Technical Brief
AN234Rev B1

M21 and M22 *Tech Series* Modems for SCADA Applications

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Summary

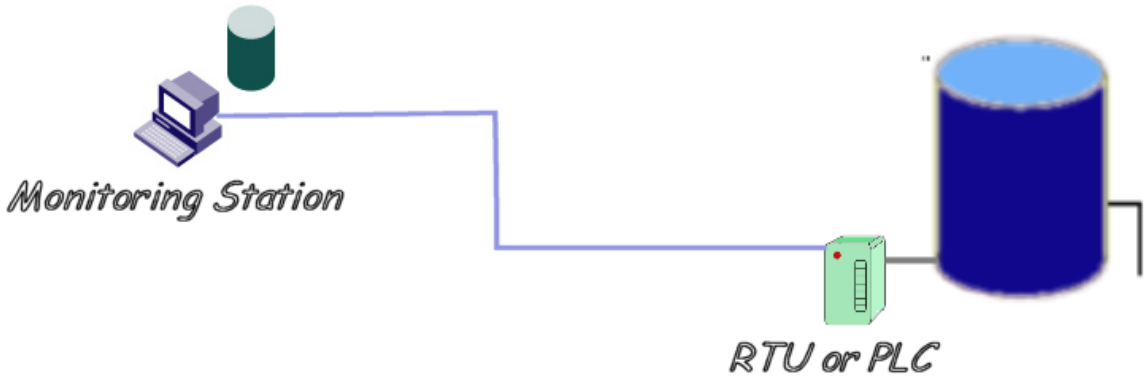
SCADA stands for Supervisory Control and Data Acquisition. The ***MRV-M21*** and ***MRV-M22*** data radios from Raveon Technologies are called the "*Tech Series*" modems. The *Tech Series* modems make ideal wireless modems for SCADA gateways and Remote Terminal Units (RTUs) for SCADA and telemetry systems. This Application Brief describes the general requirements for a wireless SCADA modem and then provides the information needed to configure an M21 series modem to work in common SCADA applications.

Many telemetry and SCADA systems run on private networks or connect things to the Internet. Raveon's wireless modems are excellent devices to connect your things to networks or the Internet.

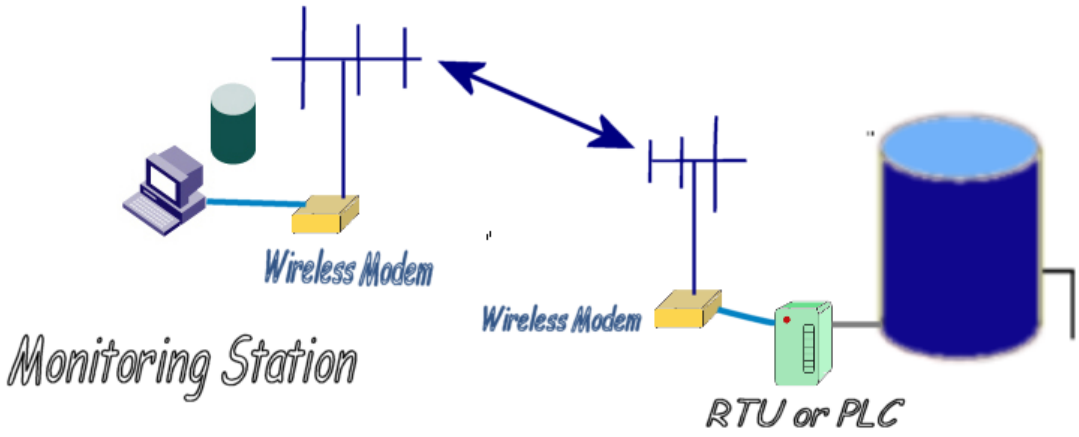
Wireless SCADA

In a wired SCADA system, a device or sensor is monitored by some type of computer or other human-to-machine interface. The user may have something as simple as an LED indicator, or as complex as a computer server for the operator. The human interface communicates to another electronic device that is remotely located at the monitored location. Often this remote device is a Remote Terminal Unit (RTU) or Programmable Logic Controller (PLC).

