Technisonic FM Radio Guide

Understanding the complex world of
airborne tactical communication
from **installation** to **operation**

TFM + TDFM Series

(Photo courtesy Baltimore City Police Aviation Unit)

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Guide Revision History

Revision	Page	Description	Date	Edited By

☑CAUTION

These units contain **static sensitive devices**. Wear a grounded wrist strap and work at a static-safe workstation when handling internal printed circuit boards.

☑WARRANTY & ASSISTANCE INFORMATION

Technisonic Radio and Audio equipment is under warranty for one year from date of purchase. Failed units caused by defective parts or workmanship should be returned for warranty service to:

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Iintroduction:

This manual provides information for Installation of TiL TFM and TDFM Series Transceivers, and understanding of the FM radio technology behind them.

Audience:

This Installation manual is written for Avionics Technicians responsible for the installation of Technisonic TFM and TDFM tactical radio systems, with detailed installation drawings and wiring notes, and those using the systems after installation.

Online Documentation:

This document is also found in its PDF format at **http://www.til.ca** via our general document download program

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RELEASE NOTES

Preliminary release of the FM Radio Guide.

Technisonic FM Radio Guide

Understanding the complex world of airborne tactical communication from installation to operation

Table of Contents

FM Airborne Tactical Radio System Introduction:

(Photo courtesy LASD/Heli-One)

- Getting any airframe to work well with a complex tactical radio system is not a simple process. Airframe limitations in terms of physical space and grounded surfaces, existing ATC and IFR radio system interference, and operational requirements all conspire daily to defeat a working system in some way. It takes care in every step of the process to arrive at a system that is truly functional, with minimal interference, and operationally useful to flight crews when working at their assigned task.

- Every person involved in the ship plays an important role in arriving at a workable system, the airframe OEM, the equipment manufacturer, the completion center, and flight crews. The performance of each one is critical in achieving good over-all system operation.

- It is critically important to understand that as system complexity goes up, performance suffers, and due to physical limitations, it is not possible to have totally non-interfering RF systems in a very limited space with simultaneous operation. It is possible to significantly limit the effects and problems generated by mutually interfering systems, however, so that useful flight is not materially affected.

- **The goal of this publication is to help everyone involved in the process arrive at the best possible result.**

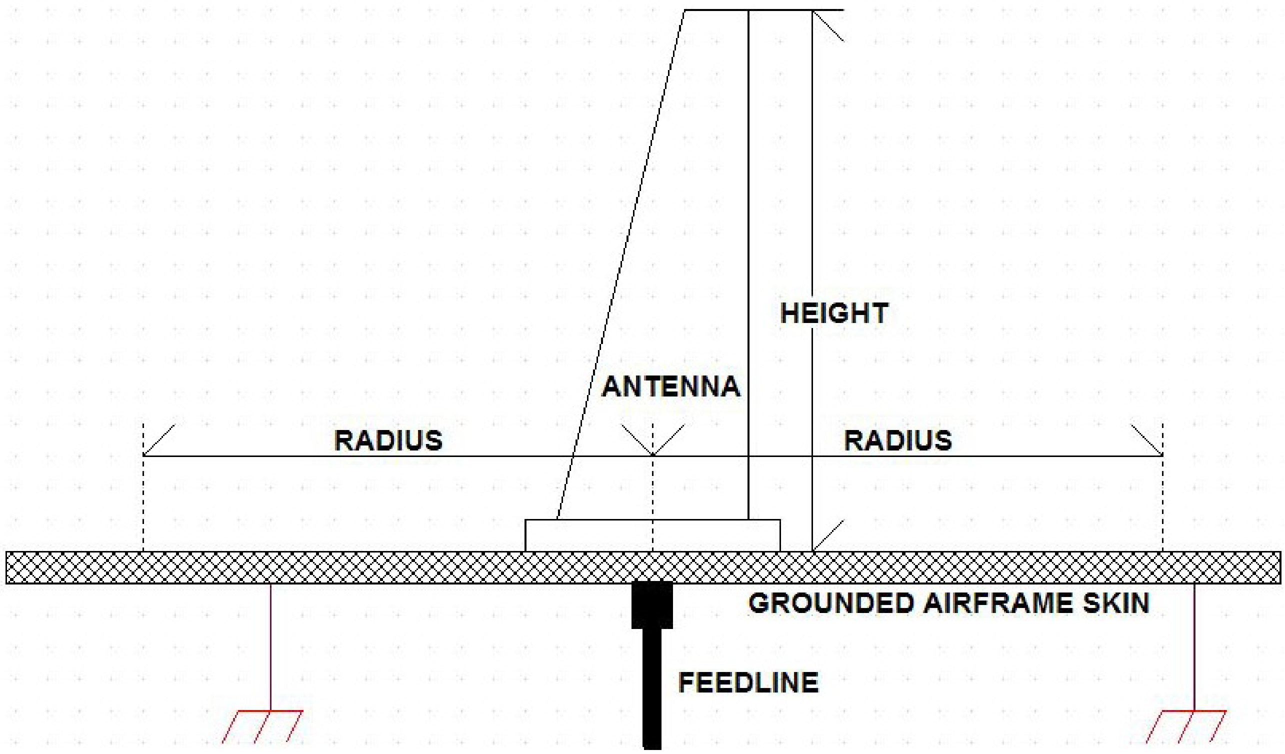
(Photo courtesy Hangar 1)

The first critical step, a well functioning installation…

Installation manuals cover the essential wiring and system interconnect of radio systems, here we will dig deeper into the underlying airframe physics and how it influences the complete radio system operation.

The physical antenna you see projecting from the aircraft is actually only **HALF of the antenna system, the OTHER HALF is provided by the grounded airframe skin**. To be truly effective, the grounded skin around the antenna should be at least equal in RADIUS to the HEIGHT of the antenna itself, as illustrated below:

A Good Antenna Site:



What makes this difficult is that very little unobstructed aircraft skin exists, and furthermore, it may NOT be grounded, but may be a non-conductive, composite material, of no value to us electrically

IMPORTANT:

1. **DO NOT** mount antennas next to windows, chin bubbles, composite covers or other non-grounded areas, this makes proper antenna loading almost impossible, and increases RF interference into other systems dramatically.

2. If an antenna MUST be mounted to a nonconductive cowling or cover, then the cover must be laminated with a suitable inside metal foil or mesh to provide the needed ground counter-poise, and then be bonded to the main airframe ground in at least 3 places with heavy braid. You will have to check any such sites for antenna reflected power both initially, and at 1000 hour inspections for degradation.

3. Every antenna **MUST** be tested for reflected power **using a thru-line wattmeter**, and the site must be corrected **if reflected power exceeds 10% of transmitted power** before an

installation can be released as acceptable. In some cases, Low Band VHF antennas cannot achieve this performance due to tuning physics, and a wider reflected power of up to 15-20% may have to be accepted, this is a physics problem that cannot always be solved in the airframe, when you consider that a ¼ wavelength for these systems is typically over 6 feet.

Typical Thru-line Wattmeters

43 Series **4304A Wideband**

4. **DO NOT** mount antennas **closer together than the required radius**, if you MUST do this, be certain they are **NOT** in adjacent or harmonically related bands. Radio performance will almost certainly suffer in some way for mounting in this manner, and it should not be done unless all other possible avenues have been completely exhausted.

Locations Matter…..

Just as with real estate, antenna location is everything. **What happens if you mount antennas too close together?**

The RF power from an adjacent radio antenna is roughly **100 million times more powerful** than the intended signal you are looking for in the victim system. The sheer power from the offending radio can overwhelm the front end of the victim radio, resulting in unwanted interference (even if **not** close in frequency), or it can dramatically de-sensitize the victim radio, making wanted signals disappear.

What happens if the antenna is obstructed in some direction by skids, lights, PA horns or fuselage area?

The result will be **uneven directional performance**, good in the un-obstructed directions, poor in those blocked by the grounded object in the way. It is quite common for ships to exhibit different TO and FROM ranges depending on how the physical ship is oriented to the station, this is caused by interfering fuselage masking or other obstructions in the way, and is not really fully correctible, it can only be optimized.

Is there a difference between TOP and BOTTOM mounted communication antennas?

Yes, sometimes dramatically so. In Helicopters, top mounted AM Comm antennas suffer from **rotor modulation**, caused by the physical interference of the rotor overhead, sometimes this effect is so dramatic above the cabin, you can actually watch the transmitter reflected power rise and fall as the blades pass overhead. FM Comms are not as severely compromised by this secondary modulation effect, and often ship performance will improve over-all if the AM Comm is bottom mounted, and the FM COM is top mounted.

