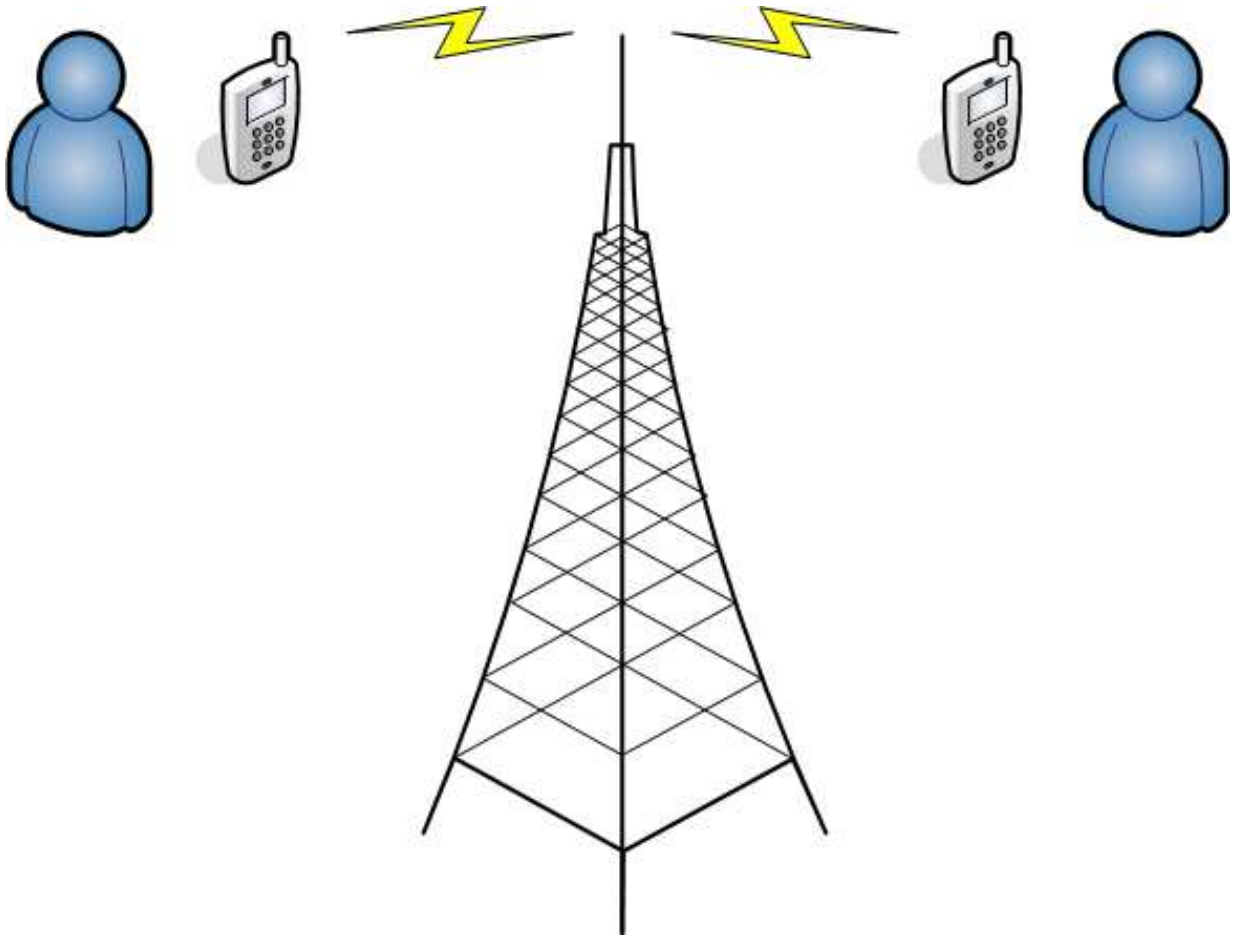
MOTOROLA

Logical Trunked Radio (LTR)

Theory of Operation

An Introduction to the Logical Trunking Radio Protocol on the Motorola Commercial and Professional Series Radios



Contents

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Theory of Operation

1. Introduction

Logical Trunked Radio (LTR) is a protocol that takes two-way radios beyond Conventional radio communication. LTR is a signaling protocol that provides a means for the logical control of repeater resources using out-of-band (i.e. low speed) signaling. The logical control of a repeater is made possible by the LTR Controller. The communication backbone of LTR is found in the sub-audible frequency range of 300Hz. At this frequency, 40 bit word messages are transmitted between the radio and the repeater at 300 Baud.

These data messages allow the radio and repeater to be in constant communication, passing messages to each other and then performing the required functions based on those messages. With this communication backbone, the radio and repeater are able to execute tasks that were not possible in the analog Conventional mode.

Conventional mode operation is not as advanced as the LTR protocol. The premise behind conventional mode operation is the “polite” usage of the RF resource. A radio user should monitor a Conventional channel for activity on that channel. If no activity is detected on the channel, the radio user may attempt to transmit on that channel and occupy that resource. Conventional does not have the capability to trunk to different repeaters when a repeater is busy and for a radio to indicate to a group on which repeater the radio is communicating. Where Conventional mode is lacking, the Logical Trunked Radio protocol finds its strength.

The strength of the Logical Trunked Radio protocol is the Trunking ability. Trunking is the ability for a radio to be redirected to free RF resources when other RF resources are busy. LTR is advantageous because a user does not have to change channels manually when the desired transmit frequency is occupied because the LTR protocol incorporates the means by which this can be accomplished.

Not only does the LTR protocol give us the Trunking capability, but it does this in a logical manner, thus the name Logical Trunked Radio. To be logical, there has to be certain rules that the radio and the LTR Controller must follow. A radio and a LTR Controller must thus be designed to follow these rules.

Basic LTR Controller via Repeater Functions and Rules

- Allow 250 groups maximum to be valid groups of each channel of an LTR system.
- Transmit an idle message at discrete time intervals as an indicator for listening radios that the channel is available for use.
- When an idle repeater receives a message from a valid group requesting the use of the repeater, the LTR controller has to transmit a message via its repeater indicating to the group that it has acknowledged it and that it has permission to transmit.

- The LTR Controller has the responsibility of administrating the messages of any of its active groups; it is to then broadcast these messages on its channel via the repeater.

- The LTR Controller has the responsibility of broadcasting messages of the active group occupying its associated repeater.

- The message from the repeater must always include the next available repeater or an indication that all repeaters are busy.

- The LTR Controller has the responsibility of broadcasting an end of call message on its channel when it has received an end of call message from a group.

- The LTR Controller must indicate the active group to the other LTR Controllers.

Basic Radio Functions and Rules

- Decode the messages coming from the repeater and check if the decoded group is the radios currently selected group. If it is the selected group, open squelch. If the group is trunked on another repeater, change frequencies to that repeater's frequency, decode a message to verify that the selected group is active, and then open squelch if it is.

- Continuously decode messages from the repeater and remember the next free repeater.

- To initiate a call if the radios selected home repeater is idle, transmit a message to the repeater indicating the intent to transmit. If the repeater responds with a message to the radios selected group, begin transmission.

- To initiate a call if the radios selected home repeater is busy, go to the next free repeater and attempt to initiate a call, wait for the message from the repeater to the radios selected group, and begin transmission.

- When the radio finishes transmission, it must indicate to the repeater via a data message that the transmission is complete.

1.1 Logical Trunked Radio Protocol

Now that we have an idea of the operation of the Logical Trunked Radio protocol, we can go further in depth and continue analyzing the protocol.

1.1.1 Group IDs

The LTR protocol was designed to distribute messages to groups of radios and not to individual radios; therefore, there is no radio individuality in the LTR protocol unless a signaling type (MDC or Quick Call) is used in addition with it. This is similar to conventional mode except that conventional does not have the Trunking capability of LTR. When a radio initiates a dispatch call on a group, the LTR system will not know which specific radio has keyed up since there is no radio ID, but it will know the Group ID and Home Repeater number of the radio requesting use of the repeater. The LTR system will then respond appropriately based on the Group ID/Home Repeater combination.

To “home” a Group ID to a repeater is to point a group to a repeater frequency that it must monitor. If the repeater is free, the group will use that repeater when it transmits. When the group transmits and the repeater is busy, it will trunk and use a free repeater on the LTR site to transmit.

For each Group ID there is an associated Home Repeater that must be programmed into the radio. In a LTR Site, Group IDs themselves are not unique; the Group ID/Home Repeater combination makes them unique. The protocol allows for a maximum of 250 Group IDs to be homed on each repeater. Since LTR can have 20 repeaters, up to 5000 Group IDs are available per Site.

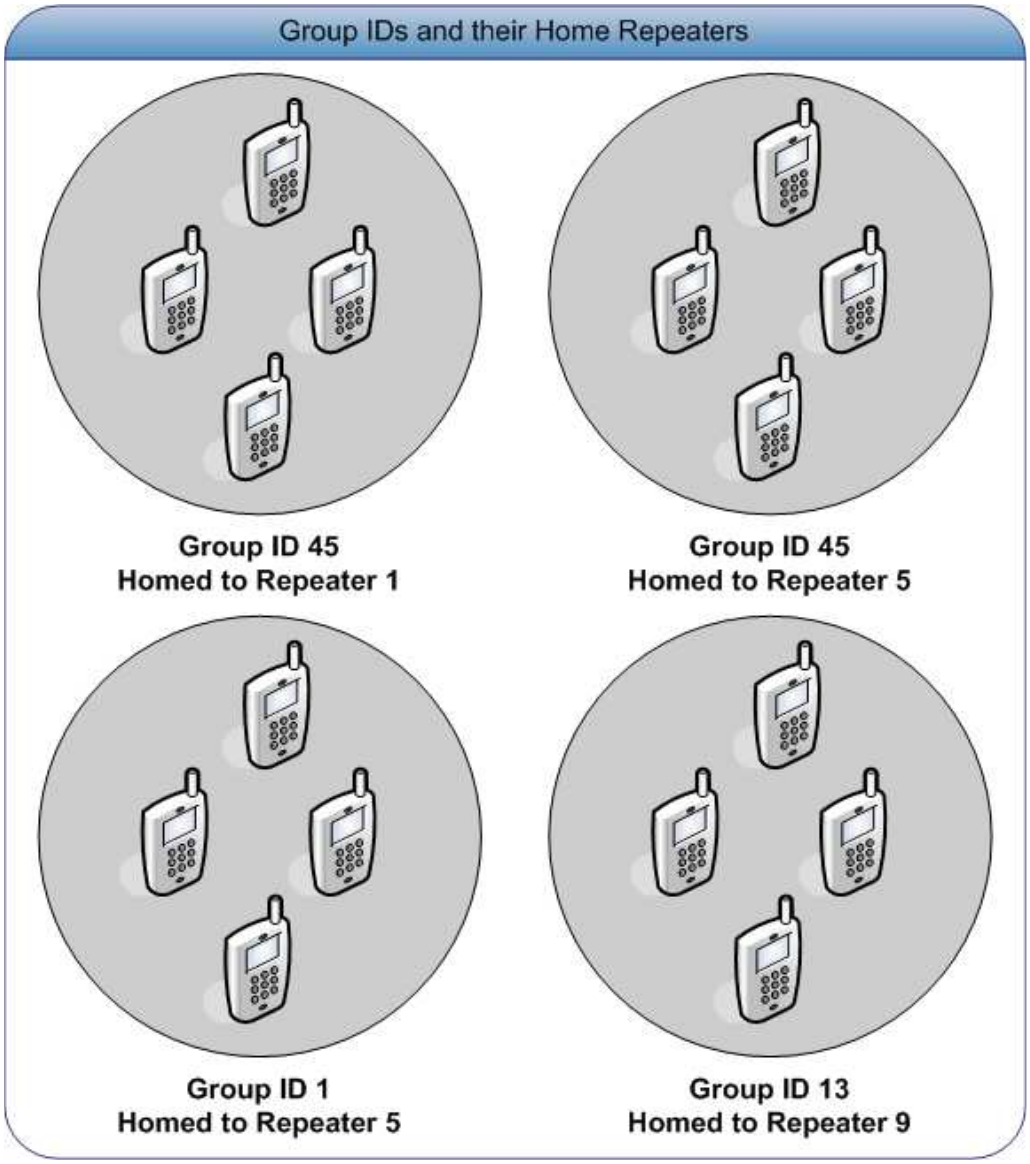

Figure 1-1 *Group IDs can be homed to different repeaters. The Group ID number can be re-used, but their Home Repeaters make them unique.*

1.1.2 Area ID

The purpose of the Area ID is to ensure uniqueness between two LTR Systems that occupy the same frequencies. The Area ID can be either a zero or a one, therefore, for one LTR system you can set the Area ID field to zero, and for the other set it to one. This Area ID field must be set in both the LTR Controller and in the radio programming.

