Appendix F - Users Manual

See attached.

This manual will be provided to the end-user with each unit sold/leased in the United States.

TS4000
Radio Modem

User's Manual

Version 4.00C
June 1998

TELEDESIGN
SYSTEMS, INC.

1710 Zanker Road
San Jose, CA 95112-4215

(408) 436-1024
(800) 663-3674
(408) 436-0321 Fax

www.teledesignsystems.com

sales@teledesignsystems.com
support@teledesignsystems.com
corpcomm@teledesignsystems.com

Emissions

FCC

Part 15

The TS4000 has been tested and found to comply with the limits for a Class B digital device, pursuant to Part15 of the FCC rules (Code of Federal Regulations 47CFR Part 15). Operation is subject to the condition that this device does not cause harmful interference.

Part 90

The TS4000 has been type accepted for operation by the FCC in accordance with Part 90 of the FCC rules (47CFR Part 90). See the label on the unit for the specific FCC ID and any other certification designations.

Industry Canada

ICES-003

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

RSS-119

The TS4000 has been certified for operation by Industry Canada in accordance with RSS-119 and RSS-210 of the Industry Canada rules. See the label on the unit for the specific Industry Canada certification number and any other certification designations.

Notice

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 cables with this device. Shielded cables are available from most retail and commercial suppliers of cables designed to work with radio equipment and personal computer peripherals.

Safety Warning

In order to ensure the safe operation of this radio equipment, the following practices should be observed.

- DO NOT operate radio equipment near electrical blasting caps or in an explosive atmosphere.
- DO NOT operate any radio transmitter unless all RF connectors are secure and any open connectors are properly terminated.
- DO NOT allow the antenna to come close to, or touch, the eyes, face, or any exposed body parts while the radio is transmitting.

Table of Contents

Introduction

The TS4000 Radio Modem is an integrated radio and modem designed for the wireless transmission of digital data. The TS4000 can transfer data at rates greater than 19,200 bits per second. The TS4000 includes a synthesized VHF, UHF or 900 MHz transceiver that can be programmed for up to 99 channels.

This product is ideally suited to OEMs and system integrators who require a versatile radio modem in a single package. The TS4000 is configured with windows based PC configuration software.

Features

Main Features

- High speed channel rates in excess of 19,200 bits per second.
- Selectable operating modes for transparent and packet data operation.
- High efficiency switching voltage regulator provides a wide input voltage range and uses minimum power regardless of the input voltage.
- Provides addressed communications for devices that are not directly addressable themselves.
- Includes store-and-forward data repeating for wide area coverage.
- Provides two individually configurable data ports.
- Supports data activation (three wire) and RTS/CTS handshake protocols.
- Includes powerful network diagnostics for non-intrusive monitoring of all radio and data network functions.
- Built-in bit error rate (BER) monitoring.
- Configurable RF output power levels.
- Programmable receive sensitivity level (squelch) for use on noisy channels.
- Watertight case option for outdoor use and marine installations.

Flexible Data Interface

- Two highly configurable user data serial ports.
- Primary port supports connection to virtually any asynchronous user device.
- Secondary port used as diagnostics port, synchronous port, or separately addressable packet data port.
- Full handshake and data activation modes supported on both ports.
- Data activation mode requires only receive and transmit data lines for full communication with user device.
- Data rates from 300 to 38,400 baud.
- RS-232, RS-485 or TTL signal levels.

Integrated RF Transceiver

- Synthesized transceivers cover VHF, UHF and 900 MHz bands.
- Programmable RF output power levels.
- Channel frequencies are stored in internal flash memory and are selectable on-the-fly using simple ASCII command strings.

Selectable Channel Protocols

- User selectable scrambling codes for private network communications.
- Optional Forward Error Correction (FEC) using block coding and interleaving corrects channel induced errors.
- User selectable transparent or AirNet packet data transfer modes.

Integrated AirNet Packet Data Protocol

- Allows user directed transmissions to only selected destinations.
- Provides addressed communications for devices that are not directly addressable themselves.
- Can be optimized for point to point, point to multi-point, and full mesh networks.
- Supports group and all-call broadcast transmissions.
- Built in CSMA/CA algorithm minimizes transmission collisions to maximize channel efficiency and utilization.
- Individual TS4000s can be configured as store-and-forward data repeaters to extend radio network coverage.

PC Configurable

- Windows based configuration software provides quick setup and testing.
- Flash memory program storage allows for easy in field firmware upgrades.

Rugged and Reliable

- Optional watertight housing and connections designed to withstand abuse from field and marine use.
- External interfaces protected against voltage transients, reverse polarity, electrical shorts and high VSWR.
- Two year no nonsense warranty.
- Free technical support provided during all phases of installation and use.

Radio Modules

The TS4000 consists internally of two modules; a modem module and a radio module. The radio module has a number of options depending on the frequency of operation, transmit power, and channel spacing. It is important that the TS4000 is ordered with the correct radio module based on the operating requirements.

Frequency Bands

The radio module of the TS4000 comes in various frequency bands including VHF, UHF and 900 MHz. Within each of these bands, there are sub-bands that define the specific frequency range over which a particular radio module will operate (i.e. 450 to 470 MHz).

Transmit Power

For some of the frequency bands, there several options for the radio module transmit power. The most common transmit power levels available are 2 watts and 5 watts. The transmit power can be reduced from the maximum power with the transmit power level setting control (See Radio Setup).

Transmit Duty Cycle

The transmit power of the radio module effects the maximum transmit duty cycle that the TS4000 can be operated with. Transmit duty cycle is the percentage of time that the modem is transmitting (i.e. 50 %). If the TS4000 is operated with too high a transmit duty cycle, then the radio module may get too hot which can result in damage. The maximum safe transmit duty can be increased by either reducing the maximum environmental temperature, adding a heat sink to the back plate of the TS4000, or reducing the transmit power output with the power level configuration control.

Power Amplifiers

If more transmit power is desired than the internal TS4000 radio module can provide then an external power amplifier can be used to boost the power. For connection to the TS4000 it is important that the power amplifier have automatic power sensing to switch between receive and transmit modes. It is also important that the power amplifier has fast power switching so that the TS4000 transmit attack time (amount of time to initiate a transmission) does not have to increased excessively.

Channel Spacing and Bandwidth

For some frequency bands, there are multiple options for the radio module channel spacing and bandwidth.

Channel Spacing
The channel spacing defines how close together the channels are within a band (i.e. 12.5 KHz). To use channels with a certain channel spacing, the radio module's frequency synthesizer must be programmable to multiples or sub-multiples of the channel spacing. The TS4000 radio module should be ordered based on the channel spacing of the channels to be used.

Channel Bandwidth
The channel bandwidth is the amount of frequency spectrum that the radio transmit signal is allowed to occupy (i.e. 16 KHz). This bandwidth must be controlled in order to minimize the interference between users on adjacent channels.

Transmit Channel Bandwidth
For the TS4000, the data rate and the type of modulation control the transmitted channel bandwidth. Therefore, it is important that the TS4000 is setup so that its transmitted bandwidth is less than that prescribed for the channels being used (See Radio Setup, Licensing).

Receive Channel Bandwidth
The receive filters of the TS4000 radio module are designed for a specific channel bandwidth. The radio module should be ordered with a receive filter bandwidth that matches the bandwidth of the channels used.

Note that if multiple channel bandwidths are to be used, then the radio module should be ordered for the channel with the highest channel bandwidth. This may result in less than optimal performance on channels with narrower channel bandwidths.

Enclosure

The TS4000 is available in either a standard or watertight enclosure (see Appendix D - Case Dimensions).

Standard

The standard enclosure has four external connectors; an antenna connector, a power connector and two serial port connectors.

Watertight

The watertight enclosure is environmentally sealed and is designed to withstand dust, rain and water splashes.

Caution: The watertight enclosure should not be submerged in water.

The watertight enclosure has two external connectors; an antenna connector and an interface connector that provides the serial port and power connections. The interface connector is a 19 pin LEMO connector. The mating connector for this is a LEMO connector model # TBD.

