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1.0	Initial Document	June 29, 2011	
1.1	Updated Transmit Power settings	July 5, 2011	

APPROVALS	DATE	
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RESPONSIBLE ENGINEER: Henry Constant		**GTECH Aircon Radio (Model GWT154)** **User's Guide**
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1.0 INTRODUCTION

1.1 Purpose, Overview & Scope

The purpose of this document is to provide details regarding the use of the GWT154 transceiver module as a cable replacement between GTECH online lottery terminals and associated peripherals. The GWT154 transceiver module is based on the IEEE 802.15.4-2006 standard, this wireless link provides a point to multipoint peripheral bus with low latency and modern security features.

The link operates in the 2.4GHz band with low power, making it suitable for license-free worldwide operation.

The link will use AES 128 bit authentication and packet encryption available as part of the 802.15.4 standard. It will also use EUI-64 (MAC address) filtering to keep rogue devices off the network. It relies on the GTECH online lottery terminal for initialization and authorization of End Device peripherals. This allows GTECH the ability to integrate the local security measures with field service installations and manufacturing operations, as well as to provide security audit trails, without on-site technical staff.

This document describes the electrical and wiring considerations when interfacing the GWT154 module with a GTECH online lottery terminal and a peripheral.

Peripheral devices include (but are not limited to) the following:

- Ticket Scan
- Accutherm Supreme and Accutherm Ultra printers
- Customer Display Units
- Jackpot Signs.

1.2 Audience

This document is intended to be read by engineers and technical management. A general knowledge of common engineering practices is assumed.

1.3 Applicable Documents

96-1886-00E, GTECH Wireless Peripheral Transceiver, Rev 3.1, June 2, 2010
96-0258-01, Spec Protocol 485 Bus Packet, Rev D
96-0320-01, RS-485 Physical Interface Specification, Rev C, September 2, 2003
33-0154-01E, System Diagram GWT154, Rev 1, June 3, 2011

2.0 KEY FEATURES

- 802.15.4-2006 compliant transceiver operating in the unlicensed Industrial, Scientific, and Medical (ISM) frequency band of 2.400 – 2.4835 GHz.
- Lost Link Prevention – The GWT154 provides a failsafe timeout in the event the GTECH Terminal doesn't receive a response from the peripheral.
- The GTW 15.4 provides security:
    - Uses AES 128 bit authentication and packet encryption
    - Uses EUI-64 (MAC address) filtering to keep rogue devices off the network
    - Uses the GTECH Terminal for initialization and authorization of End Device peripherals. This allows GTECH the ability to integrate the local security measures with field service installations.
    - Uses a peripheral addressable firewall to exclude single or multiple peripherals from accessing the GTECH 485 Bus
- The GWT154 supports the GTECH 485 Packet Protocol over the following data interfaces:
    - GTECH RS-485 (Half duplex 4-wire, DB-9)
        - Two pairs of uni-directional lines.
        - The terminal always transmits on Tx± and receives on Rx±.
        - Female 9-pin DSUB receptacle.
        - Reset-on-Break support in accordance with [3].
    - USB 2.0 Type B Mini
    - Internal 3.3V UART
- The following form factors are supported.
    - Pinned module – For new embedded designs or as an OEM module replacement
        - 1.0" (W) x 1.33" (L) (UART two 1x10 headers)
    - Dongle – For existing or legacy GTECH online terminals or RS-485 peripherals
        - 2.1" (W) x 2.6" (L) (RS-485 DB9F or USB 2.0 Type mini B interface)
- The transceiver will be used only indoors.
- RF power will be software selectable at 10mW (10dBm) or 63mW (18dBm) during operation with a 1dB resolution.
- An internal chip antenna is on the circuit board along with a software switchable RF connector for an optional external antenna connection.
- The transceiver derives its power from the following options.
    - Specific interface ports in the dongle configuration.
        - RS-485: +12V and/or +5V, 300 mA available.
        - USB: +5V BUS supply
    - PCB pins in the OEM replacement module configuration.
    - DC power connector – A wall mount power transformer with integral 6 foot cord.
- Storage Environment
    - Temperature: -40 to +80°C.
    - Rate of change: 20°C per minute
    - Humidity: 10 to 90%, noncondensing.
- Operating Environment
    - Temperature: -40 to +80°C.
    - Rate of change: 10°C per minute
    - Humidity: 10 to 90%, noncondensing.
- Radiated and conducted limits meet FCC part 15 and Industry Canada ICES-003 emission

standards.

- The product complies with all current European Union Directives applicable to CE marking.
- RoHS compliant.

3.0 GWT154 WIRELESS TRANSCEIVER APPLICATION CIRCUITS

The Radio Module is a standalone RF module with an optional external dipole antenna. It is intended to be an RS-485 cable replacement for new GTECH embedded applications or as an OEM replacement module for our suppliers of GTECH equipment.

For existing or legacy GTECH products, the Radio Module should be mounted to the Host Board via the two 1x10 headers. These mated boards are enclosed in a plastic housing and this constitutes the Dongle solution.

3.1 System Components

The GWT154 Wireless Transceiver consists of the following components:

- Radio module (51-1884-01E) – Standalone for new designs or as an OEM replacement module
  - Radio Module Label (14-2027-02E)
  - Optional External Antenna with Cable
- Carrier/Host board (51-1885-01E) – Optional for legacy products
- Plastic enclosure (Dongle) – Optional for legacy products
  - Plastic Parts (16-2104-502E & 16-2105-502E)
  - Dongle Label (14-2027-01E)
- Wall mount Power Supply – Optional for legacy products
  - US: 50-0347-01E
  - UK: 50-0347-02E
  - EU: 50-0347-03E
- Interface cables – Optional for legacy products
  - USB A to USB mini B Cable (32-1743-01E)
  - RS-485 Straight pinned Cable (32-1344-03E)
  - RS-485 Crossed pinned Cable (32-1744-01E)

Note: Optional components are used based on the specific installation requirements.

3.2 Electronics Overview

The electronic design solution for this product consists of two PC boards.

- Radio module. This stand-alone module will be the solution for new embedded designs or for an OEM module replacement. The two 1 x 10 pin headers will be the interface to the radio module for all configurations. The radio module will consist of the Texas Instruments CC2530 SOC, the Texas Instruments CC2591 Front end module, a Johanson 2450AT18A100 chip antenna, and a Hirose U.FL coaxial RF connector.
- A host board will consist of the GTECH RS-485 interface, USB 2.0 interface, DC power jack, and interface connectors to plug the radio module into. The combination of these two boards with the plastic enclosure will provide the solution for the dongle.

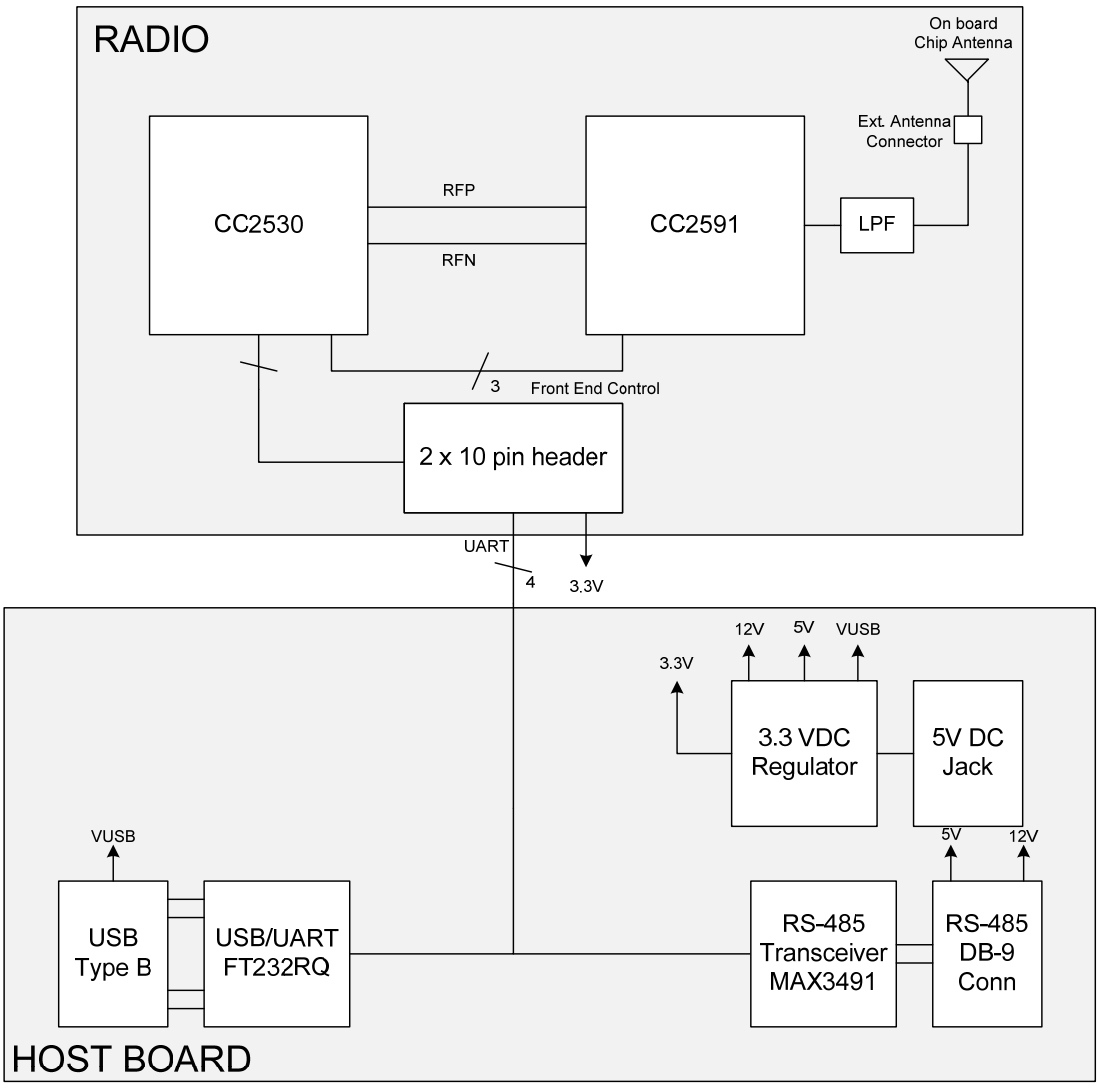


Figure 1 – Block Diagram

3.3 Radio Module Pin Definitions

The communication between the Host board and the Radio module is via UART.

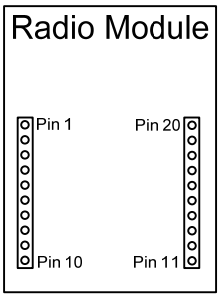


Figure 2 - The interface pin numbering (top side view)

Pin #	NAME	DESCRIPTION
1	VCC	3.3 Vdc
2	UTX	UART data out from module
3	URX	UART data in to module
4	NC	No Connect. Module option to connect to port P1_5
5	RESET_N	Module Reset
6	NC	No connect. Module option to connect to port P2_0
7	P2_2/DC	CC2530 Debug Clock. For programming and debugging of radio module CC2530
8	P2_1/DD	CC2530 Debug Data. For programming and debugging of radio module CC2530
9	DTR_N	Data Terminal Ready communication line
10	GROUND	Ground
11	NC	No Connect
12	CTS_N	Clear to Send Flow Control
13	SLEEP_N	Module status indicator
14	NC/P1_6/UTX1	No Connect. Module option to connect to alternative UART TXD
15	NC/P1_7/URX1	No Connect. Module option to connect to alternative UART RXD
16	RTS_N	Request to Send Flow Control
17	TX_EN	RS-485 driver enable output line. Disables bus driver during hardware reset
18	NC	No Connect. Module option to connect to port P1_4
19	NC	No Connect. Module option to connect to port P1_2
20	STATUS_LED	No Connect. Module option to connect to port P1_0

Table 1 - The interface pin assignments and definitions

3.4 Mechanical Drawings

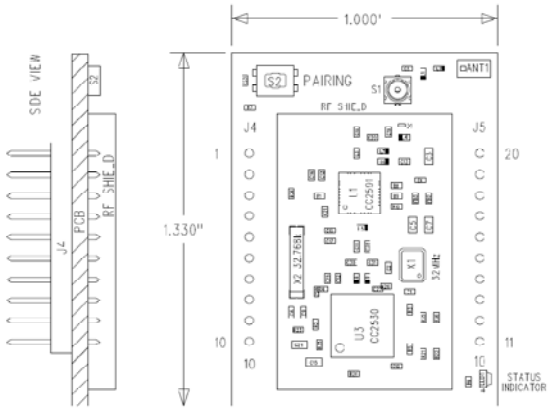


Figure 3 - Radio Module (1.0" x 1.33") (antenna option not shown)

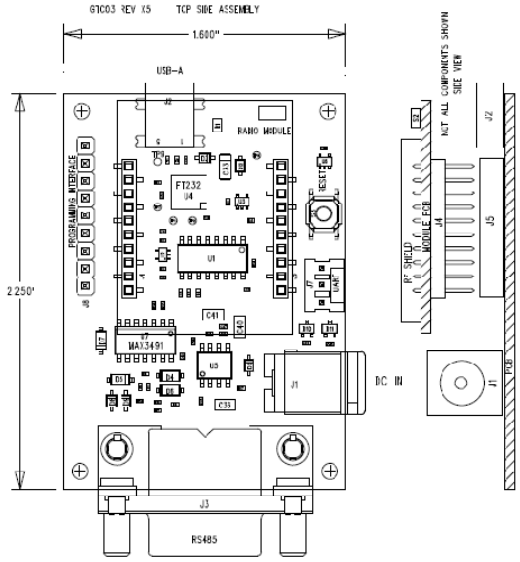


Figure 4 - Host Board with Radio Module (1.6" x 2.25")

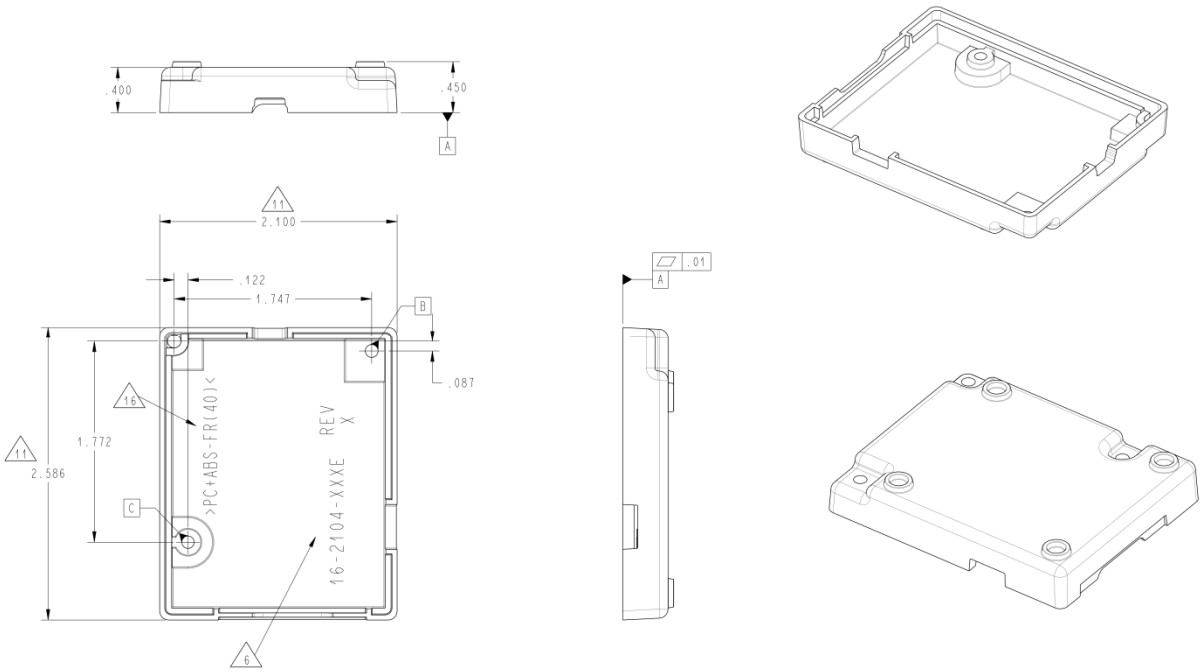


Figure 5 - Plastic Enclosure (2.1" x 2.6")

3.5 Mounting Considerations

The GWT154 Radio Module was designed to mount into a receptacle (socket) and therefore does not require any soldering when mounting it to a board.

3.5.1 New GTECH Embedded Applications or OEM Replacement Modules

For new designs, the footprint design on the host/carrier board will depend on the host/carrier board requirements, desire for compatibility with other GWT154 series modules, and the desired antenna.

(Note: Figure 6 – Example of the GWT154 Radio Module mounting to a Host/Carrier Board does not show the external antenna option.)

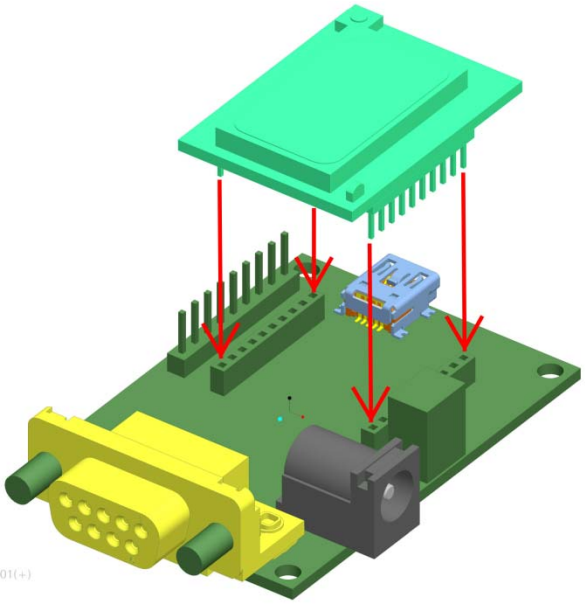


Figure 6 – Example of the GWT154 Radio Module mounting to a Host/Carrier Board

3.5.2 Legacy GTECH Products

For existing or legacy GTECH products the Radio Module mounts to the Host Board and is enclosed in a plastic housing, referred to as the Dongle. This Host board provides RS-485 and USB interface connectors and an optional DC power connection. It uses two 10-pin receptacles to receive the Radio Module.