Typical SCADA System



When the distance between the monitoring station and the device being monitored (the water tank above) is not trivial, than a wireless link between the two sites becomes a logical means of connecting them.



Tech Series Features for SCADA Applications

Reliable Long Range Connectivity. 19200bps in 25kHz channel, 9600bps in 12.5kHz.

Remote status monitoring including DC voltage, packet error statistics, modem "up time", and receiver signal strength.

Easy to use. Plug-in, Turn-on, and GO. Transmit data in = Receive data out.

A myriad of IO options. The front interface of the Tech Series M21 is fully field-reconfigurable. The following front panel interfaces are available and interchangeable:

• RS-232	[S]	5T835
• USB	[U]	5T837
• RS-485	[T]	5T836-1
• RS-422	[F]	5T836-2
• GPIO	[G]	5T833
• Analog	[A]	5T838

Lowest current draw in industry. The M21 wireless modems draw less than 90mA in the receive mode.

The M21 is a **Modbus Gateway**, to send MODBUS messages to remote devices.

Wide input voltage with high-efficiency switching voltage regulator.

Packetized AND Streaming Data. Integrated Packetized data protocol with error correction and built-in Streaming Real-Time operation. User selectable.

ARQ error correction and retransmission capability. Totally transparent to the application.

Capable of **store-and-forward repeating** operation.

Small size. Extruded aluminum enclosure is small, and very rugged.

16 bit addressing for up to 65,525 different unique device addresses per channel. Radio channels may be shared with no interference between users.

Supports **group and broadcast** transmissions. Network mask allows groups of any size.

Easily to configure. *Raveon* modems are configured using "AT" commands through the modem's serial port. Raveon also provides free of charge, *Radio Manager*, a easy-to-use PC program with a graphical user interface to configure and program all Raveon Radios.

RS-232, RS-422, or RS-485 serial port. Programmable serial baud rates up to 115200 make the *M21* radio modem compatible with most every PLC, PC, and HMI device made.

Programmable over-the-air data rates. With the *M21* radio modem, you can choose how your system will work. Set the OTA data slower for extended communication range, or set it fast for lowest latency. *Your choice*.

SkyLine compatibility mode for use in older Sonik radio systems.

Integrated Sensors

Built into the M21 modems are many features and commands that can be used as sensors for SCADA, telemetry, and remote control without having to attach an external sensor.

For many SCADA systems, the Tech Series GPIO interface is the ideal interface to monitor remote devices or control them. The ones with serial interfaces such as RS-232, USB, and RS485 can be connected to a SCADA controller or HMI to communicate with a remote Tech Series radio modem that has the GPIO interface.

The following commands in the M21 are powerful SCADA and telemetry features.

Command	Command Description	Parameters
FAILSAFE	**FAILSAFE A B** command sets the minimum message interval, and the default digital output state if an over-the-air MIMIC message is not received within the failsafe period. **A** is the minimum period in seconds, Set A to 0 to disable FAILSAFE feature. **B** is the power-on ASCII hex value of the digital outputs, and also B default values are used if the failsafe interval passes and no MIMIC messages are receive. The B values are output again if MIMIC was enabled and no messages[E1] received during the MIMIC interval.	A: Required Message Interval or interface to transmit MIMIC data (Seconds) 0 - 99999 B: Default Ascii hex value to set outputs to. 00-FF
MIMIC	MIMIC mode**. MIMIC X Y X** number of seconds to TX if input 0 is low. X=0 to disable MIMIC mode. **Y** is number of seconds between transmissions when the input 0 is high.	X: 0-255 Y:0-255
GOUT	**GOUT** Get the output bit register in hexadecimal format. Example: will return **C3** if bits 0, 1, 14, 15 are set(1) and all other clear (0).	Returns Hex value, 16 bits max.
GINP	**GINP** Get the input bit register in hexadecimal format. Example: will return **C3** if bits 0, 1, 14, 15 are set(1) and all other clear (0).	Returns Hex value, 16 bits max.
CBIT	**CBIT X** Clears output bits, **X** is hexadecimal format. Any bit in x set to 1 will cause the same output bit in the modem's output register to be cleared to 0. No bits get set. X=C3 to set bits 0, 1, 14, 15. To read the output bit register, enter **CLRBIT** with no parameter or better to use **GETOUT** command.	0-FF
SBIT	**SBIT X** Sets output bits, **X** is hexadecimal format. Any bit in x set to 1 will cause the same output bit in the modem's output register to be set. No bits get cleared. X=C3 to	0-FF

