RMX-2400

Radio & Multipoint Leased Line Modem

- 1200 & 2400 Baud
- Supports 2-wire Leased Telephone Lines
- Multidrop & Point-to-point operation
- Supports most audio radios with "Push-To-Talk"
- Message collision protection
- All software setup - NO POTS
- Easy Setup: No special programs
- Audio Monitor Jack
- Wide Input Power Range
- Wide Operating Temperature Range
- 3-year Factory Warranty

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Overview

The RMX-2400 modem is a multi-functional communication device. It is designed for the remote telemetry system with multiple sites communicating via audio radio or "dry" (no PBX) telephone leased-line in a multi-drop configuration.

The RMX-2400 has the following features:

- 1200 or 2400 baud modem operation.
- 9600, 4800, or 2400 baud RS-232 port operation.
- Audio data monitor jack (0 - 250 mV_{RMS}).
- Leased-line or radio audio interface.
- Radio trunking or non-trunking Mode.
- 10 mV_{RMS} – 1.27 V_{RMS} audio input. (Data Input)
- 30 mV_{RMS} – 1.27 V_{RMS} audio output. (Data Output)
- Built-in Push To Talk capability (active low).
- 0 – 2.55 seconds lead delay and trail delay.
- 0 – 2.54 seconds packet character gap detection.
- Internal or external carrier detect (active-high and active-low configurable).
- Software configurable (no trim pots).
- Non-volatile EEPROM memory.
- Built-in tone test generator.
- Built-in intelligent error detection.
- Half or full duplex operation (media dependent).
- Small footprint and rugged design.
- 10 – 30 Vdc power supply.

Operation and Configuration Considerations:

The RMX-2400 modem is a packetizing device that uses a micro-controller to transfer data between the DCE (Data Communications Equipment) port and modem port. This offers several advantages over a conventional serial device:

- Automatic Lead and Trail Delay for Push To Talk (PTT) control.
- Lower audio baud rates for equipment with limited bandwidth.
- Data packetizing for better error rejection.
- Serial hardware handshaking independent.
- Collision control at modem level.
- Fully software configurable.
- Configuration can be carried out at startup by DTE.
- Rejects messages from other types of systems and modems.

Some of the disadvantages are:

- 232 byte packet limit.
- Incompatible with other conventional modems (including Bell 202).
- DTE (Data Terminal Equipment) device must be tolerant of longer delays than the communication equipment would normally incur.

Example of a Typical SCADA Application.

Figure 1 illustrates a typical SCADA system with a Master communicating to three slave RTU's via the RMX-2400's radio interface. A leased-line configuration differs only in the medium used to communicate to other modems. In a leased line configuration, a "Dry Pair" of wires would be used in a multi-drop configuration.

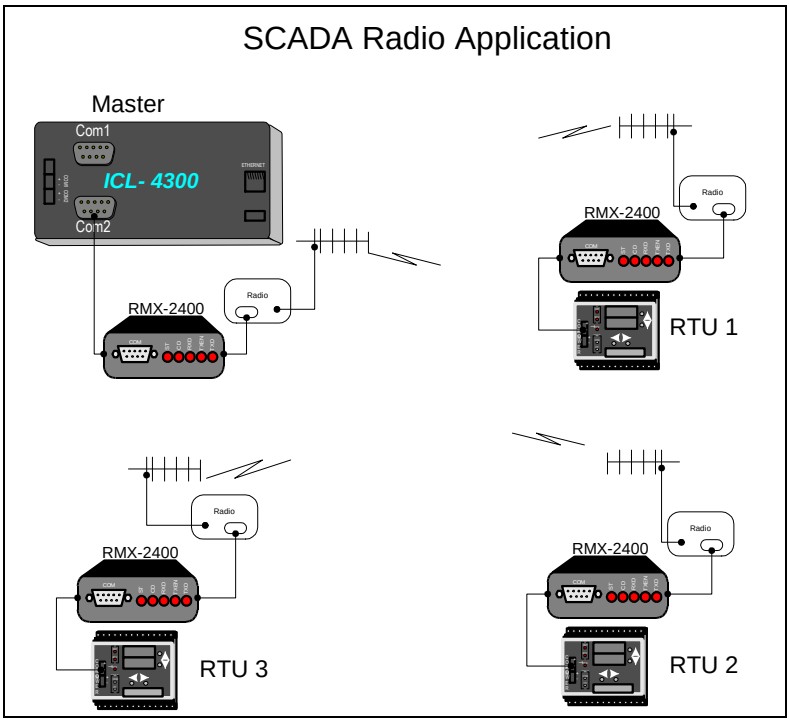


Figure 1

A leased-line configuration differs only in the medium used to communicate to other modems. In a leased line configuration, a "Dry Pair" of wires would be used in a multi-drop configuration.

Front Panel

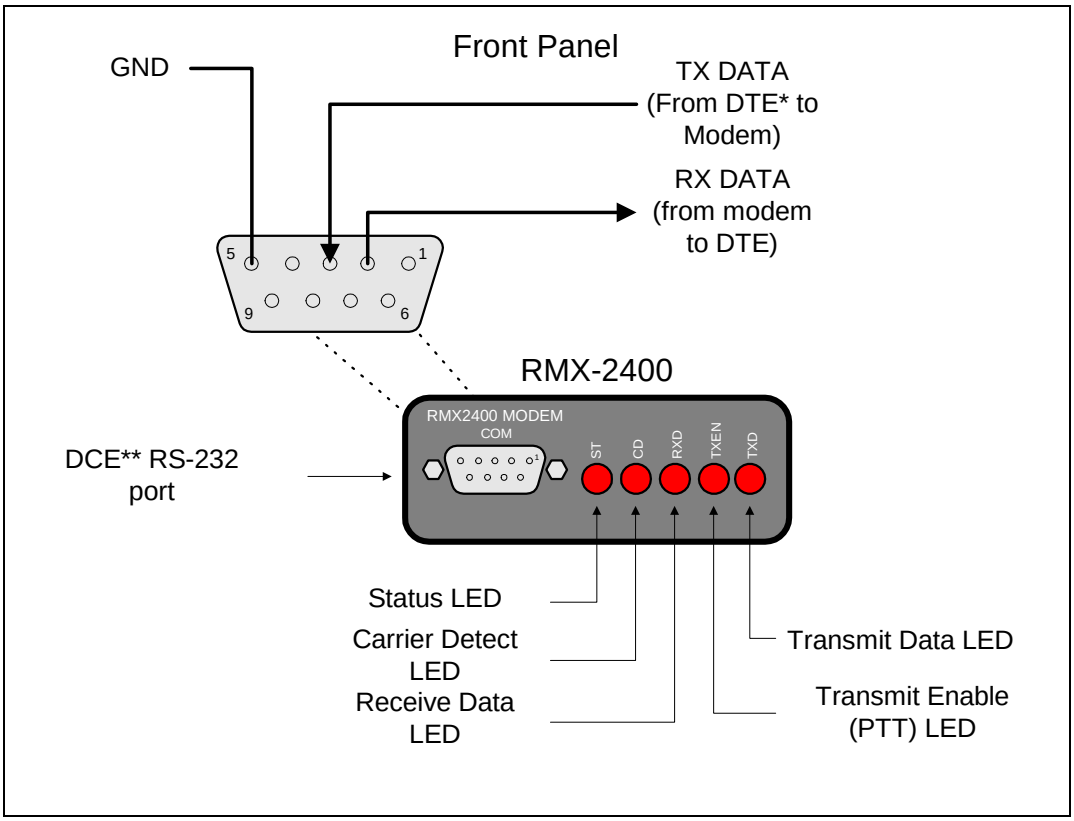


Figure 2

*DTE = Data Terminal Equipment. **DCE = Data Communication Equipment.

Front Panel LED's

The Status LED (ST) is used as a status indicator. It has three states:

Status LED Condition	Meaning
Flashing Slowly (500ms)	Normal
Flashing Quickly	Error Condition (usually an overflow)
Steady On	Configuration Mode

Table 1

The Carrier Detect LED (CD) signals the detection of either an internal carrier generated from modem discriminator or an external carrier detect from a radio or both. This is configuration dependent.

The Receive Data LED (RXD) is tied directly to the serial receive line of the RS-232 driver. It indicates data flowing from the modem to its DCE port connector (Pin 2). This may by difficult to see at times due to short message packets. (See Block Diagram section for details.)

The Transmit Enable LED (TXEN) indicates the state of the Push To Talk signal at the rear terminal block. If TXEN is lit the RMX-2400 is attempting to key the radio.