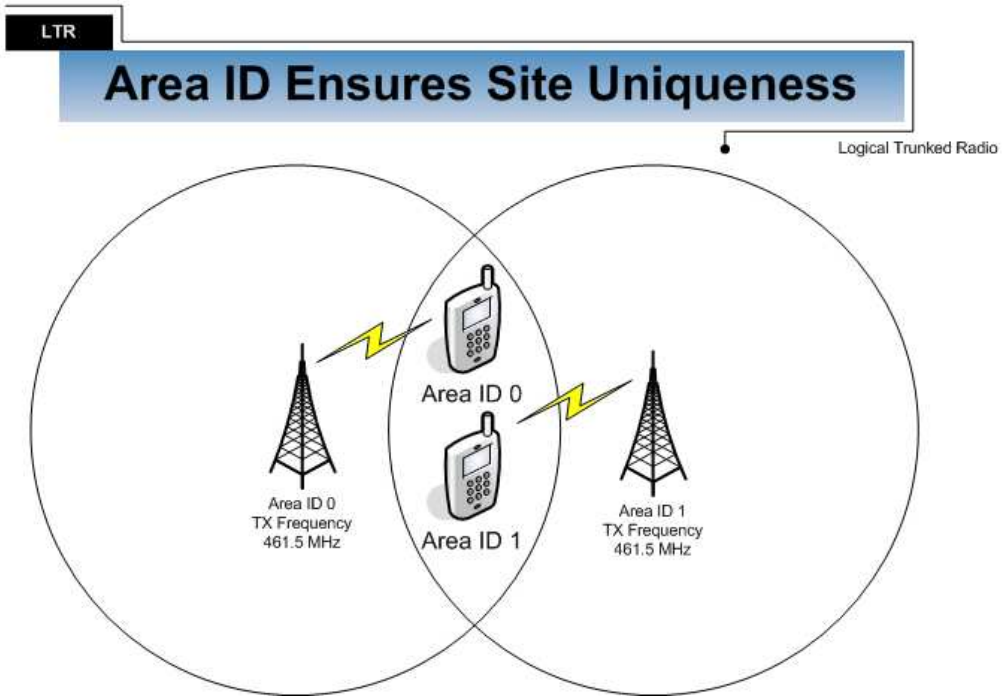

Figure 1-2 *Area ID can be used when two LTR Sites are in proximity of each other operating on the same frequency.*

As we see in the example above, the radio programmed with the Area ID set to 0 will communicate with the respective LTR System and the radio programmed with the Area ID set to 1 will communicate with its respective LTR System.

1.1.3 Trunking

The purpose of Trunking is to share a small amount of resources with a large number of users. If a site has 50 users, yet no more than 4 users will use the resources at the same time, an efficient and cost effective solution may be created with 4 resources rather than with 50. This is something that needs to be taken into consideration when designing a system. How many users will need to use the resources at peak times? How many will need to use the system on average? What is the comparison between the two? This will be discussed in Section 2 System Design on page 13.

Each LTR System can have a maximum of 20 Repeaters. A rule for LTR is that the repeater numbers must be evenly spaced. On a four repeater system, the LTR repeater numbers should be 1, 6, 11, and 16. It can be 2, 7, 12, and 17 also, as long as the repeater numbers are evenly spaced. The reason for this is discussed in Section 1.1.5 Data Bus Time Slot on page 8.

Each LTR Controller has the responsibility of ensuring the broadcast of the next free repeater in the data message. Another responsibility is to broadcast data messages for the active group on that repeater. The LTR Controller must keep track of active groups that have classified its repeater as their home repeater and broadcast, via a data message, which repeater the groups have become active on. For more information, see Section 1.1.6 Data Bus Time Slot on page 8 and Section 1.1.7 Outbound Signaling Message Distribution on page 10.

1.1.4 Transmission vs. Message Trunking

Transmission and Message Trunking depict two different ways that a channel can be released by the controller once a radio has indicated the end of transmission of a call. To clarify, these concepts do not illustrate how radios trunk to other repeaters, but rather how the controller handles the de-key, end of transmission, of a radio. When these mechanisms are combined with the logical repeater trunking mechanism, a system is built that allows conversations between users to flow. Therefore both of these concepts work and the only time that a difference would be noticed is during peak load.

Transmission Trunking

Using this concept, a repeater is released and considered available immediately after a radio has completed its transmission. The advantage is that there is no “hang” time that prevents the repeater’s resources from being used by any group other than the last active group. Saving a system for use by the last active group through the use of a hang time may be considered a waste, but it all depends on the desired operation of the system. The disadvantage of Transmission Trunking is that conversation continuity is not preserved as with Message Trunking; therefore a radio user who wishes to respond to a previous dispatch call must go through the process of attempting to gain system access, which will not be guaranteed during peak load times. With Transmission Trunking during peak load more users will be able to gain access to the system, but conversation continuity between groups is sacrificed.

Message Trunking

The Message Trunking concept is different from Transmission Trunking in that it makes use of a hang time, usually three seconds, after a radio completes a transmission. This hang time allows for a radio, in the same group, to respond to the initial transmission. The radio user is guaranteed system access on that repeater unless a different user in the same group has responded first. The advantage of Message Trunking is that conversation continuity can be preserved. The disadvantage is that the hang time can be considered a wasted resource if it is not used; for the duration of the hang time, any group other than the previous group cannot access that repeater. With Message Trunking during peak load, conversation continuity is preserved once system access is granted.

1.1.5 Data Message Types

The two types of messages of the LTR protocol are the Outbound Signaling Message (OSM, repeater to radio) and the Inbound Signaling Message (ISM, radio to repeater). These messages are the communication interface between repeaters and radios.

The data messages in LTR have a width of 40 bits and are transmitted in the sub-audible frequency range of 300Hz. These 40 bits are divided into 7 different fields; Sync, Area ID, Repeater Info, Repeater Info, Group Info, Repeater Info, and Error Check. The time

duration of each data message is 132ms. Therefore, in one second, a maximum of 7.5 data messages can be sent.

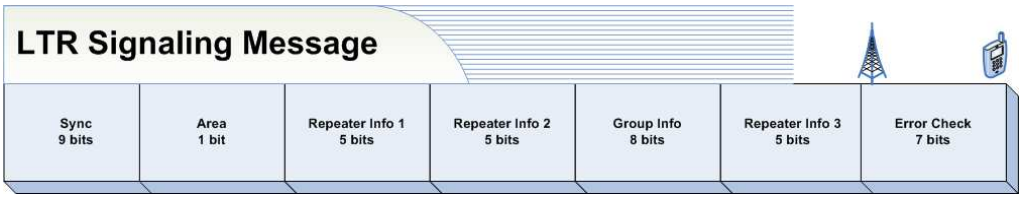

Figure 1-3 *The format of the data messages in LTR.*

The Sync bits are alternating patterns of zeros and ones that are used to signal the beginning of a message. The Area ID will be a zero or a one and depends on the LTR Controller configuration. The Error Check is a mathematical computation of the bits that were transmitted; if the radio or repeater receives a message with an invalid Error Check, it will discard the message.

Inbound Signaling Message (ISM)

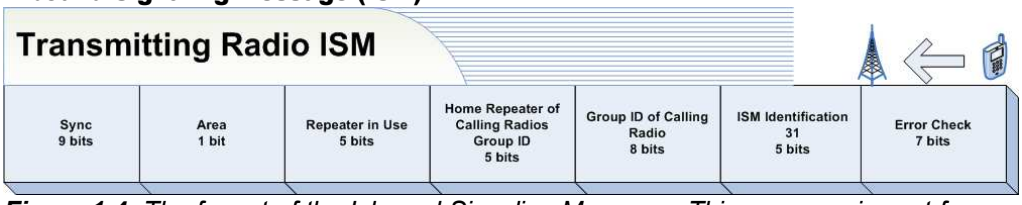

Figure 1-4 *The format of the Inbound Signaling Message. This message is sent from a radio to the repeater.*

The Inbound Signaling Message is sent from the radio to the repeater. An ISM is sent when a radio user requests access to a repeater. The radio will attempt to send this message a number of times until the radio decodes an OSM from that repeater with the radios selected group and home repeater encoded in the OSM. The radio user will then have the ability to use the radio to transmit. Another ISM is sent when the user de-keys the radio. This ISM will have a value of 31 encoded in the ISM "Repeater In Use" field.

The "Home Repeater of Calling Radios Group ID" field will always be home repeater of the calling radios group ID. The "Group ID of the Calling Radio" field will always be the group ID of the calling radio. The "ISM Identification" field will always be 31; its purpose is to distinguish the ISM from an OSM.

Repeater in Use

The value of this field will be the number of the free repeater that the radio is trying to access or is accessing during a transmission. When the value of this field is 31, the radio indicates that the call will be terminated and the transmission will end. The radio expects the repeater to relay this information to the calling radios group.

Outbound Signaling Message (OSM)

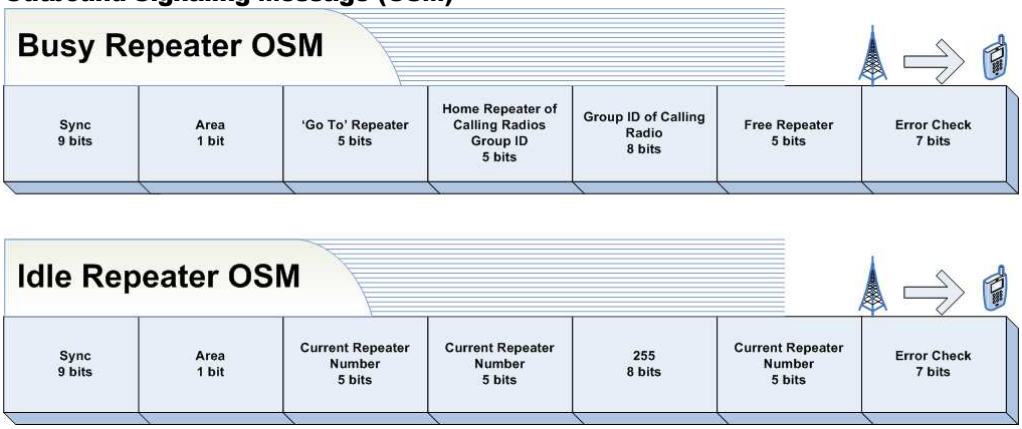

Figure 1-5 *The format of the Outbound Signaling Message. This message is sent from a repeater to the radio.*

The Outbound Signaling Message is sent from the repeater to the radio. There are two types of the OSM; the Idle Repeater OSM and the Busy Repeater OSM. The frequency of the Idle Repeater OSM is once every 10 seconds at default, but this is a programmable time. The purpose of the Idle Repeater OSM is to indicate the presence of an available channel on the repeater's frequency.

