Overcoming the Challenges of Monitoring Trunked Radio

Monitoring and recording a two-way radio system was a relatively easy task until the introduction of trunked radio presented new challenges

by
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Until the introduction of trunked radio, monitoring and recording a two-way radio system was a relatively easy task. Adapting a multi-track or multi-channel communication recorder to capture conventional two-way radio conversations is almost trivial - even though the recorder's original purpose was to record multiple telephone lines. Recording and recovering conversations from a trunked radio system presents new challenges.

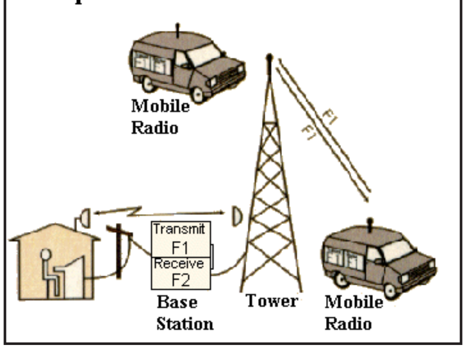
To make matters worse, trunked radio systems can also do "private" conversations which are ad-hoc two-party talk groups. The trunked system controller puts these two-party "private" talk groups together, and they exist only as long as the parties are talking. Trunked radio systems can also do radio-to-telephone interconnects. Radio-to-telephone interconnects differ from normal trunked transmissions because they typically tie up one voice channel while connected and do not trunk.

Simplex Radio

Simplex radio is the original, genuine, two-way radio as shown in Figure 1. Simplex radio uses the same frequency for both transmit and receive. Contrary to popular opinion, simplex radio is not dead and will not die for some time to come. Today, simplex radio is primarily used for applications that need to go beyond "line-of-sight". Simplex radio is also used for aviation and marine applications where repeaters would not be practical.

Monitoring and recording transmissions on a simplex radio system are elementary. A single frequency receiver or a hard wire connection and a clock connected to a recorder will accomplish the purpose. Recovery of a radio conversation consists of locating the time period of interest on the tape and playing it.

Figure 1
Simplex Radio



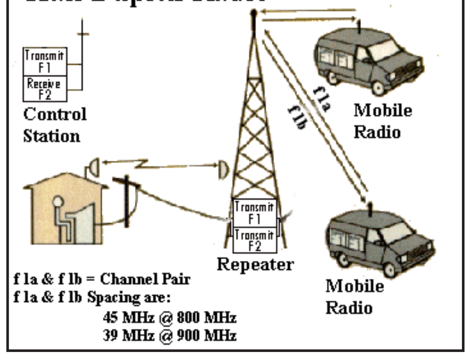
Duplex Radio

Duplex radio was a later development in two-way radio. Duplex operation provides separate talk paths (frequencies) for transmit and receive. In practice, duplex radio is sub-divided into two categories: full duplex for simultaneous transmit and receive (telephone) and half-duplex, where transmit and receive occur sequentially even though there are two talk paths.

While duplex radio is possible on the lower frequencies, it typically has used only on the higher VHF and UHF frequencies with repeaters to extend the "line-of-sight" range of a system. A radio system that uses repeaters must be a duplex system where the mobile radios transmit on one frequency ("up" frequency) to a stationary repeater receiver and listen to the repeater transmitter on another frequency ("down" frequency). The repeater is usually located on high ground with a tall antenna as shown in Figure 2.

The idea is that the repeater antenna can "see" the transmitting mobile and receive transmissions from a longer distance (20 - 30 miles). When the repeater receives a transmission from a mobile unit on the "up" frequency, it detects and re-transmits the audio on the "down" frequency so that other mobile units, which can "see" the repeater antenna, hear the transmission. This way, widely separated mobile units that cannot "see" each other, but can both "see" the repeater, can communicate.

Figure 2
Half Duplex Radio



Monitoring and recording transmissions occurring on a half or full duplex radio system are identical to the method used for simplex radio systems. A single frequency receiver tuned to the "down" frequency (which has both sides of the conversations) and a clock connected to a recorder will accomplish the purpose. Recovery of a radio conversation consists of locating the time period of interest on the tape and playing it.

How trunked systems work

The name "trunked" comes from the telephone industry. A better name for trunked radio would be "computer aided radio". Many people have heard of telephone trunk lines, but they usually do not know how they differ from the phone lines that runs to their houses. The line that runs to your house is yours and yours alone, unless you are on a party line. Part of your phone bill each month is to pay rent on your line.

Trunk lines are the telephone lines that run between telephone exchanges and are different from the line that runs to your house. If you call from your telephone exchange to another telephone exchange, the switching equipment at your exchange assigns your call a trunk line that runs to the other exchange. In effect, you "borrow" a trunk line for as long as you are connected. You have no idea which trunk line you are using, but that is not important. When you hang up, your exchange recovers the trunk line you were using and makes it available for assignment to another caller.