The Transmit Data LED (TXD) is tied directly to the serial transmit line of the modem. It indicates data flowing from the DCE port connector (Pin 3) to the modem. This may be difficult to see due to short packets. (See Block Diagram section for details).

RS-232 COM Port Connection

The RMX-2400 can be connected to any DTE (Data Terminal Equipment) that is capable of baud rates of 2400, 4800 or 9600. If the DTE port requires handshaking, this will need to be supplied with a special connector modification to ”fake out” the DTE port. The following figures show two possible configurations (although there are many more possibilities). The arrows show the direction of data flow for that signal.

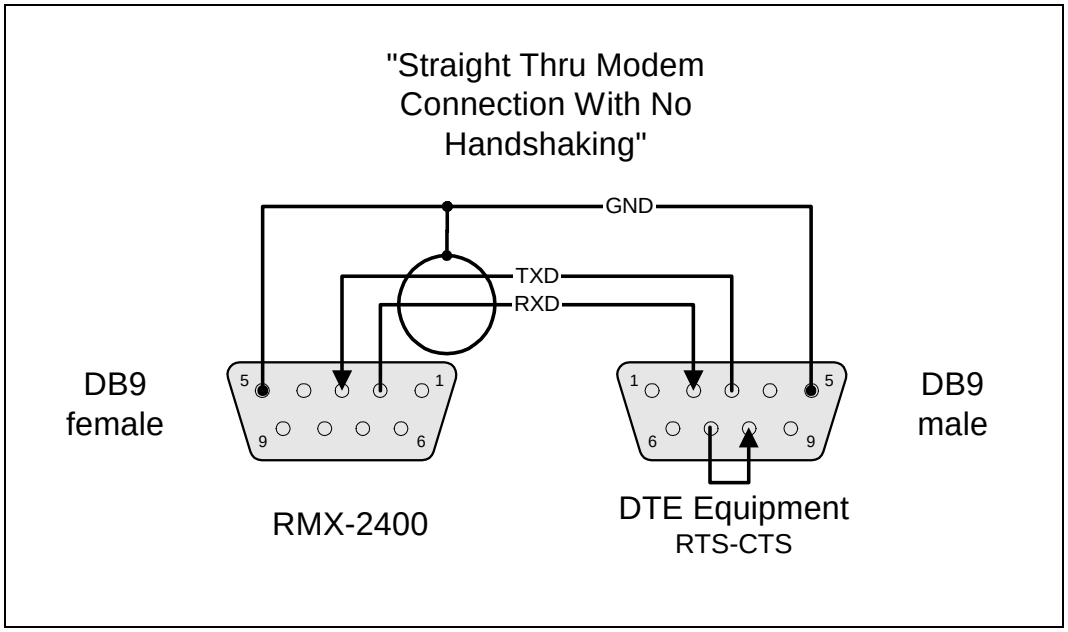


Figure 3

In this case, the DTE port only cares that Clear To Send is returned after Request To Send has been asserted to determine that the communication medium is ready for use. It will then transmit data via the TXD pin.

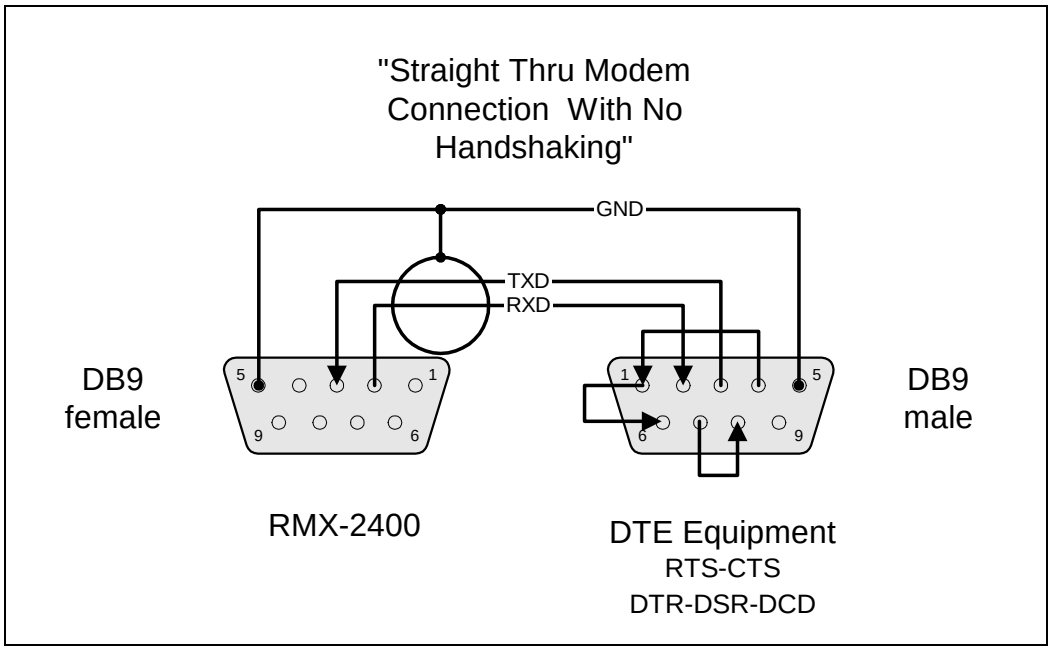


Figure 4

In this case the DTE port must be faked out into thinking that all the connection conditions are met before data will be transmitted to the port. Here the DTE needs Data Set Ready to be true to determine that the DCE is ready. The DTE also needs to think that Data Carrier Detect is also true to determine that there is a connection present. The "true" is provided by the DTE's Data Terminal Ready signal at pin 4. Typically, DTR goes true when the COM port is opened by the DTE's communication application software. CTS and RTS function as described in the previous example.

The RMX does not care about handshaking lines coming from the DTE port. The RMX-2400 looks for a character gap (time of no data flow) to signal it is time to send a message. This will be discussed in detail later in this manual (see Character Gap section).

Rear Panel

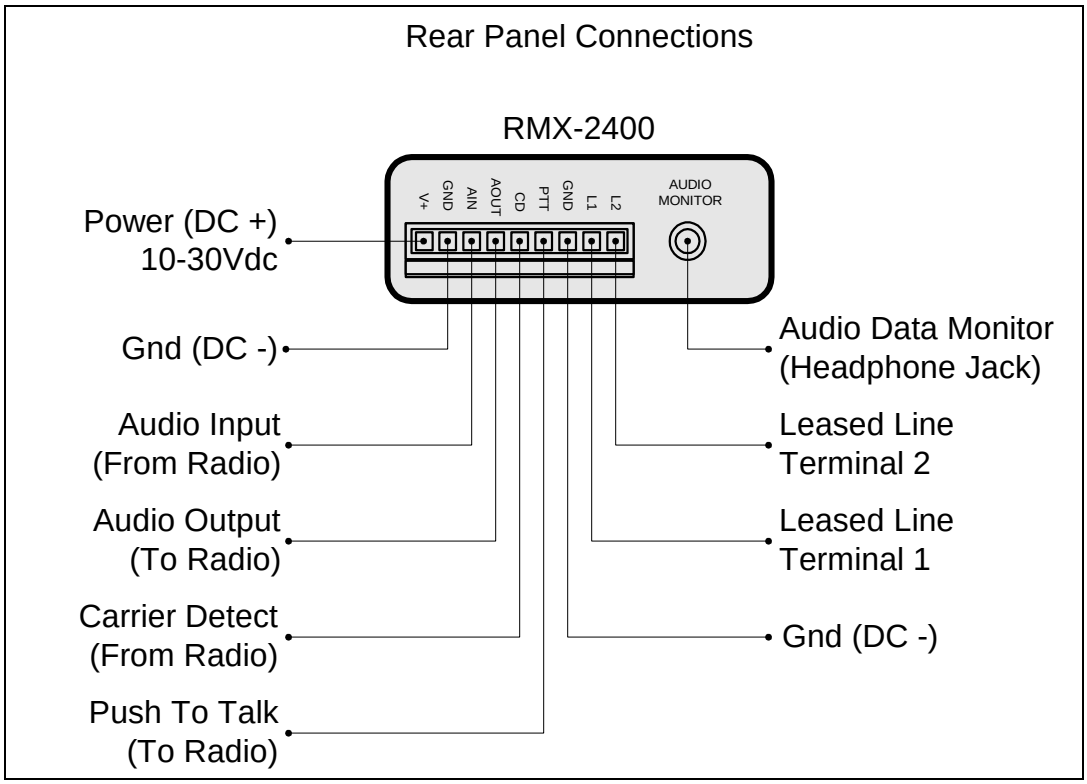


Figure 5

The RMX-2400 is DC powered and can take any DC voltage from **10 – 30 VDC**.

