RF-TWACS Based AMR System

Application Notes

Revision 1

a product of
Distribution Control Systems, Inc.
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1 AUDIENCE

This document is intended for use by customers of the RF-TWACS based AMR System, and covers the basic principles, description of the hardware units and explanation of operational features of DCSI's RF solution. Additional details are available in individual product and system level specification documents.

2 INTRODUCTION

2.1 Basic Concepts

The radio link between a water or gas meter and an electric meter is designed to be an alternative to the present day hard-wired solution that is available for a multi-port meter such as the IMT3-3P.
The radio link is designed to facilitate and enhance flexibility in the installation of the AMR solution at customer premises. Although the cost of RF hardware may be slightly higher than its hardwired counterpart, savings should result due to lower installation costs. Any location that would be difficult or impossible to trench a line could potentially benefit from the RF alternative.

2.2 Benefits

Aside from the overall cost savings, homeowners are delighted to learn that their yards do not have to be dug-up, or that a cable does not have to be stapled to their siding. In addition to the non-invasive characteristics of the installation, utilities can expect to find the flexibility of field configurations to be one of the major advantages the RF solution. Radio transmission means that connections need not be same-premise any more. A mix of radio-capable and hard-wired transponders may be deployed in a given area to reduce overall solution costs.

The system is designed to provide two main functions:

1. A "Total Consumption" reading will be frozen system-wide at a given programmable time of day.
2. A "Present Total Consumption" will be available on-demand, updated hourly, for each meter in the system.

2.3 Principles of Operation

Gas and water meters need to be wired to a nearby small radio transceiver unit called the Remote Meter Transceiver (RMTR) which can be seen in Figure 1. The RMTR will transmit data, using a UHF link, from gas and water meters to electric meters outfitted with the EMT-3C-MP transponder, these transponders will include a plug-in radio module board called the Electric Meter Transceiver (EMTR) that serve as TWACS gateway, please refer to Figure 2 . The system is intended to be compact, reliable and easy to install. It will therefore make maximal use of the RF network created by the transmitters and receivers – regardless of property boundaries.

Figure 1 – Front View of the Remote Meter Transceiver RMTR

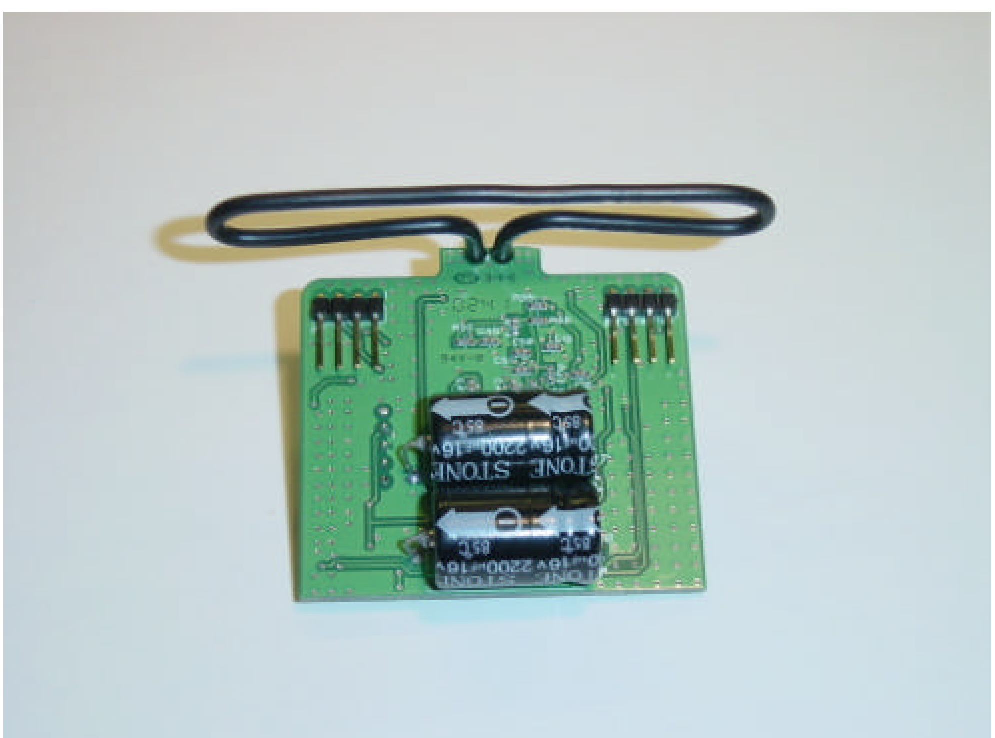

Figure 2 – Electric Meter Transceiver (EMTR) board with dipole antenna and four-pin connections to the EMA

The installer has the latitude to create any workable network on site, and is able to confirm that it functions prior to leaving the site. A hand-held radio tool called the Hand-Held Transceiver (HHTR) is available to support installation, configuration, change-outs and other field operations. An HHTR is shown in Figure 3.

Figure 3 – Hand-Held Transceiver (HHTR) Front View

Frequencies between 902 MHz and 928 MHz are used. This part of the UHF radio spectrum is known as the 900 MHz Industrial, Scientific and Medical band (ISM) and is unlicensed. DCSI's radio devices operating in this band comply with FCC regulations and rules. The radio link is a two-way half duplex, uses pseudo-random sequence frequency hopping spread spectrum technology, and FSK modulation. All transceivers include an integral received signal strength indicator (RSSI), obtain receipt verification, and perform automatic retries of failed communications.

A frequency hopping algorithm is used to: comply with FCC regulations, reduce potential interference to and from other services operating in the same band, reduce the likelihood of eavesdropping, and to minimize the effects of selective fading.

The RMTRs do not run continually. Instead, they run only in response to external events that cause power to be applied to its microprocessor. When the external event has been dealt with, the power is turned off from the microprocessor. This is done to extend battery life. They also assembly RF data packets that contain a unique transmitter serial number, the present reading, diagnostic information, and error-detection codewords.

A block diagram of the system can be seen in Figure 4 below.