The receptacles used on the Host Board are manufactured by Samtec, CUI Inc. and TYCO. Several other manufacturers provide comparable mounting solutions; however, GTECH currently uses the following receptacles:

- Surface mount 10 Pin 2mm Single Row Receptacles
  - Samtec P/N: SMM-110-02-S-S (or equivalent)
- Through hole 2.0mm DC Power Jack
  - CUI Inc. P/N: PJ-102A (or equivalent)
- Surface-mount 5 Position Right Angle Mini B TYPE USB Jack
  - Samtec P/N: MUSBR-05-F-O-B-SM-A
- Through-hole 9 Pin Right Angle Female DSUB Connector
  - TYCO P/N: 5747844-3

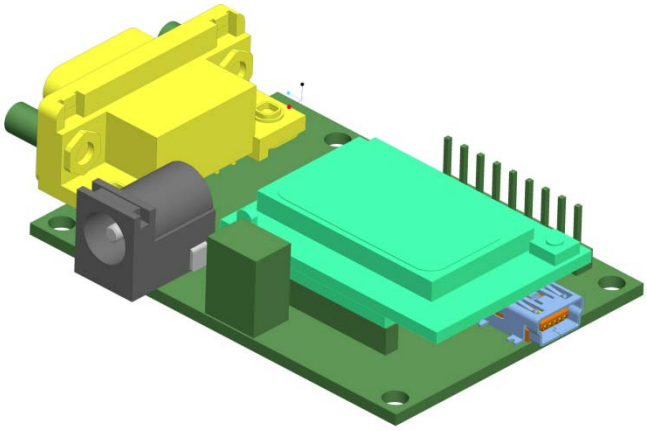


Figure 7 - Radio Module mounted to the Host Board

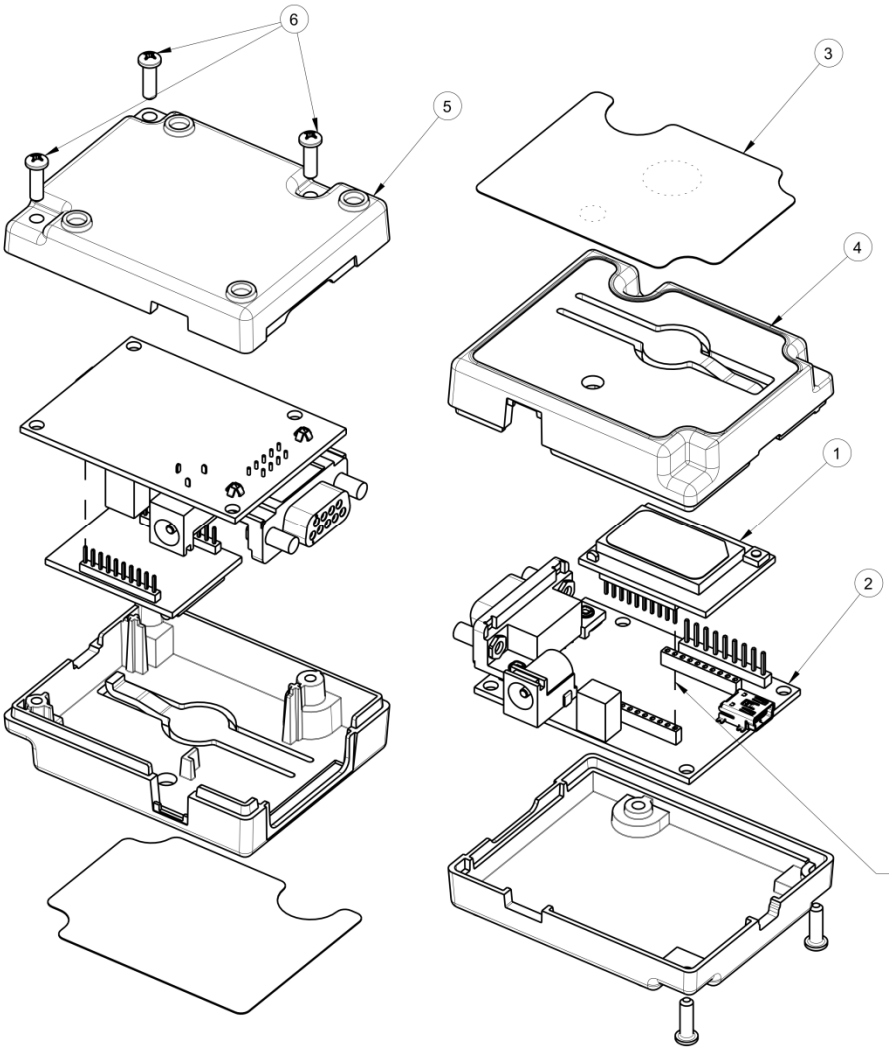


Figure 8 - Dongle Assembly (Top and Bottom view)

3.6 Radio Module Performance Characteristics

Parameter	*Min*	*Typical*	*Max*	*Unit*
Supply Voltage (VCC)	2.7	3.3	3.6	Volts
Supply Current			250	mA
Operating Temperature	-40		80	°C
Temperature rate of change			10	°C/min
Operating Humidity	10		90	%RH
Voltage on any IO pin	-0.3		VCC+0.3	Volts

Table 2 – Operating Conditions

Parameter	*Min*	*Typical*	*Max*	*Unit*
RF Frequency	2400		2480	MHz
RF Channels		16		
Radio Baud Rate		250		kbps
Radio Chip Rate		2		Mcps

Table 3 - General Radio Characteristics

Parameter	*Min*	*Typical*	*Max*	*Unit*	*Conditions*
Receiver Sensitivity	-99	-95	-85	dBm	1% PER, 802.15.4-2006
Receiver Maximum Input	-20	10		dBm	1% PER, 802.15.4-2006
Receiver Current		27	30	mA	
Adjacent Channel Rejection (±5 MHz)	0	35		dB	Wanted signal 2440 MHz at -82 dBm, 802.15.4 modulated interferer, PER = 1%
Alternate Channel Rejection (±10 MHz)	30	49		dB	Wanted signal 2440 MHz at -82 dBm, 802.15.4 modulated interferer, PER = 1%
Channel Rejection (≥ ±20 MHz)	30	56		dB	Wanted signal 2440 MHz at -82 dBm, 802.15.4 modulated interferer, PER = 1%

Table 4 - RF Receive Specifications (At 25°C – 3.3VDC)

Parameter	*Min*	*Typical*	*Max*	*Unit*	*Conditions*
Transmit Output Power	16	18		dBm	TXPOWER = 0xD5
Minimum Transmit Output Power			10	dBm	TXPOWER = TBD
Transmit Current (100mW)		165	200	mA	TXPOWER = 0xF5 (20 dBm transmit output power)
Transmit Current (10mW)		85		mA	TXPOWER=TBD
Transmit Conducted Harmonics			-20	dBc	TXPOWER = 0xF5 (Relative to fundamental)
Error Vector Magnitude (EVM)		13	35	%	TXPOWER = 0xF5 (20 dBm output power)
Carrier Center Frequency	-40		40	ppm	-40°C to +80°C

Table 5 - RF Transmit Specifications (At 25°C – 3.3VDC unless noted)

Parameter	*Limit*	*Conditions*
Minimum Operating Bandwidth	>500kHz	
Peak Output Power	<1W	
Antenna Gain Derating Limit	<6 dBi	
Spurious Emissions (standard)	20 dBc	100kHz measurement bandwidth – up to 10th harmonic
Spurious Emissions (15.205 restricted bands)	15.209 general emissions	Detector type and bandwidth specified Part 15.35 – up to 10th harmonic
Power Spectral Density	8dBm/3kHz	Conducted to antenna
Radio Frequency Exposure Classification	Mobile device	
Antenna Requirement	Fixed antenna or non-standard connector	

Table 6 - Primary EMC Certification Requirements FCC Part 15 – Modular Certification

Parameter	*Conditions*
Storage Temperature	-40°C to +80°C
Storage Temperature rate of change	20°C/minute maximum
Storage Humidity	10% to 90% RH, non-condensing

Table 7 - Environmental Requirements

3.7 Host Board Electrical Characteristics

Parameter	*Min*	*Typical*	*Max*	*Unit*
Input Voltage	4		16	Volts
Output Current			800	mA
Output Voltage	3	3.3	3.6	Volts

Table 8 - Power Supply

Parameter	*Min*	*Typical*	*Max*	*Unit*
Serial Baud Rate	2.4	19.2	230.4	kbps
Input Supply Power	5		12	Volts
Input Supply Current	300			mA

Table 9 - RS-485 Serial Bus

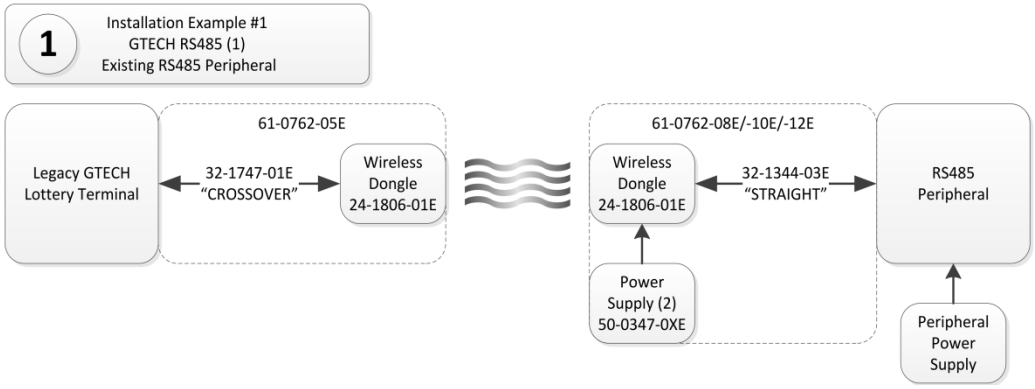
Parameter	*Min*	*Typical*	*Max*	*Unit*
Serial Baud Rate	2.4	19.2	230.4	kbps
Input Supply Power	5		12	Volts
Input Supply Current	300			mA

Table 10 - USB Interface – Fully compliant with USB 2.0 specification

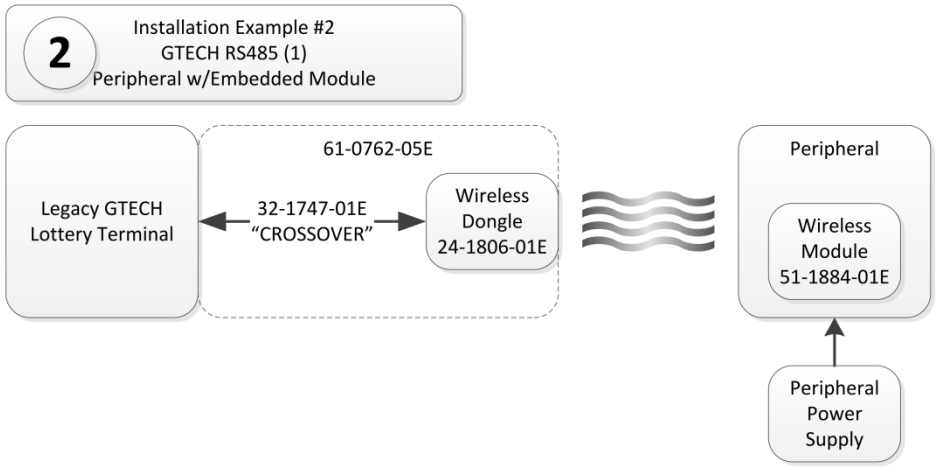
3.8 GWT154 Recommended Configurations

The following drawings identify typical GTECH installation configurations.

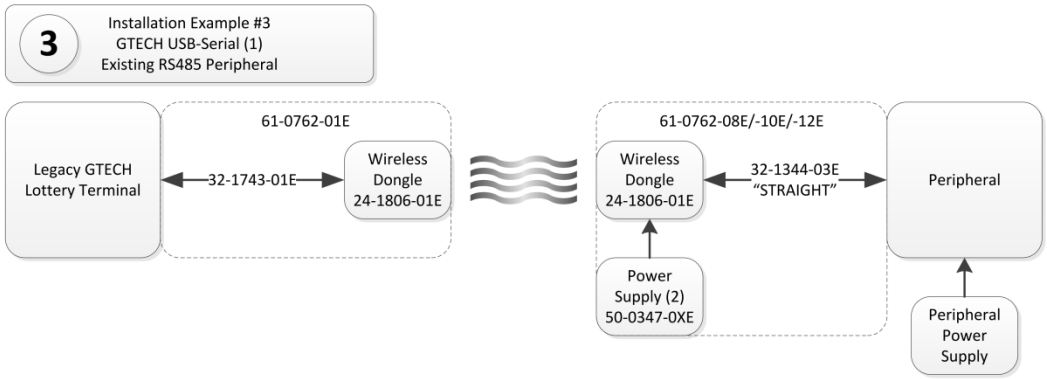
1. Installation of an existing RS485 peripheral into a legacy terminal.



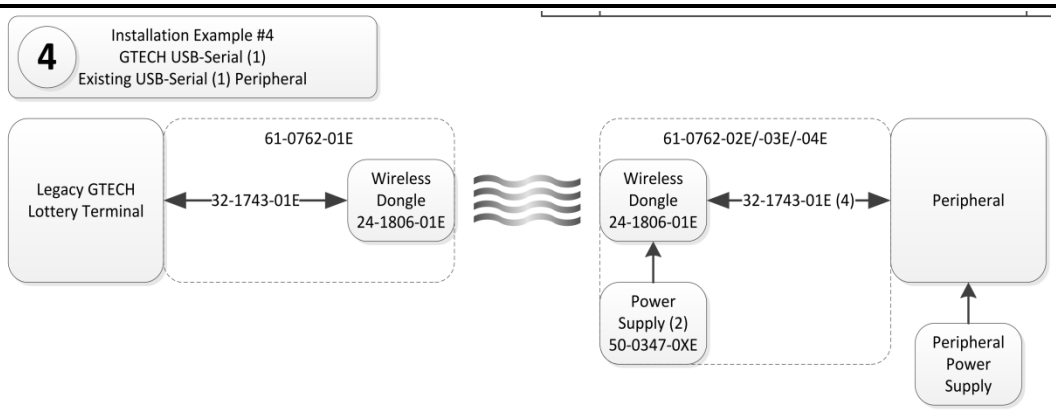
2. Installation of a new RS485 peripheral with the GWT154 embedded radio module (or modified RS485 peripheral with the GWT154 OEM module replacement).



3. Installation of an existing USB Serial peripheral running GTECH 485 Packet Protocol into a legacy terminal.



4. Installation of a new USB Serial peripheral running GTECH 485 Packet Protocol with the GWT154 embedded radio module (or modified peripheral with the GWT154 OEM module replacement).



3.9 RF Module Operation

- Network is non-beacon enabled 802.15.4 Medium Access Control (MAC).
- Security is CCM* with 128-bit encryption keys.
- Random network encryption key assigned during initial commissioning.
- Peripheral End Devices are at minimum RFD's with radio always-on.
- Data transfers are Direct mode (Indirect not supported).
- PAN ID assigned network Coordinator short address.

With the exception of a smaller maximum fragment size and longer/variable ACK latency, GTECH's User Data payloads will pass through the wireless link transparently, with virtually the same GTECH485 protocol presented at both ends.

The PAN Coordinator radio will be attached the GTECH Terminal Host CPU, which is responsible for initializing and managing the wireless network. Thus, the Terminal can control the RF channel and other infrastructure parameters, in addition to commissioning peripherals and controlling security. Only one radio may be connected to any single Terminal serial port. In a system where a single Terminal Host CPU is to control multiple Coordinator radios, a dedicated Host serial interface port must be allocated to each Coordinator radio.

By operating the serial host interface at a higher data rate than the GTECH485's original 19.2Kb, the latency introduced by packet buffering within the radio modules can be minimized. The radio module host serial interface will operate at data rates up to 230K BAUD.

Due to the packet nature of the network, the typical data flow will proceed as follows: The Host CPU sends a GTECH485 packet to the Coordinator radio via the local wired 485 link. The wired serial stream is buffered by the Coordinator radio until the entire packet is received. The radio then encrypts the buffered payload using the network key (randomly generated during wireless network commissioning). The Coordinator radio then sends the secure packet to the Peripheral connected to the currently selected End Device radio. The Peripheral's radio receives the packet, authorizes it, decrypts its encapsulated payload and sends the entire payload contents to the Peripheral's Host CPU over the local 485 wired bus. The End Device radio acts as a local Host CPU proxy to its GTECH485 bus, sending the packet and receiving one of the ACK responses (ACK, NAK, CAN) from a Peripheral on the bus. The End Device radio encrypts and sends this ACK back to the Coordinator radio as a secure packet. The Coordinator receives and decrypts this ACK and, in the role of proxy for the Peripheral,

transmits the ACK back to the Coordinator's Host CPU.

