Application Note

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Understanding 800 MHz and VHF/UHF Implicit P25 Trunking Functions using the IFR 2975.

by Rob Barden

As mobile radio communication systems become more complex and as more users are added to bandwidth-limited mobile radio networks, the implementation of trunking technology will undoubtedly become more common in the future. This application note covers the basics of how the P25 trunking operates and functions. In particular, it applies to the implicit mode of operation for P25 versus the explicit mode. Implicit operation means that the radio's own internal programming in conjunction with the P25 network messages will determine what channel/frequency pair the radio uses when a particular channel grant is recieved from the network. The explicit mode of operation assigns the actual channel/frequency over the air by providing the exact TX and RX frequency assignments directly to the radio. See the application note "Understanding Advanced P25 Trunking Functions" for explicit mode operation.

Typically, the implicit mode of operation uses something called single block messaging, where explicit uses multi-block messaging to convey trunking messages. However, both single and multi-block messages can be

used on a P25 network.

Why Use trunking?

The trunking is an optional implementation for P25 systems. Using a dedicated trunking is desirable in that it provides additional control of spectrum in larger systems. It allows for the control of system resources, and also offers added features not available in conventional radio communications.

Trunking Functions

To understand trunking functions, we need to remember that control messages are already utilized in some form by many conventional mobile communication systems. The difference is that with a P25 trunked system, a dedicated trunking provides additional management of the system resources.

The P25 trunking is a separate channel that is designated as the control resource and is different from the traffic channel in that it functions as a resource allocation and digital communication message bearer and handler between the RFSS (RF Sub-System) and the SU (Subscriber Unit).

Review of Key Terminology

In any wireless mobile communication system, acronyms abound. P25 is no different and there are certain acronyms and terms used that you need to be familiar with before moving on to using the IFR 2975 for testing P25 radios and repeaters. The following is a list of terms you should be familiar with:

ARQ	Automatic Retry Request
CAI	Common Air Interface
CRC	Cyclical Redundancy Check
EIA	Electronic Industries Alliance
EXPLICIT	The means in which the SU and FNE utilize messaging to channel assignments using advanced trunking messaging techniques
FNE	Fixed Network Equipment
GROUP ID	A collection of users assigned a particular ID number to designate them as a unique category of users
ID	Identifier
IMPLICIT	The means in which the SU and FNE utilize messaging to access pre-programmed channel parameters to establish channel assignments
INTERCONNECT	A call made to or from the Public Switched Telephone Network
ISP	Inbound Signaling Packet
LB	Last Block Flag - indicates if this block is last or more are to follow
LC	Link Control Word
LCF	Link Control Format

LCO	Link Control Opcode
LDU1	Logical Link Data Unit 1
LRA	Location Registration Area
LSB	Least Significant Bit
MFID	Manufacturer's Identity
MI	Message Indicator
MOBILE	For this application note, a mobile denotes either a portable or mobile.
ms	Millisecond
MSB	Most Significant Bit
NARROW BAND	12.5kHz bandwidth operation
TX	Transmit
Octet	8 bits of information used in messaging
Opcode	Identifies the message type
OSP	Outbound Signaling Packet
P	Protected Flag
PARAMETRICS	The RF performance of a radio system including RF Error, Power and Modulation Accuracy, as well as radio sensitivity
PROTOCOL	A series of communication processes defined to set up calls and to send various forms of data to and from the mobile.
PSTN	Public Switched Telephone Network
REGISTRATION	The initial handshake process that allows the radio to communicate
RFSS	RF Sub-System
RX	Receive
SCCB	Secondary trunking Broadcast
SS	Status Symbols
SU	Subscriber Unit - the mobile or portable radio
TIA	Telecommunications Industry Association
TILE	This applies to the IFR 2975. A tile is a window view of various functions within the IFR 2975. There are two tiles. One is a ¼ tile and the other is ⅛ tile. The ¼ tiles are used for displaying repeater simulators, minimized spectrum analyzers and oscilloscopes, and take up ¼ of the total screen area. ⅛ tiles are used for meters and take up ⅛ of the total

screen area.

| TSBK | Trunking Signaling Block |
| TX | Transmit |

The P25 Trunking

The P25 trunking feature for trunking is not specific (proprietary) to any P25 manufacturer or P25 RFSS configuration. All mobiles supporting P25 formats should be able to access a P25 trunking function as either standard configuration or as an option.

In the P25 standard, the trunking maintains compatibility between conventional operation in that the modulation format and the bit rate are the same. In the case of P25, the trunking is a 9600-baud (data rate) channel using C4FM modulation to impart the digital 1's and 0's to the receiving radio. The difference is that the trunked version uses packet access techniques and requires a command/response process to a resource controller which coordinates the users access, while the conventional version permits user's to control their own access. An example of how a trunking operates can be seen in figure 1.0.
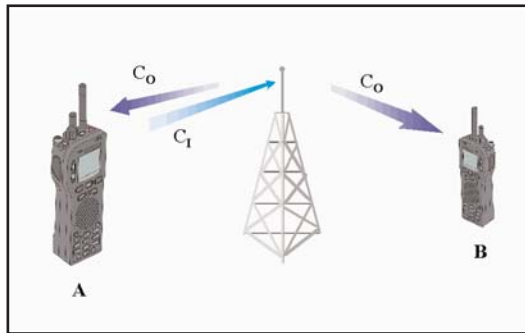

Figure 1.0 Trunking Operation

As you can see, the repeater is putting out an outbound trunking (C_o) that both mobiles are monitoring. In P25 Trunking systems, the outbound trunking sends information in "packets" and those words are called Outbound Signaling Packets or OSPs.

Let's assume that mobile "A" wants to place a call to another user on the system. Mobile A transmits a request to the repeater on an inbound trunking (C_I). In P25 Trunking systems, the inbound trunking sends information words called Inbound Signaling Packets or ISPs. The repeater station and network processes the request, and then sends an alert on the outbound trunking that the designated user, mobile "B", recognizes as a call that is part of its group or that is designated specifically for itself.

As you can see in figure 2.0, the calls are then assigned to particular voice channels that operate on separate frequencies (f_1, f_2, f_3, f_4). The transmit and receive frequencies for the mobiles are offset from each other (f_1 and f_2) (f_3 and f_4). This is called duplex offset. In the 800 MHz band, the offset is 45 MHz. Control of these resources is accomplished through the trunking that the mobile unit monitors continuously when not engaged in a communication session with another user or with the network.
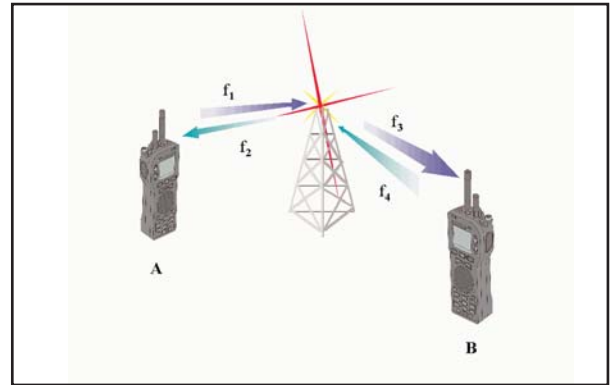

Figure 2.0 Two-way radio communications using trunked operation

How the Subscriber Unit Locates a P25 Trunking

Once the mobile user switches the SU on, how does it actually "find" the trunking? In the P25 standard, the mobile unit will search a particular band, dependent upon its own internal programming, look for a valid trunking, verify the WACN ID, System ID and optionally the NAC, and then decode the trunking information. This information is pre-programmed into the radio and requires coordination in large-scale systems to ensure that mobiles that "roam" can properly access the network.

Outbound trunking Signaling Messages - The Key to Communication

The P25 trunking communicates a variety of information through signaling messages to the SU so that proper access to the system can be achieved. The P25 standard utilizes system status (overhead messages) and control messages to accomplish this. The following are examples of system status messages that are sent from the RFSS repeater to the SU:

Mandatory Outbound Signaling Messages (RFSS to SU)

The RFSS must generate a Network Status Broadcast Message (NET_STS_BCST). The SU uses this information for the registration procedure. These messages are sent continuously.

The RFSS must generate a System Status Broadcast Message (RFSS_STS_BCST). The SU uses this information for the registration procedure and the random access procedure. These messages are sent continuously.

The RFSS must generate an Identifier Update (IDEN_UP) message, informing the SU of the channel characteristics of the RFSS. This message may be sent periodically, as long as it is part of the overhead messaging.

Optional Outbound Signaling Messages (RFSS to SU)

The RFSS may generate System Service Broadcast (SYS_SRV_BCST) messages, informing SUs of the current system services available and currently supported.

The RFSS may generate Protection Parameter Broadcast (P_PARM_BCST) messages, informing SUs of the initialization value to be used for the protection process on the trunking.

The RFSS may generate Adjacent Status Broadcast (ADJ_STS_BCST) messages, informing SUs of the existence and status of sites adjacent to this current site.