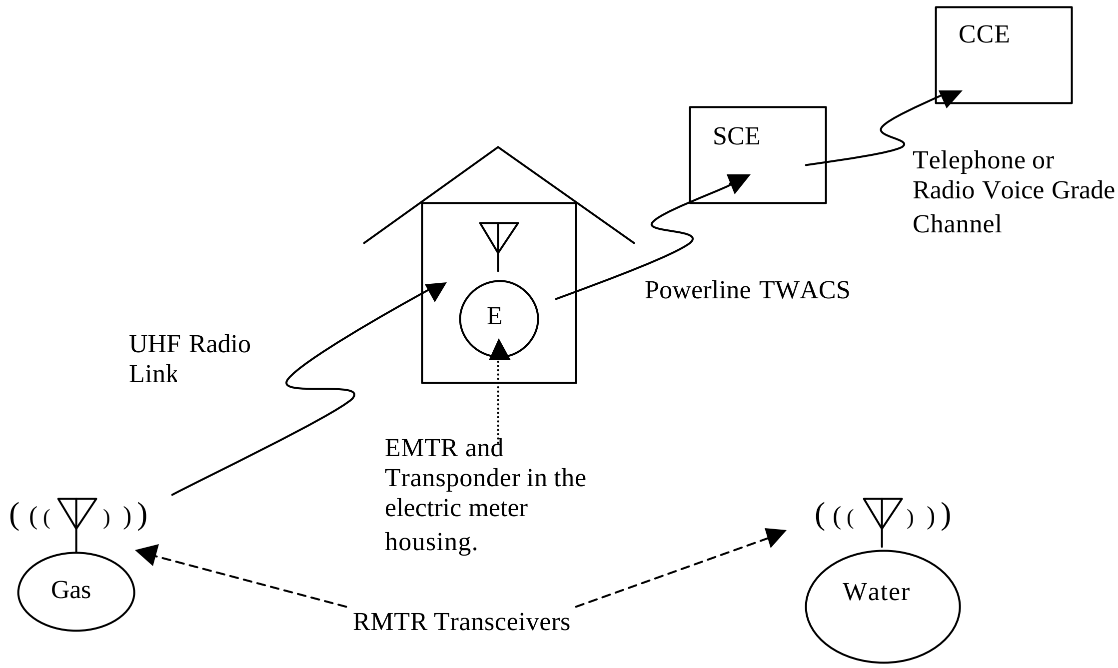

Figure 4 – Block Diagram for DCSI's RF based AMR System

3 SYSTEM NOMENCLATURE

The nomenclature normally employed for the TWACS product line needs a little clarification at this point.
The Remote Communication Equipment (RCE) is called an Electronic Metering Assembly (EMA) in this instance, and is not simply a single electronic module that has been retrofitted to an existing electric meter, but it also includes a radio transceiver (EMTR) with its own microcontroller and is powered by the electric meter.

External to the electric meter, and connected to the gas or water meters, is another DCSI radio transceiver module (RMTR). It houses a battery, folded dipole antenna, RF circuitry, RF engine code, microcontroller, and cable to the remote metered device. Please refer to Figures 5a and 5b.

Figure 5a

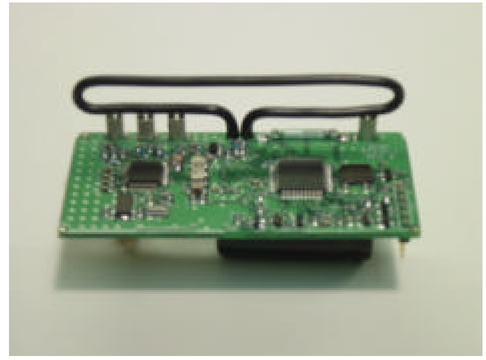

Figure 5b

Figures 5a and 5b – a) Rear view of the RMTR without cover showing the battery. b) RMTR board showing the RF circuitry, folded dipole, microcontroller and reed relay.

Finally at the bottom of the hierarchy is the remote metering device (gas or water) from which data is obtained. None of the meters are DCSI devices, however it is possible that certain instances of EMA integration may cause DCSI to supply some of the services for the electric meter (such as hosting the LCD). Please see Figure 6 for a better understanding of the naming convention adopted for the hardware units.

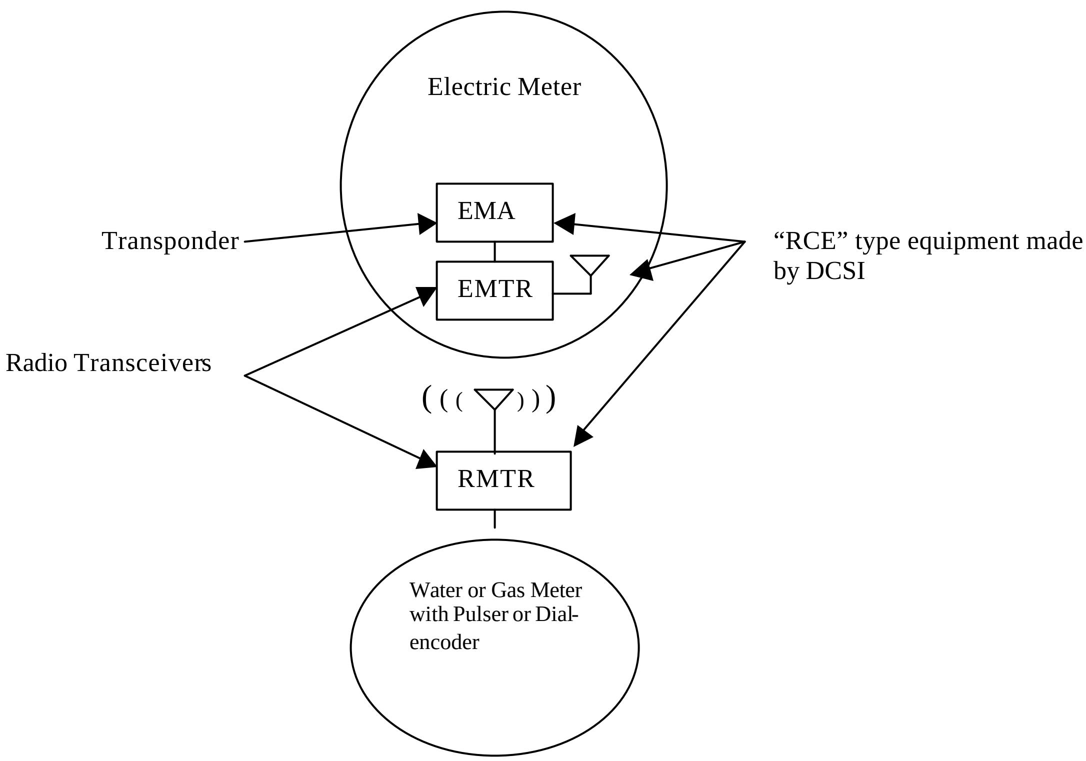

Figure 6 – EMA, EMTR, and RMTR Hardware Modules

This product includes a Schlumberger Centron Solid-State Electric Meter, outfitted with our EMT-3C-MP EMA module, and the optional EMTR plug-in RF board, all under the same meter canopy. The RMTR connects to a gas or water metering device which is either a pulser or dial encoder. The RMTR is external to the gas or water meters, and for adequate radio coverage must be mounted elevated above the ground, possibly on a wall.