A trunked radio system operates much like the trunk lines on a telephone system. When you press your microphone PTT button, your radio sends an inbound digital message to the trunked system controller on the control channel. The message contains your ID, talk group, and a request for assignment of a voice channel. The trunked system controller locates an idle frequency in its pool of frequencies and broadcasts an outbound digital message on the control channel that directs your radio and any other radios associated with your talk group to change to the selected available idle frequency. The sequence of events to request and assign a frequency occurs in about one-third of a second.

When you have finished your transmission and released the PTT button, the trunked controller waits a predefined time (usually two seconds). If there is no response to your transmission within that time, the trunked system controller recovers the previously assigned frequency and waits for the next request to transmit from your talk group. When the next request to transmit occurs, the trunked system controller repeats the sequence of locating and assigning an idle frequency. Most trunked system controllers are programmed to intentionally assign a different frequency for each transmission when the pause between transmissions exceeds the predefined time limit.

The advantages

You might ask, "Why go to all this trouble?" The answer is that trunked radio massively increases the productivity and usefulness of a multi-channel two-way radio system. In fact, the inherent efficiency of trunked radio is such that the Federal Communications Commission (FCC) has specified that any system with 5 channels or more will be trunked and that the number of channels licensed is based on 70 - 100 radios per channel. This begs the question:-"How can several hundred radios share a system without chaos during heavy traffic periods?"

The answer is found in the interrelationship of three factors: organization, queuing theory, and the nature of radio transmissions. Trunked radio systems are inherently complex and good organization is vital. Depending on the trunked radio system manufacturer's architecture, a trunked radio system may have many fleets (typically less than 16); a fleet may have several talk groups (typically 16); and there can be many individual radio Ids. Theoretically, a maximum of 65,535 address are available, and the number assigned will depend on the number of radios in the system. Generally, talk groups are rigidly assigned to fleets. Individual radios however, may be programmed for operation in one fleet and one talk group or in highly efficient user-managed systems, they may be programmed for operation in all fleets and talk groups.

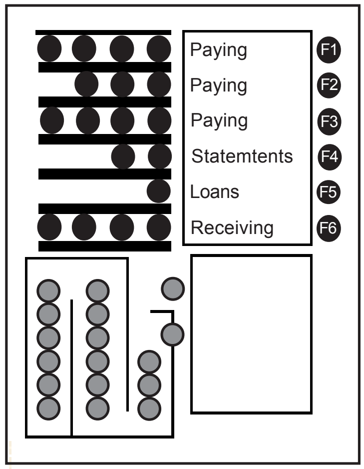


Figure 3: Queueing Theory

A "queue" in this instance is a line-up of people wanting to use a two-way radio system. However, it can be applied to almost any situation where people line-up to receive some service.

Figure 3 shows an analogy between queues in a bank and queues waiting to use a radio system. The illustration shows 6 specialized tellers (frequencies) in a bank. If you wanted to make a deposit, you must wait your turn in the receiving teller's (F6) line although the loan teller (F5) is free. The bottom illustration shows a single line of people being served by 5 general tellers (F1, F2, F4, F5, F6) who can perform any task (serve any talk group). Even if we use one of the tellers (F3) to control traffic, the 5 remaining tellers (frequencies) will service the customers more efficiently than in the upper example.

The nature of radio transmissions

Two-way radio voice transmissions have a very important characteristic that makes trunked radio work so well. The average transmission is less than 10 seconds long. With this short transmission time, the trunked system controller can almost always find a frequency that is open for a transmission.

Figure 4 represents the individual transmissions on a typical small trunked radio system. The top line represents the trunked control channel. The other lines represent available voice channels that are assigned by the trunked system controller. The colored blocks on the voice channels represent several types of transmissions; six different talk groups, a private conversation , and a telephone interconnect. Notice that most transmissions are short and that the trunked system controller distributes the individual radio transmissions among the available frequencies. The exception is the telephone interconnect which ties up a radio channel for the entire duration of the call.

The disadvantage

Trunked radio systems have one major disadvantage—they cannot be monitored and recorded very easily.

During normal operation, each individual radio receives and de-trunks the transmissions in his talk group. The method is for each individual radio to assignment instructions of the trunked system controller and "follow" the transmissions as they move from one frequency to another.

While it is possible to monitor and record the individual radio channels on a multi-track or multi channel recorder, the only thing you will capture are the individual transmissions that are portions of many separate conversations. It should be obvious that it would take considerable effort to assemble the scattered transmissions into a meaningful reconstruction of a conversation.

Fortunately, there is a solution, and it can be found in three different ways: de-trunking prior to recording; de-trunking after recording using an adapted multi-channel recorder; and de-trunking after recording using a digital recording system for trunked radio.

Solutions

There are three ways to record a trunked radio system.