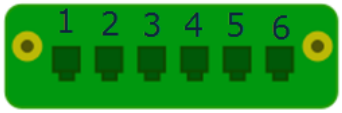
	set bits 0, 1, 14, 15. To read the output bit register, enter SETBIT with no parameter or better to use **GETOUT** command.	
TBIT	**TBIT XX MMM** Sets output bits for a specific time, **XX** is hexadecimal format. Any bit in x set to 1 will cause the same output bit in the modem's output register to be set. **MMM** is in mS. 1000=one second, 60000=one minute,…To set bit #3 to 1 for 250mS: **TBIT 4 250** After the time expires, the bits that was st in XX is cleared to 0.	0-FF 2 – 4000000000 (2mS – 1100hours)
CNTTM	**CNTTM B SS** Configure a timer to reset the bit's binary counter. **B** is the bit number (0-15) that is being configured. **SS** is the interval number of seconds that the transition counter will be reset to 0. Set **SS** to 0 to never automatically reset the counter.	B: 0 - 15 SS: 0 - 65536
IOPIN	**IOPIN XX M** Set the GPIO bits on the Tech Series GPIO front panel to inputs or outputs. XX parameter are the hexadecimal representation of the pins being configured. M is the mode for the XX pins. Mode M values: **A**:Digital TTL Input, **B**:Digital TTL Output. **C**:Open Drain MOSFET output, **D**:DC Power switch output. **E**:Analog Input	XX=Hex 00-FF M=(A,B,C,D)

The Tech Series SCADA features support custom "safe zones" and alert you automatically if the sensor detects conditions outside of that range. Some safe zone settings can report: On, OFF, XX number of transitions, pulses per second, pulses per minute.

General Purpose IO (GPIO)

The M21 and M22 *Tech Series* radio modems have a GPIO interface option and telemetry software built into the modem, so that the User can use standard telemetry apps and MODBUS to communicate to the M21 GPIO to monitor, manage, and control devices using the Tech Series radio modem's GPIO interface.

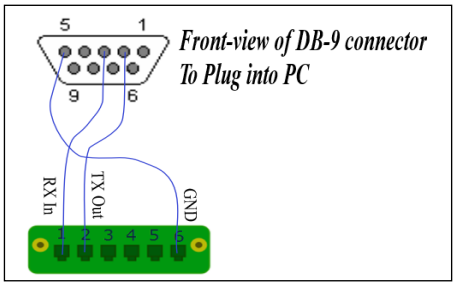
The GPIO has serial IO and general purpose IO functions that are software configurable. The GPIO pins are as show here:



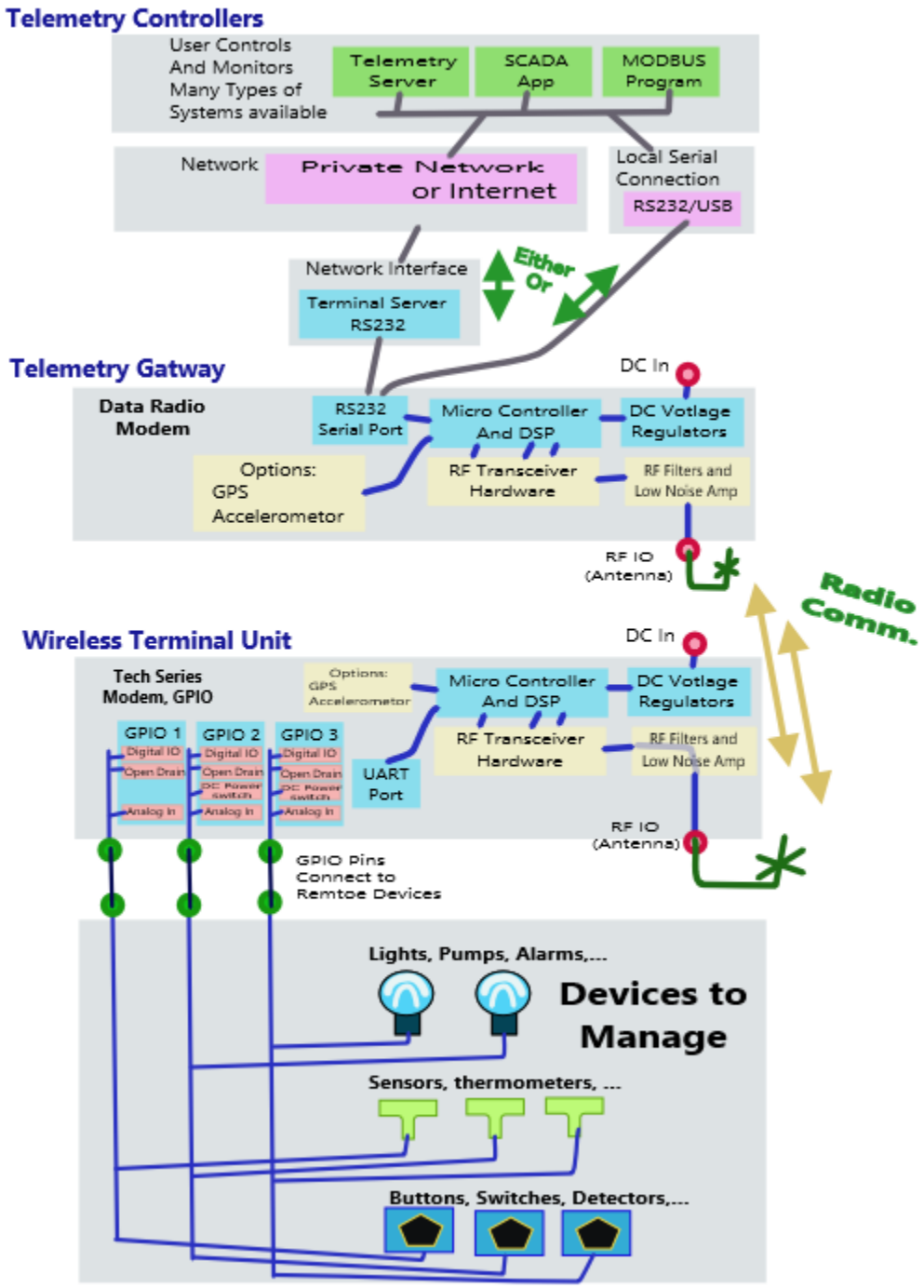
Pin #	Name	Direction	Function	Level / Specification
1	**RX**	In	Serial data Input	RS232
2	**TX**	Out	Serial Data Output	RS232
3	**IO1**	I/O	I/O Pin 1	Configurable General Purpose IO (GPIO). Does not support DC Switched output mode (D).
4	**IO2**	I/O	I/O Pin 3	Configurable General Purpose IO (GPIO)
5	**IO3**	I/O	I/O Pin 3	Configurable General Purpose IO (GPIO)
6	**GND**	-	Ground	Connect to earth ground.

An RS232 serial cable can be connected to pins 1, 2, and 6 to configure the internal radio modem and the MIMIC mode features. Here is a wiring diagram for an RS232 DB9 connector to be wired to the GPIO connector.

Or contact Raveon to have the device pre-configured when it is purchased.



For SCADA and Telemetry, RTUs are not needed with this radio. The GPIO features of this radio modem also incorporate many telemetry features that external RTUs are often required for. But this powerful GPIO interface has so many IO features, that external RTUs are not required for reading or writing digital IO, switched voltages, or open-drain output switches.



The **IOPIN** command is used to configure the functions of the GPIO pins. **IOPIN XX M** command set the GPIO IO pins on the Tech Series GPIO front panel to inputs or outputs.

XX parameter is the hexadecimal representation of the pins being configured. For example, the IO pins are defined as shown here:

IO1=1, IO2=2, IO3=4, IO1 and IO2 = 3, IO1, IO2, and IO3 = 7,

M is the mode for the XX pins.