Product Related Terms

CCE, Central Communication Equipment. Also referred to as the "Master Station", the current model sold to customers is called TWACS Net Server (TNS).

EMA, Electronic Metering Assembly. This can be viewed as either the traditional "transponder module" or merely as the function in a consolidated assembly that serves as the TWACS gateway.

EMT-3C-MP, Electric Meter Transceiver Multiport. Also called the EMA, Centron MP, RCE or transponder.

EMTR, Electric Meter TRransceiver. This unit serves as the RF gateway between the RMTR and the EMA. This unit continually scans channels, listening for communication from an RMTR.

HHTR, Hand Held TRansceiver. This hand-held test tool is used to monitor RF traffic, force link-assignments, as well as facilitate installations and change-outs.

IED, Intelligent End Device. This is an IEEE term. The end device in this case is a metering device. It may or may not have much intelligence. If the meter is a solid state meter, or some other metering device that supports two-way electronic communication, such a device could be termed an "Intelligent End Device."

RCE, Remote Communication Equipment. Historically known as the "Transponder", the RF project affects 3 different types of Remote Communication Equipment: the EMA, EMTR and the RMTR. If any one of them now had to be called a "transponder" it should be the EMA since it serves as the TWACS gateway. All of them can still be considered RCE's. Transponders are two-way powerline devices while transceivers are two-way radio devices.

RMTR, Remote Meter TRansceiver. A module separate and distinct from the gas or water meter that contains a connecting cable, microprocessor, RF circuitry, battery, and antenna. It normally sleeps, and occasionally wakes to establish an RF link with an EMTR. It maintains or obtains meter readings and conveys them to the EMTR.

SCE, Substation Communication Equipment. Also known as the "Substation", the current model sold to customers is based on the "93-CRU."

Communication Related Terms

Channel, The selected RF band (902 to 928 MHz) gives opportunity for 79 channels within the band. The DCSI RF TWACS system makes use of 50 channels. FCC limits the amount of energy that can be emitted in a given channel for a certain length of time. The transceiver design has one antenna that the transmitter and receiver portions of the circuit must alternately share. (The same unit cannot simultaneously transmit on one frequency while receiving on another). This causes all two way communication to be half duplex.

FSK, Frequency Shift Keying. Modulation technique where'1'/'0' transmission occurs by means of frequency shifting. One frequency is used to represent the logical '1' and a different frequency to represent the logical '0'.

Link, A path between two units in a communications system.

Manchester encoding, A signal transmission method defined for the representation of binary data bits on the radio channel. Manchester encoding specifies two "half-bits", so that a guaranteed mid-bit transition occurs in the transmitted signal.

RSSI, Received Signal Strength Indicator. This feature available in the receiver portion of the circuit measures the strength, relative to a noise background, with which a signal is obtained.

RX, Receive / Receiver.

Session, A series of transactions exchanged between two units in a communication system within each other communications zone.

TR, Transceiver

TX, Transmit / Transmitter

Data Related Terms

Frozen Read, The transponder sees many readings in the course of a day. It can be programmed to save one of them as the official "frozen read" for a given time of day. In the case of a hard-wired solution, the read can be performed at a set time of day. For an RF link, the end devices are set to perform a read at the appointed time, then transmit it some time later during the hour. The receiver in turn captures the transmission time-stamped nearest the appointed time and applies it as the "frozen read".

Interval Read, Is the relative amount of consumption registered by the metering device over an interval of time. The standard interval for this design is 1 hr. Therefore, we speak of hourly interval data – the amount of consumption that occurs in one hour time.

Present Read, The most up-to-date reading available from the meter. For an integrated module such as an EMA, the energy consumption can be obtained immediately. For cases where the TWACS gateway is not integrated within the meter being read, there is a certain amount of data latency. In the case of the RF link, the system should broadcast an update hourly. The "present read" then becomes at most one hour old, and on average a half hour old.

Shifted Read, In metering terminology, when a copy is made of a register, it is called "shifting." The idea is that a snapshot of a given register is made by copying the present value of a dynamically moving register into a static register. Both the "present read" and "frozen read" represent shifted readings.

Total Consumption (TC), Is the total amount of consumption registered by the device since installation. Rollover of the count (to zero) may occur at some point during the life of the product. Units of measure vary by service and model.

STU, Serial Time Unit. Is the unit of measure for DCSI's proprietary Serial Time system. Serial Time measures the number of 2.5 second intervals after midnight. Midnight (00:00:00) corresponds to "0 STUs". Five seconds after midnight (00:00:05) corresponds to 2 STUs. Likewise the Serial Date is the number of days after Jan 1, 1900. This differs from the commonly used units for time. The ANSI C12.19 standard supports a variety of methods, the nearest ones of which measure the universal (GMT) time since midnight Jan 1, 1970 in minutes, or the local time since midnight in seconds.

4 SYSTEM OVERVIEW

4.1 General System Theory Overview

The RF link between TWACS transceivers uses a range of frequencies between 902 MHz and 928 MHz. This range is divided into 79 channels. Fifty channels are needed to satisfy the FCC's minimum channel set requirements, so 50 of the 79 were chosen for use.

Five of these 50 channels are reserved for link acquisition and the other 45 are used for link maintenance (packets transmitted after a link has been acquired). The acquisition channels are spaced evenly throughout the upper end of the 50-channel set. The 45 link maintenance channels are used in a random manner while a link is active between transceivers.

The radio transceivers are equipped with folded dipole antennas. Folded dipoles were chosen because of their broader radiation pattern as compared with regular dipoles, this guarantees a better radio coverage under a variety of field installation conditions utilities may find.

Operationally, TWACS transceivers can play one of two roles during an RF session: A transceiver that requests a link is the *requestor* transceiver. A transceiver that replies to that request is an *acceptor* transceiver.