Connections

Serial Port

The TS4000 has two serial ports that provide a data connection between the TS4000 and the host equipment. The serial ports are standard RS-232 asynchronous serial interfaces and are setup as DCEs. The serial ports provide all the standard RS-232 handshake lines. In addition, the TS4000 provides a number of configuration options that allow the serial port line usage to be customized for different host equipment (see Serial Port Configuration Options).

Signal Levels
Serial port 1 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 A - Serial Port, Appendix E - PCB Component Locations, Appendix F - Internal Jumper Block).

Standard Case
The serial port connectors are standard 9 pin subminiature D with female pins. These ports can be mated to with standard PC serial cables. To minimize emissions and interference, the serial cables used should be good quality shielded cable (See Appendix A - Serial Port).

Watertight Case
The watertight case provides the serial port connections through a single sealed interface connector (See Appendix A - Serial Port).

Antenna Connector

A variety of antennas can be used with the TS4000, but it is important that the antenna provides a 50 ohm load at the radio's operational frequencies. In addition, all cabling used with the antenna must be good quality coaxial cable with a 50 ohm characteristic impedance.

Caution: The modem should never be allowed to transmit without an antenna or dummy load attached to the antenna connector.

Standard Case
The standard case comes with a 50 ohm female BNC antenna connector.

Watertight Case
The watertight case comes with a 50 ohm female TNC antenna connector.

Power Connection

The TS4000 requires a DC supply voltage between 9 and 28 volts. Note that the minimum supply voltage depends on the particular radio module in the TS4000. In addition, the power (watts) used by the TS4000 also depends on the particular radio module.

Switching Voltage Regulator
Internally, the TS4000 has a high efficiency switching voltage regulator (as opposed to a linear voltage regulator). The switching regulator minimizes the amount of power that the TS4000 requires. Also, the power required (watts) is independent of the input supply voltage.

Power Supply Current

The power supply current required depends on the input voltage used. This can be calculated with the following formula.

Max Power Supply Current (amps) = Max Power (watts) / Input Voltage

Example:

Max Power = 10 watts (The actual value depends on the particular radio module in the TS4000).
Power Supply Voltage = 20 volts

Max Power Supply Current = 10 / 20 = 0.5 amps

Standard Case

With the standard case power can be connected through either the power connector or one of the serial port connectors. The power connector is a 2 pin Molex Micro-Fit 3.0 (Model # TBD) with pin TBD as ground and pin TBD as power. See the Serial Port section for details on connecting power through the serial ports.

Watertight Case

With the watertight case power is connected through the sealed interface connector.

Fuses

The TS4000 has an internal 4 amp fuse for each of the three possible power connections (See Appendix E - PCB Component Locations). The power source used with the TS4000 should also be fused with an in-line power fuse.

Mounting

The preferred method of mounting the TS4000 is to use the mounting bracket supplied with the modem. An alternative is to use the threaded mounting holes in the bottom of the TS4000 (see Appendix D - Case Dimensions).

Configuring the TS4000

The TS4000 is supplied with a windows based PC configuration program. Configuring the TS4000 consists of configuring the modem operating parameters and also configuring the frequency channels. For details on how to load and start the configuration program see Installation in the TS4000 Configuration Program section.

Making selections with the controls on the various configuration screens sets a configuration. Once set, configurations can be programmed into the TS4000. In addition, configurations can be retrieved from the TS4000. 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.

Testing the TS4000

Teledesign provides general-purpose wireless modem test software called AirTest. AirTest can send data and gather performance statistics, including BER (Bit Error Rate), about the link between two modems. AirTest can be started with the AirTest button on the main screen of the configuration program (See Testing).

Upgrading the TS4000 Firmware

The TS4000 comes with flash program memory that allows the firmware to be easily upgraded in the field. Firmware is upgraded with the upgrade program which is included as part of the TS4000 configuration program. The upgrade program is started with the Upgrade Firmware button on the main screen of the configuration program (See Upgrading Firmware).

Status LEDs

The TS4000 has three LED indicators to 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.

TS4000 State	LEDs	Indicator State
Normal Operation	PWR	On when the TS4000 is powered.
	RX	On when the TS4000 detects activity on the radio channel.
	TX	On when the TS4000 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 TS4000 is fully operational when the flashing begins.
Transmit Test Mode	TX	Flashes for the duration of the test.
Invalid Frequency Channel Fault	RX, TX	Alternately flash. This fault occurs if the TS4000 is set for a channel that does not have a valid frequency programmed.
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 TS4000 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 TS4000 Configuration Program, Diagnostics).
Catastrophic Fault	RX, TX	Alternately flash until the fault is cleared and the TS4000 is reset. In this mode the TS4000 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 TS4000 Configuration Program, Diagnostics).

The configuration program is used to configure the TS4000 for operation. Configuring the TS4000 consists of independently configuring both the modem operation and the radio frequency channels. The configuration program consists 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.

In addition to configuring the TS4000, the configuration program provides access to the AirTest wireless modem test software and the TS4000 firmware upgrade program (see Testing, Upgrading Firmware).

Using Help

The configuration program has on-line help that contains information on how to use the program and also detailed information on specific controls and menus. Help is accessed by selecting a command from the help menu, pressing the question button or pressing the F1 key.

System Requirements

- Personal computer using a 486 or higher microprocessor (Pentium recommended).
- Microsoft Windows 3.1, Windows 95 or Windows NT 3.51 or later.
- 4 MB of RAM (16 MB recommended).
- 4 MB of available hard-disk space.
- High-density (1.44 MB) 3.5" disk drive.

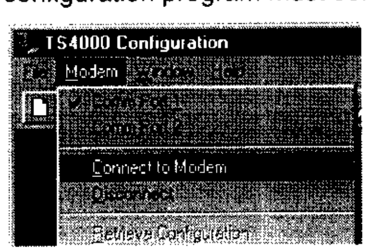
Installation

1) Put the first installation disk into the PC.
2) Run the installation program (Install.exe).
3) Follow the installation program instructions.

TS4000 to PC Serial Port Connection

Serial Cable
To transfer configurations between the TS4000 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).

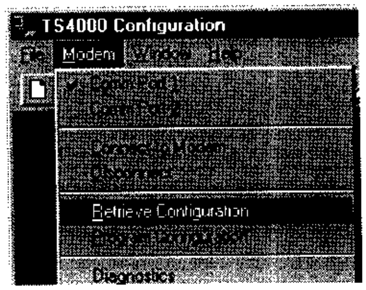
Software Connection
Before configurations can be retrieved from and programmed into the TS4000 the configuration program must connect to the TS4000. To connect, select the Connect to Modem command from the Modem menu or press the Connect to Modem button. Connecting to the TS4000 puts it into program mode. When in program mode the TS4000's RX and TX LEDs remain on continuously.



When connected to the TS4000 the configuration program may disable (lighter shade) some of the controls. These disabled controls are options that are not available with that particular TS4000's version of firmware. These controls are re-enabled when the connection is broken (using the Disconnect command from the Modem menu or the Disconnect button).

Programming and Retrieving Configurations

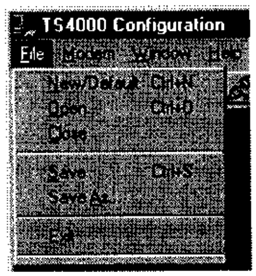
The configuration of the TS4000 can be read out of the modem by selecting the Retrieve Configuration command from the Modem menu or by pressing the Retrieve Configuration button.



To program a configuration into the TS4000, use the Program Configuration command from the Modem menu or the Program Configuration button.

CAUTION: Programming a configuration into the TS4000 will write over (destroy) the configuration currently in the TS4000. To avoid losing the TS4000's configuration information, save the configuration by retrieving it and then saving it as a PC file.