The RFSS may generate Secondary Trunking Broadcast (SCCB) messages, informing the SUs of the existence and status of secondary trunkings at this site.

In addition to the system status messages, there are control messages sent to handle communications access between the RFSS and the SU. These include messages used in the registration, affiliation and call process. They also control voice and data communications. Some control messages include:

Registration, Affiliation, Authentication and Roaming Messages

Authentication Command (AUTH_CMD)

Group Affiliation Query (GRP_AFF_Q)

Group Affiliation Response (GRP_AFF_RSP)

Unit Registration Command (U_REG_CMD)

Unit Registration Response (U_REG_RSP)

Roaming Address Command (ROAM_ADDR_CMD)

Roaming Address Update (ROAM_ADDR_UPDT)

Extended Function Command (EXT_FNCT_CMD)

Acknowledgement Messages

Acknowledge Response - FNE (ACK_RSP_FNE)

Authentication Command (AUTH_CMD)

Deny Response (DENY_RSP)

De-Registration Acknowledge (U_DE_REG_ACK)

Specific Response Messages to SU Requests

Call Alert (CALL_ALRT)

Message Update (MSG_UPDT)

Protection Parameter Update (P_PARM_UPDT)

Queued Response (QUE_RSP)

Status Query (STS_Q)

Status Update (STS_UPDT)

Location Registration Response (LOC_REG_RSP)

Radio Unit Monitor Command (RAD_MON_CMD)

Voice Service OSPs

Group Voice Channel Grant (GRP_V_CH_GRANT)

Group Voice Channel Grant Update
(GRP_V_CH_GRANT_UPDT)

Group Voice Channel Update-Explicit
(GRP_V_CH_GRANT_UPDT_EXP)

Unit to Unit Answer Request (UU_ANS_REQ)

Unit to Unit Voice Service Channel Grant (UU_V_CH_GRANT)

Telephone Interconnect Voice Channel Grant
(TELE_INT_CH_GRANT)

Telephone Interconnect Answer Request
(TELE_INT_ANS_REQ)

Unit to Unit Voice Channel Grant Update
(UU_V_CH_GRANT_UPDT)

Tel. Interconnect Channel Grant Update
(TELE_INT_CH_GRANT_UPDT)

Inbound Trunking Signaling Messages - The SU Communication

In addition to the OSPs, the SU responds and initiates communication using its own set of messages called ISPs. These include:

Voice Service ISPs

Group Voice Service Request (GRP_V_REQ)

Unit to Unit Voice Service Request (UU_V_REQ)

Unit to Unit Voice Service Answer Response (UU_ANS_RSP)

Telephone Interconnect Request-Explicit Dialing
(TELE_INT_DIAL_REQ)

Telephone Interconnect Request-Implicit Dialing
(TELE_INT_PSTN_REQ)

Telephone Interconnect Answer Response
(TELE_INT_ANS_RSP)

Control and Status ISPs

Acknowledge Response - Unit (ACK_RSP_U)

Authentication Query (AUTH_Q)

Authentication Response (AUTH_RSP)

Call Alert Request (CALL_ALRT_REQ)

Cancel Service Request (CAN_SRV_REQ)

Emergency Alarm Request (EMRG_ALRM_REQ)

Extended Function Response (EXT_FNCT_RSP)

Group Affiliation Query Response (GRP_AFF_Q_RSP)

Group Affiliation Request (GRP_AFF_REQ)

Identifier Update Request (IDEN_UP_REQ)

Message Update Request (MSG_UPDT_REQ)

Protection Parameter Request (P_PARM_REQ)

Status Query Request (STS_Q_REQ)

Status Query Response (STS_Q_RSP)

Status Update Request (STS_UPDT_REQ)

Unit Registration Request (U_REG_REQ)

De-Registration Request (U_DE_REG_REQ)

Location Registration Request (LOC_REG_REQ)

Radio Unit Monitor Request (RAD_MON_REQ)

Roaming Address Request (ROAM_ADDR_REQ)

Roaming Address Response (ROAM_ADDR_RSP)

Understanding the Implicit Mode of Operation

In a P25 radio system, channel/frequency combinations can be programmed into the radio. These programmed values match the network channel/frequency combinations. In the channel grant, the system tells the radio, through the use of a channel identifier, what channel to go to. In the implicit mode of operation, the radio internally looks up the channel identifier, and then tunes to the requested channel. Implicit messaging typically uses single block TSBK messages which is a relatively simple means of getting the proper information to the radio from the trunking to then act upon. This works fine in bands with fixed channel assignments like the 800 MHz band and implicit messaging is used in undefined bands as well, such as the VHF and UHF bands.

However, in undefined bands, the implicit mode of operation can limit the use and the inherent flexibility of the band. This is caused by the radio having to be pre-programmed for all the various channel/frequency combinations. If the channel is not pre-programmed, the radio cannot tune to that channel because it simply doesn't know better.

To get around this, the explicit mode of operation was developed. See application note "Understanding Advanced P25 trunking Functions" for explicit mode operation.

Single Block Messaging Operation

Implicit messaging uses Single Block Messaging consisting of single TSBK (trunking signaling blocks) to provide information to the SU. Figure 3.0 shows the configuration of a single TSBK. As you can see, the first two octets are used for the LB, P and Opcode information. The following 8 octets are used for the arguments or the actual message information. The final two octets are used for the TSBK CRC that is a validation check that the data was processed correctly.
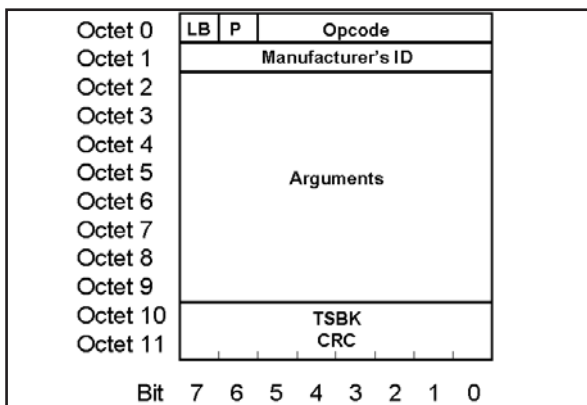

Figure 3.0 Single Block TSBK format

As seen in figure 4.0, single TSBK messages take up a total of 196 bits. We know from figure 3.0 that the single block structure takes up 12 octets at 8 bits each, totaling 96 bits. So where do the remaining 100 bits come from?

The TIA/EIA-102 standard provides for two types of channel coding dependent upon the type of message transmission, confirmed and unconfirmed. Both messages use a type of error correction called trellis coding. Trellis coding is a process where the message information is protected using a trellis, or look up table for a set input state. More about trellis coding can be found in TIA/EIA-102.BAAA. The important thing to remember about trellis coding is that it provides error protection for the transmitted data blocks and that the input data is expanded in the trellis coding process.
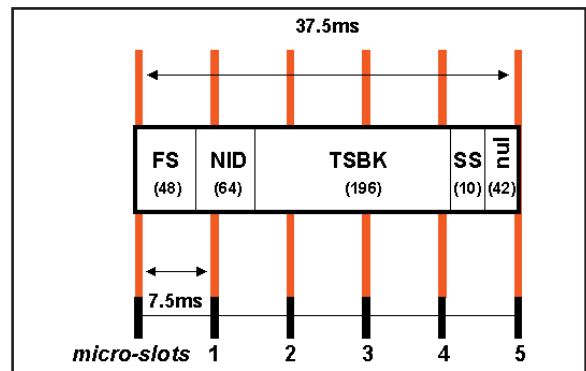

Figure 4.0 Transmitted TSBK format in relation to the Micro-slots

Confirmed messages use ARQ technology to confirm that the data was received correctly. Since ARQ uses a data check, confirmed messages are protected using only a ¾ rate trellis that means for every 144 bits in, 196 bits will be generated out of the trellis coding process. This equates to less protection for the data bits, which is what you would expect for confirmed messages.

Unconfirmed messages do not use a confirmation process and therefore receive a stronger error protection trellis coding process. For every 96 bits in, 196 bits are generated out. This is called ½ rate trellis coding and where we see the 96 bits from a single TSBK transformed into the 196 bit actual transmitted data.

You will also notice in figure 4.0 that there are Status Symbols (SS) that accompany the message information. The figure shows that the symbols are at the end of the TSBK, which is just an easier way of depicting how many status symbol bits are actually used during the transmission of the message. In reality, the status symbols (2 bits) occur at the micro-slot boundaries (every 7.5 ms) and are interleaved within the message structure. Status symbols provide valuable information about the status of the channel, specifically if it is idle, busy or being used to mark inbound timing parameters for ISPs.

OSP Status Symbols for trunking operation are as follows:

01   Busy - Inbound trunking is not available

10   Unknown - Used to space out microslots to a slot boundary

11 Indicates start of Inbound slot

ISP Status Symbols from the SU for trunking operation consist of only one state. That is 10 which is reserved for ISP Status Symbols.

