DCSI RF System

EMT-3C/EMTR-2 + Orion + HHTr-2 + RMTr-2 (Possible Future Development)

DISTRIBUTION CONTROL SYSTEMS, INC
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Y56527-SFS Rev (-)
RF System Functional Spec.

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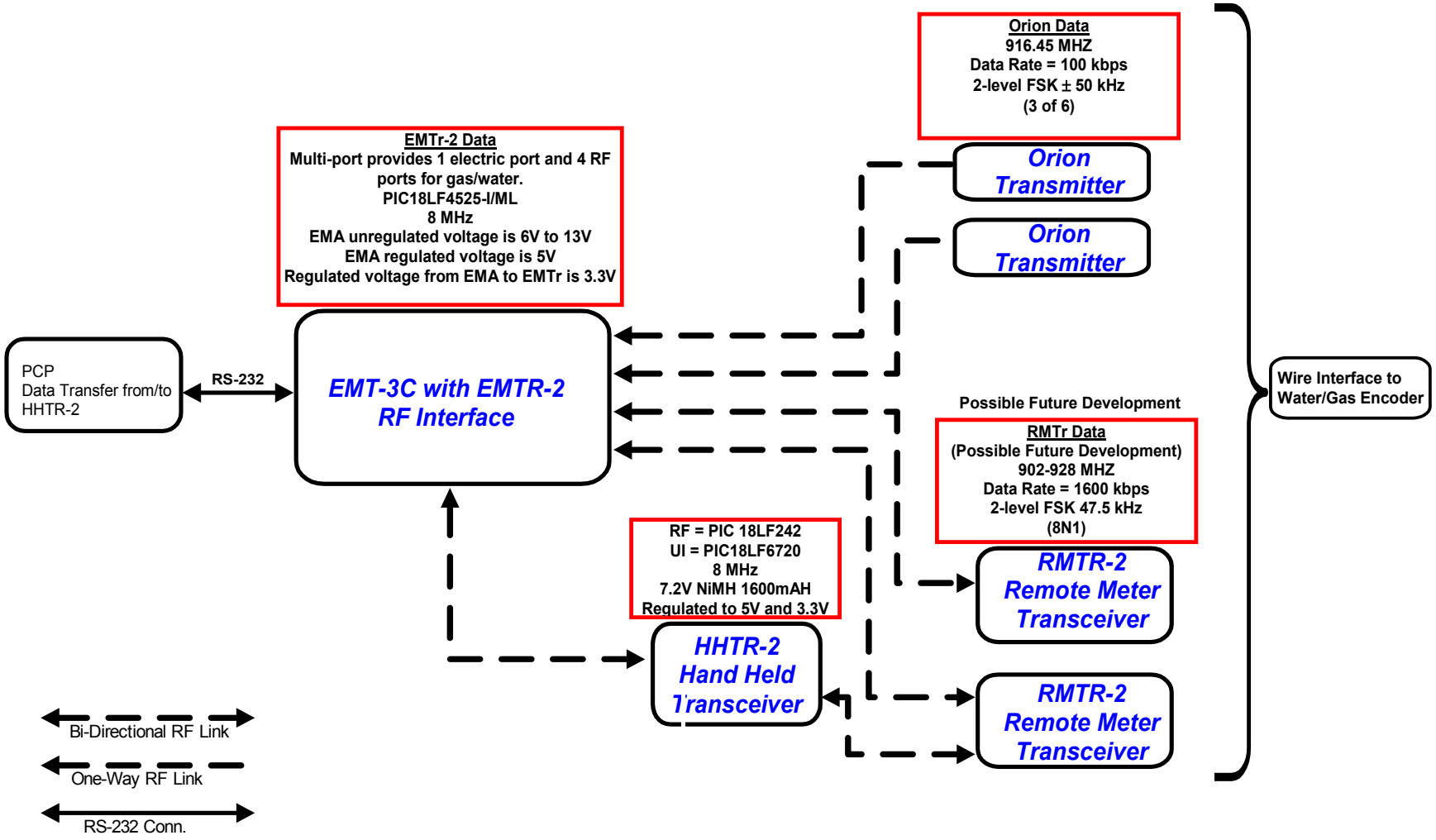
Table of Contents