The Idle Repeater OSM fields will be as shown in the above diagram. The "Current Repeater Number" will always be the number of the idle repeater transmitting the OSM. All repeaters in a LTR Site transmit this message when they are idle.

The Busy Repeater OSM is broadcasted continuously once the LTR Controller has granted access of its repeater to the calling radios Group ID. There is no delay between OSMs on a busy repeater, they are sent one after another. Busy repeaters are to broadcast the Busy Repeater OSM. The "Home Repeater of Calling Radios Group ID" field will always be the home repeater of the calling radios group ID. The "Group ID of Calling Radio" field will always be the group ID of the calling radio. The two fields that vary in function are the "Go To Repeater" and the "Free Repeater" fields.

Go To Repeater
The value of this field is the repeater number that a radio with the same group and home repeater should trunk to in order to hear the dispatch call. When this field has the value of 31, it signifies the end of transmission for that group and that the radio should then squelch its speaker and trunk to the home repeater for continual monitoring of data messages.

Free Repeater
The value of the "Free Repeater" field is the available free repeater on that LTR Site. Radios should keep track of the next available repeater so that the radio can be ready to transmit on that repeater when a radio user presses PTT to initiate a call. When this field is set to 0, there is no free repeater and All Trunks are Busy (ATB), therefore a radio user will hear the busy tone when the LTR Site is in the ATB state.

1.1.6 Data Bus Time Slot

The Data Bus Time Slot is the mechanism used by the LTR Controllers in an LTR System to communicate individual repeater status. Each LTR Controller has a unique time slot that must be managed and used to indicate the status of a free or busy repeater. When

busy, the information held in the time slot would be a group ID and its associated home repeater. By checking another repeaters time slot, a repeater can verify if any groups homed to that repeater are trunked on another repeater. The other function of the Data Bus Time Slot is to provide information of an available free repeater. The LTR Controllers use this information to encode the next free repeater in the OSM data message in the "Free Repeater" field.

As mentioned earlier, repeater numbers must be evenly spaced. On a 5 repeater LTR Site the repeater numbers should be the following: 1, 5, 9, 13, and 17. Using this convention, a LTR Controller will read the free repeater numbers in the following manner.

1 – 1 – 1 – 1 – 5 – 5 – 5 – 5 – 9 – 9 – 9 – 9 – 13 – 13 – 13 – 13 – 17 – 17 – 17 – 17

When a repeater is busy, the repeater number will not be included as a free repeater; rather, it will continue to use the previously found free repeater as the free repeater until a new free repeater is found. An example would portray this logic best. Assume that repeaters 9 and 17 are busy.

1 – 1 – 1 – 1 – 5 – 5 – 5 – 5 – 5 – 5 – 5 – 5 – 13 – 13 – 13 – 13 – 13 – 13 – 13 – 13

The usefulness of the Data Bus Time Slot is that a LTR Controller can verify activity of any groups trunked onto different repeaters. It will then send Outbound Signaling Messages for each trunked group so that a group may be redirected to the correct repeater. For example, repeater 1 on a 5 channel LTR System has 4 groups homed to it; 1, 15, 30, and 45. Groups 15, 30, and 45 are active on repeaters 5, 9, and 13 respectively. Therefore the Data Bus Time Slot will be updated accordingly and the LTR Controller for repeater 1 will know that it must transmit Outbound Signaling Messages that direct groups 15, 30, and 45 to Repeaters 5, 9, and 13 respectively. The free repeater encoded in the OSM is repeater 17.

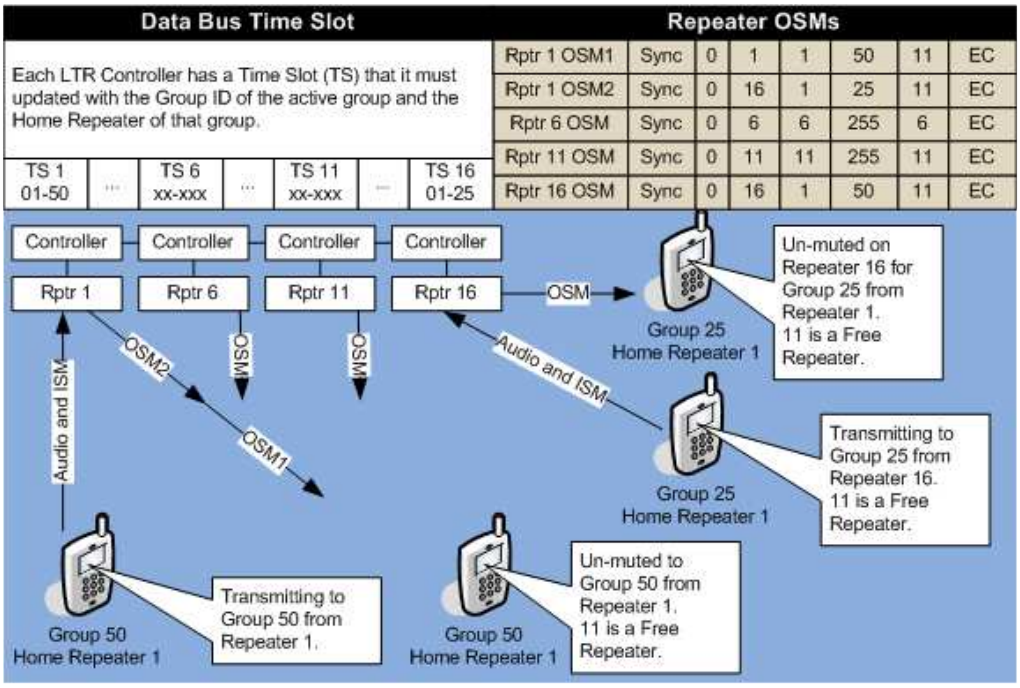

Figure 1-6 *An example of the Data Busy Time Slot being updated on a 4 channel LTR Site with groups 50 and 25 active on Repeaters 1 and 16 respectively. The LTR*

Controller for Repeater 1 knows that it has to redirect group 25 to Repeater 16 because it is active, according to the Data Busy Time Slot.

1.1.7 Outbound Signaling Message Distribution

Outbound Signaling Message Distribution is a very important mechanism in the LTR Protocol. Each data message has duration of 132ms; this allows 7.5 continuous Outbound Signaling Messages to be sent per second. An OSM is formatted to encode the ID of one unique group per OSM. If multiple groups that are homed to the same repeater are trunked, it is the responsibility of the LTR Controller to handle the distribution of the messages so that radios monitoring their home repeaters may know to trunk to the repeater where their group is active.

Outbound Signaling Message Distribution Rules

- If the repeater is idle and if no groups homed to the repeater are active on other repeaters in the system, transmit the Idle Repeater OSM at discrete times based on the Idle Repeater OSM timer.

- If the repeater is idle and a group homed to the repeater is active on a different repeater, continuously transmit the OSM specific for that group.

- If the repeater is busy and none of its groups are active on other repeaters, continuously transmit the OSM specific for the group that is active on the repeater.

- If the repeater is busy and a group homed to the repeater is trunked on another repeater, each OSM for the specific groups are to be sent every other message.

- If the repeater is busy and three groups homed to the repeater are trunked on other repeaters, every third message should be an OSM for the group that is active on the busy repeater and the other three messages should be distributed equally in a round-robin fashion.

- If the repeater is idle and three groups homed to the repeater are trunked on other repeaters, the three messages should be distributed equally in a round-robin fashion.

Based on these rules the period between OSMs for trunked groups from the same home repeater can be calculated. The following formula can be used to approximately calculate the period:

Period = 132 *(FLOOR (1.5*Number of Groups))
FLOOR rounds the number down to the nearest integer.

Approximate OSM Distribution Period for Trunked Groups			
Number of Trunked Groups	Time (ms)	Number of Groups	Time (ms)
1	132	11	2112
2	396	12	2376
3	528	13	2508
4	792	14	2772
5	924	15	2904
6	1188	16	3168
7	1320	17	3300
8	1584	18	3564
9	1716	19	3696
10	1980		

Table 1-1 *The chart shows the approximate period between OSMs for trunked groups homed to the same repeater. This period is the time between OSMs with the same Group ID. The Number of Trunked Groups column is the number of trunked groups homed to the repeater*

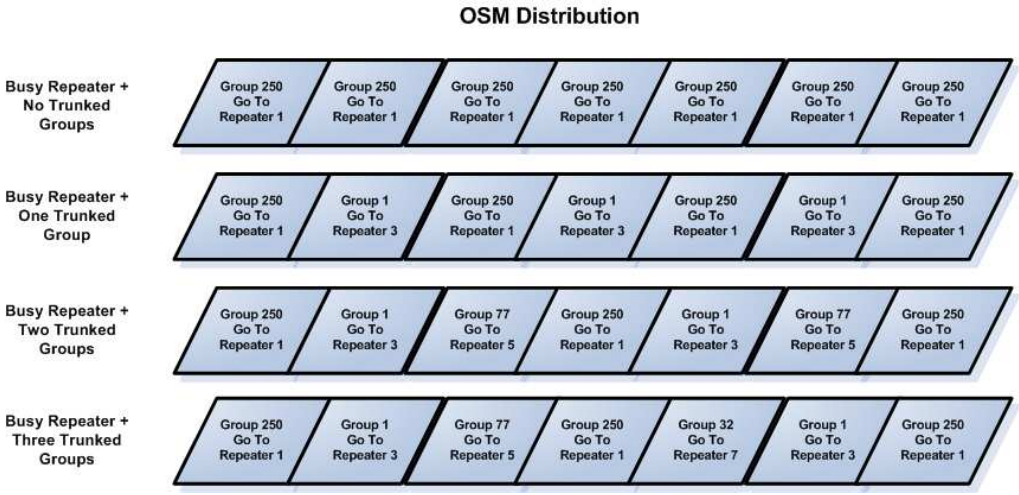

Figure 1-7 *This is an example of how OSMs would be distributed from a repeater. In the four examples, Group 250 is communicating on its home repeater and all other groups are trunked. Notice that Group 250's OSM is transmitted every third message since it communicates on the home repeater.*

1.1.8 Scenarios

The following is a call scenario of a radio attempting to access its idle Home Repeater, getting access of the repeater, transmitting on the repeater, and the de-key of the radio.