Typical Trunking Configuration

Since the P25 standard states that a trunking requires a minimum of the RFSS_STS_BCST, NET_STS_BCST and the IDEN_UP messages, the minimum configuration one would expect to see on a P25 trunking would include these messages. Although this would appear to be the case, a simplified version using only the RFSS_STS_BCST and NET_STS_BCST messages would actually work in an implicit messaging environment. That is because the IDEN_UP message contains data already pre-programmed into the radio in the implicit mode. We'll see more about this later on in this application note.

A typical "basic" trunking configuration would be shown in figure 5.0, where "1" would designate an IDEN_UP message, "2" would designate an RFSS_STS_BCST message and "3" would designate a NET_STS_BCST message.

Figure 5.0 A "Basic" P25 Trunking Configuration

Now that we know how the basic messages are put together, we need to look at the messages closer to gain a better understanding of the trunking operation.

Network Status Broadcast Message

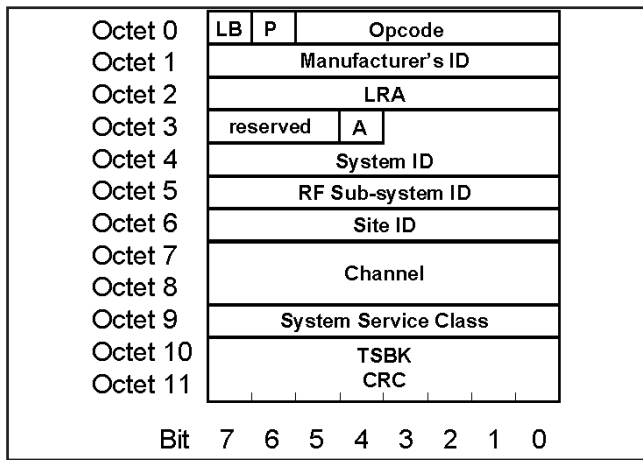The Network Status Broadcast message contains fields or information elements as outlined in figure 6.0.
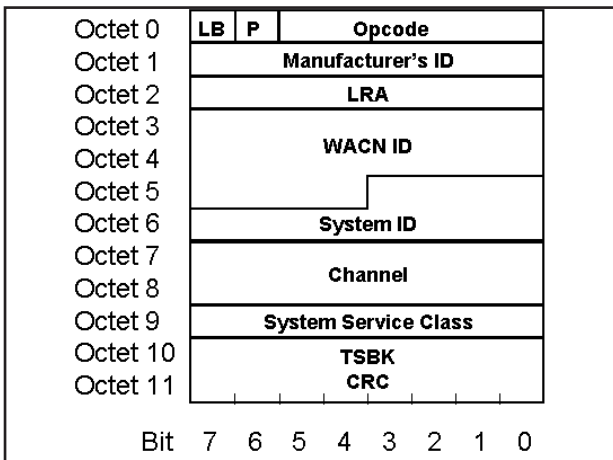
Figure 6.0 The Network Status Broadcast message

The fields within this message are defined as follows:

LB: The LB field is the last block flag. This field indicates whether more TSBKs should be expected in this packet: 0 = other TSBKs to follow for this packet, 1 = last (only) TSBK for this packet. Note: The 2975 does not allow you to modify this parameter. This is established based on the type of messaging used - "implicit or explicit."

P: The P-bit is a single bit indicator that states if the remaining portions of the TSBK (Trunked Signaling Block) are encrypted. 0 is not encrypted, 1 is encrypted. See page 12 of TIA/EIA-102 AABB for more details.

Opcode: This field defines the contents of the TSBK. It assigns what type of message the TSBK is (e.g. unit to unit voice service request, system status broadcast, etc.), and defines how the Arguments field will be parsed and populated pertaining to this trunking message. (The opcodes are meant to be system independent definitions, with the same opcodes depicting the same information in any system.) Note: Opcodes are not definable in the 2975 since they are specific message elements required to establish and maintain a call.

The MFID or the Manufacturer ID: It identifies the manufacturer for non-standard trunking messaging. The Standard Project 25 Manufacturer's ID is defined as all zeros ($00). This differs in that hybrid systems, such as Motorola's ASTRO 25 SmartNet/SmartZone™ system that uses a 3600 baud SmartNet trunking with P25 Traffic Channels use a different MFID. Throughout this document, the Manufacturer's ID field is to assume the standard Project 25 Manufacturer's ID.

LRA: The LRA defines the region of a registration area in which a subscriber unit may roam without the need to indicate a location update to the network. The registration area may consist of a number of LRAs. The LRA may be a single site or a collection of sites of an RFSS. The exact meaning is up to the system designers. This is a single octet in length with valid entries of $0000 - $FFFF. See TIA/EIA-102 AABC and AABD.

The WACN ID: This field is a 20 bit field that sets the Home network identity which is hard coded into the radio SU through the use of a data interface to set the various parameters within the radio. This dictates the Home network upon which the radio can work. Valid entries are $0 0001 - $F FFFE.

System ID: The System ID identifies the home system in a 12-bit field. The radio may be programmed to operate in up to 8 other systems through the combination of the (WACN ID + System ID). Valid entries are $001 - $FFE.

Channel: This is the actual channel resource that is assigned for a particular service. Note: The 2975 sets this in the P25 trunking tile. See TIA/EIA-102-AABC for details.

System Service Class: This is the 8-bit System Service Class field that indicates the basic functions of what the trunking will support. The defined values are:

$01 - composite trunking

$02 - no service requests; update trunking only

$04 - backup trunking only

$08 - reserved for future definition

$10 - data service requests only

$20 - voice service requests only

$40 - registration services only

$80 - authentication service only

These values may be ORed together to give different service class definitions. A few of the many possibilities are given below for examples. Other values not listed here are also allowed.

$00 - no services, either trunked or conventional

$F0 - all service, not a backup trunking

TSBK CRC: This is a Cyclical Redundancy Check that verifies the reassembled transmitted bits are coded properly. The user cannot set this field.

RFSS Status Broadcast Message

The RFSS Status Broadcast (RFSS_STS_BCST) messages contain fields or information elements as outlined in figure 7.0.

Figure 7.0 The RFSS Status Broadcast message

The RFSS Status Broadcast message provides additional information about the sub-system capabilities. It shares some of the same fields as the Network Status Broadcast Message, but also has additional fields as follows:

A: This field in the RFSS_STS_BCST message will specify if the site has an active network connection with the FSS controller, i.e., communication with other sites is possible. A value of 1 will indicate a valid RFSS network connection is active.

RFSS ID: The 8-bit RFSS ID field identifies the RF subsystem in a P25 network. Valid entries are $01 - $FE. See TIA/EIA-102 AABD for more information.

Site ID: The 8-bit Site ID field indicates the identity of the site. The Site ID is unique within an RFSS. Valid entries are $01 - $FE. See TIA/EIA-102 AABD for more information.

IDEN_UP and IDEN_UP_VU Messages

IDEN_UP Messages

The IDEN_UP and IDEN_UP_VU messages contain fields or information elements as outlined in figures 8.0 and 9.0. The primary difference between the two messages is that the IDEN_UP is used for frequencies outside the VHF/UHF band (136 MHz to 172 MHz and 380 MHz to 512 MHz), where the IDEN_UP_VU is used specifically in the VHF/UHF band. Figure 8.0 shows the IDEN_UP message structure.
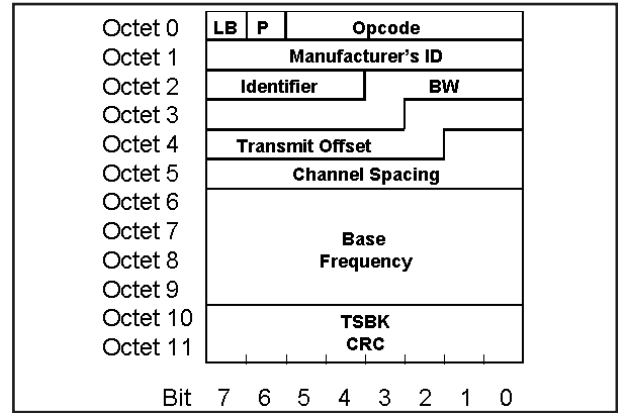

Figure 8.0 The IDEN_UP message

For the IDEN_UP message, the fields are defined as follows:

Identifier Field: This is the assigned identifier for the channel, and is a 4-bit field used to reference a set of frequencies and channel characteristics that are used to determine the corresponding frequency information. Each trunking can send multiple IDEN_UP messages and there can be up to 16 unique channel set references allowed per trunking.

BW: This defines the receiver bandwidth and uses this information in a calculation to determine the actual bandwidth. The formula used is to determine the bandwidth (kHz) is (BW) x (0.125 kHz). The BW value of zero is reserved and currently not valid.

Transmit Offset: This field represents the separation from the subscriber receive frequency to the subscriber transmit frequency and is a multi-part field where particular bits indicate different functions. The most significant bit, b8 (octet 3, bit 2), is used to describe the relationship between the TX and RX frequency and is known as the High/Low flag. If the bit is set to zero (0) then the SU transmit frequency IS LESS THAN the SU receive frequency. Consequently, if the bit is set to one (1) then the SU transmit frequency IS GREATER THAN the SU receive frequency.

