TS2000
Mobile Radio Modem

User's Manual

Version 3.03A

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FCC Notice

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Canada

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations (reference ICES-003).

Warning

Changes or modifications not expressly approved by Teledesign Systems Inc. could void the user’s authority to operate this equipment.

Shielded cable must be used with this equipment in order to ensure that it meets the emissions limits for which it was designed. It is the responsibility of the user to obtain and use good quality shielded interface cables with this device. Shielded interface cables are available from most retail and commercial suppliers of interface cables designed to work with personal computer peripherals.

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Introduction

The TS2000 Mobile Radio Modem is designed to send data over any voice radio systems. The modem operates with all brands of mobile and hand held radios and supports both conventional and trunked radio repeater systems including LTR, Motorola, Ericsson EDACS and MPT1327. PC configuration software provided with each modem allows the TS2000 to be configured for any radio and host system.

The TS2000 supports both transparent and AirNet packet data transfers. Transparent operation transfers data with minimal overhead providing the highest channel transfer rate possible. AirNet packet data operation provides error checking and automatic re-transmission of data in the event there are errors during transmission.

Features

Versatile Radio Connection
A Universal radio interface allows connection to any mobile or hand held radio, including radios operating through conventional and trunked repeater systems.

- No modification of the radio or repeater system required.
- Allows data traffic to share a channel with voice communications or use a separate channel or group.
- Audio mute and channel management functions isolate voice and data communications on the same channel.
- Provides radio link data rates of 1200 and 2400 bits per second.
- Compatible with NPSPAC certified public safety radios.

Flexible Data Interface
The serial port supports connection to any asynchronous equipment.

- Supports all RS-232 handshake lines.
- Optional data only mode requires only the receive and transmit data lines.
- Works with RS-232 and TTL signal levels.
- Supports data rates of 300 to 9600 baud.

Optional Forward Error Correction
Optional Forward Error Correction (FEC) coding utilizes block coding (Hamming 12,8) with interleaving to provide error correction of blocks of errors up to 16 bits long. FEC coding is ideal for combating errors induced from multipath fading common in mobile environments.

Selectable Protocols
Selection of low overhead, highest throughput transparent mode or full packet data operation. Transparent mode sends data with minimum delay and overhead. AirNet packet data operation provides transfer management of data and includes addressing, error checking and automatic re-transmission of data packets to guarantee error free data transfers.

AirNet Features

- CSMA/CA algorithm minimizes collisions.
- Selective repeat sliding window ARQ provides high channel efficiency.
- Operates in point to point, point to multi-point and full mesh networks.
- Supports subgroup and all call broadcast transmissions.
- Modems can be configured as store and forward data repeaters for extended radio coverage.

PC Configurable

- PC software with menu interface allows simple setup, testing and diagnostics.
- Flash memory program storage allows easy in field firmware upgrades.

Rugged and Reliable

- Rugged extruded aluminum housing is designed to withstand the abuse of mobile environments.
- All external interfaces protected against voltage transients and shorts.
- Two year no nonsense warranty.
- Free technical support provided during all phases of installation and use.

Related Documents

This document focuses on the basic operation and interfaces of the TS2000. This document does not include information on interfacing the TS2000 to specific radios. For more information refer to the following manuals.

- Radio Interface Manuals - A number of interface manuals for specific radios are available. Contact Teledesign Systems for details.

Connections

The TS2000 has two external connectors; the serial port connector and the radio interface connector. To minimize emissions and interference, the cabling used to connect to both connectors must be good quality shielded cable.

Serial Port

The serial port provides a data connection between the TS2000 and the user's host equipment. The serial port is a standard RS-232 asynchronous serial interface configured as a DCE. The serial port connector is a standard 9 pin subminiature D with female pins and provides all of the standard RS-232 handshake lines (see Appendix A - Serial Port). The TS2000 provides a number of configuration options which allow the serial port to be customized for different host equipment (see Serial Port Configuration Options).

The serial port can be configured for either RS-232 or TTL signal levels. To change the signal level setting, the modem must be opened and the four jumper plugs next to the serial port connector moved to the desired position. See Appendix E for the jumper positions and Appendix A for the serial port signal level specifications.

Radio Interface

The radio interface connects the TS2000 to the radio which handles the data transmission and reception. The radio interface configuration parameters allow the TS2000 to be configured for connection to any mobile or hand held radio (see Radio Interface Configuration Options). The radio interface connector is a 25 pin subminiature D with male pins (see Appendix B - Radio Interface).

Power Connection

The TS2000 requires a DC supply voltage between 6 and 18 volts. Power can be connected through either the serial port connector or the radio interface connector. The TS2000 has a separate 1 amp internal fuse for each of these external power connections (see Appendix E for the fuse positions). The power source used with the TS2000 should also be fused with an in-line power fuse.

Status LEDs

The TS2000 has three LED indicators which provide operational status of transmit (TX), receive (RX) and power (PWR) functions. Special combinations of these indicators are used to indicate secondary operating modes and fault conditions.

TS2000 State	LEDs	Indicator State
Normal Operation	PWR	On when the TS2000 is powered.
	RX	On when the TS2000 detects activity on the radio channel.
	TX	On when the TS2000 is transmitting.
Program Mode	RX, TX	Both on continuously.
Reset	RX, TX	Flash together four times. Although the reset indication takes about four seconds to complete, the TS2000 is fully operational when the flashing begins.
Transmit Test Mode	TX	Flashes for the duration of the test.
Transmit Buffer Overflow	TX	Flashes ten times for each occurrence.
Receive Buffer Overflow	RX	Flashes ten times for each occurrence.
Diagnostics Fault	PWR	Flashes for the duration of the fault. In this mode, the TS2000 has detected a fault but continues to operate. Operation may be unreliable due to the fault. The most common cause of this state is an out of range power source. The source of the fault can be diagnosed with the configuration program (see TS2000 Config Program, Diagnostics).
Catastrophic Fault	RX, TX	Alternately flash until the fault is cleared and the TS2000 is reset. In this mode, the TS2000 has detected a catastrophic fault and is non-operational until the fault is corrected. The source of the fault can be diagnosed with the configuration program (see TS2000 Config Program, Diagnostics).

Adjustments

The TS2000 has two adjustments; transmit level and receive level. The levels are adjusted with potentiometers which are accessible through the back panel of the TS2000. The transmit adjustment sets the transmit signal level out of the TS2000 for the appropriate radio modulation level. The receive adjustment sets the receive signal out of the radio for the input level required by the TS2000 (see Alignment and Testing).

Configuring the TS2000

The TS2000 is supplied with a PC based configuration program. For details on how to load and start the configuration program see Installation in the TS2000 Configuration Program section. A configuration is set by making selections with the controls on the various configuration screens. Configurations can be programmed into the TS2000 and retrieved from the TS2000. Configurations can also be stored and recalled as PC files. Details about the configuration controls are available later in this manual and in the on line help of the configuration program.

Mounting

The preferred method of mounting the TS2000 is to use the mounting bracket supplied with the modem (see Appendix D - Case Dimensions). An alternative to using the mounting bracket is to use the threaded mounting holes in the bottom of the TS2000.

CAUTION: When inserting screws directly into the threaded mounting holes in the bottom of the TS2000, make sure that the screws do not penetrate more than one-eight of an inch (0.125”) into the aluminum housing to prevent touching and potentially damaging internal components.

Firmware Upgrades

The TS2000 comes with flash program memory which allows the firmware to be easily upgraded in the field. Firmware is upgraded using a PC based upgrade program which downloads new firmware into the TS2000 via the PC serial port.

TS2000 Configuration Program

The configuration program is used to configure, adjust, test and monitor the TS2000. The program consists of a set of controls and menus. The controls set the configuration and test options. The menus (line items at the top of the screen) execute program commands.

Using Help

The configuration program has on-line help which contains information on how to use the program and also detailed information on specific controls and menus. From the main screens, help can be accessed by selecting a command from the help menu or by pressing the F1 key. From daughter screens, help is accessed by pressing the help button.

System Requirements

- Personal computer using an 8088 or higher microprocessor (some test functions require a 386 or higher microprocessor).
- DOS operating system version 3.0 or higher.
- 640KB of RAM.
- High density (1.44 MB) 3.5” disk drive (5.25” and lower density disks available on request).

Installation

1) Create a directory to hold the software.
2) Copy the files from the distribution disk to the desired directory.
3) The program files may come in compressed form. This is indicated by there being only a single file on the disk with a .EXE extension. To uncompress the files type the base name of the file (without the .EXE) followed by the ENTER key.
4) To run the program, type the base name of the executable file (has a .EXE extension) followed by the ENTER key.
5) To run the program from a directory different from the one which contains the files, a path to the directory must be created using a path statement in the AUTOEXEC.BAT file (see DOS help for more information). Note that to use the on-line help capability the program must be run from its source directory.

TS2000 to PC Serial Port Connection

To transfer configurations between the TS2000 and a PC, their serial ports must be connected together. The serial cable used should be a standard straight through (i.e. pin 1 to pin 1, pin 2 to pin 2, etc) serial cable. This is the same type of cable used to connect a PC to a standard phone modem (see Serial Port section for more details). To minimize emissions and interference, the cabling used to connect to the TS2000 serial port should be good quality shielded cable.

Before configurations can be retrieved from and programmed into the TS2000 the configuration program must connect to the TS2000. This is done by selecting the Make Connection command from the Modem menu. Connecting to the TS2000 puts it into program mode. When in program mode the TS2000's RX and TX LEDs remain on continuously.

When connected to the TS2000 the configuration program may disable (lighter shade) some of the controls. These are options which are not available with that particular TS2000's version of firmware. These controls are re-enabled when the connection is broken (use the Break Connection command from the Modem menu).

Programming and Retrieving Configurations

The configuration of the TS2000 can be read out of the modem by selecting the Retrieve Config from Modem command from the Modem menu.

To program a configuration into the TS2000, use the Program Config into Modem command from the Modem menu.

CAUTION: Programming a configuration into the TS2000 will write over (destroy) the configuration currently in the TS2000. To avoid losing the TS2000's configuration information, the configuration can be saved by retrieving it and then saving it as a PC file.

Storing Configurations

Configurations of the modem can be stored and recalled as PC files. This is done using the commands under the File menu.

Command	Action
New-Default	Create a new file with default values. If another file is open and has been changed, the user will be prompted to save it.
Open	Open a previously stored file. The user is prompted with a directory and file list.
Save	Save the current file under the current name.
Save As	Save the current file under a different name or in a different directory. The user is prompted with a directory and file list.
File List	This shows the last four open files. A file can be recalled by selecting its name from the list.

Diagnostics

The configuration program can access diagnostics information from the TS2000. This is done using commands under the Modem menu.

Command	Action
Show Hardware Config	Read and display the hardware configuration, which includes details on firmware versions and memory configuration.
Show Diagnostics	Run, read and display diagnostic status of the TS2000. The diagnostics tests all major components of the modem and also monitors the power supply (source) voltage and the receive and transmit levels.

Aligning the TS2000

The configuration program can also be used to align or adjust the TS2000 for a specific radio. Selecting the Test button from the main screen opens the test screen and displays the transmit and receive test selections. The tests are used to adjust the transmit and receive data levels and also to run data tests between two TS2000s (see Alignment and Testing).

Testing the TS2000

Teledesign has several different versions of general purpose AirTest data test software. AirTest allows a user to send various types of data and gather performance statistics about the link between two modems (see Alignment and Testing). AirTest comes in both a DOS version and an enhanced windows version.

Serial Port

The serial port provides an asynchronous data connection between the TS2000 and the host equipment. The TS2000 serial port is a standard RS-232 serial port with a number of options to allow connection to a wide variety of serial host equipment.

RS-232 Serial Port Basics

The EIA (Electronic Industries Association) RS-232C standard is a standard for short distance (less than 50 feet) serial communications. The standard defines the electrical signal levels, interface characteristics and the operation of the control signals (handshake lines). Although the standard defines the operation of the handshake lines, there is significant variation in the way these signals are used by different equipment.

Connectors

The RS-232 standard does not require the use of a specific connector. However, most asynchronous RS-232 serial ports use either a 9 pin or 25 pin subminiature D connector. The same signals are provided with both connectors, but of course the pinouts are different (see Appendix A - Serial Port).

DCE vs. DTE

RS-232 serial ports come in two varieties; DCE (Data Communication Equipment) and DTE (Data Terminal Equipment). This defines the direction of the serial port's lines (driven or received). It also typically defines the polarity of the connector. DCEs typically use female pin connectors and DTEs typically use male pin connectors.

Connecting a DCE port to a DTE is the most common setup and requires a standard straight through cable (i.e. pin 1 to pin 1, pin 2 to pin 2, etc.). When connecting two DCEs or two DTEs together a null modem cable is required. The purpose of a null modem cable is to cross connect the appropriate signals. However, null modem cables are not all the same and therefore it is important to verify that a specific cable is appropriate for a specific application.

Asynchronous Data

The TS2000 is designed to work with asynchronous serial ports. Asynchronous ports do not use clocks or timing signals to synchronize data transfers. Instead data is framed into asynchronous characters which the ports synchronize to.

An asynchronous character consists of a start bit, data bits and stop bits. The start bit indicates the beginning of a character. The number of data bits varies, but is typically between 7 and 9 bits. The data bits sometimes include a parity bit which provides error check information with each character. The number of stop bits also varies but is typically 1 or 2 bits.

Flow Control

Flow control is the method for controlling the flow of data between the DCE and DTE. Flow control is used to prevent the DTE and DCE data receive buffers from overflowing. There are several different methods used for flow control and as with everything related to RS-232 there is no one standard. The two main variations of flow control are hardware flow control which utilizes the RS-232 handshake lines and software flow control which utilizes characters sent along with the normal data.

Hardware Flow Control

Hardware flow control typically uses two control lines, one for each direction of data. When a port activates its flow control signal it is indicating its readiness to receive data. Deactivating the flow control signal indicates that the port can no longer receive data because its buffer is full or close to full.

