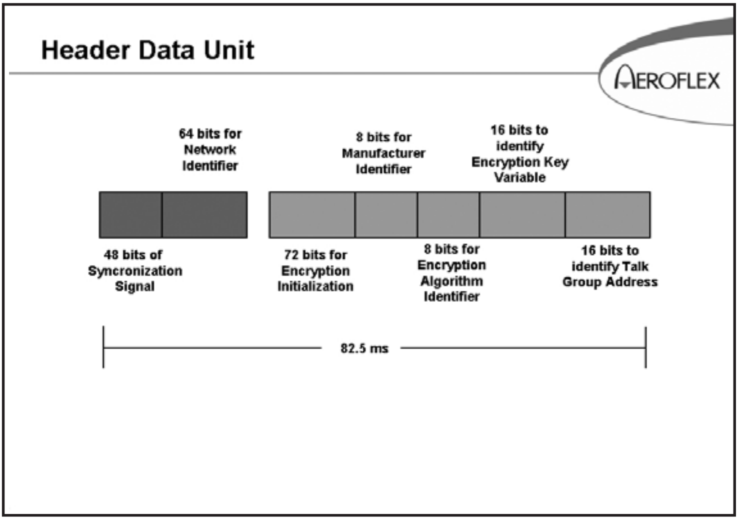


Project 25 - Logical Message Structure

The Logical Data Units, types 1 and 2, are combined into a superframe which has a transmission time of 360ms. The superframes are repeated for as long as the message lasts.

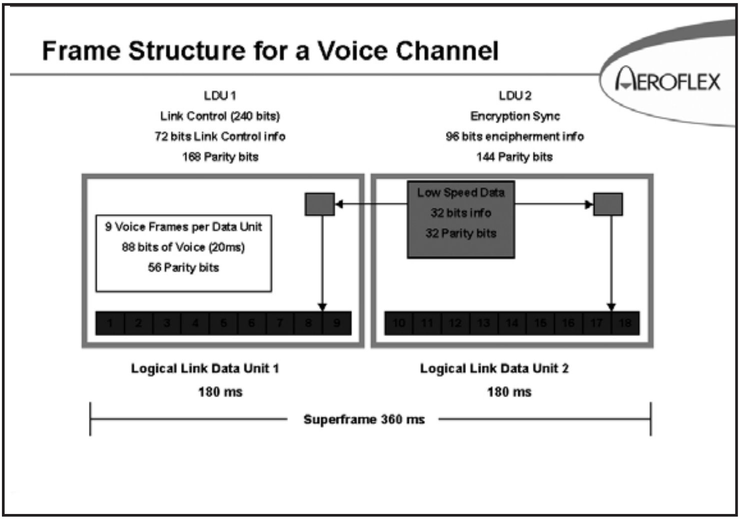
Many other types of channel structures are available to support packet data services and other system capabilities.

This illustration shows the Logical Message Structure for Project 25 data transmissions. A transmission begins with a Header Data Unit followed by repeating LDU1 (Logical Link Data Unit) and LDU2 Data Units, followed by a Terminator Data Unit at the end of a transmission.



Header Data Unit

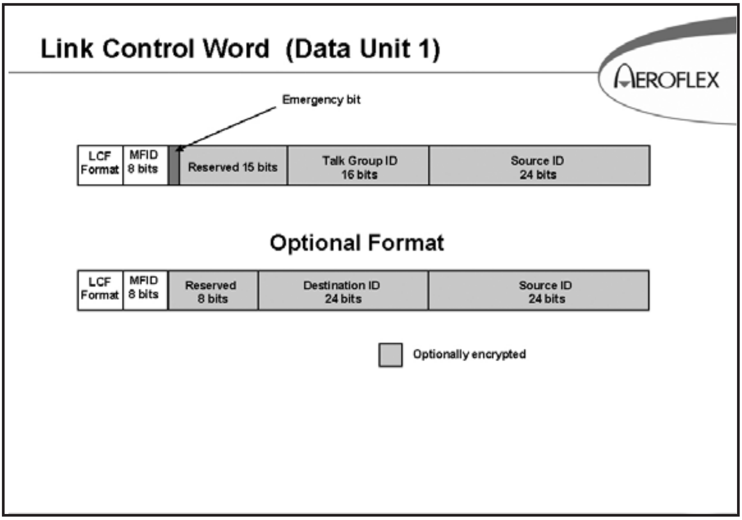
The Header Data Unit begins with 48 bits of Synchronization along with 64 bits for the Network Identifier. The Network Access Code (NAC) contains values expressed in HEX format that range through 4096 values. A subset of these codes are intended to map into Continuous Tone Coded Squelch (CTCSS) and Digital Coded Squelch (DCS) codes. NAC codes 023 through 271 directly correlate to DCS codes 023 through 271. NAC code 293 is the default for carrier squelch.