No satellite-based functions work with bottom-mounted antennas (SATCOM, GPS, XM, etc.) **except by accident**, they must have **a top position**, and on helicopters will inevitably suffer from Mast blocking in some alignment geometries. This is the space-system analog of fuselage masking for bottom mounted antennas.

Further, when parked or landed, the bottom mount antennas (if belly mounted) will not be good performers, although under-side tail boom mounts will still generally be good. Bottom and under-boom mounts work very well in flight, however. Finally, almost no matter where an antenna is sited, it WILL be compromised in some direction to a station, and this must be considered in light of the ship's primary missions. **No physical antenna site is universally optimal; every one is an operational compromise.**

Are some aircraft systems MORE susceptible to interference than others?

YES, close-in navigation systems, such as Glide Slope, Localizer and Marker beacons are usually working with very short range/low level signals, and as a result, they are often easily influenced by adjacent high powered FM Comms, and may be triggered by small amounts of **harmonic emission** or **sheer bulk energy** from closely spaced antennas. **Glide Slope** radios in particular are often not very selective radios, and may use nose-mounted antennas very close to forward mounted, offending FM antennas. Interference has been seem from both Low band VHF and UHF radios into these systems, simply due to antenna proximity. **Always examine the required navigation and VHF AM comm system radios first, and make sure your proposed sites are not a potential conflict**. You may decide to move VHF AM comm antennas to a bottom mount (to improve rotor mod rejection), and site an FM antenna in the top position, especially above the cabin.

Further, **no transmitting RF system antenna** should be placed near (<10 feet) any **magnetic flux valves** that drive an on-board compass/RMI system. Interference both from gross magnetic affects due to internal ferromagnetic components and mounting screws, plus RF interference can be very severe. This interaction is often over-looked initially, and becomes a significant problem later as soon as the radios are used in flight.

Low Band VHF is an especially problematic system for antennas…

Because a **wavelength** in the 30-50MHz range is between **10 and 6 meters in length, a truly effective antenna on any aircraft is difficult to achieve**. It is very awkward to site even a ¼ wavelength monopole (2.5 - 1.5 meters or 8 - 4.5 feet) anywhere, and as a result, most low band antennas resort to either a lossy broadband antenna, a fixed antenna and an external coupler, or a very narrowband mechanically tuned antenna. In all cases, getting both a good antenna match, and efficient transmission is difficult, and it is not uncommon for such antennas to have a –10 to –14dBi antenna factor, or significant signal loss when operating. This is just physics, and very little can be done about it. Even when a coupler is employed, its primary job is to electrically match the woefully undersized antenna during transmission, so that a huge mismatch does not occur, but it can only marginally improve true emission and reception performance. **In addition, the remote coupler also generates some spurious emission of its own**, worsening the chance of unwanted radio interference. Further, use of an outboard tunable **harmonic filter** is typically required for use with these radios in IFR aircraft to suppress unwanted harmonic energy, and avoid unwanted system interference. The elements in this filter are physically too massive to be incorporated within the panel mounted radio system due to the low frequencies involved.

What Exactly is Radio Interference?

When one radio communicates with another **in an unintended way**, that is **interference**.
Any transmitter can theoretically be a source of interference for **any receiver**, but usually the right conditions have to be present, such as tight antenna spacing, bad cable coupling, or harmonic frequency relationships. Also, not all interference is really problematic, such as the odd squelch break, but NAV system interference is serious, and has to be corrected before flight.

It is possible to generalize about how interference appears, but that does not rule out some other way that you may encounter, as interference events often can result from **combinations of effects and circumstances**, and thus the final result you encounter may differ.

When FM radios interfere with AM Comm radios, the results are generally squelch breaking on the AM Comm, and possibly distorted audio, because the modulation formats are not compatible. When harmonically related, the effect will be on very specific channel relationships both in terms of the offending and victim radios. When the effect is caused by bulk power, this is not so well defined, and large band areas may be affected.

When FM radios interfere with NAV aids, the effects may be loss of existing Nav signals and useful navigation, indicator swings that are linked to transmissions, and sometimes garbled or noisy NAV audio. The effect is typically to make the NAV aid unusable. When harmonically related, the effect will be on very specific channel relationships both in terms of the offending and victim radios. When the effect is caused by bulk power, this is not so well defined, and large band areas may be affected.

When FM radios interfere with other FM radios, the result is sometimes distorted audio, or squelch breaking, but is usually harmonically related, from the lower frequency radio to the higher one. The effect will be on very specific channel relationships both in terms of the offending and victim radios. When the effect is caused by bulk power, this is not so well defined, and large band areas may be affected. This can be an antenna or cable coupled problem. In-band interference is also possible when two radios of the same band are installed, just as with AM Comms.

When AM Comm radios interfere with FM radios, the results are typically squelch breaking on the FM radio, and sometimes garbled audio or simply noise. These effects can be harmonically related in which case specific channels on both systems cause the problems, or bulk energy related, in which case the effect is more generalized.

When AM Comms interfere with other AM Comms, the result is usually squelch breaking, and distorted audio, sometimes mis-interpreted as bad side tone. This problem is VERY common, and the antennas MUST be located so they are not in line of sight with each other, such as one top and one bottom mount, etc. Many newer comms even have mutual muting lines to prevent unwanted squelch breaking, because the power levels are high (12-20W), and the probability of mutual interference is also very high. Problems can result from both antenna interference and cable coupling. Keep in mind, these radios can in fact be set to the same frequency, resulting in very loud interference. Interference is usually of the bulk power type, and is not harmonically related.

Troubleshooting Interference problems…

Effective troubleshooting is NOT always possible within a hangar, as ground **reflections** and hangar **reflections** dramatically increase **coupling** in a way that is simply not possible in flight. This is especially true for bottom mounted antennas, so consider this fact carefully when testing. Free space or in-flight testing is always preferred.

Further, some non-radio objects can create their own RF interference when pumped with RF from onboard radios, basically any external diode can do it, which includes powered-off ELT final stages, and other electronics, dissimilar metals and corrosion, loose or badly grounded cowlings and covers and other **seemingly un-related mechanical problems**. These items **can generate RF harmonic content**, which in turn can cause radio interference. **Testing out in open areas is always best.**

The Complex Problem of Harmonics…

Sometimes radios talk to each other and produce interference, even when they are NOT on the same frequency. This can be caused by several mechanisms.

The radios may be **harmonically related**, such as high band (150MHz) VHF and UHF (450MHz), in this case, it is **third harmonic interference**, typically caused by the VHF radio, into the UHF radio. **If dual radios are used IN THE SAME BAND, it is critical to keep them isolated by as much distance as possible**, and preferably site the antennas on opposite sides of the fuselage, to increase RF isolation.

It is important to note that **harmonic interference** is **exact channel interference, and not a general degradation or blanket problem**, it occurs at integer multiples of the problem radio frequency. You can often verify this simply by advancing the victim radio up or down a few channels, and seeing if the problem vanishes.

In the following charts, the range of active frequencies for each radio type and band segment are mapped, along with potential harmonic interference from other radios. **Where radios have data in the same vertical column, it indicates possible interference, and their antennas should NOT be sited closely on the fuselage, or in direct line of sight with each other.**

Note that the **Low Band VHF antenna has the most harmonic overlap of any radio**, and it should be sited away from any other potentially related radio. **As the harmonic number rises, the energy decreases**, so a pairing at the 8^{th} harmonic is not nearly as troublesome as on at the **2^{nd}** or **3^{rd}** harmonic. Note also that the spacing of channels is multiplied as the harmonic rises, so they are farther apart, the harmonic zone is NOT blanketed by continuous emission from the radio, it has **discrete channel data at the fundamental frequency times the harmonic number**. The harmonic levels are typically 60dB or lower from the fundamental frequency. Most of the harmonic content is at the second harmonic, but all harmonics do exist at some level.

Possible Antenna Sites

(Photo courtesy Baltimore City Police Aviation Unit)

RED Arrows show typically good FM Antenna Positions
GREEN Arrows show good VHF AM Antenna Positions

So, What does this all of this really mean for optimizing antenna siting?

Keep as much distance as possible between possibly interfering radios, and ideally place some shielding fuselage between them. Adding the external filter to the VHF Low Band radio is also highly recommended to avoid system interference.

Some important math….