The most common form of hardware flow control and the one used by most full duplex wired (as opposed to wireless) modems is RTS/CTS. With RTS/CTS flow control, RTS provides flow control for the DTE and CTS provides flow control for the DCE. One problem with RTS/CTS flow control is that for many half duplex modems (most wireless modems) the RTS signal is used to frame transmit data going from the DTE to the DCE. This use of RTS conflicts with using RTS for flow control of data to the DTE.

An alternative form of hardware flow control is DTR/DSR. With DTR/DSR flow control, DTR provides the flow control for the DTE and DSR provides the flow control for the DCE.

Software Flow Control

Software flow control uses characters sent over the data lines to control data flow. These characters are sent along with the normal flow of data between the DTE and DCE. There is typically one character which is used to stop the flow of data and a different character to restart data flow. Software flow control can use any characters to start and stop flow. However the most common characters used are the ASCII XON (starts flow) and XOFF (stops flow) characters. Because these are the most common characters used, software flow control is often referred to as XON/XOFF flow control. The ASCII XON character is the decimal character 17 (0x11 hex) and is also known as DC1 or Ctrl-Q. The ASCII XOFF character is the decimal character 19 (0x13 hex) and is also known as DC3 or Ctrl-S.

A problem with software flow control is that the normal data passed over the communications link cannot include the flow control characters. If it does, the flow of data will be incorrectly stopped or started. This limits the characters which can be used by the host application and also prevents the sending of binary (all character numbers) data.

TS2000 Connector

The TS2000 uses a 9 pin subminiature D serial port connector with female pins, and is configured as a DCE (see Appendix A for the TS2000 serial port pinout).

Power can be applied to the TS2000 through pin 9 of the serial connector. This is a non-standard use of pin 9. However, for most serial ports this is not a problem because pin 9 is typically either unused (left unconnected) or used as RI (Ring Indicator). Since RI is a modem (DCE) output and the TS2000 power supply falls within the allowed voltage range for RS-232 signals, this is interpreted as an active RI signal. For systems which use this signal differently, or cannot operate with power on this pin, this pin should be disconnected between the TS2000 and the host equipment.

Signal Levels

The serial port can be configured for either RS-232 or TTL signal levels. To change the signal levels, the modem must be opened and the four jumper plugs next to the serial port connector set to the desired position (see Appendix E for the jumper positions and Appendix A for signal level specifications).

Configuration Options

The serial port provides a number of configuration options to allow it to be connected to virtually any asynchronous host equipment. These configuration options are set using the TS2000 configuration program.

Protocol Options

Selection	Description
Hardware Handshake	This mode uses the RTS handshake line to frame transmit data into bursts. The TS2000 begins transmission when RTS is activated and at least one character (non-control string) is received. Transmission ends when RTS goes inactive and the burst has been completely transmitted.
Data Activation	This mode uses a character timer to frame the transmit data into bursts. The TS2000 begins transmission when one character (non-control string) is received. The transmit burst is completed when the transmit data line is idle (no data) for the number of character periods defined by the data activation timeout control.
Data Activation Timeout (Timeout Time)	This control sets the number of character periods of idle required on the serial port's transmit line to declare the end of a transmit burst. Char Period = (Char Length + 2) / (Baud Rate) Char Length is the value selected from the async character list and Baud Rate is the value selected from the baud rate list. The 2 added to the Char Length accounts for the start and stop bits in the asynchronous character.

Baud Rate List

The baud rate list provides selection of the serial port asynchronous baud rate. The available selections are 300, 1200, 2400, 4800 and 9600 baud.

Async Character Options

This option list allows selection for the length of the asynchronous characters. This can be set for values of 8 or 9 data bits. The following table shows the appropriate selection for typical configurations.

Data Bits	Parity	Stop Bits	Setting
7	Off	2 or more	8 bits
7	On	1 or more	8 bits
8	Off	1 or more	8 bits
8	On	1 or more	9 bits
9	Off	1 or more	9 bits

Wait For Complete Burst Before Transmitting

Selection	Description
Disabled	The modem begins transmitting as soon as it receives the first non-control character of a transmit burst.
Enabled	The modem waits for a complete transmit burst before it begins transmitting.

Other Serial Options

These options are accessible by pressing the Options button in the serial port interface frame.

DCD Options

Selection	Description
Active when Sending Receive Data to User	DCD is active when receive data is sent out of the TS2000 via the serial port.
Active when Receiving	DCD is active when the TS2000 detects a signal on the radio channel. This mode can be used to remote the receive LED.
Both	DCD is active when receive data is being sent out the serial port or when the a signal is detected on the radio channel. Note that for most conditions and configurations these states overlap.

Receive Data Options

Selection	Description
Idle Time Between Bursts	This timer controls the minimum amount of time (in character periods) that the receive data (RXD) line will be idle (inactive) between received bursts of data. If the value is set to zero, the receive data line may remain active continuously when multiple bursts of receive data are transferred to the user. If the DCD line option is set for the Active when Sending Receive Data to User then the DCD line will also be inactive during the receive data line idle times.

DTR Options

Selection	Description
Disabled	DTR has no effect on the operation of the modem. All data received by the TS2000 is sent to the host equipment via the serial port.
Enabled	DTR acts as flow control for receive data coming from the TS2000 via the serial port. When DTR is inactive, data received by the TS2000 is stored in an internal buffer and inhibited from being sent to the host equipment. The flow of receive data out of the serial port resumes when DTR is activated.

DSR Options

Selection	Description
Active when Operational	DSR is active when the TS2000 is powered and has passed self test.
Active when Receiving	DSR is active when the TS2000 detects a signal on the radio channel. This mode can be used to remote the receive LED.
Active when Transmitting	DSR is active when the TS2000 is transmitting. This selection can be used to remote the transmit LED.

CTS Options

Selection	Description
Always active	The CTS line is active.
Active when transmitter is sending data	CTS is normally inactive and is activated when the TS2000 is transmitting and the radio channel is ready for the transmission of data.
Active when transmitting	CTS is normally inactive and is activated when the TS2000 is transmitting. Note that the modem begins transmitting only after it has received at least one character of data. This selection can be used to remote the transmit LED.
Activated when RTS is active	CTS is normally inactive and is activated a fixed time after RTS becomes active. The time is controlled with the RTS to CTS delay value.
Deactivate CTS when transmit buffer is full	When this is enabled, CTS is deactivated when the transmit buffer is full. This setting effects all of the above options.

Scramble Code

The scramble code determines the pseudo random sequence used to scramble the transmitted data. This provides data privacy and also randomizes the data for optimum signal detection. The same scrambling code must be used by all TS2000s operating in the same data network.

Radio Interface

The radio interface provides the connection between the TS2000 and the radio.

Connector

The radio interface uses a 25 pin subminiature D connector with male pins (see Appendix B for the pinout). To minimize emissions and interference, the cabling used to connect to the radio interface must be good quality shielded cable.

Configuration Options

The radio port has a set of configuration options which allow it to be setup for a specific radio. These configuration options are set using the TS2000 configuration program.

Channel Rate Options

Selection	Description
1200 bps	1200 bps provides better BER (bit error rate) performance than the 2400 bps selection. 1200 bps is also much less sensitive to distortion caused by radios and repeaters.
2400 bps	This selection provides the highest data throughput.

Enable Coding

Selection	Description
Disabled	This minimizes the amount of overhead required to send data.
Enabled	Transmitted data is block coded (12,8 Hamming) and interleaved (16 bits). This provides error correction for strings of errors up to 16 bits long. Coding requires an extra 50 % overhead on top of formatted data. This type of coding is ideal for combating errors induced from multipath fading common in mobile environments.

Transmit Timeout Timer

Selection	Description
Disabled	The TS2000 will transmit continuously for any amount of time.
Enabled	The TS2000 stops transmitting after a specified period of time. This is used to avoid locking up the radio channel due to a continuous transmission caused by an equipment fault.

Force Transmit Over Receive

Selection	Description
Disabled	The modem will not transmit while receiving. Transmit data is buffered and then transmitted when the TS2000 stops receiving. This selection has effect only if the TS2000 is configured for half duplex mode and packet operation is disabled.
Enabled	The modem transmits as soon as data is ready without regard to the receive state.

RCD Required for Receive

Selection	Description
Disabled	The receive state is enabled based on an internal data detection circuit. The TS2000 may flicker in and out of receive mode when used with radios which do not shut off their audio (data) output when not receiving.
Enabled	Receive is enabled when both the internal data detection circuit and the Receive Carrier Detect input signal are active. This requires attaching the RCD (Radio Carrier Detect) signal from the radio to the Receive Carrier Detect input of the TS2000. The active level of the Receive Carrier Detect input signal is set on the radio options screen.

Share Voice Channel

Selection	Description
Enabled	The radio used with the TS2000 is used for both voice and data communications. This option requires the use of the Voice PTT input line. To see the details of the radio channel options press the Channel button which opens the radio channel options screen.
Disabled	The radio connected to the TS2000 is used only for data.

Radio Options

These selections are available by pressing the Show Radio button in the radio interface frame.

Transmit Attack Time Options

Attack time is the amount of time necessary to establish the radio channel. This includes the power up time for the transmitter and the time for the receiver to sense and demodulate the transmit signal.

Selection	Description
Fixed	The attack time is a fixed time set with the attack time control.
Channel Driven	The attack time is controlled by the Transmit Channel Grant signal. In this mode the attack time may vary for each transmission.

Channel Grant Options

Control	Description
Active Level	The signal polarity at which the Transmit Channel Grant input signal is active.
Dwell Time	The amount of time that the Transmit Channel Grant signal must be active before the channel is declared ready for data transmission.
Timeout Time	The maximum amount of time the TS2000 will wait for the Transmit Channel Grant signal to become active. When a timeout occurs the TS2000 will stop and then re-start the transmission.

Transmit Decay Time

Decay time is the amount of time necessary to end a transmission. This includes the power down time for the transmitter and the time for the receiver to detect the loss of the transmit signal. The decay time controls the minimum amount of time between transmissions.

In half duplex mode the decay time also defines the minimum time from when a transmitting TS2000 finishes transmitting data to when it can start to receive data from other TS2000s.

Data PTT Level The signal polarity at which the Data PTT output line is active.

Transmit Data Level This control selects the range of levels over which the transmit data signal can be adjusted.

Selection	Description
Low	0 to 0.3 volts peak to peak (0 to 0.1 volts rms).
High	0 to 5.0 volts peak to peak (0 to 1.7 volts rms).

Duplex Options

Selection	Description
Half	The TS2000 operates as half duplex which implies that it cannot receive and transmit simultaneously. Note that the serial port will still send and receive data simultaneously in this mode.
Full	The TS2000 operates as full duplex which means that it can receive and transmit simultaneously. To operate as full duplex, the radio used must be also be full duplex.

Radio Carrier Detect Level The signal polarity for which the Receive Carrier Detect input signal is active. This signal is used only if the RCD Required for Receive control is enabled.

Radio Channel Options

These selections are available by pressing the Channel button in the Radio Interface frame. This button can only be pressed when the Share Voice Channel control is enabled.

Voice PTT Controls

Control	Description
Voice PTT Detect Level	The signal polarity for which the Voice PTT Detect input is active. This input is used to detect when the radio is transmitting voice. The Voice PTT line is only detected when the Data PTT output line is inactive.
Data Hold Off Time	This control defines the amount of time that data transmissions will be held off after a voice transmission. This prevents data traffic from interrupting a voice conversation. Voice transmissions are detected with the Voice PTT Detect input.

Speaker Mute Controls The Speaker Mute output is used to mute the speaker so that voice users do not hear data receptions. When the speaker mute operation is enabled the speaker is always muted except for voice receptions and transmissions. When speaker mute operation is disabled, the Speaker Mute control line is always set to the unmuted state.

For the speaker mute option to operate correctly the Receive Carrier Detect input must be used and the RCD Required for Receive control on the main configuration screen must be enabled (see Configuration Options - RCD Required for Receive).

Control	Description
Data Detect Timer Enable	Activate speaker mute operation and use the data detect timer to differentiate voice and data receptions.

Control	Description
Voice Rx Detect Input Enable	Activate speaker mute operation and use the Voice Reception Detect input to differentiate voice and data receptions.
Speaker Mute Active Level	The signal polarity for the Speaker Mute output which mutes the speaker.
Data Detect Time	This is the time between the Receive Carrier Detect signal going active and the time when the TS2000 should be synchronized to incoming data if data is being sent. If the TS2000 has not synchronized to data by the end of the Data Detect Time then the reception is declared to be a voice reception and the speaker is unmuted. Note that the speaker will be unmuted for data receptions that are too noisy for the TS2000 to synchronize to.
Voice Rx Detect Input Dwell Time	The amount of time that the Voice Reception Detect input line must be active before a reception is declared to be a voice reception and the speaker unmuted. Once unmuted, the Speaker Mute signal will remain inactive until the Receive Carrier Detect signal goes inactive.
Voice Rx Detect Input Active Level	The signal polarity for which the Voice Reception Detect input line is active.

Channel Select Output Controls

The channel select outputs are used for systems where the radio transmits data on one channel or group and voice on a different channel/group. For multiple channel/group operation, the radio is normally set on the voice channel/group. When a data transmission is to occur the TS2000 switches the radio to the data channel/group. After the data transmission is finished the TS2000 switches the radio back to the voice channel.

While on the data channel/group the TS2000 monitors the Voice PTT line. If the Voice PTT line is detected to be active then the TS2000 will switch the radio back to the voice channel/group as soon as possible. As soon as possible is as soon as the data is transmitted and the Voice PTT line is inactive. Note that the Voice PTT line is only monitored when the data PTT line is inactive. This is because for many radios the PTT lines are wire ORd together.

Control	Description
Enable Channel Select Output	Activate channel select output operation using a static channel select signal on the Channel Select line. In this mode, the Channel Select line is set to the data level before a data transmission and reset after a data transmission.
Enable Channel Switching	Activate channel select output operation using pulsed channel switching signals on the Channel Select Up and Channel Select Down lines. Before a data transmission, the radio channel or group is switched using pulses on the Channel Select Up line. The channel is switched until the Data Channel Detect input line becomes active. After a data transmission, the radio channel/group is returned to the voice channel using pulses on the Channel Select Down line.