Mode **M** values: A:Digital TTL Input, B:Digital TTL Output. C:Open Drain MOSFET output, D:DC Power switch output.

Going Wireless

Telemetry Gateway

Wireless modems are the gateway to the wireless telemetry system. When a system uses MODBUS or any other ASCII, RTU, or serial protocol, an M21 data radio modem is the telemetry gateway to dozens of hundreds of remote devices communicating over the radio channel.

Wired Connection

For transporting Data Back to Your SCADA Master, the telemetry industry has standardized on a number of different protocols to use in these types of applications. Most protocols were based upon the assumption that the cabling between the monitoring station and the RTU/PLC is an RS-232 or RS-422 serial link. The protocols commonly used on these serial links are MODBUS-RTU, MODBUS-ASCII, DF1, DNP-3, and IEC870. All of these protocols can operate using hard-wired connections. Because the Raveon Radios mimic a hard-wire (data-in equals data-out), in most cases, the protocols will also work using a wireless modem.

M21 Modems with Modbus

Raveon radio modems support Modbus-ASCII networks with no special configuration. Modbus-ASCII was designed specifically to work well over wired and wireless modems, and uses 7-bit data. All *Raveon* modems support 7-bit data.

Modbus-RTU uses 8-bit data. Some modems and older systems do not work with 8-bit data, but *Raveon's* wireless modems support both 7 bit and 8 bit data. There are some considerations when using radio modems with Modbus-RTU:

Latency The difference between *M5 and M21* series wireless modems and a multi-drop wired network is that the wireless modems introduce some additional latency (delay) into the system. Most Modbus-RTU applications can tolerate this latency, but some cannot. If your Modbus application does not tolerate latency, then use Modbus –ASCII. Modbus-ASCII is compatible with *Raveon* radio modems. The following table shows Latency vs. Over-the-air bit rate for Raveon narrow band *radio* modems in the packetized mode.

Bit Rate	*ATR2 Setting*	*Latency (Seconds)*
800 (2L)	0	0.8-0.9
1200 (2L)	1	0.5-0.6
2400 (2L)	2	0.3-0.4
4800 (2L)	3	0.2-0.3
5142 (2L)	7	0.2-0.3
8000 (4L)	4	0.2-0.3

Time-Outs Some versions of the Modbus protocol have short response timeout requirements that may not be compatible with radio modem latencies. Modbus-RTU is compatible with the normal *FireLine* latencies but does have inter-character delay requirements that must be met. *Raveon* modems have programmable time-outs to facilitate the control of latency.

Modem IDs The M5 and M21 series modems have 16 bit IDs. Most SCADA systems work in a broadcast configuration, where all modems hear all other modems. To do this, set the net mask to all zeors (***ATMK 0000***). Be sure to set each unit ID in each modem to a unique ID number, so that the duplicate packet filtering works properly. All Raveon modems filter out duplicate packets, so that operation with repeaters does not cause duplicate packets being received.

For lowest latency, Raveon's unique "Streaming" mode of operation provides data transfer with latency only slightly higher than wired configurations. No other radio modem on the market offers both error-free packetized operation AND Streaming data operation.

Tech Series Modems with DF1

The DF1 protocol works well with the Raveon radio modems as long as the over-the-air data rate is set to 4800 bps or higher. The stock-configuration of the radio modem works with the Rockwell "*DF1 Polling Driver*".

To reduce latency in the polling, it is suggested that certain stock-parameters in the *FireLine* be a adjusted to values more optimized for use in a polled environment. The following is a list of parameters in the radio that may be adjusted to reduce latency when using the DF1 protocol.

1) Reduce the serial-port time-out value down to 2mS (**ATR3 2**)
2) Set the serial port to 19200bps (**ATBD 4**)
3) Configure the Over the air data rate to 8000bps (**ATR2 4**) This will reduce the communication range, so only do this if the link-margin on the system is adequate.
4) Use the "Streaming Mode" of communications. (**ATMT 2**) The factory default is the "Packet Mode", where all data is error checked and sent in packets. The Streaming mode initiates transmissions faster, and sends characters over-the-air as they stream in, but does not check for errors. DF1 is tolerant of noise and over-the-air bit errors, and in most cases works well in streaming mode. In mission-critical or safety situations, packet mode would be more appropriate as it's data transmission is more deterministic.