A 5 W FM tactical radio generates a **+37dBm** carrier, so the 2nd harmonic is **60 dB below that**, or equal to a **–23dBm** signal. Since most airborne radios can operate down to the 1-3uV range, this means they are looking for a **roughly –100dBm** signal to break the squelch. To BLOCK the unwanted spurious content from appearing on your victim radio, **you need roughly 77dB of isolation or shielding**, which clarifies why this is a potential problem in the limited airframe space.

5 feet of spacing is only 20dB of signal reduction at 150MHz, which really brings this into perspective! It is only 6dB of signal reduction at 30Mhz. At 330MHz, or the GS area, 5 feet is only 27dB of signal reduction. Clearly, some physical fuselage shielding or filtering between potentially offending antennas is mandatory. You can use the site here:
http://www.worleys.com/ieee80211/conversion.index.html
To do some quick level conversion and loss calculation (.001 mile is 5.28 feet, to get a quick value)

Quick values (rounded off):

Power Levels in dBm:

20W transmitter:	**43**	**dBm**
12W transmitter:	**40.8**	**dBm**
10W transmitter:	**40**	**dBm**
7W transmitter:	**38.5**	**dBm**
5W transmitter:	**37**	**dBm**
3W transmitter:	**34.7**	**dBm**
1W transmitter:	**30**	**dBm**
0.1W transmitter:	**20**	**dBm**

Approximate Free-space signal loss:

50 MHz	**10.5dB/5ft**	**16.6dB/10ft**	**20dB/15ft**
150MHz	**20dB/5ft**	**26dB/10ft**	**29.7dB/15ft**
330MHz	**27dB/5ft**	**33dB/10ft.**	**36.5dB/15ft**
450MHz	**29.7dB/5ft**	**35.7dB/10ft**	**39.2dB/15ft**
1000MHz	**36.6dB/5ft**	**42.6dB/10ft**	**46.1dB/15ft**
1500MHz	**40dB/5ft**	**46.1dB/10ft**	**49.7dB/15ft**
Note:	*5ft =5.28 feet,*	*10ft=10.56 feet,*	*15ft=15.84 feet*

General airframe shielding effect if loss of line of sight, and physical grounded area separates the antennas is **~75-80dB**, if NOT grounded (composite or window in the way), then use the above distance factor loss only.

Airframe Radio Frequency Charts: Fundamental Signals and Unwanted Harmonics

These charts can help you identify potential inter-system problems. Do not co-locate any antennas on the airframe that have the potential for mutual interference as indicated.

Color codes:

Aircraft VFR/IFR Radio (fundamental)	**Airborne FM Radio (fundamental)**	**Harmonic Operation**	***Specific Harmonic Emission***

Note that all radios have MANY harmonics, and all occur at once when transmitting. Harmonic energy from a **transmitter** that appears in the **same vertical column** as another **receiver** should be carefully examined for antenna position on the fuselage, as interference is possible. Note that lower order harmonics contain the most energy.

0-200MHz

Radio	0-50MHz	50-100MHz	100-150MHz	150-200MHz
Marker		**75**		
VOR/LOC			**108-118**	
VHF AM Comm			**118-137**	
Low Band VHF	**30-50**	***60-100 2nd***		
Low Band VHF			***90-150 3rd***	
Low Band VHF				***120-200 4th***
Low Band VHF				***150-250 5th***
Low Band VHF				***180-***
VHF			**136**	**-174**

Both Analog (A) and Digital (D) FM bands are noted.

200-400MHz

Radio	200-250MHz	250-300MHz	300-350MHz	350-400MHz
Glide Slope			328.6-335.4	
Low Band VHF	*150-250 5th*			
UHF AM Comm (Mil)		225-400	225-400	225-400
Low Band VHF	*180-300 6th*	*180-300 6th*		
Low Band VHF		*210-350 7th*	*210-350 7th*	
VHF			*272-348 2nd*	
UHF Low Band D				
Low Band VHF		*240-400 8th*	*240-400 8th*	*240-400 8th*
Low Band VHF			*270-450 9th*	*270-450 9th*
Low Band VHF			*300-500 10th*	*200-500 10th*
Low Band VHF				*330-550 11th*
Low Band VHF				*360-600 12th*

400-600MHz

Radio	400-450MHz	450-500MHz	500-550MHz	550-600MHz
UHF Low Band D	380-470			
UHF Low Band A	403-512			
UHF Hi Band D		450-520		
Low Band VHF	*270-450 9th*			
Low Band VHF	*200-500 10th*	*200-500 10th*		
VHF	*408-522 3rd*	*408-522 3rd*		
Low Band VHF	*330-550 11th*	*330-550 11th*	*330-550 11th*	
Low Band VHF	*360-600 12th*	*360-600 12th*	*360-600 12th*	
VHF				*544-696 4th*

600-800MHz

Radio	600-650MHz	650-700MHz	700-750MHz	750-800MHz
700/800MHz				764-870
VHF	*544-696 4th*	*544-696 4th*		
UHF Low Band D				*760-940 2nd*
VHF			*680-870 5th*	*680-870 5th*

800-1000MHz

Radio	800-850MHz	850-900MHz	900-950MHz	950-1000MHz
DME TX				
700/800MHz	764-870			
UHF Low Band D	*760-940 2nd*	*760-940 2nd*	*760-940 2nd*	
UHF Low Band A	*806-1024 2nd*	*806-1024 2nd*	*806-1024 2nd*	*806-1024 2nd*
UHF High Band D			*900-1040 2nd*	*900-1040 2nd*
VHF	*680-870 5th*			*952-1218 7th*
VHF		*816-1044 6th*	*816-1044 6th*	*816-1044 6th*

1000-1200MHz

Radio	1000-1050MHz	1050-1100MHz	1100-1150MHz	1150-1200MHz
DME TX		962-1213		
DME RX		1025-1150		
Transponder + TCAS	1030 RX	1090 TX		
UHF Low Band A	*806-1024 2nd*			
UHF High Band D	*900-1040 2nd*			
VHF	*816-1044 6th*		*1088-1392 8th*	*1088-1392 8th*
VHF	*952-1218 7th*	*952-1218 7th*	*952-1218 7th*	*952-1218 7th*
UHF Low Band D				*1140-1410 3rd*

1200-1400MHz

Radio	1200-1250MHz	1250-1300MHz	13000-1350MHz	1350-1400MHz
DME TX				
GPS L2 1227.6MHz	+			
UHF High Band D				*1350-1560 3rd*
UHF Low Band A	*1209-1536 3rd*	*1209-1536 3rd*	*1209-1536 3rd*	*1209-1536 3rd*
UHF Low Band D	*1140-1410 3rd*	*1140-1410 3rd*	*1140-1410 3rd*	*1140-1410 3rd*
VHF		*1224-1556 9th*	*1224-1556 9th*	*1224-1556 9th*
VHF	*1088-1392 8th*	*1088-1392 8th*	*1088-1392 8th*	*1088-1392 8th*

1400-1600MHz

Radio	1400-1450MHz	1450-1500MHz	1500-1550MHz	1550-1600MHz
GPS L1 1575.42MHz				+
700/800MHz				*1528-1740 2nd*
UHF High Band D	*1350-1560 3rd*	*1350-1560 3rd*	*1350-1560 3rd*	
UHF Low Band A	*1209-1536 3rd*	*1209-1536 3rd*		
UHF Low Band D				
VHF	*1224-1556 9th*	*1224-1556 9th*	*1224-1556 9th*	

Interference Can Also Be From Raw Power…

Interference can also be caused by **sheer bulk energy**, overwhelming the front end of one radio by another, regardless of frequency, due to antenna proximity. The energy can be >100dB greater than the receiver threshold, far more than the front end rejection of the radio, resulting in unwanted interference. Distance or shielding is the cure, and even small increases in separation can be useful, thanks to the inverse square law.