RF Operational Block Diagram



1 Hardware Criteria and Communications Settings

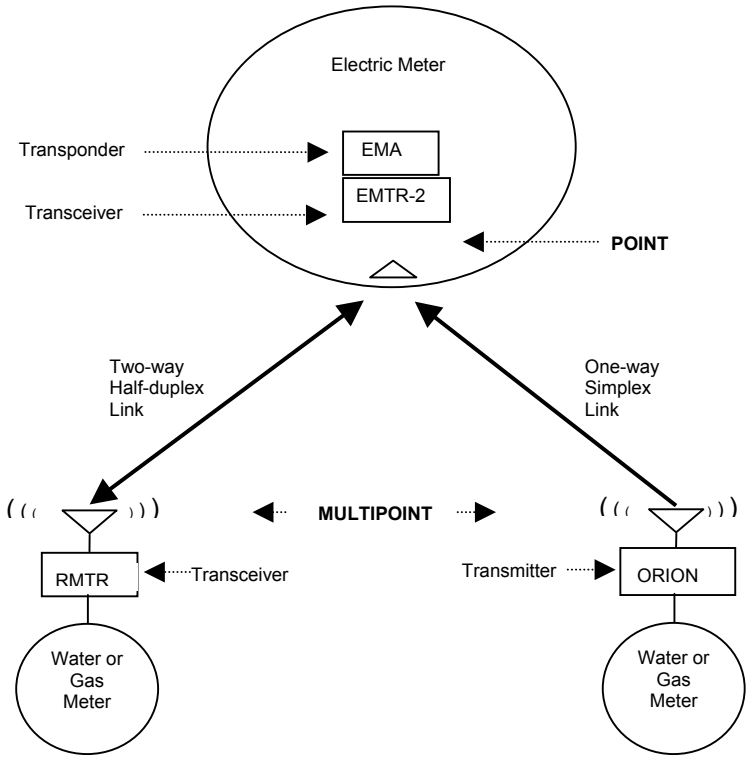
Communication Range:	ORION: 400 ft. LOS @ 15 dBm
Frequency of Operation:	902-928 MHz unlicensed Industrial Scientific and Medical band. (ISM)
Number of Channels:	50 half-duplex + 1 simplex
Frequency Selection:	RF TWACS: Tx employs Pseudo-Random Sequence Frequency Hopping (method # 0). The 5 link acquisition channels are not part of this sequence. ORION: Single channel (Channel 43A)
Clear Channel Selection Method:	EMTR-2 stays tuned to channel 43A trying to decode an ORION packet for 11s, then the EMTR-2 walks through the RMTR-2 Link Acquisition channels in ascending order for 2 seconds. The cycle 11/8.. is repeated 35 times.
Clear Channel Signal Strength Criterion:	RMTR: Finds a clear channel by tuning to each and recording the RSSI, the channel with the lowest RSSI is used. ORION: Always uses the same channel.
Gain Control:	RF TWACS: One discrete low level of transmitter power. ORION: Tx Level fixed (+15 dBm at transmitter)
Acquisition retry limit:	HHTR: All transmissions must comply with FCC limits. This includes the acquisition process. Acquisition is attempted on each channel at each power level. ORION: If after the 35 cycles of 11/8/11/8…, the EMTR-2 fails to acquire packets, it shall abandon channel 43A and re-attempt to acquire ORION packets one hour later following the same sequence.
TX Power Amplifier Gain:	No gain is allowed at this time. Only one low power level is used for TX power amplification.
Data Flow:	RMTR: Asynchronous, half duplex. ORION: Burst mode fixed length packet, simplex
Data Format:	RMTR: 8N1, Manchester Encoding ORION: 3-of-6
Modulation:	RMTR: 2 level FSK, +/- 47.5 KHz from center frequency ORION: 2 level FSK, +/- 50 KHz from center frequency
Coding:	RMTR: Biphase-L Manchester encoding ORION: Non Return to Zero - NRZ
Data Rate:	RMTR: 1600 bps ORION: 100 kbps, +/- 1 Kbps
Data Encryption:	RMTR: DCSI proprietary method #1 ORION: Not Encrypted
Maximum Packet size:	RMTR: 17 + 255 bytes (Shall comply with FCC rules) ORION: 150 bits (See section 3.2 for details)
Maximum Packet Transmission Time:	RMTR: (Shall comply with FCC rules) ORION: 2 ms (See section 3.2 for details)
Retry Qty.:	RMTR: Negotiable parameter (0 by default) ORION: 0

Channel	Center Frequency FC (MHz)	Channel Use
1	902.628145	optional
2	902.950726	optional
3	903.273306	session
4	903.595887	session
5	903.918468	session