Configuring the Tech Series Radio (M21, M22)

For SCADA applications, configure the radio as per the user manual. In most cases, the factory defaults are the best place to start. Set the frequency using the **ATFX xxx.xxxx** command. Then, based upon your system, configure the following parameters:

"AT" command	*Function*
ATBD	Set the baud rate of the *FireLine*'s serial port. Typically set the serial-port rate to 2400 or 9600bps, whichever matches your hardware's setting. Given a choice, Raveon suggests you set it at a high rate to reduce latency. 9600 is set with the **ATBD 3** command. 19200 is set with the **ATBD 4** command.
ATBC	Enable/disable Busy Channel Lockout. Normally, the radio modem does not check for a busy channel. If you are running a large system, with asynchronous data on the radio channel, you should enable BCL so the modem does not transmit while another device is on the air. For polled telemetry systems, do not enable this feature.
ATCH	Enable/Disable hardware flow control. By default this is off and will work fine in most applications. Enabling hardware flow control will ensure that the modem buffers data and only outputs it to the user's device or RTU when the device is ready to receive it.
ATFX	Used to set the radio frequency of the modem.
ATNB	Set the parity bit method of the serial port. Odd, even, none, mark or space. You must configure this to match the device the *FireLine* is communicating with. Note: Parity, baud Rate, and stop bits may be configured differently on different ends of the radio link.
ATR2	The over-the-air data rate. For long-range, set it at 4800bps. For lowest latency, set it at 8000bps or 9600bps. **ATR2 3** for 4800baud. **ATR2 4** for 8000 baud.
ATR3	Serial port time out. This is the amount of idle-time (in mS) before the *FireLine* will begin to transmit a packet of data. When no data comes into the modem for this amount of time, the *FireLine* will transmit the contents of its data buffer over the air. The factory default setting is 20mS. For SCADA systems using MODBU, 2mS is suggested (**ATR3 5)**.
ATMY	The M5 and M21 series modems have 16 bit IDs. Most SCADA systems work in a broadcast configuration, where all modems hear all other modems. Be sure to set the unit ID in each modem to a unique ID number, so that the duplicate packet filtering works properly.
ATMK	To turn off address filtering, and allow all units to receive data from all other units, set the net mask to all zeros (***ATMK 0000***).

For example, with *a* modem configured for 8000 baud over the air, 9600baud serial ports, 2mS time-out, the total time for a MODBUS "Read Module Name" command ($01M) command to receive the response back is 150mS in Packet Mode.

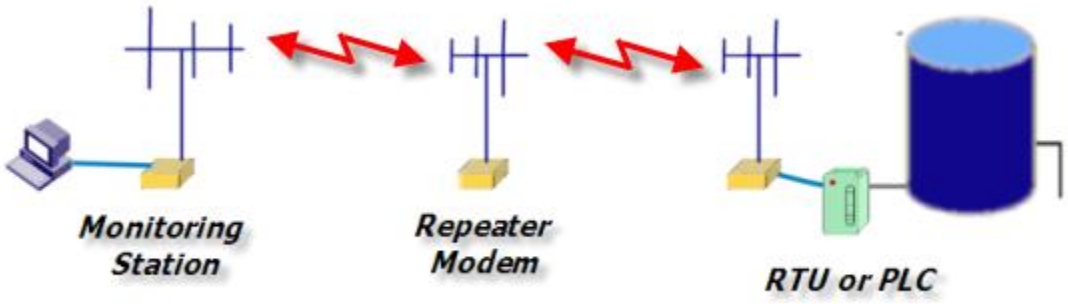
A DF1 polling system with *M5 Fireline or M21* modems configured for 8000 baud over the air, 9600baud serial ports, 2mS time-out, and Streaming Mode will allow RTU's to be polled and responses returned in about 80mS round-trip.