The Audio In, Audio Out, Push To Talk, and Carrier Detect all get referenced to the DC negative input and are used for radio communication only. The two ground pins are internally connected.

The L1 and L2 pins are transformer coupled and reference only each other.

The Audio Monitor is internally connected to the Audio In signal and buffered. Connection is a $1/8^{th}$ inch monaural phono-jack ideal for earphone or headphone monitoring.

Wiring The RMX-2400

Radio System Wiring

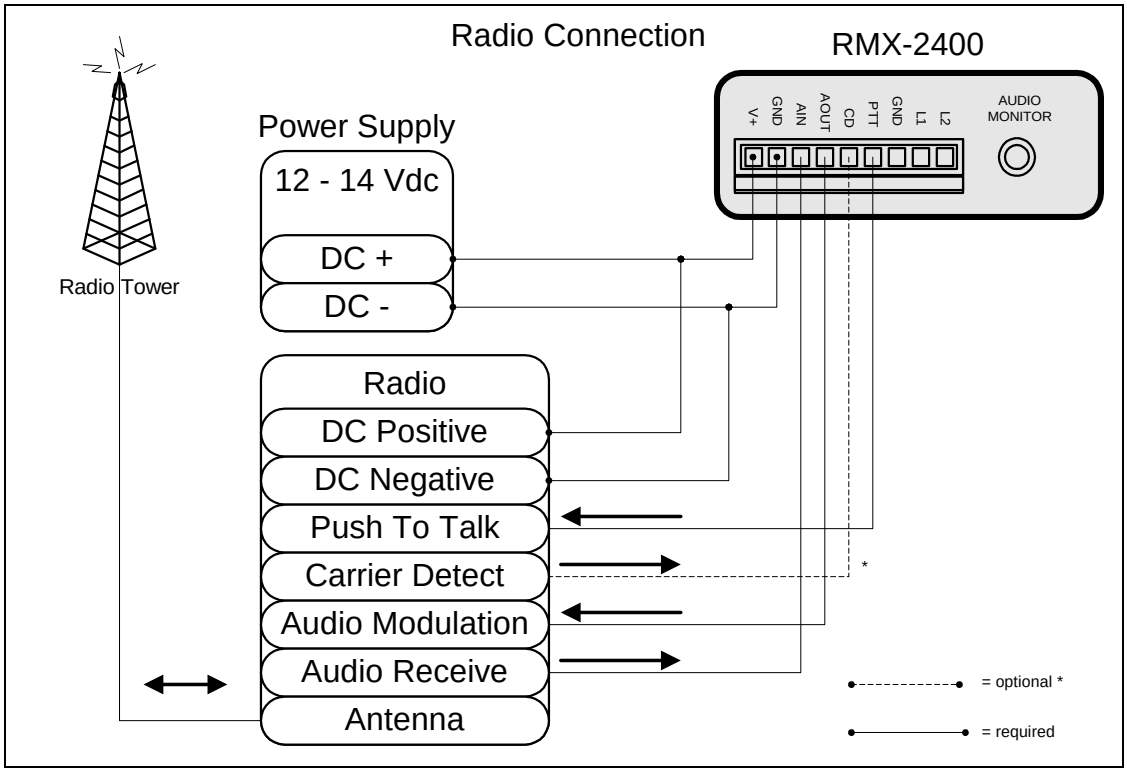


Figure 6

Notice that Carrier Detect is an optional signal. It can be configured to either active-high (1) or active-low (0) mode. The RMX-2400 does not need this signal to operate. It can also internally detect a carrier from modem audio coming from the radio.

Leased Line Wiring

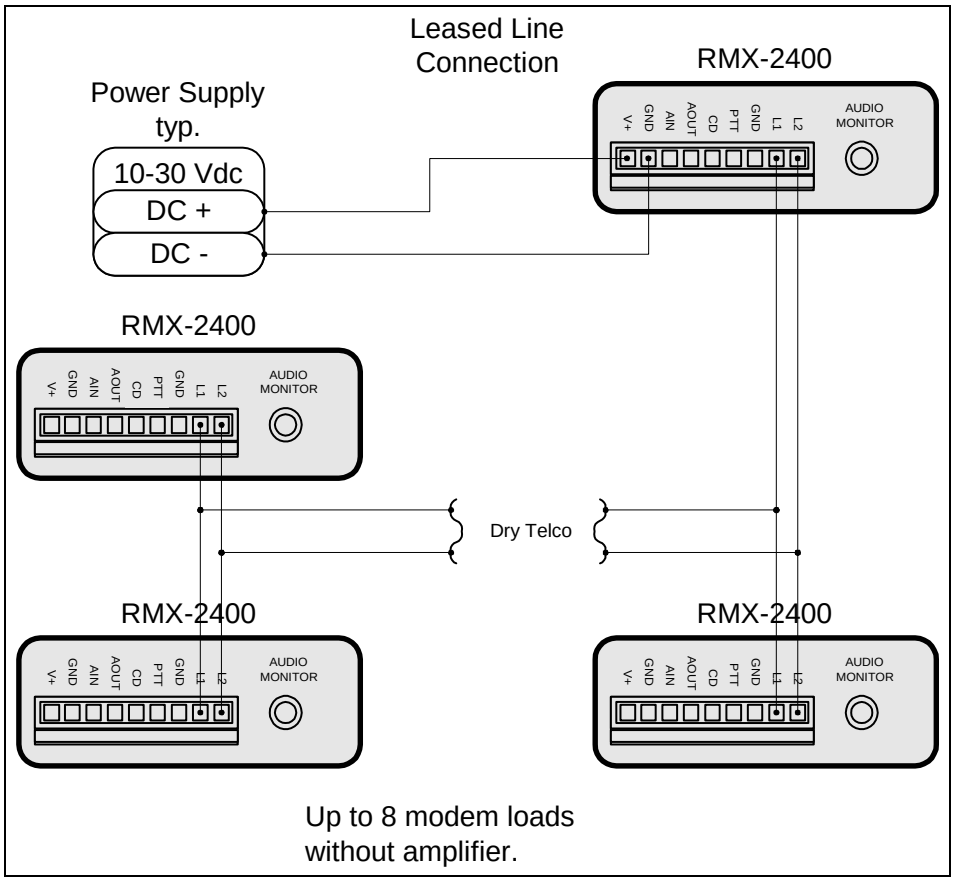


Figure 7

The RMX-2400 can be used as a Leased Line modem and can by wired into "dry" telephone wiring to cover long distances or into twisted pair to handle inter-building or inter-plant telemetry. The distance specification is difficult to predict due to the following variables.

- Condition and type of wiring.
- Number of modems or nodes. (Each is an additional load).
- Layout of system.
- Impedance of protection devices. (Lightning arrestors, MOV, and transorbs).
- Routing of telephone company wires. **

If communication is accomplished over telephone Leased-Line, the use of lightning arrestors is highly recommended.

Each modem presents a 600 ohm load (AC Impedance) to the system. Each modem you add reduces the system audio level proportionately. The RMX-2400 can be configured to receive very low signals by setting its input gain high. Transformer coupling rejects a high degree of common-mode noise.

** Telephone companies are notorious for having bad lines and often route around problems leaving the bad lines in place. It is sometimes hard to find a good pair in a buried cable.

Configuration

Radio or Leased Line Hardware Configuration

The RMX-2400 comes configured as a radio modem from the factory. To use in leased-line mode, the modem must be disassembled and the internal dip switches changed using the following procedure.

Disassembly Procedure:

1. Remove power from RMX-2400.
2. Looking at the front of the RMX-2400, remove the two #1 Phillips head screws.
3. Remove rear terminal block from rear connector.
4. Gently slip out modem main board from rear to front.
5. See following diagram.
6. Select the mode best suited to your application. Be sure to switch both switches.
7. Reassembly is the reverse of the Disassembly Procedure.