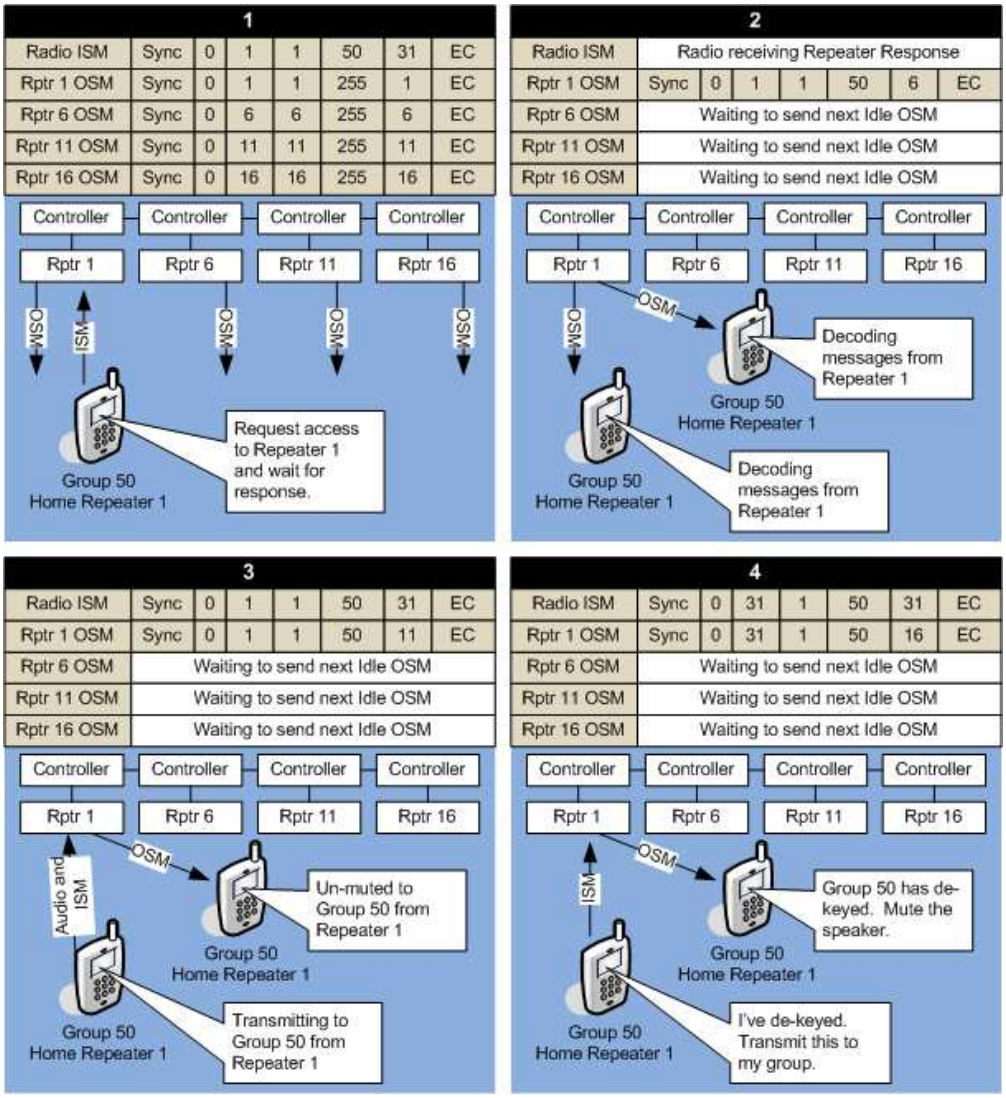

Figure 1-8 *A call scenario showing the process of a radio attempting to get access to its home repeater, decoding the messages from the repeater, beginning transmission once the radio detects that the repeater has granted it access, and sending an ISM to the repeater when the radio de-keys.*

2. System Design

Maximum Repeaters per Site	20
Maximum Groups per Repeater	250
Maximum Groups per Site	5000
Data Message Length in Bits	40 bits
Data Message Duration	132 ms
Data Message Frequency Range	300 Hz
Message or Transmission Trunking	Transmission

Table 2-1 *LTR Protocol specifications.*

To design an LTR System that performs effectively and efficiently as designed requires knowledge of the capabilities of the Logical Trunked Radio protocol and that of the Radios. A system designed without sufficient planning can lead to poor system performance. The result will be half-missed or missed conversations and poor scan performance. This can cause a user to believe that a radio is not functioning as designed even though the root of the problem is in the system design.

The system designer should ask a few questions: What is the system load during peak times? What is the system load on average? How many unique groups or collection of groups will be using the system? Is it possible to home the highly active groups onto separate repeaters? If, on average, there will be 4 groups using the system at the same time, the LTR Site should be designed to have 4 repeaters at the least. During peak load, will there be 10 groups accessing the system, or will there be 7? The number of repeaters should not be greater than the number of groups accessing the system at peak load. Another good habit is to split up sets of groups to be homed onto different repeaters. This technique is called Load Balancing.

2.1 Load Balancing

Load Balancing is the technique that frequently active groups should be homed to different repeaters to improve system performance and reduce system delays. This method should be used for LTR Sites that have more than 5 repeaters. For large LTR Sites with more than 7 repeaters, the importance of using Load Balancing to distribute the groups becomes more critical.

For example, on a 20 repeater LTR site with 20 active groups homed to the same repeater, the repeater will transmit the OSMs for trunked groups at a period of 3.6 seconds due to the LTR Controller having to distribute Outbound Signaling Messages for 20 groups. This is unacceptable performance especially in mission critical applications.

To prevent from having 20 groups become active from the same home repeater, they should be homed to different repeaters. The groups should be separated so that under peak load no more than 5 groups homed to the same repeater are active. If the system is designed in such a way, there will be a small probability of more than 5 groups becoming active from the same repeater. The LTR Controller could then distribute those messages in less than a second.

To further clarify the thought process of Load Balancing, here is an example. The LTR Site of example is a 10 repeater LTR Site with four sets of groups: {1, 2, 3, and 4}, {10, 11, 12, and 13}, {20, 21, 22, and 23}, and {30, 31, 32, and 33}. The groups within each set are

related and the first group in each set is usually the most active group. Using the Load Balancing Technique, each set of groups should be homed to different repeaters; the first set to a repeater, the second set to different repeater and so on. Radio-side, this makes it easier to switch between the related groups and allows advanced scan features found in the Professional Series Radios to work efficiently.

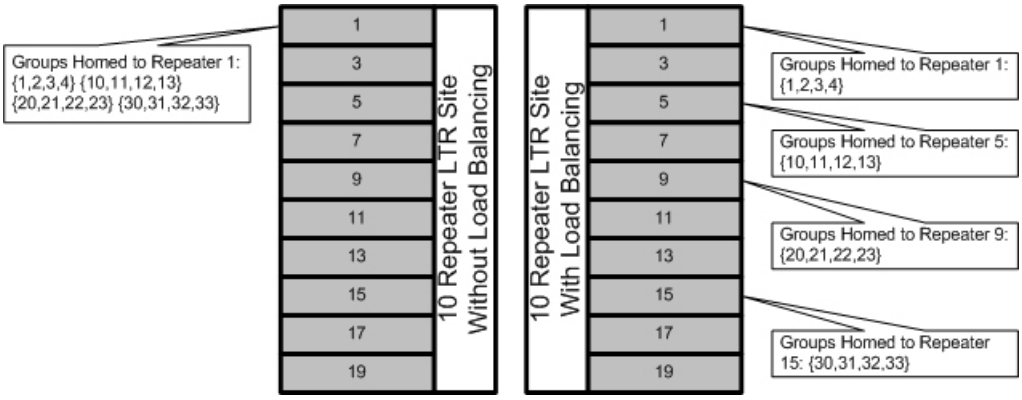

Figure 2-1 *An example of how groups should be homed onto different repeaters. For the Site on the left, all groups are homed to the first repeater. The Site on the right has the groups' homed to different repeaters.*

3. Radio Programming

3.1 Professional Series

The purpose of the following section is to provide the reader with knowledge of Professional Series Radio programming for LTR Operation. Professional Series CPS is designed for Groups to be assigned to LS Trunking Personalities, LS Trunking Sites to be assigned to LS Trunking Personalities, and LS Trunking Personalities or Conventional Personalities to be assigned to Zones.

The steps for programming a radio for LTR Operation are the following:

1. Add a LS Trunking Site. Verify that the LTR Site is programmed according to the configuration of the LTR Site.

2. Add a LS Trunking Personality and associate a LS Trunking Site and Home Repeater to that Personality.

3. Add the groups in the LS Trunking Personality and select the group options specific for those groups. Select a Scan List or Universal ID List if needed.

4. If selected, modify the Universal ID List to match the radio user desired operation.

5. If selected, modify the System Scan List to adhere to the correct scan operation for the LTR Sites being scanned.

6. Assign the LS Trunking Personality to a new or existing Zone.

The following will be LTR programming related screenshots from the Professional Series Radio CPS Application.

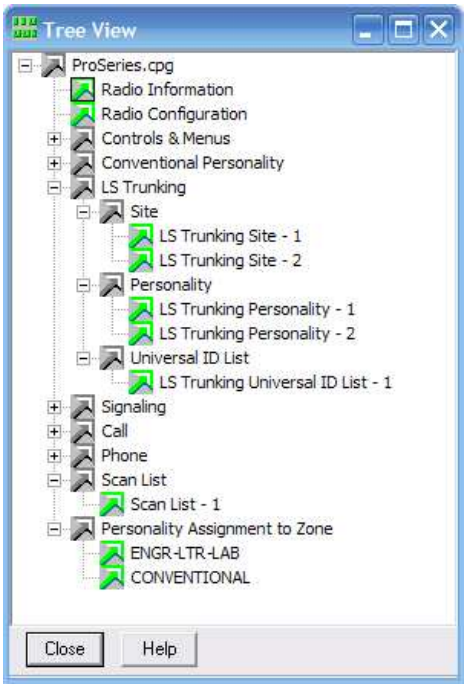

Figure 3-1 *Tree View – This view shows that the radio can be programmed to have multiple LS Trunking Sites (LTR), LS Trunking Personalities, Universal ID Lists, Scan Lists, and Zones.*

LTR Sites

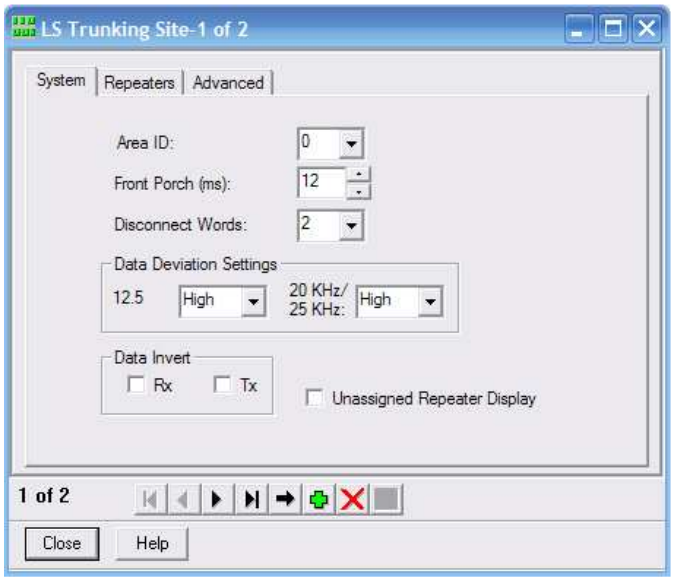

Figure 3-2 *LS Trunking Site – Area ID, Data Deviation, and Data Invert must match the LTR Site settings for the radio to operate properly.*

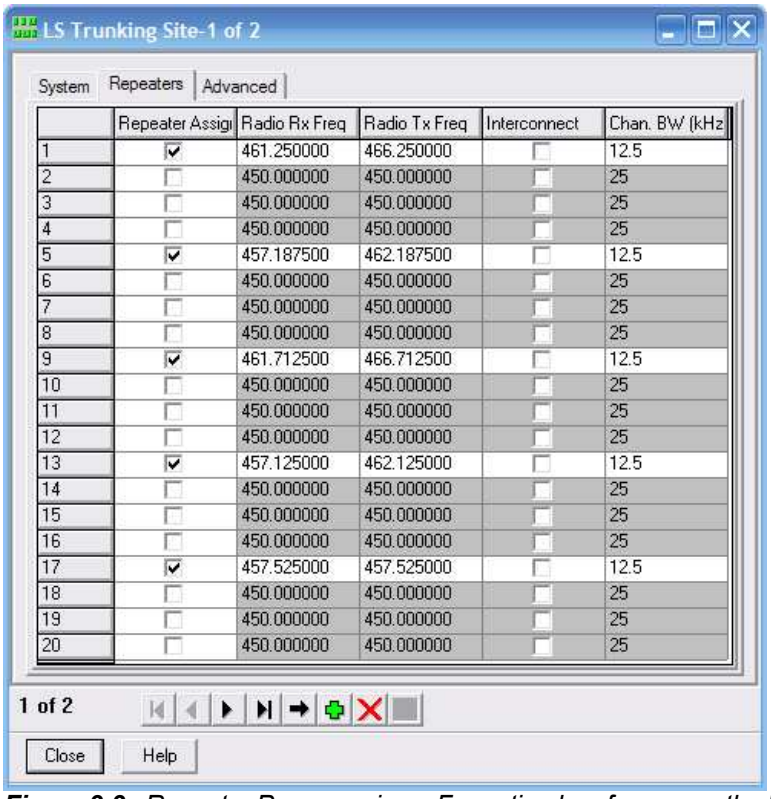

Figure 3-3 *Repeater Programming – For optimal performance, the LTR Site repeater numbers must be spaced evenly as shown in Repeater programming window.*