6	904.241048	session
7	904.563629	session
8	904.886210	session
9	905.208790	session
10	905.531371	session
11	905.853952	session
12	906.176532	session
13	906.499113	session
14	906.821694	optional
15	907.144274	optional
16	907.466855	optional
17	907.789435	optional
18	908.112016	optional
19	908.434597	optional
20	908.757177	optional
21	909.079758	optional
22	909.402339	optional
23	909.724919	optional
24	910.047500	optional
25	910.370081	optional
26	910.692661	optional
27	911.015242	optional
28	911.337823	optional
29	911.660403	optional
30	911.982984	optional
31	912.305565	optional
32	912.628145	optional
33	912.950726	optional
34	913.273306	optional
35	913.595887	optional
36	913.918468	optional
37	914.241048	optional
38	914.563629	optional
39	914.886210	optional
40	915.208790	optional
41	915.531371	acquisition
42	915.853952	session
43	916.176532	session
43A	916.450000	***ORION session***
44	916.499113	session
45	916.821694	session
46	917.144274	session
47	917.466855	session
48	917.789435	session
49	918.112016	session
50	918.434597	acquisition
51	918.757177	session
52	919.079758	session
53	919.402339	session
54	919.724919	session
Channel	**Center Frequency FC (MHz)**	**Channel Use**
55	920.047500	session
56	920.370081	session
57	920.692661	session
58	921.015242	session

59	921.337823	acquisition
60	921.660403	session
61	921.982984	session
62	922.305565	session
63	922.628145	session
64	922.950726	session
65	923.273306	session
66	923.595887	session
67	923.918468	session
68	924.241048	acquisition
69	924.563629	session
70	924.886210	session
71	925.208790	session
72	925.531371	session
73	925.853952	session
74	926.176532	session
75	926.499113	session
76	926.821694	session
77	927.144274	acquisition
78	927.466855	session
79	927.789435	session

**BLOCK DIAGRAM OF THE
INTEGRATED DCSI RF Communication SYSTEM**



2 DCSI RF Communication Overview

This document describes RF communication between the RF TWACS nodes; EMTR-2 transceiver, HHTR transceiver, Badger ORION® RF transmitter, and RMTR-2 transceiver (possible future development). The EMTR-2, Orion, and RMTR-2 are shown in the figure above.

We have chosen an RF technique using a commercial available chip (XEMICS XE1203 TrueRF UHF Transceiver) that employs 2-level FSK modulation to transmit/receive data.

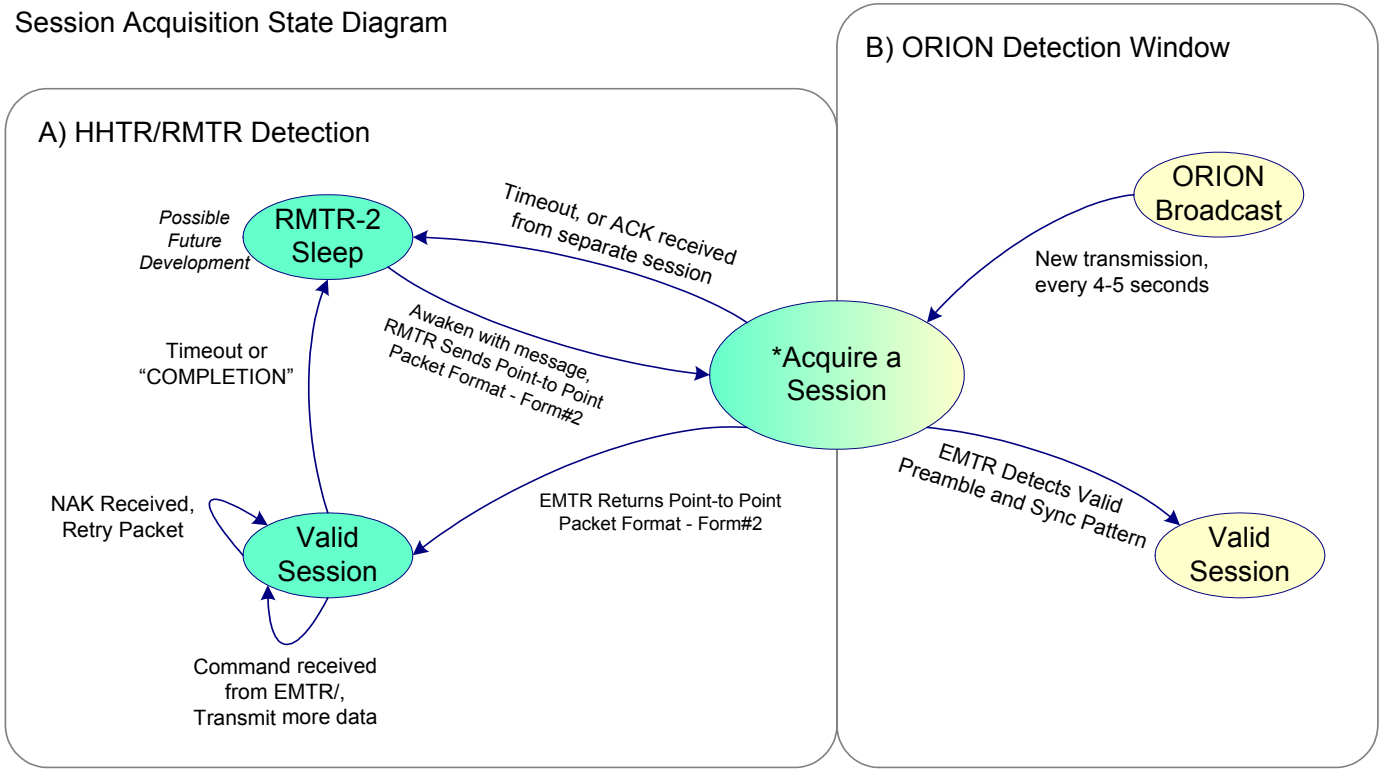
For communication between the RF TWACS nodes (EMTR, RMTR, and HHTR), 5 acquisition and 45 session frequency channels within the 902 to 928 MHz band will be used (Refer to the channel table above). The carrier will frequency hop in order to spread energy within the band, offer protection from multipath fading, as well as to overcome jammers. Message lengths are constrained by FCC requirements that limit the amount of energy placed on a given channel over a period of time.

