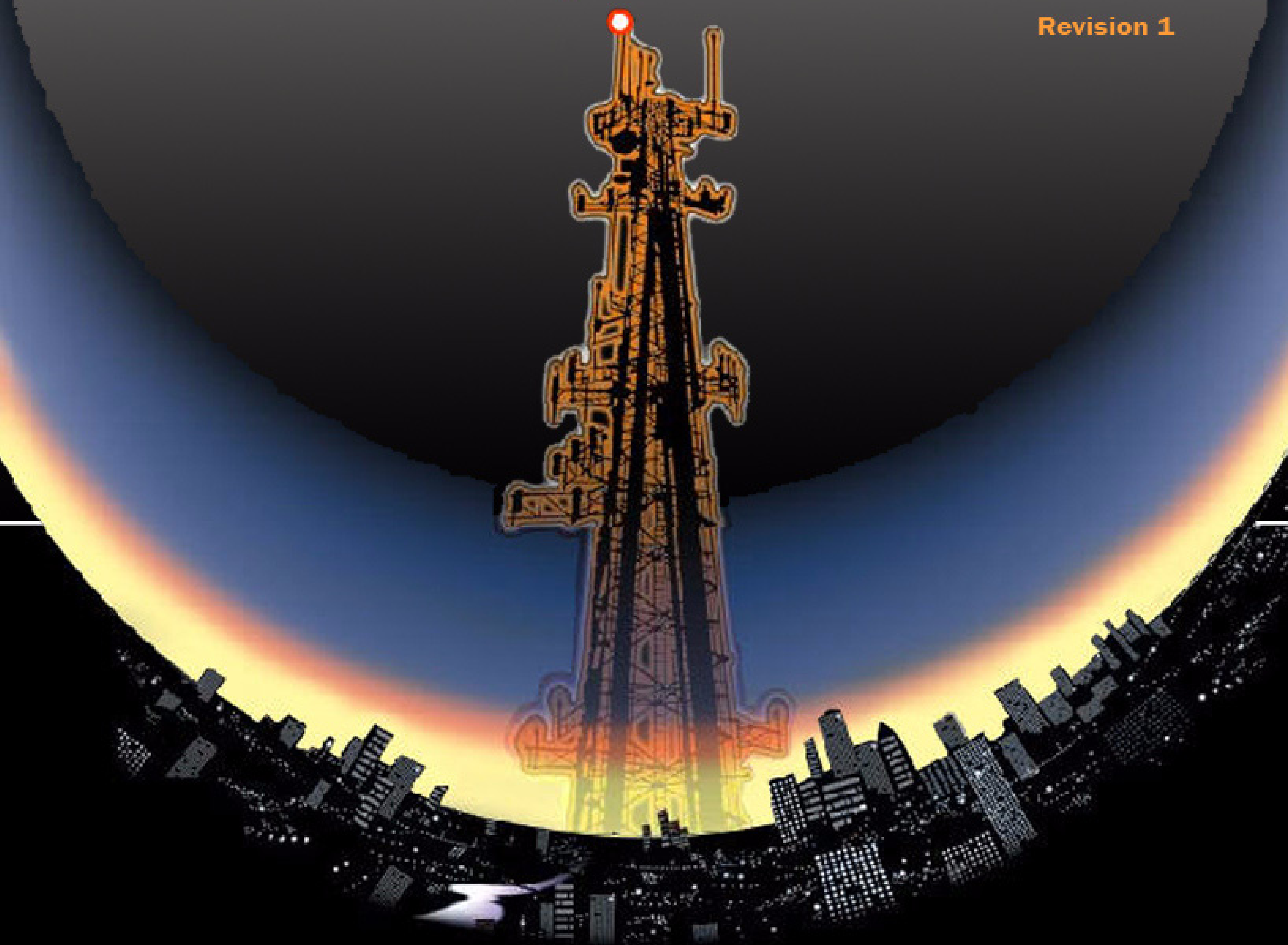
SENSUS METERING SYSTEMS

FlexNet

SmartPoint™ Module for the Elster Alpha® A3 Meter

Revision 1



Revisions

Rev No.	Date	Description
Rev 1	6/26/2008	Updated for hardware and firmware updates to SmartPoint Module.

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Table of Contents

1 Introduction

1.1Purpose

This manual provides technical information for the FlexNet SmartPoint module installed in the Elster A3 meter.

This document is intended for technically qualified personnel of energy supply companies and their contractors who are responsible for the system planning, installation, commissioning, operation, maintenance, decommissioning, and/or disposal of meters.

1.2Safety

WARNING

Hazardous voltages are present while power is applied to meters, meter sockets, or other metering equipment. Any work on the energized equipment presents the danger of electrical shock and can result in death or serious injury. The information contained within this manual is intended to be an aid to qualified metering personnel. It is not intended to replace the extensive training necessary to handle metering equipment in a safe manner.

Use extreme care when servicing the meter while power is applied.

CAUTION

All work on this product should be performed by qualified electricians and metering specialists in accordance with local utility safety practices, utility requirements, and procedures outlined in Chapter 14 of *The Handbook for Electricity Metering, 10th Edition*. Failure to comply with this caution can result in the destruction of or damage to the equipment.

You must observe all industry safety precautions during all phases of operation, service, and servicing of the meters. Failure to comply with these precautions or with specific warnings in this manual violates safety standards of design, manufacture, and the intended use of the metering instrument. Sensus Metering Systems assumes no liability for the customer’s failure to comply with these requirements.

2 SmartPoint Module Overview

2.1 FlexNet SmartPoint Assembly

The SmartPoint assembly consists of a SmartPoint printed circuit board and a separate antenna printed circuit board. A 20-pin connector joins the SmartPoint module to the sensor board.

The SmartPoint module is installed on three plastic standoffs inserted in the sensor board. The antenna is fitted into a slot on the side of the base. A 20-pin connector joins the SmartPoint module to the sensor board.

The FlexNet SmartPoint module contains a micro-controller, a FlexNet transceiver, and a FlexNet AMI antenna. See Section 2.3 for more information on the FlexNet System, and see Appendix A for a more detailed FlexNet SmartPoint overview.

The transceiver operates between 800 and 960 MHz, with each 100 MHz operation band (800, 900 MHz) requiring a slightly different build, using alternate capacitors, inductors, possibility layouts, and antennas.

The authorized SmartPoint bandwidth is 25 kHz.

- The transceiver is capable of multiple on-air modulation formats, including:
- Normal mode, for standard transmissions,
- Message Pass mode for messages optionally repeated by a receiver-capable meter, and
- Poll/Response mode, for providing a clear channel for responses from tower commands.

2.2 Labels

2.2.1 FCC Label

The FCC label may:

- contain patent and part numbers,
- provide relevant FCC Part 15 compliance information for the integrated AMI card,
- describe the operating conditions, or
- contain a warning for disposal in the event that the AMI card contains Mercury.

If installing a new AMI card, this label is attached to the register cover.

2.3 FlexNet System Overview

The FlexNet System enhances the Elster meter by providing Advanced Metering Reading (AMR) capability. See Appendix A for a more detailed overview of the FlexNet SmartPoint.

2.3.1 Description of Operation

The FlexNet data collection and command network is comprised of two parts:

- Local RF Network, and
- Regional Network Interface (RNI).

: FlexNet Fixed Base AMI Network Overview2-1, FlexNet AMI Network Overview, exhibits the general structure of the communications network employed to access and retrieve meter data.

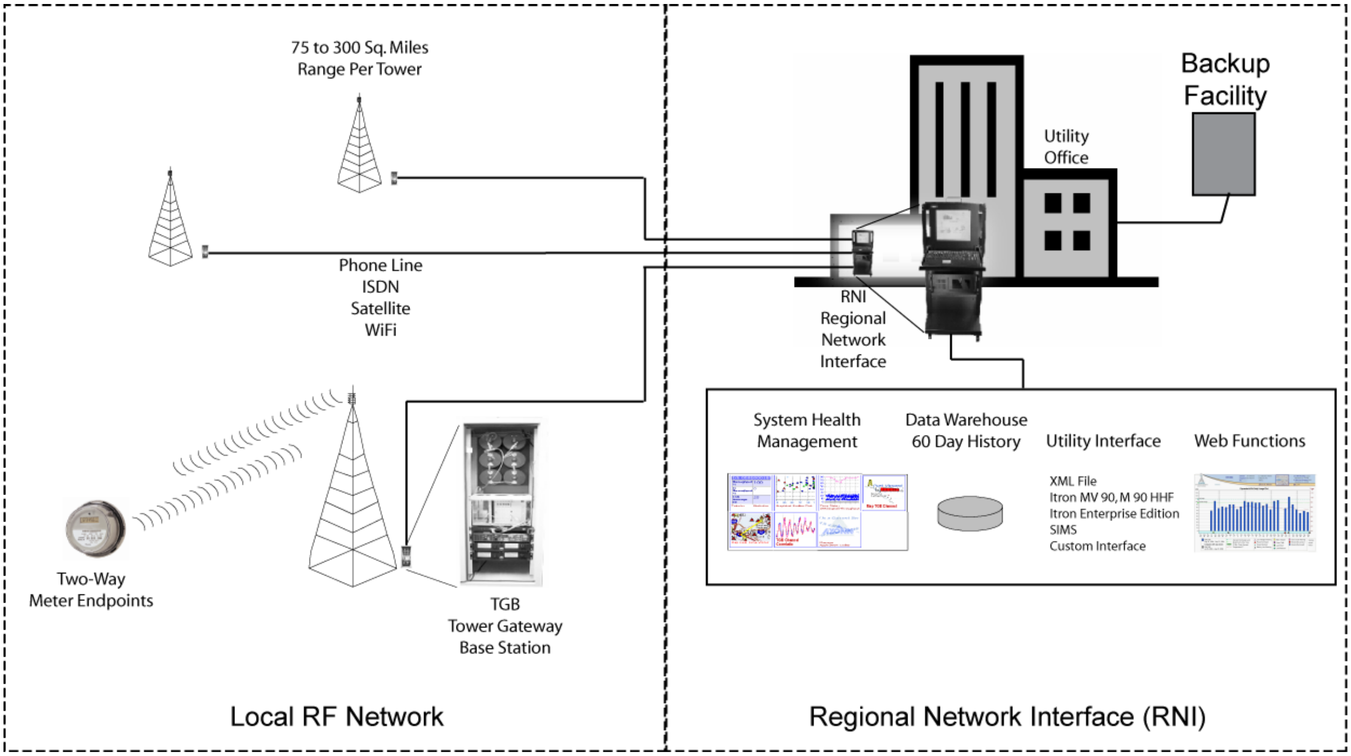

Figure 2-1: FlexNet Fixed Base AMI Network Overview

2.3.2 FlexNet AMI Local RF Network

The Local RF network consists of FlexNet SmartPoint modules (transceivers) located at each meter, and a network of FlexNet Tower Gateway Base Stations (TGBs).