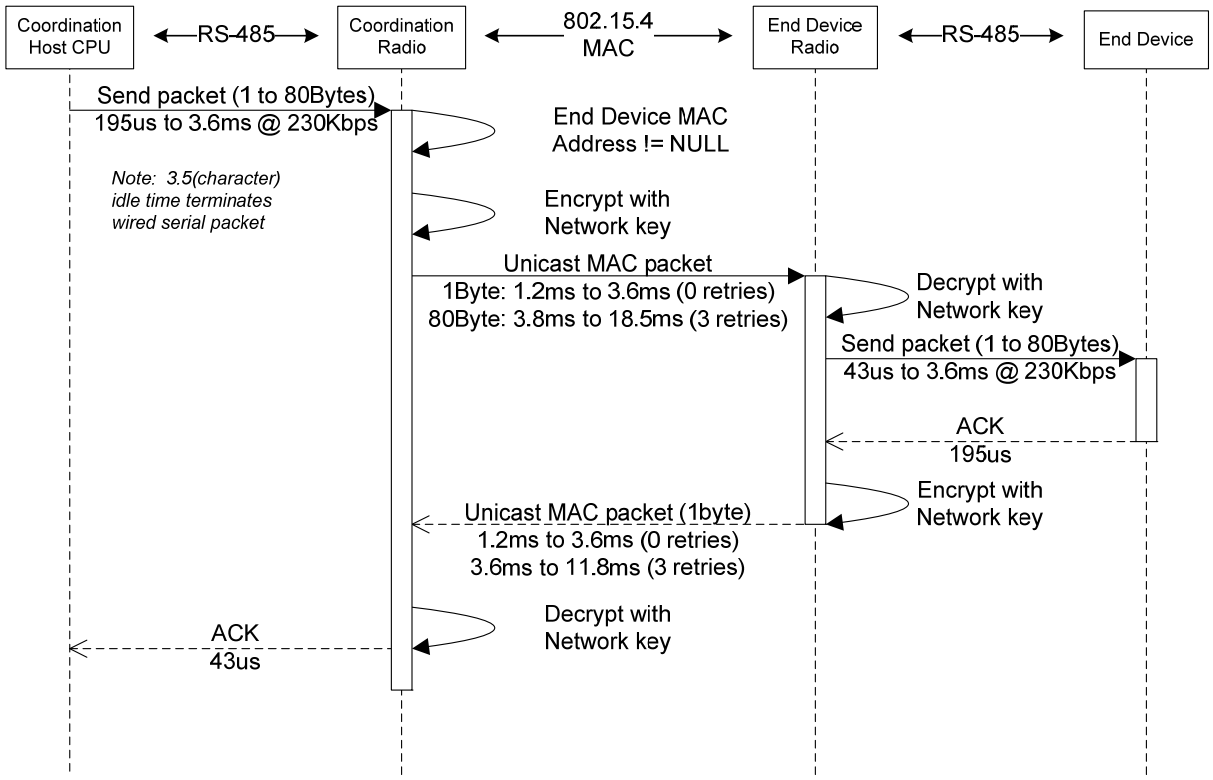


Figure 9 - Typical Data Flow

3.9.1 Break Processing

Legacy GTECH Peripherals recognize a UART Break condition on the GTECH485 bus as a hardware reset. The Coordinator radio hardware does not include dedicated UART Break detect hardware, but the Coordinator radio firmware will monitor the GTECH485 bus for a UART Break condition. In addition, the Host CPU may issue a Break command packet to the Coordinator. In either event, the Coordinator will broadcast a Break command packet to all the currently Associated End Devices in its PAN. The End Device radios will software self-reset which, by virtue of the radio's power-on initialization sequence, will assert a Break on its wired 485 bus.

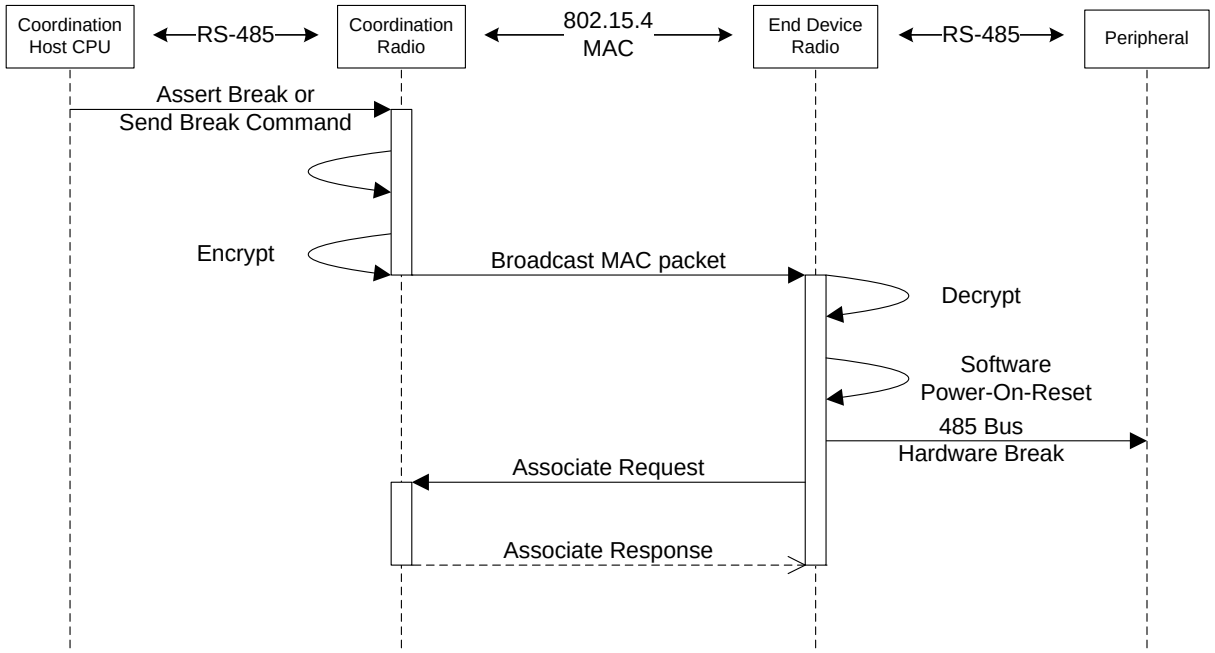


Figure 10 - Break Emulation Sequence

3.9.2 Network Startup

The Coordinator will not automatically create the network; it is commanded by the Host CPU to do so. The Host CPU configures the radio with the required network parameters such as Channel and PAN before initiating network startup.

3.9.3 End Device Association

Devices previously joined to a PAN automatically attempt to associate with their joined network as soon as they are powered up. The TIMAC will issue an 802.15.4 Beacon Request on every channel enabled and wait to see if it receives a response from its PAN Coordinator. If an association attempts fail on all channels, there is a random 10-15 second wait time before the next attempt is made.

3.9.4 802.15.4 MAC Acknowledge Transaction

At a low level, each unicast 802.15.4 data transmission is actually a transaction with acknowledgement. This low-level acknowledgement and retry mechanism serves to increase the reliability of the wireless link enormously. This functionality is hidden from the application layer and the user.

The GTECH485 protocol ACK is actually a separate transaction. At the low level it looks exactly the same as any other data transaction.

3.9.5 Transmit Power Level

The TIMAC Application Programming Interface allow setting of the radio's with a 1dB resolution

between -25dBm and +19dBm. This range is only available on radio modules with the TI CC2591 Power-Amplifier/LNA IC, -25dBm to +11dBm with the CC2590 PA/LAN and the CC2530 by itself is -25dBm to 0dBm.

3.10 Setting Compliance Limits When Using Host Software

The GTECH485 Test Tool Programming Interface allow setting of the radio's transmit output power level with a 1dB resolution between -25dBm and +19dBm. This range is only available on radio modules with the Power-Amplifier/LNA IC and by itself is limited to -25dBm to 0dBm. Refer to **Error! Reference source not found.** for a list of settable transmit output power levels.

Refer to **Table 11 - Compliance Limits** for setting up the proper compliance limits.

RF Channel	Max Host RF Power Value (dBm)		TX_PWR Register Value		RF Output Power (mW)	
	US	EU	US	EU	US	EU
11	18	11	0xC5	0x75	63.1	12.6
12	18	11	0xC5	0x75	63.1	12.6
13	18	11	0xC5	0x75	63.1	12.6
14	18	11	0xC5	0x75	63.1	12.6
15	18	11	0xC5	0x75	63.1	12.6
16	18	11	0xC5	0x75	63.1	12.6
17	18	11	0xC5	0x75	63.1	12.6
18	18	11	0xC5	0x75	63.1	12.6
19	18	11	0xC5	0x75	63.1	12.6
20	18	11	0xC5	0x75	63.1	12.6
21	18	11	0xC5	0x75	63.1	12.6
22	18	11	0xC5	0x75	63.1	12.6
23	18	11	0xC5	0x75	63.1	12.6
24	18	11	0xC5	0x75	63.1	12.6
25	18	11	0xC5	0x75	63.1	12.6
26	13	13	0x85	0x85	20.0	20.0
Note: When using Optional External Dipole Antenna, RF Channel 26 reduces for FCC Compliance:						
26	9	13	0x65	0x85	7.9	20.0

Table 11 - Compliance Limits

4.0 WIRELESS NETWORK INFRASTRUCTURE

4.1 Establishing Network

The PAN Coordinator radio will establish an RF channel, PAN-ID, and network security key with direction from the Host CPU. Either the Host can force it to use a particular channel, or the radio module can do an energy scan of all available channels. The Host CPU can also pre-set the PAN-ID or it can automatically select an unused PAN-ID during network commissioning. The GTECH 802.14.5 wireless network will be implemented as a non-beacon-enabled network.

Often in beacon-less systems, an End Devices may still expect to periodically receive communication from its Coordinator, often referred to as a heartbeat. In the event an End Device does not receive a heartbeat within a reasonable period, the End Device may attempt to recover by scanning all channels and requesting to rejoin its coordinator if found. This feature is not implemented in this design.

4.2 Device Joining

Once a wireless network PAN Coordinator radio has been configured and started, the peripheral radios may be joined to the PAN. End Device joining will be implemented in accordance to the 802.15.4 standard. Upon pairing activation by the End Device radio's User Interface, the MAC will scan all 802.15.4 (mapped) RF channels by broadcasting a Beacon Request and registering any successful responses in a PAN Descriptor list.

Once all enabled channels have been scanned, or the PAN Descriptor list is at maximum, the End Device will sequentially unicast an Associate Request to each of the PAN Coordinators found in the Descriptor list, and wait for a response. If it does not receive a response in a random amount of time (between TBD seconds) it will try the next PAN in the Descriptor list, or if only one PAN, retry. This time delay will keep the network from being overloaded with requests and reduce the chance of RF collisions with other End Device radios.

When the Coordinator receives an Associate Request and successfully decrypts using the default factory key, it saves the End Device's 64-bit EUI address in a list for later processing by the Host CPU. Subsequently, the End Device will issue a Data Request to the Coordinator, if the previous Associate Request was accepted, the Coordinator will reply with an Associate Response. The End Device has temporarily been joined to the PAN and will remain so until it is later permanently joined to the PAN, or it times-out.

A failsafe timeout should be employed in the End Device radios during joining to ensure that if the sequence fails to end in success, the radio discards any joining parameters obtained, and return the radio to its inactive state.

The Host CPU will determine the length of time the Coordinator will accept Association Requests; multiple End Devices may be associated during any given joining session. After terminating the association period, the Host CPU gets the EUI-64 address list from the Coordinator.

Based upon each End Device's EUI-64, the Host CPU will decide whether that device is allowed on the PAN. The Host CPU instructs the Coordinator to enter an End Device into the Access Control List

(ACL) by sending a configuration packet containing the device's EUI-64. The Coordinator will create a unique 16-bit short address for the End Device to use in the Coordinator's PAN and will verify that it has a non-zero network key from a previous join session, generating a random network key as required. A radio configuration packet is unicast to the End Device secured using the factory default key. If an End Device radio receives a Join PAN configuration packet from the Coordinator, it extracts its Short address and the network key. The End Device then sends a response packet back to the Coordinator secured using the new network key. The Short address and network key are saved in non-volatile memory when the MAC-layer Acknowledge is received.

Upon receiving the Join PAN response configuration packet from the End Device, the Coordinator will also store the new End Device's EUI-64 and Short addresses to the ACL in its non-volatile memory.

Once the joining session has successfully completed, the Host CPU should initiate a communication test either automatically, or from a User Interface request.

4.3 Device Security

The "CCM*" security protocol within 802.15.4 will be used to encrypt data and authorize End Devices. The Coordinator generates a random network key at the time of commissioning. The random nature of the key is ensured by dedicated hardware in the CC2530 that samples bits in the I and Q data streams in the radio receiver

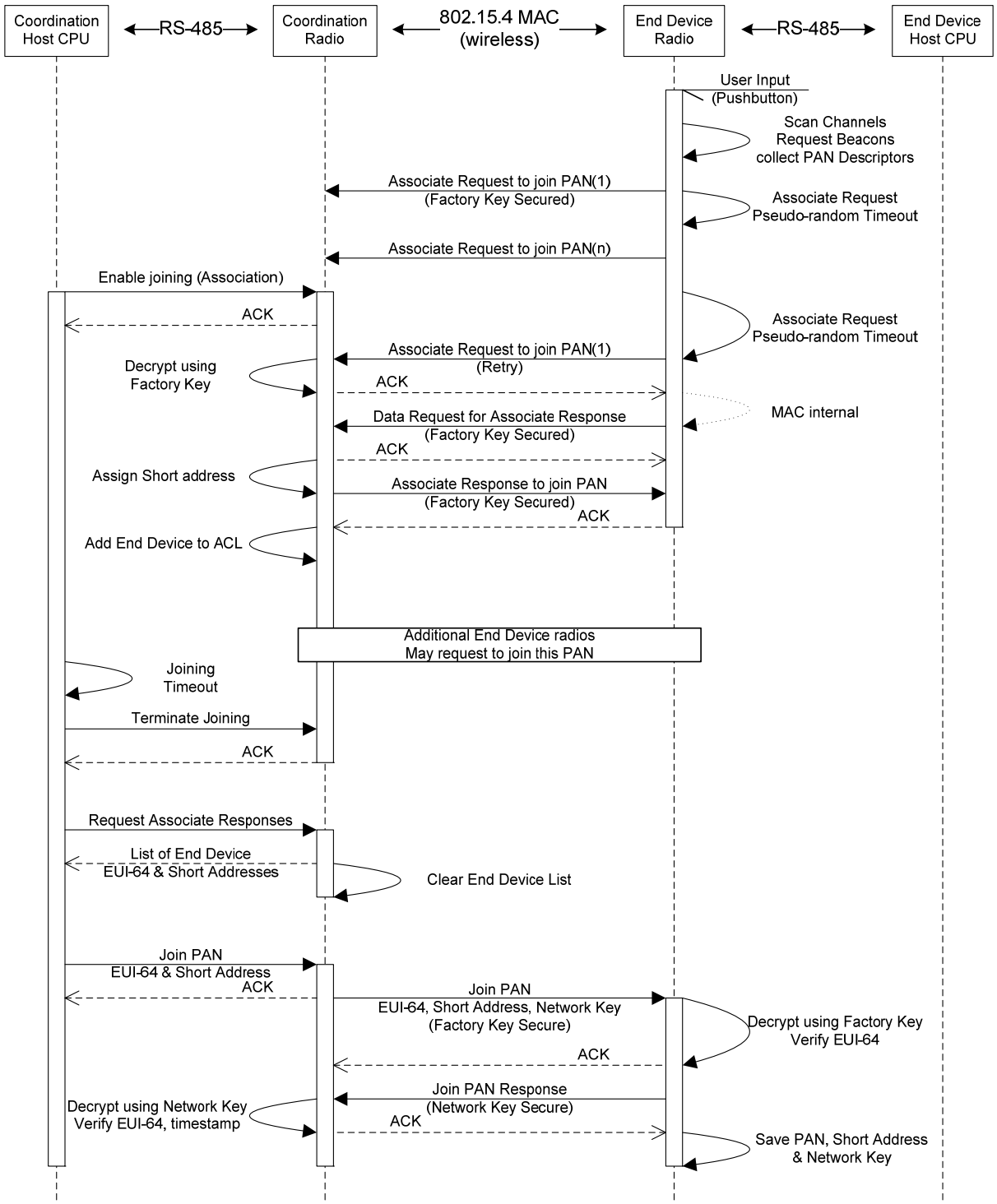


Figure 11 - Pairing Sequence

4.4 Non Volatile Settings

Both the Coordinator and End Device radios must retain the PAN, EUI-64, Short Address, encryption key, etc., after a successful joining sequence. In addition, certain system configuration parameters like BAUD rate, transmit power, etc. may also be saved in non-volatile memory.

The CC2530 may reserve sectors in its on-chip Flash memory to store non-volatile data. Once a CC2530 has been factory programmed with the executable code binary image, factory default key, EUI-64 and PIN, a Debug Lock bit is permanently set in Flash that prevents further access to the Flash memory image via the In-System-Programming (ISP) interface. Only the CHIP_ERASE command may be executed by the ISP after a CC2530 has been Debug Locked, allowing only the full erasure of the embedded Flash memory.

It is important to note that after network commissioning; only the radios know the randomly generated network key. The Host CPU only knows of the End Devices by their Short Address and EUI-64. In addition, no ability to access the network key value stored in the radio's non-volatile memory will be provided by the Host CPU's serial interface protocol. The Host CPU will have no knowledge, nor access to, a radio network's unique encryption key.

5.0 WIRELESS DATA TRANSPORT

5.1 End Device selection

The destination address of the currently selected End Device radio is interpreted by the Coordinator from the GTECH485 SYN address packet. When the Coordinator intercepts the GTECH485 SYN protocol character it is to broadcast that packet to all radios in the PAN, to place any currently connected Peripherals in the OFF-line state. The Coordinator radio will inhibit any further communication with End Device radios by setting its connected radio address to NULL. The End Device radio's Peripheral addressed by the broadcast SYN address packet will reply with the appropriate response packet. The Coordinator radio upon receiving a SYN response packet from an End Device radio will save that radio's address as the new connected End Device radio address. The response packet from the addressed Peripheral is relayed back to the Host CPU.