Frame Structure for a Voice Channel

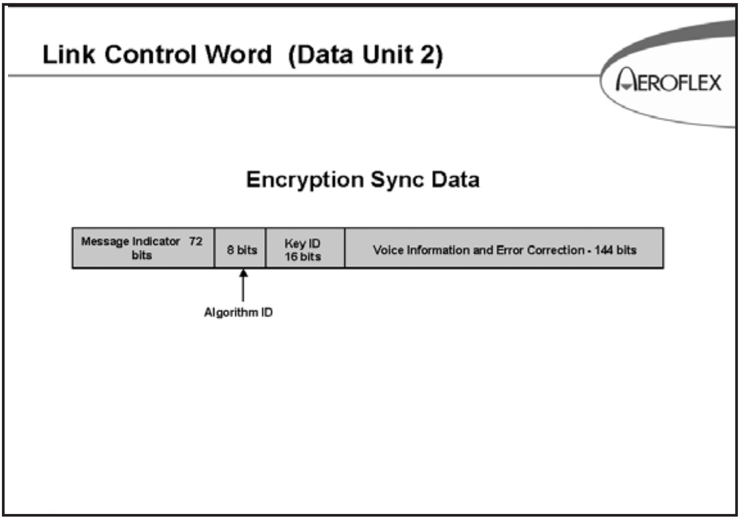
The frame and message structure of the Project 25 system is briefly described in the following graphics. As mentioned earlier, the speech is divided up into 20ms segments, each being represented by 88 bits of data. To these 88 bits a further 56 bits of parity data are added to complete a voice frame. Nine of the voice frames are concatenated along with some system messaging to form a Logical Link Data Unit of 180ms in length. Additional protection is given to the speech frames by interleaving them throughout the Data Unit. This ensures that if the transmission is impaired for a short period of time, many small and thus insignificant segments of the speech are lost rather than a complete word.

The Logical Link Data Units are of two types for a voice channel. Unit 1 contains the link control information which is used to maintain the communication channel. Unit 2 contains the encryption synchronization information. Both Unit 1 and Unit 2 also contain some low speed data service divided equally between the units.



Link Control Word (Data Unit 1)

The Link Control Word used in the Logical Link Data Unit 1 can be of several formats. Two of the more common ones are shown in this illustration. The first bits transmitted identify the particular format in use. This is followed by the terminal manufacturer's identity code which is common to all of the link control formats. Other information conveyed in this 72 bit field includes the Emergency bit which is set when a high priority call is made, the Talk Group identity of the mobile and the individual identity within the talk group. Several fields are left unused for future applications allowing further system growth. Again, as with the voice frame, additional parity bits are included, 168 in this case to provide error correction of the transmitted data.



Link Control Word (Data Unit 2)

The other basic data units are described on this graphic. The Encryption synchronization data is included in Logical Data Unit 2 and consists of 96 data bits which comprise 72 bits of message indicator, 8 bits describing the encryption algorithm and 16 bits identifying the encryption key in use. Again, this is protected by a further 144 parity bits.