2.3.2.1 Meter Endpoints

The integrated SmartPoint module communicates with the Elster A3 bus to provide internal AMR capability to the Elster meter for use on commercial services. The module:

- directly reads the data in the meter (energy),
- provides control capabilities to reset the meter Demand and operate control relays, and
- monitors service voltage to provide real-time outage and restoration alarms.

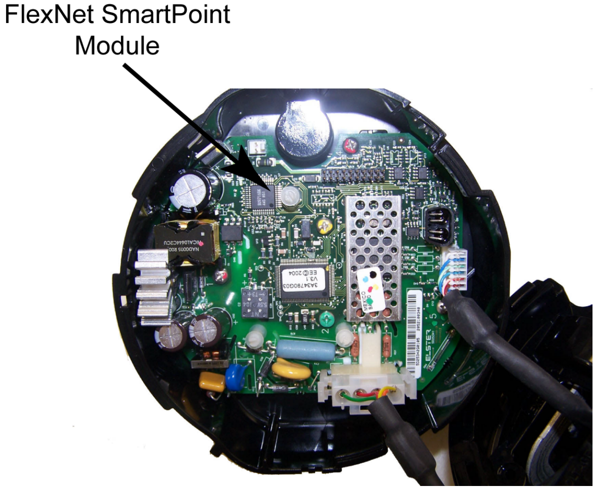

Figure 2-2: Elster Meter with SmartPoint Module Installed

The SmartPoint modules transmit the meter consumption and status information at regular intervals. Critical meter status and power outage alarms are also monitored on a real-time basis. The SmartPoint module transmits the meter data to the fixed network using long-range, licensed, narrowband radio.

The SmartPoint is also able to use mPass Mode, which allows a SmartPoint module to repeat a data transmission from another SmartPoint device that is blocked from the TGB transceiver, and allows the TGB transceiver to communicate with a blocked SmartPoint module through another SmartPoint module.

2.3.2.2 Tower Gateway Base Station

These transmissions are received by one or more TGBs. The TGBs use existing radio towers; antennas are installed at heights of 200’-650’, providing coverage of 75 to 300 sq. mi. The TGB includes a Linux computer that communicates to the RNI (see below) via modem. The TGB forwards the data to the Regional Network Interface (RNI) via phone line, ISDN, Satellite, or WiFi links, and stores the information locally in the event of RNI communications path interruption. The transceiver allows for two-way communication over the FlexNet AMI network, allowing commands to be issued to the SmartPoint modules.

2.3.3 FlexNet AMI Regional Network Interface

The RNI consists of modems and Linux computers with backup power. The RNI controls the TGB sites and keeps a 60-day log of metering data. It also includes an SQL database that generates reports for billing and other external system elements. Interfaces are available to a variety of metering databases: Sensus SiMS, Itron MV-90 and Enterprise Edition. XML and customized interfaces are available.

2.4 SmartPoint Terminology

On-Air Messages (see Chapters 3 and 4). This term is used to describe messages sent by FlexNet endpoint devices. The exception to this is the command message, which carries On Air Commands from the RNI through the TGB to the endpoint (see Section 4.6).

Serial Commands (see Chapter 5). These messages are used to control a FlexNet endpoint device over a serial interface. Many devices have a receive-only inductive coupled interface (called the Mag Loop), while others feature a RS-232 serial interface. This creates a situation where devices receive commands over the serial interface but respond over RF. For example, devices will respond to Ping Commands received on the serial interface by sending a response out of the Flexnet RF interface. Devices that have RS232 interfaces support 2-way serial communications in certain cases, such as when supporting firmware upgrade over the srerial port.

On Air Commands (see Chapter 6): The various types of command messages are used for configuring and querying the endpoint devices.

Ping Commands (see Section 6.2.9): This is a specific On Air Command (Type 8) that is used to query status and readings from the endpoint devices.

For example, to get a meter to send a Setup/Configuration Message (defined in Section 4.3), you send it an On Air Command (7) message with a command-type of Ping (8) and a Ping type Setup (15); the meter will respond with the Setup/Command On Air Message.

3 On Air Message Format

All fields are sent least-significant byte first.

The basic format of the on air message is as shown in the following table:

Bytes (Bits)	Field	Description	Value
0-18	Leader		0xAA
19	Sync	Start of Msg	0x36
20-23(0:3)	Meter ID		
23(4:7)	Customer ID		0x0
24	Control	Control: 4 bits; Flags: 4 bits	
25	Length		0x03 – 0xFF
26	Repeat Level/Status	Repeat Level: 2 bits; Status: 6 bits	
27	App Sequence		
28	App Code		
29-56	App Data	0-252 bytes, currently fixed at 28 bytes	
57-60	CRC		

3.1 Field Definitions

3.1.1 Message Leader

This is a repeating stream of the value 0xAA used by the receiver to trip and synchronize to the transmitted message. The leader is 152 bits or 19 bytes long.

3.1.2 Sync

8 bit Start of Message signal (0x36).

3.1.3 Meter ID Number

A unique identifier, different and fixed for each end point device, 28 bits long.

3.1.4 Customer ID

4 Bits of Customer ID.

3.1.5 Control

Provides status data to the receiver.

Bits	Control
0-3	RF Sequence Number
4	AC Power Failed
5	Power Restored
6	Low Battery Detected
7	Payload Encrypted

3.1.5.1 RF Sequence Number

A 4 bit modulo 16 counter, increments each RF transmission.

3.1.5.2 AC Power Fail

Set if AC Power is not present. In AC only powered end point devices, set in Last Gasp messages.

3.1.5.3 Battery Low

Tested under load, this bit is set if the input voltage is below a certain threshold. The bit is valid on next transmitted message.

3.1.5.4 Power Restore

Set in the first new message after a power up, cleared otherwise.

3.1.5.5 Payload Encrypted

Set if the payload data has on-air encryption turned on, cleared otherwise.

3.1.6 Length

The number of remaining data bytes in the on air message not including the CRC bytes. Initially, there will be 1 fixed value of length to facilitate receiver firmware functionality: 31 bytes.

3.1.7 Repeat Level / Status

Bits	Repeat Level / Status
0	History Overflow
1	In Time Sync
2	Tamper
3	Brown Out
4	Meter Read Failure
5	RF Sequence Number MSB
6-7	Repeat Level

3.1.8 Application Sequence

An 8 bit modulo 256 counter that increments every time new application data is transmitted by the end point device.

3.1.9 Application Code

An 8 bit code used to determine the format of the data in the Application Data field.

3.1.10 Application Data

Between 0 and 252 bytes of application data in the future, fixed at 28 for now.

3.1.11 CRC

The 32 bit CCITT Cyclical Redundancy Check sum of all of the bytes from the ID field to the last Application Data field. Allows for bit error detection and single bit error correction.

3.2 On Air Time Requirements

On air messages take differing amounts of airtime depending on modulation format. The message length of every message is fixed at 31 bytes. The table below shows the transmission time for each combination:

Modulation	Error Correction	Rate (Hz)	Msg Time (msec)
Normal Baud	Interleaved, Convolutionally Encoded	8044.5544	107.40
mPass Baud	Interleaved, Convolutionally Encoded	5000.0000	157.60
Boost Baud	Interleaved, Convolutionally Encoded	804.4554	1074.02
Half Baud	Interleaved, Convolutionally Encoded	4022.2772	214.80

3.3 Addressing

Endpoint addresses are also called Meter ID, FlexNet ID, or Tx ID. In a FlexNet protocol packet, the endpoint address is carried in the Meter ID field defined above.

3.3.1 Command Addressing

The Receiver will accept commands that are addressed to it via the Device ID of the on air message. The three accepted addresses are one that matches its own Device ID, one using the Broadcast Address, or, lastly, one using the Group Address.

3.3.2 Broadcast Addressing

A message sent with the Broadcast Address, which is all 1's or 0xFFFFFFF = 268435455, is processed by all meters if the message is a command type that can be broadcast. Broadcast messages are not acknowledged.

3.3.3 Group Addressing

FlexNet group addressing can follow one of two conventions.

3.3.3.1 Group Addressing, Preferred Method

The preferred method is to set the Group Address Indicator bit in the Repeat Level/Status byte as described in Section 3.1.7 and then place the destination group address in the Meter ID Number field as described in Section 3.1.3. All modern FlexNet endpoints support this method. This does not work with early FlexNet devices.

3.3.3.2 Group Addressing, Legacy Method (deprecated)

A message sent with the Tx Id Number field set to Group Address, which is all 1's except for the last bit or 0xFFFFFFE = 268435454 is a legacy Group Addressed message. For legacy group addressed messages except for Ping Command types, the group address is found at byte offset 23-26 of the application data. For Ping Command messages, the group address is found at byte offset 9-12 of the application data, see Section 5.3.4.

4 On Air Message Types

All fields are sent least-significant byte first unless otherwise specified.

The format of the data in the Application Data field dependent on the value of the Application Code field as follows and is always 28 bytes in length.