Cable Interference and Mis-Matches…

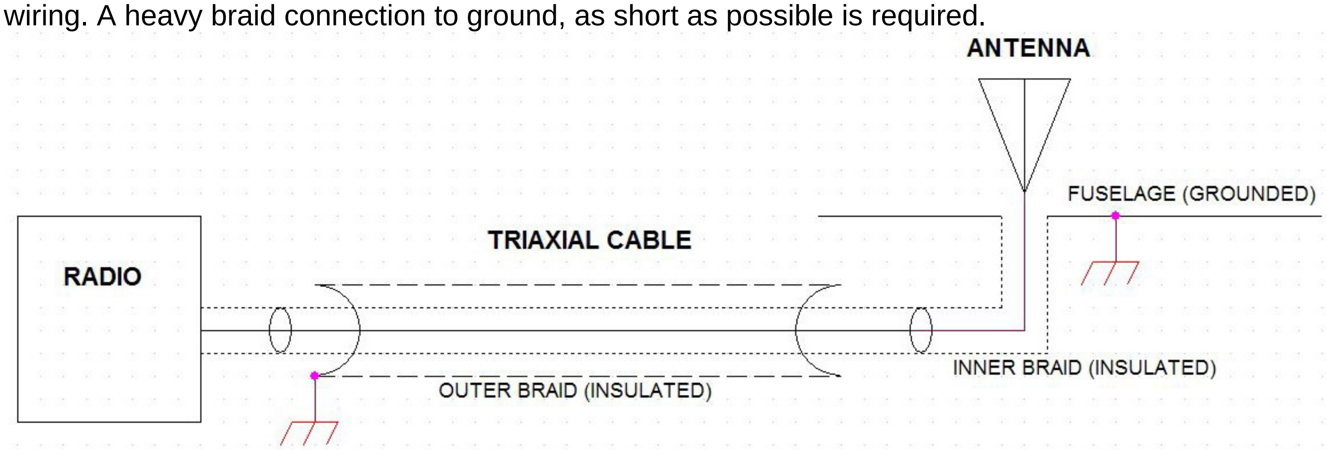
Interference can be caused by spurious emissions and **cable radiation**, caused by severe antenna mis-matches. This can be due to antenna damage, a poor antenna site, corrosion, or use of the wrong antenna, accidentally or through misapplication.

VERY IMPORTANT!

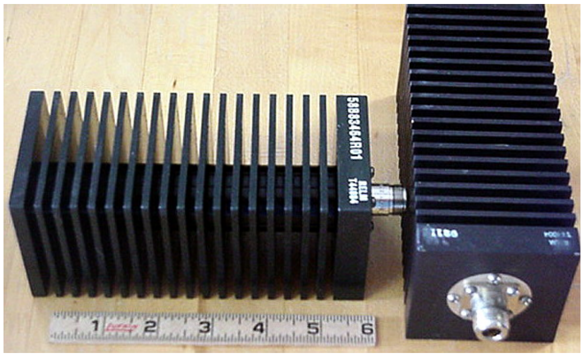
Serious antenna mis-match problems can occur accidentally when cables are removed from the back of a multi-band radio, and are not re-connected to the proper port. Be certain all antenna connections are correct, and work with only one cable at a time to prevent mistakes.

DO NOT bundle coax feedlines together from FM radios, or with any other radio coax cables. Unwanted signal coupling may result, and may be very hard to isolate.

Cable emission can be dramatically reduced by use of **Triaxial cable (TRF58 or similar)**, where the outer shield is terminated at **one end only** (normally the radio end), so it serves as a **true shield (carries no current)**, this grounded shield can help reduce cable coupling when the cables must travel together for mechanical reasons. It is especially helpful on AM Comm radios to reduce radio-to-radio interference, and to prevent AM Comms from injecting RF interference into audio wiring. A heavy braid connection to ground, as short as possible is required.



How to know what to do when interference problems occur…



One of the quickest ways to test for **antenna-generated coupling** is simply to remove the **offending** radio coax from its **antenna**, and connect it to a **shielded, RF 50 ohm dummy load, as pictured at the left**. This will reduce radiated power from the offending radio to almost zero. If the victim radio interference suddenly disappears, you probably have **an antenna coupled RF harmonic or bulk power interference problem**.

You can also differentiate between **cable coupled** and **antenna coupled** problems in this way: if the interference still remains with the dummy load at the antenna end, remove the coax from the radio end, and attach it directly to the dummy load. If interference problems disappear, then they were actually **cable coupled**.

If the interference is frequency selective, and occurs on only specific channel pairs, It is **harmonic interference**. If the problem is more generalized, it is a **bulk power** problem. Distance or intervening skin or fuselage shielding or both are needed to eliminate antenna-coupled interference. In the case of Low Band VHF generated interference, use of the accessory output filter to kill high order harmonics is strongly advised.

The problem can also be caused by **cable coupled interference**, **created by tightly bundling coax cables together of potentially interfering radios together**. If the previous dummy load tests do not solve the problem, or if the problem still remains, but at a lower level then you should suspect this mechanism. Check cable routing, and make sure no offending cables are tied together, even a small amount of separation can be very effective, or triaxial cable (such as TRF58) can be used (with the outer shield grounded at one end only) to reduce this effect where physical distance is not possible.

Note that **bad antenna sites** and large amounts of **reflected power** (and incidentally harmonic generation) make cable coupled and radiated interference **much worse**. Sometimes correcting this problem situation requires several steps, starting with the best possible antenna site and lowest reflected power, and progressing to cable separation.

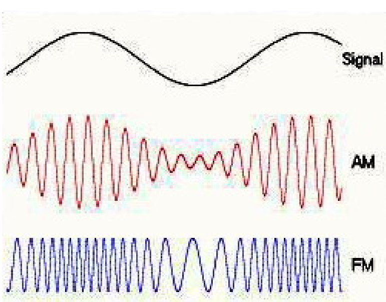
Radio Terms and Concepts

The radio universe is filled with acronyms and jargon just like every other, so here's a quick index of the most important items to help you navigate safely.

ADP™, Advanced Digital Privacy This is a **short key length** (40 bit) proprietary encryption technique from Motorola being offered as an option to **AES** at very low cost on **P25** compliant radios.

AES, Advanced Encryption Standard
This is a US Government adopted specification for the encryption of electronic data. Established by the U.S. National Institute of Standards and Technology (NIST) in 2002, it largely replaces the previous **DES** encryption scheme. **AES** is a symmetric coding scheme (the same key both encrypts and decrypts) and it is the first publicly available cipher that can be used for top-secret data under NSA conditions. Keys can be **128**, **192** or **256** bits in length (**AES-256**), using a 128-bit data block length, with multiple cycle processing required. This is a digital radio technique of high robustness, and is the corner store encryption standard now for new **P25** radio systems.

Agile A radio is referred to as **Frequency Agile** if it can be tuned or programmed for frequency in the field by the user. The aircraft's VHF AM Comm radios are agile radios, because user control of frequency is essential for operation. **Most FM land mobile radios are fixed frequencies** however, because channel assignments are private, and assigned under license. Only Aeronautical FM radios have a special exemption to support this agile tunable mode for public service operation. **Because a radio is agile, it DOES NOT confer the right to operate on every frequency that can be tuned, it merely offers the capability to do so**. Radio operators must be aware of these restrictions when using this type of equipment.



AM or Amplitude Modulation A method for modulating a radio frequency with voice or data signals by changing the **level** or **amplitude** of the carrier frequency. This is the method used by normal aircraft VHF AM Comm radios (118-136MHz). Because the **level** contains the information, these signals are adversely affected by rotor modulation in helicopters, due to its direct effect on the carrier level. This method requires considerable bandwidth, and is no longer widely used except for this aeronautical radio channel task, and simple AM broadcast radio.

APCO, Association of Public Communications Officials **APCO** International is the Association of Public Communications Officials and details about them are found at http://www.apco911.org/about-apco.html They are the originators of the **APCO25** or **P25 standard** now used to describe the requirements for interoperable digital public service/safety radio operations with trunking. The **P25** spec is now administered by the TIA (**Telecommunications Industries Association**), and is now called **TIA-102.**

APCO-16, Project 16

The original **APCO** definition for land mobile radio (**LMR**) **trunking techniques**. Public service radio manufacturers working with Associated Public-Safety Communications Officers (**APCO**) developed the **APCO-16** requirements document for trunked radio systems. It was more of a functional recommendation than a formal standards document, however. **Project 16** describes the characteristics and capabilities of public safety trunked radio systems such as radio channel access times, system priority recognition, data interfaces, system user IDs, network command and control flexibility, future system growth, channel frequency use and over-all reliability.

The problem was the standard was written in a fashion that **allowed compliance with closed proprietary systems**. Hence the resultant **APCO-16** compliant trunking systems included Motorola **SmartNet™** and **SmartZone™**, **EDACS**, and other techniques. The hidden problem with this plan was that radios that were compliant could not always communicate **with each other**.

Base Station

A communication radio, generally located on the ground and with fixed frequency assignments, used for central dispatching and coordination to vehicles and aircraft. This generally has a much larger antenna and more powerful transmitter than airborne radios, because it has no altitude advantage to improve **line of sight** communication, but normally has very limited channel capability.