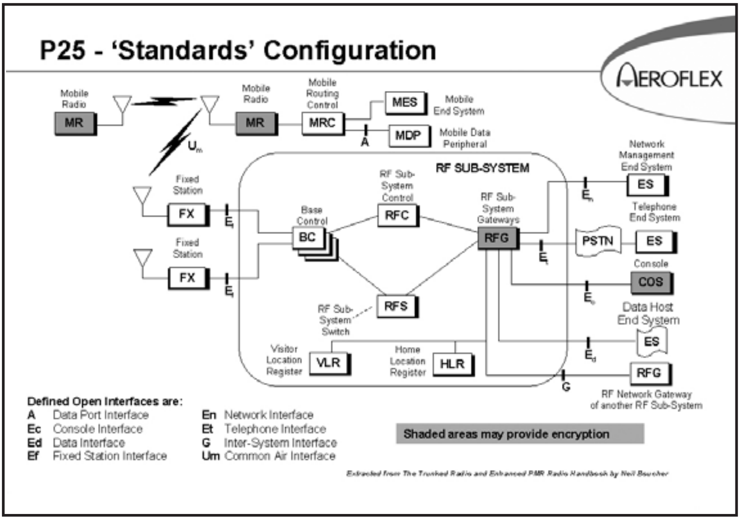
Every message is preceded by a Header Data Unit and followed by a Terminator Data Unit. The Header Data Unit contains the Message Indicator and the Manufacturer's Identity as well as encryption and talk group information.

The Terminator Data Unit is a modified form of the Link Control Word previously described. The data units are then built up into a message structure shown on the graphic.

Terminator Data Unit

- There are two terminating data units for voice messages
  - **The simple one consists solely of a frame sync and Network ID**
  - **A more elaborate terminator adds a Link Control word**

- The terminating data unit may follow either LDU1 or LDU2



Project 25 - 'Standards' Configuration

The Project 25 Standard Configuration block diagram provides a 'typical' implementation of a Project 25 system.

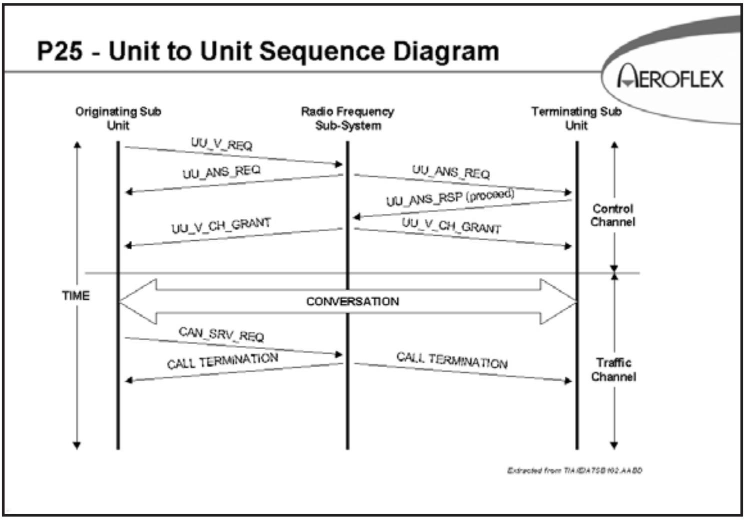
The Mobile Radio (MR) has the ability to transmit and receive both voice and data, thus requiring two different types of mobiles. The voice/data mobile is considerably more complex than the voice only mobile. When data is transmitted, the MR uses the Mobile Routing Control (MRC) to route the data through a data connector to a Mobile Data Peripheral (MDP).

The base station equipment can be made up of many different components, depending on user requirements. The above diagram provides a block diagram of a 'fully functional, fully featured' system.

The Base Control (BC) controlling multiple Fixed Station (FX) units removes much of the work load from the RF Sub-System Control (RFC).

The main function of the RFC is to provide direction to the different modules. Given the situation where the BC connects mobile xyz to frequency A on voice path 2, the RF Sub-System Gateway (RFG) connects voice path 2 to the PSTN and dials the digits 12345.

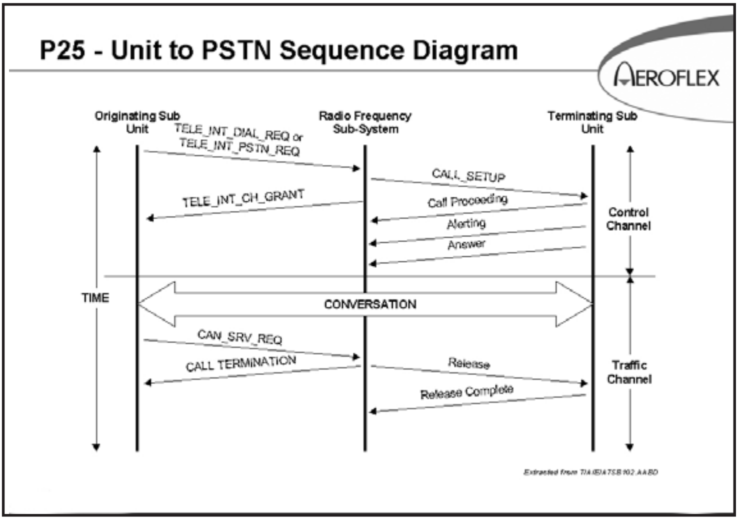
The Visitor Location Register (VLR) acts as a dynamic database that constantly changes depending on the users on the system at any given moment. The Home Location Register (HLR) is a static database of all the possible users on the system. By separating the functionality of the VLR and HLR, the system can access and approve user access quicker than if just HLR were used.