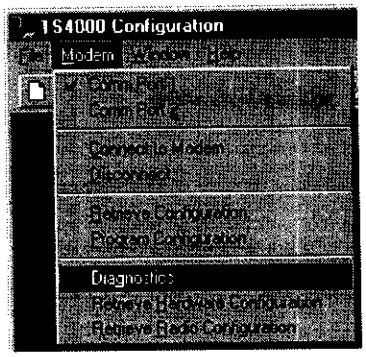
Storing Configurations



Configurations can be stored and recalled as PC files. This is done using the commands under the File menu or the corresponding buttons.

Command	Action
New-Default	Create a new file with default values.
Open	Open a previously stored file. The user is prompted with a directory and file list.
Close	Close the active file.
Save	Save the active file under the current name.
Save As	Save the active file under a different name or in a different directory. The user is prompted with a directory and file list.
Recent File List	This shows the last ten open files. A file can be recalled by selecting its name from the list.

Diagnostics



The configuration program can access diagnostics information from the TS4000. This is done using commands under the Modem menu or the corresponding buttons.

Command	Action
Diagnostics	Run, read and display diagnostic status of the TS4000. The diagnostics tests the major components of the modem and also monitors the power supply voltages.
Retrieve Hardware Configuration	Read and display the hardware configuration. This includes details on the firmware version and memory configuration.
Retrieve Radio Configuration	Read and display the radio configuration. This includes details about the radio's frequency, channel spacing and transmit power.

The serial port provides an asynchronous data connection between the TS4000 and the host equipment. The TS4000 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 TS4000 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 that 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 that utilizes the RS-232 handshake lines and software flow control that 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 that 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 (See Appendix B - ASCII Character Set).

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 that can be used by the host application and also prevents the sending of binary (all character numbers) data.

Serial Port Connector

The TS4000 serial ports are setup as DCEs (Data Communication Equipment). The TS4000 with the standard case uses two 9 pin subminiature D connectors with female pins for the serial ports. The TS4000 with the watertight case uses a 19 pin environmentally sealed LEMO connector (see Appendix A - Serial Port).

Signal Levels

Serial port 1 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 A - Serial Port, Appendix F - Internal Jumper Block).

Serial port 2 is always set for RS-232 signal levels.

Signal Options

The serial ports can be setup to provide different internal electrical connections to the DTR, DSR and RI pins. To change the pin connections, the modem must be opened and the jumper plugs next to the serial port connector set to the desired position (see Appendix F - Internal Jumper Block).

RI Pin Signal Options

The RI (Ring Indicator) pin is pin 9 of a standard 9 pin subminiature D connector and is an output for DCEs (the TS4000). For the TS4000, the RI pin is normally setup as a power input pin. This is non-standard use of this pin and therefore care should be taken when connecting the TS4000 to other serial devices. For most serial devices this is not a problem because RI is a modem (DCE) output and the TS4000 power supply falls within the allowed voltage range for RS-232 signals. Therefore the power voltage on this pin is interpreted as an active RI signal. For systems that use the RI signal differently, or cannot operate with power on this pin, this pin should be disconnected between the TS4000 and the host equipment.

Alternate Connection
As an alternative, the RI pin can be connected to the internal DSR output signal.

DSR Pin Signal Options

The DSR (Data Set Ready) pin is pin 6 of a standard 9 pin subminiature D connector and is an output for DCEs (the TS4000). For the TS4000, the DSR pin is normally connected to the internal DSR output signal.

Alternate Connection
As an alternative, the DSR pin can be set to always be in the active high state. In this case it is internally connected to +5 volts through a 1 K ohm resistor.

DTR Pin Signal Options

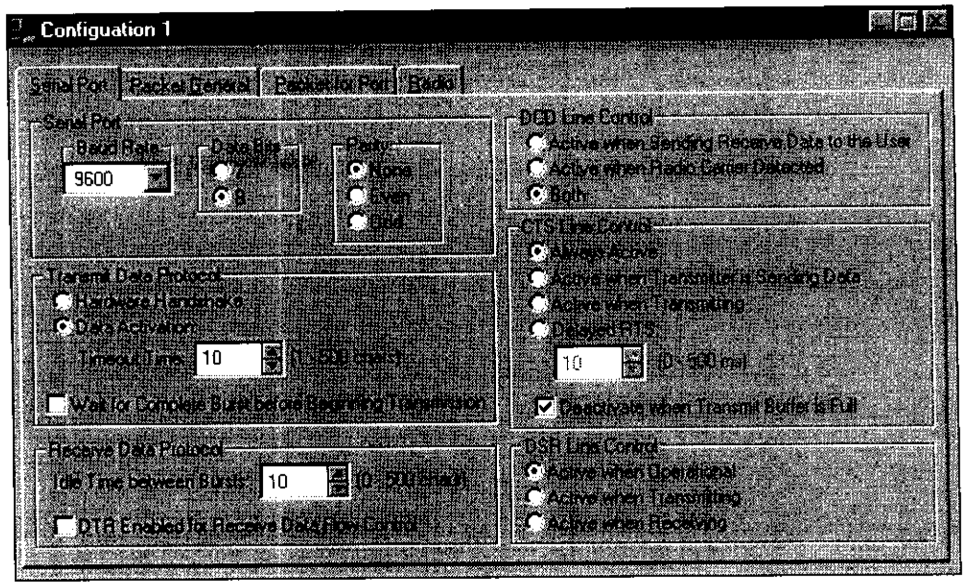
The DTR (Data Terminal Ready) pin is pin 4 of a standard 9 pin subminiature D connector and is an input for DCEs (the TS4000). For the TS4000, the DTR pin is normally connected to the internal DTR input signal.

Alternate Connection
As an alternative, the DTR pin can be connected as a power pin into the TS4000.

> ***Caution: The use of the DTR pin for power is non-standard. Therefore the TS4000 serial port must not be connected to a standard serial device that drives the DTR pin (i.e. a PC).*** This results in the power supply voltage of the TS4000 being shorted to the DTR output of the host serial port, which could damage to the host device. Therefore, when connecting the TS4000 to a PC for configuration, make sure that the cable does not have a DTR (pin 4) connection.

Configuration Options

The serial port provides a number of configuration options that allows it to be connected to virtually any asynchronous host equipment. These configuration options are set using the Serial Port tab of the Modem Configuration.



Baud Rate List The baud rate list provides selection of the serial port asynchronous baud rate. The available selections are 1200, 2400, 4800, 9600, 19200 and 38400 baud.

Data Bits These options set the number of data bits in each asynchronous character.

Parity These options set the parity of the asynchronous characters.

Protocol Options

Selection	Description
Hardware Handshake	In this mode the RTS handshake line is used to frame transmit data into bursts. The TS4000 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 TS4000 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 data line to declare the end of a transmit burst. Char Period = Char Length / Baud Rate Where: Char Length = Data Bits + Parity + 2 Data Bits is the value selected from the Data Bits control. Parity is 0 if none is selected from the Parity control and 1 if even or odd is selected. The 2 added to the accounts for the start and stop bits of an asynchronous character. Baud Rate is the value selected from the baud rate list.

Wait For Complete Burst Before Beginning Transmission

This option only has effect if packet operation is not enabled.

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.

Receive Data Protocol

Selection	Description
Idle Time Between Bursts	This sets the minimum amount of time (in character periods) that the receive data (RXD) line will be idle (inactive) between received bursts of data. If this value is set to zero, the receive data line may remain active continuously when multiple bursts of receive data are transferred to the host. If the DCD line option is set for the Active when Sending Receive Data to the User then the DCD line will also be inactive during the receive data line idle times.
DTR Enabled for Receive Data Flow Control	When enabled, DTR acts as flow control for receive data coming from the TS4000 to the host. When DTR is inactive, data received by the TS4000 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.

DCD Line Control

Selection	Description
Active when Sending Receive Data to the User	DCD is active when receive data is sent out of the TS4000 via the serial port.
Active when Receiving	DCD is active when the TS4000 detects a signal on the radio channel. This mode can be used to remote the receive LED.
Both	DCD is active when either receive data is being sent out the serial port or when a signal is detected on the radio channel. Note that for most conditions and configurations these states overlap.