Personalities

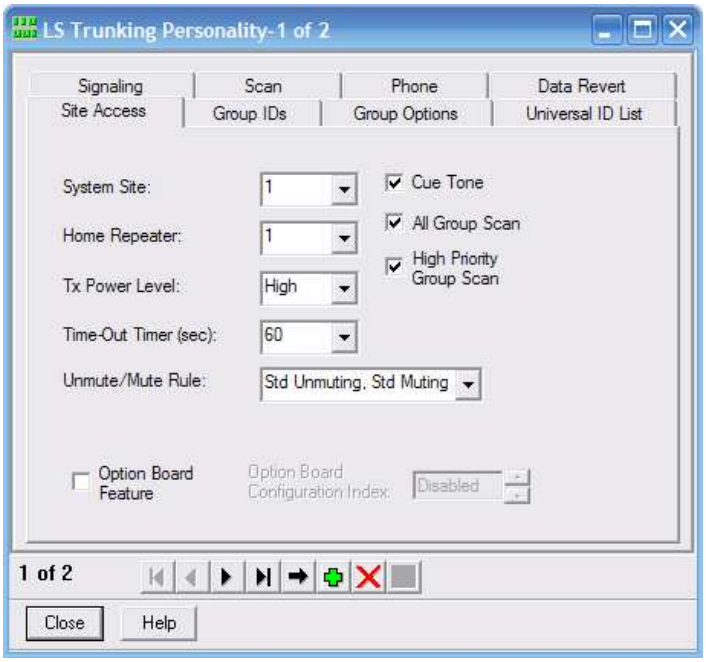

Figure 3-4 *LS Personality/Site Access – In this window, the correct System Site and Home Repeater must be selected for the radio to operate properly. All Group Scan and High Priority Group Scan can be selected here for each LS Trunking Personality.*

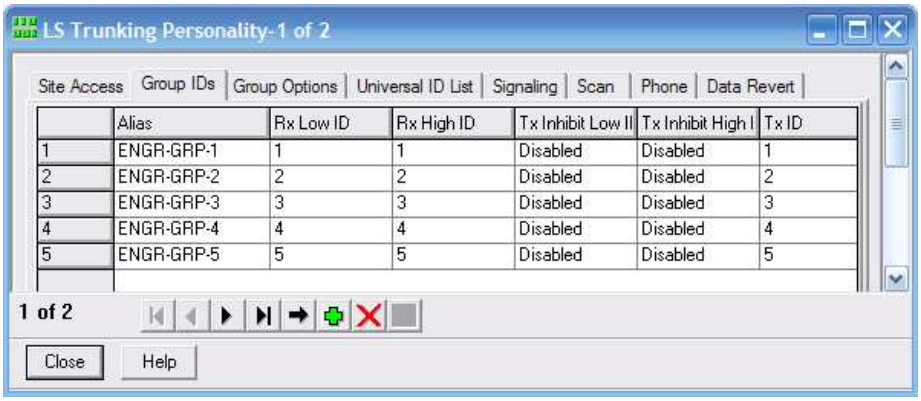

Figure 3-5 *Group IDs – Group IDs and their Aliases can be programmed in this window for the each LS Trunking Personality. Entries are assigned an index, the top-most entry being index 1 and the following entries are assigned a consecutive index number. High Priority and Prioritized Auto Group Scan uses these indexes to assign priorities based on the indexes.*

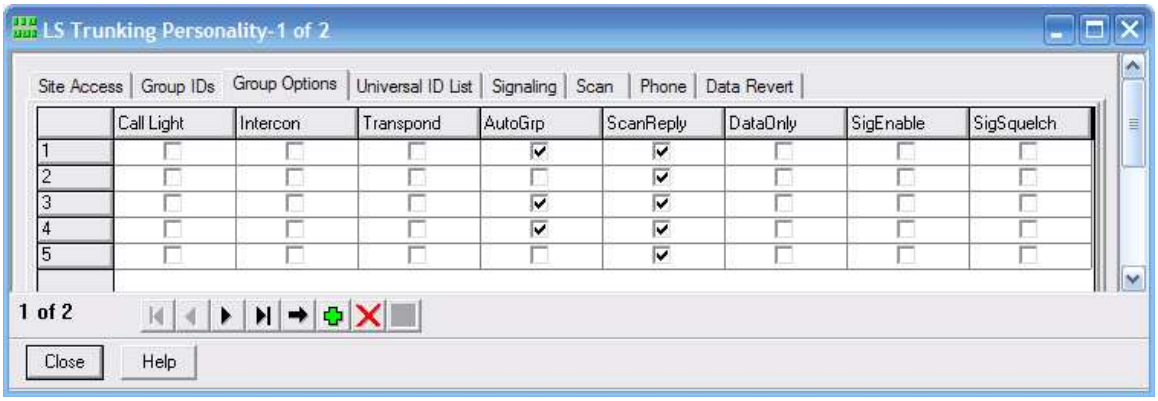

Figure 3-6 *Group Options – Different Group Options. Groups can be assigned to be Auto Group Scan members.*

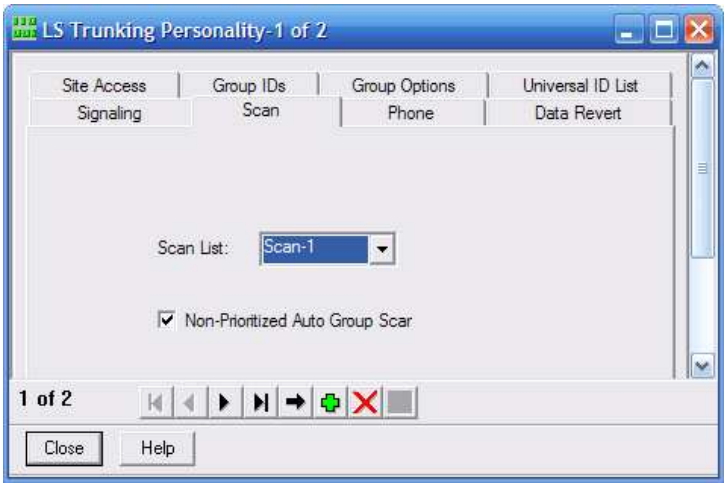

Figure 3-7 *LS Trunking Personality/Scan –Scan List refers to a System Scan List that can be chosen for the each LS Trunking Personality. When the Non-Prioritized Auto Group Scan box is un-checked, the radio will perform Prioritized Auto Group Scan, when enabled, on the groups selected for Auto Group Scan in the Group Options window. Auto Group Scan and the Scan List are not related features.*

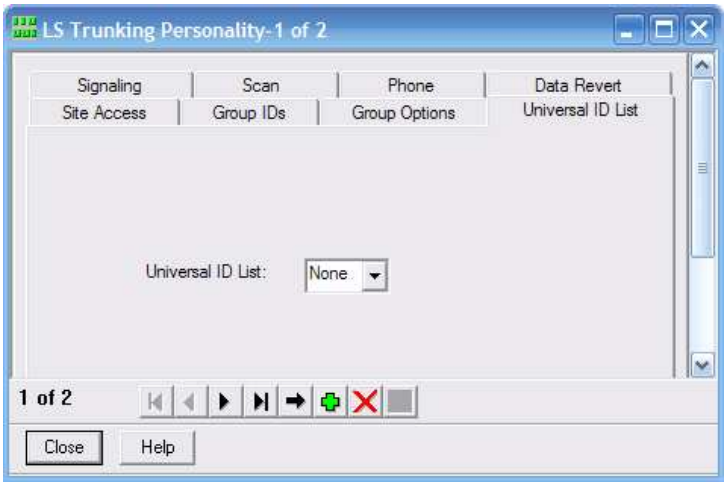

Figure 3-8 *Universal ID List – An Universal ID List can be chosen to assign aliases to Group Rx IDs matching the groups in the LS Trunking Personality.*

Universal ID List

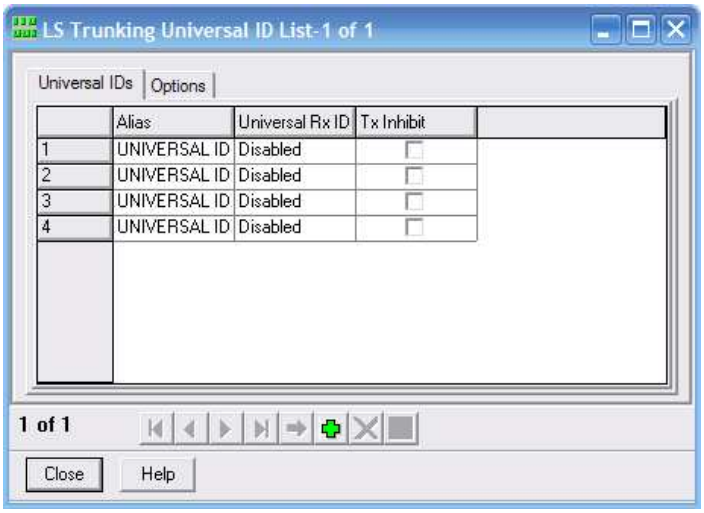

Figure 3-9 *Universal IDs – Universal ID Aliases and Options may be assigned to Group Rx IDs.*

Scan List

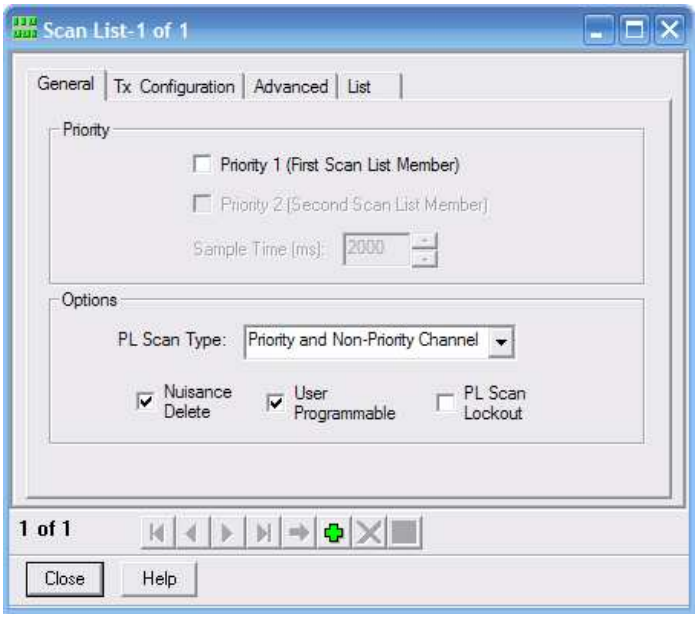

Figure 3-10 *The System Scan List general options. Note that if Priorities are chosen for LTR Scan List members, the time to fully scan a list increases.*