CTCSS, Continuous Tone-Coded Squelch System

A technique using low frequency tones (below 300Hz) added to the normal radio modulation to allow selective calling or identification of radios. Because they are normally filtered out of the receive audio, they are sometimes called “**sub-audible tones**”. The presence of the tone acts like a key to enable a function, activate the radio’s squelch, or open a repeater path. Tones are not easily understood by flight crews, because their presence or absence is largely invisible to the user, and often communication can be inadvertently defeated because the wrong tone or no tone has been programmed to a specific radio frequency, which can be highly frustrating. There is a digital version of the analog sub-audible tones called **DPL™** or **Digital Private Line™**, this is also a low frequency 3 character code that allows selective calling and control. All TiL radios support this feature.

DES, Data Encryption Standard

An early cryptographic standard developed in the 1970’s that was widely adopted for secure communication by many equipment makers and agencies. Because it had so many key combinations, no synchronizing signals, and the key was never broadcast, it was felt to be very secure. **DES** was also used to encrypt early satellite PAY-TV broadcasts. It was eventually found to be breakable in the late 1990’s due to its (by then) short key length (56 bits) and as a result was largely replaced by **AES** in new secure communications. This was sometimes a very complex system when deployed by the federal government (**DES FS-1027**), with physical keys to enable it, and with secure code loaders, etc., all in an attempt to make it more difficult to circumvent, and to improve physical security of the system components. **GE** called this **DES** system **Voice Guard**, and **Digital Voice Guard**. In radio systems, **DES** was originally set at 9600 baud data rates, but was then extended by **Motorola** to 12.kB and 14.4kB, in **DES II**, making inter-operability difficult between rival **DES** systems. This is an analog radio technique.

DES-XL™ **DES-XL™** was a Motorola format of the original **DES** used with analog radios that allowed the range of the radio to be extended while using encryption. Use of **DES** or **DVP™** reduced the range of radios by about 30%, because digital data errors at marginal reception range cause the decoding to fail. **DES-XL™** overcame this problem and is a legacy encryption format supported in the analog mode. It is incompatible with the original **DES**, but can be locally reconfigured to be **DES** compatible, so a **DES-XL™** encrypted radio has the ability to work in both modes. This is an analog radio technique. Most TiL P25 compliant radios can support this as an optional feature.

DES-OFB™ **DES-OFB™** is another **DES** encryption variant that includes Output FeedBack for error correction, and was the initial **P25** encryption scheme proposed, later replaced by **AES** with longer key lengths. Most TiL P25 compliant radios can optionally support this feature.

DPL™, Digital Private Line See **CTCSS** for operational details. Originated by Motorola, also called **CDCSS** (**Continuous Digital-Coded Squelch System**) or **DCS** codes, and **Digital Channel Guard** by GE. There are more **DPL** codes possible in the allotted audio bandwidth (below 300Hz) than sub-audible tones, so it provides individual calling or selection in larger radio fleets, allowing many channels or groups to be made available to users privately. Most TiL analog and digital radios support this as a standard feature.

DTMF, Dual Tone Multi-Frequency DTMF tones are the **audible tone pairs** you hear when you use a **touch-tone phone**. They are sometimes used for discrete signaling or dialing via a radio link, and can have many control functions within a network, although none are standardized outside of the telephone world.

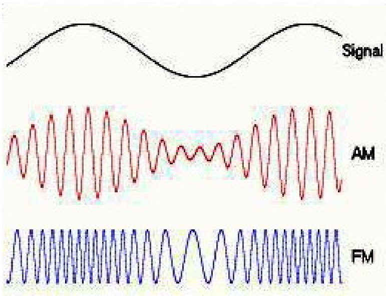
Duplex Radio operation where the **transmit** and **receive** frequencies are different, typically over a repeater network. **Full Duplex** operation means the split frequency functions can occur at the same time (RX and TX), **Semi-Duplex** means the transmit function is press-to-talk, and only one mode at a time is possible. Duplex operation is sometimes also called **Repeater** operation, because that is the most common application of it. Sometimes there is a subset of Repeater operation called **Direct** (radio to radio) **Simplex** operation, as well as a long distance **Duplex** or **Repeater** channel. It is important to remember that the radio's assignments (RX and TX) are backwards relative to the repeater!

A Typical Channel Example

	Simplex or Direct	Duplex or Repeater
Radio RX Frequency	156.50MHz	156.50MHz
Radio TX Frequency	156.50MHz	151.50MHz
Repeater RX Freq.	N/A	151.50MHz
Repeater TX Freq.	N/A	156.50MHz

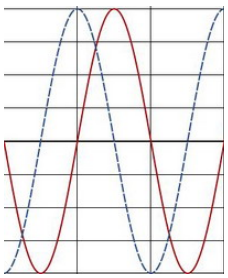
EDACS™, Enhanced Digital Access Communications System A fault tolerant, large-scale trunking system developed originally by GE in competition with Motorola's **SmartNet™**. If a device or channel stopped working, the remaining devices in the network voted, and could remove it if found to be defective. The remaining units could then continue to carry the network traffic around it, similar to how the Internet functions.

This technology passed on to Ericsson-GE, then Comm-Net Ericsson, then M/A-Com and currently Harris RF. Not all versions of **EDACS™** are compatible with each other, as this technology has been in place for some time. It exists in VHF, UHF and 800/900MHz frequency bands, and in both 12.5kHz (narrowband) and 25kHz (wideband) formats. TiL radios are **not** currently compatible with **EDACS™** systems.



FM or Frequency Modulation

A method for modulating a radio frequency with voice or data signals by slightly changing the **frequency of the carrier frequency**. This is the method used by extensive land mobile and public service communication in a very wide range of frequencies, and for broadcast FM stereo radio. Because the carrier **level** contains NO information, these signals are largely un-affected by rotor modulation in helicopters. This method requires very little bandwidth, and so permits very tight channel spacing and high spectrum utilization, but as a result, also requires very tight frequency control, far beyond typical AM radio requirements.



Frequency

Radios operate on a **specific frequency**, usually specified in **Megahertz** (millions of cycles per second or **MHz**). Many different modulation methods can be used on any given frequency, plus other signaling like sub audible tones or **DPL** codes, which can also be expressed as frequencies, usually in **Hz** (**Hertz**) or **kHz** (**Kilohertz**). The **frequency** is the primary piece of information about any radio channel.

Guard or Guard Frequency

A continuously monitored receiver (usually operated in tandem with the main receiver) that is used for receiving key incoming information, emergency or dispatching data. It can be a scanned channel, or a complete secondary receiver, depending on the radio design and user requirements. There can be more than one guard channel, and also an automatically associated TX channel paired with it.

Hz, Hertz

Frequency expressed in **cycles per second** (abbreviation). Usually audio or sub-audible frequencies, like 141.3Hz.

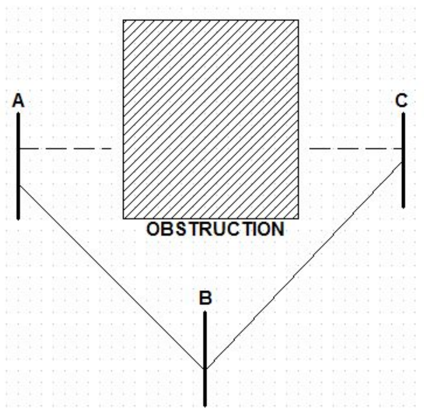
Key

A **key** is the **cryptographic code** that allows you to unscramble a digital radio transmission. The key **strength** is usually expressed in terms of bit length, such as 56, 128, 192 or 256 (binary) bits long. The required key can be present in many ways, it can be hand or computer loaded into the radio system, supplied over the air via an **OTAR** transmission technique, or via a specialized keyloader in the case of DES FS-1027. Without the **decryption key**, a secure digital radio is useless, even if it can tune to the correct frequency. Control of **keys** is a highly secure operation, and is carefully managed, and frequently changed to keep it from being compromised.

kHz, Kilohertz

Frequency expressed in **thousands of cycles per second** (abbreviation). Usually audio frequencies, like 2.5kHz.

Line-of-Sight This refers to the geometry between antennas, if they can see each other (regardless of distance) with no intervening obstructions, we say there is a **line of sight path** between them, and signal coupling will be high. The earth's curvature provides a built in line of sight cut-off of roughly 7 miles. Very High frequency radio waves (VHF and above) are limited to line of sight propagation (**this is why radio range is so dramatic when airborne, the line of sight can be very long when at altitude**). Lower frequencies (to 30MHz) propagate as ground waves, and can travel much longer distances, as they do not require line of sight alignment. The higher the frequency, the closer its propagation matches that of light. In the example below, propagation will be good from A to B and B to C, but **bad from A to C**.