The EMTR/Orion /HHTR transmitter sections, when communicating with each other, have 1-level-of-gain PA. This is minimized to avoid interference to neighboring systems.

Refer to “RF Transmission: Session Acquisition State Diagram” for an overview of the RF system.

RF Transmission:

Session Acquisition State Diagram

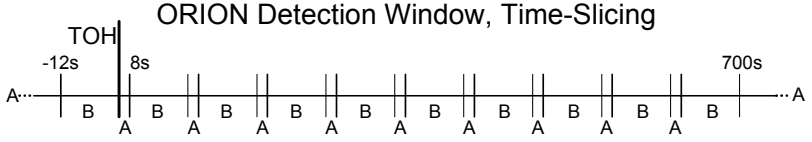


*The EMTR constantly scans for incoming messages while time-slicing between two separate device protocols (See Y56111PDS Rev. -, section: 3.1.4). The following defines the processes within the "Acquire a Session" state above, for the two protocols:

1. HHTR
   a. EMTR scans 5 "link acquisitions channels" searching or a channel with an RSSI energy level significantly higher than the average for the channels.
   b. Attempts to decode training sequence for a preamble.
2. ORION
   a. Scans single ORION channel attempting to decode preamble followed by a sync pattern.

ORION packets contain: ID, status, consumption data, and error detection. No Timestamp!

ORION Detection Window, Time-Slicing



REFERENCES:
Electric Meter Transceiver (EMTR-2) Y56111PDS Rev.(-) pg17
RF TWACS + Orion RF Communications Y56256DS Rev.(-) pg.10

2.1 EMTR-2 Overview

The Electric Meter Transceiver – Model 2 (EMTR-2) is the device that will serve as a gateway to the TWACS network for the remote RF units: Orions and/or RMTRs (possible future development). As shown in the above figure, the EMTR-2 is attached as an option board to the Electronic Module Assembly.

2.2 Orion Overview

The Orion Transmitter is a radio transmitter that is integrated with a water meter. The Orion collects data from the water meter then broadcasts the data packets via RF to the EMTR-2. The Orion data packet includes ID, status, consumption, and error detection.

The ORION broadcasts packets every 4 to 5 seconds with duration of approximately 2 ms each (dependent on temperature). The digital signal frequency is 100 KHz. The ORION transmitter is qualified under 47CFR Paragraph 15.205.