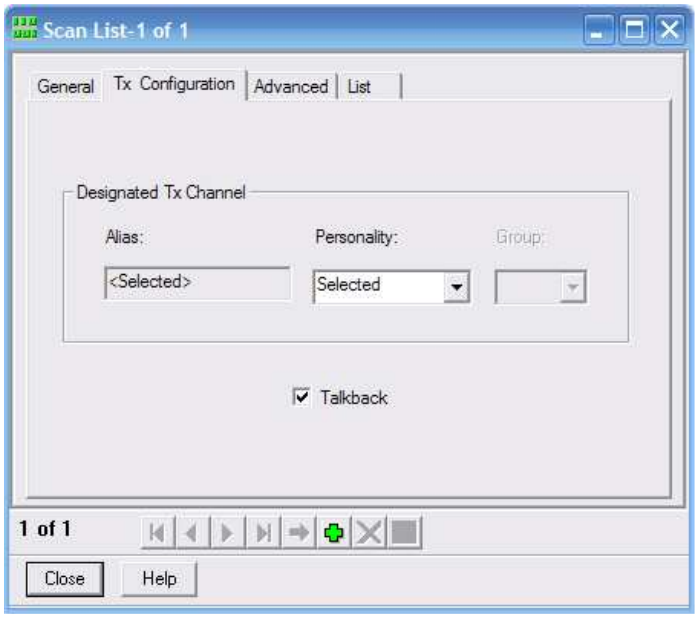

Figure 3-11 *Designated Tx Channel and Talkback can be selected here. When Talkback is not selected, the Designated Tx Channel is the channel that the radio user may transmit on when the radio is operating in System Scan. Else, if Talkback is selected, the radio user may transmit on the landed scan member channel.*

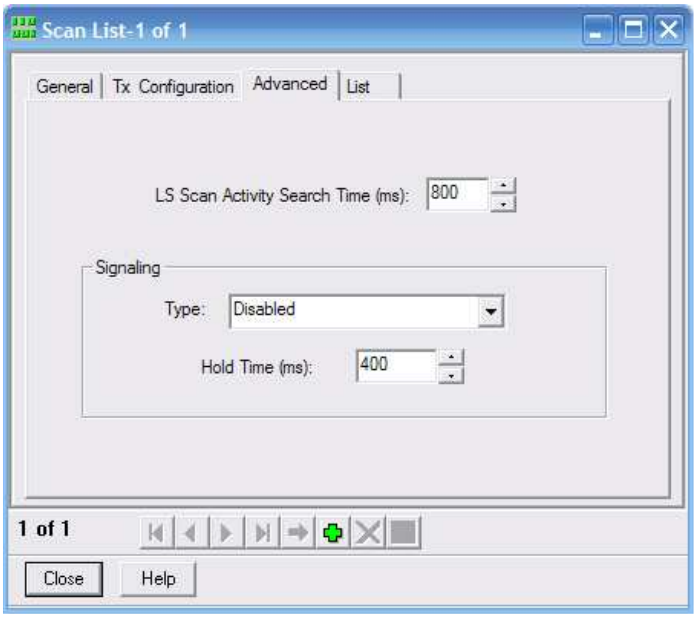

Figure 3-12 *The LS Scan Activity Search Time can be changed here. This timer is used to determine the duration the radio will decode messages on a LTR Scan List member that the radio detects activity on. Optimally, the timer should be 800ms at minimum. The Hold Time is used only when a signaling system such as MDC is used.*

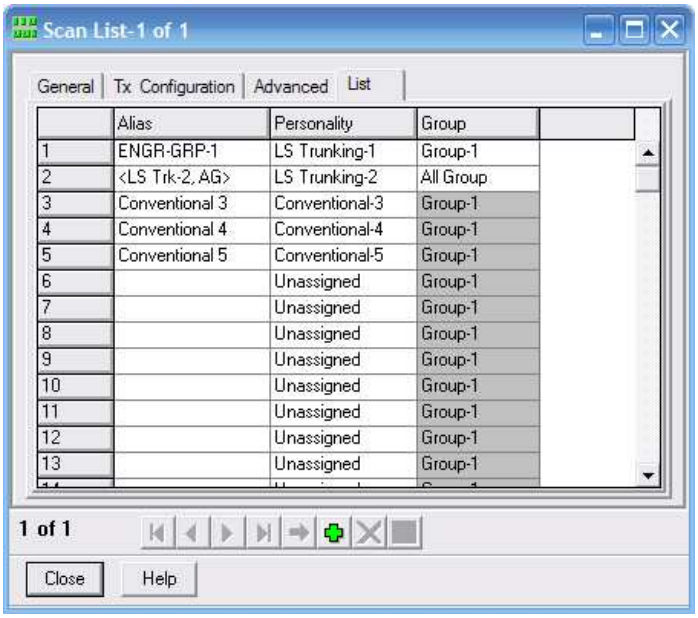

Figure 3-13 *The System Scan List windows is where scan list members may be added. The members may be Conventional Personalities, groups in a LS Trunking Personality, or All Groups within a LS Trunking Personality. A scan list should never have more than one LS Trunking Personality with the same LTR Site and Home Repeater.*

Personality Assignment to Zone

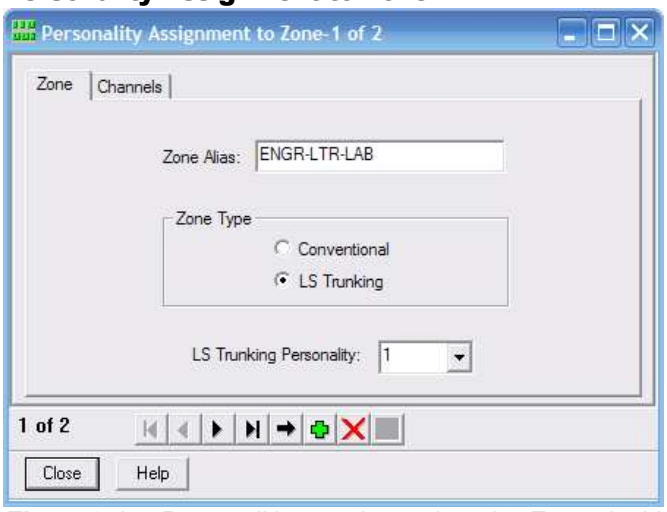

Figure 3-14 *Personalities can be assigned to Zones in this window.*

Figure 3-15 *This window displays the Groups that reside within the selected Zone.*

3.2 Commercial Series

The purpose of the following section is to provide the reader with knowledge of Commercial Series Radio programming for LTR Operation.

Commercial Series CPS has two modes: Basic and Expert. The Expert mode was used for the screenshots in this section, though not all the Expert mode features will be discussed.

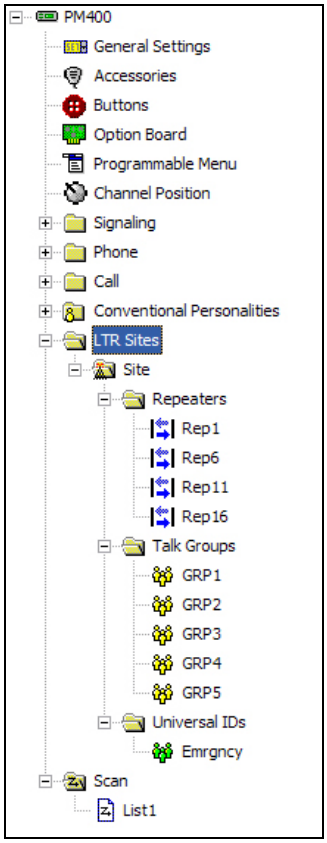

Figure 3-16 *Commercial Series CPS allows the creation of multiple LTR Sites and Groups that can be assigned to the Repeaters within those sites.*

LTR Sites

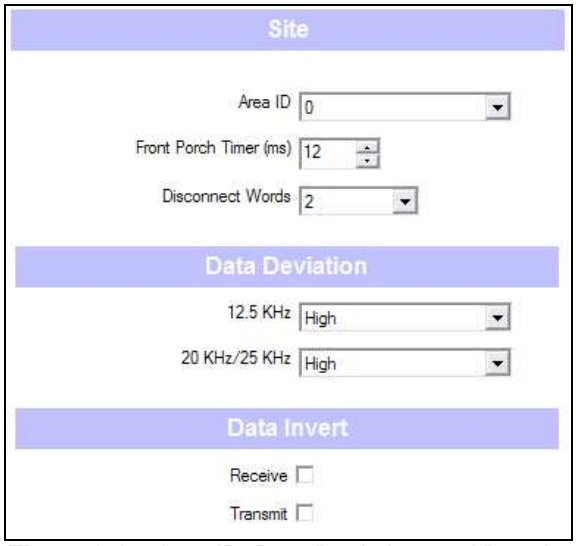

Figure 3-17 *Area ID, Data Deviation, and Data Invert must match the LTR Site settings for the radio to operate properly.*

Repeaters

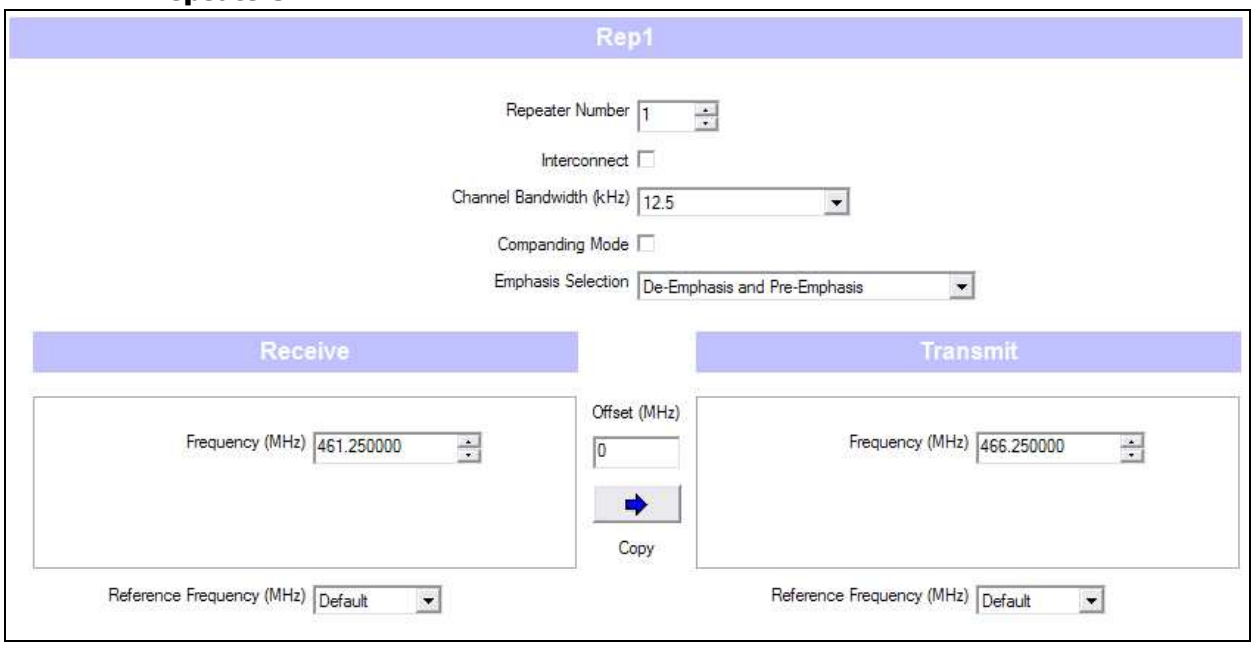

Figure 3-18 A repeater must be assigned a repeater number. The repeater configuration programmed here must match the repeater configuration on the LTR Site. The LTR Site should be configured to have evenly spaced repeater numbers.