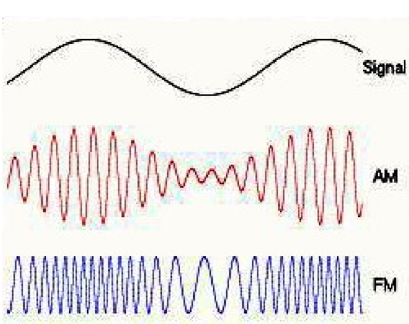
Obstructions can be mountains, buildings, aircraft fuselage structure, canyons, or **anything** that is grounded and interrupts the straight path of radio transmission.

This concept is important when siting antennas on the airframe, as you need to avoid a line of sight path between antennas that may be on the same, close or harmonically related frequencies. **The curvature of the airframe, fuselage, mast or tail boom can all provide important shielded obstructions to interrupt the line of sight between antennas, and keep unwanted coupling to a minimum.**

LMR, Land Mobile Radio Also called **Public Land Mobile Radio** or **Private Land Mobile Radio**, it is a radio communication system for terrestrial users both in vehicles (mobiles) and on foot (portables). These systems can be used for emergency services, public works, company and fleet communication. Tactical Airborne FM radios are designed to communicate with **LMR** systems used by public service and other organizations on the ground.

MHz, Megahertz **Frequency** expressed in **millions of cycles/second**, (abbreviation). Usually radio frequencies like 118.5MHz or 168.625MHz.

Microwave(s) This generally refers to frequencies **above 1GHz** (1,000MHz). Aeronautical services like Transponder, DME and GPS are all microwave frequencies. In this frequency range, cable losses, skin effects, cable bends, connector attachments and mechanical resonance all become supercritical. Losses in even 5 feet of coax cable can be extreme.



Modulation The signal or data that is added to a radio carrier frequency is **modulation**, which can be in many forms, **AM** (through a change in level of the carrier), **FM** (through a change in frequency of the carrier), and others. The modulation is the **useful part of the radio signal we extract for communication**.

Multi-Key™

Multi-key™ is an advanced feature of encryption-capable radios from Motorola. **Multi-key™** operation allows an encrypted radio to accept multiple decryption keys. These unique keys can be programmed on a channel by channel basis or manually assigned from the front panel by the user. Most TiL **P25** radios can support this as an option.

Narrowband

In radio terms, this refers to a **channel spacing** tighter than **20kHz**, so **12.5kHz** is a typical **narrowband** channel spacing. Future developments in narrowband technology are expected to result in channels only **6.25kHz** apart.

NAC, Network Access Code

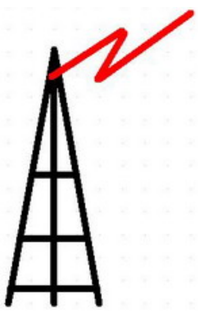
Another **P25** non-trunked system code similar to tones, expressed as decimal or Hexidecimal numbers, used in conjunction with **Talkgroups**.

Non-Volatile Memory (NOVRAM)

This is data storage within the radio system that can retain channel frequency data and other information, even with no power present. It can be re-programmed, off-loaded and erased under user control.

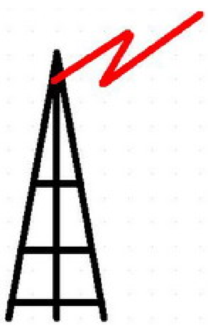
Open Sky™

This is a Harris RF **trunking** scheme that combines data and voice in a Voice-Over-IP (VOIP) protocol. Originally developed for FedEx, it has been used in several wide-area LMR radio networks. TiL radios are **not** compatible with this format.



OTAP, Over The Air Programming/Provisioning

Radios with this option are capable of having the **channel frequency** information reprogrammed over the air, and even operating firmware. This feature eliminates the need to have a technician manually service the radios when the programming or other information must be updated. This process works on a radio ID basis, so stolen or unauthorized radios can be automatically excluded from the secure network. This is a digital radio technique, supported as an option in most P25 TiL radios.



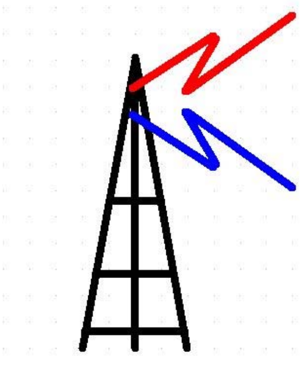
OTAR, Over The Air Re-Keying

This is a method for sending new **encryption keys** via radio transmission from a secure source to a remote radio. This process works on a radio ID basis, so stolen or unauthorized radios can be automatically excluded from the secure network. This is a digital radio technique. Most TiL P25 radios can optionally support this function.

P25, Project 25 or APCO 25

This is the umbrella specification that describes the capabilities and hardware requirements for secure digital radio systems, and backwards-compatible analog legacy capability. It was created originally to make an FM, narrow-band, encrypted, trunked digital radio standard that member manufacturers could follow to make a widely acceptable system for use by all public agencies and emergency services. Radio equipment that demonstrates compliance with P25 is able to meet a set of minimum requirements to fit the needs of public safety. The published P25 standards suite outlines the P25 requirements for certain optional features such as Trunking and encryption. So while a P25 compliant radio must meet the common air interface standard and be capable of talking with all other P25 radios in the conventional mode, P25 radio using optional features can only communicate with other P25 radios supporting those same features. The Project 25 standard was designed with interoperability in mind, but manufacturers can also introduce additional proprietary features only available on their specific radios if they choose. TiL radios designated P25 compliant are fully compatible with the P25/TIA-102 standard.

Relay Operation Tactical radios can be configured to transfer communication from one band (say a ground handheld UHF portable) to a main dispatching VHF radio system. This is a useful tool at emergency sites and when inter-agency communication is required but radio services are physically different. See also **Repeater** and **Simulcast**.



Repeater A repeater is a radio (usually at a strategic height), which can take a transmission from one user, and repeat it to another who could not normally get it due to an insurmountable obstruction like a mountain. Mountaintops are a favorite location for repeaters, and they can allow two groups in isolated valleys to communicate when **line of sight propagation** would be impossible. Aircraft can also serve as mobile repeaters during firefighting and other emergencies, and can even function as **Cross-Band Repeaters**, linking one radio type to another (**VHF** to **UHF** for example) to allow different agencies with different radio types to communicate with each other.

RX **Receive** (abbreviation).

Scanning Is a technique that allows an agile radio to quickly re-channel through a number of channels (scan list), looking for active communication. It can have complex features like specific channel priority, multiple lists, and so forth. For this to work, the radio must be able to lock the synthesizer very quickly, check for a carrier, then re-channel and repeat this process.

Simplex In simplex radio operation, the receive and transmit frequencies are the **same**. This is some times called **Direct** mode. See also **Duplex**.

Simulcast This is a technique where **radios transmit on more than one band at a time,** such as VHF and UHF, so that two groups can get the same messages at the same time, without delay. This is a common requirement where different agencies or services are working on a common emergency site. See also **Repeater** and **Relay** operation.

SmartNet™ This refers to a set of proprietary features that make Motorola Type I and II trunked systems, **APCO-16** compliant. These include better security, emergency signaling, dynamic regrouping, remote radio monitoring, and other features. These are the key features of a Type II **SmartNet™** system:

- Up to 28 system Channels
- Up to 65,534 Unique Radio IDs
- Up to 4,094 **Talkgroups**
- Use of odd-numbered **Talkgroups**
- Priority Scanning of **Talkgroups**

Most TiL radios designated P25 compliant can have this as an option.

SmartZone™ These are Motorola Type II systems that are networked together via microwave or land-line data circuits to provide multi-site, wide-area communication. Many large public safety and state agencies use **SmartZone™** systems for wide-area communications much like a private cellular network.

The characteristics of a Motorola **SmartZone™** system are similar to **SmartNet™** systems but with these differences:

- Up to 28 channels per Site
- Up to 64 sites (older Zone Controller versions were limited to 48)
- Analog and/or Digital Voice and/or Analog/Digital encryption.

Most TiL radios designated P25 compliant can have this as an option.

SQ or Squelch

This is the threshold set in the radio that suppresses background noise until a valid incoming signal is present, and at which point, receive audio is heard. There are several methods for this technique, and most also provide a manual SQ or Squelch panel button to over-ride the threshold, and allow you to listen, regardless of signal conditions (usually you hear background noise when this button is pressed).