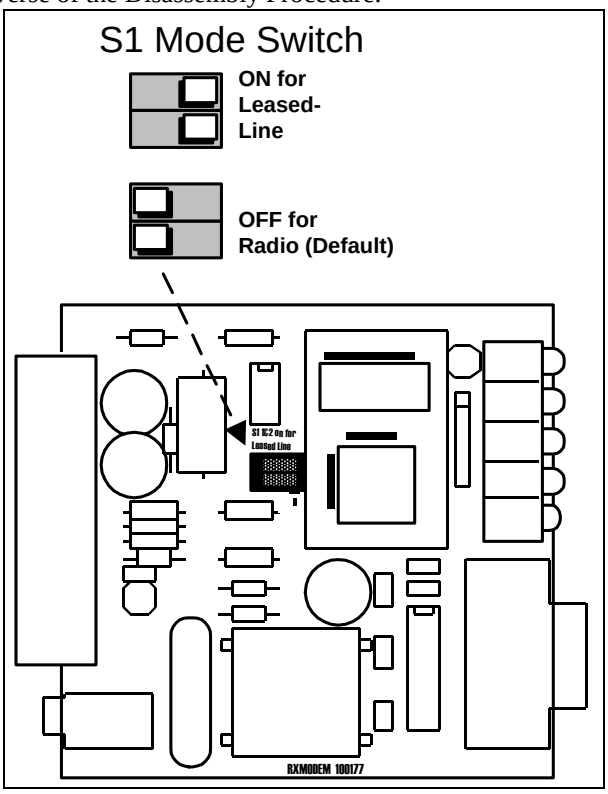


Figure 8

Setting switches to "ON" connects the leased line transformer to the Audio In and Audio Out signals. See Block Diagram for more details.

Software Configuration

Most of the configuration of the RMX-2400 is accomplished via a terminal and the configuration interface.

Equipment Required:

1. Terminal or PC with Terminal Emulation Program Software.
2. Straight Through Modem Cable. (See Figure 2).
3. RMS or Average AC Meter or Multi-meter.
4. RF FM Deviation Meter (optional for radio)
5. Headphones (optional).

Setting up a Terminal Emulation Link

For this example HyperTerminal from Hilgrave Corporation will be used. This is the standard terminal program that ships with Windows NT / 98 /95 and is available when the Communications option is installed from Microsoft.

Terminal Setup Procedure:

- Click on the Start Menu on the PC and select *Programs*, *Accessories*, *Communications* and open *HyperTerminal* folder
- Double click on Hypertrm.exe to make a new connection.
- Give the connection a name such as "RMX2400" and click *OK*.
- Select an available COM port on your computer. Most computers have COM1 and COM2 available. For this example we will select "Direct to COM1".
- Set up the Port Settings Window to the following parameters:

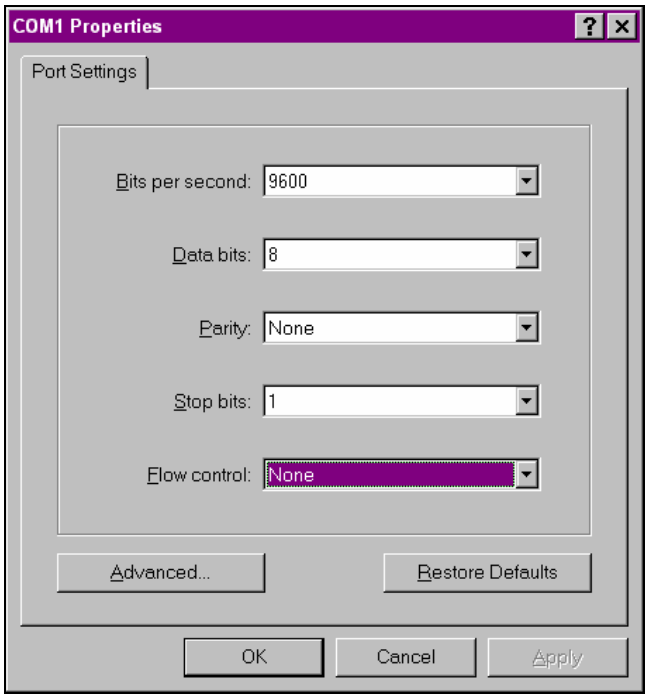


Figure 9

- There is no need to set up the Advanced parameters. They do not affect operation.
- Click *OK* to continue to the terminal.
- Connect the PC COM port you specified to the RMX-2400 COM port using a "Straight Thru" modem cable with at least the following pins connected:

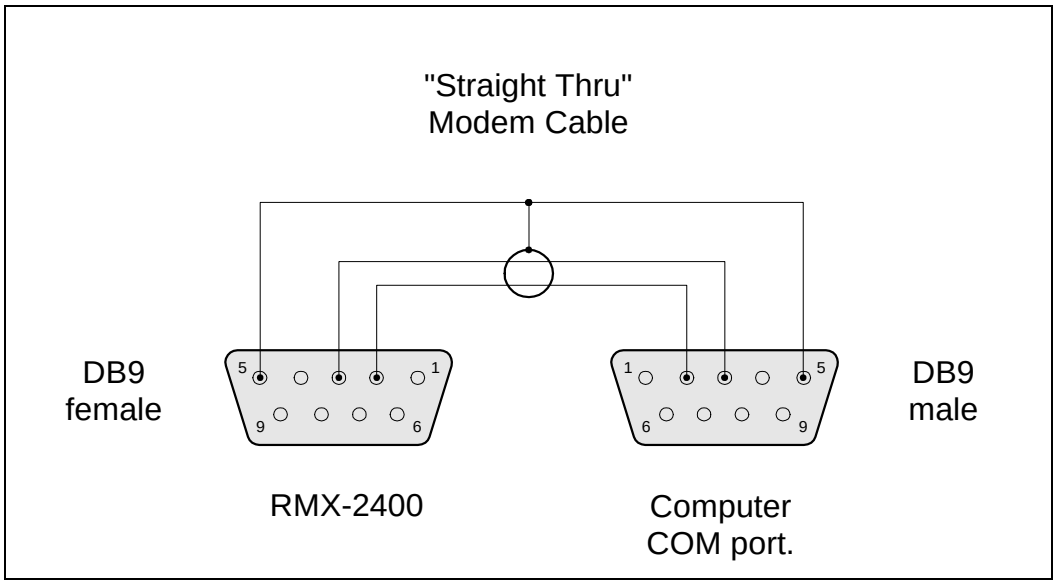


Figure 10

- This same cable can be used as the installed communications cable as well. It is **NOT** a "**null modem**" cable.

- At this point, pressing keys at the computer keyboard should cause at least the TXEN and the TX light to flash on the RMX-2400. If not, try a jumper from pin 2 to 3 on the computer COM port. This is called a "loop-back" connection. Whatever is typed at the keyboard should be "looped back" or echoed on the terminal screen. If this works, check the cable connection to the RMX-2400. If not, try a different COM port on the PC. There may be a hardware configuration problem on the PC or another program using the port.

The RMX-2400 Configuration Interface

Getting Into Configuration Mode

1. Wait 1 second.
2. Hit the "+" key three times in quick succession (within one second).
3. Wait 1 more second.
4. You should see the "OK>" prompt of the RMX-2400 user interface.
5. The "ST" LED will change to steady on if configuration mode has been entered.

Troubleshooting Modem Connection

If this does not work check some of these items:

- Using the "+" located on the "+" / "=" key, be sure that you pressing the "Shift" key at the same time.
- Using the "+" key on the keypad is okay. Most keyboards have this key and it does not require the "Num Lock" to be on to use it. But the key is not used often and is sometimes bad.
- Be absolutely sure you hit nothing for one second, enter "+++" and then hit nothing for another second. This is the way the RMX-2400 knows that this data is not part of an actual message.
- If the "TXEN" light and the "TX" light do not flash momentarily, communication to the modem is not working from the terminal.
- If the modem's "ST" light changes to steady on and the "OK>" prompt does not appear the RX pin is probably disconnected in the cable or the cable is the wrong type.
- If all else fails try `Call Disconnect` and `Call Reconnect` menu options in HyperTerminal. Do this several times with a new connection until the modem responds with an "OK>" prompt. Once this works, save the HyperTerminal session and open that HyperTerminal session **EVERY** time you use HyperTerminal to configure RMX modems.
- Try a different terminal emulation program.
- Be sure that another program is not using the COM port.