1. **De-trunk prior to recording—multi-channel.** This method uses available multi-track or multi-channel recorders and a de-trunking device or trunked radio for each talk group to be recorded. The de-trunking devices or trunked radios follow the conversations in a pre-set talk group and the subsequent audio is recorded on a designated track of the multi-track recorder.

But, de-trunking prior to recording is inefficient because very little of what is recorded is ever recovered (estimated to average less than 1/2 of 1per cent); the recorder typically records everything, including silence; a trunked radio (approximately $2000 each) is required for each talk group; and dedicated track or channel is required for each talk group. (Several recorders may be required).

2. **De-trunk after recording using an adapted multi -channel recorder (patent pending)**. This method involves using a standard "off-the-shelf" multi-track recorder and a proprietary "pre processor" and "post processor."

Conventional audio from either standard (non-trunked) radio receivers or raw audio from other audio sources are connected to the standard multi-track audio recorder so that each discrete radio channel is

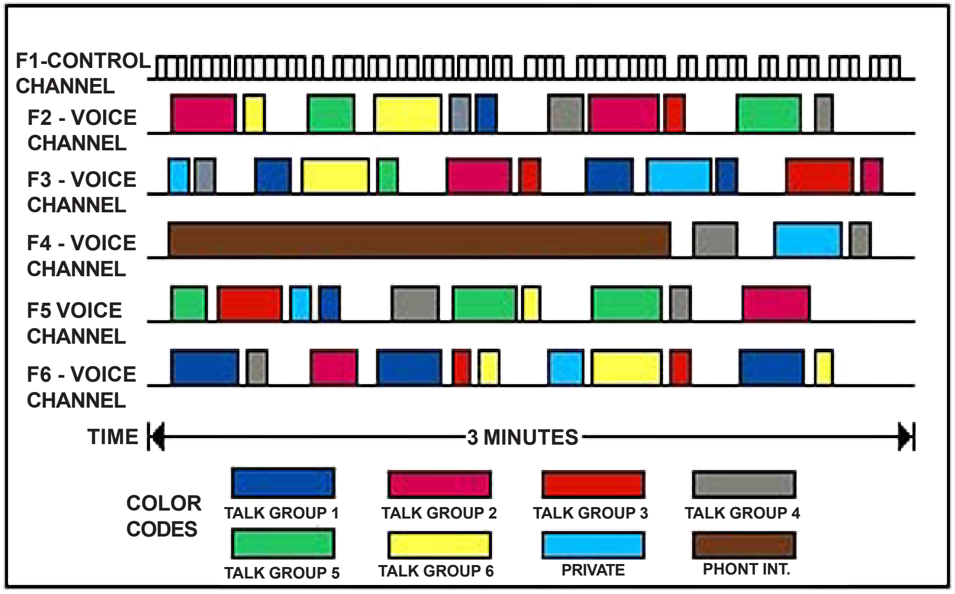


Figure 4: Trunking Radio System Typical Frequency Usage

connected to a track of the audio recorder.

A pre-processing device monitors the trunked radio control channel, interprets the channel instructions, and outputs playback control instructions in a modem-like digital format to the audio recorder. The pre-processor output is recorded on several tracks (for redundancy) that parallel the audio recordings of the various radio channels.

To recover a conversation, the user must transfer the recording function to another tape unit, rewind the tape with the desired recording, specify a "time window" as a search parameter, and play the tape. The "post processor " will decode the playback control instructions and display the time, unit identification, and talk group of each transmission that occurred in the time window. The user will then select all transmissions of interest, rewind the tape, and start the recovery process. The system will play the tape and at the appropriate moments, connect the track with the desired transmission to the output of the tape deck, thus reconstructing the trunked radio conversation.

3. **De-trunk after recording using a digital recording system for trunked radio: *SwiftSTOR*™**. This method involves a specially designed intelligent digital logging recorder system which has been named the ***SwiftSTOR***™ for use with Motorola trunking systems or the ***SwiftSTOR***™ for use with other radio manufacturers systems.

The ***SwiftSTOR***™ uses "raw" audio from each of the RF channels in the trunked radio system. This audio can be supplied by either conventional (non-trunked) radio receivers or directly from the trunking system controller if it is available. There is an advantage in obtaining the audio from a receiver because you can monitor the audio quality as received by the field radios which will help locate and diagnose repeater problems.

The recorder simultaneously processes the trunking control channel instructions while digitizing and compressing the incoming audio. It then combines the processed control information (time, talk group, radioID, and RF channel) and the digitized/compressed audio information into a data packet which is indexed and stored on a hard disk. During processing, the recorder eliminates silence to improve efficiency and reduce tape consumption.

To recover a conversion, the user specifies a time window and a talk group number, name, or individual radio ID. While the ***SwiftSTOR***™ continues to record incoming signals, it searches the disk or the tape to locate the desired conversations. When they are found, the recorder assembles the individual data packets of the desired conversation and re-plays them back. The user has a choice of listening to the recovered radio transmissions or having the audio written to a cassette tape.

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