Sub-Audible Tones

See **CTCSS** for full details.

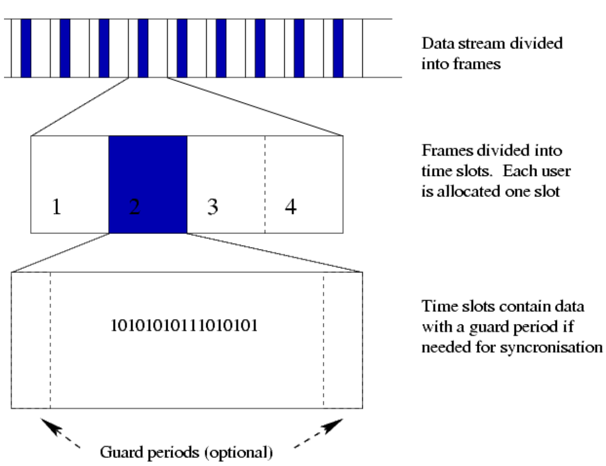
Synthesized

Synthesized radios use a digital technique (Phase-Locked Loop or Direct Digital Synthesis) to generate the tuning (Local Oscillator Injection and Tracking Pre-selector) required for both **receive** and **transmit** frequencies. Channel data can be synthetically generated based on a specific channel interval and frequency band. This differs from crystal-controlled radios, which can have only one frequency per crystal, a common technique in early land mobile and base station radios, where only one or two frequencies were permitted under license. If the synthesizer is fast to lock on a new frequency, then it can also **scan** frequencies as an operating function.

Talkgroups

Talkgroups are logical groupings of users, on a regular or **trunked** radio network. This technique allows groups of users to dynamically get as much channel space as needed at any specific moment, rather than rigidly assigning them to a specific frequency for their task. The **talkgroup** shares a common channel or trunked system in this way:

- In conventional analog systems, the **talkgroups** that share single channels are separated by **CTCSS** tones or **DPL** codes.
- In **P25** they are separated by **NAC** codes and **talkgroup** codes. The radio PTT is locked out when the shared channel is busy when another **talkgroup** is using it. If the channel is not busy then the radio can be keyed. In a trunked system, the shared resource is a set of channels rather than one and the **talkgroup** control is handled by the system infrastructure.



TDMA, Time Division Multiple Access

TDMA is a radio channel access technique that allows many users to share a **single frequency or channel** by dividing the signal into individual, synchronized, **time slots**. The individual users transmit in their assigned time slot, greatly increasing the utilization of the channel. **TDMA** technology is used in the 2G cellular network, the **GSM** (Global System for Mobile Communications) cellular network and many satellite and military tactical systems. Timing is very difficult to control if the objects are moving quickly, so this is not an ideal technology for aircraft use. TiL radios do not currently support **TDMA** operation, but release is planned for 1Q/2Q 2013.

TETRA, Terrestrial Trunked Radio

TETRA is the European functional equivalent of the North American **P25** public service / emergency service network trunking structure, an **ETSI** European Telecommunications Standards Institute standard. **TETRA** is a **TDMA** based trunking system with **4 user channel slots** in each 25kHz spaced carrier. Normally based in lower frequencies than P25 trunking (low band 380-450MHz **UHF**), it can have better mobile unit range, and very good spectrum utilization, but has lower data rates than P25. Unlike many **TDMA** techniques, it can work at high physical speed (up to 500km/h), and so it is very feasible for airborne use. Not currently supported in TiL **P25** radios, but **TETRA** is planned for future development.

TIA, TIA-102

The **P25** spec is now administered by the TIA (**Telecommunications Industries Association**), and is now called **TIA-102. You can find them here:** http://www.tiaonline.org/

Tones

See **CTCSS** for details.

Trunking

To allow more independent users to communicate at one time using a specific number of channels over a wide area, a scheme called **Trunking** is used. A **trunked** system will have several repeater channels on a tower, and towers throughout the operating area. One channel is dedicated as a **control channel.** At idle the **trunked** user radio will monitor the **control channel** in case a call comes in on its assigned **talkgroup**. The **control channel** will address the **user radio** and command it to go to a particular channel in the system to receive the voice (or data) traffic. Once the traffic has been passed, the user's radio goes back to the control channel again. If a user wants to make a call, when he keys the radio, it makes a request to the controller to contact other radios in its group. The controller directs the radio to next available RF channel, and calls the other radios to the same channel. Then it gives the user a **go ahead tone to start talking**. When the user is done talking, the radio is un-keyed and goes back to the control channel to wait for further instructions. Channels are assigned on a **next available basis**. So it is possible on a busy **trunked** system that every transmission that is made may use a different channel, to maximize usable radio network capacity. It resembles a **cellular** network, but is driven by the PTT or press-to-talk commands of the user's **trunked** radio. Trunking is used in North America in these bands: **VHF** 136-174MHz, **UHF** 406-512MHz, 764-870 MHz. And 928-960 MHz (utility), although most of the **trunked** systems deployed are in the 764-870MHz band.

TX

Transmit (abbreviation).

UHF

Ultra High Frequency (abbreviation), generally refers to those frequencies above 200MHz, and ending at 1000MHz or 1GHz. Most common UHF designated frequencies are 380-512MHz, the zones higher up are now often given unique names like 800MHz for better user clarity.

uV

Microvolt (abbreviation), a measure of signal strength, **one millionth of a volt**. Typical FM radio sensitivity extends down to 1uV or even lower, VHF AM Comms generally have a sensitivity of 3uV.

VHF

Very High Frequency (abbreviation), generally refers to those frequencies from 30MHz to 200MHz. Common VHF aeronautical bands are **30-50MHz-FM** (optionally 60-88MHz), **118-136MHz-AM** and **136-174MHz-FM**.

VGE™, Voice Guard Encryption

This is **GE's** enhanced version of the **DES** encryption scheme, using a key with increased length. It is not compatible with their standard **DES** or **DVG™** (**Digital Voice Guard**), but differs only in key length.

Wideband

In radio terms, this refers to channel spacing of **20kHz or greater**.

COAX CABLE LOSS TABLE (note, power is cut in half for each 3dB of loss)

Frequency	M17/28- RG-58C (+triax)	M17/84- RG-223/U	M17/60- RG-142
30MHz	2.47dB/100ft	2.14dB/100ft	2.05dB/100ft
50MHz	3.20dB/100ft	2.78dB/100ft	2.66dB/100ft
120MHz	5.01dB/100ft	4.36dB/100ft	4.18dB/100ft
160MHz	5.82dB/100ft	5.06dB/100ft	4.85dB/100ft
225MHz	6.94dB/100ft	6.04dB/100ft	5.79dB/100ft
400MHz	9.38dB/100ft	8.18dB/100ft	7.84dB/100ft
500MHz	10.56dB/100ft	9.21dB/100ft	8.82dB/100ft
800MHz	13.57dB/100ft.	11.87dB/100ft	11.37dB/100ft
1000MHz	15.30dB/100ft	13.40dB/100ft	12.84dB/100ft

You can make any cable calculation at this site:
http://www.timesmicrowave.com/cgi-bin/calculate.pl

Cable losses are significant as frequency rises, so if is useful to keep the highest frequency antennas closest to the radio, and to use the lowest loss cable for the longest runs. UHF and above must be carefully cabled, to prevent serious power loss.