Talk Groups

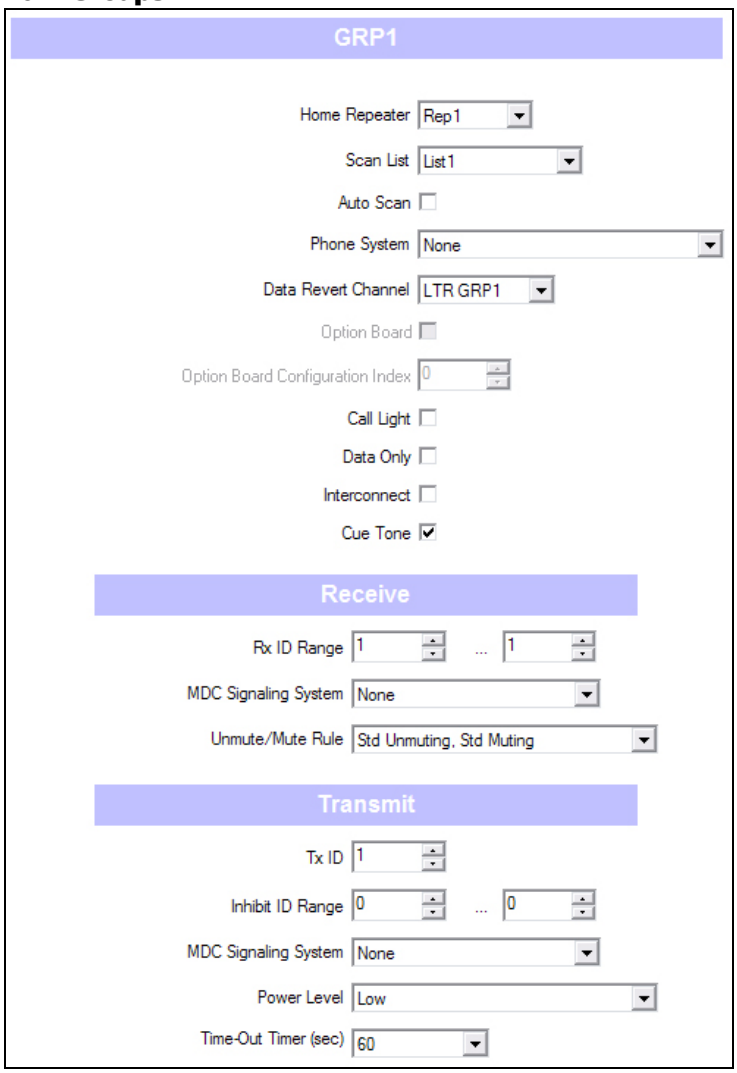

Figure 3-19 *Talk Groups must be assigned a Home Repeater.*

Universal IDs

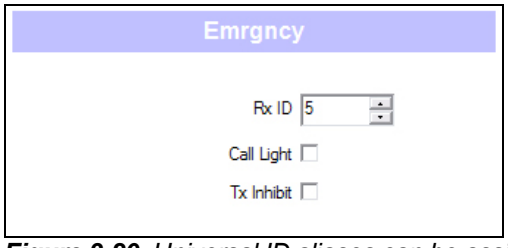

Figure 3-20 *Universal ID aliases can be assigned for Rx IDs within a LTR Site.*

Scan

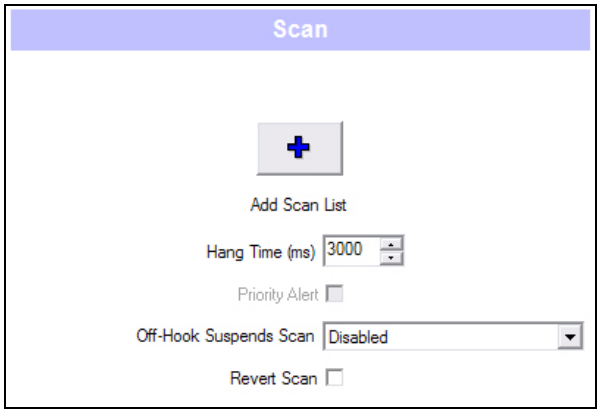

Figure 3-21 *The System Scan Hang Time can be changed in this window. Off-Hook Suspends Scan is a Mobile Radio feature.*

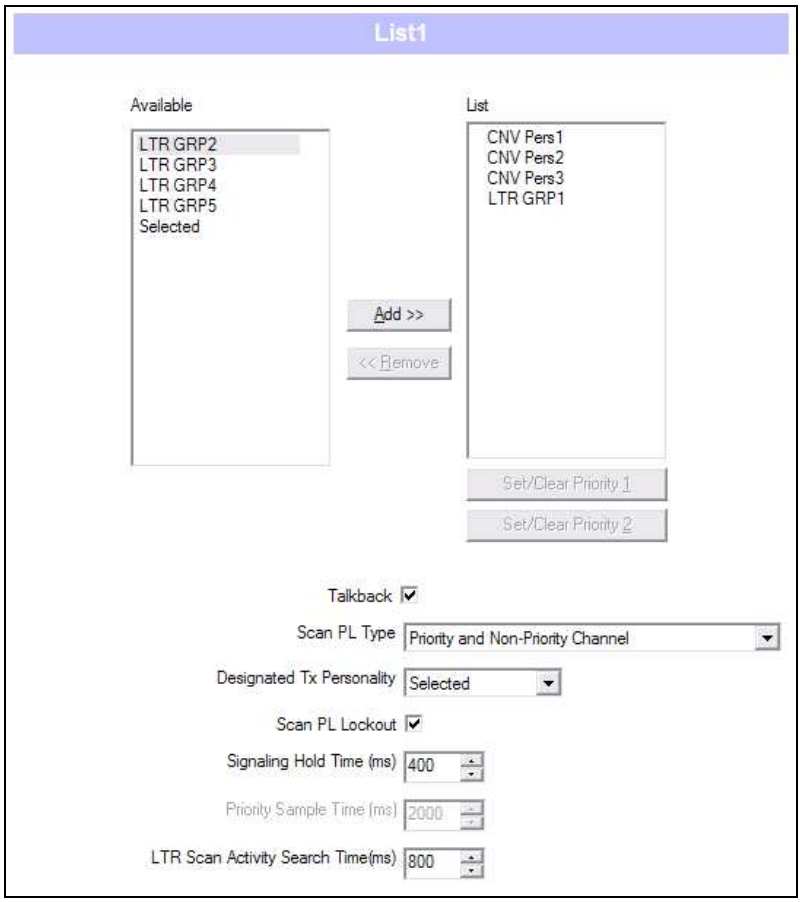

Figure 3-22 *The System Scan List can be modified in this window. The Scan List members may be Conventional Personalities or LTR Groups. Priorities may be assigned to the list members. Talkback allows the radio user to transmit on the landed scan channel rather than the Designated Tx Personality. The LTR Scan Activity Search Time should be programmed to be at minimum 800ms for optimal performance.*

4. Scan

4.1 Introduction

The chart below shows that the Professional Series Radio is designed to utilize more advanced Scan features than the Commercial Series Radio. Therefore, most of this appendix will be specific to Professional Series Radios.

Professional Series				
Zone	All Group	Auto Group	High Priority	System Scan
LTR Trunked	X	X	X	X
Conventional				X
Commercial Series				
Zone	All Group	Auto Group	High Priority	System Scan
LTR Trunked				X
Conventional				X

Table 4-1 *Scan features available in Motorola Professional and Commercial Series.*

The System designer should take into consideration the desired implementation of scan on their radios. Are multiple LTR Sites being scanned? Are groups within the same LTR Site being scanned? A common mistake is to implement the use of the Scan List without sufficient planning. The Scan List should only be used for System Scan, which is used to scan different LTR Sites and Conventional Channels. If the desired scan operation is to scan groups homed to the same home repeater, then All Group, Auto Group, or High Priority Group Scan are the scan types that should be used.

Scan Functionality				
Desired Function	All Group	Auto Group	High Priority	System Scan
Scan Different LTR Sites and Conventional Channels				X
Scan Groups Homed to the Same Repeater	X			
Scan Groups Homed to the Same Repeater with Priority			X	
Scan Pre-Selected Groups Homed to the Same Repeater		X		

Table 4-2 *Selecting a scan type based on the desired operation of scan. (Professional Series Radios Only)*

4.2 All Group Scan

All Group Scan is a LTR specific feature found in Professional Series Radios that gives the radio the ability to scan each group within the selected LTR Zone. Therefore, if the selected LTR zone has 16 groups, the radio will un-mute to any of the 16 groups that become active.

4.3 Auto Group Scan

Auto Group Scan is a LTR specific feature in Professional Series Radios that gives the radio the ability to scan pre-selected groups in a LTR Zone. This scan type should be used when the radio user wants to choose which groups to scan. There are two types of Auto Group Scan: Non-Prioritized and Prioritized.

Non-Prioritized Auto Group Scan

When the radio selected group is a Non-Prioritized Auto Group Scan member, the radio will un-mute to any Auto Group Scan member in the LTR Zone. To enable this feature, Auto Group Scan members must be selected and Non-Prioritized Auto Group Scan must be enabled.

Prioritized Auto Group Scan

The radio will un-mute to any Auto Group Scan member that has a list index number lower than or equal to the selected Auto Group Scan member index number. Lower list index numbers have a higher priority over higher indexed groups. The radio will not scan Auto Group Scan members with a list index number higher than the selected Auto Group Scan member. Let's follow up with an example.

Groups at index number 1, 3, 4, 6, and 7 are selected for Auto Group Scan. The group at index 6 is the selected group. The radio will never un-mute to the group at index 7 but will un-mute to the lower indexed groups if they ever become active. The group at index 1 will have a higher priority than the group at index 3. If the group at index 7 was the selected group the radio could un-mute to all the Auto Group Scan members. If the group at index 3 was the selected group then the radio would un-mute to only the groups at index 1 and 3.

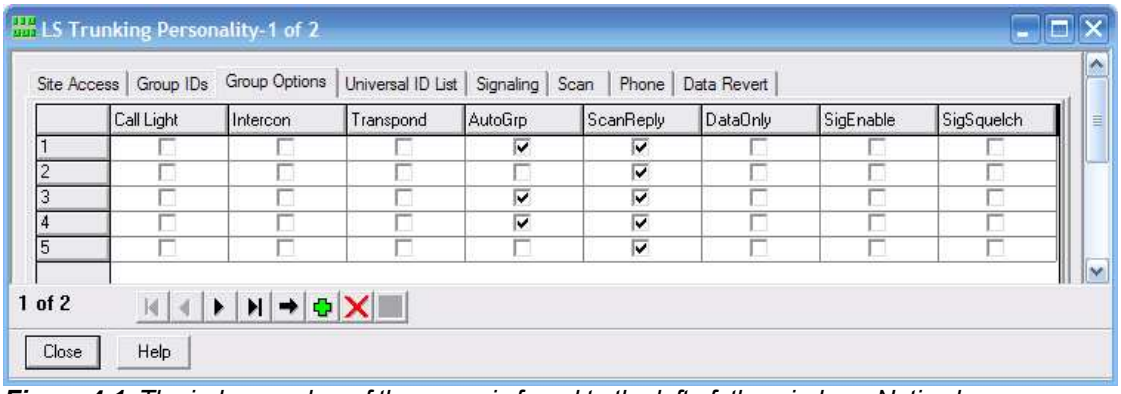

Figure 4-1 *The index number of the group is found to the left of the window. Notice how the groups at index 1, 3, and 4 are selected for Auto Group Scan.*

The list index number can be found on the left of the LS Trunking Personality, Group IDs or Group Options window. Note that the Group ID and the list index number is not the same thing. To enable this feature, Auto Group Scan members must be selected and Non-Prioritized Auto Group Scan must be disabled.

4.4 High Priority Group Scan

High Priority Group Scan is a LTR specific feature found in Professional Series Radios that when used with All Group Scan, has the function of assigning higher priorities for lower indexed groups in the list, with the Universal ID being the highest priority. As the list index number decreases, the priority of the group at that index increases. This scan feature only works when communicating on the home repeater. Thus if a radio is un-muted to a lower priority group on the home repeater, and a higher priority group becomes active, the radio will trunk to un-mute to the higher priority group.