CTS Line Control

Selection	Description
Always Active	The CTS line is active.
Active when Transmitter is Sending Data	CTS is normally inactive and is activated when the TS4000 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 TS4000 is transmitting. Note that the modem begins transmitting only after it has received at least one character (non-control string) of data. This selection can be used to remote the transmit LED.
Delayed RTS	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 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.

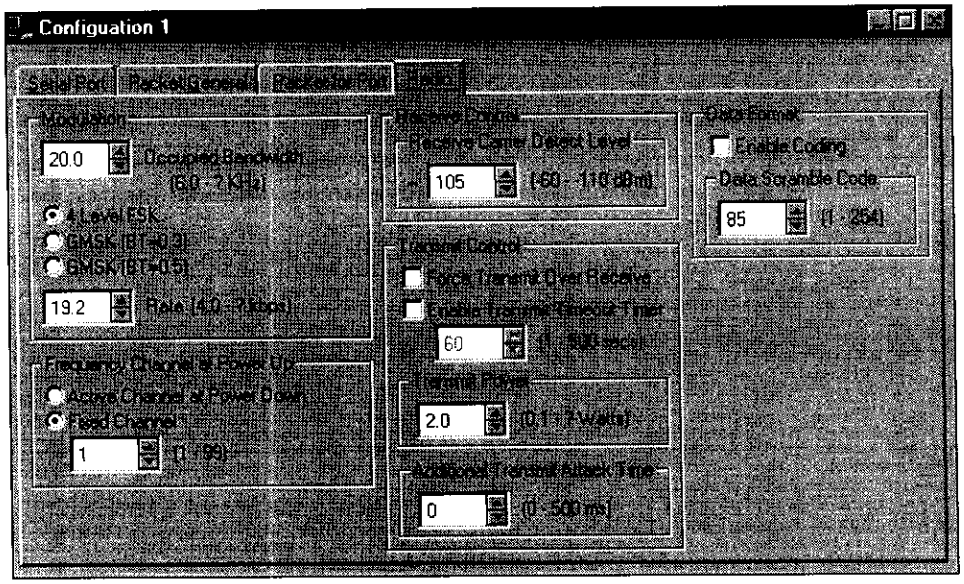
DSR Line Control

Selection	Description
Active when Operational	DSR is active when the TS4000 is powered and has passed self test.
Active when Transmitting	DSR is active when the TS4000 is transmitting. This selection can be used to remote the transmit LED.
Active when Receiving	DSR is active when the TS4000 detects a signal on the radio channel. This mode can be used to remote the receive LED.

The radio setup requires setting the modem configuration options and also setting the radio frequencies. The modem configuration options are accessed on the Radio tab of the Modem Configuration. The frequency programming is accessed with the Frequency Configuration button on the main screen of the configuration program.

Configuration Options

The radio configuration options set the operation of the radio. These configuration options are set using the Radio tab of the Modem Configuration portion of the configuration program.



Modulation

Selection	Description
Occupied Bandwidth	The occupied bandwidth sets the amount of frequency bandwidth that the transmitted signal will use. A higher value corresponds to more bandwidth and therefore provides better BER (Bit Error Rate) performance. The occupied bandwidth should be set to equal to or lower than the occupied bandwidth that is allowed for the channels in use. Example: The FCC licenses many channels with a 12.5 KHz channel spacing for an 11K2 (11.2 KHz) emission designator. Therefore the occupied bandwidth must be set for 11.2 KHz or lower. The maximum value that occupied bandwidth can be set for is dependent on the specific radio module ordered with the unit. This is set at the factory when the unit is manufactured. This maximum value will be shown in the range label when the configuration program is connected to the modem.

Selection	Description
4 Level FSK	Four level FSK modulation. This is the most spectrally efficient modulation. Therefore, this modulation allows the highest data rate for a given occupied bandwidth. However, it also requires the highest receive signal level to achieve a given BER (Bit Error Rate).
GMSK (BT=0.3)	Gaussian Minimum Shifted Keyed modulation with a BT = 0.3. This is the less spectrally efficient than 4 Level FSK modulation and more spectrally efficient than GSMK (BT=0.5) modulation.
GMSK (BT=0.5)	Gaussian Minimum Shifted Keyed modulation with a BT = 0.5. This is the least spectrally efficient modulation. However, it provides the best BER for a given receive signal level.
Rate	The over the air modulation bit rate. All TS4000s that communicate together must use the same setting. Lower settings result in better signal demodulation which results in a better (lower) BER (Bit Error Rate) for a given receive signal level. The maximum rate that can be set depends on the settings of occupied bandwidth and modulation type

Frequency Channel at Power Up

Selection	Description
Active Channel at Power Down	The channel activated at power up is the channel that was active when the modem was last powered down.
Fixed Channel	The channel activated at power up is the channel set in the corresponding control.

Receive Carrier Detect Level

This sets the receive signal level at which the receiver is activated. This is similar to the squelch control on mobile radios. Normally this level is set slightly lower than the level at which the TS4000 can correctly demodulate the incoming data.

When using the TS4000 in a high noise environment, this level can be raised so that the TS4000 is more selective about the signals that it attempts to demodulate. This is important for configurations that do not allow the TS4000 to transmit while it is receiving. These include configurations with packet operation enabled or with the Force Transmit over Receive control disabled.

Force Transmit Over Receive

This control has effect only if packet operation is disabled.

Selection	Description
Disabled	The modem will not transmit while receiving. Transmit data is buffered and then transmitted when the TS4000 stops receiving.
Enabled	The modem transmits as soon as data is ready without regard to the receive state.

Transmit Timeout Timer

When enabled, the timeout timer stops the TS4000 from transmitting after the specified period of continuous transmission. This is used to avoid locking up the radio channel due to a continuous transmission caused by an equipment fault.

Transmit Power

This sets the transmit power level. The maximum transmit power that can be set depends on the specific radio module in the TS4000. Therefore the maximum value that can be set is listed only when the configuration program is connected to the TS4000.

Additional Transmit Attack Time

This is additional attack time added to the radio transmission process. This is used in setups where the TS4000 is used with a power amplifier or repeater system that creates an extra delay in establishing the radio channel.

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. The TS4000 is preset for the appropriate attack time of the installed radio module. Therefore, this control should normally be set to zero.

Enable Coding

Selection	Description
Disabled	This minimizes the amount of overhead required to send data.
Enabled	Transmit 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 multi-path fading common in mobile environments.

Data Scramble Code

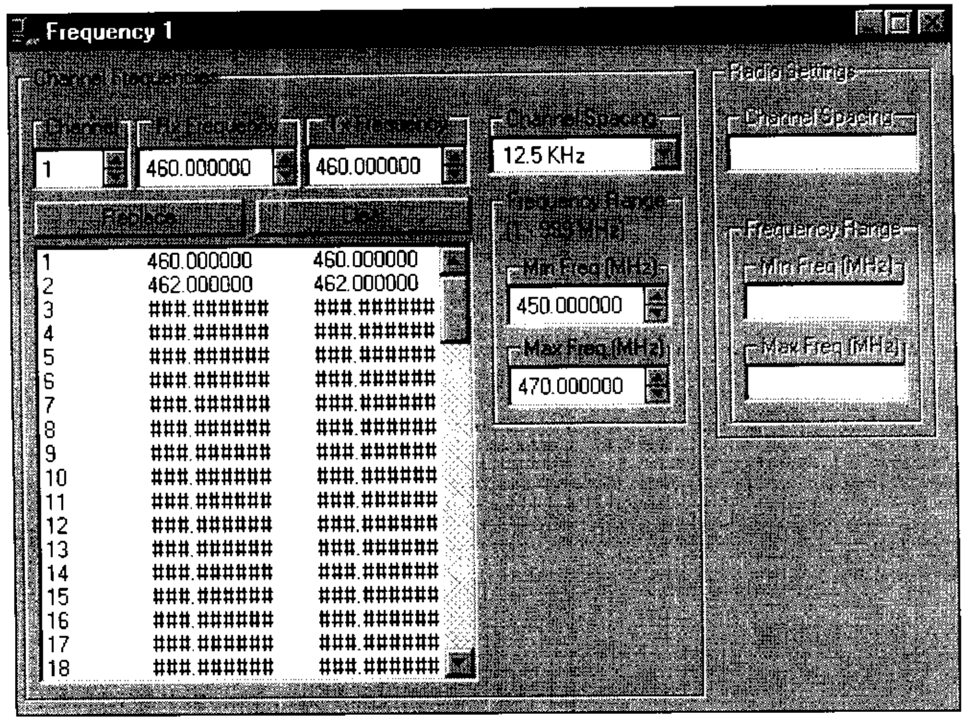
The scramble code determines the pseudo-random sequence used to scramble the transmitted data. This provides data privacy and also randomizes the data for optimum signal detection. All TS4000s operating in the same network must use the same scrambling code.