The End Device radio remains selected until another SYN protocol character is detected. All GTECH485 data packets seen by the Coordinator are relayed to the selected End Device radio and to the Peripherals on its local 485 bus.

In the event the Coordinator is selected by the SYN address packet as the Peripheral, the Coordinator will broadcast the SYN Unlisten address to set all peripherals OFF-line.

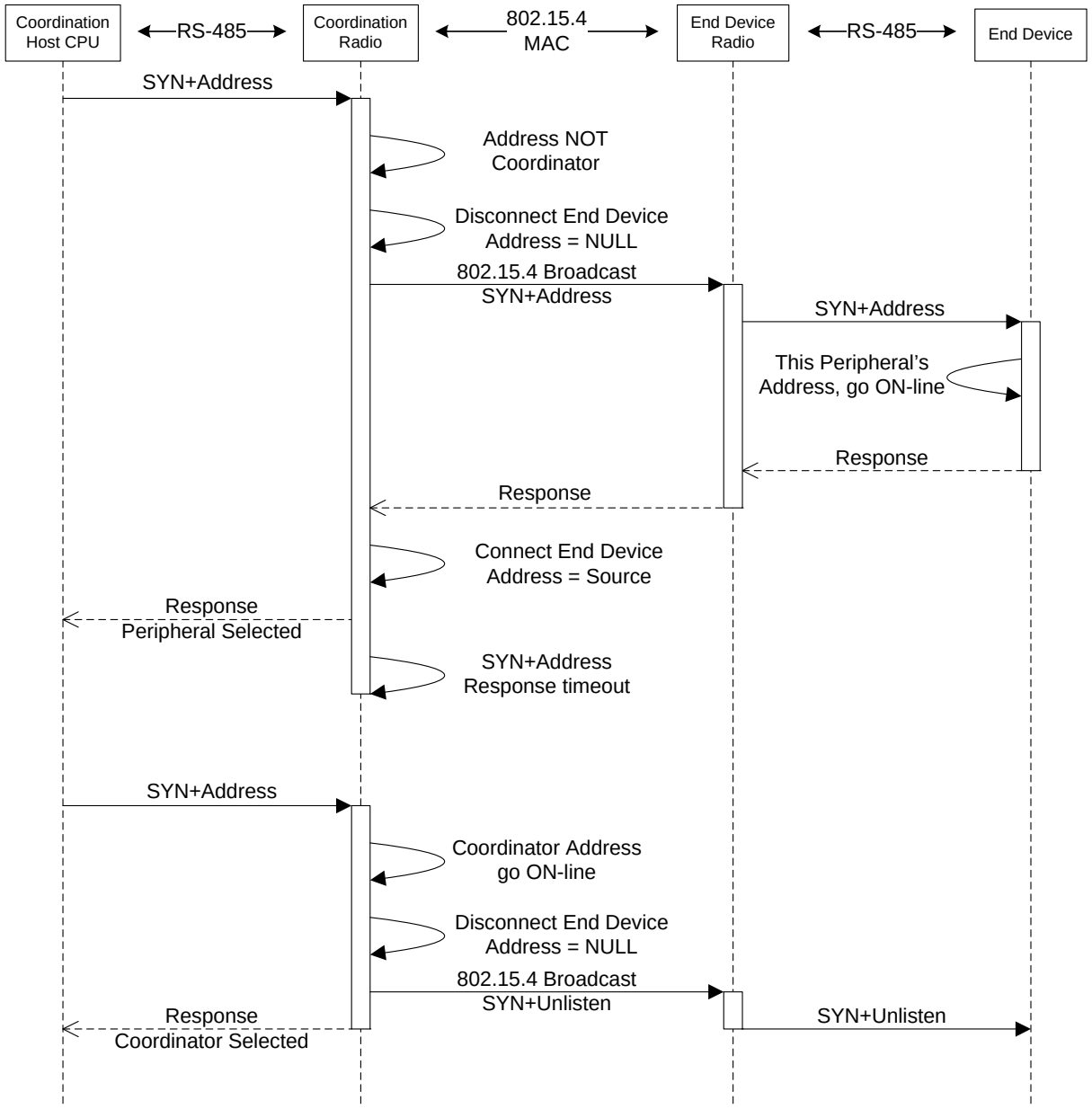


Figure 12 - End Device Address Selection

5.2 Data Security

The "CCM*" security protocol within 802.15.4 will be used to encrypt the data packets. Network encryption key generation is performed at network commissioning time and saved in non-volatile memory. The network's key does not change over the life of the network. The Texas Instruments stack TIMAC version 1.3.0 does not currently support security per the 802.15.4-2006 standard; however TI is promising to add this functionality to the stack in a future release.

The initial release of the firmware will used CMM* encryption with fixed keys. Key management, the

ability to periodically regenerate new network keys, is promised to be added to future releases of TI's TIMAC. This feature will not be supported by the radio firmware at this time.

The entire GTECH485 data packet will be encrypted and encapsulated into the data payload section of the secure 802.15.4 packet. Using CCM* security and AES-128 bit key, the maximum safe data length for a single 802.15.4 packet ~80 bytes. The entire packet up to 80 bytes is encrypted/decrypted using the 802.15.4 standard security functions. Using the 802.15.4 Short Addressing option, additional bytes may become available for user data.

TIMAC and the 802.15.4 standard do not directly support fragmentation of message streams of more than 80-bytes (secure packet). A higher-level network layer is required to fragment/defragment large messages. This may be performed by the Host CPU or the radio's application layer. Fragmentation requires additional overhead with each 802.15.4 packet that will reduce the maximum packet payload length.

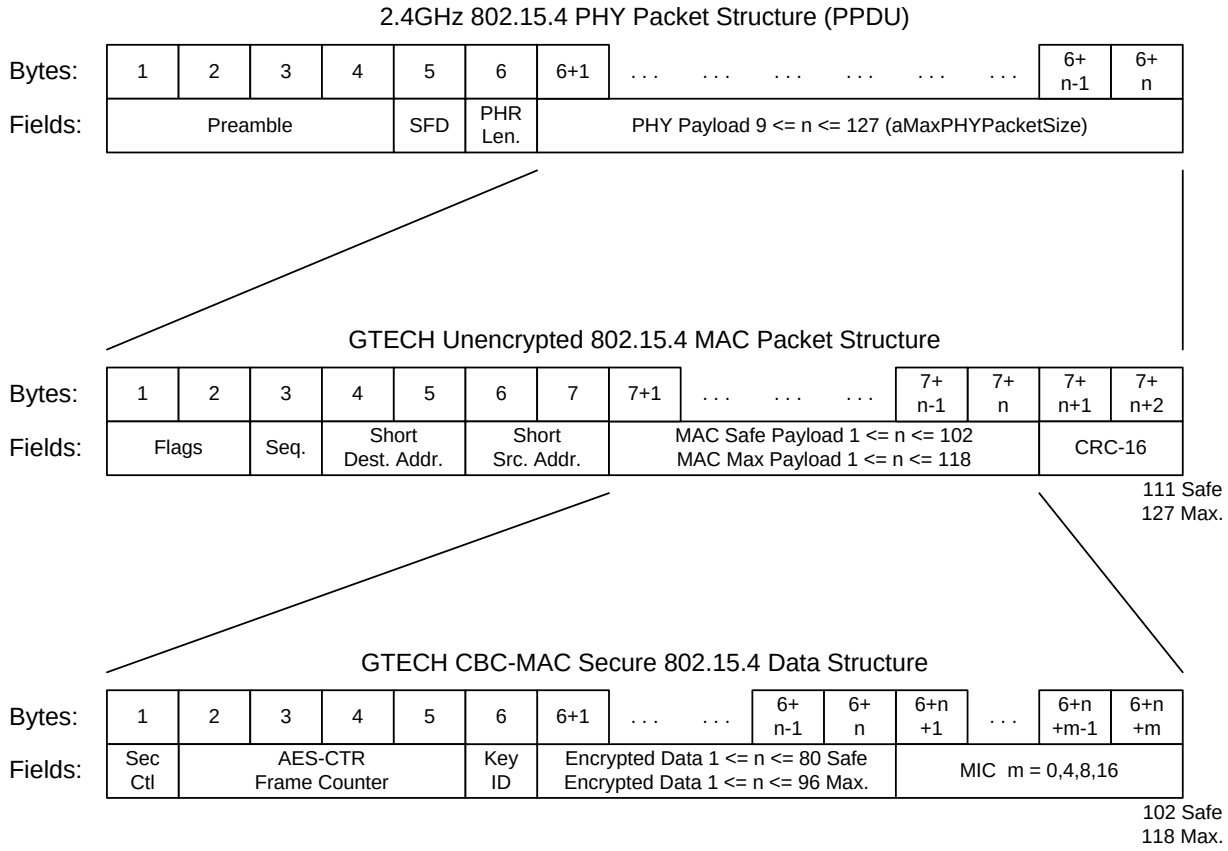


Figure 13 - Packet Encapsulation

5.3 Acknowledgement

The 802.15.4 MAC layer acknowledges MAC packets and attempts retries when an acknowledge fails to be received.

The GTECH485 protocol acknowledges are encrypted and encapsulated into the MAC payload just as data above, using CCM* security and AES-128 bit key.

5.4 Single Unicast MAC Packet

GTECH485 packets less than the maximum 802.15.4 payload capacity are encapsulated in a single MAC packet. The currently selected End Device address in the Access Control List is the packet's destination.

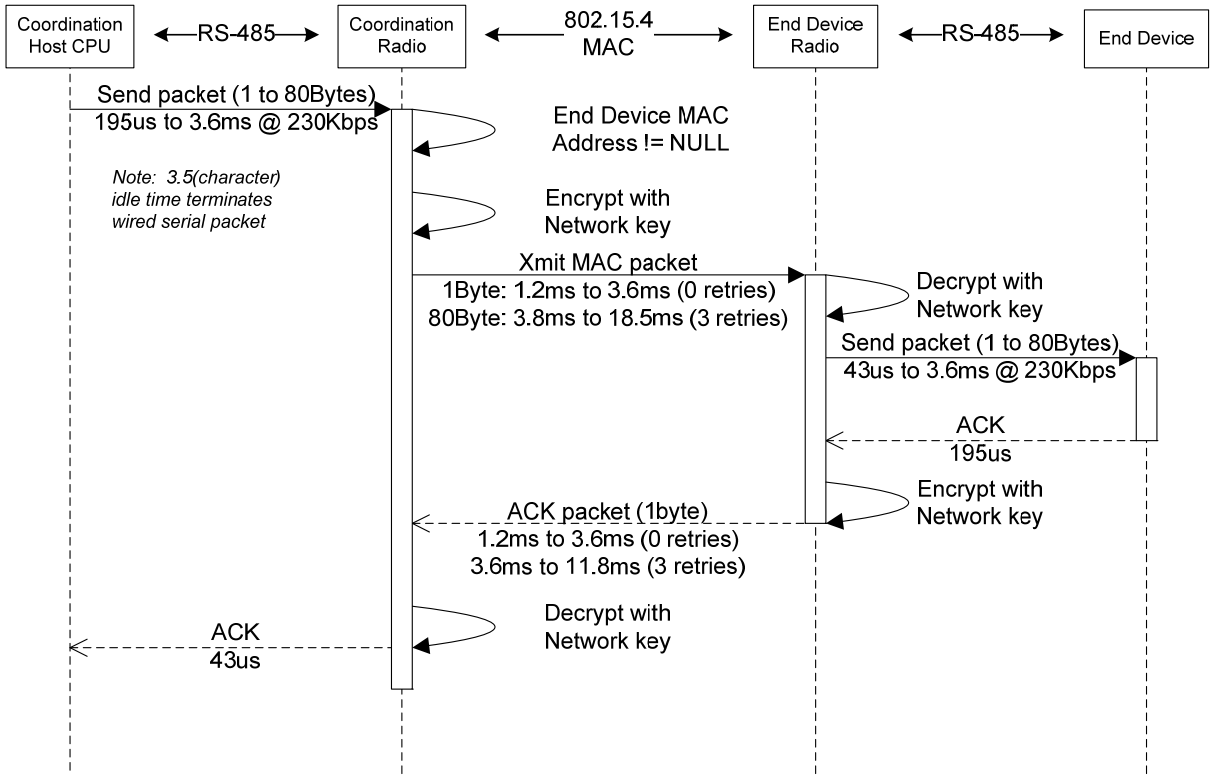


Figure 14 - Single MAC Packet Exchange

5.5 Fragmented Packets

Host CPU packets greater than the maximum 802.15.4 payload capacity, it must be subdivided into smaller fragments. Fragmentation may be performed by either the Host CPU or the Radio module. The following fragmentation is for the proposed Radio module method.

Serial data from the Host CPU to the Coordinator radio is buffered until the entire packet (up to 544-bytes) is received, before beginning the RF transfer. The radio does not begin the RF transfer as soon after 80 (or more) bytes have been received via the serial port as this would add complexity to the sequence if the transfer were to be truncated, or in error. By increasing the Host interface serial data rate to 230.4Kbps results in the serial latency being a relatively small percentage of the over-all packet transmission time.

The End Device radio reassembles fragments into a buffer until the entire packet has been received, before sending it to the peripheral.

Fragments must be sent and received in sequence; a fragment received out of sequence implies a lost

fragment, and the entire packet is discarded. To minimize the radio's overhead, it does not issue a Negative Acknowledge (NAK) to the Host CPU, nor does it perform any clean-up of the un-sent packet fragments. The Host CPU needs to implement a failsafe timeout. After a packet timeout, the Host CPU may send a new packet to the Coordinator radio, overwriting the serial buffer and triggering a new RF transmission.

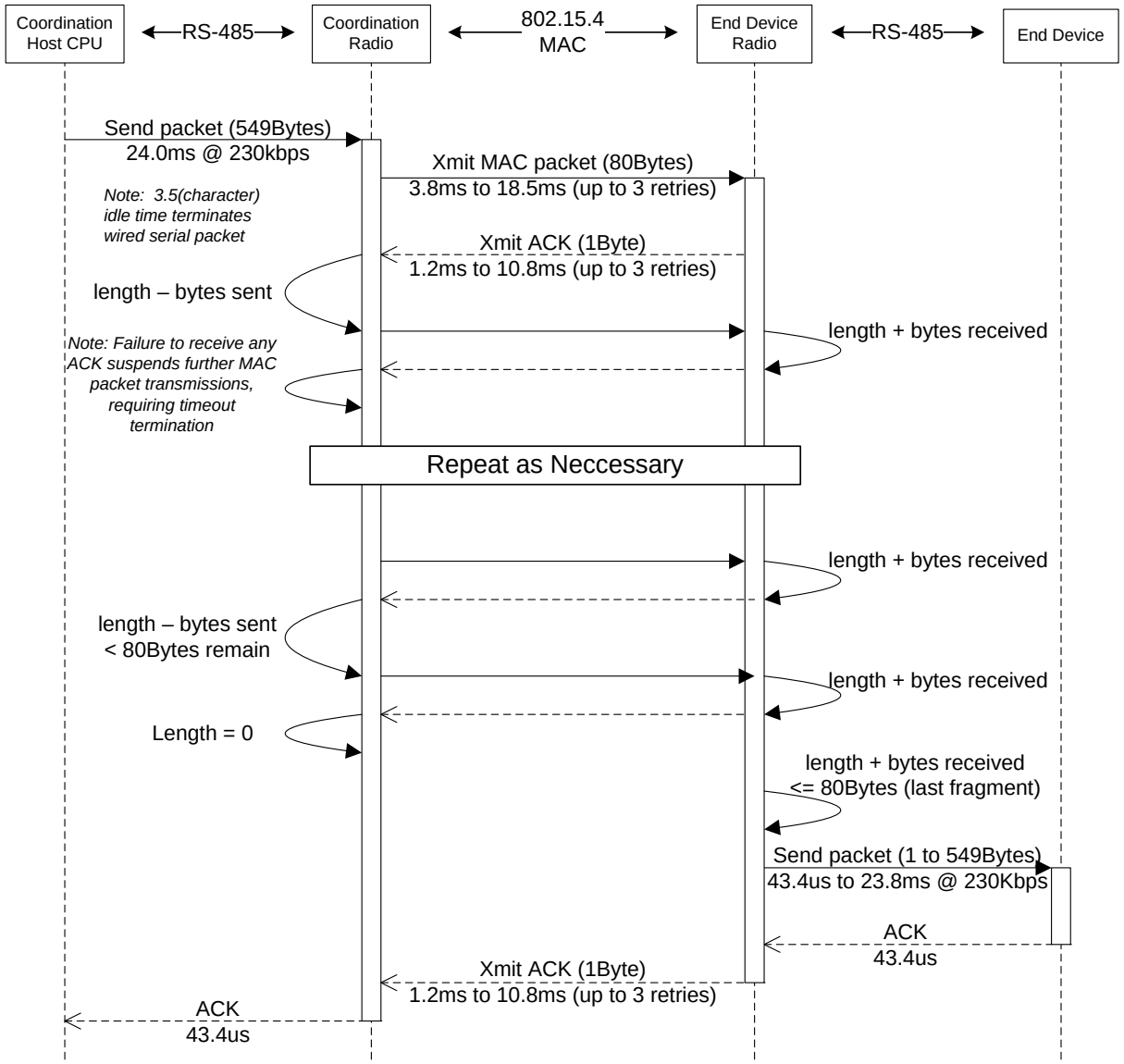


Figure 15 - Data Fragmentation Sequence

5.6 Fragmentation Packet Structure

One byte in the secure 802.15.4 packet payload is allocated for the fragmentation header, leaving a minimum of 80 user data bytes. The Length/Index field in the fragmentation header has two functions depending on the state of the fragmentation flag bit. Host CPU serial packets requiring just one RF packet clear the fragmentation flag and the remaining 7-bit files is the absolute byte-count of the payload up to the maximum safe 802.15.4 encrypted packets payload size.