4.1 On Air Message Types

Application Code	Message
220	Testing Message
1	Meter Setup and Configuration
5	Serial #/Postition Binding
6	GPS Mapping Message
8	Buddy Information Message
13	C&I Meter Read with History
14	C&I Tier Data
15	C&I C12.19 Tunneling Read
16	C&I Alarm Message
22	Extended Setup Information
25	Demand History Message
28	Load Profil Meta Data
29	Load Profile Block Data
30	Firmware Image Check
38	High Res. C&I Meter Read with History
48	Generic Ping Response
55	C&I High Res Read with Pulse Data
57	Scratch Pad Image Check

4.2 Testing Message – App Code 220

Message Format: This is a test only message and has mostly static Application Data. Application Data byte 1 has a sequence counter field which counts up one every time the 4 bit sequence counter in the control byte rolls over (every 16 messages). The Application Data below show an example of the Testing Message with a sequence number of 0x64:

```
0x00640001020304050607080900a0b0c0d0e0f10111213141516171819
```

4.3 Meter Setup / Configuration Message—App Code 1

Message Format: After an end point is configured to read meter data, it transmits a Meter Setup / Configuration message containing a report on how it is configured; it has the following Application Data field format:

Byte (Bits)	Field
0	Firmware Version
1	Device Type
2 (0:2)	Meter Sample Rate
2 (3:7)	Supervisory Transmit Rate
3	Base Frequency
4-5	Transmit Channel A
6-7	Transmit Channel B
8-9	Transmit Channel C
10-11	Transmit Channel D
12-13	Receiver Channel
14-15	Boost Mode Channel
16 (0:3)	Boost Mode Sub-Channel
16 (4)	Boost Mode Hopping
16 (5:7)	Transmit Channel Mask
17 (0:3)	Transmitter Operational Mode
17 (4:6)	Receiver Operational Mode
17 (7)	Enable Encryption
18-19	Real Time Clock
20-21	TXCO Correction
22-24	A/D Calibration
25	Minimum Click Duration
26 (0:5)	Minimum Voltage Threshold
27 (0:3)	Outage Time Threshold

Byte (Bits)	Field
27 (0:3)	Outage Time Threshold
27 (4:7)	Restored Time Threshold

Specific definitions for these fields are shown in Chapter 5, with the exception of the first two fields, Firmware Version and Device Type. Firmware version contains the version of the firmware of the device. If the most significant bit of Firmware version is set, the firmware is a beta test set.

The **Device Type** is currently defined as Device Type 5.

4.4 Meter Serial Number/Position Binding—App Code 5

4.4.1 Message Format

This message contains the meter Serial Number and also the installation latitude and longitude (if position is programmed in at installation time). The message has the following format.

App Data Byte	0	1-13	14-17	18-21	22-23	24
Data	Status Flags	Meter Serial Number	Latitude	Longitude	Programmer ID	Setup Flags

4.4.2 Status Flags

Only bit 0 is currently used and is the Just Programmed Bit. It is set if the device has received a static setup in the last 5 minutes. The remaining bits are (reserved) and are set to 0.

4.4.3 Meter Serial Number

A 13 byte field containing the ASCII Serial Number reported by the end point device's associated meter display board.

4.4.4 Latitude / Longitude

These fields contain a floating point representation in degrees of the end point device's installation latitude and longitude. These fields are set using the installer with the installation tool, the end point has no on board GPS capability.

4.4.5 Programmer ID

The 16 bit ID of the handheld programmer used to setup the device.

4.4.5.1 Setup Flags

An 8 bit field indicating which setup messages have been received by the device. The individual bits in the byte are defined below:

Bit	Setup Message Received
0	Set ID
1	Static Setup
2	Set Crystal Offset
3	Set Lat / Long
4	Set Meter Reading
5	Set Voltage Quality Levels
6	Set Encryption Key
7	(reserved)

4.5 GPS Mapping Message

4.5.1 Message Format

This is a special message used for radio coverage mapping and requires an attached GPS module. Bytes 16 to 27 are reserved.

App Data Byte	Data
0-2	Reserved
3-5	Latitude (MSB First)
6-8	Longitude (MSB First)
9-10	Speed
11-12	Heading
13-14	Altitude

4.5.1.1 Latitude

These fields contain a representation, in degrees of the end point device's installation latitude as presented by the attached GPS module. The actual latitude can be calculated using the following formula:

```
Latitude (degrees) = (3 Byte App Data Latitude) * 90.0/8388608
```

Negative values are in the southern hemisphere; positive values are in the northern hemisphere.

Longitude

These fields contain a representation in degrees of the end point device's installation longitude as presented by the attached GPS module. The actual longitude can be calculated using the following formula:

```
Longitude(degrees) = (3 Byte App Data Longitude) * 180.0 / 8388608
```

Negative values are in the western hemisphere, positive values are in the eastern hemisphere. For example, an App Data Latitude of 0x bff2d7 yields a latitude in degrees of -90.07229, or 90.07229 West.

4.5.1.2 Speed

This field contains the velocity of the endpoint device in 0.01 knot resolution and is sent LSB first.

4.5.1.3 Heading

This field contains the device's heading in 0.01 degree resolution and is sent LSB first.

4.5.1.4 Altitude

This field contains the device's altitude in 0.1 meter resolution.

4.6 Command Message—App Code 7

4.6.1 Message Format

This is a Command Message sent by a TGB (Tower Gateway Basestation) or a repeating two-way device. The format of bytes 1-27 are variable based upon command type.

App Data Byte	0	1 - 27
Data	Command Type	Command Data

4.6.2 Command Type

This field contains the type of data in the command as shown below, specific formats for each message can be found in Section 6.2, Receiver On-Air Command Formats.

4.7 Buddy Message—App Code 8

4.7.1 Message Format

This is a message sent by a relaying two way transmitter sent after repeating a message in order to build routing information in the central database. Meter reading data from the repeating device has been added to the previously unused portion of the Buddy Message for extra system redundancy. The format of the Buddy Message is shown below:

App Data Byte	Data
0-3	Buddy ID
4	Buddy App Code
5	Buddy RF Sequence
6	Buddy App Sequence
7	Received Signal Level
8	Received Noise Level
9 (0:6)	Queue Time
9 (7)	Extended Buddy Report
10-11	Relative Time Stamp
12-14	Current Reading
15-27	History Samples

If the Extended Buddy Report bit is set, bytes 10 to 27 are set as follows:

App Data Byte	Data
10	Embedded App Code (13)
11-12	Relatvie Time Stamp
13-15	Delta Data Type/Current Reading
16-19	Peak Demand
20-27	History Samples

4.7.2 Buddy Id

This field contains the Id of the unit that has been relayed.

4.7.3 Buddy Fields

These fields represent the values received in the message from the device that has been buddy relayed.

4.7.4 Queue Time

The time in seconds that the buddy device stored the message before forwarding it.

4.7.5 Meter Reading Fields

These fields, Relative Time Stamp, Current Reading and History Samples have the same format as that defined in the Type 12 Meter Read Message.

4.8 C&I Meter Read With History—App Code 13

4.8.1 Message Format

This is the standard meter reading message and has the following format:

App Data Byte	0-1	2-4	5-8	9-11	12-27
Data	Relative Time Stamp	Delta Data Type / Current Reading	Peak Demand Reading	Phase A, Phase B, Phase C Voltage	History Samples

4.8.2 Relative Time Stamp

16 bits of byte 0-1, elapsed time since last meter reading. Time is always represented in two-second resolution.

4.8.3 Delta Data Type

3 bits, bits 0-2 of byte 2. Used to define the amount of time represented by each History Sample in bytes 8-27. The valid values for Delta Data Type are defined in the table below.

Delta Data Type	History Samp Interval (min)	Max Pulses per Interval	Likely Transmit Rate
0	5	28.33	30 min
1	15	85.00	1 Hr
2	60	340.00	4 Hr
3	360 (6 Hours)	2040.00	6 Hr
4	720 (12 Hours)	4080.00	12 Hr
5	1440 (24 Hours)	8160.00	12 Hr

4.8.4 Compression Enabled

1 bit, bit 3 of byte 2. If set, the History Sample in bytes 8-27 are sent in the data compression enabled format. If cleared, the History sample bytes are sent in the fixed bin width format.

4.8.5 Current Meter Reading

20 bits, bits 4-7 of byte 2 and all of bytes 3 and 4. The total power consumption represented in binary in kWh.

4.8.6 Peak Demand Reading

32 bits, all of bytes 5-8. The peak demand reading is represented as a four byte floating point number in W.

4.8.7 Phase A, B and C Meter Voltages

Three 8 bit fields containing meter line voltage readings of the voltage for all available phases at the time of the meter reading. The values in the fields can be converted to voltage using the following formula which provides voltages from 50 to 560 volts:

```
Voltage = Value*2 + 50
```

4.8.8 Compression Enabled History Samples

All bits of bytes 12-27 compressed using a Huffman Binary Tree compression algorithm. As many History Sample bins as possible are packed into the remaining space in the on air message, up to 136 bins in the minimum case. Each history sample is stored as the difference from the last reading.

The Codex used to encode the histories is shown in the following table:

Key Bit Pattern (binary)	History Value	Required Number of Bits	Comment
0	0	1	
10	1	2	
110	2	3	
1110	3	4	
11110	4	5	
111110	5	6	
1111110xxxxx	6-37	11	If 0x7E is detected, the next 5 bits + 6 = value
11111110xxxxxxxxxxxxx	38-8213	21	If 0xFE is detected, the next 13 bits + 38 = value
11111111	N/A	N/A	End of usable history, end history processing

Scanning begins at bit 0 of byte 0 and goes to ms bit of byte 0 before rolling down to the ls bit of byte 1 on through the history buffer..

To decode, scan through the buffer counting consecutive 1’s. When a 0 is reached, that denotes the end of the Key Bit Pattern. The number of consecutive ones indicates the specific symbol.

If the end of the buffer is reached before a complete valid symbol is reached, ignore that history value.

4.8.9 Fixed Bin Width History Samples

All bits of bytes 12-27. As many History Sample bins as possible are packed into the remaining space in the on air message. Each history sample is stored as the difference from the last reading. Note: A residential meter at maximum load can generate 346 counts per hour. The size and number of History Sample bins in the message are determined by the Delta Data Type field are shown in the following table (6-7 are reserved).

Delta Data Type	History Sample Interval (min)	Max Pulses per Interval	Required # Bits	# Available Bins	Total History (Hours)	Likely Transmit Rate
0	5	28.33	5	25	2.333	30 min
1	15	85.00	7	18	5	1 Hr
2	60	340.00	9	14	16	4 Hr
3	360 (6 Hours)	2040.00	11	11	78 (3.25 days)	6 Hr
4	720 (12 Hours)	4080.00	12	10	144 (6 days)	12 Hr
5	1440 (24 Hours)	8160.00	13	9	264 (11 days)	12 Hr

4.9 C&I Tier Data—App Code 14

4.9.1 Message Format

This message is used to transmit tier data from the C12.19 Standard Table 23 and has the following format (Note that Tier 7 is a special case to report Service Quality and has a different format).