Configuring the GPIO for Telemetry

The GPIO Front panel option on the Tech Series enclosures is a flexible General Purpose IO feature. The 3 IO pins can be configured for

Repeating For Extended Range

For longer communication ranges, high RF noise environments or obstructed line of sight applications it may be necessary to use a repeater to establish a reliable communications link.



Incorporated in the radio is a built in store-and-forward repeater function. The repeater function works only in the Packet Mode, and will not repeat streaming messages. A repeater can extend the range of a system by 2-20X, depending upon how high-up above the average terrain the repeater is mounted.

The following table shows a typical repeater system configuration in packetized mode.

AT Command	Monitoring Modem	Repeater Modem	Remote Modem	Notes
ATMY	1000	2000	0001-0999	Individual unit address for this particular modem. Each remote modem should get a unique ID.
ATDT	0001	N/A	1000	Destination address to send data to.
ATMK	F000	0000	F000	Address mask. F000 means that to receive, the first digit of the MYID must match the first digit of the TOID.
ATXR	0	1	0	Enable/Disable repeater function. Only enable it on the particular radio that will be the repeater.
ATX1	N/A	1000 0000 1000 0000	N/A	In the repeater, set the addresses this unit will store-and-repeat to/from. By setting the repeater address mask to 0000, this repeater will repeat any and all data packets .

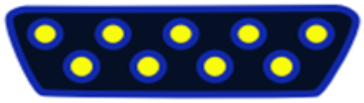
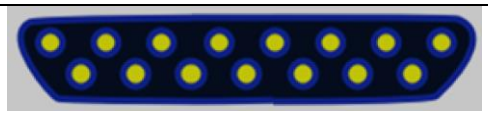
M21/M22 Serial Communications

Refer to application note ***AN236(****SerialComm****)*** for more detailed information on serial communication for telemetry. Raveon's Tech Series radio modems come with a myriad of IO options such as RS232,485,422, USB, GPIO. Serial protocols have various advantages.

Serial Protocol Comparison Chart

	RS-232	RS-422	RS-485	USB
Cable	Single ended	Single ended multi-drop	Multi-drop	Single ended
Number of Devices	1 transmitter 1 receiver	1 transmitter 10 receivers	32 transmitters 32 receivers	1
Communication Mode	Full duplex	Full duplex, Half duplex	Full duplex, Half duplex	Full duplex
Maximum Distance	50 feet at 19.2 kbps	4000 feet at 100 kbps	4000 feet at 100 kbps	20 feet
Max Data Rate (50 feet)	1 mbps	10 mbps	10 mbps	100mbps

The Tech Series radio enclosure from Raveon is the most flexible radio platform in the industry. 6 I/O options, 6 RF band options, GPS option, wide/narrow channels, Arduino option, MODBUS option, and wide DC input voltage range.

I/O Connector Type	Connector Code	IO Function
	S	RS232
	U	USB
	G, T, F	GPIO RS422 RS485
	A	Analog

For SCADA systems, a typical configuration is to have the radio modem connected to the HID/computer to have an RS-232 serial port. The RTUs in the field usually use RS-485, so the radio modems connected to the RTUs should have the RS-485 option

installed. A system may mix RS232 and RS485 modems with no adverse consequences.

Buffer Status

Tech Series radios have a command ATJF that will allow the user to set the CTS threshold. By default, this is set to 80% of the buffer's size. When the internal data buffer of the M21 reaches this threshold, the CTS hardware handshake line is negated.

The user may change this threshold. If you want the modem's CTS line to indicate when the buffer is empty (all data has been transmitted), then set the **ATJF** parameter to 1 (**ATJF 1**). This will have the effect of negating CTS whenever there is any data in the M21's data buffer. When all data has been transmitted over-the-air, the CTS line will be asserted again. It is a handy way to receive a hardware indication that a transmission has gone out, and the radio is ready for more data.

Regardless of the ATJF setting, the radio modem's data buffer can hold thousands of bytes of data, queuing them up to be sent over the air. The ATJF command only affects the threshold where CTS is asserted, not the size of the internal data buffer.

For additional information, contact:

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