Control	Description
Channel Setup Time	This control sets the amount of time between the switch to the data channel and the activation of the Data PTT line.
Channel Hold Time	This control sets the time between the data transmission (including the transmit decay time) and the switch back to the voice channel. This hold time is used to wait on the data channel for a data response (receive).
Channel Select Output - Data Level	The signal polarity of the Channel Select output which sets the radio for the data channel or group (as opposed to the voice channel/group).
Channel Switch Outputs - Active Level	The signal polarity of the Channel Select Up and Channel Select Down output lines that switches the radio channel.
Channel Switch Outputs - Active Pulse	The amount of time used for the active level pulse of the Channel Select Up and Channel Select Down output lines.
Channel Switch Outputs - Inactive Pulse	The amount of time used for the inactive level pulse of the Channel Select Up and Channel Select Down output lines.
Data Channel Input - Active Level	The level of the Data Channel Detect input line which indicates that the radio is on the channel (or group) used for data transmissions.

Connecting to Radios

The radio interface connector on the TS2000 provides a very flexible interface for connecting the TS2000 to mobile and portable radios. This interface includes all of the signals necessary to support basic data operation with radios dedicated exclusively for data communications as well as the signals required to control radios used for both data and voice communications. A TS0122 radio interface cable is supplied with each TS2000. One end of this cable connects to the 25-pin radio interface connector on the TS2000, the other end is supplied with flying leads and connects to the radio's accessory connector or internal circuitry. Refer to Appendix B for a detailed listing of the TS2000 radio interface connector pinout.

The use and functionality of most of the TS2000's radio interface signals are configurable to allow these signals to be tailored to virtually any voice radio. The configuration of these signals is set using the TS2000 configuration program. Detailed information on configuration options for these signals can be found in the Radio Interface section of this manual.

For many radios currently in use, Teledesign Systems has available installation guides which provide information on connecting the TS2000 to specific radios. Each guide includes detailed information on the radio pinout, wire-out or accessory connector signals used by the TS2000 and includes the preferred configuration of the TS2000 for operation with the radio. Please call Teledesign's technical support for the availability of a guide for the radio you are connecting to.

Radio Connection

Although mobile and portable radios are available in a wide variety of styles and support a varied complement of features, the fundamental set of building blocks that make up these radios are virtually all the same. Each radio includes circuitry for receive and transmit audio processing, logical control of sub-audible signaling and trunking control data, carrier frequency synthesis, receive demodulation, transmit modulation and exciter functions, and transmit RF power amplification. The TS2000 typically interfaces with a radio at only the receive and transmit audio processing and logic control levels. Typically these functions are concentrated on a single printed circuit board in the radio. The interface cable used to connect the TS2000 to the radio will typically need to be connected to only this one area in the radio.

Radio Options Connector

Many new radios now on the market include an options connector for supporting connection of external equipment to the radio. This connector usually includes connections for tone signaling equipment supporting DTMF and ANI applications, mobile data terminals, and data modems. These options connectors typically include receive and transmit audio, transmit push to talk, receiver squelch control, serial control lines for controlling radio functions, and power and ground connections. Where possible, it is advantageous to connect to the radio through this external options connector.

Basic Radio Connections

The basic radio connections are interface lines which are required for all TS2000 installations. These lines include power and ground, transmit audio, receive audio and data push to talk. All other radio interface connections provide enhancements to the basic operation of the TS2000 to support shared voice and data operation and radios operating with advanced radio repeater systems.

Ground Three ground lines on the TS2000 radio interface connector provide common signal returns for all of the power, audio and control signals to and from the radio.

At a minimum pins 1 and 7 should be connected to the ground or signal common on the radio. Pin 7 is the primary power return pin. Pin 13 is optional but should be connected to the common of the radio's logic board if many of the radio interface connector's optional control signals are used. If the connection to the radio supports a separate microphone return (ground) line, use pin 1 of the radio interface connector for this connection since pin 1 terminates closest to the audio circuitry in the TS2000. All three ground pins are connected to a common ground inside the TS2000.

Power This is the primary power input for the TS2000. This power input must be in the range of 6 to 18 volts DC. This power range is designed to accommodate standard automotive voltages as well as portable radio battery supplies. Internal TS2000 circuitry connected to this input is designed to withstand voltage spikes up to 50 volts. All internal circuitry connected to this power input is reverse polarity protected to protect the TS2000 from damaged if the power and ground leads of the TS2000 are connected to power with the wrong polarity.

This input is internally connected to the power input pin of the TS2000 serial port connector. Either input can be used to power the TS2000 and each input is protected with a separate internal fuse. However, the power inputs of the TS2000 radio interface connector and serial port connector are not reverse polarity protected from each other.

Transmit Audio This single-ended output supplies the TS2000 transmit data modulation tones to the radio. The modulation tones switch between 1200 Hz and 1800 Hz for the 1200 bps channel rate, and between 1200 Hz and 2400 Hz for the 2400 bps channel rate.

The output driver is capable of driving low impedance audio inputs and becomes high impedance when the TS2000 is not transmitting. The level of this output is adjusted using the transmit level control which is accessible through the back panel of the TS2000. This output is factory configured for AC coupling but may be set for DC coupling by installing a jumper resistor on the TS2000's circuit board.

For best results, this output should be connected to the flat transmit audio input of the radio. The flat transmit audio input provides the least distorted path through the transmit audio circuitry by bypassing the microphone high-pass filtering and pre-emphasis. If a flat transmit audio input is not available, connect this output to the microphone input of the radio. In some cases, connection to the microphone input may limit the usable channel rate to 1200 bps due to excessive group delay distortion.

Receive Audio This pair of inputs provides a differential connection for the demodulated data tones received by the radio. These inputs support both differential and single-ended connections to the radio. Both Receive Audio + and Receive Audio - are high impedance AC coupled inputs. Care should be taken not to exceed the maximum input signal levels of these inputs and to minimize stray pick-up of noise and unwanted signals on these high impedance lines . The level of this input signal used internally in the TS2000 is adjusted using the receive level control which is accessible through the back panel of the TS2000.

For most radios Receive Audio - should be connected to the discriminator output or flat receive audio output of the radio. Receive Audio + should left unconnected or be connected to the radio's audio ground. The discriminator output provides the least distorted path through the receive audio circuitry and bypasses the receive audio low and high-pass filters, de-emphasis circuitry and speaker amplifier.

If a discriminator or flat receive audio output is not available, connect these inputs into the receive audio path just before the radio's volume control. This connection will provide a filtered but constant level receive signal to the TS2000. If these connections are not possible, connect the TS2000 receive audio inputs across the speaker output of the radio. Note that in this case the speaker's volume control will affect the signal level into the TS2000. In some cases, connection to the speaker output may limit the usable channel rate to 1200 bps due to excessive group delay distortion.

A differential type connection is most commonly used when connecting the TS2000 to the speaker leads of the radio. Many radios actively drive both leads of the speaker with the speaker floating above ground.

Data PTT

This output is used to activate the radio's transmitter when the TS2000 is sending data. This output is an open collector output which can be configured to activate transmission in either the low or the high impedance state (see the Radio Options section). Data PTT should be connected to either the radio's microphone push to talk line or to a separate data transmit request (enable) input if the radio provides one.

Enhanced Radio Connections

Receive Carrier Detect

This input is used to notify the TS2000 when the radio is receiving a radio signal. The use of the Receive Carrier Detect input is enabled only when the RCD Required for Receive option is enabled. If Receive Carrier Detect is not used then the TS2000 determines when to receive based on an internal data detection circuit only. When the Receive Carrier Detect signal is used then the TS2000 receives when both the internal data detection circuit and the Receive Carrier Detect input signal are active. The active level of the this signal is set with the Radio Carrier Detect Level control on the radio options screen.

The Receive Carrier Detect signal is typically used for radios which do not mute their audio output when not receiving. Radios of this type typically output a strong noise signal when not receiving. This strong noise signal can cause the TS2000 to flickers in and out of receive mode (Rx LED flickers).

The Receive Carrier Detect signal can also be used to qualify different radio signals on a channel which enables the TS2000 to demodulate data only from specific radio channel signals. For best results, connect this input at the point in the radio where the radio's carrier detect or squelch control signal is active only when the radio is detecting the proper sub-audible signaling (if used with simplex operation and conventional repeaters) or valid trunk group or sub-fleet ID codes (if used with trunking repeaters). This internal radio signal is typically the same signal used to control the receiver's audio muting circuitry. For radios operating with trunking repeater systems, this internal radio signal is the logic squelch output of the radio's logic control board.

The Receive Carrier Detect signal must be used if the Voice Reception Detect input is used for shared voice and data operation (see below).

Transmit Channel Grant

This input is used to indicate to the TS2000 that a transmit channel has been assigned to the radio and that the TS2000 can begin sending data. This input is typically used when connecting the TS2000 to radios operating through trunking repeater systems. Connect this input to the radio's internal transmit enable line controlling the transmitter's exciter and RF amplifier. This signal is usually found on the logic control board of the radio or as an options signal provided on the radio options connector. This input is used only when the Channel Driven Transmit Attack Time option is enabled. The active level of this signal is set with the Channel Grant Options - Active Level control on the radio options screen.

Shared Voice Channel Connections

These connections are used by the TS2000 to arbitrate active control of the radio between a voice user and the data modem. When configured for shared voice and data operation the TS2000 is designed to give voice traffic priority over data.

Voice PTT Detect

This input is used to detect when the radio's microphone PTT switch is pressed. This line is typically connected to the microphone PTT line in the radio. For many radios this connection is the same point where the Data PTT output of the TS2000 is connected. Because these are the same point for most radios, the TS2000 cannot detect the voice PTT line during a data transmission (when the Data PTT line active). Therefore the TS2000 only monitors the Voice PTT Detect line when the Data PTT line is inactive.

The active state of this signal is set with the Voice PTT Detect Level control on the radio channel options screen. The TS2000 can be configured to hold off data transmissions for a period of time after the radio's microphone PTT line is activated (see the Data Hold Off Time control on the radio channel options screen). This prevents data transmissions from interrupting voice conversations.

Channel Select/ Channel Select Up

This output has two modes of operation. For both of these modes it is used to select a specific radio channel, sub-audible tone, trunk group or sub-fleet for data transmissions.

The static mode is enabled when the Enable Channel Select Output control on the radio channel options screen is activated. In this mode, the Channel Select signal is activated during data transmissions. This output should be connected to the radio option connector signal or the internal radio signal which controls the channel selection between the voice and data channel. The active state is set with the Channel Select Output - Data Level control option on the radio channel options screen.

The dynamic mode is enabled when the Enable Channel Switching control on the radio channel options screen is activated. In this mode, this Channel Select Up and Channel Select Down signals are used to select the data or voice channel. This Channel Select Up signal is used to toggle the channel/group of the radio up to the data channel/group before transmitting data. This output toggles until the Data Channel Detect input signal becomes active (see below) which indicates that the radio is on the data channel/group. This output should be connected to the increment channel/group button. For more information, refer to the installation guides for radios supporting this feature.

Channel Select Down

This output is used in conjunction with the dynamic mode of the Channel Select Up output. This output is used to toggle the channel or group of the radio down to the voice channel/group after transmitting data. This output should be connected to the decrement channel/group button. For more information, refer to the installation guides for radios supporting this feature.

Data Channel Detect This input is used in conjunction with the dynamic mode of the Channel Select Up and Down outputs. This input is used to detect when the radio has been switched to the data channel/group. This input should be connected to a signal of the radio which is only activated when the radio is on the data channel/group.

Speaker Mute This output is used to mute the radio's speaker during data receptions so that the voice user does not have to listen to the data activity. Speaker Mute is an open collector output which can be configured to mute the speaker in either the low or high impedance state. How the TS2000 decides when to mute the speaker depends on the settings of the Speaker Mute Controls on the radio channel options screen (see Speaker Mute Controls).

This output is normally connected to the radio receiver's audio mute circuitry used by the radio to squelch and unsquelch the receiver's speaker audio. As an alternative, some radios provide a low logic level speaker mute control line as part of the their options connector.

Voice Reception Detect This input is used to detect when the radio is receiving a voice transmission. The TS2000 uses this input to determine when to mute and unmute the speaker for shared voice and data channel operation. This signal is only used if the Voice Receive Detect Input Enable control option (under the Speaker Mute options) of the radio channel options screen is enabled. The active state of this line is configured with the Voice Receive Detect Input Active Level control on the radio channel options screen.

This input should be connected to an option signal provided by the radio that can be programmed to be active only on selected channels, trunk groups or sub-fleets. The Horn Alert output of some radios can be used for this purpose. In this case, the radio should be programmed to activate its Horn Alert output for only those channels or trunk groups that are used for voice communications.

Microphone Mute This pair of outputs forms an isolated switch used to mute the radio's microphone during data transmissions. The switch formed by these two outputs is closed only when the Data PTT output is active (TS2000 transmitting data).

For most installations, connect Microphone Mute - to audio ground on the radio and Microphone Mute + to the radio's microphone input.

For radios that provide a microphone mute logic control line, this isolated switch can be used to provide an active high or active low logic control signal. For most radios the microphone mute logic control line is by default pulled to the unmuted logic state. For an active high mute, connect Microphone Mute + to the radio's logic supply and Microphone Mute - to the microphone mute logic control input. For an active low mute, connect Microphone Mute + to the microphone mute logic control input and Microphone Mute - to the radio's logic ground.

Auxiliary Connections

Receive Calibration Test Point This output can be used as an alternate alignment point for setting the receive audio level in the TS2000. This output is connected internally to the same monitoring point where the receive audio level is measured and displayed by the TS2000 configuration software's modem test.

Reserved Connections

Signal	Description
Switched Power	This output can be used as a source of power for an external device requiring switched power from the TS2000. It can also be used as a logic output to the radio, switching between approximately ground and the TS2000 power input supply level.
Analog Input 2 Analog Input 3	These two inputs can be used to sense and measure two different analog voltages in the range of 0 to 20 volts. These inputs can also be used as logic inputs for logic levels up to 20 volts.