Fragmented packets have the fragmentation flag set and are sequenced using a range of index values above the maximum byte count of the secure 802.15.4 packet. An indexed fragment is assumed to hold the maximum number of payload bytes. The exception being the end packet in a fragment sequence where the fragmentation flag is set, but the Index/Length field contains a valid byte count for the remaining bytes of the packet.

The maximum safe payload is derived from packets using extended addresses and PANs. Networks using short addressing have the option of reallocating the unused extended address bytes to the payload field. The fragmentation process described here uses the maximum safe payload length for its calculations. If a larger encrypted payload length is employed, the calculations need to be adjusted accordingly.

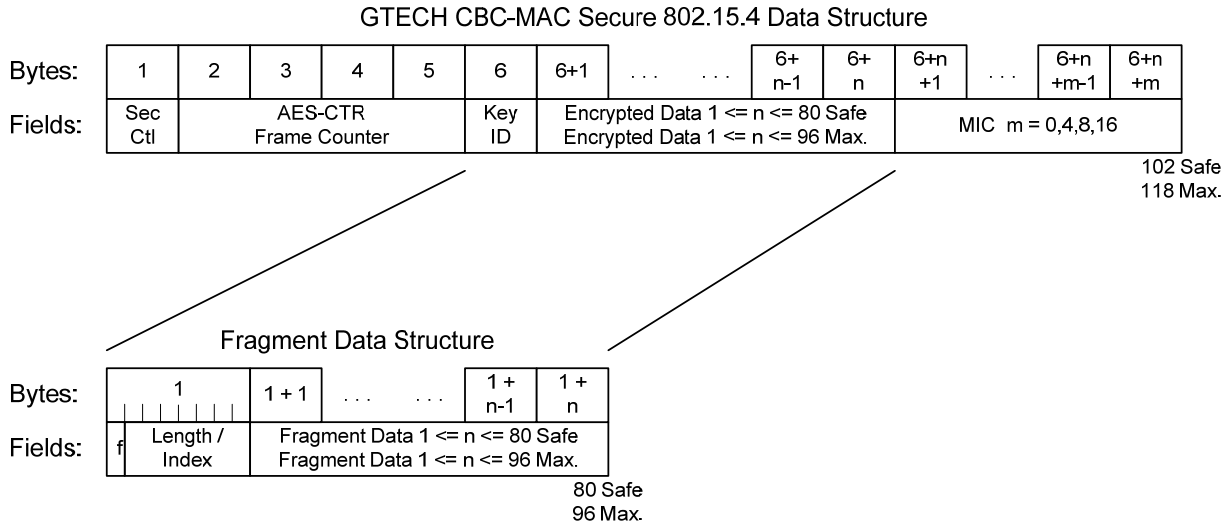


Figure 16 - Data Fragment Structure

Fragment Flag (f)	Length / Index	Fragment Index	Fragment Length (n)
0	Length = 0 Radio Configuration Packet	-	-
0	1 <= Length <= 80	-	n = Length
0	81 <= Length <= 111 reserved	-	n = Length
0	112 <= Length <=127 illegal	-	-
1	112 (0x70)	0	n = 80
1	113 (0x71)	1	n = 80
1	114 (0x72)	2	n = 80
1	115 (0x73)	3	n = 80
.	.	.	
.	.	.	
.	.	.	

1	125 (0x7D)	13	n = 80
1	126 (0x7E)	14	n = 80
1	127 (0x7F)	15	n = 80
1	1 <= Length <= 80	END	n = Length

Table 12 - Fragmentation Codes

6.0 WIRELESS INTER-COMMUNICATION

Configuration parameters for the End Device radios must be exchanged with the Coordinator radio, but not conflict with the encapsulated GTECH485 protocol packets. A reserved protocol character in the range between 0x0F and 0x1B could be used to indicate the start of a dedicated radio command packet. This protocol character would need to be reserved for radio configuration packets in all future versions of the GTECH485 protocol.

A more transparent method is to exploit the zero-length fragment shown in **Table 12 - Fragmentation Codes** above. By definition, all radio configuration packets include a byte length as part of the header. A radio configuration packet's checksum may be calculated and verified without knowing the received 802.14.5 packet's absolute payload length.

7.0 HOST AND PERIPHERAL WIRED INTERFACES

7.1 Wired Inter-communication

7.1.1 Host Protocol Endianness

Both 802.15.4 and the CC2530's 8051 processor core are native little-endian. 16 (2-byte), 32 (4-byte) and above integers communicated serially between the Host and Coordinator radio will be sent Least Significant Byte (LSB) first.

Bytes:	1	2	3	4	5	6	7
Words:	0x01	0x1234		0x0A0B0C0D			
Serial:	0x01	0x34	0x12	0x0D	0x0C	0x0B	0x0A

Structure 1: Host Serial Interface Endian

Bytes are transmitted serially from left to right beginning with byte 1.

7.1.2 GTECH Protocol Control Characters

The following table lists the special character codes used by the GTECH485 protocol to identify message type and length. The Protocol characters in grey are reserved for exclusive use by the GTECH485 protocol.

Type Code	*Name*	*Data Length*	*Description*
0x00	NUL		Unused
0x01	SOH		Unused
0x02	STX		Unused
0x03	ETX		Unused
0x04	EOT	0	End of Packet
0x05	ENQ	variable	Start of Data Packet
0x06	ACK	0	Packet Acknowledge
0x07	BEL		Unused
0x08	BS		Unused
0x09	HT		Unused
0x0A	LF		Unused
0x0B	VT		Unused
0x0C	FF		Unused
0x0D	CR		Unused
0x0E	SO		Unused
0x0F	SI		Reserved: Legacy Exception
0x10	DLE		Reserved
0x11	DC1/XON		Reserved
0x12	DC2		Reserved
0x13	DC3/XOFF		Reserved
0x14	DC4		Reserved

0x15	NAK	0	Packet Negative Acknowledge
0x16	SYN	1	Set Peripheral Address / return Status
0x17	ETB		Reserved
0x18	CAN	0	Abort packet request
0x19	EM		Reserved
0x1A	SUB		Reserved
0x1B	ESC	1	Exception prefix
0x1C	FS		Unused
0x1D	GS		Unused
0x1E	RS		Unused
0x1F	US		Unused

Table 13 - GTECH Packet Type Codes

7.1.3 GTECH Address Packet

The GTECH485 protocol uses query/response method to address individual Peripherals in a multi-drop wired network. The Terminal issues a specific address command to select the active Peripheral, all other Peripherals are to un-assert themselves from the bus. A reserved SYN (0x16) protocol character is used to identify an address command packet.

Peripheral addresses are limited to a range between 0x21 and 0xFF. By default, if a peripheral receives an address packet with an address other than its own, it is to un-assert itself from the bus.

The 802.15.4 radio module will need to parse the Host CPU interface serial stream for the GTECH485 protocol SYN character to properly route packets received from the Host CPU.

Bytes:	1	1
Fields:	0x16 SYN	0x21 <= a <= 0xff Peripheral Address (a)

Structure 2: GTECH Address Packet

A peripheral addressed by an Address Packet is to reply with a response. The first byte is the repeated address value. The second byte is a bit-mapped status byte. The radio module is required to send a Response Packet when it is the addressed peripheral. At this time the Status will always be 0x00.

Note: Because the GTECH485 bus is a 4-wire bus, the radio does not receive another peripheral's Response Packet.

Bytes:	1	1
Fields:	0x21 <= a <= 0xff Peripheral Address (a)	Address Status

Structure 3: GTECH Address Response Packet

Bits:	7	6	5	4	3	2	1	0
Field:	Fault	Reset	Busy	Req ?	Req 3	Req 2	Req 1	Req 0

Structure 4: GTECH Protocol Address Status

Refer to [2] for bit field assignments in Address Response Status byte.

A special Un-Listen address (0x16) in the restricted range may be issued by the Host CPU to force all peripherals off-line. It is assumed the Un-Listen address does not receive an Address Response from any peripheral.

The radio module should interpret Un-Listen as any address other than its own and forward it to the End Device radios. Packets receive from the Host CPU, after the Un-Listen address has been issued, should be discarded until another valid Peripheral address packet is received from the Host CPU and acknowledged by an End Device.

The End Device radio will be required to act as a Terminal proxy whenever it receives a SYN address packet from the Coordinator. The End Device radio outputs the SYN packet on its local wired 485 bus, and then triggers a response acceptance period timer. Typically, a two-byte packet should be received by the End Device radio's 485 bus with the first byte equaling the prior SYN packet's address value. A successful response message is encapsulated in an RF packet and returned to the Coordinator radio. In the event of a timeout, or invalid response message, no RF response is issued. The Terminal Host CPU is expected to provide its own failsafe timeout.

Bytes:	1	1
Fields:	0x16 SYN	0x16 Un-Listen

Structure 5: GTECH Un-Listen Address Packet

An optional Extended Address (0x1C) is defined by the GTECH485 protocol. This feature will not be supported by the radio firmware at this time.

Bytes:	1	1	1
Fields:	0x16 SYN	0x1C Extend	0x21 <= a <= 0xff Extended Address (a)

Structure 6: GTECH Address Response Packet

7.1.4 GTECH Data Packet

The GTECH485 protocol does not employ a length parameter; detection of the reserved EOT (0x04) byte denotes the end of a data packet. The peripheral may detect the EOT to determine when it has received a complete message from the Host CPU, but will be required to implement a secondary failsafe timeout in the event the termination character is missed or corrupted. An idle period of more than 3.5 characters, since receiving the last character, will be inferred by the radio module to also indicate termination of a Host packet.

The maximum payload length specified for a single GTECH485 Data Packet is 544 characters. This does not include header bytes, but includes any exception character insertions that have taken place.

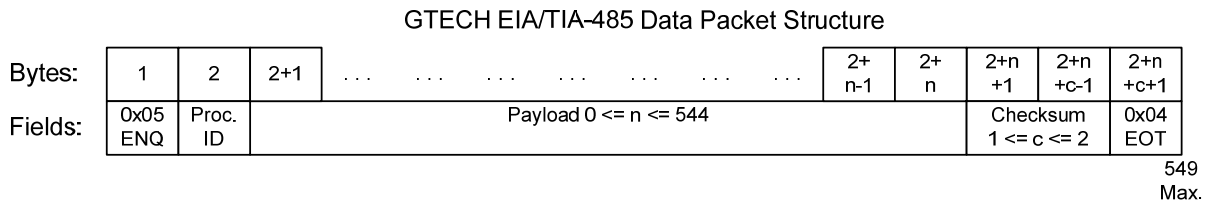


Figure 17 - GTECH Data Packet Structure

7.1.5 Data Exception Handling

Special handling is required for binary data with values between 0x04 to 0x06 and 0x0F to 0x1B because these ranges are reserved for GTECH485 protocol control characters. The control character ESC (0x1B) is used as an escape prefix to signal that the following byte was in the range of the control characters and has been modified (1's complemented) to place it outside the reserved range. All characters following the ESC are expected be in the range of 0x21 to 0xFF. In the event an ESC is followed by a reserved protocol character, special exception handling is required.

The following example illustrates ESC insertion on a data packet with the string "Hello" as its payload. Process-ID, Carriage-Return, Line-Feed and Checksum characters all fall in the reserved range; they are 1's complemented and prefixed with ESC before being transmitted. Other than being complemented as necessary, the Checksum is unchanged from the value calculated on the raw data.

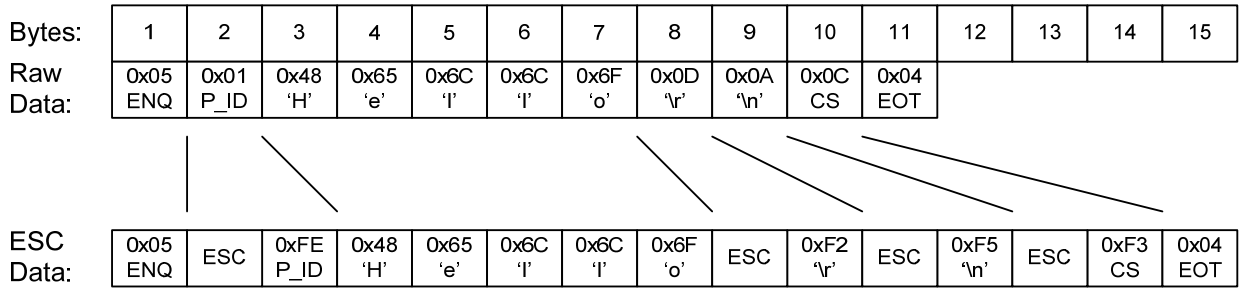


Figure 18 - Escape Character Insertion

Referring to **Error! Reference source not found.**, the UART receive process is reset to the idle state. The protocol characters ACK, NAK, CAN and SI are encapsulated and unicast to the currently connected radio. The protocol character SYN must be intercepted by the Coordinator radio to initiate a new peripheral address selection sequence. The Coordinator radio will clear any current connection's address and broadcast the SYN address packet to all radios.

Anytime the ESC protocol character is received on the 485 bus, the exception state is entered. Generally, the byte following ESC only needs to be inverted to restore it to its original value. It is documented in [2], the GTECH485 Bus Packet Protocol Specification, how a peripheral receiver is to respond in the event a protocol character does follow the ESC. ACK, NAC, CAN and SI are to be processes as if the ESC had not occurred, though the byte immediately following is to be inverted. A SYN address change will be processed normally, but any data received and buffered prior to that is discarded. Start of a new data packet ENQ discards any previously buffered data and starts over. The end of data packet EOT forwards the data packet to the connected radio, or processes locally if this radio is the selected peripheral.

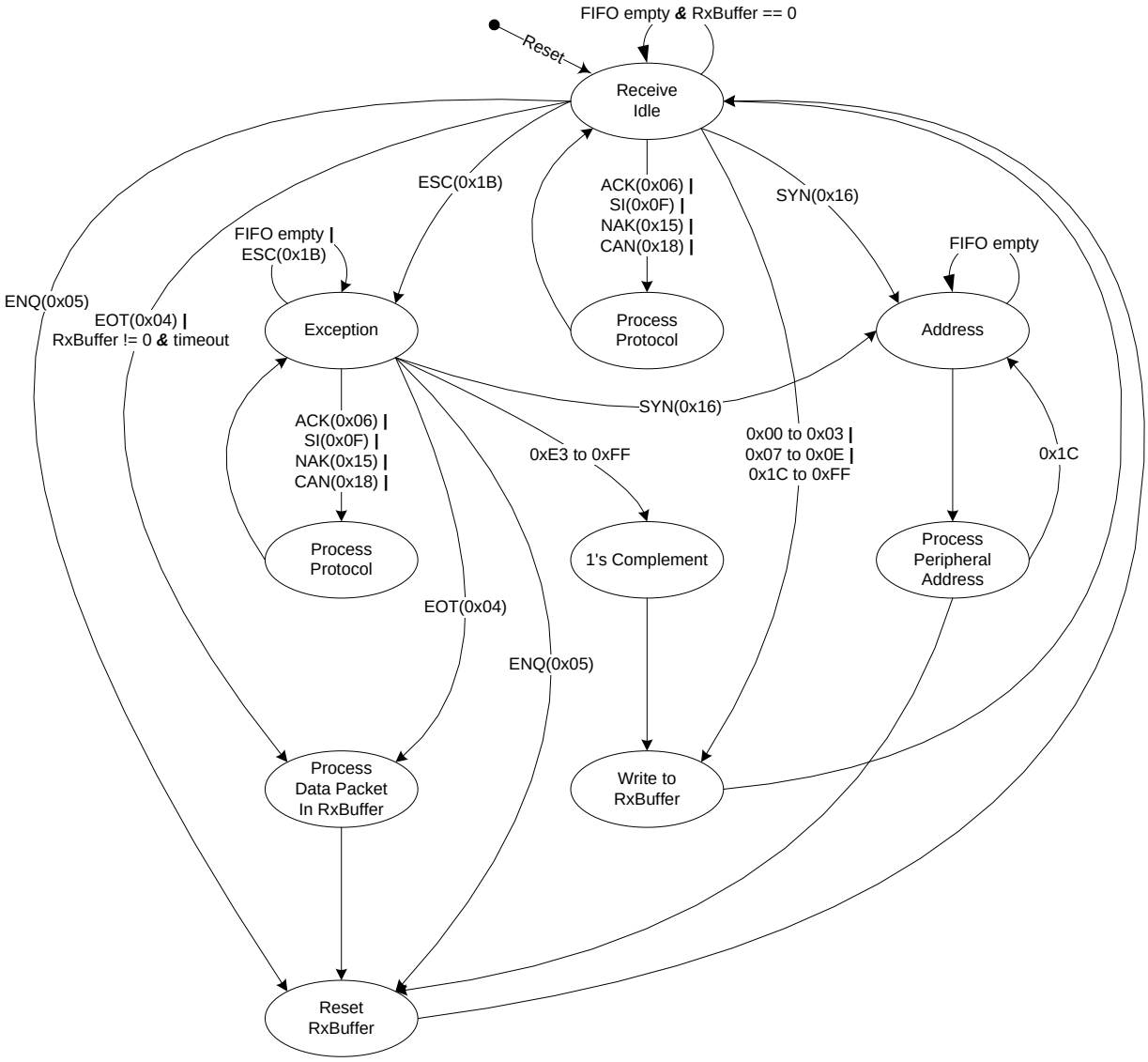


Figure 19 - Escape Sequencing State Machine

7.2 Wired Interface Infrastructure

7.2.1 Radio Set-up and Configuration

The Coordinator radio is controlled by the Host CPU by encapsulating configuration messages in a GTECH485 protocol data packet. Radio configuration packets must implement the GTECH485 exception protocol so not to be misinterpreted by any other legacy GTECH peripherals that share the same wired 485 bus as the Coordinator radio.