Frequency Programming

The TS4000 comes in various frequency bands (i.e. 450 to 470 MHz) and can be programmed for any valid channel within a given frequency band. The TS4000 can be set for up to 99 frequency pairs. A frequency pair is a receive frequency and a transmit frequency which can be set to the same or different frequencies.

Frequency channels are programmed into the TS4000 using the configuration program. To access the frequency program screen press the Frequency Configuration button on the main screen of the configuration program. Frequency channel configuration settings are programmed into and retrieved from the TS4000 the same as the modem configuration settings.

> The FCC rules state that only authorized service/maintenance personnel should be allowed to change the frequencies programmed into radio devices. Because of this, a software enable code is required to enable the frequency programming capability of the TS4000 configuration program. Note that this enable code is not required to retrieve and display the channel frequencies programmed in the TS4000.
>
> Please contact Teledesign Systems for information on finding the nearest authorized service center.



Radio vs. File Settings

The minimum and maximum frequencies and the channel spacing depend on the specific radio module in the TS4000. The configuration program does not know this information unless it is connected to the TS4000. Therefore, these fields in the Radio Settings frame only show up when the configuration program is connected to the TS4000. When the user creates a new frequency configuration file these values can be set in the channel frequencies frame. This allows the user to create, modify and store frequency files without being connected to a TS4000. When a file is used to program frequency channels into the TS4000, the configuration program compares the radio values with the file values and determines if they are compatible. If they are compatible then the programming continues. If they are not compatible then the user is prompted to make the necessary changes in these values so that only valid frequency channels are programmed into the TS4000.

Channel Switching

During normal operation, the frequency channel can be switched on the fly. This is done with the following ASCII character string.

+TSxx Where: **xx** = Channel number from 01 to 99

Note: The letter characters must be upper case.

The channel change control string is sent to the modem the same as standard transmit data. For the control string to be recognized it must be the first characters of a burst of transmit data. If the control string is sent alone (no data following), then the TS4000 will switch to the receive frequency of the new channel pair and wait in receive mode. If the control string is sent with a transmit data burst following it, then the TS4000 will switch to the transmit frequency of the new channel pair and transmit the burst.

Invalid Channel Selection

If a frequency channel is selected that has not been programmed with valid frequencies, the modem will not receive or transmit and the RX and TX LEDs will alternately flash.

Channel at Power Up

The channel that the TS4000 activates at power up depends on the setting of the Frequency Channel at Power Up control.

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.

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.

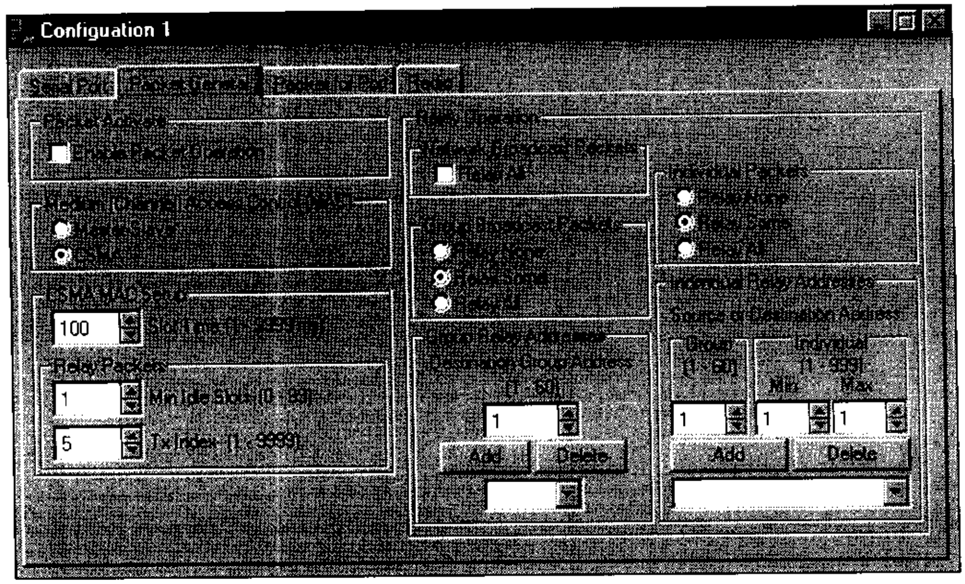
Store and Forward Data Repeater

- 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 General

These configuration options are set using the Packet General tab of the Modem Configuration.



Packet Activate

Selection	Description
Enable Packet Operation	This activates packet operation for all user data.

Medium (Channel) Access Control (MAC)

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 Setup

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). These values are set on the Packet for Port tab.
ACK Packets	These are the acknowledgment packets for the individually addressed data packets. These values are set on the Packet for Port tab.
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.

Network Broadcast Packets - Relay All

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

Group Broadcast Packets - Relay Activate

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

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.

Individual Packets - Relay Activate

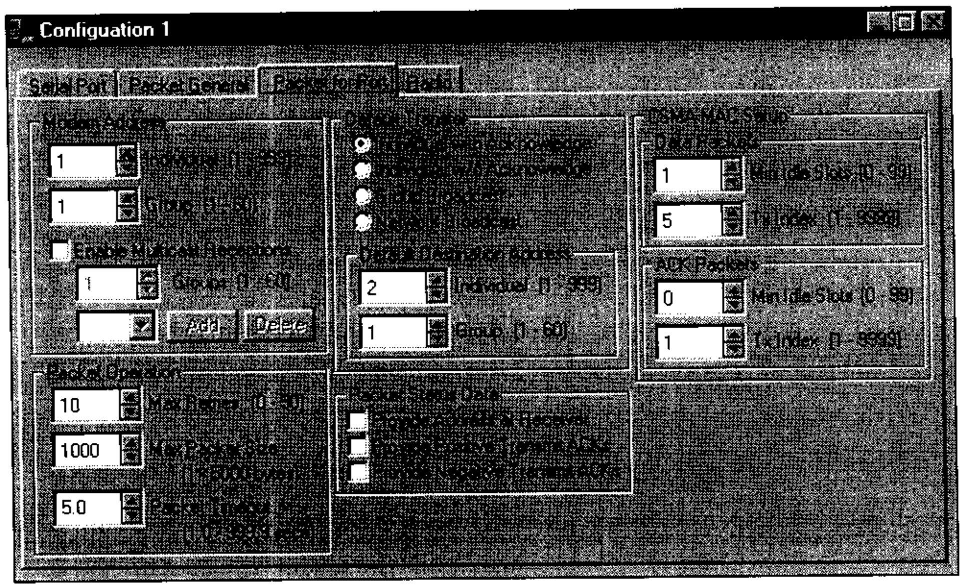
Selection	Description
None	No individually addressed packets are relayed.
Some	The individual packets that are relayed is determined by the individual relay addresses control.
All	All individually addressed packets are relayed. The exception is packets whose final destination is the relay node.

Individual Relay Addresses

This control consists of a list of address ranges. Each item in the list represents a range of addresses that 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.

Packet for Port

These configuration options are set using the Packet for Port tab of the Modem Configuration.



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.

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.

Packet Operation

Control	Description
Max 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.
Max 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.
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).

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.

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.