AirNet Packet Protocol

Overview

AirNet is an embedded packet protocol available in some Teledesign Systems modems. AirNet provides a complete protocol that manages the end to end data transfers of wireless networks. The AirNet protocol is flexible and configurable so that it can be used with any host (user) system or network architecture. This includes networks that use either conventional or trunked repeaters.

Packet Basics

The basic purpose of the AirNet packet protocol is to ensure that data is reliably transferred between nodes in the network. This means preventing data from being lost, repeated or corrupted at the receiving nodes. This is accomplished by combining transmit data into packets which contain user data and control information. The control information includes addressing, sequencing and error detection. Addressing information allows receiving nodes to determine if a packet is intended for them and also who the source of the packet was. Sequence information is used so that the data can be reconstructed in the correct order, and so that repeated packets of the same data are not given to the user. Error detection is provided by adding a CRC (Cyclic Redundancy Check) onto the packet so that any corruption of the packet can be detected.

Addressability

The key feature of any packet data protocol is its ability to identify and coordinate data transfers between individual nodes in a network. In order to move data between nodes, each node is assigned a unique address. With the AirNet protocol each node is assigned a unique individual and group address. Group addresses allow the nodes in a network to be partitioned into classes of service or segmented into regions. The AirNet protocol allows a data packet to be transferred to an individual node, to all nodes in a group (group broadcast), or to all nodes in all groups (network broadcast).

The AirNet protocol also includes multicast reception. Multicast reception is the ability of a node to receive group broadcasts for groups other than its own. This allows a node to be a member of a number of different groups at the same time.

Acknowledgment and Retries

Individual node to node data transfers can be sent with or without positive acknowledgment from the destination node. Positive acknowledgment is the process where a destination node which receives an error free packet sends a return packet (without user data) to tell the source node that the packet was received correctly. This allows the source node to be sure that the data has been transferred. If the sending node does not receive an acknowledgment (ACK) packet within a preset period of time then it automatically re-sends (or retries) the data packet.

Note that broadcast packets are never acknowledged and therefore the source node cannot be sure that they have been received correctly by all the destination nodes.

Channel Access

For most wireless data networks, there is the possibility that more than one node will attempt to transmit simultaneously. This is termed a collision and typically results in the data from both nodes being lost. To minimize collisions, the nodes must have an orderly means of accessing the shared channel. The AirNet protocol uses a CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) protocol to coordinate channel access (see CSMA System for details).

Store and Forward Relay

In many networks some nodes are unable to directly communicate with all other nodes in the system due to insufficient RF coverage. To combat this many systems use frequency translating repeaters that are located at advantaged (mountaintop) locations. In some situations, the use of a repeater may be logistically difficult and may not completely solve all propagation problems. The AirNet protocol provides an option where nodes can be set up as store and forward relays. The relay nodes store packets that they receive and repeat (forward) the packets when the channel is idle. The relay nodes can be set to relay all packets or only packets with certain source or destination addresses.

Features

Complete Packet Capability

- Nodes automatically re-send packets which are not received correctly.
- Robust 32 bit CRC ensures that packets are received correctly.
- Adjustable maximum number of retries.
- Adjustable maximum packet size - Large packets can be automatically broken up into smaller packets for reliable transmission.

Easy to Use Host Control and Status

- The host (user equipment) controls operation of the packet protocol with simple ASCII command strings.
- No special formatting of user data is required.
- Status strings can be enabled to provide information on the success or failure of packet transmissions.

Addressing

- Individual addresses from 1 to 999.
- Group addresses from 1 to 60.
- Various transfer types
  - Individual (point to point with acknowledge) - The acknowledgment provides for guaranteed delivery of the data packets.
  - Individual without acknowledgment.
  - Group broadcast - Unacknowledged transfer to all members of a group.
  - Network broadcast - Unacknowledged transfer to all modems.
- Multicast receptions - Allows a modem to receive group broadcasts to groups other than its own. This can be used to create sub-groups or super-groups of modems.

Channel Access

- CSMA/CA - Carrier Sense Multiple Access with Collision Avoidance.
- Adjustable Transmission Index (transmit probability) - Allows a network to be optimized for maximum efficiency.
- Adjustable Slot Time - Allows the modem to be optimized for different radios and repeater systems.

Store and Forward Data Repeater

- Any unit can be configured as a relay node. Allows for easy expansion of the network.
- Relay filter allows for relaying of only packets to or from select nodes. This minimizes the amount of relay traffic created.

Configuration Options

Packet Activate

Selection	Description
Packet for Data	This activates packet operation for all user data.
Basic Packet	This activates basic packet operation. Basic packet does not provide some advanced features like store and forward repeating. It is only recommended for setups that need to be compatible with previously installed modems using older firmware (pre Ver 3.00).

Modem Address

Control	Description
Individual Address	The individual address of this modem.
Group Address	The group address of this modem. The group address is used to isolate different sets of individual addresses. It is also used to filter group broadcast transfers.

Multicast Group Reception

Multicast groups allow a modem to receive group broadcasts to groups other than its own. This allows modems to be combined in subsets and supersets of their basic groups.

Control	Description
Enable Multicast Reception	This control enables the multicast capability of the modem and also enables the entry of multicast groups.
Multicast Groups	This control is a list of multicast addresses. These addresses have the same range as the group addresses. The user can use as few or as many (up to the list size) multicast groups as desired. When an address in the list is disabled, stars ("***") are displayed in place of the address.

By default, a modem accepts two kinds of broadcasts.

- Network broadcasts are received by all modems.
- Group broadcasts are received by modems with the same group address as the transmitting modem.

Default Transfer

This field selects the type of transfer that the modem defaults to at power up. This will remain as the transfer type until it is switched using the appropriate control string.

Selection	Description
Individual Transfer	This is a standard point to point data transfer with acknowledgments.
Individual Transfer w/o Acknowledge	This is a point to point data transfer but without any acknowledgments. This implies that there are no transmit retries if the packet is received with errors.
Group Broadcast	This is a broadcast to a group of modems. Receiving modems will accept two types of group broadcasts. ■ Group broadcasts - Broadcasts where the destination group matches the receiving modem's group. ■ Multicast broadcasts - Broadcasts where the destination group matches a group from the receive modem's multicast group list. For these broadcasts to be received the receiving modem must have multicast reception enabled.
Network Broadcast	This is a broadcast to all modems.

Default Destination Address

These fields select the default destination address that the modem defaults to at power up. This address will remain as the default until it is switched using the appropriate control strings.

Type	Description
Individual Address	The default destination individual address.
Group Address	The default destination group address.

Medium Access Control Options

The type of Medium Access Control (MAC) determines how a modem decides when to transmit packets. This effects the transmission of both data and acknowledgment packets.

Selection	Description
Master-Slave	The modem will transmit data as soon as the channel becomes idle. This mode should only be used for master-slave systems where two modems will never attempt to transmit at the same time. This also implies that store and forward relays are not used in the system.
CSMA	Carrier Sense Multiple Access. This mode should be selected for systems where multiple modems may attempt to transmit simultaneously. With this setting, the modem waits until the channel becomes idle and then transmits in each following idle slot based on a random probability of transmission (see CSMA MAC Options - Transmission Index). This minimizes the potential for collisions in multi-access systems.

CSMA MAC Options

Control	Description
Slot Time	This sets the transmit slot time (see Setting Slot Time).
Min Idle Slots	This sets the minimum number of idle slots before a modem attempts transmission (see Setting Min Idle Slots). If the minimum number of idle slots is set to zero the modem randomizes its transmission attempts with the first slot after the channel becomes idle. For values greater than zero, the modem waits that many slots before randomizing its transmission attempts.
Tx Index	The transmission index (TI) is the inverse of the probability of transmitting in an idle slot. An index of 4 corresponds to a 1/4 or 25% chance of transmitting in an idle slot. The goal of setting TI is to maximize efficiency on the channel. If TI is set too low then transmissions collide too often. If TI is set too high then there is excessive unused channel time in the system (see Setting Transmission Index).

Min Idle Slots and Tx Index can be set differently for different types of packets. The following table describes the different packet types.

Type	Description
Data Packets	These are any packets that carry user data. These include data packets for all the different types of transfers (i.e. Individual, Individual w/o ACK, Broadcast).
ACK Packets	These are the acknowledgment packets for the individually addressed data packets.
Relay Packets	These are any packets that are relayed with the store and forward relay option. Both data packets and ACK packets can be relayed.

Packet Operation

Control	Description
Maximum Packet Size	This control defines the maximum packet size in bytes. Any burst that is larger than this number of bytes will be broken up into multiple packets with this maximum packet size. Note that there is a difference between bytes and asynchronous characters. A byte is always eight bits of data. The number of bits in an asynchronous character is dependent on the setting of the asynchronous character control fields.
Maximum Number of Retries	This control sets the maximum number of transmit retries. A retry is attempted if a packet is sent and an acknowledge is not received within the time defined by the packet timeout control. After the maximum number of retries have been attempted the packet is cleared from the transmit buffer. Retries do not apply to any kind of broadcast transfers or individual transfers without acknowledgment.
Packet Timeout	The packet timeout is the amount of time the modem waits for an acknowledgment before re-sending a packet (see Network Setup - Setting Packet Timeout).

Packet Status Data

Control	Description
Provide Address at Receiver	When this control is activated, the source address of each received packet is sent as a prefix status string to the data (see Control and Status Strings).
Provide Positive Transmit ACKs	When this control is activated, a status string is sent to the user when an acknowledgment is received for a packet. The corresponding packet number of the packet will be provided as part of the status string (see Control and Status Strings). This does not apply to any type of broadcast transfer or individual transfers without acknowledgment.
Provide Negative Transmit ACKs	When this control is activated, a status string is sent to the user when the transfer of a packet is unsuccessful (all retries have been sent and no acknowledgment has been received). The corresponding packet number of the packet will be provided as part of the status string (see Control and Status Strings). This does not apply to any type of broadcast transfer or individual transfers without acknowledgment.

Store and Forward Data Repeater Options

Individual Packet Relay Activate

Selection	Description
None	No individually addressed packets are relayed.
Some	The individual packets which are relayed is determined by the individual relay addresses control.
All	All individually addressed packets are relayed. The exception to this are packets for whom the final destination is the relay node.

Broadcast Packet Relay Activate

Selection	Description
None	No broadcast packets are relayed.
Some	The broadcast packets which are relayed is determined by the broadcast relay addresses control.
All	All broadcast packets are relayed.

Network Broadcast Packet Relay Activate

Selection	Description
Disabled	No network broadcast packets are relayed.
Enabled	All network broadcast packets are relayed.

Individual Relay Addresses

This control consists of a list of address ranges. Each item in the list represents a range of addresses which are relayed. A packet is relayed if the packet's source or destination address matches an address range in the list. The addresses consist of a group address and a minimum and maximum individual address. The user can use as few or as many (up to the list size) address ranges as desired. When an address in the list is disabled, stars ("***") are displayed in place of an address.

Broadcast Relay Addresses

This control consists of a list of broadcast addresses. Each address in the list is a group address for which broadcast packets are relayed. The user can use as few or as many (up to the list size) addresses as desired. When an address in the list is disabled, stars ("***") are displayed in place of an address.

Control and Status Strings

Control strings are used to control the operation of the modem. Status strings are used to provide status information from the modem. Status strings from the modem can be disabled if they are not needed for a given application. All control and status strings begin with the ASCII string “+TS”, followed by specific ASCII letters and numbers corresponding to the particular control field or status value provided (See Appendix F - ASCII Character Set).

All numbers are formatted as ASCII digits and sent most significant digit first.

iii - Represents a three digit individual address.
gg - Represents a two digit group address.
nn - Represents a two digit packet number.

Control Strings

Control String	Description
+TSI	Set for individual transfer.
+TSIAiii	Set for individual transfer with address change. The three address characters change the individual destination address.
+TSICggiii	Set for individual transfer with complete address change. The first two characters are for the group address and the remaining three are for the individual destination address.
+TSN	Set for individual without acknowledgment transfer.
+TSNAiii	Set for individual without acknowledgment transfer with address change. The three address characters change the individual destination address.
+TSNCggiii	Set for individual without acknowledgment transfer with complete address change. The first two characters are for the group address and the remaining three are for the individual destination address.
+TSG	Set for group broadcast transfer.
+TSGAgg	Set for group broadcast transfer with address change. The two address characters change the group destination address.
+TSB	Set for a network broadcast transfer (to all modems).
+TSFAggiii	Change the modem destination address. The first two address characters are for the group address and the remaining three are for the individual address. The type of transfer remains unchanged.
+TSSnn	Set the packet number of the next packet transmitted. Packet numbers are used in status strings to indicate the success or failure of the transmission of a particular transmit packet. The packet number is set to 0 when the modem is reset.

Status Strings

Status String	Description
+TSIAggiii	Received an individual packet from this address. The first two address characters represent the group address and the next three the individual address.
+TSNAggiii	Received an individual without acknowledgment packet from this address. The first two address characters represent the group address and the next three the individual address.
+TSGAggiii	Received a group broadcast packet from this address. The first two address characters represent the group address and the next three the individual address.
+TSBAggiii	Received a network broadcast packet from this address. The first two address characters represent the group address and the next three the individual address.
+TSSFnn	Indicates that the transfer of this packet number was not successful. This status string is returned after the last retry of this packet has timed out. This does not apply to any type of broadcast packet or individual without acknowledgment packets.
+TSSPnn	Indicates that the transfer of this packet number was successful. This does not apply to any type of broadcast packet or individual without acknowledgment packets.

Master-Slave System Setup

A master-slave system is one where the host application is designed so that only one node will ever attempt to transmit at a given time. An example of this type of system is a polled system with a base station that sequentially poles a number of remote nodes. In this case the base always initiates a pole and the remotes respond with the desired data.

To set up AirNet for this type of system, select the Master-Slave selection in the Packet General tab of the modem configuration. With this selection, the modem transmits waiting packets as soon as it detects an idle channel. The master-slave setting should not be used with systems that use store and forward repeaters.

Setting Packet Timeout

The packet timeout timer is used for only for individually addressed packets that expect an acknowledgment (ACK). The packet timeout timer is started after a data packet is sent. If an ACK is not received before the timer expires, then a retry transmission of the data packet is sent. This timer should be set longer than the worst case time it takes to receive an ACK packet.