App Data Bytes	Data
0	Tier Information
1 (0:5)	Meter Type
1 (6:7)	Selected Data Table
2-4	Data Flags / Peak Demand Time
5-8	Summation Reading (10^3 resolution)
9-12	Demand Reading (10^0 resolution)
13-16	Cumulative Demand Reading (10^2 resolution)
17-20	Coincident Reading (10^3 resolution)

App Data Bytes	Data
21	# Demand Resets
22	Summation Source Index
23	Demand Source Index
24	Coincident Source Index
25	Quantity of Tier Information

4.9.2 Tier Information

8 bits of byte 0 (bit 7 is reserved). Used to identify the tier and sub tier of the data in this message. A separate message is sent for each Tier and SubTier configured in the meter as defined in the following tables:

Bits	Description
0-2	Tier
3-6	Sub Tier
7	(reserved)

4.9.2.1 Tier

Bits 0-2 of the Tier Information byte is defined in the following table:

Value	Tier
0	Totalization
1	Tier A
2	Tier B
3	Tier C
4	Tier D
5-6	(reserved)
7	Service Quality

4.9.2.2 Sub Tier

Bits 3-6 of the Tier Information byte is used when individual Tiers have more than one Summation, Demand or Coincident reading in a single Tier

4.9.3 Meter Type

Lower 6 bits of byte 1. The type of data and unit of measure reported in the tier data message is dependant on the meter type as defined below:

Value	Meter Type
0	(reserved)
1	Elster A3R
2	Elster A3K
3	Elster A3D
4	Elster A3T
5	Elster A3Q
6-255	Reserved

4.9.4 Selected Data Table

Upper 2 bits of byte 1. This selects data from table ST-23, ST-24, or ST-25:

Value	Table
0	ST-23 Standard Data Table
1	ST-24 Previous Season Data Table
2	ST-25 Demand Reset Data Table
3	Reserved

4.9.5 Data Flags / Peak Demand Time

Bytes 2-4. Data flags which data fields are available in this message. Peak Demand Time contains the time and date of the Peak Demand.

Byte (Bits)	Description
2 (0)	Cumulative Demand Type: 0 – Cumulative 1 – Continuously Cumulative
2 (1)	Summation Available This Message 0 – No 1- Yes
2 (2)	Demand Available This Message 0 – No 1- Yes
2 (3)	Coincident Available This Message 0 – No 1- Yes

2 (4-7)	Peak Demand Month 0-11 = Jan-Dec
3 (0-4)	Peak Demand Day 1-31 = 1st to the 31st
3 (5-7), 4 (0-1)	Peak Demand Hour 0-23 = Midnight to 11:00pm
4 (2-7)	Peak Demand Minute 0-59

4.9.6 Summation Reading (10^3 resolution)

Bytes 5-8. The Summation for this Tier and Sub Tier in represented as a floating point number in kilo resolution.

4.9.7 Demand Reading (10^0 resolution)

Bytes 9-12. The Demand for this Tier and Sub Tier represented as a floating point number in 10^0 unit resolution.

4.9.8 Cumulative Demand Reading (10^3 resolution)

Bytes 13-16. The Cumulative Demand Reading for this Tier and Sub Tier represented as a floating point number kilo resolution. Whether this value is Cumulative or Continuously Cumulative is defined by Bit 0 of Byte 1.

4.9.9 Coincident Reading (10^3 resolution)

Bytes 17-20. The Coincident Reading for this Tier and Sub Tier represented as a floating point number in kilo resolution.

4.9.10 # Demand Resets

All bits of Byte 21. The number of Demand Resets detected by the meter.

4.9.11 Source Indices

The definitions for the ANSI C12.19 Source Index fields (bytes 22 to 25) are based upon the Meter Type in byte 1. The Source Index definitions are meter-manufacturer specific. Refer to the Elster A3 technical manual for the meter's ANSI C12.19 details.

4.9.12 Quantity of Tier Information

8 bits of byte 23 (bit 7 is reserved). Used to report the total number of tiers and sub tiers in all of the tier data in this messages as defined in the following tables:

Bits	Description
0-2	Number of Tiers
3-6	Number of Sub Tiers
7	Reserved

4.9.12.1 Number of Tiers

Bits 0-2 of the Quantity of Tier Information byte which represent the number of reported tiers not including the Totalization tier. For example, if Tiers A,B,C, and D were configured in a meter, then Number of Tiers would be set to 4. 5 sets of tier information would actually be sent, 1 for the Totalization, and 1 for each of the 4 tiers.

4.9.12.2 Number of Sub Tier

Bits 3-6 of the Quantity of Tier Information byte which represent the number of Sub Tiers sent for each tier. The minimum is 1, the maximum is 10.

4.9.13 Service Quality Message Format

This message is used to transmit Service Quality and is identified by being special Tier number 7.

App Data Bytes	Data
0	Tier Information (Tier = 7, SubTier Field reserved)
1-2	Service Frequency (0.1 Hz resolution)
3-4	RMS Amps Phase A (0.1 Amp resolution)
5-6	RMS Amps Phase B (0.1 Amp resolution)
7-8	RMS Amps Phase C (0.1 Amp resolution)
9-10	RMS Volts Phase A (0.1 Volt resolution)
11-12	RMS Volts Phase B (0.1 Volt resolution)
13-14	RMS Volts Phase C (0.1 Volt resolution)
15-16	Phase Angle B-A (0.1 degree resolution)
17-18	Phase Angle C-A (0.1 degree resolution)
19-20	Power Factor Angle Phase A (0.1 degree resolution)
21-22	Power Factor Angle Phase B (0.1 degree resolution)
23-24	Power Factor Angle Phase C (0.1 degree resolution)

4.10 C&I Tunneling Read—App Code 15

Message Format: This message is used to transmit raw C12.19 table data in response to a C12.19 Table Read Command. The Application Sequence number of this message matches that of the Table Read Command. The C12.19 table and offset of the raw data also match the command. If the number of returned bytes is 0, then an error has occurred reading the table.

App Data Bytes	Data
0	Number of returned bytes
1-27	Raw Data bytes

4.11 C&I Alarm Message – App Code 16

4.11.1 Application Data

This message contains alarm data from the meter and is also used to report power failures.

App Data Bytes	Data
0	Voltage Phase A
1	Voltage Phase B
2	Voltage Phase C
3	Click Count
4	Time Since Event
5-6	Extended Time Since Event
7-9	Current Reading
10	Device Temperature
11	µP Errors
12	Lock Errors
13-14	Meter Alarm Flags
15	# Manual Demand Resets
16-19	Time of Last Power Fail
20-23	Time of Last Power Restore
24	Total # of Outages
25	Flags

4.11.2 Voltage Phase A,B, and C

The current voltage reported by the meter for all three phases:

```
Voltage Phase n = Value*2
```

4.11.3 Click Count

An 8 bit field containing the number of times AC voltage loss has been detected by the meter.

4.11.4 Time Since Event

An 8 bit fields containing the time in 6 second resolution since a power failure or power restoration actually occurred.

4.11.5 Current Meter Reading

20 bits, of the meter setting. All 6 decimal meter digits represented in binary.

4.11.6 Extended Time Since Event

A 16 bit fields containing the MS two bytes of Time Since Event in 1536 second resolution since a power failure or power restoration actually occurred. This yields over 3 years of possible measurement. The overall Time Since Event can be calculated using the following formula:

```
Total Time Since Event = (Extended Time Since Event)* 1536 + (Time Since Event)*6
```

4.11.7 Device Temperature

An 8 bit signed value containing the current device temperature in degrees Celsius.

4.11.8 µP Status

Microprocessor Status, 8 bits with 3 fields. RAM and ROM Tests are run once at boot-up. Processor Rests is a one up counter that increments once every time the microprocessor is reset. This field is cleared by a static setup message. The bit fields are defined in the table below:

Bits	Description
7:6	Reserved
5	RAM Test Failed
4	ROM Test Failed
3:0	Processor Resets

4.11.9 Lock Errors

Voltage Controlled Oscillator Errors, 8 bits with 2 fields. Rx Calibration Errors is a one up counter that increments once every time the receiver chip is commanded to calibrate and fails. Synthesizer Lock Failures is a one-up counter that increments once every time the transmitter is commanded to lock to a frequency and fails. These fields are cleared by a static setup message. The bit fields are defined in the table below:

Bits	Description
7:4	Receiver Calibration Errors
3:0	Synthesizer Lock Failures

4.11.10 Alarm Data

All bits, bytes 13-14. The Alarm provides 16 bit fields, each of which can represent a different failure mode as shown in the table below.

Byte, Bit	Description
13, 0	Meter Unprogrammed
13, 1	Configuration Error
13, 2	Self check Error
13, 3	RAM Failure Error
13, 4	ROM Failure Error
13, 5	NONVOL Error
13, 6	Clock Error
13, 7	Measurement Error
14, 0	Low Battery Error
14, 1	Low Loss Potential
14, 2	Demand Overload
14, 3	Power Failure
14, 4-7	Reserved

4.11.11 Time of Last Power Failure

The time and date of the last power failure, as defined in the table below:

Byte	Description
15	Month (1-12)
16	Day (1-31)
17	Hour (0-23)
18	Minute (0-59)

4.11.12 Total # of Outages

The total number of outages since meter was configured.

4.11.13 Flags

An eight-bit field containing two status flags, one indicating an EEROM is available on the board, and another indicating that the temperature exceeds the programmed threshold.