CSMA MAC Setup

Control	Description
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. These values are set on the Packet General tab.

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 B - 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.

Control String	Description
+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

Where:
Decay Time = Tx Decay Time + Additional Transmit Attack Time
Attack Time = Tx Attack Time + Additional Transmit Attack Time

Tx Decay Time and Tx Attack Time are fixed values that are preset for the radio in the TS4000. These values can be read out of the TS4000 using the retrieve radio configuration menu or button. The Additional Transmit Attack Time is the value set on the radio tab of the modem configuration.

ACK Packet Transmit Time = ACK Packet Length / Modulation 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: Tx Attack Time = 20 ms
Tx Decay Time = 12 ms
Additional Transmit Attack Time = 0 ms
Over air channel rate = 9600 bps
Coding = Enabled

ACK Packet Transmit Time = 192 / 9600 = 20 ms
Packet Timeout Time = 12ms + 20 ms + 20 ms = 52 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

Where:
Attack Time = Tx Attack Time + Additional Transmit Attack Time

Note that the packet delay time does not include the transmit decay time. This is because the packet is available at the receiving modem as soon as all the data is transmitted.

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:

Tx Attack Time = 20 ms
Additional Transmit Attack Time = 0 ms
Over air channel rate = 9600 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 / 9600 = 88 ms
Total Packet Delay Time = 20 + 88 = 108 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 is a summary of the suggested settings for a basic CSMA system. A basic system does not have any store and forward relays. Note that more detail on the parameters and equations can be found later in this section.

Slot Time

Slot Time = Attack Time + Maximum Carrier Detect Time Variation
= 1.5 x Attack Time
Where:
Attack Time = Radio Attack Time + Additional Transmit Attack Time

Tx Decay Time and Tx Attack Time are fixed values that are preset for the radio in the TS4000. These values can be read out of the TS4000 using the retrieve radio configuration menu or button. The Additional Transmit Attack Time is the value set on the radio tab of the modem configuration.

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:
$$\text{Attempt Rate} = \sqrt{\text{Packet Detection Ratio}}$$
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 = Decay Time + Attack Time + ACK Packet Transmit Time
Where:
Decay Time = Tx Decay Time + Additional Transmit Attack Time
Attack Time = Tx Attack Time + Additional Transmit Attack 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 - Setup Summary

The following is a summary of the suggested settings for a system that has one or more store and forward relays. Note that more detail on the parameters and equations can be found later in this section.

Slot Time

Slot Time = Attack Time + Maximum Carrier Detect Time Variation
= 1.5 x Attack Time
Where:
Attack Time = Radio Attack Time + Additional Transmit Attack Time

Tx Decay Time and Tx Attack Time are fixed values that are preset for the radio in the TS4000. These values can be read out of the TS4000 using the retrieve radio configuration menu or button. The Additional Transmit Attack Time is the value set on the radio tab of the modem configuration.

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 simultaneously want to transmit) = the greater of
A) Average Number of Backlogged Nodes or
B) 1/4 Maximum Possible Number of Backlogged Nodes

$$\text{Attempt Rate} = \sqrt{\text{Packet Detection Ratio}}$$

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 = 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

ACK Packet Delay at Destination Node = Decay Time
+ 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 = 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

Decay Time = Tx Decay Time + Additional Transmit Attack Time
Attack Time = Tx Attack Time + Additional Transmit Attack 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
= 1.5 x Attack Time

Attack Time = Tx Attack Time + Additional Transmit Attack Time

Tx Attack Time is a fixed value that is preset for the radio in the TS4000. This value can be read out of the TS4000 using the retrieve radio configuration menu or button. The Additional Transmit Attack Time is the value set on the radio tab of the modem configuration.

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

Decay Time = Tx Decay Time + Additional Transmit Attack Time
Attack Time = Tx Attack Time + Additional Transmit Attack Time

Tx Decay Time and Tx Attack Time are fixed values that are preset for the radio in the TS4000. These values can be read out of the TS4000 using the retrieve radio configuration menu or button. The Additional Transmit Attack Time is the value set on the radio tab of the modem configuration.

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

$$\text{Attempt Rate} = \sqrt{\text{Packet Detection Ratio}}$$

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.

Tx Attack Time = 20 ms
Tx Decay Time = 12 ms
Additional Transmit Attack Time = 0 ms
Over air channel rate = 9600 bps
Coding = Disabled
Average Packet Size = 400 bits
Average Backlogged Nodes = 10
Maximum Backlogged Nodes = 100
Slot Time = 30 ms

Packet Length = (Data Bits + 112) x 1.1 = (400 + 112) x 1.1 = 564
Packet Transmit Time = Packet Length / Channel Rate
= 564 / 9600 = 59 ms
Total Packet Time = Attack Time + Packet Transmit Time + Decay Time
= 20 ms + 59 ms + 12 ms = 91 ms
Packet Detection Ratio = Slot Time / Total Packet Time
= 30 ms/ 91 ms = 0.33
Attempt Rate = sqrt(Packet Detection Ratio) = sqrt(0.33) = 0.57

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 / 0.57 = 44

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

Decay Time = Tx Decay Time + Additional Transmit Attack Time
Attack Time = Tx Attack Time + Additional Transmit Attack 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

Decay Time = Tx Decay Time + Additional Transmit Attack Time
Attack Time = Tx Attack Time + Additional Transmit Attack 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 = $\frac{T_{slot} \times (1 + PDR - PR^N)}{PDR \times \ln(1/PR)}$

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 = 30 ms = 0.03 sec
PDR = Packet Detection Ratio = 0.33 (from previous example)
TI = Transmission Index = 44 (from previous example)

PR = (TI - 1)/TI = (44 - 1)/ 44 = 0.977

$$\text{Average Delay} = \frac{T_{slot} \times (1 + PDR - PR^N)}{PDR \times \ln(1/PR)} = \frac{0.03(1 + 0.33 - 0.977^N)}{0.33 \ln(1/0.977)}$$

$$= \frac{0.03(1.33 - 0.977^N)}{0.00768} = 3.91(1.33 - 0.977^N)$$

Backlogged Nodes (N)	10	25	50	75	100
Average Delay (sec)	2.1	3.0	4.0	4.5	4.8

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.

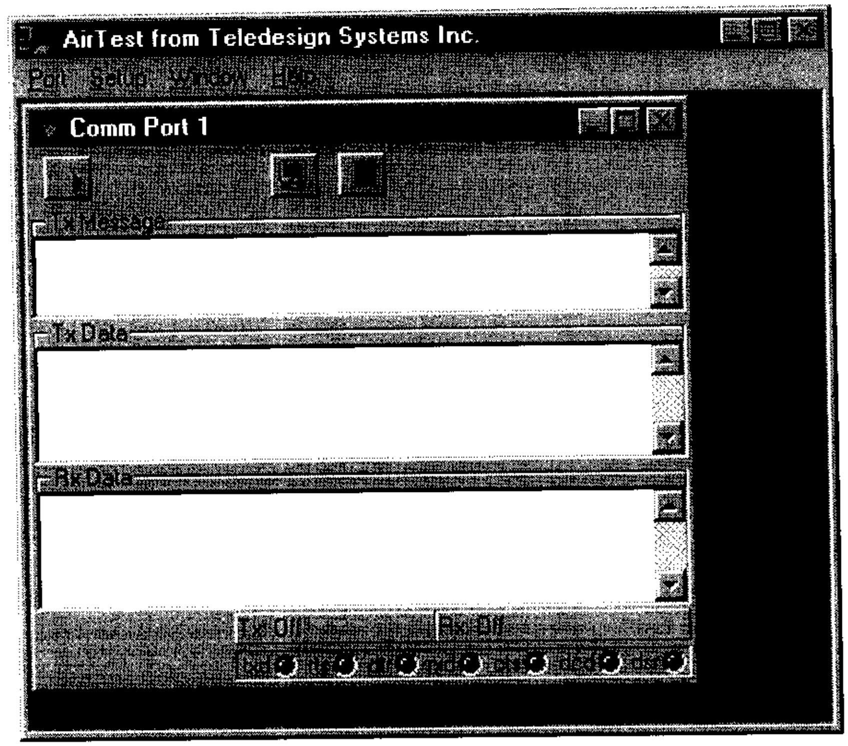
Probability of Sending (%)	25	50	75	90	95	99	99.9
Probable Delay (Avg. Delays)	0.29	0.69	1.38	2.30	3.00	4.61	6.91

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.