For a master-slave system, an ACK packet is sent as soon as the data packet is received and the channel is idle. This can start as soon as the decay time of the originating modem is finished.

Packet Timeout Time = Decay Time + Attack Time
+ ACK Packet Transmit Time

For radios with a channel driven attack time, the attack time value should be set to the worst case (longest) attack time which is the Channel Grant Timeout Time.

Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

ACK Packet Transmit Time = ACK Packet Length / Channel Rate

An ACK packet fits in one data frame (16 bytes) of data. If coding is used, then 50 % coding overhead is added to this.

ACK Packet Length -Uncoded = 16 bytes x 8 bits per byte = 128 bits
-Coded = 128 bits x 1.5 = 192 bits

Example

Decay time = 50 ms
Attack time (fixed) = 250 ms
Over air channel rate = 2400 bps
Coding = Enabled

ACK Packet Transmit Time = 192 / 2400 = 80 ms
Packet Timeout Time = 50ms + 250 ms + 80 ms = 380 ms

Data Packet Transmit Time

For a master-slave system, the data packet transmit time is constant for a given packet size. As long as the channel is not busy, a data packet will be sent immediately upon becoming available for transmission.

Calculating the delay is very similar to the calculation for the packet timeout time above.

Total Packet Delay Time = Attack Time + Packet Transmit Time

Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Note that the packet delay time does not require the transmit decay time. This is because the packet is available at the receiving modem as soon as all the data has been transferred.

Packet Transmit Time = Packet Length / Channel Rate

Packet Length = (Data Bits + Overhead Bits)
x Framing Overhead x Coding Overhead

Overhead Bits = 14 bytes x 8 bits per byte = 112 bits
Framing Overhead = 1.1
Coding Overhead (optional) = 1.5

Packet Length = (Data Bits + 112) x 1.1 { x 1.5 }

Example

Attack time (fixed) = 250 ms
Over air channel rate = 2400 bps
Number of async chars in packet = 50
Number of data bits per async char = 8
Coding = Enabled

Packet Length = ((50 x 8) + 112) x 1.1 x 1.5 = 845 bits
Packet Transmit Time = 845 / 2400 = 353 ms
Total Packet Delay Time = 250 + 352 = 603 ms

CSMA System Setup

The CSMA MAC (Medium Access Control) is used for systems in which multiple modems will attempt to access the radio channel simultaneously (multi-access systems). If two modems attempt to transmit simultaneously, a collision results which prevents both transmissions from being successfully sent. The AirNet protocol uses CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) to provide multi-access capability. The CSMA refers to monitoring the channel to ensure that it is unused before transmitting a packet.

Collision Avoidance
For multi-access radio systems CSMA alone is typically not enough to prevent excessive collisions. The problem occurs when one modem is transmitting and multiple other modems receive data for their hosts and become ready to transmit. These other modems will wait until the first modem finishes its transmission and then all attempt to transmit simultaneously, resulting in a collision. This creates the need for collision avoidance. The AirNet protocol provides this by having modems randomize their transmissions once they detect an idle channel. In each slot after a modem detects an idle channel, it will decide with some probability (based on the Transmission Index) whether or not to transmit. This does not eliminate collisions, but, if the probability is set correctly, minimizes the collisions to allow for efficient multi-access use of the radio channel.

Slot Time
The AirNet protocol uses timing slots to determine when to attempt transmissions. These slots are slightly different from the slots used in conventional multi-access slotted MACs. The AirNet slots are the minimum channel detection times or the minimum time from when one modem begins transmission to when all other modems will detect that transmission. This size slot guarantees that modems waiting to transmit in consecutive slots will not collide and allows for very efficient use of the radio channel.

Basic System - Setup Summary

The following summarizes the suggested settings for a basic CSMA system. A basic system should not have any store and forward relays.

Slot Time

Slot Time = Attack Time + Maximum Carrier Detect Time Variation
Where:
Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Min Idle Slots

Min Idle Slots - ACK Packets = 0
Min Idle Slots - Data Packets = 1

Tx Index

Tx Index - ACK Packets = 1
Tx Index - Data Packets = Estimated Backlogged Nodes / Attempt Rate
Where:
Attempt Rate = (Packet Detection Ration)$^{0.5}$
Packet Detection Ratio = Slot Time / Total Packet Time
Total Packet Time = Attack Time + Packet Transmit Time + Decay Time
Packet Transmit Time = Packet Length / Channel Rate
Packet Length = (Data Bits + Overhead Bits) x Framing Overhead x Coding Overhead
= (Data Bits + 112) x 1.1 { x 1.5 }

Overhead Bits = 14 bytes x 8 bits per byte = 112 bits
Framing Overhead = 1.1

Coding Overhead (optional) = 1.5

Packet Timeout Packet Timeout = Transmit Decay Time + Transmit Attack Time + ACK Packet Transmit Time

Where:

Transmit Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time
ACK Packet Transmit Time = ACK Packet Length / Channel Rate
ACK Packet Length -Uncoded = 16 bytes x 8 bits per byte = 128 bits
-Coded = 128 bits x 1.5 = 192 bits

System with Relays

The following summarizes the suggested settings for a system which has one or more store and forward relays.

Slot Time Slot Time = Attack Time + Maximum Carrier Detect Time Variation

Where:

Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Min Idle Slots Min Idle Slots - ACK Packets = 0

Min Idle Slots - Relay Packets (Relay #1) = 1
Min Idle Slots - Relay Packets (Relay #2) = 2
...
...
Min Idle Slots - Relay Packets (Relay #Z) = Z

Min Idle Slots - Data Packets = Highest Relay # + 1 = Z + 1

Tx Index Tx Index - ACK Packets = 1

Tx Index - Relay Packets = 1

Tx Index - Data Packets = Estimated Backlogged Nodes / Attempt Rate

Where:

Estimated Backlogged Nodes (number of nodes that simultanesouly want to transmit) = the greater of
A) Average Number of Backlogged Nodes or
B) 1/4 Maximum Possible Number of Backlogged Nodes

Attempt Rate = (Packet Detection Ration)$^{0.5}$
Packet Detection Ratio = Slot Time / Total Packet Time
Total Packet Time = Attack Time + Packet Transmit Time + Decay Time
Packet Transmit Time = Packet Length / Channel Rate
Packet Length = (Data Bits + Overhead Bits) x Framing Overhead x Coding Overhead
= (Data Bits + 112) x 1.1 { x 1.5 }

Overhead Bits = 14 bytes x 8 bits per byte = 112 bits
Framing Overhead = 1.1
Coding Overhead (optional) = 1.5

Packet Timeout Packet Timeout = Relay Delays for Data Packet + Ack Packet Delay at Destination Node + Relay Delays for ACK Packet

Where:

Relay Delays for Data Packet = Relay #1Data Packet Delay
+ Relay #2 Data Packet Delay
...
...
+ Relay #Y Data Packet Delay

Relay #Y Data Packet Delay = Transmit Decay Time
+ (Y x Slot Time)
+ Transmit Attack Time
+ Data Packet Transmit Time

Data Packet Transmit Time = Data Packet Length / Channel Rate
Data Packet Length = (Data Bits + Overhead Bits)
x Framing Overhead x Coding Overhead
Overhead Bits = 14 bytes x 8 bits per byte = 112 bits
Framing Overhead = 1.1
Coding Overhead (optional) = 1.5

ACK Packet Delay at Destination Node = Transmit Decay Time
+ Transmit Attack Time
+ ACK Packet Transmit Time

Relay Delays for ACK Packet = Relay #1ACK Packet Delay
+ Relay #2 ACK Packet Delay
...
...
+ Relay #Y ACK Packet Delay

Relay #Y ACK Packet Delay = Transmit Decay Time
+ (Y x Slot Time)
+ Transmit Attack Time
+ ACK Packet Transmit Time

ACK Packet Transmit Time = ACK Packet Length / Channel Rate
ACK Packet Length -Uncoded = 16 bytes x 8 bits per byte = 128 bits
-Coded = 128 bits x 1.5 = 192 bits

Transmit Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Setting Slot Time

The slot time should be set to the attack time of the radio plus the maximum variation (uncertainty) in the carrier detection circuit. The variation in the carrier detection circuit is the difference in the carrier detect time between the radio with the fastest carrier detect time and the radio with the slowest carrier detect time. Note that the attack time is made up of the worst case transmitter power ramp up time plus the worst case carrier detect time. Typically the maximum variation of the carrier detect circuit is less than half (50 %) of the attack time.

Slot Time = Attack Time + Maximum Carrier Detect Time Variation
Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Conventional Repeater

The calculation of slot time does not change for radios which operate through conventional repeaters. However, normally when a radio is operated through a repeater, the attack time has to be increased to account for the addition of the repeater attack time. This also typically causes a corresponding increase in the carrier detect time variation.

Trunked Repeater Radios

A trunked repeater system is a group of repeaters which are coordinated with a central controller. Before transmitting user information (data or voice) a trunked radio must first request and obtain a channel assignment. When a channel is assigned, the central controller commands all the radios of the transmitting radio's group to use a specific channel (repeater). Note that the amount of time to obtain a channel assignment can vary for each transmission. Also, some transmission attempts will fail because no repeater channel is available and therefore no channel assignment is made.

Because of the nature of trunked repeaters, modems which are connected to trunked radios are typically set up for a transmit attack time which is channel driven as opposed to fixed. With a channel driven attack time setting the modem activates the radio's transmitter and then waits until the channel is ready (as indicated by the channel grant signal from the radio) before transmitting data. If no channel is available, then the modem will turn off the radio's transmitter when the channel grant timeout time is reached.

For most trunked systems, the radio makes repeated attempts to access a channel as long as the modem is activating the radio's transmitter. For the most efficient operation in a CSMA network, the channel grant timeout time should be set to timeout after the radio makes a single channel access attempt. Correspondingly, the modem's slot time should be set equal to the channel grant timeout time.

Setting Min Idle Slots

The minimum idle slot setting defines the number of slots which a modem will leave vacant after the modem detects an idle channel and before the modem attempts to transmit. A setting of 0 means that the modem will begin attempting transmission in the very first slot after the channel becomes available (idle). A setting of 1 means that the modem will wait 1 slot after the channel is available before attempting to transmit. The number of minimum idle slots can be set differently for each packet type (data, ACK or relay).

Systems without Relays

The simplest and most efficient system setup is where ACK (acknowledgment) packets are sent immediately after a valid data packet is received. With this setup the ACK packets do not contend for the channel the way data packets do. Correspondingly, the data packets are set so that they will leave the first slot open for the ACK packets.

This type of setup has the advantage that the delay for receiving an ACK packet is consistent and predictable. This makes it much easier to set an appropriate packet timeout (see Setting Packet Timeout).

Min Idle Slots - ACK Packets = 0
Min Idle Slots - Data Packets = 1

Tx Index - ACK Packets = 1 (Always transmit in the first slot)
Tx Index - Data Packets = Attempt Rate (see Setting Tx Index)

Systems with Relays

For systems with one or more relay nodes, the simplest and most efficient system setup is where each relay is assigned a particular slot. This way the relays do not collide or contend for the channel the way data packets do. The data packets are set so that they will leave the necessary number of slots open for the relays and ACK packets.

This type of setup has the advantage that the delay for sending data through the relay(s) is consistent and predictable. This makes it much easier to set an appropriate packet timeout (see Setting Packet Timeout).

Min Idle Slots

Min Idle Slots - ACK Packets = 0

Min Idle Slots - Relay #1 = 1
Min Idle Slots - Relay #2 = 2
...
...
Min Idle Slots - Relay #N = N

Min Idle Slots - Data Packets = Highest Relay # + 1 = N + 1

Tx Index

Tx Index - Relays (All) = 1 (Always transmit in their assigned slot)
Tx Index - ACK Packets = 1 (Always transmit in the first slot)
Tx Index - Data Packets = Attempt Rate (see Setting Tx Index)

Setting Tx Index

The transmission index (TI) is the inverse of the probability of transmitting in an idle slot. A TI of 10 corresponds to a 1/10 = 10% chance of transmitting in an idle slot. The goal of setting TI is to maximize efficiency on the channel. If TI is set too low then transmissions collide too often. If TI is set too high then there are an excessive number of unused slots.

AirNet allows TI to be set differently for each packet type (data, ACK or relay). For most systems, TI is set to 1 for ACK and relay packets (see Setting Min Idle Slots). The setting of 1 corresponds to always transmitting (100% probability) in a particular slot.

To set TI, the user must make some practical estimates and then do some calculations based on these estimates. First it is necessary to estimate the average data packet length. To do this, estimate the average number of data bits in a packet using the following formulas.

Packet Length = (Data Bits + Overhead Bits)
x Framing Overhead x Coding Overhead

Overhead Bits = 14 bytes x 8 bits per byte = 112 bits
Framing Overhead = 1.1
Coding Overhead (optional) = 1.5

Packet Length = (Data Bits + 112) x 1.1 { x 1.5 }

With this average packet length number, calculate the packet transmit time. Note that the formulas require the configuration values for transmit attack and decay time.

Packet Transmit Time = Packet Length / Channel Rate

Total Packet Time = Attack Time + Packet Transmit Time + Decay Time

Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Calculate the packet detection ratio, which is the slot time normalized to the total packet time. Then, using packet detection ratio, calculate the attempt rate as its square root.

Packet Detection Ratio = Slot Time / Total Packet Time

Attempt Rate = (Packet Detection Ration)$^{0.5}$

To finally calculate the transmission index we need to estimate the number of backlogged nodes (the number of nodes that may want to transmit at the same time). The difficulty in estimating this value is that for most systems this number is dynamic and can change dramatically depending on what is occurring in the system.

For systems where the backlog can vary, estimate the average number of backlogged nodes for the most common scenario and also estimate the maximum number of backlogged nodes that will ever occur. If the average number of backlogged nodes is more than 1/4 of the maximum, then use the average as the backlog number. Otherwise use 1/4 of the maximum as the backlog number. The reason for this is that the system must operate under the worst case conditions. If the backlog is set too low then under worst case conditions, there will be an excessive number of collisions and the system will be very slow.