Project 25 - Unit to Unit Sequence Diagram

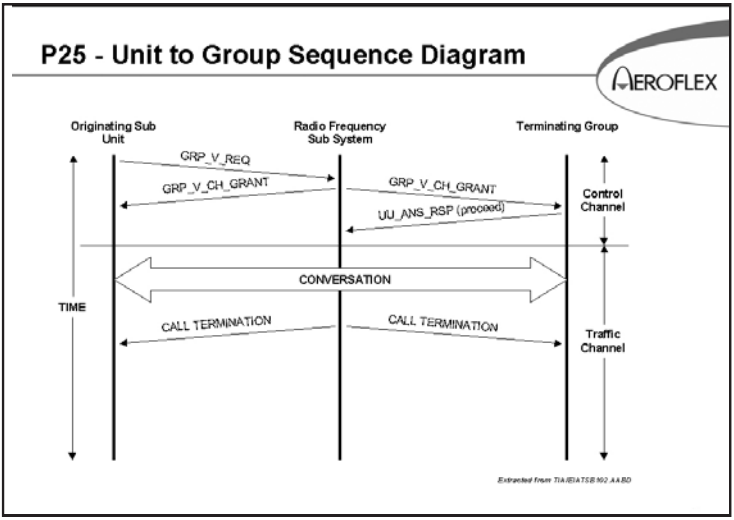
The following call processing ladder diagrams show the generic message sequences used in various Project 25 calling scenarios.

Message Acronym	Definition
UU_V_REQ	Unit to Unit Voice Service Request
UU_ANS_REQ	Unit to Unit Answer Request
UU_V_CH_GRANT	Unit to Unit Voice Channel Grant
UU_ANS_RSP	Unit to Unit Answer Response
CAN_SRV_REQ	Cancellation of Service Request



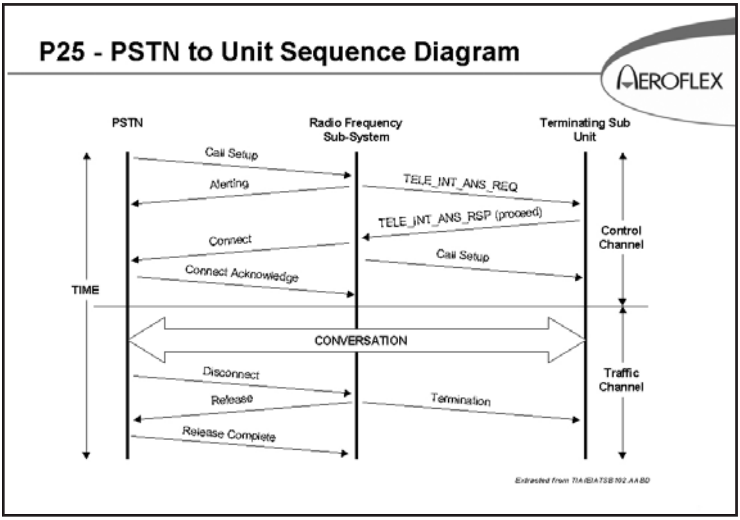
Project 25 - Unit to PSTN Sequence Diagram

Message Acronym	Definition
TELE_INT_DIAL_REQ	Telephone interconnect voice service request (Explicit dialing)
TELE_INT_PSTN_REQ	Telephone interconnect voice service request (Implicit dialing)
CAN_SRV_REQ	Cancellation of Service Request