AirTest

The TS4000 configuration program is provided with AirTest, Teledesign's general purpose wireless modem test software. AirTest can send data and gather performance statistics about the link between two modems.

To start AirTest press the AirTest button on the main screen of the configuration program. For details on using AirTest consult AirTest's on line help.



Data Test

To test the operation of the TS4000, AirTest can be used to pass data between two modems.

1) Attach two TS4000s each to a PC serial port.
2) Setup AirTest for the correct serial port baud rate, data bits and parity (matches the TS4000's setting).
3) Transmit data between the TS4000s by typing a message into the Tx Message box of the Comm Port window followed by the ENTER key.
4) Automated tests can be run that will send data and verify that it is 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

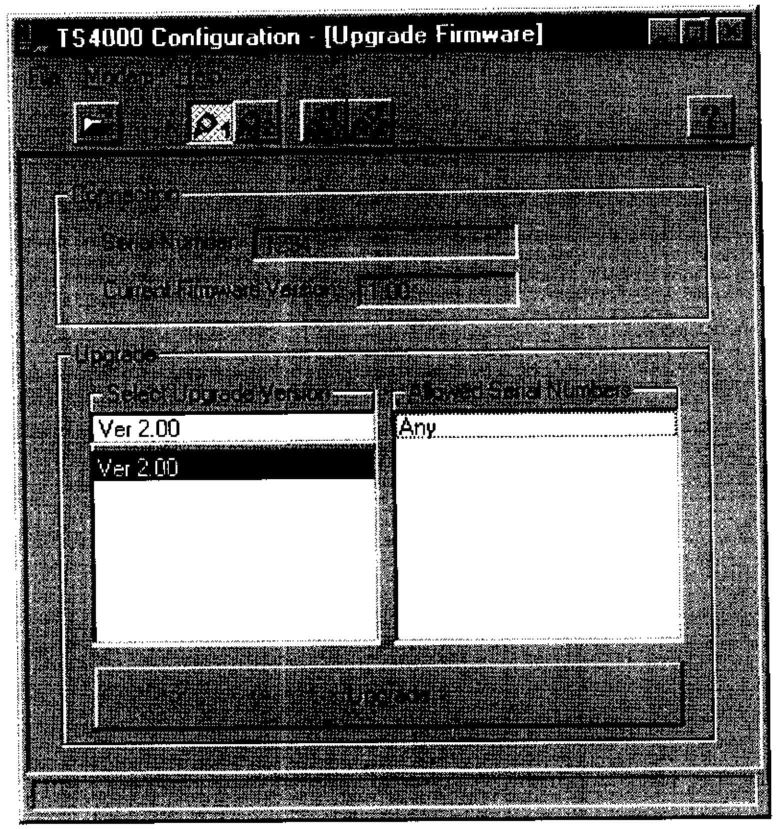
A BER (Bit Error Rate) test is used to determine how good a radio environment is for transmitting data. The BER result tells the percentage of bits that are corrupted. A BER of 3.0×10^{-4} means that 3 out of 10,000 (10^4) bits are corrupted.

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 value. However, in a relatively error free environment this can take a very long time. An alternative is to run the BER test until at least 10 errors have been received which provides a 68% confidence level.

AirTest can be setup to run a BER test. To run a BER test, the TS4000s must be configured with packet operation disabled. This is because when the TS4000 is setup for packet operation it discards corrupted packets and does not send them out the serial port.

1) Attach two TS4000s each to a PC serial port.
2) Setup AirTest for the correct serial port baud rate, data bits and parity (matches the TS4000's 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.

The TS4000 comes with flash program memory that allows the firmware to be easily upgraded in the field. Firmware is upgraded with the upgrade program which is included as part of the TS4000 configuration program.



Upgrading

1) Attach the TS4000 to a PC serial port.
2) Start the upgrade program by pressing the Upgrade Firmware button on the main screen of the configuration program.
3) Select the firmware version to upgrade to.
    a) If the desired firmware version does not show up, us the Find File button (or menu) to manually search for the necessary file.
4) Press the Connect to Modem button to connect the upgrade program to the TS4000.
5) Press the Upgrade button and wait for the upgrade to complete.

To be operated legally, radio equipment requires two types of licensing; the manufacturer's license that the manufacturer obtains and the user license that the user must obtain.

User's License

For most radio equipment, the user is required to obtain an operating license. This is done so that the government can coordinate radio users in order to minimize interference.

It is the user's responsibility to obtain the necessary licenses prior to transmitting over the air with the TS4000. The user is also responsible for proper setup, operation, and maintenance of the TS4000 so that it complies with the limits specified by the license.

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.

Channel Spacing and Occupied Bandwidth

Within the different frequency bands (i.e. VHF, UHF, 900 MHz etc.) channels are licensed with a specific channel spacing (i.e. 25 KHz, 12.5KHz, etc.). The channel spacing corresponds to difference between the center frequency of adjacent channels. The TS4000 can be ordered with various channel spacing options.

For each frequency band and channel spacing, there is a corresponding maximum occupied bandwidth. The maximum occupied bandwidth is the amount of frequency bandwidth that the user on a channel is allowed to occupy. This is typically (but not always) less than the channel spacing in order to minimize interference between users on adjacent channels.

The occupied bandwidth of the TS4000 can be configured by the user (see Radio Setup). The occupied bandwidth must be set to a value less than or equal to the maximum allowed occupied bandwidth of the channels that the user is operating on. Note that the setting of occupied bandwidth limits the maximum over the air data rate that the TS4000 can operate at. The maximum over the air data rate is also dependent on the modulation type selected.

For each TS4000 there is a maximum occupied bandwidth that cannot be exceeded and is dependent on the bandwidth of the specific radio module that the unit was ordered with. This maximum occupied bandwidth is configured when the unit is manufactured and cannot be changed by the end user.

Within the US, the FCC indicates the maximum occupied bandwidth as part of the channel emission designator. For example, an emission designator of 16K0F1D corresponds to a 16.0 KHz occupied bandwidth. The emission designator of the licensed channel or channels shows up on the license form that is received when the FCC (or other appropriate licensing agency) grants a license.

USA (FCC)

The TS4000 is licensed under the FCC (Federal Communications Commission) Part 90 rules. The FCC regulates the operation and licensing of radio equipment in the US. 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 license (voice, data, paging, etc.), type of user (business, government, etc.) and the frequencies

Licensing Service Companies

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

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

Phone Numbers

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

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 and to make sure that the TS4000 meets the licensing requirements.

Manufacturer's License

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

USA (FCC)

Part 15

The TS4000 has been tested and found to comply with the limits for a Class B digital device, pursuant to Part15 of the FCC rules (Code of Federal Regulations 47CFR Part 15). Operation is subject to the condition that this device does not cause harmful interference.

Part 90

The TS4000 has been type accepted for operation by the FCC in accordance with Part 90 of the FCC rules (47CFR Part 90). See the label on the unit for the specific FCC ID and any other certification designations.

Industry Canada

ICES-003

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

RSS-119

The TS4000 has been certified for operation by Industry Canada in accordance with RSS-119 and RSS-210 of the Industry Canada rules. See the label on the unit for the specific Industry Canada certification number and any other certification designations.

International

Many countries allow radio equipment that meets the FCC rules to be operated. However, some countries have their own rules which radio manufactures must comply with. It is the user's responsibility to ensure that the TS4000 meets the required regulations.

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) MODEMS4 (USA & Canada only)
(408) 436-1024
(408) 436-0321 (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.
1710 Zanker Road
San Jose, CA 95112-4215
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.

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.