The actual value of the offset is then determined by the remaining 8 bits. The transmit offset frequency (MHz) is computed as (offset value) x (0.250 MHz).

Therefore, if b8 = 0 then this frequency is subtracted from the computed SU RX frequency.

If b8 = 1 then this frequency is added to the computer SU RX frequency.

The value of $00 is reserved to indicate that transmit and receive occur on the same frequency. A value of $80 is reserved to indicate that there is no standard transmit offset associated.

Channel Spacing: This is a frequency multiplier for the channel number. It is used as a multiplier in other messages that specify a channel field value. The channel spacing (kHz) is computed as (Channel Spacing) x (0.125 kHz).

Base Frequency: This field determines the absolute frequency which is used to determine the frequency for a channel assignment as referenced by an Identifier. The frequency is calculated as (Base Frequency) x (0.000005 MHz). A Base Frequency value of zero is reserved and not valid.

IDEN_UP_VU Messages

The Identifier Update for VHF/UHF Bands is slightly different than the IDEN_UP message used outside the VHF and UHF bands. The two fields affected are the BW and Transmit Offset fields. Of course, the Base frequency field must contain information regarding frequencies that are only valid in the VHF/UHF bands. The IDEN_UP_VU message uses a shorter (more defined) BW field and a longer, more flexible Transmit Offset field. Figure 9.0 shows the IDEN_UP_VU message with the longer Transmit Offset VU field.
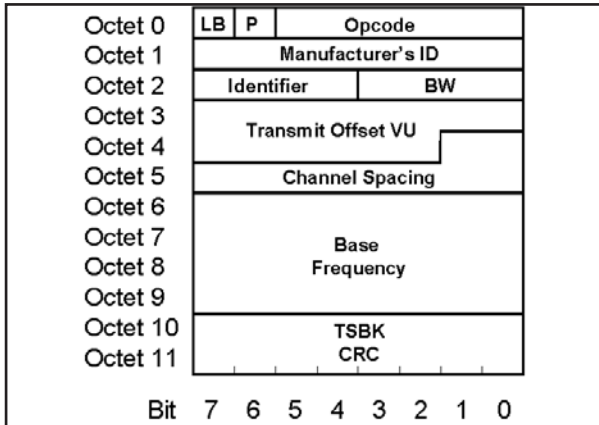
Figure 9.0 The IDEN_UP_VU message

In the IDEN_UP_VU message, the two fields affected are defined as follows:

BW VU: This field (octet 2, bits 3-0) takes on the following values for receiver bandwidth.

%0000 - %0011 reserved

%0100 6.25 kHz receiver bandwidth

%0101 12.5 kHz receiver bandwidth

%0111 - %1111 reserved

These values are essentially non-variable and only the values above are used in a VHF/UHF mode of operation.

The BW field differs in that the IDEN_UP uses a calculated field, whereas the IDEN_UP_VU message uses a shorter, more defined structure limited to 6.25 kHz and 12.5 kHz respectively.

Transmit Offset VU: This field of 14 bits represents the separation from the subscriber receive (SU RX) frequency to the subscriber transmit frequency and is a multi-part field.

A multi-part field is defined as where particular bits indicate different functions within the field. The most significant bit (octet 3, bit 7) is used to describe the relationship between the TX and RX frequency. If the bit is set to zero (0) then the SU transmit frequency IS LESS THAN the SU receive frequency and therefore the sign is -1. Consequently, if the bit is set to one (1), then the SU transmit frequency IS GREATER THAN the SU receive frequency and therefore the sign is +1. This is then followed by the actual offset information in the remaining 13 bits (octet 3,

bits 6-0) and (octet 4 bits 7-2).

It is important to note that the IDEN_UP_VU message can be used with either implicit or explicit messaging.

The IDEN_UP message is used to inform the subscriber unit of the channel parameters to associate with a specific channel identifier. For example, an identifier will have an associated base frequency, transmit offset, bandwidth and channel spacing. Each system can have multiple identifiers (up to 16). For implicit P25 radios, the IDEN_UP message provides information about the network, but in actuality already provides information already programmed into the radio.

Registration in a P25 Trunked System

As with most trunking systems, the P25 format requires that the SU register with the RFSS or network. This is done when the user turns on the mobile radio or when the user moves into a new zone. The primary purpose for registering a SU with the network is to ensure that only authorized users access the network, and that the network can track where the SU is located. This reduces the amount of time and resources that the network needs to locate the mobile, reducing call setup time and trunking loading.

There are two types of registration in a P25 trunked network, a full registration and a location registration. In a full registration the network will check the validity of the SU. A full registration occurs when the SU is first switched on, enters a new registration area, the user selects a new network or when the RFSS requests registration.

During a location registration, the SU monitors the trunking and then performs a location register in the event the user has moved to another site within the coverage area.

In both cases, the registration can be protected (encrypted) for enhanced security. Figure 10.0 shows a typical full registration process. The blue messages are ISPs and the red messages are OSPs.
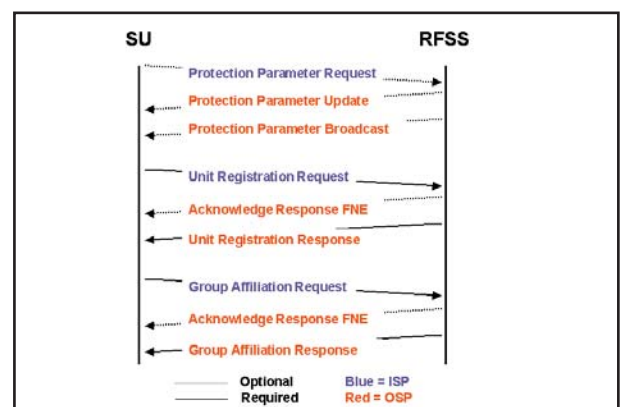

Figure 10.0 Full registration process

Unit Registration Request and Group Affiliation Request (SU Originated ISP)

If we look at the registration process, the basic implementation requires a registration message and an affiliation message. The first is the Unit Registration Request (U_REG_REQ). The detailed

Unit Registration Request message from the radio is shown in figure 11.0.
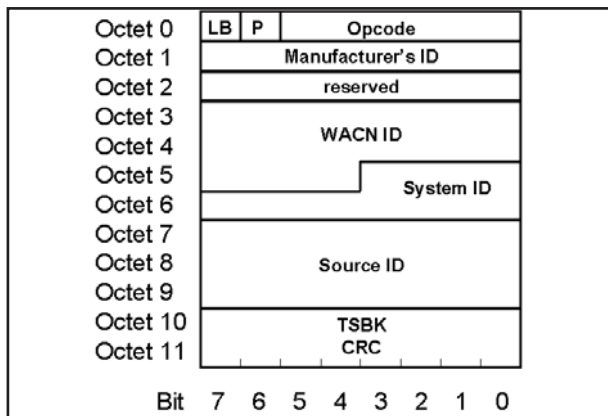

Figure 11.0 Unit Registration Request (Originated from the Mobile Radio)

All the definitions noted earlier for OSPs from the RFSS trunking apply. In addition, however, there is a new field, not previously defined, called Source ID.

Source ID: A 24-bit unit identity portion of the unique subscriber unit identity. This field along with the WACN ID and System ID uniquely addresses a subscriber unit.

This can also be called the Unit ID.

Note the unit has the appropriate WACN ID that is reflected back to the network for verification that the SU accepted the Wide Area Communication Network code.   This message utilizes the Last Block flag identifier field, the encryption P-Bit and the appropriate Opcode that identifies this message as a Unit Registration Request. The System ID is preprogrammed into the SU as is the Source ID (UID).   Manufacturer ID is also shown, which for a P25 system is 00.

Unit Registration Response (RFSS Originated OSP)

This message includes an assigned source address which "tells" the SU what its "new" identifier is. This source address is the unit's new "WU ID" or working unit ID. Figure 12.0 shows the Unit Registration Response message.
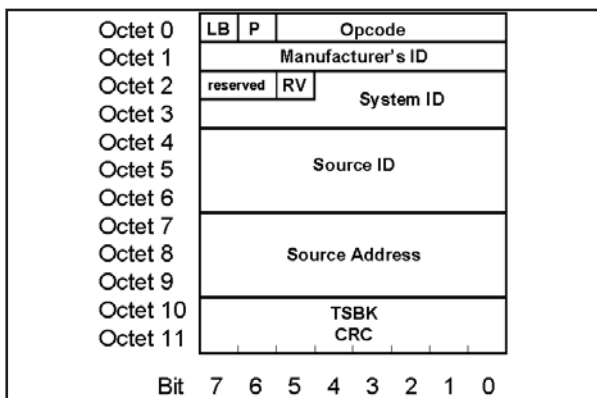
Figure 12.0 The Unit Registration Response message.

The Unit Registration Response assigns the new Source address

(WU ID) and the RV field.   Their functions are defined as follows:
RV: The RV field is a 2-bit field that designates the Registration Value. The following values are defined.