TWACS transceivers can be characterized by their roles as shown in Table 1:

Transceiver	**Type**	**Can request a link from…**	**Can grant a link to…**
EMTR	Acceptor	None	an RMTR or an HHTR
RMTR	Requestor	an EMTR or an HHTR	None
HHTR	Both	an EMTR	an RMTR

Table 1 – Roles of DCSI's Radio Transceivers

As can be seen, EMTRs never request a link; they are always acceptor transceivers. By contrast, RMTRs never grant a link; they are always requestor transceivers. The HHTR, since it must be able to communicate with both EMTRs and RMTRs, can act as either an acceptor transceiver (with an RMTR) or a requestor transceiver (with an EMTR).

The reason this distinction is important is that the acceptor transceiver always controls the channels hop sequence. This means that an EMTR always controls the hop sequence. An HHTR controls the sequence when communicating with an RMTR. An RMTR never controls the hop sequence.

Bear in mind that this distinction between acceptor and requestor transceivers is strictly operational. It is not a functional difference because the same RF transceiver and RF engine code are used on all transceivers.

The RMTR is a battery powered device. In order to maximize battery life, the RMTR is powered off as much as possible. The requirement to maximize battery life drives a number of other factors in the system. One implication of this is that the normal Master/Slave relationship, evident throughout the design, which begins at the CCE, now ends at the EMTR. The EMTR cannot wake up the RMTR to establish a session, but can take control of a session once it is established by the RMTR.

The RMTR is designed to wake up once an hour and create a session with an EMTR. Any unknown data is uploaded at that time from the RMTR to the EMTR. At any given time, the EMTR knows nearly everything the RMTR knows, plus it maintains engineering data to describe the quality of the radio link. The CCE may access this data upon demand.

The EMTR maintains an "acquisition list" table. Each RMTR is categorized as belonging to a certain type of service. The various types are: Electric, Water, Gas, and Propane. A number of ports are supported for each service type. The CCE reads data from the appropriate port in order to obtain information.

4.2 RF Hardware Specifications, Installation, Operations & Maintenance

4.2.1 Centron Meter

In addition to supporting TWACS communication, the EMT-3C-MP module hosts the LCD and the metering components from Schlumberger. The EMA also supports the connection to the EMTR board which is housed under the same canopy, this is shown in Figure 7. Figure 8 shows the EMT-3C-MP transponder integrated with an Schlumberger solid state Centron electric meter.

Figure 7 - EMT-3C-MP board hosting the Centron's LCD/Metering Components and the EMTR RF Board

Figure 8 – Schlumberger Centron + EMT-3C-MP Assembly

4.2.1.1 Initial Installation and Change-outs

The installation of a Centron meter that is integrated with the EMT-3C-MP TWACS module is handled like any ordinary meter change-out. The installer must record the final reading of the meter that is removed, replace it with a Centron meter that is outfitted with a TWACS module, record the customer number, date, initial reading, and meter serial number. Other data items may be required as part of the utility's data process.

Once the data from the installer has entered the CCE, the integrated assembly will be "searched", and the electrical path to the unit determined. Additional steps will be taken to set it up as part of the daily electric meter AMR process.

4.2.2 Remote Meter (gas/water) Transceiver (RMTR)

4.2.2.1 RMTR Specifications

Power Source:	3.6 Volts battery Design Operational Lifespan: Minimum: 10 years Expected: 15 years
Communication Range:	1200 ft. open field @ max. power amplifier gain
Frequency of Operation:	902 to 928 MHz
Number of Channels:	5 link acquisition + 45 link maintenance, bi-directional
Frequency Selection:	Pseudo-random Frequency Hopping Spread Spectrum. (The link acquisition channels are not part of the hopping sequence).
Signal Strength Indicator:	Integral Received Signal Strength Indicator (RSSI).
Clear Channel Selection Method:	Walkthrough acquisition channel list in ascending order, and then use the quietest. Occupied channels are immediately passed over.
Clear Channel Signal Strength Criterion:	The RMTR finds the quietest channel by tuning to each and recording the RSSI, the channel with the lowest RSSI is used.
Gain Control:	3 discrete auto-adjustable levels of transmitter power.
Acquisition Retry Limit:	All transmissions comply with FCC limits. This includes the acquisition process. Acquisition is attempted on each channel at each power level.
TX Power Amplifier Gain:	A value is maintained by the RMTR that records the level used for the last successful transaction. This value is used until an RF session has failed and a successful session is acquired with a new power level. All packets are transmitted at this level until every acquisition channel has experienced the retry limit. After one cycle through the channels, the gain is increased to the next level (if available) and the channels cycled again.

Data Flow:	Asynchronous, half duplex.
Data Format:	8N1
Modulation:	FSK
Coding:	Manchester encoding (3200 bps)
Data Rate:	1600 bps
Data Encryption:	DCSI proprietary method #1
Maximum Packet size:	Complies with FCC rules.
Max. Packet Transmission time:	Complies with FCC rules.

4.2.2.2 Initial Installation and Change-outs

When an RMTR is installed, it must be configured for operation.
The installer must note the:

- Serial Number of the RMTR that is installed
- Date
- Customer number
- Initial dial reading
- Meter type
- Service Type
- Number of dials
- The unit of measure as displayed on the dial face
- The multiplier to convert pulses to a valid dial reading
- Any other items required by the utility's process

The installer, using an HHTR must configure the RMTR as to the:

- Service Type (Water / Gas)
- IED configuration (Encoder vs. pulser operation, selecting the appropriate supported model).
- Number of dials

Once the RMTR is installed, a nearby EMTR must be selected by the installer to convey the data. The installer must use the HHTR tool to make this assignment in the EMTR.

The installer should test the system after all of the devices have been configured. The installer can use the HHTR to cause the RMTR to initiate a data upload to the EMTR. The tool will confirm that the test was successful.

The change-out process is just like a new installation of the RMTR described above, with the exception that any previous EMTR assignments should be reused, or accounted-for, with the use of the new RMTR.

4.2.2.3 RMTR Operations

The RMTR wakes up once an hour (hourly after the freeze time; for example: if the freeze time is at 9:15 actual time, then hourly updates will occur at 10:15, 11:15, and so on) to obtain a reading and updates its present total consumption register. In the case of a dial encoder it wakes up once an hour to read the encoder then write a table. In the case of a pulser it wakes up to record a pulse event, and also once an hour (relative to the freeze time) to update the table.