(Photo courtesy Hangar One)

Technisonic Tones/DPL Codes Reference Tables

CTCSS/PL/MOT Codes (Digital Radios)

PL(Hz)	MCODE
67.0	XZ
69.3	WZ
71.9	XA
74.4	WA
77.0	XB
79.7	WB
82.5	YZ
85.4	YA
88.5	YB
91.5	ZZ
94.8	ZA

PL(Hz)	MCODE
97.4	ZB
100.0	1Z
103.5	1A
107.2	1B
110.9	2Z
114.8	2A
118.8	2B
123.0	3Z
127.3	3A
131.8	3B
136.5	4Z

PL(Hz)	MCODE
141.3	4A
146.2	4B
151.4	5Z
156.7	5A
162.2	5B
167.9	6Z
173.8	6A
179.9	6B
186.2	7Z
192.8	7A
203.5	M1

PL(Hz)	MCODE
206.5	8Z
210.7	M2
218.1	M3
225.7	M4
229.1	9Z
233.6	M5
241.8	M6
250.3	M7
254.1	OZ
CSQ	CSQ

CTCSS/PL Codes (Analog Radios)

TONE #	PL (HZ)
0	CSQ
1	67.0
2	71.9
3	74.4
4	77.0
5	79.7
6	82.5
7	85.4
8	88.5
9	91.5
10	94.8

TONE #	PL (HZ)
11	97.4
12	100.0
13	103.5
14	107.2
15	110.9
16	114.8
17	118.8
18	123.0
19	127.3
20	131.8
21	136.5

TONE #	PL (HZ)
22	141.3
23	146.2
24	151.4
25	156.7
26	162.2
27	167.9
28	173.8
29	179.9
30	186.2
31	192.8
32	203.5

TONE #	PL (HZ)
33	33.0
34	35.4
35	36.6
36	37.9
37	39.6
38	44.4
39	47.5
40	49.2
41	51.2
42	53.0
43	54.9

TONE #	PL (HZ)
44	56.8
45	58.8
46	63.0
47	69.4
48	150.0
49	165.5
50	171.3
51	177.3
52	183.5
53	189.9
54	196.6

TONE #	PL (HZ)
55	199.5
56	206.5
57	210.7
58	218.1
59	225.7
60	229.1
61	233.6
62	241.8
63	250.3
64	CSQ

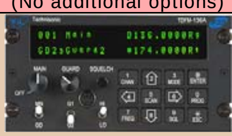
DPL/DCS Codes

023	072	152	244	343	432	606	723
025	073	155	245	346	445	612	731
026	074	156	251	351	464	624	732
031	114	162	261	364	465	627	734
032	115	165	263	365	466	631	743
043	116	172	265	371	503	632	754
047	125	174	271	411	506	654	
051	131	205	306	412	516	662	
054	132	223	311	413	532	664	
065	134	226	315	423	546	703	
071	143	243	331	431	565	712	

Aircraft Radio Communication Bands:

Frequency	Normal Modulation	Name & Details	Channel Spacing
30-50MHz	FM	Low Band VHF	12.5 / 25kHz
66-88MHz	FM	Low Band VHF (Export)	12.5 / 25kHz
118-136MHz	AM	VHF (high band) AM Aeronautical	25kHz
136-174MHz	FM	VHF High Band	12.5 / 20 / 25 / 30kHz
225-400MHz	AM	UHF AM Aeronautical (Military)	25kHz
380-470MHz	FM	UHF Low Band	12.5 / 20 / 25kHz
450-520MHz	FM	UHF High Band	12.5 / 20 / 25kHz
764-870MHz	FM	700/800MHz	12.5 / 20 / 25kHz

Technisonic P25 Compliant Radios (2012)

TECHNISONIC MODEL	VHF LO	VHF HI (!)	UHF LO (!)	UHF HI (!)	700-800 MHz (!)	# of Radios	Memory Locations	Guard RX	Disp. Lines	Height [inch]	WT.	Temp. Range
 **TDFM-7300** Analog/Digital/Encrypted Trunked/ Multi-band FM **Options: see below+**	**30-50** Analog Only	**136 to 174**	**380 to 470**	**450 to 520**	**764 to 870**	**5/1**	**1000 ch/band (200 ch for VHFLO)**	**No Scan only**	**6**	**4.5”**	**6.0 Lbs 2.7 Kg**	**-30C/ +60C (Short term +70C)**
 **TDFM-7000** Analog/Digital/Encrypted Trunked/ Multi-band FM **Options: See below+**		**136 to 174**	**380 to 470**	**450 to 520**	**764 to 870**	**4/1**	**1000 ch/band**	**No Scan only**	**5**	**3.75”**	**6.0 Lbs 2.7 Kg**	**-30C/ +60C (Short term +70C)**
 **TDFM-6000 (+AMS6000)** Analog/Digital/Encrypted Trunked/ Multi-band FM **Options: see below+**		**136 to 174**	**380 to 470**	**450 to 520**	**764 to 870**	**4(*)**	**1000 ch/band**	**No Scan only**	**2**	**3.0"**	**4.2 Lbs 1.9 Kg**	**-45C/ +50C**
 **TDFM-636** Dual VHF FM Transceiver (No additional options)		**136 to 174**				**2**	**1000 ch**	**No Scan only**	**2**	**3.0"**	**4.2 Lbs 1.9 Kg**	**-45C/ +60C**
 **TDFM-136A (-136 Discont.)** Digital/Analog VHF FM (no additional options)		**136 to 174**				**1**	**230 ch**	**Scan + 2ch syn.**	**2**	**3.0"**	**3.5 Lbs 1.6 Kg**	**-45C/ +70C**

+ Additional Optional Features such as AES, DES-XL™, DES-OFB™, Mulit-Key™, OTAP, OTAP, P25 Trunking, SmartZone™ Trunking, and SmartNet™ Trunking are available as additional charge options for these specific radios (except on Low Band), at time of order.

Additional Notes:

1. All Radios Operate at 28VDC +/-15% , are DZUS mounting (5.75” wide.
2. All have FCC/IC approvals EXCEPT 66-88MHz, which are for export only.
3. **(!) P25** Frequency modules can be in **any combination** in the radio.
4. Modular-based radio channels are **now upgraded to 1000 total**, 255 max./zone, ***older units will have reduced capability***. Early units also have slightly narrower frequency ranges per module.
5. Radio shown as **3/1**, **2/1** etc. can work EITHER as independent radios **OR** as a single multi-band radio, depending on the system interconnect. **(*)** needs an **AMS6000** for single radio operation.
6. TDFM7000 is essentially the AMS6000 and TDFM6000 combined into a single unit. The TDFM-6000, 7000 and 7300 can have **UP TO** the number of radios shown, the TDFM-7300 can have Lo band + 4 modules, 5 in total.

Technisonic Analog Radios

TECHNISONIC MODEL	VHF LO	VHF HI	UHF	# of Radios	Memory Locations	Guard RX	Disp. Lines	Height	Weight	Temp. Range
 **TFM-566** VHF Hi/Lo band FM Transceiver (export only)	66 to 88	138 to 174		2 / 1	400 ch total	Scan + 2ch syn	4	3.75”	5.1 Lbs (2.3 Kg)	-45C / +70C
 **TFM-556** UHF + VHF Hi/Lo band FM. (export only)	66 to 88	138 to 174	403 to 512	3 / 1	600 ch total	No Scan only	4	3.75”	5.2 Lbs (2.4 Kg)	-45C / +70C
 **TFM-550** UHF, VHF Hi/Lo band FM	30 to 50	138 to 174	403 to 512	3 / 1	600 ch total	No Scan only	4	3.75”	5.1 Lbs (2.3 Kg)	-45C / +70C
 **TFM-530** VHF Hi/Lo band FM	30 to 50	138 to 174		2 / 1	400 ch total	Scan + 2ch syn	4	3.75"	5.1 Lbs (2.3 Kg)	-45C / +70C
 **TFM-500** VHF/ UHF FM		138 to 174	403 to 512	2 / 1	400 ch total	Scan + 2ch syn	4	3.75"	4.7 Lbs (2.2 Kg)	-45C / +70C
 **TFM-403** UHF FM			403 to 512	1	120 ch	2ch syn.	2	3.0"	3.1 Lbs (1.4 Kg)	-45C / +70C
 **TFM-138D** **(DF Signal Output)** VHF/FM (DPL Standard)		138 to 174		1	120 ch	Scan + 2ch syn	2	3.0"	3.1 Lbs (1.4 Kg)	-45C / +70C
 **TFM-138B** VHF/FM (DPL Standard)		138 to 174		1	120 ch	Scan + 2ch syn	2	3.0"	3.1 Lbs (1.4 Kg)	-45C / +70C

 **TFM-138** VHF FM (No DPL)		138 to 174		1	100 ch	Scan + 2ch syn	2	3.0"	3.1 Lbs (1.4 Kg)	-45C / +70C
 **TFM-66** VHF Lo Band FM (export only)	66 to 88			1	120 ch	Scan + 2ch syn	2	3.0"	3.1 Lbs (1.4 Kg)	-45C / +60C
 **TFM-30** VHF Lo Band FM	30 to 50			1	120 ch	Scan + 2ch syn	2	3.0"	3.1 Lbs (1.4 Kg)	-45C / +70C

FM Radio Remote Control Units

			
RC-7000	**RC-6000**	**RC-7300**	**RC-500 / 550**

Technisonic radios have essential harness compatibility, and many types can be upgraded in place with little or no harness changes, except for adding any additional radio interconnects.