%00 = REG_ACCEPT indicates that registration is accepted.

%01 = REG_FAIL indicates that the RFSS was unable to verify registration.

%10 = REG_DENY indicates that registration is not allowed at the location.

%11 = REG_REFUSED indicates that the WUID is invalid but the SU need not enter trunking hunt and the SU may attempt to re-register after a user stimulus.

See TIA/EIA-102-AABC

WU ID: Within a Registration Area, each Subscriber Unit is assigned a unique abbreviated address known as the Working Unit ID (WUID). Once a SU has been assigned a WUID for a Registration Area, the WUID will normally be used to address the SU. The SU will use a WUID to identify target addresses whenever possible or appropriate. The WUID is a 24-bit field.

While within the registration area, a SU will be able to respond to messages that are addressed to its WUID. Also, while in the domain of the registration area, a SU shall initiate messages using its WUID for that registration area.   Valid entries are $00 0001 - $FF FFFD. See TIA/EIA-102 AABD.

In some instances the assigned WUID will be the same Unit ID or Source ID received by the SU in the Unit Registration Request. This is an automatic copy back function that simply reassigns the SU's Unit ID as the WUID.

Group Affiliation Request (SU Originated ISP)

After a registration request, the SU will send a Group Affiliation Request (GRP_AFF_REQ). The detailed Group Affiliation Request message is shown in figure 13.0
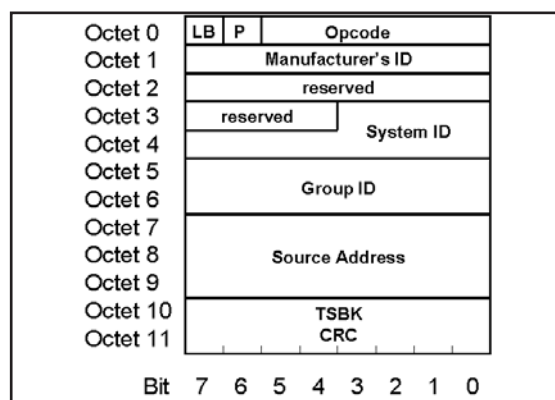

Figure 13.0 Group Affiliation Request (Originated from the Mobile Radio)

The message contains all the fields that the Unit Registration Request contains, except that the WACN ID is removed and the Group ID field is added. This message can be invoked by the RFSS at any time by broadcasting the Group ID Query command.

The Group ID is pre-programmed into the SU.

Group ID: This defines the 16-bit group identifier that together with the WACN ID and System ID uniquely defines a group.

Group Affiliation Response (RFSS Originated OSP)

The Group Affiliation Response message assigns to the SU a Group Address, which is the "WG ID". The WGID works similar to the WUID. Figure 14.0 shows the Group Affiliation Response message.
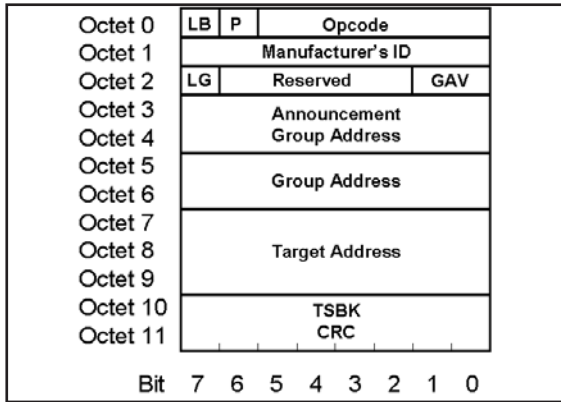

Figure 14.0 The Group Affiliation Response message

Announcement Group Address: This field denotes a special Group Address which addresses a grouping of Groups. This is unique within a System. There needs to be some prior arrangement to associate the Groups to an Announcement Group Address.

WG ID: Here the Group Address is now the WG ID. Within a System, a SGID or Subscriber Group ID (comprised of the WACN ID, System ID and Group ID) is assigned a unique abbreviated address known as the Working Group ID (WGID). This is a 16-bit field. See TIA/EIA-102 AABD for more details.

A WGID may be assigned to more than one SU, but will only be associated with a single SGID at any given time. The 16-bit address space of the WGID is customer defined to accommodate dynamic address capability. Valid entries are $0001 - $FFFE. See TIA/EIA-102 AABD.

As with the WUID, in some instances the assigned WGID will be the same Subscriber Group ID received by the SU in the Group Affiliation Request. This is an automatic copy back function that simply reassigns the SU's Group ID as the WGID.

LG: The LG bit indicates Local or Global affiliation.

LG=0 for Local and

LG=1 for Global.

GAV: The GAV argument is a Group Affiliation Value.

%00 = AFF_ACCEPT indicates affiliation acceptance

%01 = AFF_FAIL indicates affiliation failure

%10 = AFF_DENY indicates affiliation denial

%11 = AFF_REFUSED indicates that the WGID is invalid

and that the SU need not enter trunking hunt and the SU may attempt to re-affiliate after a user stimulus.

Understanding the Unit to Group Call Sequence

As the call is initiated and managed, additional messages are involved in the call sequence. For example, Figure 15.0 shows the required messages to establish a P25 unit to group voice call after the Unit Registration and Group Affiliation process is complete.
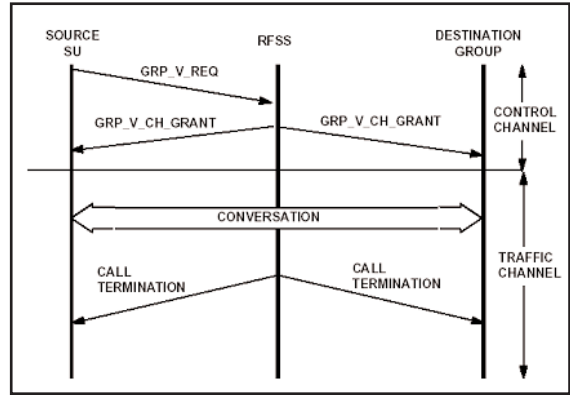

Figure 15.0 Unit to Group Call Sequence Chart

Once the mobile is registered and has affiliated, the only commands required to move the mobile to a particular channel, is to issue a channel grant. The channel grant can be a group voice channel grant, a unit to unit voice channel grant or a telephone interconnect (PSTN) voice channel grant.

Establishing a Group Call in an Implicit P25 Trunked System

As in any communication system, a user initiates a call. This call can be defined as two types, either a SU originated call or a SU terminated call. The difference is that the SU either generates the call request or the SU receives a call request. Either action ends up with a channel grant being delivered to the SU to begin voice communications. In figure 15.0 above, the group call sequence begins with a Group Voice Request from the SU to the RFSS. Let's look further at the messages involved in this transaction.

Group Voice Request

The SU will send this when initiating the Unit to Group call sequence. Here, an additional message is sent, the Group Voice Request (GRP_V_REQ). This message is shown in figure 16.0.
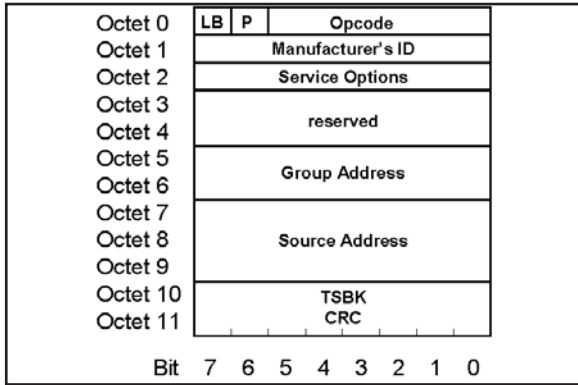
Figure 16.0 Group Voice Request Message

Note that this message reflects the newly created WG ID as the Group Address. It also contains a new field as follows:

Service Options: Service requests and service grants allow for special service extensions called the Service Options field. This feature provides extended flexibility to tailor the requested service to the needs of the requesting unit or process capability of the system.   Figure 17.0 shows the Service Option field definition.
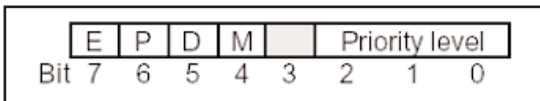

Figure 17.0 The Service Option Octet

The following are definitions for each bit:

7:        Emergency - this is the status indication to determine if this service is to be specially processed as an emergency service.

    0 =   Non-emergency - indicates the normal processing status.

    1 =   Emergency - indicates special processing required.

6:        Protected - indicates whether the resources (other than trunking resources) to be associated with this service should be presented in protected mode (e.g. encrypted) or not.

    0 =   not protected - indicates normal mode presentation for the resource(s).

    1 =   - indicates protection mode presentation for the resource(s).

5:        Duplex - indicates the way the channel resource is to be utilized by the unit(s) involved in the call.

    0 = Half duplex - indicates the unit will be capable of transmitting but not simultaneously receiving on an assigned channel

    1= Full duplex - indicates the unit will be capable of simultaneous transmit and receive on an assigned

channel.