The transmission of data from the RMTR to the EMTR follows this sequence:

1. The RMTR wakes up once an hour and attempts to create a session with an EMTR in order to upload readings and tamper information. The RMTR attempts to create a session on a quiet channel using a low-power amplifier-gain. After each Request-to-Send (RTS) packet is transmitted, the RMTR listens on the return frequency of the same channel for an acknowledgment to indicate acquisition by a suitable EMTR. The acknowledgment contains the EMTR's serial number so that a certified link can be established.

   Acquisition Sequence:
   The RMTR attempts to acquire a session by transmitting an RTS packet on the clearest channel at the same power level of the last successful session (in the case of a first time acquisition, it begins with the lowest power level). If this acquisition fails, it tries each of the remaining 4 acquisition channels at that power level, then, if the attempt on each channel fails, it will increase power to the next higher power level. After cycling through each of the channels and escalating up to the highest power level (attempting as many as 15 retries), it will go back to "sleep" and reattempt later.

2. If the link is accepted by the EMTR, it replies with a confirmation packet including the RMTR's serial number in the transmission, forming a "source - destination" routing packet.
3. The data field in all packets is encrypted for security purposes.
4. After the EMTR accepts the link, it takes control of the session and issues commands to harvest data.
5. The EMTR informs the RMTR that it is has completed all necessary exchanges by sending a "completion" message to the RMTR. This message is important to the RMTR, without it the RMTR must assume that a jam has occurred and that the data upload must be retried at a later time on another channel beginning with the first exchange.

Figure 9 below shows a state diagram that summarizes the described operations.

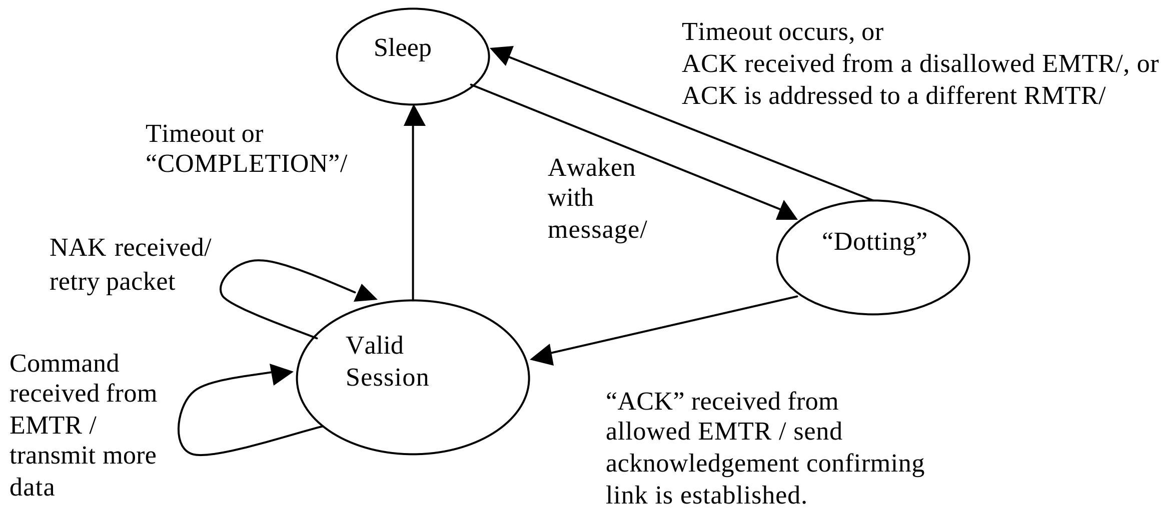

Figure 9 – State Diagram for the RMTR

4.2.2.4 RMTR Maintenance

The RMTR requires a battery change-out approximately once every 15 years. Expended batteries should be disposed of in accordance with local regulations. Battery voltage levels may be remotely checked by the CCE.

4.2.3 Electric Meter Transceiver (EMTR)

4.2.3.1 EMTR Specifications

Power Source:	EMT-3C-MP power supply
Communication Range:	1200 ft. open field @ max. power amplifier gain
Frequency of Operation:	902 to 928 MHz
Number of Channels:	5 link acquisition + 45 link maintenance, bi-directional.
Frequency Selection:	Pseudo-random Frequency Hopping Spread Spectrum. (The link acquisition channels are not part of the hopping sequence).
Signal Strength Indicator:	Integral Received Signal Strength Indicator (RSSI).
Occupied Channel Selection Method:	Walkthrough channel list in ascending order. RTS packets from a suitable RMTR, or HHTR are accepted. Any other traffic causes the EMTR to immediately abandon the channel and move on.
Gain Control:	3 discrete auto-adjustable levels of transmitter power.
TX Power Amplifier Gain:	The EMTR reciprocates with the same Tx Gain that the Requesting device uses.
Data Flow:	Asynchronous, half duplex.
Data Format:	8N1
Modulation:	FSK

Coding:	Manchester encoding (3200 bps)
Data Rate:	1600 bps
Data Encryption:	DCSI proprietary method #1
Maximum Packet size:	Complies with FCC rules.
Max. Packet Transmission time:	Complies with FCC rules.

4.2.3.2 Initial Installation and Change-outs

The intent of this section is to provide general guidelines for the initial installation and subsequent troubleshooting and replacement of EMTR units.

A Centron meter that has been outfitted with the EMT-3C-MP and EMTR modules is both TWACS and RF-TWACS capable. If they are deployed in advance of the RMTRs, then the electric metering capability of the Centron meter may still be used prior to deployment of any gas or water metering.

If a Centron meter has been initially deployed without an EMTR, it always can be converted later, at the meter shop, to a radio-capable unit by plugging in an EMTR and properly initializing the assembly.

The change-out procedure for a failed EMTR is the nearly same as described below in Section 4.2.4.2.3 – EMTR Installation. If the installer finds that the EMTR is still alive, it is advisable that he use the HHTR to first upload the "Acquisition List" table from the unit, swap it out, then download the same Acquisition List into the new unit.

If on the other hand, the installer finds that the EMTR is not functional, he must treat this as a new installation and load the Acquisition List with the proper assignments. The only way to know for sure which assignments are necessary is for him to be armed with this information from the CCE before he goes out into the field. All RMTRs that were assigned to the old EMTR need to be assigned to the new EMTR (or other EMTRs) in order to restore network integrity.

4.2.3.3 EMTR Operations

Creation of a Session

The EMTR scans acquisition channels and determines the average RSSI energy level. If the EMTR hears a channel which contains energy significantly above the average, it stops on that channel and attempts to establish communication. If it cannot do this successfully, the EMTR abandons the channel and resumes scanning. If it decodes a valid packet, and it is an RTS from an HHTR or from an RMTR for which it is responsible, it replies with a Clear-to-Send (CTS) packet or with a valid command packet.