Bits	Description
7:2	Reserved
1	Hot Socket Alarm
0	Interval EEPROM Available

4.12 Demand History Message—App Code 25

4.12.1 Message Format

This message is sent in response to Demand Reset commands and Demand History pings. All values are read from C12.19 tables in the meter including date and time. The message has the following Application Data field format:

Byte (Bits)	Field
0	Number of Demand Resets
1(0:3)	Last Demand Reset Month (1-Jan -> 12 Dec)
1(4:7), 2(0)	Last Demand Reset Day (1-31)
2(1:5)	Last Demand Reset Hour (0-23)
2(6:7),3(0:3)	Last Demand Reset Minute (0-59)
3(4:7)	Last Peak Demand Month (1-Jan -> 12 Dec)
4(0:4)	Last Peak Demand Reset Day (1-31)
4(5:7),5(0:1)	Last Peak Demand Reset Hour (0-23)
5(2:7)	Last Peak Demand Second (0-59)
6-9	Last Peak Demand (floating point Watts)
10-13	Last Consumption Reading
14(0:3)	2nd Demand Reset Month (1-Jan -> 12 Dec)
14(4:7), 15(0)	2nd Demand Reset Day (1-31)
15(1:5)	2nd Demand Reset Hour (0-23)
15(6:7),16(0:3)	2nd Demand Reset Second (0-59)
16(4:7)	2nd Peak Demand Month (1-Jan -> 12 Dec)
17(0:4)	2nd Peak Demand Day (1-31)

Byte (Bits)	Field
17(5:7),18(0:1)	2nd Peak Demand Hour (0-23)
18(2:7)	2nd Peak Demand Second (0-59)
19-22	2nd Peak Demand (floating point Watts)
23-26	2nd Consumption Reading (floating point Wh)

4.12.2 Number of Demand Resets

Number of times this meter reports that it has had it's Peak Demand reset.

4.12.3 Last Demand Reset Date and Time

The time and date that this meter last had its' demand reset via on air command.

4.12.4 Last Peak Demand Date and Time

The time and date of the Peak Demand immediately prior to the last demand reset.

4.12.5 Last Peak Demand

A 4 byte floating point representation of the Peak Demand immediately prior to the last demand reset.

4.12.6 Last Consumption Reading

A 4-byte floating point number in Wh.

4.12.7 2nd Demand Reset Date and Time

The time and date that this meter last had its' demand reset via on air command prior to the last demand reset.

4.12.8 2nd Peak Demand Date and Time

The time and date of the Peak Demand immediately prior to the last peak demand.

4.12.9 2nd Peak Demand

A 4 byte floating point representation of the Peak Demand immediately prior to the last peak demand.

4.12.10 2nd Consumption Reading

A 4-byte floating point number in Wh.

4.13 Load Profile Metadata Message—App Code 28

Message Format: This message is sent in response to a Load Profile Metadata ping. All values are read from C12.19 tables in the meter. Elster document "DD228-01.05/01.02 A3 Tables for 3rd Party Developers" can be used as additional reference. The references ST-xx and MT-xx represent C12.19 Standard Table xx and Manufacturer's Table xx respectively. The message has the following Application Data field format:

Byte (Bits)	Field
0 (0:6)	Reserved
0 (7)	LP Read Failure
1-2	Number of Blocks Set (ST-61)
3-4	Number of Intervals Per Block (ST-61)
5	Number of Channels (ST-61)
6	Interval Size (minutes) (ST-61)
7	Adjusted Kh Scale Factor,power of 10 (MT-15)
8-13	Adjusted Kh (MT-15)
14	Adjusted p/r (MT-15)
15	Unit of Measure (MT-17)
16	Flow (MT-17)
17-21	Block End Time, Year,Month, Day, Hour Minute (ST-64)
22-23	Simple Interval Status (ST-64)

4.14 Load Profile Block Data Message—App Code 29

Message Format: This message is sent in response to a Load Profile Block Data ping. All values are read from C12.19 tables in the meter. Elster document "DD228-01.05/01.02 A3 Tables for 3rd Party Developers" can be used as additional reference. The message contains raw interval block data, and as many messages as necessary are sent to complete and entire block. The length of the block can be determined using the following equation using variables from the Load Profile Metadata Message:

```
SizeOfBlock = 5 + ((NumberOfIntervalsPerBlock + 7)/8) + (NumberofChannels * 2)) *
                         NumberofIntervalsPerBlock)
```

The app sequence number in the FlexNet header is set to the LSB of the LP block's sequence number, as calculated based on Last_Block_Seq_Num - N (where N is the requested block number).

The format of the message is as follows:

Byte (Bits)	Field
0 (0:3)	Message Sequence Number
0 (4:6)	Number of Messages
0 (7)	LP Read Failed
1 - n	LP Samples, from ANSI C12.19 table ST-64
n+1 - n+4	(Last Message Only) The ANSI C12.19 Sequence Number of the Block Requested

4.15 Firmware Image Check Response—App Code 30

Message Format: The device responds back to the download host with a Firmware Image Check Response packet containing the number of bad blocks in the response, followed by a sequence of block numbers (word-sized, 2 bytes each, little endian) which have not been received by the device since the last Load Start message was received. If all blocks have been received and the CRC is correct, the response contains only the sub-command and a single byte of 0. If the CRC is incorrect, but the device has received all blocks, the response contains the sub-command, a single byte of 1 and 2 bytes of 0xFFFF. The format of the Firmware Image Check Response is:

App Data Byte	0	2	2-n
Data	App Code = Firmware Image Check Resp (30)	# of bad blocks	List of Block Numbers

4.16 High Res C&I Meter Read with History—App Code 38

Message Format: The device sends this message in response to a

4.17 Generic Ping Response—App Code 48

The generic ping response is sent in response to pings which do not generate on-air message types. The ping response sub-type identifies the type of ping response.

App Data Byte (Bits)	Field
0	Ping Response Sub-Type
1-27	Ping Response Data

Currently defined ping response sub-types are descibed in the following sections:

4.17.1 Demand Enable Status/Interval Configuration

Ping Response to Data Byte (Bits)	Field
0 (0)	Message Sequence Number
0 (1:7)	Number of Messages
1	LP Read Failed
2	LP Samples, from ANSI C12.19 table ST-64
3	(Last Message Only) The ANSI C12.19 Sequence Number of the Block Requested
4 - 26	Reserved

4.17.2 TOU Enable Status/Tier and Season Configuration

Ping Response to Data Byte (Bits)	Field
0(0)	TOU Enabled
0(1:7)	(reserved)
1-2(0)	Season A: Start Date (Julian Day 0-365)
3	(A) Tier 1: First 15-Min Interval (1-96)
4	(A) Tier 1: Last 15-Min Interval (1-96)
5	(A) Tier 2: First 15-Min Interval (1-96)
6	(A) Tier 2: Last 15-Min Interval (1-96)
7	(A) Tier 3: First 15-Min Interval (1-96)
8	(A) Tier 3: Last 15-Min Interval (1-96)
9	(A) Tier 4: First 15-Min Interval (1-96)
10	(A) Tier 4: Last 15-Min Interval (1-96)
11-12(1)	Season B: Start Date (Julian Day 0-365)
13	(B) Tier 1: First 15-Min Interval (1-96)
14	(B) Tier 1: Last 15-Min Interval (1-96)
15	(B) Tier 2: First 15-Min Interval (1-96)
16	(B) Tier 2: Last 15-Min Interval (1-96)
17	(B) Tier 3: First 15-Min Interval (1-96)

Ping Response to Data Byte (Bits)	Field
18	(B) Tier 3: Last 15-Min Interval (1-96)
19	(B) Tier 4: First 15-Min Interval (1-96)
20	(B) Tier 4: Last 15-Min Interval (1-96)
21 (0:3)	Weekend Tier
21 (4:7)	Holiday Tier
22-26	(reserved)

4.17.3 TOU Current Year Holidays

Ping Response Data Byte (Bits)	Field
0-1(0)	Holiday 1: Julian Day (0-366)
2-3(0)	Holiday 2: Julian Day (0-366)
4-5(0)	Holiday 3: Julian Day (0-366)
6-7(0)	Holiday 4: Julian Day (0-366)
8-9(0)	Holiday 5: Julian Day (0-366)
10-11(0)	Holiday 6: Julian Day (0-366)
12-13(0)	Holiday 7: Julian Day (0-366)
14-15(0)	Holiday 8: Julian Day (0-366)
16-17(0)	Holiday 9: Julian Day (0-366)
18-19(0)	Holiday 10: Julian Day (0-366)
20-21(0)	Holiday 11: Julian Day (0-366)
22-23(0)	Holiday 12: Julian Day (0-366)
23(1:7)-26	Reserved

4.17.4 TOU Next Year Holidays

Ping Response to Data Byte (Bits)	Field
0-1(0)	Holiday 1: Julian Day (0-366)
2-3(0)	Holiday 2: Julian Day (0-366)
4-5(0)	Holiday 3: Julian Day (0-366)
6-7(0)	Holiday 4: Julian Day (0-366)
8-9(0)	Holiday 5: Julian Day (0-366)
10-11(0)	Holiday 6: Julian Day (0-366)
12-13(0)	Holiday 7: Julian Day (0-366)
14-15(0)	Holiday 8: Julian Day (0-366)
16-17(0)	Holiday 9: Julian Day (0-366)
18-19(0)	Holiday 10: Julian Day (0-366)
20-21(0)	Holiday 11: Julian Day (0-366)

Ping Response to Data Byte (Bits)	Field
22-23(0)	Holiday 12: Julian Day (0-366)
23(1:7)-26	Reserved

4.17.5 Click History

Ping Response to Data Byte (Bits)	Field
0-3	Epoch Time of Click 1
4-7	Epoch Time of Click 2
8-11	Epoch Time of Click 3
12-15	Epoch Time of Click 4
16-19	Epoch Time of Click 5
17-20	Epoch Time of Click 6
21-24	Epoch Time of Click 7
25-26	Reserved

4.17.6 Load Limit Status/Threshold

Ping Response to Data Byte (Bits)	Field
0 (0:6)	(reserved)
0 (7)	Enable Current Limit
1	Current Limit (1-255 A) (1 amp steps)
3-26	(reserved)

4.17.7 Advanced Voltage Quality Settings

Ping Response to Data Byte (Bits)	Field
0	Brownout Voltage Threshold
1 (0)	Enable Brownout Reporting
1 (1)	Enable Over Rated Current Reporting
1 (2)	Enable Reverse Power Reporting
1 (3:7)-26	Reserved

4.17.8 TOU Auto-Push Options

Ping Response to Data Byte (Bits)	Field
0 (0:2)	Auto-push interval
0 (3:6)	(reserved)
0 (7)	Enable Auto TOU push
1 (0)	Push Tier 1
1 (1)	Push Tier 2
1 (2)	Push Tier 3
1 (3)	Push Tier 4
1 (4)	Push Critical Peak
1 (5)	Push Tier 5
1(5:7)	(reserved)
2	TOU Sample Hour (0-23) 0 – Midnight (iConA only)
3-26	(reserved)

4.18 C&I High Res Read with History Data—App Code 55

4.18.1 Application Data

This message contains the C&I High Res Read with History Data as defined in the table below, sent in response to a Meter Read Ping message when the meter is in high res mode.