7.2.1.1 Persistent Configuration Parameters

Once set, certain configuration parameters must return to their configured values after a power-on-reset or software reset event. Non-volatile memory is reserved on the CC2530's Flash EEPROM to store images of the configuration settings.

Persistent Configuration Parameters	
Command Code	**Description**
Mode	Coordinator / End Device
PAN ID	Short and Extended PAN ID
Address	Short & Extended (EUI-64)
Set Channels - Default	Coordinator only
Set Channels - Mask	Channels End Device scans
Set RF - Tx Power	Default Transmit Power
Set RF - Antenna	Chip / External
Set RF - Failsafe	End Device only
Peripheral Address Firewall	Address filtering mask

Table 14 - Persistent Settings

7.2.1.2 Configuration Packet Structure Format

The radio configuration packet consists of a Command Code and Length, followed by variable number of Parameter bytes. The packet is terminated with a Checksum that the sum of the Command Code, Length and Parameter fields.

Bytes	*1*	*1*	*0-255*	*1*
Field	Command	Length	Parameters	Check sum

Structure 7: Coordinator Command Packet

The Host CPU to Radio interface employs a query/response protocol where the Host CPU must always poll for parameters from the Radio; the Radio never spontaneously transmits a packet over the Host serial interface. The Radio should reply to all Host CPU data packets when it is the addressed peripheral.

By definition, all Host CPU configuration packets requesting Parameters from the Radio are assigned even Command Code values (the Least Significant Bit (LSB) is cleared). Host CPU configuration packets writing Parameters to the Radio all have odd values (the LSB is set).
Host CPU write configuration packets should receive a reply packet from the Radio with the same Command Code, zero Length and the Acknowledge bit set to one(1) if the Parameters were set as instructed, or zero(0) if something failed.

Host CPU's read configuration packets are sent to the Radio with zero Length. The Radio is to reply with the same Command Code, the correct Parameter Length and the Acknowledge bit set to one(1) if the requested parameters are in the Parameter field. If the requested parameters are not available, the Radio should reply with the same Command Code with the Acknowledge bit set to zero(0) and zero Length.

Command packets with failed checksums, unknown Command codes, or of incorrect Length, will be ignored. The radio will not respond to failed command packets.

The Host CPU must implement a fail-safe timeout in the event it does not receive a response from the Radio.

Bits:	7	6	5	4	3	2	1	0
Field:	Ack.	Res.	Code					
			Command					Dir

Structure 8: Coordinator Command Byte

Bit 7: Acknowledge, command packets sent from the Host CPU to the Radio should always set the Acknowledge bit to zero(0).

The Radio is to respond to all configuration writes (odd code values) with either Acknowledge set to one(1) indicating success, or zero(0), if the Parameter(s) failed to be set as requested or the action failed.

The Radio is to reply to all configuration reads (even code values) with either Acknowledge set to one(1) indicating valid Parameters in the Parameter field, or zero(0) indicating the Parameter field is invalid. *Note: a zero(0) Acknowledge may be normal for a Parameter request like Join Request.*

***Bit 6*:** Reserved, should be set to zero(0).

***Bits 5 to 1*:** Radio configuration commands, see **Error! Reference source not found.** below.

Bit 0: Direction, when zero(0) the command packet is requesting Parameters from the Radio be sent to the Host CPU. When one(1) the command packet is writing Parameters from the Host CPU to the Radio.

Code	Name	Length	Parameters	Description
0x00	Status	18	Status	Gets current radio configuration and status parameters
0x01	Mode	1	Mode	Initializes and configures the radio's operating modes
0x02	Get Channels	5	Bit mask	Retrieve the current 802.15.4 Channel Mask.
0x03	Set Channels	5	Bit mask	Set the 802.15.4 Channel mask and default Channel.
0x04	Get PAN-ID	2	ID	Get Coordinator's PAN ID
0x05	Set PAN-ID	2	ID	Set Coordinator's PAN ID
0x06	Get Energy Scan	16	RSSI per Channel	Radio's reply to energy scan of all Channels of the 2.4GHz 802.15.4 band
0x07	Set Energy Scan	0	0	Start energy scan on all 802.15.4 Channels.
0x08	Get PAN Scan	Variable	PAN Coordinators	List of PAN Descriptors retrieved from Active scan.

Code	Name	Length	Parameters	Description
0x09	Set PAN Scan	0	0	Start Active scan for PAN Coordinators
0x0A	Get Device List	Variable	Address List	Gets Associated End Devices list EUI-64 and Short Address.
0x0B	Join PAN	10/26	Address Network key	Short & EUI-64 address of End Device to join to PAN (RF packet includes network key).
0x0C	Get ACL	Variable	Access Control List	Get list of End Devices joined to this PAN Coordinator radio.
0x0D	Delete ACL	10	Address	Removes a single End Device from the Access Control List
0x0F	Set End Device	1/2/8	Address	Select End Device radio using either SYN(1), Short Address(2) or EUI-64(8)
0x11	Set BAUD	2	BAUD	Sets the EIA485 BAUD rate for the currently selected End Device
0x12	Get RF Config.	3	Tx power(dBm) Antenna Sel.	Gets the transmit power setting & antenna for the currently selected End Device
0x13	Set RF Config.	3	Tx power(dBm) Antenna Sel.	Sets the transmit power & antenna for the currently selected End Device
0x14	Get Periph Addr Mask	32	Bit-mapped address mask	Gets the current Peripheral address filtering mask contents
0x15	Set Periph Addr Mask	32	Bit-mapped address mask	Sets the Peripheral address filtering mask
0x16				Reserved
0x17				Reserved
0x18	Get Ping Response	10	Addresses	Reply with the address of End Device responding to a Ping request.
0x19	Send Ping	2/8	Address	Send Ping to End Device radio using either Short Address(2) or EUI-64(8)
0x1A	Get RF Registers	Variable	CC2530 RF configuration	Reply with current CC2530 radio configuration register settings
0x1B	Set RF Registers	Variable	CC2530 RF configuration	Sets select CC2530 radio configuration registers with compliance test parameters
0x1C	Get LoopBack	Variable	PER	Packet Error Test Results
0x1D	Set Loopback	1	Mode	Selects diagnostic loopback test mode
0x1E	Get Version	Variable	ASCII string	Firmware version in the format: YYYY_MM_DD
0x1F	Reset / Break	1	Target	Force all End Devices to Reset and assert a Break condition on their 485 bus.

Table 15 - Coordinator Radio Command Codes

7.2.2 Radio Configuration Packet Structures

7.2.2.1 Status 0x00 (Radio to Host)

This configuration command causes the radio to respond with its current operating state and network parameters.

Bytes:	*1*	*1*	*1*	*1*	*2*	*2*	*8*	*4*
Field:	0x00 Code	18 Length	State	Channel	PAN-ID	Short Addr	EUI-64	Up Time

Structure 9: Coordinator Status Packet

State: `0x00` Uninitialized.
`0x01` End Device, idle.
`0x02` End Device, attempting to join a PAN
`0x03` End Device, associated with a PAN (not joined).
`0x04` End Device, joined with PAN and active.
`0x05` End Device, attempting to re-join PAN.

`0x20` Coordinator, network idle.
`0x21` Coordinator, network started.
`0x22` Coordinator, network joining, is accepting new End Devices.

`0x23 to 0x7F` Reserved.

`0x80` Test Mode, compliance testing state.

`0x81 to 0xFF` Reserved.

Channel: Current 2.4GHz 802.15.4 network channel assignment.

PAN-ID: Currently assigned network Private Area Network ID.

Short Addr: Short (16-bit) address assigned by PAN during joining.

EUI-64: Local radio's Extended Unique Identifier (MAC address) permanently set at factory.

Up Time: Seconds elapsed since Power-On/Reset event. Rollover occurs in about 136-years.

7.2.2.2 Mode 0x01 (Host to Radio)

This configuration command defines the basic operating modes of the radio and provide low-level network control functions.

Bytes:	*1*	*1*	*1*
Field:	0x01 Code	1 Length	Mode

Structure 10: Coordinator Initialize Packet

Mode:

`0x00` Null. No operation.
`0x01` to 0x0F Reserved.

`0x10` Select un-configured. Neither a Coordinator nor End-Device radio.
`0x11` Selects Coordinator radio mode.
`0x12` Selects End-Device radio mode.

`0x13 to 0x1F` Reserved.

`0x20` Start Network. If Coordinator mode selected, start the PAN.
`0x21` Stop Network. If Coordinator mode, disable the PAN.

`0x22 to 0x2F,` Reserved.

`0x30` Stop Joining. If Coordinator mode, stop responding to any new associate requests. If End-Device, stop requesting to join a PAN.
`0x31` Enable Joining. If Coordinator mode, respond to associate requests from End-Device radios.
`0x32` Request Joining. If End-Device, begin issuing periodic associate requests to known PANs.

`0x33 to 0x3f` Reserved.

`0x40` Save Non-volatile memory. Saves persistent radio configuration parameters to Flash memory.
`0x41` Erase Non-volatile memory. Restores radio configuration parameters in Flash memory to factory default values.

`0x42 to 0x7E` Reserved.

`0x7F` Reset. If Coordinator, broadcasts reset message to radios in PAN.

7.2.2.3 Get Channel Mask (0x02)

Returns the current 802.15.4 / 2.4GHz Channel Mask bit settings.

Bytes:	*1*	*1*	*4*	*1*
Field:	0x02 Code	5 Length	Channel Mask	Default Channel

Structure 11: Channel Mask Status Packet

Channel Mask: 2.4GHz 802.15.4 Channel Mask bit fields.

Bits:	*31*	*30*	*29*	*28*	*27*	*26*	*25*	*24*
Channel:	-	-	-	28	27	26	25	24
Bits:	*23*	*22*	*21*	*20*	*19*	*18*	*17*	*16*
Channel:	23	22	21	20	19	18	17	16
Bits:	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*
Channel:	15	14	13	12	11	-	-	-
Bits:	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
Channel:	-	-	-	-	-	-	-	-

Structure 12: Channel Mask Bit Fields

Default Channel: Coordinator's operating channel or End Device's default.

7.2.2.4 Set Channel Mask (0x03)

The Channel Mask is used by the MAC when performing an initial scan for existing 802.15.4 radios in its immediate vicinity. A Channel bit set to one(1) enables that channel to be scanned. Channel bits set to zero(0) are skipped during the scan.

When powering-up or after a reset, the End Device will always scan the channels in the channel mask for its associated coordinator. The Coordinator, when restarted, will use the Default Channel for its operating channel.

Bytes:	*1*	*1*	*4*	*1*
Field:	0x03 Code	5 Length	Channel Mask	Default Channel

Structure 13: Channel Mask Selection Packet

Channel Mask: 802.15.4 / 2.4GHz Channel Mask bit fields, see **Error! Reference source not found.**.

Default: 0x07FFF800

0	1	2	3
0x00	0xF8	0x7F	0x00

Default Channel: Coordinator's start-up channel.

7.2.2.5 Get PAN-ID (0x04)

GTECH 802.15.4 radios will employ short (16-bit) Personal Area Network IDs. Get PAN-ID return the Coordinator radio's PAN address.

Bytes:	*1*	*1*	*2*
Field:	0x04 Code	2 Length	PAN-ID

Structure 14: Current Personal Area Network ID Packet

PAN-ID: `0xFFFF` Broadcast PAN, used when pairing.

`0xFFFE to 0x0000` Assigned PAN ID for this radio.

7.2.2.6 Set PAN-ID (0x05)

The Coordinator radio will generate a short (16-bit) PAN-ID based on its factory assigned EUI-64 address. The Host CPU may use this configuration command to overwrite the default with another PAN-ID.

Bytes:	*1*	*1*	*2*
Field:	0x05 Code	2 Length	PAN-ID

Structure 15: Assign PAN ID Packet

PAN-ID: `0xFFFF` Reserved for Broadcast PAN, do not use.

`0xFFFE to 0x0000` Host CPU assigned PAN-ID.

Default: `0x0000.`

7.2.2.7 Get Energy Scan (0x06)

Returns a list of Received Signal Strength Indication (RSSI) for all 802.15.4 / 2.4GHz channels found by the radio.

When initially commissioning an 802.15.4 network every effort should be made to identify a clear channel to assign the new network. Energy Scan will enable the radio receiver on each channel in an attempt to detect any interfering signal sources. In the event an interferer is detected, that channel may be disabled for use by this Coordinator by clearing its bit in the Channel Mask.

Returns Length = 0 if radio busy scanning. Length = 1 if Energy Scan failed.

Bytes:	*1*	*1*	*1*	*1*	*1*	…	*1*	*1*	*1*
Field:	0x06 Code	18 Length	CH 11 RSSI	CH 12 RSSI	CH 13 RSSI	…	CH 26 RSSI	CH 27 RSSI	CH 28 RSSI

Structure 16: RSSI Scan Result

Length: `0` Busy scanning.

`1` Energy Scan failed.

`2 to 15` Undefined.

`16 to 18` Channels scanned.

19 to 255 Undefined.

RSSI: 0x80(-128) Minimum RSSI, channel likely unoccupied.

0x80(-127) to 0xFF(-1) Channel's measured RSSI.

7.2.2.8 Set Energy Scan (0x07)

Initiates the Radio's Received Signal Strength Indication (RSSI) energy scan sequence.

Bytes:	*1*	*1*
Field:	0x07 Code	0 Length

Structure 17: Initiate RSSI Scan Packet

No parameters.

7.2.2.9 Get PAN Scan (0x08)

Returns a list of PAN-Descriptor structures for every PAN Coordinator discovered during a scan of all channels.

Energy scan may not detect adjacent 802.15.4 networks that are configured for beacon-less operation. PAN scan broadcasts a beacon request on all enabled channels and generates a list of PAN-Descriptors for every PAN Coordinator that responds. During network commissioning, the Host CPU can use the PAN-Descriptor list to identify a suitable channel for the new PAN.

The format of the PAN-Descriptor structure is a subset of the full TIMAC descriptor.

Returns Acknowledge = zero(0) (NAK) in its Command Byte and Length = 0 if radio busy scanning.

Length = 1 indicates PAN scan completed, but no PAN Coordinators detected.

Bytes:	*1*	*1*	*11*	*11*	*11*	…	*11*
Field:	0x08 Code	0 to n Length	PAN1 Desc.	PAN 2 Desc.	PAN 3 Desc.	…	PAN n Desc.

Structure 18: Network Scan Result list

Length: 0 Busy scanning.
1 PAN scan failed to locate a coordinator.
7n Seven bytes per PAN Descriptor.

Descriptor: PAN Descriptor Structure for each network beacon response.

Bytes:	*2*	*2*	*1*	*1*	*1*	*TBD*
Field:	Address	PAN-ID	Channel	Link Quality	Security Fail	Security Parameters

Structure 19: PAN Descriptior

Address: Short (16-bit) address of beacon Coordinator.

PAN-ID: Short (16-bit) PAN-ID for the received beacon's network.

Channel: Channel number for beacon's network.

Link Quality: 0x00 to 0xFF, relative quality of received beacon.

Security Fail: Boolean flag indicating security processing failed.

Security Parameters: Refer to 802.15.4 MAC API swra192 V1.5, Texas Instruments

7.2.2.10 Reserved (0x09)

Initiates the Radio's PAN-ID scan sequence.

Bytes:	*1*	*1*
Field:	0x09 Code	0 Length

Structure 20: Initiate RSSI Scan Packet

No parameters.

7.2.2.11 Get Device List (0x0A)

Returns a list of EUI-64 and Short address structures for any End Devices that sent an Associate Request while the Coordinator radio.

When the Coordinator is enabled to join new End Device to its network, and it receives Association Requests from one or more devices, the following information is returned to the Host CPU.
If no End Devices have attempted to Associate, the Coordinator radio will return a Length = 0 in its response.

The Coordinator radio will clear the list of End Device Association Requests list after it has sent the response packet back to the Host CPU.

Bytes:	*1*	*1*	*10*	*10*	*10*	…	*10*
Field:	0x0A Code	0 to 10n Length	End Device 1	End Device 2	End Device 3	…	End Device n

Structure 21: Associating Devices Address list

End Device: End Device address structure with EUI-64 and Short addresses.

Bytes:	*8*	*2*
Field:	EUI-64	Short Address

Structure 22: End Device Address Structure

EUI-64: Extended Unique Identifier (MAC Address) for End Device.

Short Address: Coordinator assigned 802.15.4 Short Address.

7.2.2.12 Join PAN (0x0B)

Joins a newly associated End Device to the Coordinator's PAN.

Based on the results of the Device List generated by the Coordinator radio during a joining session, the Host CPU may instruct the Coordinator radio to permanently register the new device in its Access Control List (ACL). In addition, the Coordinator radio sends a secure message to the selected End Device with the Coordinator's randomly generated network key that the device is to use for all future re-associations to this PAN.

Bytes:	*1*	*1*	*2*	*8*	*16*
Field:	0x0B Code	10/28 Length	Short Address	EUI-64	Network Key

Structure 23: End Device Join Response Packet

Short Address: Coordinator assigned Short Address for the End Device as obtained from the Get Device List response packet.

EUI-64: Extended Unique Identifier (MAC Address) for the End Device as obtained from the Get Device List response packet.

Network Key: (Optional) only sent wirelessly from the Coordinator radio to the End Device radio when the device has been joined to the PAN.