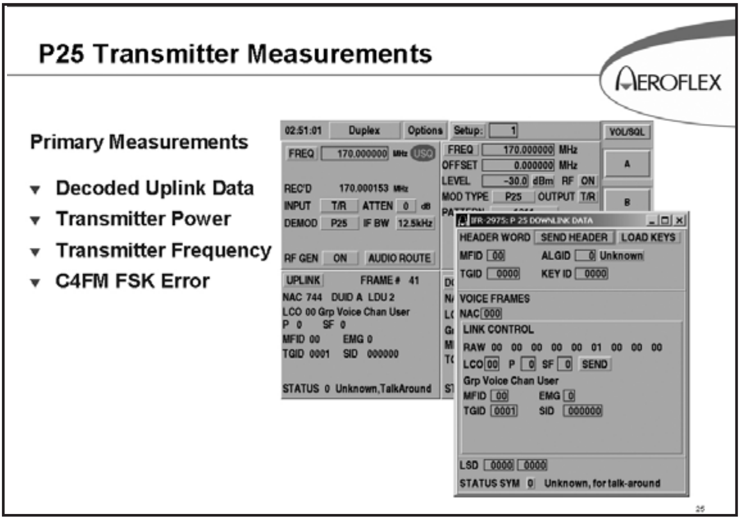
Project 25 - Unit to Group

Message Acronym	Definition
GRP_V_REQ	Group Voice Service Request
GRP_V_CH_GRANT	Group Channel Grant
UU_ANS_RSP	Unit to Unit Answer Response



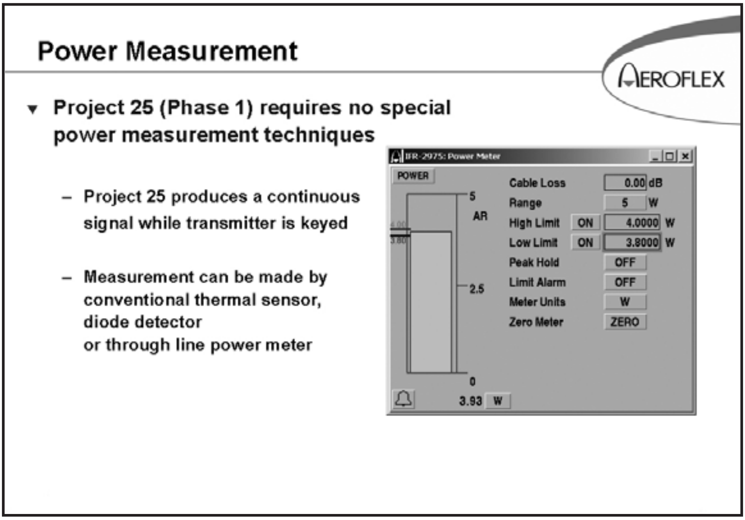
Project 25 - PSTN to Unit Sequence Diagram

Message Acronym	Definition
TELE_INT_ANS_REQ	Telephone Interconnect Answer Request
TLE_INT_ANS_RSP	Telephone Interconnect Answer Response



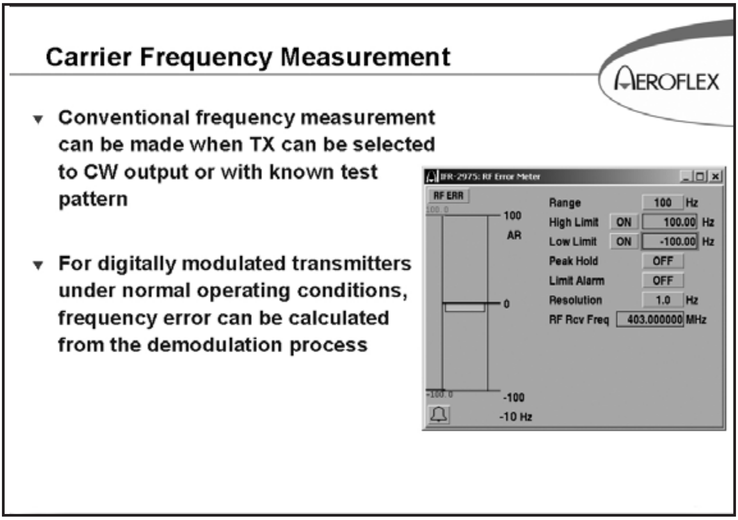
Project 25 Transmitter Measurements

Decoding of the Uplink data from a Project 25 transmitter allows verification of radio programming. The NAC, TGID (Talk Group ID) and SID (System ID) are the primary fields required to establish communications.