The Modem Configuration Screen

At the “OK>” prompt, hit the “Enter” key to get to the Configuration Screen: You should see the following :

```
COMMANDS v1.03
==============
FD        (Full Duplex mode)
HD*       (Half Duplex mode)
EC        (External Carrier detect signal)
IC*       (Internal Carrier detect signal)
CL=0      (Carrier detect Level -- 0/1 for active low/high)
TC=0      (Transmit Continuously for time specified in 0.1s increments)
TT=1      (Transmitter Type -- 1=conventional, 2=trunking)
MB=24     (Modem Baud 12/24 for 1200/2400 bps)
PB=96     (Port Baud 96/48/24 for 9600/4800/2400 bps)
LD=10     (Lead Delay in 0.01s increments)
TD=5      (Trail Delay in 0.01s increments)
CG=10     (Character Gap in 0.01s increments)
CT=1      (Command mode Timeout in 1 min increments)
DM=5      (Data Monitor level -- in 0.01Vrms increments)
DI=100    (Data In audio level -- in 0.01Vrms increments)
DO=100    (Data Out audio level -- in 0.01Vrms increments)
DE        (Default all parameters to factory settings)
SA        (Save current settings)
LO        (Load last saved settings)
EX        (Exit out of command mode)

OK>
```

**The parameters and their values seen here are the factory defaults as set by the DE command

Entering Modem Configuration Commands

To enter commands, simply type in the command and hit the <Enter> key. Examples:

```
EC <Enter>

SA <Enter>
```

Modifying Modem Configuration Parameters

To modify a configuration value, type the parameter desired followed by the “=” character or a space and the value desired. Examples:

```
LD=20 <Enter>

DI 50 <Enter>
```

Modem Parameter Detail

Parameter/ Command	Parameter/ Command Name	Description	Comments	Radio Only
FD	Full Duplex mode	Configures the modem to operate in Full duplex mode.	Full duplex and half duplex are exclusive. Not supported for leased line or single frequency radios.	Yes
HD	Half Duplex mode	Configures the modem to operate in Half duplex mode.	FD and HD are mutually exclusive. The active parameter is marked with an asterisk (see above).	
EC	External Carrier detect	Uses Carrier Detect connection and modem audio to determine if carrier is present. Lights "CD" LED.	Radio Equipment must supply Carrier Detect signal. If EC is set to 1, Leaving the "CD" pin floating could inhibit operation.	Yes
IC	Internal Carrier detect	Only uses modem audio to determine carrier presence. Lights "CD" LED.	Open squelch on a radio sometimes generates "white noise". This can fool the modem discriminator into thinking there is a modem carrier.	
CL	Carrier detect Level	Configures the active state of the External Carrier Detect. Active high (1) or active low (0).	Only works when the "EC" parameter is set.	Yes
TC	Transmit Continuously	Configuration and troubleshooting aid. Turns on transmitter and modem tone for setting up audio levels and checking leased-line operation.	In this mode the transmitter will stop periodically.10 seconds On 1 second off. This is an FCC compliance issue and is normal operation.	

Parameter/ Command	Parameter/ Command Name	Description	Comments	Radio Only
TT	Transmitter Type	"1" sets the Transmitter Type to Conventional. "2" sets the Transmitter Type to Trunking mode.	Trunking mode uses the radio's Carrier Detect signal as a Clear To Send signal. After Push To Talk is asserted the modem will hold off transmitting data until Carrier Detect is asserted by the radio. The RMX2400 modem **MUST** be set to External Carrier Detect (EC parameter) for this to work.	Yes
MB	Modem Baud	The actual baud rate that is transmitted via the modem connection.	This rate must be less than the Port Baud (PB) parameter.	
PB	DCE Port Baud	Baud rate that the DTE to DCE connection is configured as.	This rate must be greater than the Modem Baud (MB) parameter.	
LD	Lead Delay	Time between asserting Push To Talk and transmitting data. Allows slow radios to key up the transmit carrier.	Excessive Lead Delay can limit message throughput.	Yes
TD	Trail Delay	Time from the end of data to the release of Push To Talk signal.	Too long Trail Delay can cause excessive collisions. Most radios require no Trail Delay.	Yes
CG	Character Gap	Configure time by which an end of message is determined by modem.	Excessive Character Gap will cause buffer overflows. Insufficient Character Gap will cause messages to be truncated or missed altogether.	
CT	Command Timeout	Time in seconds to stay in command mode (this user interface).	Setting this to "0" will disable timeout.	
DM	Data Monitor Level	Sets volume level on the Audio Data Monitor.	Data Monitor level is also effected directly by the Data In level.	

Parameter/ Command	Parameter/ Command Name	Description	Comments	Radio Only
DI	Data In Level	Input audio gain in .01V_{RMS} units at "AIN" terminal.	This number is what the "AIN" terminal expects to see from radio. For leased line, multiply measured incoming level across "L1" and "L2" by .75 and enter result in this parameter (this is due to transformer loss).	
DO	Data Out Level	Output audio gain in .01V_{RMS} at "AOUT" terminal.	Output at "L1" and "L2" will be about .75 of this setting in leased line mode.	
DE	Load Defaults	Load factory Defaults (values shown above).	Values are not saved until the SA command is executed. If this is not done, the modem parameters will return to their previous state at power up.	
SA	Save Settings	Save current settings.	Save all configurations to EEPROM memory. Parameters will return at next power up.	
LO	Load Settings	Load last saved settings.	If experimental changes are not working, user can return to previously saved settings. This can be used as an "UNDO".	
EX	Exit	Exit Configuration Mode.	Return to normal operation of modem.	

Table 2

Audio Configuration

Radio Configuration

Equipment Needed:

- RMS or Average AC Meter.
- Terminal Emulator.
- RF Dummy Loads.
- FM Deviation Meter (optional)

Procedure

This procedure is intended as a pre-installation configuration. It is not recommended that this procedure be done in the field unless absolutely necessary. Use the following diagram to setup the test on the "bench". Please refer to the Radio Wiring section for details. Note that this may also be an ideal time to set up the "LD" and "TD" parameters if necessary. See Advanced Topics section.

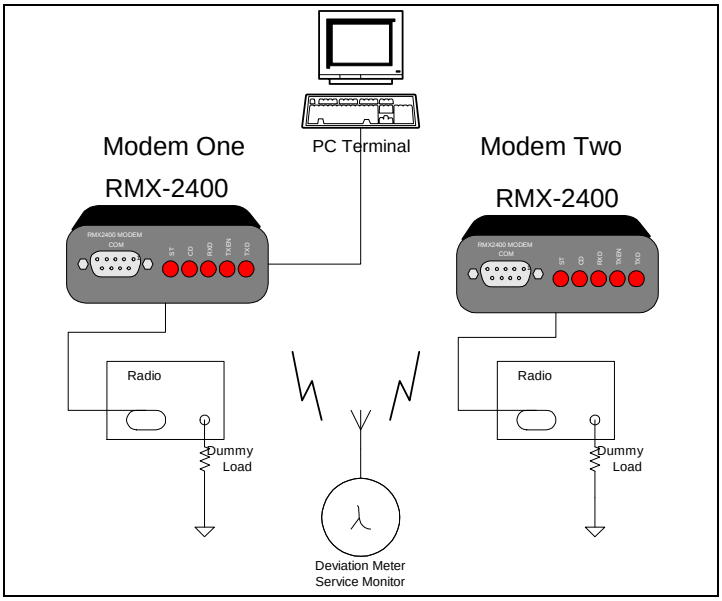


Figure 11

1. Attach AC meter to the "AIN" (Audio In) connector on the back of the Modem Two. "AIN" should be connected to the radio's audio output.
2. At the Terminal Emulator, get into configuration mode (refer to Getting Into Configuration Mode section).
3. At the "OK>" prompt type "TC=30<enter>".
4. Note the AC Voltage measured at the "AIN" terminal on Modem Two.
5. Make note of AC Voltage Reading.

6. Move the Terminal Emulator to the COM port of Modem Two. (Many times it is easier to switch modems rather than the equipment).
7. Get into command mode and at the prompt, type "DI=xx <enter>" where xx is the AC reading measured divided by ten (the DI parameter in 10mV increments). Example "DI=20<Enter>".
8. Use the "SA" command to save changes.
9. While Modem Two is in command mode the above steps can be repeated and results measured at Modem One.
10. If possible, take a deviation reading as well to insure FCC compliance. Proper specifications can be found in the FCC license or the radio manual.
11. Repeat "DI" configuration for Modem One and save using the "SA" command.
12. Test the modem and radio link with real communication equipment to verify there are no communication faults.

Leased Line Configuration

Equipment Needed:

- Two RMS or Average AC Meters.
- Two Terminal Emulators. (Laptops work well).
- Two Communication Devices.

Procedure

Leased Line audio configuration must be done in the field. It is a recommended practice to use two people communicating with cell phones or other two-way communication devices to save time and frustration. Some system considerations are defined in the Leased Line Wiring section. Refer to the following diagram for set up and configuration procedure.