7.2.2.13 Get ACL (0x0C)

Returns the entire Access Control List of structures from the Coordinator radio. The ACL is updated during network commissioning and saved in non-volatile memory.

Bytes:	*1*	*1*	*11*	…	*11*
Field:	0x0C Code	0 to 11n Length	ACL 1 Struct.	…	ACL n Struct.

Structure 24: Access Control list

ACL: Access Control Structure. An unused ACL structure will be filled with all ones, or 0xFF bytes, the erased state of the non-volatile memory.

Bytes:	*1*	*2*	*8*
Field:	Key Index	Short Address	EUI-64

Structure 25: End Device Access Control Structure

Key Index: Auxiliary Security Header Key Index value for this ACL entry.
`0x00` No AES encryption key assigned.
`0x01` Factory AES key (requesting to join).
`0x02` Network AES key (joined).

0x03 to 0xFF Unassigned key indices.

Short Address: Short address of End Device registered in this ACL entry.

EUI-64: Extended address of End Device registered in this ACL entry.

7.2.2.14 Delete ACL (0x0D)

Removes a single End Device's Access Control List entry from the Coordinator radio's memory. A deleted Access Control entry has all its fields filled with 0xFF bytes.

Bytes:	*1*	*1*	*2*	*8*
Field:	0x0D Code	10 Length	Short Address	EUI-64

Structure 26: Delete ACL Entry Command Packet (Extended Address)

Short Address: Short address for the Access Control List entry to be removed.

EUI-64: Extended Unique Identifier (MAC address) for the Access Control List entry to be removed.

7.2.2.15 Get End Device (0x0E) (unimplemented)

Returns the EUI-64 and Short address of the currently selected End Device used to tunnel GTECH485 protocol messages between the Terminal and Peripheral on the selected radio.

Bytes:	*1*	*1*	*2*	*8*
Field:	0x0E Code	10 Length	Short Address	EUI-64

Structure 27: Get End Device Address Request Packet

EUI-64: Extended Unique Identifier (MAC address) for End Device.

Short Address: Short Address for selected End Device.

7.2.2.16 Set End Device (0x0F)

Selects the End Device radio connection for tunneling GTECH485 protocol messages. The Type field contains the GTECH485 protocol code identifying the encapsulated message. This configuration command is also overloaded to allowing either Short or Extended addresses also to be encapsulated. Type set to 0(zero) identifies an address overloaded message, Short or Extended address length is determined by the Length field.

Bytes:	*1*	*1*	*1*	*n*
Field:	0x0F Code	1+n Length	Type	GTECH Address

Structure 28: Set End Device Address Request Packet (GTECH Address)

Type: `0x00` Short or EUI-64 address (as determined by Length)
`0x06` GTECH485 ACK
`0x15` GTECH485 NAK
`0x16` GTECH485 SYN
`0x18` GTECH485 CAN

GTECH485 protocol ACK, NAK and CAN messages are tunneled from End Device to Coordinator using the Type field.

GTECH Address: 802.15.4 encapsulated GTECH485 protocol SYN Address string broadcast from the Coordinator to all End Devices in the PAN. Presently only single-byte GTECH SYN addresses are supported though longer Extend address strings may be handled by the command structure in the future. SYN Response messages from End Devices to Coordinator are also identified by the SYN type with the GTECH Address field containing the Address and peripheral Status response bytes.

Bytes:	*1*	*1*	*1*	*8*
Field:	0x0F Code	9 Length	0x00 Type	EUI-64 Address

Structure 29: Set End Device Address Request Packet (Extended Address)

EUI-64 Address: Extended Unique Identifier (MAC address) for End Device.

Bytes:	*1*	*1*	*1*	*2*
Field:	0x0F Code	3 Length	0x00 Type	Short Address

Structure 30: Set End Device Address Request Packet (Short Address)

Short Address: Short Address for End Device to Select.

7.2.2.17 Get BAUD (0x10) (unimplemented)

Returns the BAUD rate setting for the Coordinator, or the most recently selected End Device radio's EIA485 serial bus interface. BAUD and Device fields are unused when Get BAUD configuration is issued, the Coordinator radio response fills them in response.

Bytes:	*1*	*1*	*1*	*1*
Field:	0x10 Code	2 Length	Device	BAUD

Structure 31: Get Current Device BAUD

Device `0x00` Currently selected End Device radio.
`0x01` Coordinator radio.
`0x02 to 0xff` Reserved.

BAUD:	0x00	230,400
	0x01	115,200
	0x02	57,600
	0x03	38,400
	0x04	19,200
	0x05	9,600
	0x06	4,800
	0x07	2,400
	0x08	1,200
	0x09	600
	0x0A	300
	0x0B to 0xFF	Unassigned.
Default:	0x04	

7.2.2.18 Set BAUD (0x11)

Sets the BAUD rate setting for the Coordinator, or most recently selected End Device radio's EIA485 serial bus interface.

Bytes:	*1*	*1*	*1*	*1*
Field:	0x11 Code	2 Length	Device	BAUD

Structure 32: Set Current Device BAUD

Device:	0x00	Currently selected End Device radio.
	0x01	Coordinator radio.
	0x02 to 0xFF	Unused / Reserved.
BAUD:	0x00	230,400
	0x01	115,200
	0x02	76,800
	0x03	38,400
	0x04	19,200
	0x05	9,600
	0x06	4,800
	0x07	2,400
	0x08	1,200
	0x09	600
	0x0A	300
	0x0B to 0xFF	Unassigned.

7.2.2.19 Get RF Configuration (0x12)

Returns the signed 8-bit Transmit power setting and Antenna selection and Lost Coordinator Failsafe time for the Coordinator, or most recently selected End Device's radio. The Device field must be to for the target device; the Transmit Power, Antenna and Failsafe fields are unused when Get RF is issued, the Coordinator fills them in response.

Bytes:	*1*	*1*	*1*	*1*	*1*	*1*

Field:	0x12 Code	4 Length	Device	Transmit Power	Antenna Select	Failsafe Timeout

Structure 33: Get Current Device RF Configuration

Device	`0x00`	Reserved.
	`0x01`	Coordinator radio.
	`0x02 to 0x20`	Unused / Reserved.
	`0x21 to 0xff`	Currently selected End Device radio.
Transmit Power:	`-128 to -1`	Illegal
	`0 to +19`	Output power in dBm
	`+20 to +127`	Illegal
Antenna Select:	`0x00`	Internal
	`0x01`	External
Failsafe Time:	`0`	Lost Coordinator Failsafe inhibited.
	`1 to 99`	Failsafe timeout period in seconds.

7.2.2.20 Set RF Configuration (0x13)

Sets the signed 8-bit Transmit power setting and Antenna select for the Coordinator, or currently selected End Device radio.

Bytes:	*1*	*1*	*1*	*1*	*1*	*1*
Field:	0x13 Code	4 Length	Device	Transmit Power	Antenna Select	Failsafe Time

Structure 34: Set Current Device Transmit Power

Device:	`0x00`	Currently selected End Device radio.
	`0x01`	Coordinator radio.
	`0x02 to 0xFF`	Unused / Reserved.
Transmit Power:	`-128 to -1`	Illegal
	`0 to +19`	Output power in dBm
	`+20 to +127`	Illegal

Transmit Power dBm	Power	CC2530 Register
19	79 mW	0xD5
18	63 mW	0xC5
17	50 mW	0xB5
16	40 mW	0xA5
15	32 mW	0x95
14		0x95
13	20 mW	0x85
12	16 mW	0x75
11		0x75
10	10 mW	0x65
9		0x65
8	6.3 mW	0x55
7		0x55

6		0x55
5	3.2 mW	0x45
4		0x45
3	2.0 mW	0x35
2		0x35
1		0x35
0	1.0 mW	0x25

Table 16 - Transmit Power Settings

Antenna Select: `0x00` Internal
`0x01` External

Failsafe Time: `0` Lost Coordinator Failsafe inhibited.
`1 to 255` Failsafe timeout period in seconds.

7.2.2.21 Get GTECH485 Peripheral Address Mask (0x14)

Returns the current Peripheral address filtering mask.

Bytes:	*1*	*1*	*32*
Field:	0x14 Code	0 Length	Peripheral Address Mask

Structure 35: Get Current Peripheral Address Mask

Peripheral Address mask: See **Error! Reference source not found.** below.

7.2.2.22 Set GTECH485 Peripheral Address Mask (0x15)

Sets the GTECH485 Peripheral address filter mask. The Coordinator radio will forward GTECH485 messages to End Devices with their corresponding mask bit set true(1) in the Peripheral Address Mask. Attempts to select End Devices that are blocked by the filter (bit set to 0) disconnects the Coordinator from any previously selected End Device radios. The mask structure consists of 32 8-bit bytes for a total of 256 GTECH Peripheral addresses that are filtered.

Bytes:	*1*	*1*	*32*
Field:	0x15 Code	32 Length	Peripheral Address Mask

Structure 36: Set Current Peripheral Address Mask

Address Mask: One bit per GTECH485 Peripheral address. Setting a mask bit to 1 allows that Peripheral address to be accessed wirelessly. Setting a mask bit to 0 inhibits over-the-air communication with Peripherals of that address.

Offset	*Bits:*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
0	Address:	0x07	0x06	0x05	0x04	0x03	0x02	0x01	0x00
1	Address:	0x0F	0x0E	0x0D	0x0C	0x0B	0x0A	0x09	0x08
2	Address:	0x17	0x16	0x15	0x14	0x13	0x12	0x11	0x10
3	Address:	0x1F	0x1E	0x1D	0x1C	0x1B	0x1A	0x19	0x18
4	Address:	0x27	0x26	0x25	0x24	0x23	0x22	0x21	0x20

5	Address:	0x2F	0x2E	0x2D	0x2C	0x2B	0x2A	0x29	0x28
6	Address:	0x37	0x36	0x35	0x34	0x33	0x32	0x31	0x30
7	Address:	0x3F	0x3E	0x3D	0x3C	0x3B	0x3A	0x39	0x38
8	Address:	0x47	0x46	0x45	0x44	0x43	0x42	0x41	0x40
9	Address:	0x4F	0x4E	0x4D	0x4C	0x4B	0x4A	0x49	0x48
10	Address:	0x57	0x56	0x55	0x54	0x53	0x52	0x51	0x50
11	Address:	0x5F	0x5E	0x5D	0x5C	0x5B	0x5A	0x59	0x58
12	Address:	0x67	0x66	0x65	0x64	0x63	0x62	0x61	0x60
13	Address:	0x6F	0x6E	0x6D	0x6C	0x6B	0x6A	0x69	0x68
14	Address:	0x77	0x76	0x75	0x74	0x73	0x72	0x71	0x70
15	Address:	0x7F	0x7E	0x7D	0x7C	0x7B	0x7A	0x79	0x78
16	Address:	0x87	0x86	0x85	0x84	0x83	0x82	0x81	0x80
17	Address:	0x8F	0x8E	0x8D	0x8C	0x8B	0x8A	0x89	0x88
18	Address:	0x97	0x96	0x95	0x94	0x93	0x92	0x91	0x90
19	Address:	0x9F	0x9E	0x9D	0x9C	0x9B	0x9A	0x99	0x98
20	Address:	0xA7	0xA6	0xA5	0xA4	0xA3	0xA2	0xA1	0xA0
21	Address:	0xAF	0xAE	0xAD	0xAC	0xAB	0xAA	0xA9	0xA8
22	Address:	0xB7	0xB6	0xB5	0xB4	0xB3	0xB2	0xB1	0xB0
23	Address:	0xBF	0xBE	0xBD	0xBC	0xBB	0xBA	0xB9	0xB8
24	Address:	0xC7	0xC6	0xC5	0xC4	0xC3	0xC2	0xC1	0xC0
25	Address:	0xCF	0xCE	0xCD	0xCC	0xCB	0xCA	0xC9	0xC8
26	Address:	0xD7	0xD6	0xD5	0xD4	0xD3	0xD2	0xD1	0xD0
27	Address:	0xDF	0xDE	0xDD	0xDC	0xDB	0xDA	0xD9	0xD8
28	Address:	0xE7	0xE6	0xE5	0xE4	0xE3	0xE2	0xE1	0xE0
29	Address:	0xEF	0xEE	0xED	0xEC	0xEB	0xEA	0xE9	0xE8
30	Address:	0xF7	0xF6	0xF5	0xF4	0xF3	0xF2	0xF1	0xF0
31	Address:	0xFF	0xFE	0xFD	0xFC	0xFB	0xFA	0xF9	0xF8

Structure 37: GTECH485 Peripheral Address Filter Mask

7.2.2.23 Reserved (0x16)

7.2.2.24 Reserved (0x17)

7.2.2.25 Get Ping (0x18)

Polls the Coordinator radio for any response to a Host CPU Send Ping. Replies with Length = zero(0) if no Ping response has been received.

Bytes:	*1*	*1*	*1*	*1*	*1*

Field:	0x18 Code	15 - 80 Length	Coordinator RSSI	Coordinator LQI	End Device RSSI
Bytes:	*1*	*1*	*2*	*8*	*0 - 65*
Field:	End Device LQI	Transmit Power	Short Address	EUI-64	Test Data

Structure 38: End Device Ping Response Packet

RSSI: Coordinator RSSI is the Receive Signal Strength Indication as received by the pinged End Device radio. The End Device RSSI is the signal strength of the ping response packet received by the Coordinator.

LQI: Link Quality Indication, like RSSI above, is the packet link quality of the packet when received by the End Device and Coordinator.

Transmit Power: End Device's transmit power index.

Short Address: Pinged End Device's 16-bit address.

EUI-64: Extended Unique Identifier (MAC address) of End Device.

Test Data: Optional test patterns from Host CPU, End Device returns test data image unchanged.

7.2.2.26 Send Ping (0x19)

Sends a wireless test packet to the addressed or selected End Device. If and End Device radio is not selected, or fails to respond to the ping packet, an Acknowledge will not be returned to the Host CPU. When a Send Ping configuration command is Acknowledged, the Host CPU may then issue a Get Ping request to the Coordinator radio to obtain the Ping metrics.

Bytes:	*1*	*1*	*1*	*1*	*1*
Field:	0x19 Code	15 – 80 Length	Coordinator RSSI	Coordinator LQI	End Device RSSI
Bytes:	*1*	*1*	*2*	*8*	*0 - 65*
Field:	End Device LQI	Transmit Power	Short Address	EUI-64	Test Data

Structure 39: End Device Ping Request Packet

RSSI: Reserved for Ping response, Host CPU should fill with zero(0).

LQI: Reserved for Ping response, Host CPU should fill with zero(0).

Transmit Power: Reserved for Ping response, Host CPU should fill with zero() .

Short Address: 802.15.4 Short Address for End Device to Ping, setting to Broadcast 0xFFFF (255, 255) will instead address the most recently selected GTECH Peripheral's End Device radio.

EUI-64: Reserved for Ping response, Host CPU should fill with zeros(0.0.0.0.0.0.0.0).

Test Data: Optional test patterns.

7.2.2.27 Get CC2530 RF Registers (0x1A)

Bytes:	*1*	*1*	*n*

Field:	0x1A Code	n Length	CC2530 RF Registers

Structure 40: CC2530 Get CC2530 RF Registers Packet

Registers: Array of current RF registers 8-bit register values.

7.2.2.28 Set CC2530 RF Registers (0x1B)

Bytes:	*1*	*1*	*n*
Field:	0x1B Code	n Length	CC2530 RF Configuration

Structure 41: CC2530 Set CC2530 RF Registers Packet

Configuration: Array of RF registers values to be used by the radio.

7.2.2.29 Get Loopback Results (0x1C)

Bytes:	*1*	*1*	*1*	*2*	*2*
Field:	0x1C Code	n Length	Reserved	Packets Sent	Packets Received

Structure 42: Loopback Test Result Packet

7.2.2.30 Set Loopback Mode (0x1D)

Selects a loopback mode for diagnostic and compliance test purposes.

Bytes:	*1*	*1*	*1*
Field:	0x1D Code	1 Length	Mode

Structure 43: Set Loopback Packet

Mode:

`0x00`	Loopback tests disabled.
`0x01`	Start/Reset Packet Error Rate (PER) test.
`0x02`	Enable continuous packet transmit test.
`0x03 to 0xFF`	Unassigned.

7.2.2.31 Get Version (0x1E)

Responds with current firmware version using a null-terminated ASCII string.

Bytes:	*1*	*1*	*variable*
Field:	0x1E Code	variable Length	Version string

Structure 44: Get Version

Version: ASCII byte string in the format YYYY_MM_DDr(null) where:

YYYY	4-digit year i.e. 2000.
MM	2-digit month i.e. 04 (April).
DD	2-digit day.
r	revision letter (a to z).
null	0 (‘/0’).

7.2.2.32 Set Break (0x1F)

Simulates a Coordinator radio's response to a hardware Break condition on its EIA485 interface. The Coordinator radio will broadcast a configuration message to all End Devices in its PAN forcing them perform a hardware Reset and assert a hardware Break condition on each End Device's EIA485 serial bus as part of its startup sequence.

Bytes:	*1*	*1*	*1*
Field:	0x1F Code	1 Length	Target

Structure 45: Generate Reset / Break Sequence

Target:

`0x00`	Resets Terminal radio (coordinator).
`0x01`	Broadcasts Reset command to all End Devices.
`0x02 to 0xFF`	Reserved

8.0 USER INTERFACE

The basic GWT154 Radio Module has one user LED status indicator and one momentary contact pushbutton switch input. The following radio modes are initiated and indicated by the following:

8.1 Uninstalled Radio

An un-commissioned radio from the factory defaults as an End Device that has not been joined to a PAN Coordinator. When initially powered the indicator LED may flash Red, then it will be extinguished.