Standard Case

Connector
The standard case uses a 9 pin subminiature D connector with female pins for each serial port.

Serial Port 1 Pinout

Pin	Signal	Direction	Notes
1	DCD - Data Carrier Detect	Output	
2	RXD - Receive Data	Output	
3	TXD – Transmit Data	Input	
4	DTR - Data Terminal Ready	Input	[1] [2]
	Alt) Modem Power	Input	
5	Ground	--	
6	DSR - Data Set Ready	Output	[1] [3]
	Alt) Always in the high state.	Output	
7	RTS - Request to Send	Input	
8	CTS - Clear to Send	Output	
9	Modem Power	Input	[1] [4]
	Alt) DSR - Data Set Ready	Output	

Serial Port 2 Pinout

Pin	Signal	Direction	Notes
1	DCD - Data Carrier Detect	Output	
2	RXD - Receive Data	Output	
3	TXD – Transmit Data	Input	
4	DTR - Data Terminal Ready	Input	
5	Ground	--	
6	DSR - Data Set Ready	Output	[1] [3]
	Alt) Always in the high state.	Output	
7	RTS - Request to Send	Input	
8	CTS - Clear to Send	Output	
9	Modem Power	Input	[1] [4]
	Alt) DSR - Data Set Ready	Output	

Watertight Case

Connector
The watertight case uses a single 19 pin LEMO connector (part # TBD).

Pinout

Pin	Port	Signal	Direction	Wire Color [5]	Notes
1	1	DCD - Data Carrier Detect	Output	TBD	
2	1	RXD - Receive Data	Output		
3	1	TXD - Transmit Data	Input		
4	1	DTR - Data Terminal Ready	Input		[1] [2]
		Alt) Modem Power	Input		
5	--	Ground	--		
6	1	DSR - Data Set Ready	Output		[1] [3]
		Alt) Always in the high state.	Output		
7	1	RTS - Request to Send	Input		
8	1	CTS - Clear to Send	Output		

Pin	Port	Signal	Direction	Wire Color [5]	Notes
9	1	Modem Power	Input	TBD	[1] [4]
		Alt) DSR - Data Set Ready	Output		
10	2	DCD - Data Carrier Detect	Output		
11	2	RXD - Receive Data	Output		
12	2	TXD - Transmit Data	Input		
13	2	DTR - Data Terminal Ready	Input		
14	--	Ground	--		
15	2	DSR - Data Set Ready	Output		[1] [3]
		Alt) Always in the high state.	Output		
16	2	RTS - Request to Send	Input		
17	2	CTS - Clear to Send	Output		
18	--	Ground	--		
19	--	Modem Power	Input		

Notes:

[1] These pins have multiple internal signals that they can be connected to. The connection options are selected with internal jumper plugs (see Appendix F - Internal Jumper Block).

[2] This pin is normally setup as the serial port DTR (Data Terminal Ready) line, which is an input for DCEs (input to the TS4000). As an alternative, this pin can be setup to feed power into the TS4000.

> ***Caution: The use of the DTR pin for power is non-standard. Therefore the TS4000 serial port must not be connected to a standard serial device that drives the DTR pin (i.e. a PC).*** This results in the power supply voltage of the TS4000 being shorted to the DTR output of the host serial port, which could damage to the host device. Therefore, when connecting the TS4000 to a PC for configuration, make sure that the cable does not have a DTR (pin 4) connection.

[3] This pin is normally setup as the serial port DSR (Data Set Ready) line, which is an output for DCEs (output of the TS4000).

As an alternative, this pin can be set to always be in the active high state. In this case the pin is internally connected to +5 volts through a 1 KΩ resistor.

[4] This pin is normally setup as a power input pin. As an alternative, this pin can be setup as the serial port DSR (Data Set Ready) line which is an output for DCEs (output of the TS4000).

For standard RS-232 ports this pin is the RI (Ring Indicator) line, which is an output for DCEs (the TS4000). Therefore the use of this pin as a power pin is non-standard and therefore care should be taken when connecting the TS4000 to standard serial devices. For most serial ports this is not a problem because RI is a modem (DCE) output and the TS4000 power supply falls within the allowed voltage range for RS-232 signals. Therefore the power voltage on this pin is interpreted as an active RI signal. For systems that use the RI signal differently, or cannot stand power on this pin, this pin should be disconnected between the TS4000 and the host equipment.

[5] These are the wire colors of the internal wires for the standard cable provided with the watertight version of the TS4000.

Standard RS-232 Serial Port Pinout

Signal Name	Signal Mnemonic	Connector Pinout 9 Pin	Connector Pinout 25 Pin	Direction DCE	Direction 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

Standard Usage of the RS-232 Control Signals

Signal	Description
RTS - Request to Send	Request for transmission from the DTE.
CTS - Clear to Send	Response (to the Request to Send) from the DCE indicating a readiness to transmit data.
DCD - Data Carrier Detect	Status from the DCE indicating that it is receiving.
RI - Ring Indicator	Status from the DCE indicating that it has detected the ring state.
DSR - Data Set Ready	Status from the DCE indicating that it is operational.
DTR - Data Terminal Ready	Status from the DTE indicating that it is operational.

Signal Levels

Serial port 1 can be configured for either RS-232 or TTL signal levels. The signal level selection is controlled with internal jumper plugs (see Appendix F - Internal Jumper Block).

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 that are different from the specification.

Type	Level (volts DC) Low	Level (volts DC) High
Drivers (into a 3k to 7k ohm load)		
RS-232 Specification	-15 to -5	+5 to +15
Actual TS4000 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 TS4000 Receive Levels	-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)	+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)

Appendix B – 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

Data Interface	Data Rates	300, 1200, 2400, 4800, 9600, 19200, 38400 baud
	Data Format	Asynchronous, 8 or 9 bit words
	Signal Levels	RS-232, TTL (Port 1 only) or RS-485
	Handshake Protocols	Full Handshake: Supports RTS, CTS, DCD, DSR, DTR Data Activation (3 wire): Requires only TXD, RXD and SG
	Data Only Time Out	1 to 500 character periods
	Data Connector	9 pin D, female, DCE (standard case) LEMO sealed connector (watertight case)
Radio - General (varies based on specific model)	Frequency Ranges	132-208, 380-520, 928-960 MHz
	Number of Channels	99 receive/transmit pairs (in non-volatile memory)
	Channel Spacing	5, 6.25, 7.5, 10, 12.5, 15, 25, 30 KHz
	Channel Rate	2,400 to 19,200 bps
	Modulation	Filtered MSK, GMSK and 4 Level FSK
	RF Output Power	100 milliwatts to 5 watts, External amplifiers available for up to 100 watts
	Receive Data Sensitivity	-104 dBm for less than 1 x 10^{-6} BER (Bit Error Rate) (typical)
	Carrier Detect Threshold	-110 to -60 dBm, programmable
	RF Connector	BNC, female, 50 Ω (standard case) TNC, female, 50 Ω (watertight case)
Channel Options	Data Protocol	Transparent or Packet
	Data Security	254 Selectable Scrambling Codes
	FEC (Coding)	None or 12,8 Hamming code with 16 bit Interleaving
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 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 20 other groups)
	Relay Operation	Store and Forward with Address Filtering
General	Supply Voltage	9 to 28 VDC
	Power	0.5 watts - Standby (typical) 0.75 watts - Receive (typical) 7 to 22 watts - Transmit (depends on transmit power)
	Power Connector	2 pin Molex or through serial port
	Data Buffer	32 KByte SRAM
	Program Storage	512 KByte Flash ROM (supports in field firmware upgrades)
	LED Indicators	Transmit, Receive, Power
	Operating Temperature	-22 to +140 °F (-30 to +60 °C)
	Dimensions	4.3" x 3.1" x 1.8" (109 mm x 79 mm x 46 mm)
	Weight	12 ounces (340 grams)
	Enclosure Options	Standard and Watertight

Appendix E - PCB Component Locations

Appendix F - Internal Jumper Block

Appendix H - Relevant Components Specification Sheets

See attached.