In general it is a good idea to set the transmission index higher than expected as opposed to lower. This allows the system to more gracefully handle peak traffic. However, this also causes average efficiency to drop and packet delay time to increase.

Transmission Index = Estimated Backlogged Nodes / Attempt Rate

Estimated Backlogged Nodes = the greater of
A) Average Number of Backlogged Nodes or
B) 1/4 Maximum Possible Number of Backlogged Nodes

Example

Calculation of the transmission index.

Decay time = 50 ms
Attack time (fixed) = 100 ms
Over air channel rate = 2400 bps
Coding = Disabled
Average Packet Size = 400 bits
Average Backlogged Nodes = 10
Maximum Backlogged Nodes = 100
Slot Time = 150 ms

Packet Length = (Data Bits + 112) x 1.1 = (400 + 112) x 1.1 = 564
Packet Transmit Time = Packet Length / Channel Rate
= 564 / 2400 = 235 ms
Total Packet Time = Attack Time + Packet Transmit Time + Decay Time
= 100 ms + 235 ms + 50 ms = 385 ms
Packet Detection Ratio = Slot Time / Total Packet Time
= 150 ms/ 385 ms = 0.39
Attempt Rate = (Packet Detection Ration)$^{0.5}$ = (0.39)$^{0.5}$ = 0.62

Since: Max Backlogged Nodes / 4 > Average Backlogged Nodes
Estimated Backlogged Nodes = Max Backlogged Nodes / 4 = 100 / 4 = 25
Transmission Index = Estimated Backlogged Nodes / Attempt Rate
= 25 / 0.62 = 40

Setting Packet Timeout

The packet timeout timer is used for individual packets that expect an acknowledgment (ACK). This timer is started after a data packet is sent. If an ACK is not received before the timer expires then a retry transmission of the data packet is sent. This timer should be set longer than the worst case typical amount of time it takes to receive an ACK packet.

Systems without Relays

The following calculations are for systems that are setup so that ACK packets are sent immediately after the data packet transmission is completed without contending for the channel (see Setting Min Idle Slots). For this type of CSMA system the packet timeout time is the same as for a Master/Slave system. The ACK is sent as soon as the decay time of the sending modem is finished.

Packet Timeout Time = Decay Time + Attack Time
+ ACK Packet Transmit Time

For radios with a channel driven attack time, the attack time value should be set to the worst case (longest) attack time which is the Channel Grant Timeout Time.

Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

ACK Packet Transmit Time = ACK Packet Length / Channel Rate

An ACK packet fits in one data frame (16 bytes) of data. If coding is used, then 50 % coding overhead is added to this.

ACK Packet Length -Uncoded = 16 bytes x 8 bits per byte = 128 bits
-Coded = 128 bits x 1.5 = 192 bits

Systems with Relays

The following calculations are for systems that are setup as described in the Setting Min Idle Slots section. The packet timeout should be set to the amount of time it takes to send the data packet and then the amount of time it takes to get back an acknowledgement.

Packet Timeout = Relay Delays for Data Packet
+ Ack Packet Delay at Destination Node
+ Relay Delays for ACK Packet

The amount of time it takes to send a data packet is the sum of the amount of time it takes each relay to send the data packet.

Relay Delays for Data Packet = Relay #1Data Packet Delay
+ Relay #2 Data Packet Delay
...
...
+ Relay #Y Data Packet Delay

The time it takes each relay to send the packet is basically the packet transmit time. Added to this must be the number of idle slots between the last transmission and when the current relay decides to transmit.

Relay #Y Data Packet Delay = Decay Time
+ (Y x Slot Time)
+ Attack Time
+ Data Packet Transmit Time

Data Packet Transmit Time = Data Packet Length / Channel Rate
Data Packet Length = (Data Bits + Overhead Bits) x Framing Overhead x Coding Overhead
Overhead Bits = 14 bytes x 8 bits per byte = 112 bits
Framing Overhead = 1.1
Coding Overhead (optional) = 1.5

The ACK packet delay at the destination node is the amount of time it takes for the destination node to send the ACK packet.

ACK Packet Delay at Destination Node = Decay Time
+ Attack Time
+ ACK Packet Transmit Time

After the ACK packet is transmitted by the destination node, it must be re-transmitted by the various relays in the system. This is the sum of the time it takes each relay to transmit the ACK packet.

Relay Delays for ACK Packet = Relay #1ACK Packet Delay
+ Relay #2 ACK Packet Delay
...
...
+ Relay #Y ACK Packet Delay

Relay #Y ACK Packet Delay = Decay Time
+ (Y x Slot Time)
+ Attack Time
+ ACK Packet Transmit Time

ACK Packet Transmit Time = ACK Packet Length / Channel Rate
ACK Packet Length-Uncoded=16 bytes x 8 bits per byte=128 bits
-Coded = 128 bits x 1.5 = 192 bits

Transmit Attack Time -Fixed = Attack Time setting
-Channel Driven = Channel Grant Timeout Time

Data Packet Delay

Average Delay

The average delay is the average amount of time from when a packet is ready for transmission to when the packet is actually transmitted. This number is for a single attempt and does not include the time for any retries due to corrupted transmissions. Note that the average delay varies based on the number of backlogged nodes in the system at a given time. Also note that the average delay varies substantially even with constant conditions due to the random nature of events.

For ease of notation we shall rename some of the parameters.

Tslot = Slot Time
PDR = Packet Detection Ratio
TI = Transmission Index
N = Backlogged Nodes

PR = (TI - 1)/TI

Average Delay = $\underline{Tslot \times (1 + PDR - PR^N)}$

PDR x ln(1/PR)
Where: ln symbolizes the natural log function.

Example

Using the values from the previous example, calculate the average delay for various backlogs.

Tslot = Slot Time = 150 ms = 0.15 sec
PDR = Packet Detection Ratio = 0.39
TI = Transmission Index = 40

PR = (TI - 1)/TI = (40 - 1)/ 40 = 0.975

$$\text{Average Delay} = \frac{\text{Tslot} \times (1 + \text{PDR} - \text{PR}^N)}{\text{PDR} \times \ln(1/\text{PR})} = \frac{0.15(1 + 0.39 - 0.975^N)}{0.39 \ln(1/0.975)}$$

$$= \frac{0.15(1.39 - 0.975^N)}{0.00987} = 15(1.39 - 0.975^N)$$

Backlogged Nodes (N)	10	25	50	75	100
Average Delay (sec)	9.2	12.9	16.6	18.6	19.7

Probable Delay

The probable delay calculation allows the user to calculate the expected delay given some probability that the transmission actually occurs. The probable delay value can be used for calculating a packet timeout value for a system where the ACK packets do not use an immediate ACK and have a transmission index the same as the data packets. It can also be used to calculate timeouts for layers of the protocol stack above the modem on the host system. Note that the probable delay value does not include any transmission times due to relays and acknowledgement packets.

The basis of the probable delay is the average delay calculated above. As noted before, the average delay will vary based on the actual number of backlogged nodes in a system.

Probable Delay = Average Delay x ln(1/(1 - Probability of Sending))
Where:
The Probability of Sending is a fractionalized percentage (i.e. 50% = 0.50, 95% = 0.95).

Example

Calculate the probable delay for various probabilities of sending in terms of the average delay.

Probability of Sending (%)	25	50	75	90	95	99	99.9
Probable Delay (Avg. Delays)	0.29	0.69	1.38	2.30	3.00	4.61	6.91

Note that the 50% probability of sending value is not equal to the average delay. This is because the delay spread is a statistical distribution where the mean and median delays are not the same.

Alignment

To operate correctly, the TS2000 must be aligned with the specific radio it will be used with. This alignment consists of setting the transmit level out of the TS2000 and the receive level into the TS2000. These levels are adjusted with potentiometers which are accessible through the back plate of the TS2000.

The easiest way to align the TS2000 is to use the Modem Test screen of the TS2000 configuration software. The Modem Test screen is accessed by pressing the Modem Test button on the main screen of the configuration program.

Alignment Using a Service Monitor

The best way to align the TS2000 with its radio is using a service monitor. A service monitor is used to monitor and generate radio signals.

Transmit Level Alignment

1) Attach the TS2000 to the appropriate radio and to a PC with the modem test program.
2) Attach the radio's antenna port to the service monitor. Set the service monitor to monitor a transmit signal on the appropriate frequency and to measure transmit deviation (amount of modulation).
3) Set the modem test program to the Low tone only (1200 Hz sine wave) transmit test and activate the transmit test.

> **CAUTION:** Some radios cannot stand to continuously transmit for long periods of time.

4) Adjust the transmit level potentiometer for the appropriate transmitter deviation based on the radio channels used. The following table lists typical deviation settings for various channel spacings. Note that the deviation reading includes the deviation of the sub audible Call Guard or trunking signaling data.

Channel Spacing	Deviation Setting
12.5 KHz	1.5 KHz
25 KHz	3.0 KHz

5) On the service monitor, observe the demodulated transmit signal to ensure that it is not distorted due to filtering, loading or noise.

Receive Level Alignment

1) Attach the TS2000 to the appropriate radio and to a PC with the modem test program.
2) Attach the radio's antenna port to the service monitor. Set the service monitor (signal generator) to generate a transmit signal on the appropriate frequency and to modulate the signal with a 1200 Hz sine wave. Set the deviation of this signal to the appropriate level based on the channel used (see table in Transmit Level Alignment section). Set the signal level to at least 30 dB higher than the specified 12dB SINAD level of the radio.
3) Set the modem test program for the Monitor Signal Level receive test option and activate the test.
4) Adjust the receive level potentiometer until the receive level reads a value of 0.6 volts peak to peak.

5) If possible, observe the receive signal coming into the TS2000 with an oscilloscope to check for distortion of the signal caused by the radio's receiver. This can be done at the Receive Audio input pin of the radio connector (pins 3 and/or 15) or at the Receive Calibration Test Point (pin 14).

Alignment Using a Pre-Aligned Unit

An alternative way to align a TS2000 with its radio is to use a TS2000/radio combination which has had its transmit level previously aligned and is known to be aligned correctly.

Receive Level Alignment

1) Attach the pre-aligned TS2000/radio combination to a PC with the modem test program.
2) Attach the TS2000/radio to be aligned to a PC with the modem test program. This can be a different serial port on the same PC or a different PC.
3) Set the modem test program of the TS2000/radio under test to the Monitor Signal Level receive test and activate the test.
4) Set the modem test program of the pre-alignedTS2000/radio to the Low tone only (1200 Hz sine wave) transmit test and activate the test.

CAUTION: Some radios cannot stand to continuously transmit for long periods of time.

5) Adjust the receive level potentiometer of the TS2000/radio under test until the receive level reads a value of 0.6 volts peak to peak.
6) If possible, use an oscilloscope to observe the receive signal coming out of the TS2000/radio under test to check for distortion of the signal caused by the transmit radio, repeater system or the receive radio. This can be done at the Receive Audio input pin of the radio connector (pins 3 and/or 15) or on the Receive Calibration Test Point (pin 14).

Transmit Level Alignment

1) Attach the pre-aligned TS2000/radio combination to a PC with the modem test program.
2) Attach the TS2000/radio to be aligned to a PC with the modem test program. This can be a different serial port on the same PC or a different PC.
3) Set the modem test program of the pre-aligned TS2000/radio to the Monitor Signal Level receive test and activate the test.
4) Set the modem test program of the TS2000/radio under test to the Low tone only (1200 Hz sine wave) transmit test and activate the test.

CAUTION: Some radios cannot stand to continuously transmit for long periods of time.

5) Adjust the transmit level potentiometer on the TS2000/radio under test until the receive level of the pre-aligned unit reads a value of 0.6 volts peak to peak.
6) If possible, use an oscilloscope to observe the receive signal coming out of the pre-aligned TS2000/radio to check for distortion of the signal caused by the transmit radio, repeater system or the receive radio. This can be done at the Receive Audio input pin of the radio connector (pins 3 and/or 15) or on the Receive Calibration Test Point (pin 14).

Data Tests

After two TS2000s have been aligned with their radios, data can be passed between them to test complete operation. The easiest way to accomplish this is to use the AirTest program (provided with the units).

Data Test

1) Attach two aligned TS2000/radio sets each to a PC serial port.
2) Setup AirTest for the correct serial port baud rate (matches the TS2000's setting).
3) Transmit data between the TS2000s by typing a message on the keyboard followed by the ENTER key.
4) Automated tests can be run which will send data and verify that it was received correctly. To select a test use the Test Setup command from the Setup menu. Use the on line help to obtain more information about each test.

BER Test

A BER (Bit Error Rate) test is used to determine how effective a radio setup is for data operation. The BER result tells what percentage of bits are corrupted. A BER of 3.0×10^{-4} means that 3 out of 10,000 (10^4) bits are corrupted. A BER test can be run using either the Modem Test screen of the configuration program or using the AirTest program.

The longer a BER test runs the more accurate the result. To get an accurate result a BER test should be run until at least 100 errors have been received. This provides a 90% confidence level in the BER result. However, for relatively error free operation this can take too long to run. An alternative is to run the BER test until at least 10 errors have been received which provides a 68% confidence level.

Using the Modem Test Screen

1) Attach two aligned TS2000/radio sets each to a PC serial port.
2) Set one TS2000/radio set for a transmit BER test.
3) Set the other TS2000/radio set for the corresponding receive BER test.
4) Wait and observe the results.

Using AirTest

1) Attach two aligned TS2000/radio sets each to a PC serial port.
2) Setup AirTest for the correct serial port baud rate (matches the TS2000s setting).
3) Select and start one of the automated tests. To select a test use the Test Setup command from the Setup menu. Use the on-line help for details about the different tests.
4) Wait and observe the results.

Licensing

To be operated legally, most radio equipment requires two types of licensing. These are the manufacturer's license which the manufacturer obtains and the user license which the user must obtain.

Manufacturer's License

To sell most radio equipment the manufacturer must obtain a license which guarantees that their equipment meets the necessary regulations for operation. The regulations vary based on frequency of operation, transmit power levels and country of operation.

The TS2000 is designed to work with almost all mobile and hand held voice radios. This allows the user to select a radio that meets the necessary regulations.