Ping Response to Data Byte (Bits)	Field
0-1	Relative Time Stamp
2	Delta Data Type (0:2) Click Count (3:7)
3-6	Current Consumption (ST23 SUMMA-TIONS[0])
7-10	Peak Demand Reading (ST23 DEMANDS[0].DEMAND)
11	Phase A Volts ST28 RMSVOLTSA
12	Phase B Volts ST28 RMSVOLTSB
13	Phase C Volts ST28 RMSVOLTSC
14-27	History Data In 1 Wh Resolution, stored in variable bin width format

4.18.2 Relative Time Stamp

Bytes 0-1. Elapsed time since last meter reading (2 second resolution). This field is used to determine exactly when the meter reading occurred.

4.18.3 Delta Data Type

Byte 2, bits 0-2. Used to define the amount of time represented in each History Data sample. The valid values for Delta Data Type are defined in the table below:

Delta Data Type	History Samp Interval (min)
0	5
1	15
2	60
3	360 (6 Hours)
4	720 (12 Hours)

Delta Data Type	History Samp Interval (min)
5	1440 (24 Hours)
6	240 (4 Hours)

4.18.4 Click Count

Byte 2 bits 3-7: The 5 LSBs of the modulo-256 click counter, a count of short duration power outages.

4.18.5 Current Consumption (wH resolution)

Bytes 3-6. The Current Consumption in represented as a 32 bit integer number in wH resolution.

4.18.6 Peak Demand Reading

32 bits, all of bytes 7-10. The peak demand reading is represented as a four byte floating point number in W.

4.18.7 RMS Volts Phase A-C

Bytes 11-13. Represented in 2 Volt resolution.

4.18.8 History Data

Bytes 14-27. History data samples compressed using the FlexNet Variable Bin Width compression mechanism.

4.19 Scratch Pad Image Check Response—App Code 57

Message Format: The device responds back to the download host with a Scratch Pad Image Check Response packet containing the number of bad blocks in the response, followed by a sequence of block numbers (1 byte each) which have not been received by the device since the last Scratch Pad Start message was received. If all blocks have been received and the CRC is correct, the response contains only the sub-command and a single byte of 0. If the CRC is incorrect, but the device has received all blocks, the response contains the sub-command, a single byte of 1 and 2 bytes of 0xFFFF. The format of the Scratch Pad Image Check Response is:

App Data Byte	0	2	2-n
Data	App Code = Scratch Pad Image Check Resp (30)	# of bad blocks	List of Block Numbers, 1 byte each

5 Setup and Configuration

5.1 Electrical Configuration Interface

5.1.1 Magnetic Loop

When the CPU detects the presence of a modulated magnetic field, it prepares to receive a setup message. Immediately after successful programming, the transmitter sends 4 Meter Setup / Configuration (Type 0) messages in 60 seconds. The message is sent using mode commanded by the setup command and is then repeated in the mPass mode. The programming tool will wait a specified amount of time for this message to space programming message attempts. Following this message, a Meter / Setup Configuration message is transmitted on-air using the configured transmit mode every 60 seconds for 30 minutes.

5.1.2 Optical Direct Serial Connection (optional)

If the programming tool is directly connected to the device via the serial port, feedback to the setup commands is provided via serial reply messages in addition to the Meter Setup / Configuration (Type 0) messages sent on-air.

This connection should only be used by the manufacturing test fixture to prevent electrical shock.

5.2 Configurable Parameters

5.2.1 End Point ID

The 28-bit field representing an ID unique to each transmitter (up to 268 million possible ID's). This field is set at the factory and is not programmable using the field setup tool.

5.2.2 Meter Sample Rate

The 3-bit field indicating how often the meter is read using the Elster interface. The meter is sampled without dither and is synchronized to the top of the hour by a real-time clock. The field is defined as shown in the table below (6-7 are reserved):

Field Value	Meter Sample Rate
0	5 minutes
1	15 minutes
2	1 hour
3	6 hours
4	12 hours
5	24 hours
6	Reserved
7	Factory Sleep

5.2.3 Supervisory Transmit Rate

The 5-bit field indicating how often RF messages are autonomously transmitted. RF Transmissions are randomly dithered in time from 0 to +/- 20% in time in order to avoid repetitive on-air collisions by different end-point devices. The field is defined as shown in the table below:

Field Value	Supervisory Transmit Rate	20% Variation	Total Range
0	1 minute	12 sec	48 – 72 sec
1	5 minutes	1 min	4 – 6 min
2	15 minutes	3 min	12 – 18 min
3	30 minutes	6 min	24 – 36 min
4	45 minutes	9 min	36 – 54 min
5	1 hour	12 min	48 - 72 min
6	1.5 hours	18 min	72 – 108 min
7	2 hours	24 min	96 – 144 min
8	2.5 hours	30 min	120 – 180 min
9	3 hours	36 min	144 – 216 min
10	3.5 hours	42 min	168 – 252 min
11	4 hours	48 min	192 – 288 min

12	4.5 hours	54 min	216 – 324 min
13	5 hours	60 min	240 – 360 min
14	5.5 hours	66 min	264 – 396 min
15	6 hours	72 min	288 – 432 min
16	7 hours	84 min	336 – 504 min
17	8 hours	96 min	384 – 576 min
18	9 hours	108 min	432 – 648 min
19	10 hours	120 min	480 – 720 min
20	12 hours	144 min	576 – 864 min
21	18 hours	216 min	864 – 1296 min
22	24 hours (1 day)	288 min	1152 – 1728 min
23	36 hours (1.5 days)	432 min	1728 – 2592 min
24	48 hours (2 days)	576 min	2304 – 3456 min
25	60 hours (2.5 days)	720 min	2880 – 4320 min
26	72 hours (3 days)	864 min	3456 – 5184 min
27	86 hours (3.5 days)	1032 min	4128 – 6192 min
28	Factory Sleep	N/A	Do not send Supervisory Messages
29	CW Mode		Test only, continuous tone out
30	FCC Mode		Test only, continuous modulated data out
31	Fast Mode		Test only, 3 test messages / second

5.2.4 Base Frequency Channel

An 8-bit field which is used to set the base frequency for the device. This field sets the base frequency for all transmit, receive and boost mode channels. The Base Frequency is determined using the following equation:

```
Base Frequency (MHz) = 409.6 MHz + (Base Frequency Channel * 12.8 MHz)
```

5.2.5 Transmit Frequency Channels

4 16-bit fields (13 used) representing Transmit Channels A, B, C, and D each from 0-8000 spanning 50 MHz of bandwidth in 6.25 KHz slots. The end point device transmits on all N channels in pseudorandom pattern, if a single channel is selected, transmitter uses single channel. The channels actually enabled for use are selected in the Transmit Channel Mask field. Channel A is always selected. The Transmit Frequency is determined using the following equation:

```
Transmit Frequency (MHz) = Base Frequency (MHz) + (Transmit Frequency
Channel * .00625)
```

5.2.6 Receive Frequency Channel

A 16-bit field (13 used) representing the receive channel from 0-8000 spanning 50 MHz of bandwidth in 6.25 kHz slots. The Receive Frequency is determined using the following equation:

```
Receive Frequency (MHz) = Base Frequency (MHz) + (Receive Frequency Channel * .00625)
```

5.2.7 C&I Mode Channel

A 16-bit field (13 used) representing the C&I Channel from 0-8000 spanning 50 MHz in 6.25 KHz steps. The C&I Mode Frequency is determined using the following equation:

```
C&I Mode Frequency (MHz) = Base Frequency (MHz) + (C&I Mode Channel * .00625)
```

5.2.8 Priority Mode Channel

A 16-bit field (13 used) representing the Priority Mode Channel from 0-8000 spanning 50 MHz in 6.25 KHz steps. The Priority Mode Frequency is determined using the following equation:

```
Priority Mode Frequency (MHz) = Base Frequency (MHz) +
        (Priority Mode Channel * .00625)
```

5.2.9 Transmit Channel Mask

A 3-bit field containing bit flags to indicate if Transmit Channels B, C or D are active. A 1 in a bit field indicates that that transmit channel is active. The following table defines the Transmit Channel Mask field:

Bit	Transmit Channel
0	Transmit Channel B Active
1	Transmit Channel C Active

5.2.10 Transmit Operational Mode

A 4-bit field containing the transmission mode of the Transmitter as shown in the table below. Note that if the device is configured to Message Pass, it will always transmit on the Receive Frequency (all mPass transmissions are on the Rx Channel).

Setting	Tx Op Mode Bits
0	Normal Mode
1	Message Pass
2	Reserved
3	Normal, ½ Baud Rate
4	mPass / Normal Mix (1:1)
5	mPass / Normal Mix (1:2)
6	mPass / Normal Mix (1:3)
7	mPass / Normal Mix (1:4)
8	mPass / Normal Mix (1:5)
9	mPass / Normal Mix (1:8)
10	mPass / Normal Mix (1:16)
11	Reserved
12	Reserved
13	Reserved
14	Reserved
15	Reserved

5.2.11 Receiver Operational Mode

A 3-bit field containing the Receiver Operational Mode of the device as shown in the table below (modes 3-7 are reserved):

Setting	Rx Op Mode
0	Disabled
1	Listen Before Transmit (CSMA)
2	Listen Always

5.2.12 Enable Encryption

Setting	AE-256 Encryption
0	Off
1	On

5.2.13 Programmer ID

A 16-bit field code containing the Id number of the handheld programming device that set up this device.