2.3 Packet Reception Timing from Orion & RMTR

To receive from the ORION, which is a single channel device, the EMTR-2 will tune momentarily to channel 43A @ 916.450 MHz listening for packets, beginning 12 seconds before the top of each relative hour, and following a sequence of: 12 s / 8 s / 12s / 8s/… as shown in the diagram below. This means that EMTR-2 will try to acquire an ORION packet for 12 seconds, and then return to scan the 5 acquisition channels for HHTR-2 packets for 8 seconds. The 12/8/… sequences continue for a total time of 700 seconds (35 (12+8) second cycles). This is done for the sake of communications with the HHTR-2 so the operator does not have to wait a long time to acquire an EMTR-2 for reconfiguration.

Since the EMTR-2 + ORION communication differs in frequency, protocol, and timing, the EMTR-2 must handle its communications with the two systems differently. Since the ORION device operates as a one-way, single-channel device, the EMTR-2 has a means to specifically receive data from it in addition to establishing sessions with the HHTR-2.

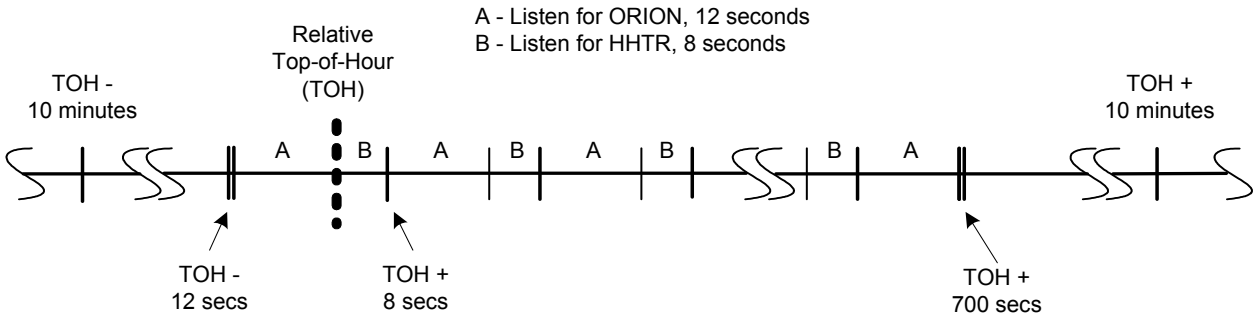
By default, the EMTR-2 constantly listens for a link request from an HHTR-2. The RMTR-2 will attempt to request a link from the EMTR-2 every hour between 10 minutes after and 10 minutes before the minute when it updates its data (with an allowable tolerance). This minute is reflected in the time set for the Hourly Read and is known to both the RMTR-2 and the EMTR-2.

The HHTR-2 can request a link at any time within the hour.

An ORION device broadcasts every 4-5 seconds continuously throughout the day.

Starting at 11 seconds before the minute in which the Hourly Read occurs (Refer to the following diagram - the “Relative Top-of-the-Hour”), the EMTR-2 will tune to Channel 43A (916.450 MHz) and listen for ORION packets. Any received packets will be processed appropriately.

Relative Top-of-the Hour Diagram



2.4 HHTR Overview

The Hand Held Transceiver Model 2 (HHTR-2) is a device that has quite a number of applications. The HHTR-2 is to be used in the following ways:

- Orion installation
- Force link assignment from a given ORION or RMTR-2 to a given EMTR-2
- EMTR-2 Routing Table maintenance during Installation and reconfiguration
- EMTR-2 replacement
- Site surveys
- Transceiver diagnostics
- RMTR-2 installation and configuration, i.e. uploading, editing, and downloading RMTR-2 device configuration tables. (possible future development)

The HHTR communication sequence with the ORION, EMTR-2, and RMTR-2 is described in section 3 and is generally similar to the ORION to EMTR-2 communication sequences.

3 General RF Communications Protocol

Conveying data over a radio link physical medium invariably involves issues with propagation, delays, noise, channel access, and using various techniques to minimize these problems. The major issues are briefly addressed below.

3.1 RF Link Usage

The RF link between TWACS transceivers uses a range of frequencies between 902 MHz and 928 MHz. This range is divided into 79 channels. 50 channels are needed to satisfy the FCC's minimum channel set requirements, so 50 of the 79 are chosen for use. The RF link was designed using a commercially available RFIC Integrated circuits to form a complete UHF transceiver. The RF modulation technique is 2-level FSK.

In the system, 5 of the 50 channels used for an RF session are reserved for link acquisition and the other 45 are used for data 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 data channels are cycled through in a pseudo-random manner while a link is active between transceivers.