Power Measurement

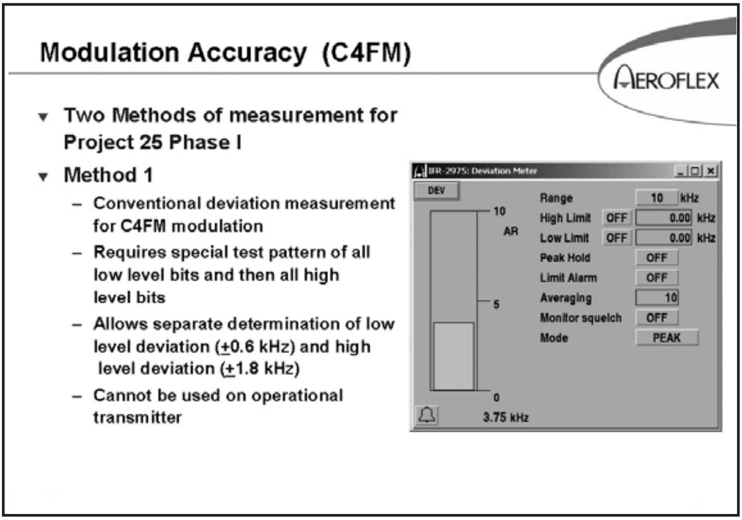
The power measurement of Project 25 transmitters can be made in the conventional manner with a power meter. The terminal or repeater produces a continuous signal whenever the transmitter is keyed.



Carrier Frequency Measurement

The carrier frequency of the transmitter can be easily measured if the transmitter is used in a conventional FM mode or using a test pattern. The Project 25 transmitters can be measured in this way. For more complex digital modulated signals such as those proposed for Project 25 II, the measurement of carrier frequency is more difficult. Here the carrier frequency can be obtained from the same analysis that is used to determine the modulation accuracy. The carrier frequency offset from the required channel frequency results in a fixed phase error for all the symbol point measurements. This can be subtracted from the measured phase angles and used to calculate the frequency with knowledge of the symbol period. Transmitter frequency is also important during the key up process. Here excessive frequency error can interfere with other users.

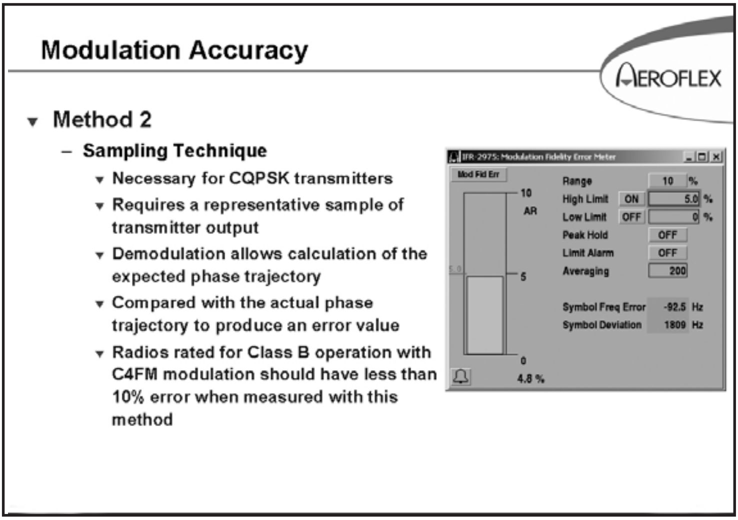
Conventionally, the TX turn on measurement is made through a complex test setup which uses a calibrated demodulator and a storage oscilloscope. The measurement can also be made using a sampled method very similar to that used for modulation accuracy.