4:        Mode - this is the indication of whether this service session should be accomplished in a packet mode or circuit mode.

    0 =   Circuit mode - will utilize resources capable of supporting circuit operation.

    1 =   Packet mode - will utilize resources capable of supporting packet operation.

3:        Reserved - currently set to null (0)

2-0:   Priority level - indicates the relative importance attributed to this service where:

    %111 Highest (top)

    %110 System definable

    %101 System definable

    %100 default

    % 011 System definable

    % 010 System definable

    % 001 Lowest (bottom)

    % 000 reserved

Group Voice Channel Grant

It is important to note that the Group Voice Channel Grant contains both the "WU ID" and "WG ID". The fields are derived from the previous dialog between the SU and the RFSS, and ensure that the SU only responds to channel grants that apply to his unique unit and group identifiers.

After the Group Voice Request is received, the RFSS responds with a Group Voice Channel Grant message (GRP_V_CH_GRANT).   Figure 18.0 shows the Group Voice Channel Grant message. Notice the channel information section shown in Octets 3 and 4.
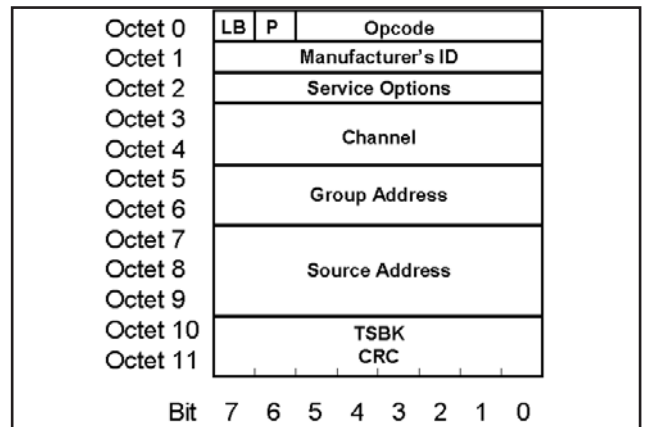

Figure 18.0   The Group Voice Channel Grant Message

The Channel field is the transmit frequency for the FNE (the SU RX) and is actually comprised of two fields of information. The first sub-field is the Channel Identifier, which determines the band of

frequencies that are associated with the Channel Number. There are up to 16 unique identifiers per site and each identifier will include information such as base frequency, channel spacing, transmit offset and bandwidth. This information coincides with the information sent in the IDEN_UP message or from the internally pre-programmed SU information.

The second is the Channel Number, which contains a value to be used to derive the actual frequency of the channel. The SU receive frequency is computed from the base frequency, channel spacing and channel number as follows: SU RX = (Base Frequency) + (Channel Number) x (Channel Spacing). Figure 19.0 shows the channel information broken into its two elements.
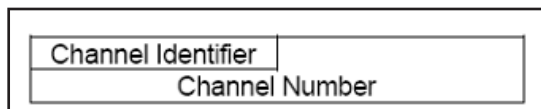
Figure 19.0 The "Channel" field elements

How Mobiles Calculate the RX and TX Frequencies

In the implicit mode of operation, the SU will use the channel identifier information and the channel number to calculate the SU RX and SU TX frequencies.

Calculating the SU RX Frequency

The SU RX Frequency is calculated as follows:

SU RX = (Base Frequency) + (Channel Number) x (Channel Spacing).

Note: Base Frequency is calculated as (Base Frequency) x (0.000005 MHz) from the IDEN_UP message.

We know that both the Base Frequency and the Channel Spacing are derived from the IDEN_UP message and/or the SU's own internal programming. The transmitted Channel Number becomes the key part of the equation for frequency assignments.

Since SU RX = (Base Frequency) + (Channel Number) x (Channel Spacing)

AND given the fact that the SU (using Implicit Messaging) pre-programs into memory the Base Frequency and the Channel Spacing, the only thing that is transmitted AND gets recognized AND acted upon is the Channel Number. This explains why we can send overhead control messages without including an IDEN_UP message when dealing with implicit messaging, but only when that information is pre-programmed into the radio. This cannot be done with Explicit Messages.

Calculating the SU TX Frequency

NON-VHF/UHF Bands

For determining the SU TX frequency for non-VHF/UHF band channels, the system uses the transmit offset in the calculation as follows:

SU TX = SU RX +/- (Transmit Offset x 0.250 MHz)

The +/- is determined from bit 8 of the IDEN_UP message or

corresponding programming in the SU. A 1 indicates that offset is above the SU RX frequency and a 0 indicates that it is below the SU RX frequency.

VHF/UHF Bands

The SU transmit base frequency is computed as follows:

SU TX = (Base Frequency) + Sign (Transmit Offset VU x Channel Spacing x 0.125 kHz)

Note: Base Frequency is calculated as (Base Frequency) x (0.000005 MHz) from the IDEN_UP_VU message.

As you can see, the way we handle VHF/UHF band functions is completely different from the way we handle other bands. This allows for more flexibility within the VHF/UHF bands.

In the equation above, the "Sign" is bit 14 of the transmit offset field of the IDEN_UP_VU message or corresponding programming in the SU.

Alternative Trunking Modes

Since we now understand the basics of the P25 trunking system, it is important that we also understand alternative trunking modes using P25 technology.

SmartNet/SmartZone™ Operation

Alternative trunking formats can also be used with P25, such as is the case with the Motorola SmartNet/SmartZone™ trunking. In this situation, a 3600-baud trunking functions to service both a conventional FM 25 kHz (or narrowband 12.5 kHz) channel as well as a new 12.5 kHz P25 digital traffic channel. This interoperability between conventional trunked radio systems and P25 is one of the benefits of having a standard that allows two separate technologies to be employed on one system, and allows for cost effective migration from one technology to another.

Composite Trunkings

The composite trunking mode has a particular channel function both as a trunking and as a bearer channel. This is a mutually exclusive use of the channel, in that the channel will be used as a trunking until a service request requires this channel resource as a bearer channel to satisfy the service request.

The trunking is not available at all times since it is a dual - mode, control and traffic channel. Other than that, it works just like a dedicated trunking where the presence of OSP overhead messaging (RFSS_STS_BCST, NET_STS_BCST) will serve as an indicator of trunking presence. In particular a System Service Class of $01 indicates that it is a composite trunking.

The mobile must be programmed to maintain presence on a channel for a set period of time to ascertain if it is a trunking and then read the System Service Class to verify composite operation.

Testing P25 Radios

Since P25 Trunking systems utilize digital voice channels controlled by a digital trunking, we do not test the inbound trunking (ISP) for parametric performance. However we do need to allow for setup and testing of the interaction between the trunking and

the transition to the traffic channel. These tests are called protocol tests, in which we test the radio's ability to respond to commands from the radio test set.

In order to do this, the test system needs to be able to emulate some of the protocol (OSPs) that the repeater sends out. In addition, the system needs to be able to respond to the ISPs the mobile is sending and react appropriately to get the unit onto a traffic channel for proper parametric testing. While on the traffic channel, the test system needs to be able to keep communication with the mobile through P25 specified LDU messages. These data units carry both voice and data information during a "call".

Being RF based, these systems also require the ability to test and verify parametric performance including frequency error, power, modulation accuracy, and other parameters.

Using the 2975 to perform P25 testing

The 2975 provides powerful test features for P25 Trunked systems. These tests include the following:

1. The ability to emulate a P25 repeater station and initiate a system originated call. With the 2975, you are not locked into a specific test sequence for the radio. You decide what pass and fail means.

2. The ability to handle a P25 mobile initiated call.

3. The ability to perform full digital test functions.

The 2975 provides access to message elements and fields that other testers do not allow. This gives the operator added flexibility in testing functionality, especially interoperability testing between mobiles and P25 networks.