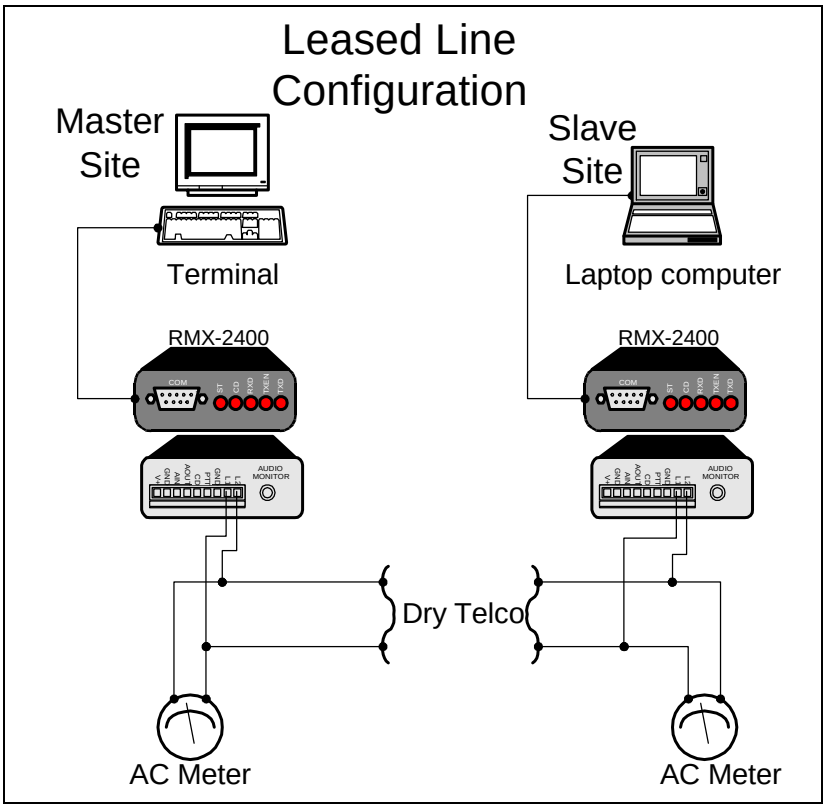


Figure 12

1. At both sites, attach an AC Voltmeter from L1 to L2.
2. At the Master Site, enter configuration mode using the Terminal Emulator (see Getting Into Configuration Mode section).
3. Enter "TC=30 <enter>" to turn on test tone.
4. Measure AC Voltage at Slave Site.
5. Multiply this reading by .75 to compensate for transformer loss.
6. Enter command mode at slave site using Terminal Emulator.
7. At the "OK>" prompt, enter "DI=xx" where xx is the result divided by 10mV.
8. Save the settings with the SA command.
9. When the Master Site test tone is activated again, the "CD" LED should come on when tone is present.
10. Repeat these steps initiating tone from the Slave Site and configuring the Master Site.

The "Master" should be configured from the most distant or weakest site and should only need to be configured once.

If the system is peer to peer, some compensation may be necessary between sites to find a happy medium for all sites to work properly. Only configure and test those sites that communicate to each other.

Advanced Topics

Lead Delay and Trail Delay

The Lead Delay parameter is the time between asserting Push To Talk before transmitting a message packet. It allows slow radios time to key up the transmitter carrier before the actual data is transmitted. This keeps the data from being clipped off at the front end or leading edge of the message thus corrupting it. The timing parameters needed vary from radio to radio and are usually proportional to the output power of the radio. This time is often referred to as "key time" or "transmitter attack time". This specification can be found in the radio's manual technical specification section.

The Trail Delay does exactly the same but for the end of the message. This keeps the end of the message from being clipped off which would corrupt it also. Please keep in mind that Trail Delay is ALMOST NEVER needed.

The following diagrams show both good and bad Lead and Trail Delay scenarios:

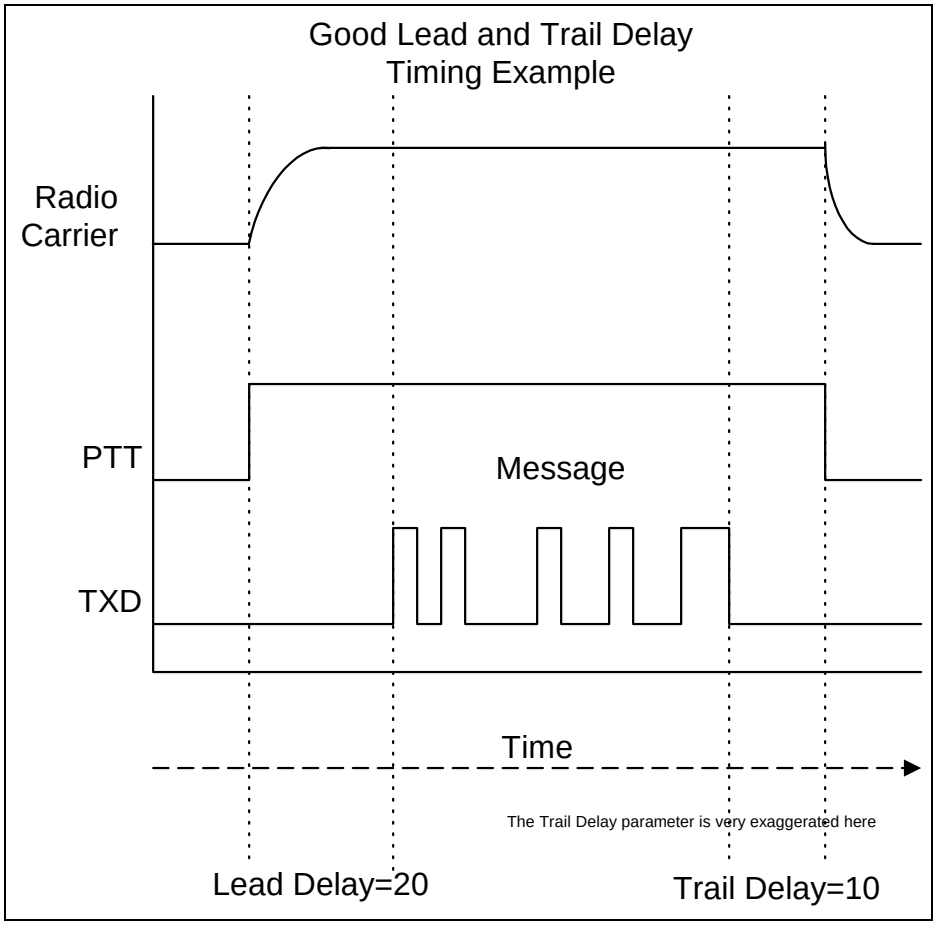


Figure 13

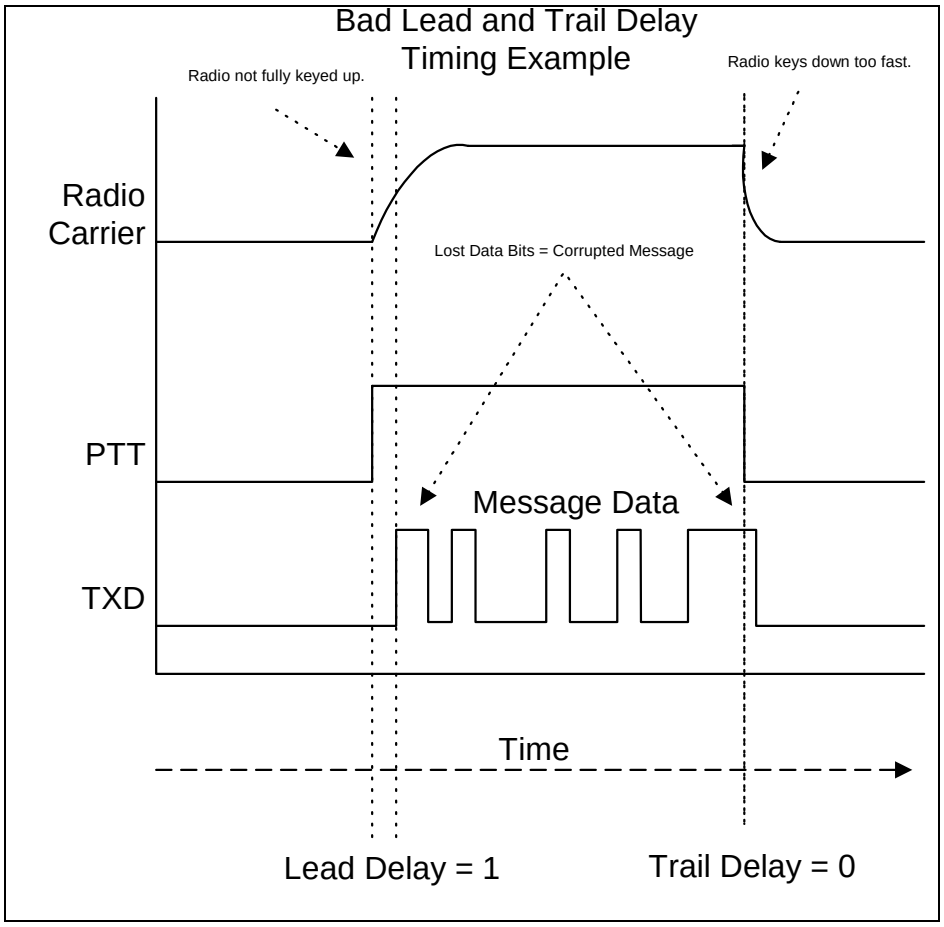


Figure 14

Character Gap

The Character Gap parameter is the way the RMX-2400 knows where the end of a packet occurs as its transmitted from the DTE device. This method is used in place hardware or software handshaking. This Character Gap is rarely critical but may need adjustment under unusual circumstances. The ideal value also depends on baud rate and should equal at least ten times a single character's transmission time. The following is the way to figure the appropriate gap time.

```
Characters Per Second (CPS) = Bits per Second /10

Milliseconds Per Character (MPC) = 1000 / Characters Per Second

Minimum Recommended Character Gap (MRCG) = 10 * Milliseconds per Character

Round up to next 10mS increment Character Gap parameter and divide by 10
```