Data Transmission

After the EMTR accepts the RTS, it takes control of the session and issues commands to harvest data.
Additional exchanges may occur between the two devices, limited only by FCC rules.
The data field in packets is encrypted (with the exception of RTS and CTS packets).

Session Conclusion (with an RMTR)

The session normally ends with a disconnect command.
The session abnormally ends whenever a packet exchange fails and the retry mechanism is exhausted.

Maintenance Session (with an HHTR)
The HHTR maintains control of the session and can exchange (read and write) any allowable data with the EMTR. The session concludes under HHTR control and ends with a disconnect command.

Data Retention
Data is retained in the EMTR until new data is uploaded during an RMTR session or an RMTR has been removed from the acquisition list.

4.2.3.4 EMTR Maintenance

There are no batteries in the EMTR, nor is any normal maintenance required. If however, RMTR's are installed or removed in the area, an EMTR within range must be configured to accept it. The "Acquisition List" maintained in the EMTR must be modified to allow the EMTR to accept session requests from the RMTR. The Acquisition List can be updated by the installer using the HHTR.

4.2.4 Hand-Held Transceiver (HHTR) – Verification and Installation Tool

4.2.4.1 HHTR Specifications

Power Source: Six rechargeable AA batteries with a minimum life of 8 hours of continuous use. (Figure 10)

Operating Modes: Work Order Entry – Field Installation Data Collection

RMTR
- *Configure* – Configures IED
- *Replace* - Swap-out an old RMTR with a new one.
- *Status* – IED Configuration and battery status
- *Install* – Add an RMTR to an EMTR's acquisition list.
- *Communication Status* – RSSI, Engineering data, IED configuration and battery status
- *Review* – Review what was just done for the present order number.

EMTR
- *EMTR Replace* – Swap-out an old EMTR with a new one (uploads the acquisition list from the old unit and downloads it to the new EMTR).
- *View Acquisition List* – Retrieves acquisition list from the EMTR and displays how they are mapped internally
- *Remove RMTR from Acquisition List* – Deletes entry.
- *Serial Port* – Isolated RS232 compliant port to logic-level *RS232 level shifter*

TWACS

HRTS – HRTS functionally equivalent installation tool

HHTR Configuration: Interface
RS232 Logic level inverted (True / False)
Keypad beep (Enabled / Disabled)
I/O port (Indicator / Control)

Power Configuration: LED backlight timer
Power off timer
Battery / charging status

Information: Firmware Revision and Password Protected FCC Compliance Code
Device Self Test

RF specs: Same as the EMTR / RMTR

Display: LCD

Keypad: 16 button keypad

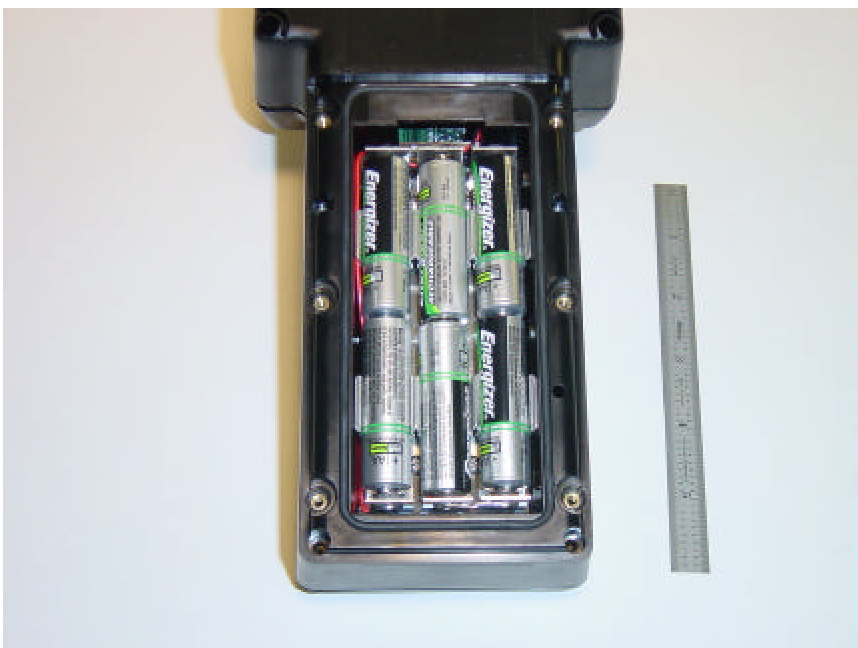

Figure 10 – HHTR battery compartment

4.2.4.2 HHTR Operation

The Hand Held Transceiver (HHTR) has a number of applications:

- RMTR Configuration
- RMTR Network Insertion
- EMTR Installation
- Site surveys

- Transceiver equipment diagnostics
- Installation Data Collection
- Other applications

4.2.4.2.1 RMTR Configuration

The RMTR must be either factory or field configured prior to successful operation. The RMTR is equipped with a reed relay that can be engaged in the field by swiping a magnet included in the HHTR, once the reed relay is engaged, the RMTR energizes its processor and is ready for a configuration session with the HHTR

Figure 11 below shows the application setup:

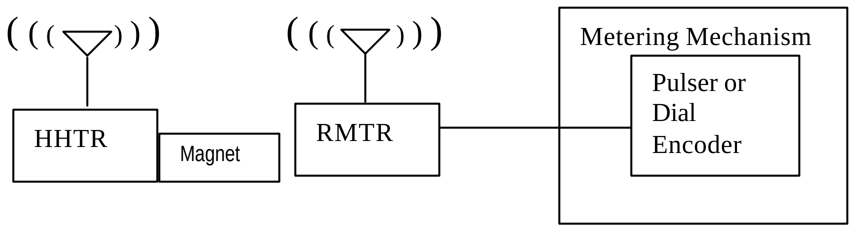

Figure 11 – RMTR Configuration Setup

The HHTR supports new RMTR installations by allowing field configuration of the device regarding meter type, number of dials, type of service, an IED device ID, etc.

4.2.4.2.2 RMTR Network Insertion

EMTRs contain the network equivalent of "routing tables" that must be maintained. Operation of the system in the forced-link assignment mode places the burden of network maintenance on the part of the installer.