8.2 End Device Joining

Pressing and holding the pushbutton switch on the radio for more than 3-seconds, but not more than 10-seconds will place the End Device radio into the network join mode. The radio will attempt to Associate with any nearby PAN Coordinators and indicates this by flashing the LED at a 500ms ON and 500ms OFF cadence.

If and when, while attempting to Associate, the radio receives a beacon from a Coordinator in response to its beacon request, the LED will be steady ON indicating it has found a PAN Coordinator.

If, after 30-seconds, the End Device radio does not successfully negotiate joining a network, the radio will abort the joining mode and turn the LED OFF.

8.3 Radio Programming

The GWT154 Wireless Transceiver is programmed using Texas Instruments' CC-Debugger in-system-debugger/programmer for CC2530 and an adapter cable.

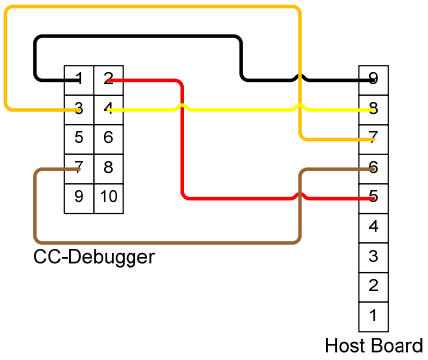


Figure 20 – Custom Adapter Cable

8.4 Alternate Configuration and Setup Tool

The GTECH485 Test Tool is a PC application developed for a Windows platform. This tool can be used in manufacturing, compliance testing and by GTECH field engineers to configure and setup the radios.

Specific information can be found in GTECH's Field Service Training manuals. Which are available

through GTECH Technical Training and Support Services, (401) 392-7961.

9.0 HOST PORT CONFIGURATION SEQUENCES

9.1 Coordinator Configuration, Network Start and Joining

To configure a factory-new radio as a PAN Coordinator, start the network and enable acceptance of new End Device radios requires the following steps. Though not necessary for configuration, initialling requesting the radio's status verifies communication has been successfully established and if the radio is factory-new or has been previously configured.

- Select Coordinator Radio as the current 485 Peripheral
- Get Status
- Perform RSSI energy scan

Once the RSSI scan has been initiated, the Terminal/Host must periodically poll the Coordinator for the scan results. Note: unless the Terminal/Host addresses another Peripheral on its wired 485 bus, the Coordinator's Peripheral address only needs to be sent at the beginning of a configuration sequence.

- Get RSSI results

After the Terminal/User has selected a suitable channel, the radio may be configured.

- Set Mode to Coordinator
- Set Channel Mask and Default Channel
- Set Mode to Start Network
- Set Mode to Enable Joining

Once the network has been started and is ready to accept new End Devices the Coordinator must be periodically polled to detect End Device associations.

- Get ACL

The Coordinator returns the entire contents of its Access Control List (ACL); this includes both new association requests and previously joined devices. New requests will have their security Key Index set to 1 (Factory Key used). The Terminal/Host may join a new End Device by responding to its associate request.

- Join PAN

The Coordinator radio will continue to accept new associated requests until the Terminal/Host disables it. If new devices have been accepted to the PAN the Terminal/Host should also instruct the Coordinator radio to save the updated ACL to persistent memory.

- Set Stop Joining Mode
- Set Mode to NV Save

Optionally, the Terminal/Host may obtain the radio's firmware version.

9.1.1 Select Peripheral Address, Set Mode

Set Mode: Coordinator.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 01 01 1B EE ED 04	06
		05 00 81 00 7F 04

9.1.2 Select Peripheral Address, Get Status

Get Status: Coordinator Idle (0x20), Channel 17 (~0xEE), PAN ID 0xC05F, Short Address 0xC05F, EUI-64 0.18.75.0.1.26.56.26, Up Time 0x000007E1.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Get Status	05 00 00 00 00 04	06
		05 00 80 1B ED 20 1B EE F5 C0 F5 C0 1B E5 38 1B E5 01 00 4B 1B ED 00 E1 07 00 00 21 04

9.1.3 Set Peripheral Address, Start RSSI Energy Scan

Set energy scan:

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Energy Scan	05 00 07 00 F9 04	06
		05 00 87 00 79 04

9.1.4 Set Peripheral Address, Get RSSI Scan Result

The Terminal/Host polls the Coordinator Radio until it receive a non-zero length response. Channels 27 and 28 are blocked by the Channel Mask and return a 0xFF.

RSSI results: 36 (channel-11), 70, 61, 11, 0, 42, 89, 47, 0, 67, 92, 100, 75, 0, 0 (channel-26), 255, 255.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Get Energy Scan	05 00 1B F9 00 FA 04	06
		05 00 86 00 7A 04
SYN-Address	16 01	01 00
Get Energy Scan	05 00 1B F9 00 FA 04	06
		05 00 86 00 7A 04

SYN-Address	16 01	01 00
Get Energy Scan	05 00 1B F9 00 FA 04	06
		05 00 86 1B ED 24 46 3D 0B 00 2A 59 59 2F 00 43 5C 64 4B 00 00 FF FF 5F 04

9.1.5 Select Peripheral Address, Set Channel Mask and Default Channel

Set Channels: Channel Mask 0x07FFF800, Default Channel-11 (0x0B).

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 03 1B FA 00 F8 FF 07 0B EF 04	06
		05 00 83 00 7D 04

9.1.6 Set Peripheral Address, Set Start Network Mode

Set Mode: Start Network.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 01 01 20 DE 04	06
		05 00 81 00 7F 04

9.1.7 Set Peripheral Address, Set Enable Joining Mode

Set Mode: Enable Joining.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 01 01 31 CD 04	06
		05 00 81 00 7F 04

9.1.8 Set Peripheral Address, Poll ACL (no devices)

Get ACL: returns zero-length response message

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Get ACL	05 00 0C 00 F4 04	06
		05 00 8C 00 74 04
SYN-Address	16 01	01 00
Get ACL	05 00 0C 00 F4 04	06
		05 00 8C 00 74 04

9.1.9 Poll ACL (one device associated)

Get ACL: AES Key Index 1, Short Address 0x0001, EUI-64 0.18.75.0.1.26.56.37

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Get ACL	05 00 0C 00 F4 04	06
		05 00 8C 0B 01 01 00 25 38 1B E5 01 00 4B 1B ED 00 92 04
SYN-Address	16 01	01 00
Get ACL	05 00 0C 00 F4 04	06
		05 00 8C 0B 01 01 00 25 38 1B E5 01 00 4B 1B ED 00 92 04

9.1.10 Select Peripheral Address, Join PAN

Using the Short Address and Extended Address (EUI) selected from the ACL, join an End Device to the network.

Join PAN: Short Address 0x0001, EUI-64 0.18.75.0.1.26.56.37.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Join PAN	05 00 0B 0A 01 00 25 38 1B E5 01 00 4B 1B ED 00 1B EA 04	06
		05 00 8B 00 75 04

9.1.11 Select Peripheral Address, Stop Joining Mode

Set Mode: Stop Joining.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 01 01 30 CE 04	06
		05 00 81 00 7F 04

9.1.12 Select Peripheral Address, Set NV Save Mode

Set Mode: NV Save.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 01 01 40 BE 04	06
		05 00 81 00 7F 04

9.1.13 Select Peripheral Address, Get Radio Firmware Version

Get Version: 2011_03_02b.

Message	Terminal	Coordinator
SYN-Address	16 01	01 00
Get Version	05 00 1E 00 E2 04	06
		05 00 9E 0C 32 30 31 31 5F 30 33 5F 30 32 62 00 AD 04

9.1.14 Select Peripheral Address, Get Channel Mask and Default Channel

Get Channel Mask: 0x7FFF800, Default Channel-11.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Get Channels	05 00 02 00 FE 04	06
		05 00 82 1B FA 00 F8 FF 07 1B EE 6A 04

9.2 Coordinator Configuration Setting Firewall Address Mask

Before the Terminal/Host may address and communicate with an End Device Peripheral, it must write the Coordinator's Firewall Address Mask. The Mask may be optionally saved to persistent memory by issuing the NV Save Mode.

- Send Address Filter Mask
- Get Address Filter Mask
- Set NV Save Mode

9.2.1 Set Peripheral Address Filtering Mask, Get Peripheral Address Mask

Set Peripheral Address Mask: 0x21 through 0x2F enabled for wireless communication.

Get Peripheral Address Mask: Matches set mask above.

Set Mode: NV Save

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Peripheral Address Mask	05 00 1B EA 20 00 00 00 00 FE FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 CE 04	06
		05 00 95 00 6B 04
Get Peripheral Address Mask	05 00 1B EB 00 EC 04	06

		05 00 94 20 00 00 00 00 FE FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 4F 04
Set Mode	05 00 01 01 40 BE 04	06
		05 00 81 00 7F 04

9.3 Coordinator Configuration – Get End Device Statistics

After a PAN has been created, and the network configuration parameters saved persistently in all devices, the Terminal/Host may acquire wireless link signal strength and quality information from all End Devices in the network. An End Device radio is selected by addressing the Peripheral wired to it. Once selected, the Coordinator – End Device link is maintained until the Terminal/Host addresses a different Peripheral.

Link quality and End Device 802.15.4 addressing may be obtained from the currently selected Peripheral End Device using a Ping diagnostic message.

- Select Peripheral address
- Send Ping
- Get Ping Response

9.3.1 Select Peripheral Address, Send Ping

Send Ping: Coordinator RSSI 0, Coordinator LQI 0, End Device RSSI 0, End Device LQI 0, End Device Transmit Power 0, End Device Short Address 0, End Device EUI-64 0.0.0.0.0.0.0.0, Test Data 0x30, 0x31 to 0x5F.

Get Ping: Coordinator RSSI 207, Coordinator LQI 89, End Device RSSI 223, End Device LQI 134, Transmit Power 15, Short Address 0x0001, EUI-64 0.18.75.0.1.26.56.37, Test Data 0x30, 0x31 to 0x5F.

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 20	20 00
Send Ping	05 00 1B E6 41 00 00 00 00 00 FF FF 00 00 00 00 00 00 00 30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F 40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F 50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F 00 00 40 04	06
		05 00 99 00 67 04
Get Ping	05 00 1B E7 00 E8 04	06
		05 00 98 41 CF 59 DF 86 1B F0 01 00 25 38 1B E5 01 00 4B 1B ED 00 30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F 40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F 50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F 00 00 4D 04

9.4 Coordinator Configuration – Setting End Device Parameters

The Terminal/Host may adjust the selected Peripheral/End Device parameters. The last selected Peripheral address is retained by the Coordinator radio even after the Terminal/Host as addressed the Coordinator using its assigned Peripheral address. When the End Device radio is selected as the configuration message destination, the last known Peripheral address is used.

- Select Peripheral address
- Set Transmit Power and Select Antenna
- Set Lost Coordinator Failsafe Timeout
- Set BAUD

9.4.1 Select Peripheral Address, Set TxPower, Select Antenna, Set Failsafe

Set RF Configuration: End Device (0x00), Tx Power 10, Antenna On-Board (0x00), lost Coordinator Failsafe 99 (seconds).

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set RF Configuration	05 00 1B EC 1B FB 00 0A 00 63 7C 04	06
		05 00 93 00 6D 04

9.4.2 Select Peripheral Address, Set BAUD

Set BAUD: End Device, 230,400

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set RF Configuration	05 00 1B EE 02 00 00 ED 04	06
		05 00 91 00 6F 04

Set BAUD: Coordinator, 38,400

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set RF Configuration	05 00 1B EE 02 01 03 E9 04	06
		05 00 91 00 6F 04

9.5 Peripheral Configuration, Status

Joining an End Device radio to a PAN may be performed entirely by using the radio module's onboard LED and Pushbutton switch. However, the Peripheral/Host may also configure the radio in a similar manner as the Terminal/Host above, though there may be differences.

9.5.1 Select Peripheral Address, Set NV Save Mode

Set Mode: NV Save

Message	Terminal/Host	Coordinator Radio
SYN-Address	16 01	01 00
Set Mode	05 00 01 01 40 BE 04	06
		05 00 81 00 7F 04

10.0 AGENCY STATEMENTS

10.1 Federal Communication Commission Interference Statement

Compliance Statement (Part 15.19)
This device complies with Part 15 of the FCC Rules.
Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

Warning (Part 15.21)
Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement (Part 15.105 (b))
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

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

RF Exposure (OET Bulletin 65)

- To comply with FCC/IC RF exposure requirements for mobile transmitting devices, this transmitter should only be used or installed at locations where there is at least 20cm separation distance between the antenna and all persons.

10.2 Industry Canada Statements

Section 7.1.2 of RSS-GEN

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

User manuals for transmitters equipped with detachable antennas shall also contain the following notice in a conspicuous location:

This radio transmitter Model GWT154 (IC: 1706AGWT1541T1R) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device. This device has been designed to operate with the antenna(s) listed below, and having a maximum gain of +2 dBi. Antennas not included in this list or having a gain greater than +2 dBi are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

List of all Antennas Acceptable for use with the Transmitter

1. 2.4 GHz chip antenna, Johanson part number: 2450AT18A100
2. 2.4 GHz dipole antenna for reverse polarity SMA connector, LS Research part number: 001-0001.
    a. Cable assembly: 105mm in length with reverse polarity SMA female bulkhead and U.FL connector using 1.13mm diameter cable, LS Research part number: 080-0001.

Section 7.1.3 of RSS-GEN

This Device complies with Industry Canada License-exempt RSS standard(s). Operation is subject to the following two conditions:

1. this device may not cause interference, and
2. this device must accept any interference, including interference that may cause undesired operation of the device.

French Translation

Section 7.1.2 of RSS-GEN

Sous la réglementation d'Industrie Canada, ce transmetteur radio ne peut fonctionner en utilisant une antenne d'un type et un maximum (ou moins) gain approuvées pour l'émetteur par Industrie Canada. Pour réduire le risque d'interférence aux autres utilisateurs, le type d'antenne et son gain doivent être choisis de manière que la puissance isotrope rayonnée équivalente (PIRE) ne dépasse pas ce qui est nécessaire pour une communication réussie.

Les manuels des transmetteurs équipés d'antennes amovibles doit également contenir l'avis suivant dans un endroit bien en vue:

Sous la réglementation d'Industrie Canada, ce transmetteur radio ne peut fonctionner en utilisant une antenne d'un type et un maximum (ou moins) gain approuvées pour l'émetteur par Industrie Canada.

Pour réduire le risque d'interférence aux autres utilisateurs, le type d'antenne et son gain doivent être choisis de manière que la puissance isotrope rayonnée équivalente (PIRE) ne dépasse pas ce qui est nécessaire pour une communication réussie.

Liste de toutes les antennes acceptables pour une utilisation avec l'émetteur

1. 2,4 GHz puce antenne, numéro de pièce Johanson: 2450AT18A100
2. 2,4 GHz Antenne dipôle pour connecteur SMA inversé la polarité, le nombre LS cadre de la recherche: 001-0001.
    a. Câble de montage: 105mm de longueur avec la cloison de polarité inversée SMA femelle et connecteur U. FL aide d'un câble de diamètre 1.13mm, numéro LS cadre de la recherche: 080-0001.

Section 7.1.3 of RSS-GEN

Cet appareil est conforme aux normes d'Industrie Canada exempte de licence RSS (s). L'opération est soumise aux deux conditions suivantes:

1. cet appareil ne peut causer d'interférences, et
2. cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement de l'appareil.

10.3 OEM Responsibilities to comply with FCC and Industry Canada Regulations

The GWT154 Radio Module has been certified for integration into GTECH products only by OEM integrators under the following conditions:

1. The antenna(s) must be installed such that a minimum separation distance of 20cm is maintained between the radiator (antenna) and all persons at all times.

2. The transmitter module must not be co-located or operating in conjunction with any other antenna or transmitter.

As long as the two conditions above are met, further transmitter testing will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed (for example, digital device emissions, PC peripheral requirements, etc.).

IMPORTANT NOTE: In the event that these conditions cannot be met (for certain configurations or co-location with another transmitter), then the FCC and Industry Canada authorizations are no longer considered valid and the FCC ID and IC Certification Number cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC and Industry Canada authorization.

10.4 End Product Labelling

The GWT154 Radio Module is labeled with its own FCC ID and IC Certification Number. If the FCC ID and IC Certification Number are not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. In that case, the final end product must be labeled in a visible area with the following:
"**Contains Transmitter Module FCC ID:** FBZ-GWT154-1T1R"
"**Contains Transmitter Module IC:** 1706A-GWT1541T1R"
or
"**Contains FCC ID:** FBZ-GWT154-1T1R"
"**Contains IC:** 1706A-GWT1541T1R"

Figure 21 – Example of an End Product Label

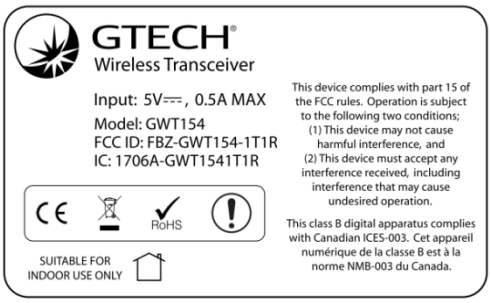


Figure 22 – Example of a Model GWT154 Radio Module Label

The OEM of the GWT154 Radio Module must only use the approved antenna(s) listed above, which have been certified with this module.
The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module or change RF related parameters in the user manual of the end product.

The user manual for the end product must include the following information in a prominent location:

> *To comply with FCC and Industry Canada RF radiation exposure limits for general population, the antenna(s) used for this transmitter must be installed such that a minimum separation distance of 20cm is maintained between the radiator (antenna) and all persons at all times and must not be co-located or operating in conjunction with any other antenna or Revision History*

11.0 CONTACTING GTECH CORPORATION

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