Modulation Accuracy (C4FM)

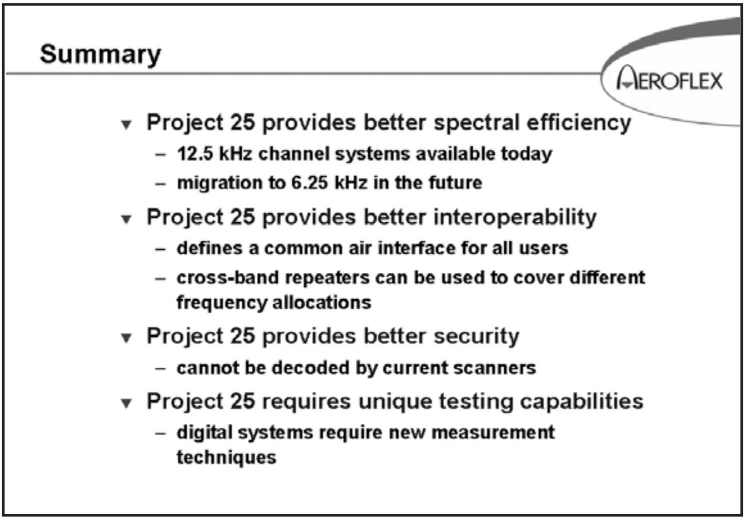
As described in the previous page, Project 25 in its first phase uses a constant amplitude modulation which is a modified form of FM. Therefore, modulation accuracy can be measured by conventional deviation measurements as long as a suitably modified data stream is transmitted. This would first consist of transmitting all the low deviation bits (i.e. 00 for + dev, 10 for –dev) to ascertain the low deviation and then a bit pattern containing the high deviation levels (i.e. 01 for +dev, 11 for – dev). This, of course, prevents conventional measurement from being used on a working transmitter where the bit pattern is controlled by the message being transmitted.

For the more complex systems such as that proposed for Project 25 II the data is represented by the instantaneous phase and amplitude of a vector. Measuring the fidelity of this type of modulation is much more difficult. One method takes a sample of the transmitted waveform over a large number of symbols (typically 100-200). From this information the demodulated data can be determined. This enables the test equipment to calculate the phase trajectory created by the data and then compare this with the sampled data. The errors in the measured data can then be determined and resolved into their various components.



Modulation Accuracy

The sampling method allows modulation accuracy to be measured on a working transmitter without any need for a test signal containing either "Low" or "High" deviation bits, hence keeping the radio in service. The method enables accurate characterization of the modulation to be made in a single measurement. For Project 25 Phase 1 equipment using C4FM modulation to the RMS vector error should not exceed 10%.



Summary

As shown previously in the booklet, Project 25 provides better spectral efficiency due to its digital modulation technique. This type of modulation provides twice as many communications channels as the traditional FM analog scheme.

Interoperability is enhanced as more public safety organizations convert to a common Project 25 compliant system.

DES Type III encryption allows for better security when specific groups need private conversations and Project 25 allows for Over-The-Air-Rekeying (OTAR) to reconfigure encryption keys.

Project 25 requires unique testing techniques due to its digital format. Transmitter modulation must be decoded and processed in order to verify that a receiver will be able to process the intended message. The Project 25 Receiver must be tested with encrypted and unencrypted messages to ensure proper operation. Cross-Band Repeaters may require testing across different frequency bands.

Aeroflex - Test Solutions for Project 25

AEROFLEX

IFR 2975 Project 25 Radio Test Set

- Project 25 parametric and protocol testing
- Project 25 Common Air Interface testing
- IMBE vocoder and data encryption testing for radios, base stations and repeaters
- Modulation and demodulation of C4FM
- AES and DES OFB Type III Encryption/Decryption Support
- Legacy FM system support
- Provides the latest features for testing PassPort® radios and repeaters
- Support for LTR® Trunking repeater simulator and mobile simulation
- Support for SmartNet™/SmartZone™ Motorola trunked radio system testing

Since 1976, Aeroflex has provided cutting-edge test solutions to the mobile radio industry. Aeroflex carries on that tradition with the IFR 2975 Radio Test Set. While the IFR 2975 pushes testing technology to a higher level, we didn't forget about the basics. For transmitter spectrum performance testing, swept antenna and transmission line testing and at-a-glance troubleshooting, the IFR 2975 comes standard with a digitized 2.7 GHz spectrum analyzer and dual-channel digital storage oscilloscope. With the functionality of over 20 discrete instruments integrated into a single platform, the IFR 2975 provides the tools you need to perform comprehensive RF testing. The IFR 2975 offers RF receive/generate with full duplex operation from 1 MHz to 2.7 GHz.

The IFR 2975 Radio Test Set is your test solution for Project 25.

Introduction to Project 25

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