P25 Trunking Control and Traffic Channel Setup

Setting up the control and traffic channel is the first thing that needs to be accomplished to begin testing P25 Trunked radios. This application note will show you how to enable the P25 Repeater Simulator for testing mobiles. In all test modes for P25 mobile systems, the instrument should be in the duplex mode. To enable the duplex mode, click on the screen selection button next to the time at the very upper left of the screen or select <MODE>, <3> as shown in figure 20.0.
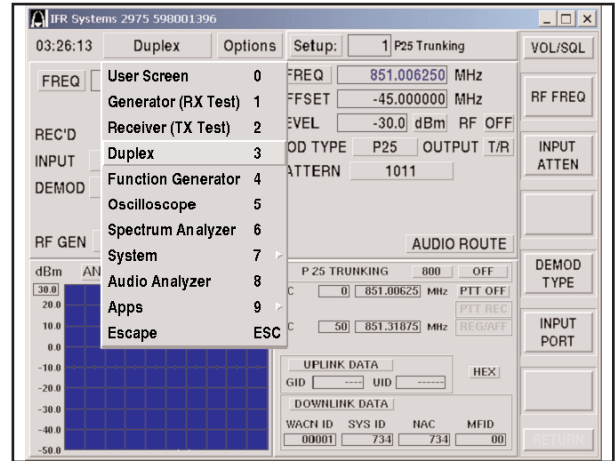
Figure 20.0 Selecting Duplex Mode

From there, we want to enable the Repeater Simulator. To do this, select the "Options" button next to the Duplex display at the top right of the display or select <SHIFT>,<MODE> and then select "P25 Repeater Sim". See figure 21.0 for this selection. Note that we have also selected the Spectrum Analyzer for display.
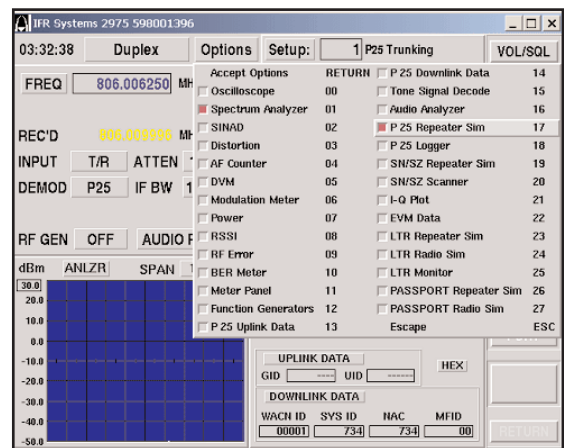

Figure 21.0 Selecting the P25 Repeater Simulator

To enable a valid trunking, we need to set up the proper control and traffic channel numbers. This is fairly straightforward for 800 MHz operation in that the channels are defined with a set frequency assignment. The duplex offset is also standard at 45 MHz. We simply enter the proper channel number or frequency in the CC and VC data fields. See figure 22.0. Note: The VHF/UHF/700 MHz Other Band P25 Trunking Option (OPT 14) needs to be installed before being able to set up this feature.
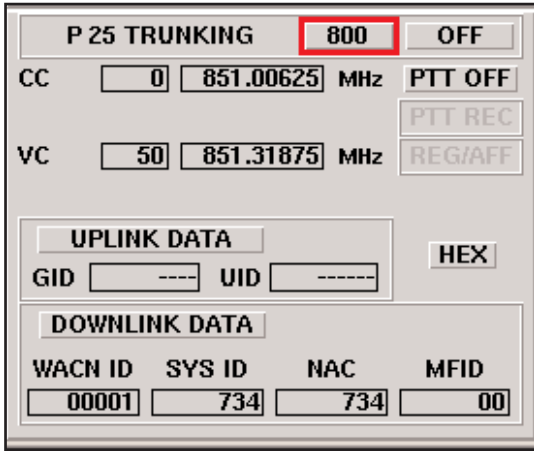
Figure 22.0 Setting up the Trunking and Voice (Traffic) Channel - 800 MHz band

For VHF/UHF operation, things become a little more complex. You still enter in the appropriate channel/frequency combination, however, you'll note upon selecting the U/V mode, that an additional button named "CONFIG" pops up under the REG/AFF indicator section. See figure 23.0 for more detail. Note: The VHF/UHF/700 MHz Other Band P25 Trunking Option (OPT 14) needs to be installed before being able to set up this feature.
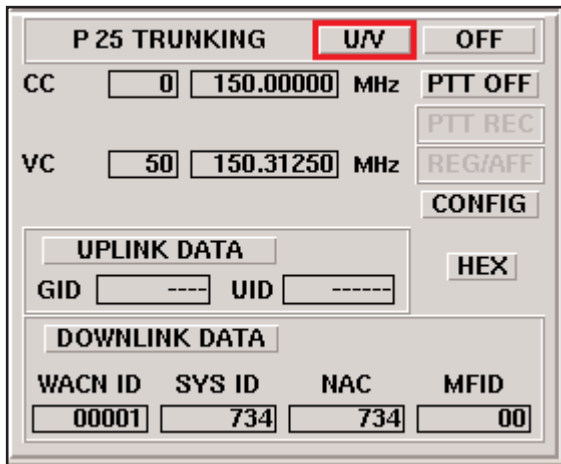
Figure 23.0 The VHF/UHF P25 Trunking Mode

Expanding the "CONFIG" button reveals in detail the Channel Identifier information we studied earlier in this application note. Figure 24.0 shows the configuration screen.
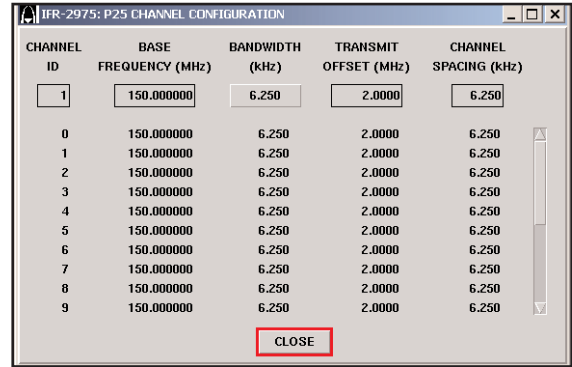
Figure 24.0 The Configuration Screen for VHF/UHF mode of operation

As you can see, the configuration screen shows all the parameters associated with the IDEN_UP_VU message. The Base Frequency, bandwidth, transmit offset and channel spacing are set equivalent to the IDEN_UP_VU information or the radio's internal programming.

Setting Trunking Protocol Elements

It is important to understand that the IFR 2975, when used in the implicit mode of operation, does not send an IDEN_UP message. The system simply relies on the internal programming of the radio and in the setup process, it determines the proper channel information and then transmits that in the voice channel grant. Figure 25.0 shows the basic trunking configuration used with the IFR 2975 for implicit messaging. Where "1" would designate a RFSS_STS_BCST message and "2" would designate a NET_STS_BCST message.
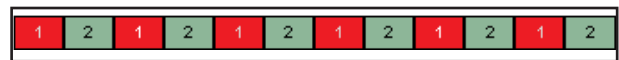
Figure 25.0 The Implicit Trunking from the IFR 2975

These messages are broadcast as packets to the radio on a continuous basis. The Unit Registration Response (U_REG_RSP) and the Group Affiliation Response (GRP_AFF_ RSP) discussed earlier are the control messages sent in response to registration and group affiliation requests from the SU.

Now that we understand the trunking broadcast messages, the registration and group affiliation process and the Unit to Group Call sequence, we can move on with setting up the 2975 to perform not only parametric tests, but also protocol tests. We have the control and traffic channel setup, however, we need to set additional parameters before proceeding. For proper operation, we need to enter a valid WACN ID and System ID, which we've already reviewed. We also need to set the NAC.

The NAC is the Network Access Code that is an 8-bit field. Typically the default, per the TIA/EIA-102BAAC standard is $293. In P25 trunking, the NAC is typically derived from the trunking messages and stored temporarily in the unit. The IFR 2975 gives the user added flexibility in allowing this field to be set for various modes of operation, including P25 conventional, SmartNet/SmartZone™ Astro 25™ and P25 trunking. With P25 trunking systems, the NAC is typically the same as the P25 System

ID, although they may be configured differently to provide added flexibility for the network operator. Figure 26.0 shows how to set up the WACN ID, NAC and System ID.
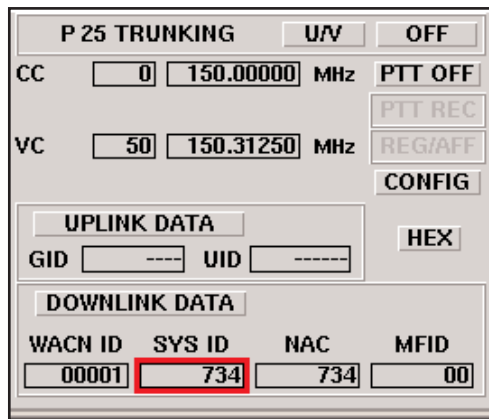

Figure 26.0 Setting the WACN ID, System ID, NAC and MFID

Setting the WACN ID, NAC and System ID is the minimum configuration for testing the mobile unit. Additional parameters for the trunking information can also be set with the exclusive protocol functions of the 2975. Figure 27.0 shows the expanded protocol features that can be set for the RFSS originated trunking messages. These parameters are the same parameters covered earlier in this application note for the NET_STS_BCST, RFSS_STS_BCST, U_REG_RSP, GRP_AFF_RSP and GRP_V_CH_GRANT.
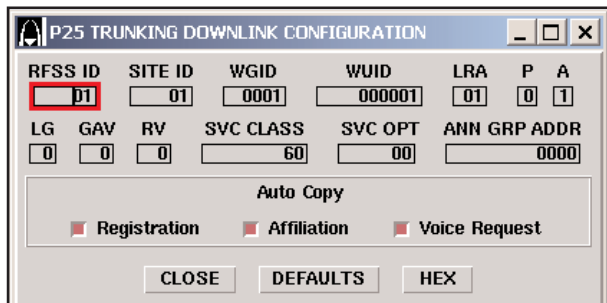
Figure 27.0 Setting additional downlink trunking features

As you can see, there is also a feature area designated as the Auto-Copy area. This area deals with the WUID and WGID issue discussed earlier. By enabling the auto-copy function, the user can have the IFR 2975 echo back (copy) the SU's pre-programmed Unit ID (Registration) and/or the Group ID (Affiliation) by enabling the appropriate box (in red). Enabling the Voice Request means that during the Group Voice Channel Grant, the system will use the Group ID instead of the WGID in the message parameters.