When the TS2000 is connected to a radio it is important that the combination is properly tuned up and tested to ensure that the combination operates within the limits of the emissions that the radio is designed and authorized for.

USA

Within the USA, the FCC (Federal Communications Commission) controls the operation and licensing of radio equipment. The most common type of manufacturer radio authorization is FCC part 90 type acceptance.

For many radios, the TS2000 can be connected to an external interface or microphone connector. In other cases, the TS2000 must be connected to internal points within the radio. In either case, it is important that the transmit audio signal of the TS2000 which modulates the radio is connected to a point prior to the transmit audio low pass filters and modulation limiters. Connecting before these points allows the TS2000 to perform with the radio the same as a microphone or other voice input and therefore prevents the need for a re-authorization of the radio with the TS2000.

TS2000 Emissions

The TS2000 has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules (see Emissions section for more details).

Canada

For many radios, the TS2000 can be connected to an external interface or microphone connector. In other cases, the TS2000 must be connected to internal points within the radio. In either case, it is important that the transmit audio signal of the TS2000 which modulates the radio is connected to a point prior to the transmit audio low pass filters and modulation limiters. Connecting before these points allows the TS2000 to perform with the radio the same as a microphone or other voice input and therefore prevents the need for a re-authorization of the radio with the TS2000.

TS2000 Emissions

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations (reference ICES-003).

International

Some countries allow radios that meet the FCC rules to be operated. However, many countries have their own set of rules which radio manufactures must comply with. The user should select radio equipment that has been designed, tested and licensed for the rules of the country of operation. Also, the user should make sure that connecting the TS2000 to a radio does not nullify the manufacturer's license of the radio.

User's License

For most radio equipment the user is required to obtain an operating license. This is done so that the regulatory agency can coordinate radio users in order to minimize interference. It is the users responsibility to obtain the necessary licenses and ensure that the TS2000 and the attached radio meet the licensing requirements of the location where they are used.

USA

The FCC regulates the operation of radio equipment in the USA. To obtain a license to operate radio equipment a user must fill out the appropriate FCC forms and pay an application fee. Many FCC licenses also require that the user obtain frequency coordination from the appropriate organization. The coordination organizations handle the up front work of qualifying applications and allocating channels. The appropriate coordination organization depends on the type of user (commercial, government, etc.), the frequency and the type of license.

To help with the licensing process, there are companies who, for a fee, will fill out and file the paperwork in order to help users obtain the appropriate license.

Some radio systems are available where a user can rent time from a service provider (i.e. trunked SMR or cellular phone). For these systems the user is not normally required to obtain a license. Instead, the service provider obtains a license which covers their customers.

Phone Numbers

FCC 888-225-5322
PCIA 800-759-0300 (Coordination agency for most business licenses)

Licensing Service Companies:

Atlas License Company	800-252-0529
LAO (Licensing Assistance Office)	717-337-9630

International

Countries other than the USA have different rules for operating radio equipment. The user should work with the appropriate government agency to obtain the necessary licenses.

Service and Support

We at Teledesign Systems are committed to providing excellent service and support to our customers. Our goal is to make using our products as easy and painless as possible. To accomplish this Teledesign provides free technical support for all our products during all phases of sales, installation, and use.

Contacting Teledesign

Service and technical support can be reached during our normal business hours of 8 AM to 5 PM (Pacific Standard Time) Monday through Friday. Teledesign Systems can be reached at the following phone numbers.

(800) 663-3674 or (800) MODEMS-4 (USA & Canada)
(408) 941-1808
(408) 941-1818 (Fax)

We can reached by email at:
support@teledesignsystems.com
corpcomm@teledesignsystems.com
sales@teledesignsystems.com

We can be reached by mail at:
Teledesign Systems Inc.
1729 South Main Street
Milpitas, CA 95035
USA

In addition we have a web site which contains our latest product information and downloads:

www.teledesignsystems.com

Returning Equipment

Before returning equipment to Teledesign, please call for an RMA number and shipping information. This allows us to plan for your shipment in order to provide the best possible service. When returning equipment, please include a note indicating the symptoms of the failure and any other pertinent information.

Warranty

Two Year Warranty Teledesign Systems Inc. warrants this product to be free from defects in materials and workmanship for a period of two (2) years from the date of shipment. During the warranty period, Teledesign Systems Inc. will, at its option, either repair of replace products that prove to be defective.

Exclusions This warranty shall not apply to any defect, failure or damage caused by misuse, abuse, improper application, alteration, accident, disaster, negligence, use outside of the environmental specifications, improper or inadequate maintenance, or incorrect repair or servicing not performed or authorized by Teledesign Systems Inc.

Limitations TELEDESIGN SYSTEMS INC. SHALL IN NO EVENT HAVE OBLIGATIONS OR LIABILITIES TO BUYER OR ANY OTHER PERSON FOR LOSS OF PROFITS, LOSS OF USE OR INCIDENTAL, SPECIAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY, OR ANY OTHER THEORY OR FORM OF ACTION, EVEN IF TELEDESIGN SYSTEMS INC. HAS BEEN ADVISED OF THE POSSIBILITY THEREOF, ARISING OUT OF OR IN CONNECTION WITH THE SALE, DELIVERY, USE, REPAIR, OR PERFORMANCE OF THIS PRODUCT (INCLUDING EQUIPMENT, DOCUMENTATION AND SOFTWARE). IN NO EVENT SHALL THE LIABILITY OF TELEDESIGN SYSTEMS INC. ARISING IN CONNECTION WITH ANY PRODUCT EXCEED THE ACTUAL AMOUNT PAID FOR SUCH PRODUCT.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, WRITTEN OR ORAL, EXPRESSED OR IMPLIED, INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Connector

The TS2000 serial port uses a 9 pin subminiature D connector with female pins.

Pinout

Signal	Pin	Direction	Description
SG - Signal Ground	5		Signal and power ground.
PWR - Modem Power	9	Input 6 to 18 VDC, 200 mA max	DC power to the TS2000. Power can also be applied through pin 8 of the radio interface.
TXD - Transmit Data	3	Input	Data to be sent over the radio link by the TS2000.
RXD - Receive Data	2	Output	Data received by the TS2000 through the radio link.
RTS - Request to Send	7	Input	Control from the DTE (host) requesting to transmit data.
CTS - Clear to Send	8	Output	Response from the TS2000 indicating a readiness to receive transmit data.
DCD - Data Carrier Detect	1	Output	Status from the TS2000 indicating that it is receiving data.
DSR - Data Set Ready	6	Output	Status from the TS2000 indicating that it is in operational mode.
DTR - Data Terminal Ready	4	Input	Status to the TS2000 that the DTE (host) is in operational mode.

Note that power can be applied to the TS2000 through pin 9 of the serial connector. This is a non-standard use of pin 9. However, for most serial ports this is not a problem because pin 9 is typically either unused (left unconnected) or used as RI (Ring Indicator). Since RI is a modem (DCE) output and the TS2000 power supply falls within the allowed voltage range for RS-232 signals, this is interpreted as an active RI signal. For systems which use this signal differently, or cannot operate with power on this pin, this pin should be disconnected between the TS2000 and the host equipment.

Signal Levels

The serial port can be configured for either RS-232 or TTL signal levels. To change the signal level setting, the modem must be opened and the four jumper plugs next to the serial port connector set to the desired position (see Appendix E for the jumper positions).

RS-232 Signal Levels

The RS-232 standard defines minimum and maximum voltage levels for the drivers and receivers. However, in practice the drivers and receivers work correctly with signal levels which are different from the specification.

Type	Level (volts DC) Low	High
Drivers (into a 3k to 7k ohm load)		
RS-232 Specification	-15 to -5	+5 to +15
Actual TS2000 Drive Levels	-9 to -6	+6 to +9
Receivers (with 3k to 7k ohm load)		
RS-232 Specification	-25 to -3	+3 to +25
Actual TS2000 Receive Levels (Unconnected inputs are pulled low)	-25 to +0.8	+2.4 to +25

TTL Signal Levels

Type	Level (volts DC) Low	High
Output (Driver)	0.0 to +0.4 (sinking up to 4 mA)	+3.0 to +5.0 (sourcing up to 4 mA)
Input (Receiver)	-25 to +0.8 (3k to 7k ohm load) (Unconnected inputs are pulled low)	+2.4 to +25

Signal Polarity

The signal polarity is the same for both RS-232 and TTL operation.

Level	State
Voltage Low	Mark Control signal inactive Stop bit state (end of async character) Logic one data bit state (within async character)
Voltage High	Space Control signal active Start bit state (beginning of async character) Logic zero data bit state (within async character)

Standard RS-232 Serial Port Pinout

Signal Name	Signal Mnemonic	Connector Type 9 Pin	25 Pin	Direction DCE	DTE
Signal Ground	SG	5	1, 7	--	--
Transmit Data	TXD	3	2	Input	Output
Receive Data	RXD	2	3	Output	Input
Request to Send	RTS	7	4	Input	Output
Clear to Send	CTS	8	5	Output	Input
Data Carrier Detect	DCD	1	8	Output	Input
Ring Indicator	RI	9	22	Output	Input
Data Set Ready	DSR	6	6	Output	Input
Data Terminal Ready	DTR	4	20	Input	Output

Appendix B - Radio Interface

Connector

The TS2000 radio port uses a 25 pin subminiature D connector with male pins.

Signals

Signal	Pin	Type	Description
Ground	1,7,13	Input	Signal and power grounds.
Transmit Audio	2	Output (ANA) 0 to 5.0 Vpp, 600 ohm drive, high impedance when not transmitting	Transmit audio to radio.
Receive Audio - Receive Audio +	3 15	Input (ANA) 0.3 Vpp min, 6.0 Vpp max, 100k ohm input impedance	Receive audio from radio (differential inputs). For single ended operation use Receive Audio - only, float or ground Receive Audio +.
Receive Carrier Detect	4	Input (TTL)	Indicates that the radio is receiving a signal.
Transmit Channel Grant	5	Input (TTL)	Indicates that the radio's transmit channel is ready.
Data PTT	6	Output (OC)	Activates transmitter during data transmissions.
Modem Power	8	Input 6 to 18 VDC, 200 mA max	DC power to modem. Power can also be applied through pin 9 of the serial port.
Switched Power	9	Output 6 to 18 VDC, 50 mA max	Reserved for future use.
Data Channel Detect	10	Input (TTL) or Input (ANA) 0.0 VDC min, 5.0 VDC max, 100k ohm input impedance	Indicates that the radio is on the data channel or group.
Analog Input 2 Analog Input 3	11 12	Input (ANA) 0.0 VDC min, 20.0 VDC max, 40k ohm input impedance	Reserved for future use.
Receive Calibration Test Point	14	Output (ANA) 0.6 Vpp nom, 1k ohm source impedance	Receive signal level monitor point. Test point for adjusting the level of the receive audio signal from the radio.
Microphone Mute + Microphone Mute -	16 17	Output (OPT)	Mutes (shuts off) the microphone. Used to mute the microphone during data transmissions.

Signal	Pin	Type	Description
Voice PTT Detect	18	Input (TTL)	Indicates that the user has activated the microphone PTT switch.
Voice Reception Detect	19	Input (TTL)	Indicates that the radio is receiving a voice transmission and that the modem should unmute the speaker.
Channel Select/ Channel Select Up	20	Output (TTL)	Selects voice or data transmit channel or group. Switches the radio to the next higher channel or group
Speaker Mute	21	Output (OC)	Mutes (shuts off) the speaker. Used to mute the speaker during data receptions.
Channel Select Down	22	Output (TTL)	Switches the radio to the next lower channel or group.
	23-25		Not connected internally.

Pinout

This following table shows the pinout of the radio interface connector. The wire colors are for the standard radio interface cable provided with the TS2000.

Pin	Signal	Standard Cable Wire Color
Shell	Shield Ground	Bare wire
1	Ground	Black
2	Transmit Audio	Brown
3	Receive Audio -	Red
4	Receive Carrier Detect	Orange
5	Transmit Channel Grant	Yellow
6	Data PTT	Green
7	Ground	Blue
8	Modem Power	Purple
9	Switched Power	Gray
10	Data Channel Detect	White
11	Analog Input 2	Pink
12	Analog Input 3	Light Green
13	Ground	Black/White
14	Receive Calibration Test Point	Brown/White
15	Receive Audio +	Red/White
16	Microphone Mute +	Orange/White
17	Microphone Mute -	Green/White
18	Voice PTT Detect	Blue/White
19	Voice Reception Detect	Purple/White
20	Channel Select/ Channel Select Up	Red/Black
21	Speaker Mute	Orange/Black

Pin	Signal	Standard Cable Wire Color
22	Channel Select Down	Yellow/Black
23	unused	Green/Black
24	unused	Gray/Black
25	unused	Pink/Black

Signal Levels

TTL Signal Levels

	Level (volts DC)	
Type	**Low**	**High**
Output (Driver)	0.0 to +0.4 (sinking up to 4 mA)	+3.0 to +5.0 (sourcing up to 4 mA)
Input (Receiver)	-25 to +0.8	+2.4 to +25
	(40k ohm input impedance including 47k ohm pull up to +5V)	

The TTL line receivers used for the radio interface have a weak pull up on each input. These inputs will be pulled high if left unconnected. They can be driven from standard TTL, CMOS or open collector drivers.

Open Collector Outputs (OC)

These outputs drive only in the low state. They are high impedance in the high state.

State	Operation
Low	The driver will sink up to 50 mA with a maximum on voltage of +0.4 volts. DC on resistance is 8 ohms maximum.
High	The driver will sink a maximum of 100 uA at voltages up to +25 volts. DC off resistance is 250k ohms minimum.

Optically Isolated Outputs (OPT)

These paired outputs form an isolated switch. Both outputs of the switch are isolated from all modem circuitry and can operate with common mode voltages up to 100 volts.