Example:

```
CPS = 9600 /10 = 960

MPC = 1000 / 960 = 1.042mS
```

```
MRCG = 1.042mS * 10 = 10.42mS
Round Up to 20.00mS
CG = 2
```

Simple example:

```
10000 / Baud Rate and round up.
10000 / 9600 = 10.42mS
Round up to 20.00ms
CG=2
```

Data Packet Formatting

The RMX-2400 uses a proprietary data packet formatting. This formatting allows the modem to synchronize incoming audio to the modem's discriminator, verify the incoming header data is from another RMX-2400 and check the message length.

Message Format

The modem receives data asynchronously through an RS-232 port onboard. When a gap (the length of which is user definable) in the incoming data occurs, the modem transmits whatever data is currently in its transmit buffer. The data is sent as a synchronous block or "packet". When a data packet is sent from one modem to another, the following bytes are what actually get transmitted:

```
SYNCH_BYTE, SYNCH_BYTE, BYTE1_PREAMBLE, BYTE2_PREAMBLE, BYTE3_PREAMBLE,
BYTE4_PREAMBLE, EXPANSION_BYTE, <packet size N>, <byte1>, <byte2>, ..., <byteN>
```

The two SYNCH_BYTEs are simply two 0xAA characters. The receiving modem chip needs this alternating pattern of 0's and 1's so it can synchronize itself with the transmitting chip at the other end.

The four BYTEx_PREAMBLE bytes make up a unique 32-bit pattern that the receiving modem looks for to determine if the data that follows is an actual packet or maybe just noise or garbage that is being received. The preamble bytes are:

```
BYTE1_PREAMBLE     0xC4
BYTE2_PREAMBLE     0xD7
BYTE3_PREAMBLE     0xAF
BYTE4_PREAMBLE     0x71
```

After the proper sequence of four preamble bytes is received, the next byte is the EXPANSION_BYTE. Currently this byte will always be a zero. In the future, this byte could be used to identify what type of data is being sent if new packet formats are ever used. For now, if this byte is non-zero, the receiving modem will simply ignore the data that follows.

After the expansion byte is received, the next byte is treated as the data packet size N. Following it, the next N bytes received are assumed to be the data packet and are sent to the modem's RS-232 port.

There currently is no way of validating the data packet itself. It is the responsibility of the user's application software or protocol to perform such validation.

Technical Data

Block Diagram

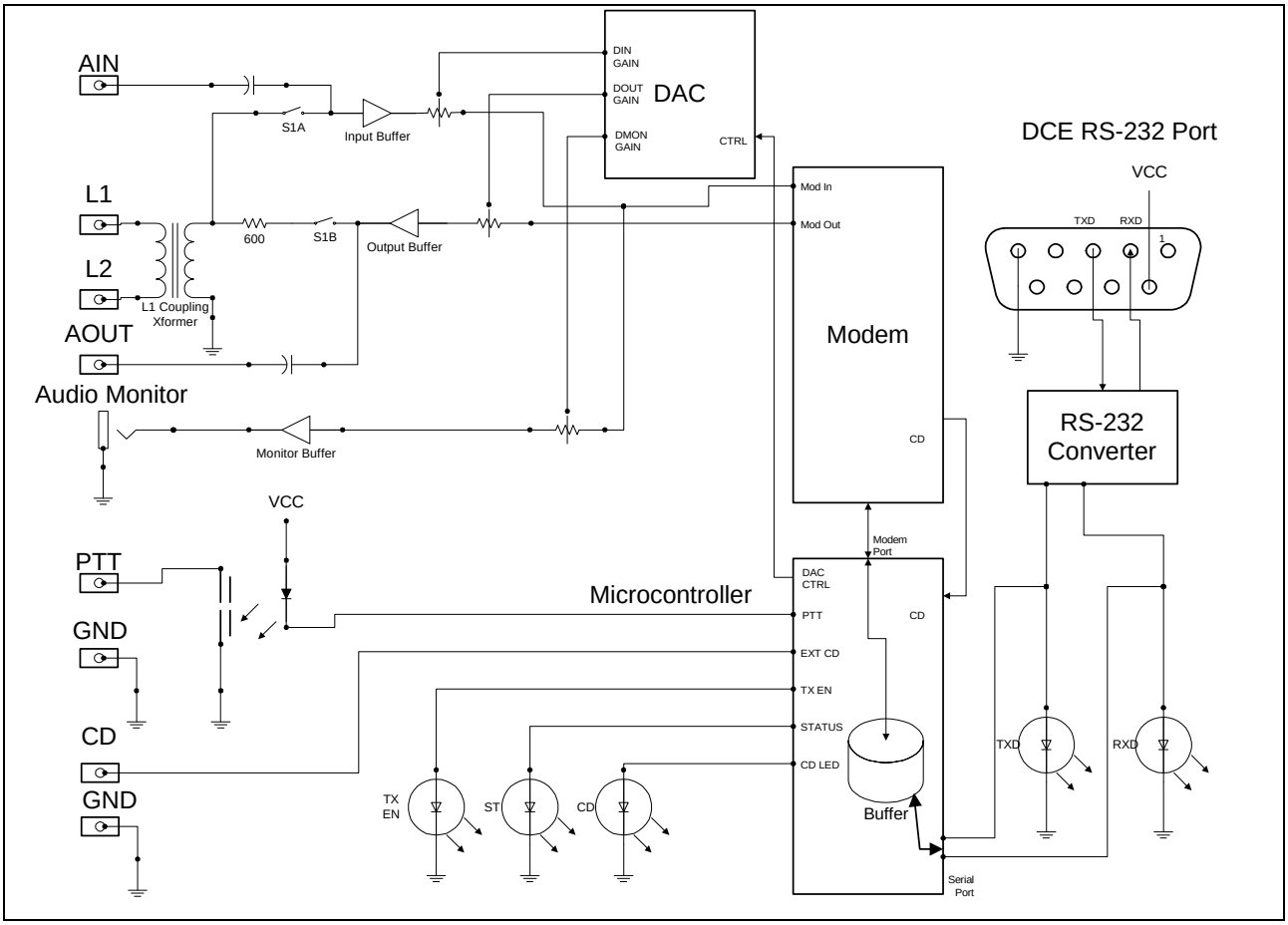


Figure 15

Specifications

Operating Temperature:
-40 to 70 degree Celsius

Humidity:
10 to 95% Non-Condensing

Power Requirements:
10 to 30 Vdc
0.3 Watts Maximum

Bit Error Rate and Noise Immunity:

$7*10^{-4}$ @Signal to Noise Ratio of -12dB @ Bandwidth.
$1*10^{-8}$ @Signal to Noise Ratio of -20dB @ Bandwidth.
Bandwidth = 1200Hz @ 1200 Baud.
Bandwidth = 2400Hz @ 2400 Baud.