Priority Level	
1	Universal ID Index 1
2	Universal ID Index 2
3	Universal ID Index 3
4	Universal ID Index 4
5	Group List Index 1
6	Group List Index 2
7	Group List Index 3
…	
20	Group List Index 16

Table 4-3 *Priority Level assignment for High Priority Group Scan.*

4.5 System Scan

System Scan is a feature found in Motorola Professional and Commercial Series Radios. A radio user can enable this feature to scan multiple LTR Sites and Conventional Channels without having to switch channels manually. When enabled, the radio will load the scan list the user created during radio programming; the radio will then begin scanning each scan list member for activity.

Scan List

A scan list member contains either a conventional channel or a Group ID/Home Repeater/LTR Site Combination. Professional Series Radios allow the All Groups/Home Repeater/LTR Site Combination which means that the radio will un-mute to any active group on the Home Repeater of the repeater specified in the scan list. The following are examples of correct and incorrect ways to program a Scan List.

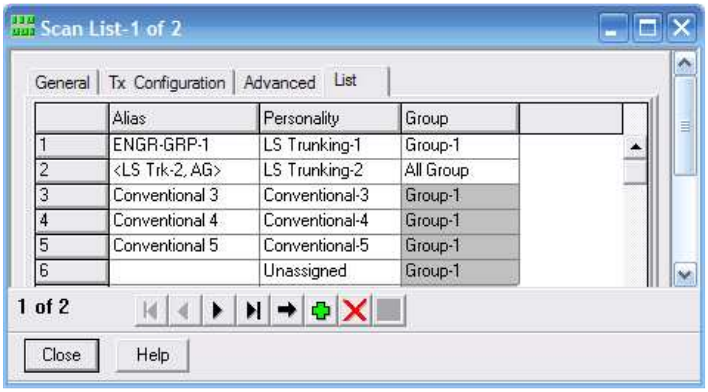

Figure 4-2 *This is an example of the correct use of a Scan List in Professional Series Radios. Notice that multiple Conventional Channels and LTR Sites are in the list.*

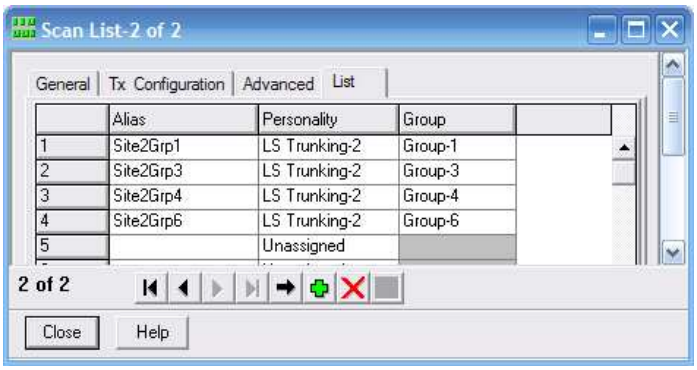

Figure 4-3 *Here is an example of the Professional Series Radio Scan List being used incorrectly. In this case, the Scan List should not be used but the radio user should use a different scan type such as Auto Group or All Group Scan which gives the radio user a more efficient scan operation.*

For Professional Series Radios, Scan Lists should not be created like the one shown in Figure 4-3. The Scan List programmed in that example would introduce large delays in the radio un-muting time. When a radio scans a LTR Group on a busy repeater, the radio must decode messages from the repeater for the duration of the LS Scan Activity Search Time. If the Group ID is not found, the radio will continue to decode messages for the duration of the timer. The problem with Figure 4-3 is that when the repeater is busy, the radio will scan each Scan List member for the duration of the LS Scan Activity Search Time, therefore the time to fully scan a list is (#Scan List Members) x (LS Scan Activity Search Time). If the LS Scan Activity Search Time is 900ms and there are 4 Scan List members, the radio will fully scan the list in 3600ms.

As an example, the repeater in Figure 4-3 is busy with Site2Grp6 and the radio is currently scanning Site2Grp1. The radio user expects the radio to un-mute to Site2Grp6, which is the active group. The radio detects activity on the repeater, but the radio is scanning for Site2Grp1, therefore, the radio must decode messages on the repeater for the duration of the LS Scan Activity Search Time. Once the timer expires, the radio moves on to the next Scan List member, Site2Grp3. Since the repeater is busy, the radio starts the timer and begins to decode activity on the repeater in search for activity of Site2Grp3. The radio has to wait for the timer to expire in search for Site2Grp3, which it never finds. This will continue until the radio scans for Site2Grp6, decodes the message from the repeater with its Group ID, and un-mutes. The radio user hears the radio un-mute after more than 3 seconds. It is evident why the Scan List should never be programmed as in Figure 4-3.

More efficient alternatives to the desired operation of scan in the previous example are All Group Scan and Auto Group Scan. Scan List members should never have the same home repeater from the same LTR Site. If this is the case and All Group and Auto Group Scan are not alternatives, another solution would be to combine the groups to scan into the same LS Trunking Personality and to then include that new LS Trunking Personality in the System Scan list with All Group as the selected scan group (see Figure 4-2, Scan List member 2). This prevents the radio from having to scan the same repeater more than once in the same Scan List pass. The following screenshots show how scan from Figure 4-3 should have been implemented with Auto Group Scan.

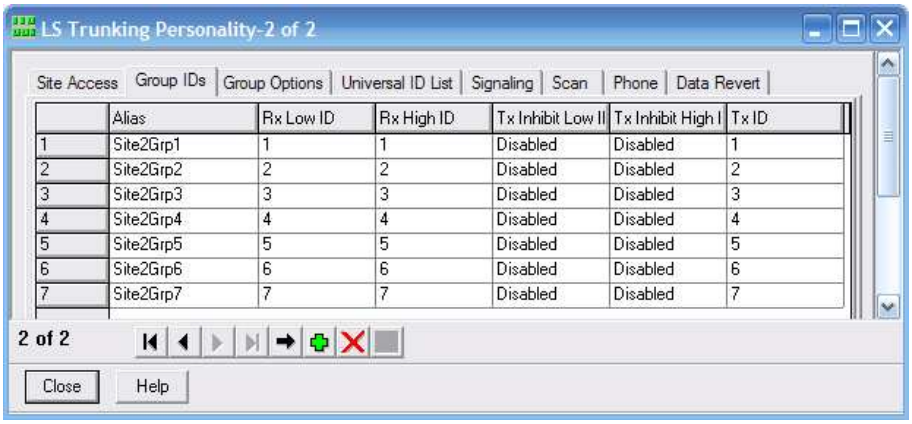

Figure 4-4 *The groups to scan are the groups at index 1, 3, 4, and 6.*

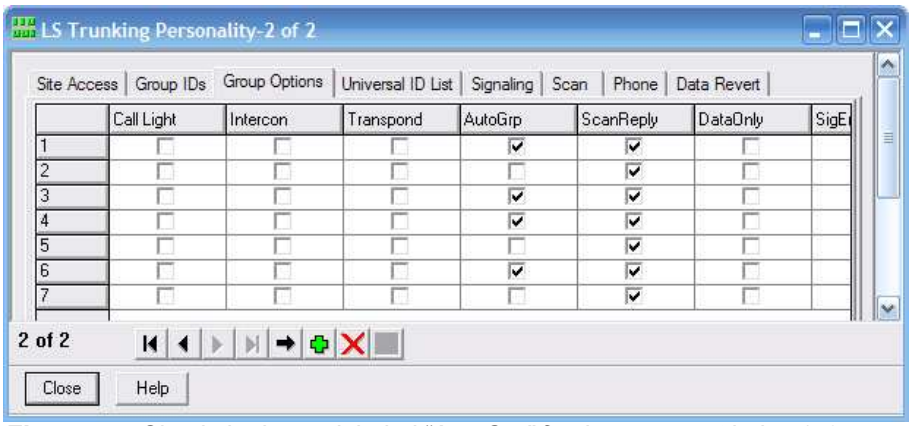

Figure 4-5 *Check the boxes labeled "AutoGrp" for the groups at index 1, 3, 4, and 6. Enable Non-Prioritized or Prioritized Auto Group Scan found under the "Scan" tab of the LS Trunking Personality window.*

LS Scan Activity Search Time

The radio uses the LS Scan Activity Search Time only when scanning LTR groups during System Scan. Its purpose is to give the radio an opportunity to decode the OSM with the Group ID that it is scanning for. If it does not decode the OSM with the Group ID that it scans for before the timer expires, the radio will attempt to scan the next member in the scan list. If a radio decodes the OSM that matches the Group ID with the Group ID in the scan list, the radio will then trunk to the repeater that the group is active on and un-mute to allow the radio user to hear the conversation. This timer is a very important and plays a crucial role in the performance of System Scan.

For System Scan to perform well, the value of the LS Scan Activity Search Time must be programmed based on the configuration of that LTR Sites and the average repeater load of the repeater being scanned on that site. Table 1-1 in Section 1.1.7 Outbound Signaling Message Distribution can be used as a guide in determining the correct value of the LS Scan Activity Search Time. For System Scan to work well, LTR Sites should be configured using Load Balancing which is discussed on page 13. Otherwise, scan will appear to perform poorly. Here is a procedure to find an appropriate value for the LS Scan Activity Search Time.

1. Find the Scan List member that is a LTR Site with the greatest number of repeaters.
2. What is the average number of active groups on that scan list members home repeater?
3. Reference Table 1-1 in Section 1.1.7 Outbound Signaling Message Distribution, subtract one from the result from the previous question, and match that result with the value in the column “Number of Trunked Groups” and use respective time as the LS Scan Activity Search Time. Round the number up to the nearest 25ms (924 = 925ms). Optimally, in all cases, the timer should not be programmed below 800ms.

It is very important that LTR Sites are configured using the Load Balancing technique. If LTR Sites are configured in this manner, the LS Scan Activity Search Time can be programmed to be 925ms because with Load Balancing groups are homed to different repeaters in a way that no more than 5 groups from the same home repeater will become active.

Priority 1 & 2

Priority scan members should be used when a radio user desires to scan a LTR Group or Conventional Channel more frequently because of the priority level they place on that group or channel. Priority members are selected through the scan list.

When only a priority 1 scan member is set, every other radio scan attempt will be the priority 1 scan member. For both priority 1 & 2 scan members, every fourth scan will be for the priority 1 scan member, and every fourth scan will be for the priority 2 scan member.

Example
N1, N2, N3, N4 = Non-Priority Scan Members; P1 = Priority 1 Scan Member; P2 = Priority 2 Scan Member.

Priority 1 Scanning Sequence
P1 → N1 → P1 → N2 → P1 → N3 → P1 → N4
Priority 1 & 2 Scanning Sequence
P1 → N1 → P2 → N2 → P1 → N3 → P2 → N4

Priority Sample Time

Priority Sample Time is the time period that the radio will use to check the Priority 1 or 2 scan member when the radio is un-muted on a Non-Priority Conventional scan member. The radio will briefly mute for the period defined by this timer to check the Priority 1 or 2 scan members for activity. The Priority Sample Time is only valid for Conventional Priority 1 or 2 scan members.

Designated TX Channel

The Designated TX Channel is the LTR Group or Conventional Channel that the radio user will be allowed to transmit on during System Scan operation. This radio user will only be allowed to transmit on the Designated TX Channel unless Talkback is enabled. If Talkback is enabled, the radio user will be allowed to talkback on the channel that the scan has landed on for the duration of the scan hang timer. The scan hang timer is used to give the radio user time to transmit on the landed scan channel.

5. Contact Information

For any questions, please contact Customer Resources at 1-800-927-2744.