Disabling any of these functions means that the pre-programmed WGID and WUID would be used as needed. This can be programmed in the top line of the P25 Trunking Downlink Configuration screen.

Uplink Data Analysis

The 2975 will automatically decode a number of fields from the mobile when the unit registers and affiliates with the 2975. This feature can be very helpful in determining if the unit has been set up correctly for use on the network. On the primary P25 trunking tile, you will see the two indicators for the GID or Group ID used for initiating group calls, and the UID or Unit ID (Source ID). Only the 2975 provides this capability for testing P25 mobiles.

Now that we understand the fields in each of the messages used during a registration and affiliation process, and during a unit to group voice call, we can use the 2975 to decode these fields to assist in testing interoperability of various SU's and systems. Figure 28.0 shows the 2975's P25 Trunking Uplink Data Decode screen.
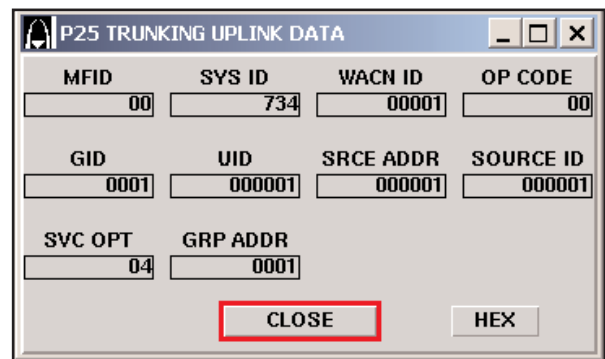

Figure 28.0 The P25 Trunking Uplink Configuration decode screen

These fields are derived from the SU's U_REG_REQ and GRP_AFF_REQ messages sent during the registration and affiliation processes discussed earlier.

Performance Testing with the 2975

We can now perform either a mobile originated call or a repeater originated (SU or RFSS - via a dispatch or another user - originated) call. To perform mobile radio transmitter tests, simply key the mobile unit and the 2975 will automatically assign the unit to the proper voice channel for performing parametric tests.

Once we have the trunking set up and running, and the mobile is talking with the 2975, we can then select any number of options to run. This includes the Oscilloscope, Spectrum Analyzer, Meter Panel, Power Meter, RSSI Meter, etc…. To enable these functions, select the "Options" button or select <SHIFT>,<MODE> and select the combinations you wish. Remember that not all screens can be displayed at one time and you will be limited to two ¼ tile "Meter" screens or one ½ tile Oscilloscope/Spectrum analyzer screen when run in conjunction with the P25 trunking simulator screen in the duplex mode. More screen modes can be defined in the user mode <MODE 0> or the receiver mode <MODE 2>.

Figure 29.0 shows the IFR 2975 setup in the Duplex Mode with the P25 repeater simulator running in the 800 MHz band and with a Spectrum Analyzer tile enabled to view the spectrum from the SU. The SU has originated a call, as seen by the lit PTT REC field on the P25 Trunking tile.
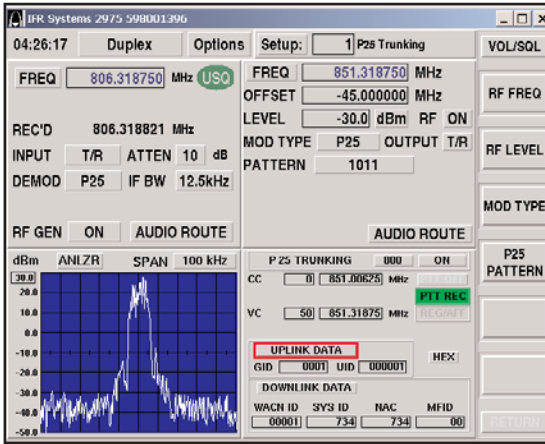
Figure 29.0 P25 Trunking screen with the Spectrum Analyzer Enabled

Notice that the duplex receiver and generator frequencies have changed since the unit is now on the voice channel with 45 MHz duplex offset. Further tests can be enabled in different modes. The IFR 2975 has every instrument constantly running in an operational state, and by simply changing modes, we change the "view" of the instrument.   As seen in figure 30.0, the IFR 2975 receiver <MODE 2>, shows the receive frequency, power meter, frequency error meter, modulation accuracy meter, and the traffic uplink decode information.
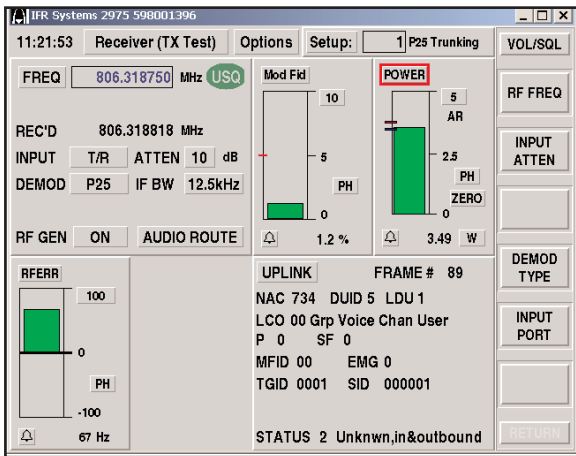
Figure 30.0   The Receiver (Transmitter Test) mode with Power, Frequency Error

Notice that the meters display green bars. This is because prior to conducting the test, we set pre-determined pass/fail limits for each of the parameters.   We know that the radio is within the range of performance for Power, RF Frequency Error and Modulation Error.

To perform mobile receiver measurements, enable the PTT mode by selecting the PTT button directly below the ON/OFF button on the repeater screen. This will cause a repeater originated call request to be sent to the mobile and the mobile will then be assigned to a voice channel in a "listen" (receive) mode.

We can now enable a unique sensitivity test called the "Speech" mode. The speech mode is a special voice file that provides a

pre-recorded voice pattern that allows the test professional to quickly determine the receiver's sensitivity. This is accomplished by listening to the pre-recorded audio voice patterns and then reducing the RF sensitivity until the voice starts to break up or sounds slurred. This test is unique to the 2975 and is another way that Aeroflex is improving technician productivity.   Figure 31.0 shows how to select the speech mode and figure 32.0 shows where to adjust the RF level.   Once you hit a level where the voice is breaking up, that becomes the receiver's "realistic" sensitivity. Tests have shown that this mode of testing typically correlates to a 5% BER test, commonly used for digital receiver testing, by a few dB.
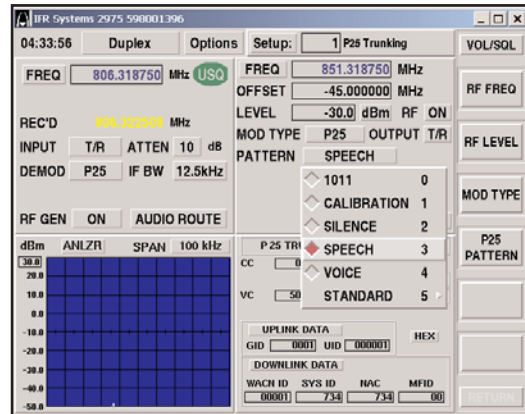

Figure 31.0 Setting the 2975 up for P25 sensitivity testing using the speech mode.
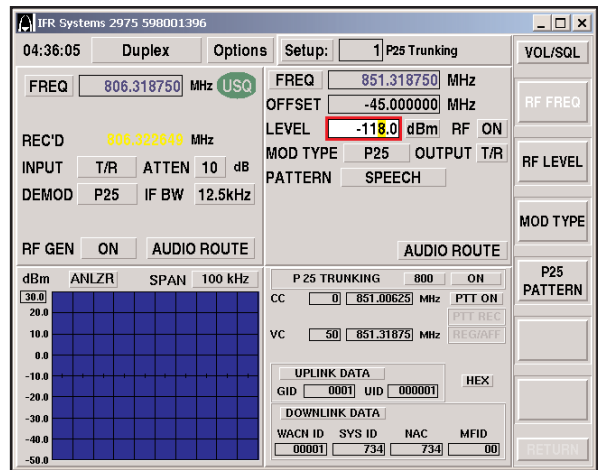

Figure 32.0 Decrease the RF output until speech quality degrades

Conclusion

Using the 2975 provides some of the most advanced testing functions ever presented in a communication test set. For testing P25 systems, the 2975 truly allows for dynamic testing through true repeater functionality. The 2975 provides the test professional with the most advanced wireless test set on the market for P25 and other PMR systems.

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A passion for performance.

Our passion for performance is defined by three attributes represented by these three icons: solution-minded, performance-driven and customer-focused.

Part No. 46891/942, Issue 1, 05/06