5.3 Setup Messages

5.3.1 Setup Messages

The end point device is configured via several setup messages which are defined in the following sections and are listed in the following table:

Type	Message
0x91	Status Request
0x92	Set Device Id
0x93	Static Setup
0x94	Set TCXO Correction
0x95	Set Latitude / Longitude
0x96	Set A/D Converter Calibration
0x97	Set Voltage Quality Thresholds
0x98	Set Encryption Key
0x99	Set Real Time
0x9A	Send Data
0x9C	Ping
0x9D	Set Customer Meter Number
0x9E	Set Customer ID
0xAF	Reset FlexNet Module
0xD0	Test Command
0xD1	Command Pass Through

5.3.2 Basic Command Message Format

All setup command messages (setup tool to device) with have the following basic format:

Byte	0	1	2	3	4->n	n+1, n+2
Description	Sync	Address	Command Type	Length	Data	CRC
Value	0x1b	0xff	0x9n	# Bytes in Data Field		

CRC is a 16-bit CRC of all of the previous fields, the algorithm used is CCITT-16 (0x1021 or 0x8408 reversed).The remainder is initialized to all 1's (0xFFFF) and the CRC is inverted before being sent, MSB first. On the following page is a sample C routine which implements the algorithm using the "reversed" technique:

```
WORD crc16_lsb(BYTE *pData, WORD length)
 {
     BYTE i;
     WORD data, crc;
     crc = 0xFFFF;
     if (length == 0)
         return 0;
     do
         {
             data = (WORD)0x00FF & *pData++;
             crc = crc ^ data;
             for (i = 8; i > 0; i--)
                 {
                     if (crc & 0x0001)
                         crc = (crc >> 1) ^ 0x8408;
                     else
                         crc >>= 1;
                 }
         }
     while (--length);
     crc = ~crc;
     return (crc);
 }
```

For example, a Status Request command:

```
1b ff 91 00
```

Would generate the following CRC:

```
1c 39
```

The complete message would be as follows:

```
1b ff 91 00 1c 39
```

5.3.3 Basic Reply Message Format

Reply Messages are only sent in response to a command, and are only sent if a direct serial connection is present (serial Reply Messages are NOT sent if the magnetic programming loop interface is used, responses can be gathered via the on-air Meter Setup / Configuration Message). All setup command messages (setup tool to device) with have the following basic format, the CRC field definition is the same as for Command Messages:

Byte	0	1	2	3	4	5->n	n+1, n+2
Description	Sync	Address	Reply Type	Length	Data Status	Data	CRC
Value	0x1b	0x01	Matches Command	# Bytes in Data Field	Bit 7: Ack/ Nack (0/1) Bit 0: EEROM Failure		

5.4 Status Request (0x91)

Request the current endpoint device configuration information (direct serial connection only). The command has the following format:

Msg Type	Length	CRC
0x91	0	0x391c

The data field reply has the following format (a detailed description of each individual field can be found in section):

Byte (Bits)	Field
4(0)	Status EEROM Write Failed(1)
4(1:6)	(Reserved)
4(7)	Status ACK(0) / NACK(1)
5	Firmware Version
6	Device Type
7-10	Device Id
11 (0:2)	Meter Sample Rate
11 (3:7)	Supervisory Transmit Rate
12	Base Frequency
13-14	Transmit Channel A
15-16	Transmit Channel B

Byte (Bits)	Field
17-18	Transmit Channel C
19-20	Transmit Channel D
21-22	Receiver Channel
23-24	Boost Mode Channel
25 (0:3)	Boost Mode Sub-Channel
25 (4)	Boost Mode Hopping
25 (5:7)	Transmit Channel Mask
26 (0:3)	Transmitter Operational Mode
26 (4:6)	Receiver Operational Mode
26 (7)	Enable Encryption
27-28	Programmer Id
28 (7)	Disable Compression
29-30	TXCO Correction
31-34	Latitude
35-38	Longitude
39-41	Meter Reading
42	Minimum Click Duration
43(0:5)	Minimum Voltage Threshold
43(6:7)	Voltage Averaging Window
44(0:3)	Outage Time Threshold
44(4:7)	Restored Time Threshold
45-46	Real Time

The Real Time field contains the number of elapsed seconds since the top of the hour (0 -3599) from the perspective of the device.

5.5 Set Device ID (0x92)

Set the 28 bit device Id (factory only, not available in setup tool). The command has the following format:

Msg Type	Length	Bytes 0-3	CRC
0x92	4	Device Id	

The data field in the reply message has the 1 byte data status byte only in the following format:

Byte (Bits)	Field
4(0)	Status EEROM Write Failed(1)
4(1:6)	(Reserved)
4(7)	Status ACK(0) / NACK(1)

5.6 Device Static Setup

Set all of the operational parameters of the device. The command has the following format:

Msg Type	Length	Bytes 0-17	CRC
0x93	18	Setup Data	

The Setup Data field has the following format (all multi-byte fields are sent lesat significant byte first):

Byte (Bits)	Field
4 (0:2)	Meter Sample Rate
4 (3:7)	Supervisory Transmit Multiple
5	Base Frequency
6-7	Transmit Channel A
8-9	Transmit Channel B
10-11	Transmit Channel C
12-13	Transmit Channel D
14-15	Receiver Channel
16-17	Boost Mode Channel
18 (0:3)	Boost Mode Sub-Channel
18 (4:7)	Transmit Channel Mask
19 (0:3)	Transmitter Operational Mode
19 (4:6)	Receiver Operational Mode
19 (7)	Enable Encryption
20-21	Programmer Id
21(7)	Disable Compression

The data field in the reply message has the 1 byte data status only.

5.7 Set TCXO Correction (0x94)

Set TCXO Correction frequency offset. The command has the following format:

Msg Type	Length	Bytes 0-1	CRC
0x94	2	TCXO Correction	

The data field in the reply message has the 1 byte data status only.

5.8 Set Latitude/Longitude (0x95)

Set the installation latitude and longitude. The command has the following format:

Msg Type	Length	Bytes 0-3	Bytes 4-7	CRC
0x95	8	Latitude	Longitude	

The data field in the reply message has the 1 byte data status only.

5.9 Set A/D Calibration (0x96)

Set slope and intercept settings for analog to digital conversion . The command has the following format:

Msg Type	Length	Bytes 0-3	CRC
0x96	4	A/D Conversion	

The data field in the reply message has the 1 byte data status only.

5.10 Set Voltage Quality Thresholds (0x97)

Set the thresholds that control voltage quality based Alarm Messages. The command has the following format:

Msg Type	Length	Bytes 0-1	CRC
0x97	3	Voltage Quality Thresholds	

The format of the Voltage Quality Thresholds is shown in the following table:

Byte (Bits)	Field
0	Minimum Click Duration
1(0:5)	Minimum Voltage Threshold
1(6:7)	Voltage Averaging Window
2(0:3)	Outage Time Threshold
2(4:7)	Restored Time Threshold

The data field in the reply message has the 1 byte data status only.

5.11 Set Encryption Key (0x98)

Set the 128 bit Encryption Key. The command has the following format:

Msg Type	Length	Bytes 0-15	CRC
0x98	16	Encryption Key	

The data field in the reply message has the 1 byte data status only.

5.12 Set Real Time Clock (0x99)

Set the current time to synchronize meter reading times. The command has the following format:

Msg Type	Length	Byte 0-1	Byte 2	Byte 3	CRC
0x99	2	Elapsed Seconds	Current Hour	Rea d Hour	

The Elapsed Seconds field contains the number of elapsed seconds since the top of the hour (0 -3599) from the perspective of the host.

The Current Hour represents the current real time hour (0-23 for midnight to 11:00pm).

The Read Hour allows setting of the time that the meters that receive this message will read their associated meters if the supervisory rate is set to 6 hours or higher. The value is in hours plus 1 (1-24 for midnight to 11:00 pm). 0 means do not change current reading hour.

The data field in the reply message has the 1 byte data status only.

5.13 Send Data (0x9A)

Send a message using the device's ID and frequency settings. The command has the following format:

Msg Type	Length	Byte 0	Byte 1	Byte 2	Byte 3-30	CRC
0x9A	31	Repeat Level/Status	App Seq	App Code	App Data	

The data field in the serial reply message has the 1 byte data status only.

5.14 Ping (0x9C)

Ping the device, which responds with on-air commands. The command has the following format:

Msg Type	Length	Byte 0	CRC
0x9C	1	Ping Type	

The data field in the serial reply message has the 1 byte data status only.

The Ping Type determines how the device will respond on air to the command as shown below:

Ping Type	Device Response
0 – Normal Ping	On Air Command Ack Message
1 – Configuration Ping	On Air Binding Message On Air Static Setup Message On Air Meter Reading Message (3 second delay between messages)
2 – Demand Read Ping	On Air Meter Reading Message On Air Alarm Message (3 second delay between messages)
3 – Handheld mPass Binding Ping – Buddy Allowed	mPass On Air Binding Message – Repeat bits cleared to allow buddy
4- Handheld mPass Binding Ping – Buddy Disabled	mPass On Air Binding Message – Repeat Level set to 1 to block buddy
5 – Alarm Ping	On Air Alarm Message
6 – Handheld mPass Alarm Ping – Buddy Disabled	mPass On Air Alarm Message – Repeat Level set to 1 to block buddy

Ping Type	Device Response
7 – Handheld mPass Demand Read Ping – Buddy Disabled	mPass On Air Demand Read Message – Repeat Level set to 1 to block buddy
8 – Meter Read Message	On Air Meter Reading Message (no alarms)
9 – Full Tier Data Meter Read	Send Meter Reading Message followed by available Tier Messages
10- Test Meter Read	On Air Meter Reading Message (no alarms) preceded by a meter reading
11 – Single Tier Data Meter Read	Single Tier Data Message – The byte after the ping type contains the Tier Information byte for the desired tier. Note: Does not re-read meter.
14 – Extended Setup	On Air Extended Setup Message
15 – Setup	On Air Static Setup Message
16 – Binding	On Air Binding Message
20 – Single Tier Data Meter Read, re-read meter	Single Tier Data Message – The byte after the ping type contains the Tier Information byte for the desired tier. Note: Does Re-read meter.
21 – Demand History	On Air Demand History Message
23 – LP Meta Data	On Air LP Meta Data Message
24 – LP Block Data	On Air LP Block Messages - The byte after the ping type contains the requested block. As many messages as are required to send a complete block are sent
25 – LP Block Data – Single Message	Single On Air LP Block Message - The byte after the ping type contains the requested block. The following byte contains the message number (0, 1, 2, 3)

5.15 Set Customer Meter Number (0x9D)

Set the 13 byte ASCII Customer meter number. The command has the following format:

Msg Type	Length	Byte 0	CRC
0x9D	13	Customer Meter Number	

The data field in the serial reply message has the 1 byte data status only.