Figure 12 summarizes the setup for this application:

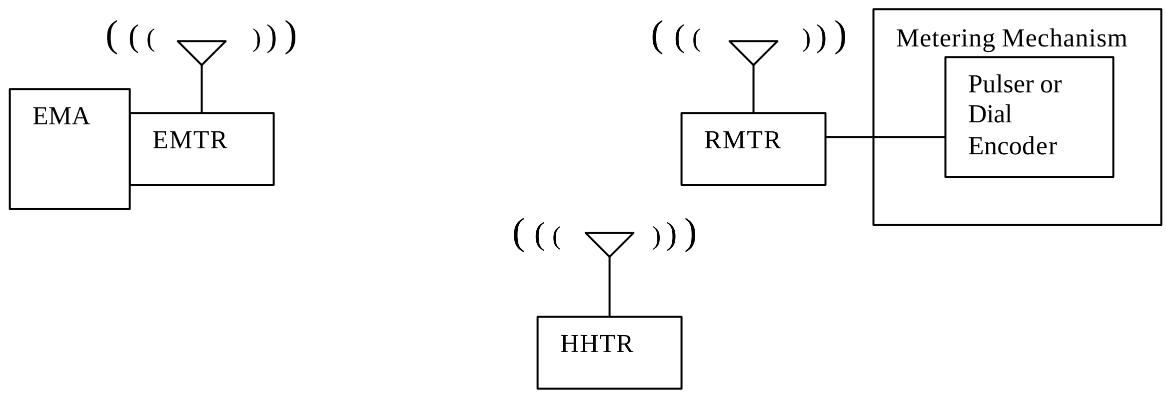

Figure 12 – Setup for Insertion of an RMTR unit to the Network

The HHTR must know the serial number of any old RMTR that must be removed from the network, the S/N of the new RMTR, and the S/N of the EMTR. Following the configuration of the new RMTR, the HHTR can (without travel on the part of the installer) acquire the EMTR, update it's table, reacquire the new RMTR, cause it to become "unsatisfied" regarding its upload, disconnect, and observe the traffic between the RMTR and EMTR.

The new RMTR must be inserted in the acquisition list matrix in the appropriate column (corresponding to the service type.) Within that column, the RMTR must be inserted in the first available port. This would be the port with the smallest number with a zeroed serial number.

4.2.4.2.3 EMTR Installation

At some point both RMTRs and EMTRs will be present in the same area. The Serial Number of every RMTR to be assigned to the new EMTR must be entered, and the service type of the RMTR known as well. Forced assignments can be made by writing to the acquisition list table in the EMTR.

If the old EMTR is still functional, the original tables may be uploaded to the HHTR prior to removal of the old EMTR. After EMTR replacement, the stored acquisition list may be downloaded to the new EMTR and operation may resume. The installer may wish to initiate an upload from a nearby RMTR to test the network.

4.2.4.2.4 Site Survey

An RF site survey is a characterization of a particular installation location from a radio propagation stand point. It's an essential element for proper operation of an RF data collection system. Site survey includes a comprehensive test at the customer site that will analyze the environment and check for any potential interference. Upon completion, the study will determine best location of antennas and RMTR devices needed for optimal coverage.

There are many different ways to evaluate a site. Some are listed below:

1. The HHTR may be used to harvest engineering data from an EMTR which has collected a history of previous RF communications with a particular RMTR. The Engineering Data register is an 8 bytes register that allows assessment of the radio link quality. Information contained in this register includes: Last Power Amplifier Gain, Last Channel, Last RSSI, Channel Abandonment, Acquisition Failures, Error Codes for Last Failure and a 24 Hour Acquisition Log.

2. The HHTR may be used prior to transceiver installation to evaluate a given site. HHTRs and special RMTRs may be positioned in various locations to evaluate signal strength and quality.

Commercially available test tools are available for RF Site Survey, but direct use of the HHTR product itself reduces the amount of tools that an installer must carry.

4.2.4.2.5 Transceiver Equipment Diagnostics

New installations as well as problematic ones will require on-site troubleshooting. (A need also exists for a meter-shop test-tool). The HHTR can be used to exercise transceivers. The HHTR is able to read the device tables, including the Engineering Data tables. The HHTR can initiate an exchange between field devices.

The HHTR will be able to read the EMTR or RMTR tables to investigate a problem. Certain tables indicate device status. Other tables, provide AMR data. The Engineering Data field from the Acquisition List can be particularly helpful in analyzing historical communcation performance.

4.2.4.2.6 Installation Data Collection

When a new RMTR is installed, the EMTR raises a diagnostic flag that causes the CCE to read tables and discover the port number, serial number, and other associated account information. The HHTR may collect installation data that serves to collaborate with information discovered via TWACS.

4.2.4.2.7 Other HHTR Applications

Other possible applications of the Hand-Held Test Tool Are:

- RCE Functional Testing
- Manufacturing and Integration Tests
- Emulation of older Test Tools (HRTS)
- Upgrade Transceivers Firmware

4.2.4.3 HHTR Maintenance

Batteries must be recharged daily.

4.3 RF-TWACS System Software – Central Communication Equipment

4.3.1 Data Available From Meters

The system is designed to supply a total consumption reading from each meter that has been frozen at a specific time of day on a daily basis. Furthermore, the system can deliver at any time, an "on-demand" or "Present" total consumption reading for each meter. The "present" gas or water reading will be pulled from the electric meter. The data in the electric meter is updated hourly.

4.3.2 CCE Data Requirements

4.3.2.1 Initial Installation

The CCE need only know that an EMA with RF capability has been installed. It will "search" the meter and install it into a daily AMR schedule. If and when RF-TWACS devices are installed at the same location, and the installer configures an EMTR (and consequently the hosting EMA) to accept an RMTR, a flag will be set indicating a change in the configuration tables. The CCE may then read various registers to self-discover the type of service and serial number of the RMTR.

4.3.2.2 Change-outs

The requirements are the same as for initial installation.

4.3.3 Data Availability

4.3.3.1 During Outage

Data cannot be conveyed over the TWACS system during an outage. RMTR's will attempt to upload data to EMTR's using RF, but be unsuccessful because EMTR's are powered from the powerline.

4.3.3.2 During non-RF communications

As described earlier, radio communications are kept to a minimum in an effort to preserve battery life. The EMTR and EMA maintain data on behalf of the RMTR. The design intends for data to be updated every hour. The latest RMTR data is readily available from the EMA via the TWACS.

4.3.3.3 Lost Data

It is possible that in some instances, RF conditions will prevent communications from occurring between an RMTR and an EMTR every hour. In this case the "present total consumption" reading maintained in the EMTR will be the last successful reading, not the latest top-of-the-hour present reading.