DCE Port Baud Rates:
9600, 4800, or 2400

Modem Port Baud Rates:
2400 or 1200

PTT Timing Range:
Lead Delay = 0 to 2.55 Seconds
Trail Delay = 0 to 2.55 Seconds

Character Gap Timing:
0 to 2.54 Seconds

Audio Level Ranges:
Data In (AIN) = 10mVrms to $1.27V_{RMS}$
Data Out (AOUT) 30mVrms to $1.27V_{RMS}$
Data Monitor (Headphone) = 0 to $250mV_{RMS}$

Modem Dimensions

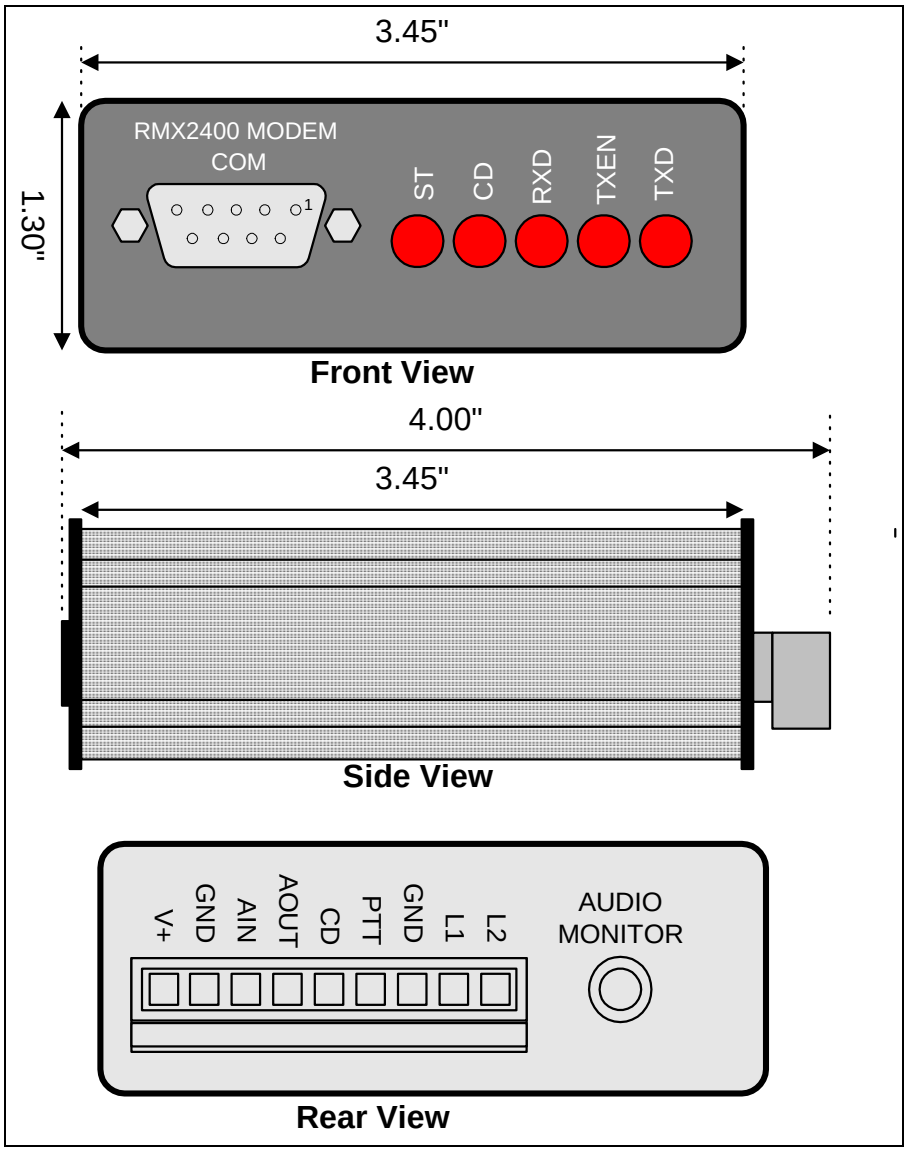


Figure 16

Mounting Bracket Dimensions

A modem bracket is shipped with each new RMX-2400.

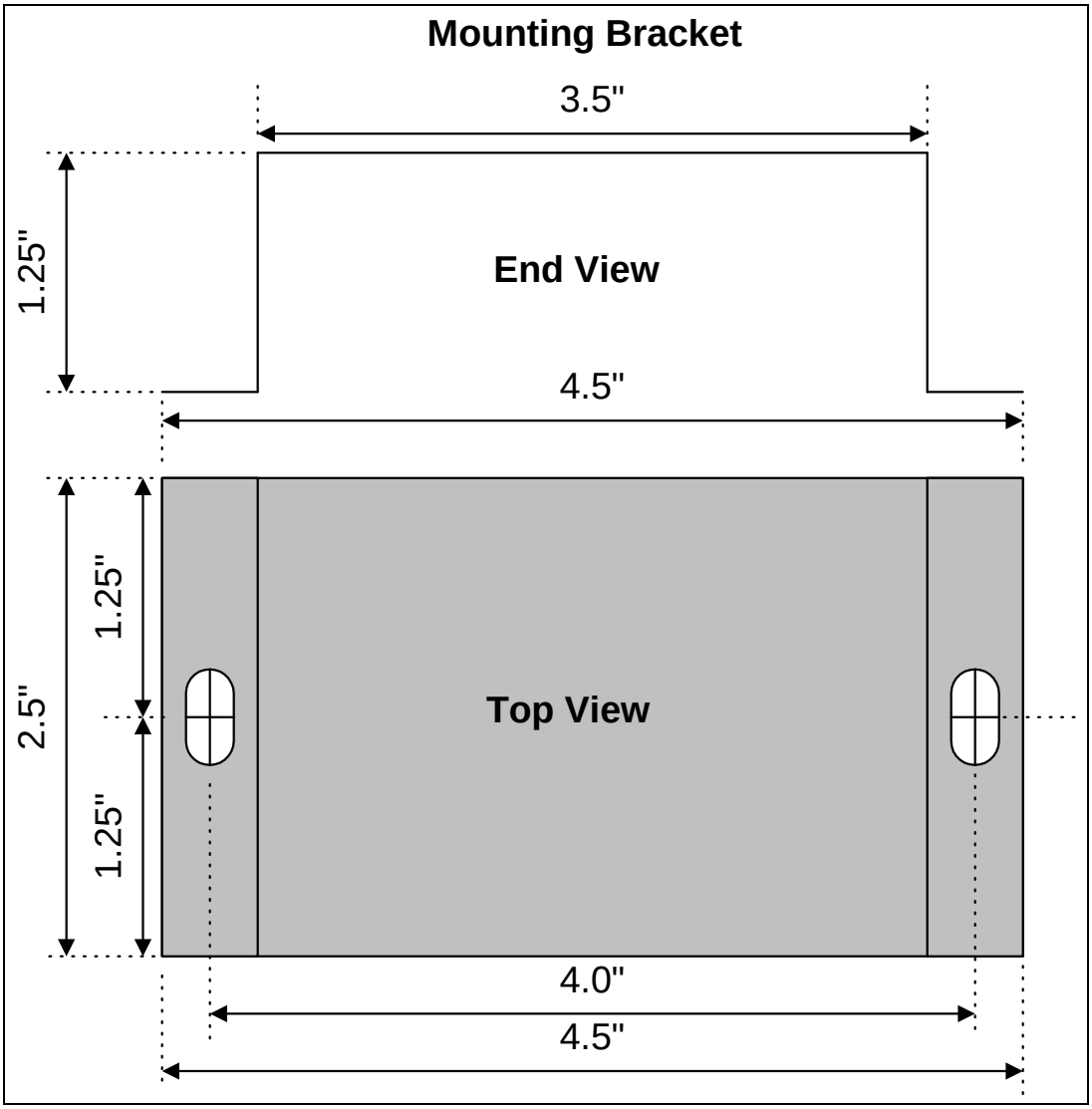
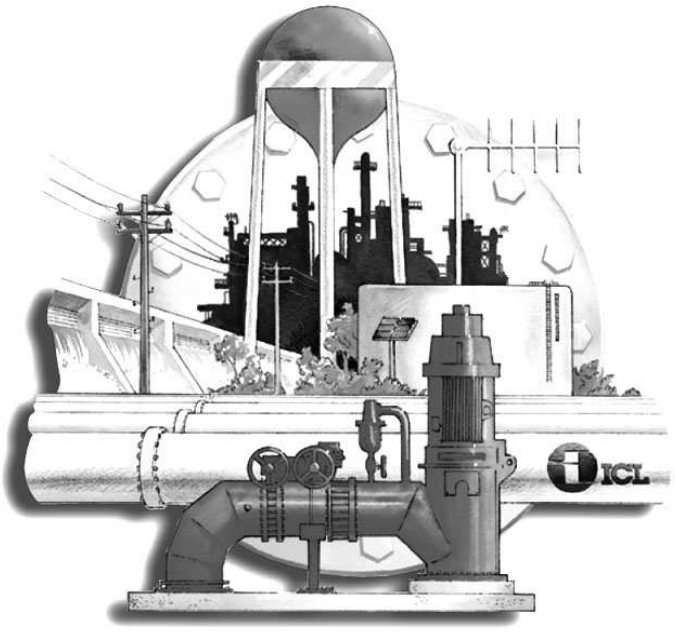


Figure 17



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