From an operation standpoint, the TWACS transceivers can play one of two roles during an RF session. A transceiver that requests a link is a *requesting* transceiver. A transceiver that replies to that request is a *granting* transceiver.

Links are always requested by sending a Request-To-Send (RTS) packet. Links can be granted by sending either a Clear-To-Send (CTS) packet or a Read or Write command packet. Either type of response indicates to a requestor that the link has been granted.

TWACS transceivers can be characterized by these roles:

Transceiver	Type	Can request a link from…	Can grant a link to…
EMTR-2	Granting	None	an HHTR-2 or an RMTR-2 (possible future development)
RMTR-2 (possible future development)	Requesting	an EMTR-2 or an HHTR-2	None
HHTR-2	Both	an EMTR-2	an RMTR

As the above table shows, EMTR-2s never request a link; they are always granting transceivers. By contrast, RMTRs never grant a link; they are always requesting transceivers. The HHTR-2, since it must be able to communicate with both EMTR-2s and RMTRs, can act as either a granting transceiver (with an RMTR) or a requesting transceiver (with an EMTR-2). With respect to the Orion, the EMTR-2 is simply a receiver as the Orion only communicates as a transmitter.

The reason this is important is that *the granting transceiver always controls the frequency hop sequence*. This means that an EMTR-2 always controls the frequency hop sequence. Also, an HHTR-2 will control the frequency hop sequence when communicating with an RMTR. An RMTR-2 never controls the frequency hop sequence.

The distinction between granting and requesting transceivers is strictly operational. It is not a functional difference because the same RF transceiver and RF engine code are used on all transceivers. For example, the EMTR-2 board electronics are capable of acting as a requesting transceiver but its firmware is designed to only act as a granting transceiver.

Since the EMTR-2, HHTR-2 and RMTR-2 all use the same RF engine; the link-level RF code is the same for all of them (with minor differences). The difference in action has to do with whether it is a requesting or granting transceiver. This is more specifically described below.

1. In order to act as a granting transceiver, an EMTR-2 or HHTR-2 must scan the 5 acquisition channels continually, watching for positive-going RSSI. This type of scan is called SCAN_ACQ, for Scan-and-Acquire.

   This is the mechanism used to detect link requests. When an EMTR-2 or HHTR-2 detects positive RSSI on one of the acquisition channels, it begins looking for bits in the RF data stream to find the start sequence (Willard code) and the rest of a packet.

2. By contrast, when an RMTR-2 or HHTR-2 needs to send an RTS packet, it first determines which of the 5 acquisition channels is the quietest. To make this determination, the requesting transceiver scans the acquisition channels once to measure their RSSI. The channel with the lowest RSSI is the quietest channel and used as the first channel for requesting a link.

3.2 Frequency Hopping and Channel Occupancy

When a granting transceiver detects a requestor's RTS packet and grants the link, it sends either a CTS packet or a command packet. This packet will contain the next channel (of the 45) for the requestor to use. The sequence is:

1. a requestor sends its RTS on an acquisition channel

2. the grantor sends a CTS or command packet (containing the next channel) on the acquisition channel
3. the second packet from the requestor will be on the channel specified in the grantor's response packet

The Orion transmitter sends 150 bits per transmission at 100K bits/second. This communication method falls under 47CFR 15.205.

For normal operation, one of the five acquisition channels is used and one of the forty-five data channels are used. The acquisition channels are used between 9 and 45 times as often and the data channels.

3.3 Link Acquisition

There are three different cases when a transceiver needs to acquire a link. These are (a) when an HHTR-2 acquires a link to an EMTR-2, (b) when an RMTR-2 acquires a link to an EMTR-2 (possible future development), and (c) when an RMTR-2 acquires a link to an HHTR-2 (possible future development). Different command codes are used for these cases so that the granting transceiver can determine the requesting transceiver's type. Interaction between the HHTR and either the EMTR-2 or RMTR-2 will occur occasionally as noted in section 2.4.

4 New DCSI RF system (EMTR-2) versus the original RF system (EMTR-1)

Changes from the first DCSI RF system (EMTR-1) to the second DCSI RF system (EMTR-2) are as follows:

1. The addition of receive capability for the Orion product at a frequency of 916.45MHz..
2. RF transmission power output is changed from +6dBm - +8dBm to +6dBm - +10dBm.
3. Antenna changed from a bent wire loop to meander type on a PC board. The new antenna has a maximum gain of +3dBi.