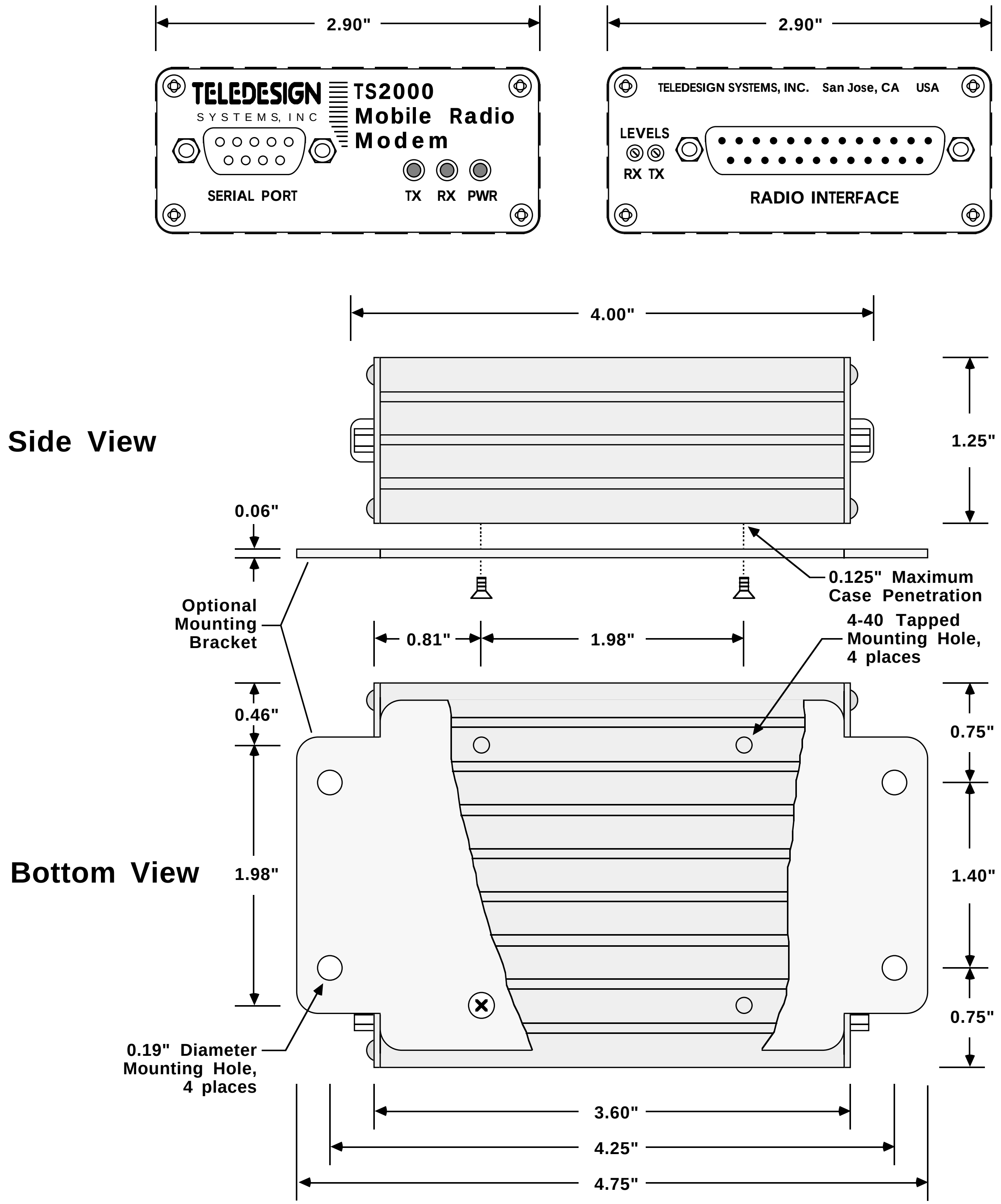
State	Operation
Active	The switch will pass up to 2 mA with a maximum on voltage of +0.3 volts. DC on resistance is 150 ohms maximum.
Inactive	The switch will pass a maximum of 10 uA at voltages up to +25 volts. DC off resistance is 2.5M ohms minimum.

Analog Inputs and Outputs (ANA)

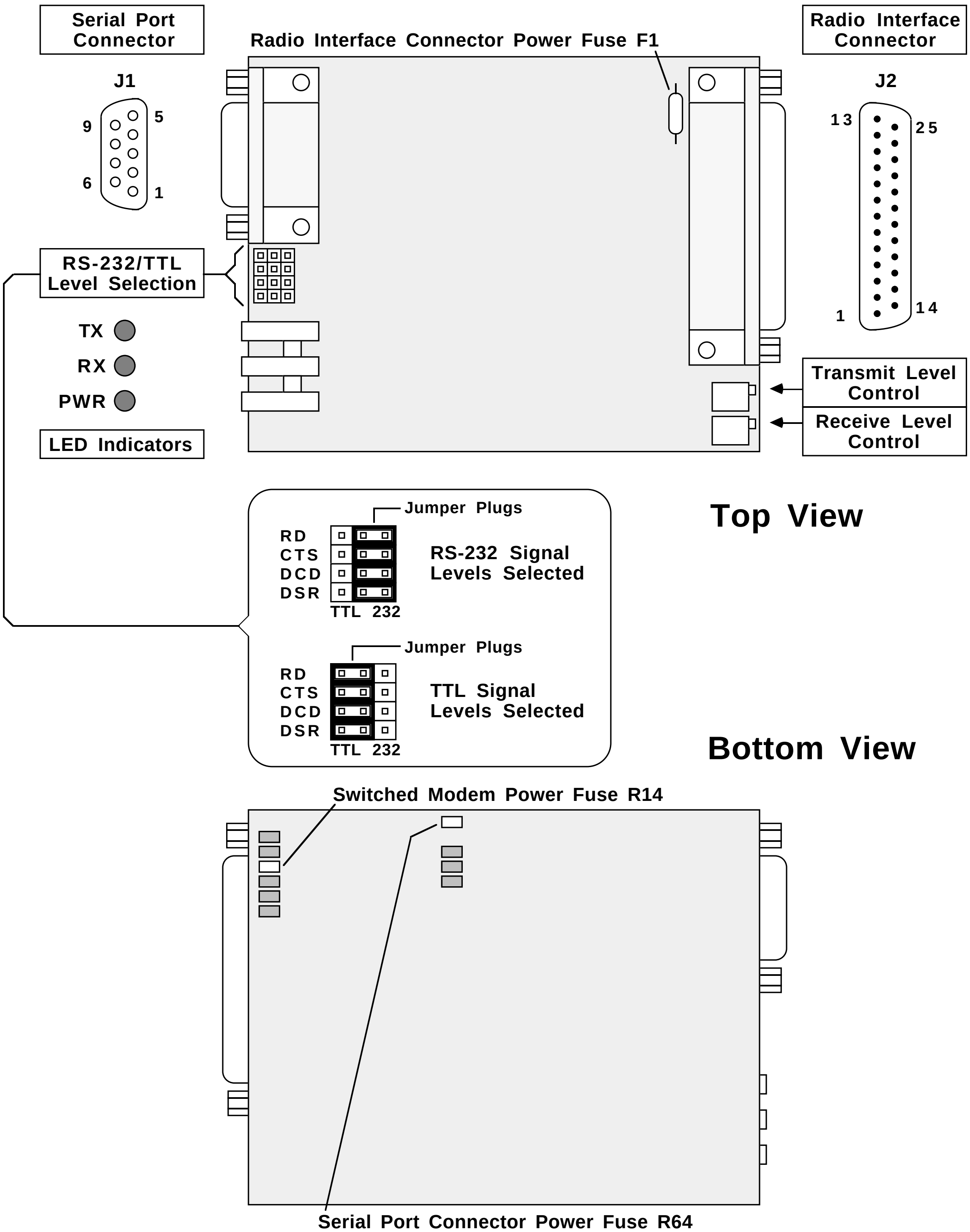
These lines are analog inputs and outputs. The operation and level is different for each of these signals. Please refer to the radio interface pinout table for operating voltages and load and drive impedances.

Appendix C - TS2000 Specifications

Data Interface	Data Rates	300, 1200, 2400, 4800, 9600 baud
	Data Format	Asynchronous, 8 or 9 bit words
	Signal Levels	RS-232 or TTL
	Handshake Protocols	Full Handshake: Supports RTS, CTS, DCD, DSR, DTR
		Data Only (3 wire): Requires only TD, RD and SG
	Data Only Time Out	1 to 500 character periods
	CTS Control Line	Buffer, Channel, Data PTT or RTS Driven
	DCD Control Line	Data and/or Channel Driven
	DSR Control Line	Active when Operational, Transmitting or Receiving
	DTR Control Line	Enabled or Disabled (receive data flow control)
	Data Connector	9 pin D, female, DCE
Radio Interface	Data Rate (Modulation)	1200 bps or 2400 bps (Continuous Phase MSK)
	Sensitivity (typical)	1 x 10^{-5} BER (Bit Error Rate) for 14 dB SINAD, Uncoded
	Receive Signal Level (100 KΩ input impedance)	0.3 to 6.0 V peak-peak (single ended or differential)
	Transmit Signal Level	0 to 300 mV peak-peak (low setting)
	(into 600Ω impedance)	0 to 5.0 V peak-peak (high setting)
	Data PTT	Open Drain with Selectable Polarity
	Tx Attack Time	Fixed: 1 to 9999 milliseconds
		Channel Driven: Static or Pulsed Transmit Channel Grant with Selectable Polarity
	Tx Time Out Timer	Disabled or 1 to 500 seconds
	Carrier Detect	Disabled or Enabled with Selectable Polarity
	Radio Connector	25 pin D, male
Channel Options	Duplex	Half or Full
	Data Security	254 Selectable Scrambling Codes
	FEC (Coding)	None or 12,8 Hamming code with 16 bit Interleaving
	Shared Voice Operation	Input Controls: Voice PTT Detect, Voice Reception Detect
		Output Controls: Speaker Mute, Microphone Mute, Channel/Group Select
	Data Protocol	Transparent or Packet
Optional Packet Protocol	Channel Access	Master-Slave or Carrier Sense Multiple Access (CSMA) with Programmable Attempt Rate
	Protocol	Automatic Repeat reQuest (ARQ)
	Packet Size	1 to 5000 characters
	Retries	0 to 50 per packet
	Address Space	999 Individual Addresses per Group, up to 60 Groups
	Transfers	Individual with Acknowledgment (to any address)
		Individual without Acknowledgment (to any address)
		Group Broadcast (to all addresses in a single group)
		Network Broadcast (to all addresses in all groups)
		Multicast Reception (from up to ten other groups)
	Relay Operation	Store and Forward with Address Filtering
General	Supply Voltage	6 to 18 VDC
	Supply Current	200 mA - max
		150 mA - Transmit or Receive (typical)
		90 mA - Standby (typical)
	Data Buffer	32 KByte SRAM
	Program Storage	128 KByte FLASH (allows for in field firmware upgrades)
	Indicator LEDs	Transmit, Receive, Power
	Dimensions	4.0" x 2.9" x 1.3" (102 mm x 74 mm x 33 mm)
	Weight	7 ounces (198 grams)
	Temperature	-22 to +158 °F (-30 to +70 °C)
	Humidity	0 to 95% (non-condensing)



The mounting bracket may be rotated 90 degrees to support an optional mounting position with the 0.19" mounting holes positioned on each side of the TS2000 case instead of at the front and rear.



Fuse F1 is a through-hole 1 amp picofuse, fuses R14 and R64 are 1 amp 1206 surface mount fuses.

Appendix F – ASCII Character Set

Control		Value			Value			Value			Value	
Char	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex
Ctrl-@	NUL	0	00	SP	32	20	@	64	40	‘	96	60
Ctrl-A	SOH	1	01	!	33	21	A	65	41	a	97	61
Ctrl-B	STX	2	02	“	34	22	B	66	42	b	98	62
Ctrl-C	ETX	3	03	#	35	23	C	67	43	c	99	63
Ctrl-D	EOT	4	04	$	36	24	D	68	44	d	100	64
Ctrl-E	ENQ	5	05	%	37	25	E	69	45	e	101	65
Ctrl-F	ACK	6	06	&	38	26	F	70	46	f	102	66
Ctrl-G	BEL	7	07	‘	39	27	G	71	47	g	103	67
Ctrl-H	BS	8	08	(	40	28	H	72	48	h	104	68
Ctrl-I	HT	9	09	)	41	29	I	73	49	i	105	69
Ctrl-J	LF	10	0A	*	42	2A	J	74	4A	j	106	6A
Ctrl-K	VT	11	0B	+	43	2B	K	75	4B	k	107	6B
Ctrl-L	FF	12	0C	‘	44	2C	L	76	4C	l	108	6C
Ctrl-M	CR	13	0D	-	45	2D	M	77	4D	m	109	6D
Ctrl-N	SO	14	0E	.	46	2E	N	78	4E	n	110	6E
Ctrl-O	SI	15	0F	/	47	2F	O	79	4F	o	111	6F
Ctrl-P	DLE	16	10	0	48	30	P	80	50	p	112	70
Ctrl-Q	DC1	17	11	1	49	31	Q	81	51	q	113	71
Ctrl-R	DC2	18	12	2	50	32	R	82	52	r	114	72
Ctrl-S	DC3	19	13	3	51	33	S	83	53	s	115	73
Ctrl-T	DC4	20	14	4	52	34	T	84	54	t	116	74
Ctrl-U	NAK	21	15	5	53	35	U	85	55	u	117	75
Ctrl-V	SYN	22	16	6	54	36	V	86	56	v	118	76
Ctrl-W	ETB	23	17	7	55	37	W	87	57	w	119	77
Ctrl-X	CAN	24	18	8	56	38	X	88	58	x	120	78
Ctrl-Y	EM	25	19	9	57	39	Y	89	59	y	121	79
Ctrl-Z	SUB	26	1A	:	58	3A	Z	90	5A	z	122	7A
Ctrl-[	ESC	27	1B	;	59	3B	[	91	5B	{	123	7B
Ctrl-\	FS	28	1C	<	60	3C	\	92	5C	|	124	7C
Ctrl-]	GS	29	1D	=	61	3D	]	93	5D	}	125	7D
Ctrl-^	RS	30	1E	>	62	3E	^	94	5E	~	126	7E
Ctrl-_	US	31	1F	?	63	3F	_	95	5F	DEL	127	7F