It is possible that the frozen daily read can be affected by adverse RF propagation conditions. In this case, the frozen daily read will be obsolete until radio communication is restored.

Once RF communication is restored, the "present" total consumption reading will be updated in the EMTR, and if necessary, the daily frozen reading as well.

4.3.3.4 Timing

The "Present" total consumption reading (updated hourly) is available at any time. The Daily Frozen total consumption reading is available for 23 hours during the day. The CCE must give the RCE time to move the frozen read up to the EMA. For this reason, harvest of the frozen reading must not begin until one hour after the service freeze time. Harvesting can continue for the next 23 hours -- until the service freeze time rolls around the next day.

4.4 RCE Registers and Tables and the CCE Response

4.4.1 Programmed Into Meter

4.4.1.1 Inbound Response Header

Important status flags are contained in the EMA response header byte which serves as a preamble in every TWACS inbound response from an RCE. The header includes Alarm, Tamper, and Diagnostic Indicators.

4.4.1.1.1 Alarm Indicators

Among the supported alarms are:

- The RMTR associated with this action indicates a near-term battery failure.
- The RMTR associated with this action indicates imminent battery failure.
- The port associated with this action is obsolete. (Obsolete is defined to mean "Unassigned".)
- Forced-assignment acquisition list maintenance has occurred. (This bit is cleared by writing '0').

4.4.1.1.2 Tamper Indicators

Among the supported alarms are:

- The associated RMTR was unplugged from its meter or IED and has now been reconnected.

4.4.1.1.3 Diagnostic Indicators

Among the supported alarms are:

- EMA Hardware failure.
- EMA to EMTR Communications failure.
- EMTR Hardware failure.
- EMTR to RMTR Communications failure.
- The RMTR associated with this action has reported a hardware failure.
- RMTR to IED communications failure.
- The IED (meter, dial-encoder, or in some cases, pulser) associated with this action has reported a diagnostic error or has behaved illegally.

4.4.1.2 EMA Registers

The data is exchanged between the CCE and EMA by means of "RCE Read Register" and "RCE Write Register" commands. The "MultiPort" series of RF capable transponders organizes data in a series of "register files." Each register-file is a series of ports with consecutive (and therefore calculable) addresses.

4.4.1.2.1 "Ported" Registers

The following registers are arranged in a register file form to permit register number computation by "port number" and service type:

- RMTR Serial Number, and Product Number
- Present Total Consumption
- Frozen Total Consumption
- RMTR Status
- RMTR RF Engineering Data

4.4.1.3 RCE Tables

This design endeavors to fully support the transport of ANSI C12.19 tables, while at the same time deploying a minimally C12.19 compliant implementation. Full compliance becomes possible when the Intelligent End Device (IED) that meters the commodity becomes C12.19 compliant.

4.4.1.3.1 Command Code

The following commands are supported at a minimum within the RF-TWACS protocol in an effort to support ANSI C12.19 compatibility:

- Read Entire Table
- Read Partial Table using Offset method
- Write Entire Table
- Write Partial Table using Offset method

4.4.1.3.2 Standard Tables

- Table 00, General Configuration
- Table 01, General Manufacturer's Identification

4.4.1.3.3 ANSI C12.19 Manufacturer's Tables

ANSI C12.19 Manufacturer's Table numbers range from 2048 to 4095. Note that the first of these is known as table number 2048, and also manufacturer's table number zero.

- Table 2048, MFG_ID
- Table 2049, 24 Hour Interval Data Table
- Table 2050, Unsatisfied-Daily-Frozen-Read Countdown
- Table 2051, RMTR Configuration
- Table 2052, RMTR Status
- Tables 2176-2207, Acquisition List

4.4.2 Conversion Factors

A consumption reading is usually conveyed in pulses, and requires multiplication by an appropriate scaling factor to be converted to a billing unit of measure. It is important that the installer of the RMTR keep good records regarding the type of unit that it is connected to. This data must be conveyed to the CCE so that it can choose the appropriate scaling factor. The installer must also indicate the number of dials on the meter. The CCE can use this information to recreate the dial face reading as it is in the field.

5 CCE SUPPORT

a. If any type of RMTR or appropriate EMTR installation (or change-out) occurs, the installer is required to update the Acquisition Table in the EMTR. This in turn causes a flag to be raised in the RCE Inbound Header, and a bit in internal Register #34, Indicator Alarm to be asserted.
b. The CCE reads the "Port Quantities by Service" internal register #751, and determines how many ports are in use for each service.
c. The CCE can then self-discover the Serial Number of the RMTR for each port assignment. The CCE reads the MFG_ID registers (#800-831) and saves the information in a database for future reference.
d. Other associated information such as RMTR configuration data can be obtained by additional register reads.

The installer should have independently recorded the serial numbers of any equipment added or removed to the system. The CCE must support the process of determining the presence or absence of serial numbers. If equipment is added and doesn't subsequently appear in the network, the cause must be evaluated. Some possible reasons are:

1. This is the first equipment (either RMTR or EMTR) in an area. It takes both in the same area for communication to occur. (A note by the installer should indicate this.)
2. The equipment is out of range. (An on-site test should have confirmed proper operation before the installer left.)
3. Unreliable communications. Perhaps RF is not the right solution for this site.
4. Equipment failure. (This should be exceptionally rare in light of the stringent manufacturing QA and the on-site test by the installer.)

The CCE must compare the list of all units that have been installed to the list of units that are operational. If the lists are not the same, it needs to be investigated.

The CCE should be able to produce an acquisition list relationship table for use by the installers. If a given RMTR is to be swapped out, the list allows the installer to reproduce the (forced) ling-assignments in the original equipment.

6 FCC COMPLIANCE STATEMENT

a. Changes not expressly approved by Distribution Control Systems, Inc. could void the user's authority to operate the equipments.

b. Note: The equipments have 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. These equipments generate, use 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 these equipments do cause harmful interference to radio or television reception, which can be determined by turning the equipments off and on, the user is encouraged to try to correct the interference by one or more of the following measure:

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

c. Operation is subject to the following two conditions: (1) These devices may not cause harmful interference and (2) these devices must accept any interference received, including interference that may cause undesired operation.

d. "To reduce potential radio interference to other users, the antenna type and its gain should be chosen that the equivalent isotropically radiated power (EIRP) is not more than that required for successful communication".

<u>Contact Information</u>:

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Or Contact your Program Manager