5.16 Set Customer ID (0x9E)

Set the 4 bit Customer Meter ID number used for routing and customer differentiation in a local market. The command has the following format:

Msg Type	Length	Byte 0	CRC
0x9E	1	Customer ID	

The data field in the serial reply message has the 1 byte data status only.

5.17 Send Data Commands

The end point device can be commanded to transmit data via one of the commands which are defined in the following sections and are listed in the following table. Two replies are sent in response to Send Data Commands, one before transmission, one following transmission. If a send data command is not accepted (NACK'ed), only one reply is sent.

Type	Message
0x9A	Send Data
0x9B	Send Whole

Send Data (0x9A): Send a message using the device's Id and frequency settings.

Msg Type	Length	Byte 0	Byte 1	Byte 2	Byte 3-30	CRC
0x9A	31	Repeat Level / Status	App Seq	App Cod e	App Data	

The data field in the reply message has the 1 byte data status only.

Send Whole (0x9B): Send a message using the provided Id and frequency settings.

Msg Type	Length	Byte 0-38	CRC
0x9B	39	Command Bytes (see table below)	

Byte (Bits)	Field
0 (0:3)	Transmitter Operational Mode
0 (4)	Disable Base Station Rx
0 (5:6)	(reserved)
0 (7)	Enable Encryption
1	Base Frequency

Byte (Bits)	Field
2-3	Transmit Channel
4-7	Device Id
8	Repeat Level / Status
9	App Seq
10	App Code
10-38	App Data

The data field in the reply message has the 1 byte data status only.

6 Receiver Section

The device receiver section may be de-populated to reduce cost for a transmit only version using the same printed circuit layout.

6.1 Receiver Requirements

6.1.1 Operation Modes

Receivers always listen for messages on a line powered end-point. Battery operated receivers listen for message only after transmitting a message. The associated tower receiver queues up commands to battery powered end-points and transmits them only after reception of an end-point message with matching ID.

6.1.2 RF Link Requirements

Uses the end point Repeat mode modulation format.

6.1.3 Sensitivity

-109 dBm @ 4800 Baud

6.1.4 Diversity

Temporal only, Interleaved and ½ bit rate Viterbi convolutionally encoded with constraint length K=3.

6.2 Receiver On Air Command Messages

6.2.1 Command Types

The Receiver can accept the Application Code 7 Command Messages with the following Command Types. The format of the data in the actual fields is the same as previously defined unless otherwise stated. The address (Id Number) in the command is always that of the final destination. The tower may add a Buddy Address for routing purposes if necessary. When the device receives a command with its address in the Buddy Address field, it will repeat the command on the mPass channel to provide an extra hop for out of range devices.

Type	Description	Broadcast	Group
0	Command Acknowledge	N/A	N/A
1	Set Static Setup	No	Yes
2	Set Crystal Offset	No	No
3	Set Lat / Long	No	No
4	Set Voltage Quality Settings	Yes	Yes
5	Set Time	Yes	No
6	Load Shed	Yes	Yes

7	Demand Read	Yes	Yes
8	Ping	No	Yes
9	Set Transmitter Id	No	No
10	Set Customer Id	No	Yes
11	Set Encryption Key	Yes	Yes
12	Set Preferred Buddy	No	No
13	Set Customer Meter Number	No	No
17	Demand Reset	No	Yes
19	Set Group Address	No	No
20	Delay Supervisory Transmissions	Yes	No

6.2.2 Command Acknowledge

A message to acknowledge a previously transmitted message by the device. The message has the following format:

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 0 – Command Acknowledge
4	Command Type being Acked (MSB Set if App Code is being Ack'ed by tower)
5 (0:4)	Rf Sequence Number of Command
5(5)	Reply To Programmer (1 / 0) (Reply from Tower Only)
5(6)	Reply From Tower (1 / 0) (Reply from Tower Only)
5 (7)	Ack / Nack (0 / 1)
6	Auxiliary Status
7	App Sequence Number of Command
8	Signal Level of Command (0 -255 dB)
9	Noise Level of Command (0-255 dB)
10-11	Programmer Id (Reply from Tower Only)

12	Setup Flags (Reply from Tower Only)
13-31	(reserved)

The definition of the Auxiliary Status and (reserved) fields can be defined differently for different Command Types. They are set to 0 unless otherwise specified per command Type.

6.2.3 Set Static Setup

A command to force the device update its static setup:

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 1 – Static Setup
4-7	Buddy Routing Address
8-25	Static Setup Data
26-31	(reserved)

6.2.4 Set TCXO Correction

A command to force the device update its crystal offset setting:

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 2 – Crystal Offset
4-7	Buddy Routing Address
8-9	TCXO Correction
10-31	(reserved)

6.2.5 Set Latitude and Longitude

A command to force the device update its position:

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 3 – Set Lat / Long
4-7	Buddy Routing Address
8-11	Latitude
12-15	Longitude
16-31	(reserved)

6.2.6 Set VoltVoltage Quality settings:

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 4 – Set Voltage Quality Set-tings
4-7	Buddy Routing Address
8	Minimum Click Count Duration
9(0:5)	Minimum Voltage Threshold
9(6:7)	Voltage Averaging Window
10(0:3)	Outage Time Threshold
10(4:)	Restored Time Threshold
11-31	(reserved)

6.2.7 Set

A command to reset the real time clock of the device:

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 5 – Set Time
4-7	Buddy Routing Address
8-9	Elapsed Time (in seconds) Since Top of The Hour (0 – 3599)
10	Hour of the Day (0 – 23)
11	Read Hour +1 (1-24) (0=don't change current Read Hour)
12-31	(reserved)

The Elapsed Seconds field contains the number of elapsed seconds since the top of the hour (0 - 3599) from the perspective of the host.

The Hour of the Day represents the current real time hour (0-23 for midnight to 11:00pm).

The Read Hour allows setting of the time that the meters that receive this message will read their associated meters if the supervisory rate is set to 6 hours or higher. The value is in hours plus 1 (1-24 for midnight to 11:00 pm). 0 means do not change current reading hour.

6.2.8 On Demand Read / Drive By Read

A command to force the device to transmit its latest meter data. If the address is set to Broadcast (0xffffff) the unit will wait 0 to Maximum Dither seconds inversely proportional to received SNR.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 7 – Demand Read
4-7	Buddy Routing Address
8	Mode (0 – Normal Mode; 1 – mPass Mode)
9	Maximum Dither (0-255 seconds)
10-31	(reserved)

Mode and Maximum Dither are only valid for Drive By Reads.

6.2.9 Ping

A command that with no setup information that only causes the device to respond with ack message or set of messages.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 8 – Ping
4-7	Buddy Routing Address
8	Ping Type
9-31	(reserved)

Ping Type: Determines how the device will respond on-air to the command as shown below:

Ping Type	Device Response
0 – Normal Ping	On Air Command Ack Message
1 – Configuration Ping	On Air Binding Message On Air Static Setup Message On Air Meter Reading Message (3 second delay between messages)
2 – Demand Read Ping	On Air Meter Reading Message On Air Alarm Message (3 second delay between messages)
3 – Handheld mPass Binding Ping – Buddy Allowed	mPass On Air Binding Message – Repeat bits cleared to allow buddy
4- Handheld mPass Binding Ping – Buddy Disabled	mPass On Air Binding Message – Repeat Level set to 1 to block buddy
5 – Alarm Ping	On Air Alarm Message
6 – Handheld mPass Alarm Ping – Buddy Disabled	mPass On Air Alarm Message – Repeat Level set to 1 to block buddy
7 – Handheld mPass Demand Read Ping – Buddy Disabled	mPass On Air Demand Read Message – Repeat Level set to 1 to block buddy
8 – Meter Read Message	On Air Meter Reading Message (no alarms)
9 – Full Tier Data Meter Read	Send Meter Reading Message followed by available Tier Messages

10- Test Meter Read	On Air Meter Reading Message (no alarms) preceded by a meter reading
11 – Single Tier Data Meter Read	Single Tier Data Message – The byte after the ping type contains the Tier Information byte for the desired tier. Note: Does not re-read meter.
14 – Extended Setup	On Air Extended Setup Message
15 – Setup	On Air Static Setup Message
16 – Binding	On Air Binding Message
20 – Single Tier Data Meter Read, re-read meter	Single Tier Data Message – The byte after the ping type contains the Tier Information byte for the desired tier. Note: Does Re-read meter.
21 – Demand History	On Air Demand History Message
23 – LP Meta Data	On Air LP Meta Data Message
24 – LP Block Data	On Air LP Block Messages - The byte after the ping type contains the requested block. As many messages as are required to send a complete block are sent
25 – LP Block Data – Single Message	Single On Air LP Block Message - The byte after the ping type contains the requested block. The following byte contains the message number (0, 1, 2, 3)

6.2.10 Set Transmitter Id

A command to change the endpoints transmitter id.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 9 – Set Transmitter Id
4-7	Buddy Routing Address
8-11	New Transmitter Id
12-31	(reserved)

6.2.11 Set Customer Id

A command to set the 4 bit customer id.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 10 – Set Customer Id
4-7	Buddy Routing Address
8 (0:3)	Customer Id
9-31	(reserved)

6.2.12 Set Encryption Key

A command to set the 16 byte encryption key.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 11 – Set Encryption Key
4-7	Buddy Routing Address
8-23	16 byte, 128 bit Encyption Key
24-31	(reserved)

6.2.13 Set Preferred Buddy Id

A command to set the 4 byte preferred buddy address for this meter.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 12 – Set Preferred Buddy Id
4-7	Buddy Routing Address
8-11	Preferred Buddy Address
12-31	(reserved)

6.2.14 Set Company Meter Number

A command to set the 13 byte customer number.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 13 – Set Company Meter Number
4-7	Buddy Routing Address
8-21	ASCII Customer Meter Number
22-31	(reserved)

6.2.15 C&I Read C12.19 Data

A command to read raw C&I Table data.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 15 – Read C&I Meter Data
4-7	Buddy Routing Address
8-9	C12.19 Table Number
10-12	Table Offset
13	# Bytes to Read (0-27)
14-31	(reserved)

6.2.16 C&I Write C12.19 Data

A command to write raw C&I Table data.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 16 – Write C&I Meter Data
4-7	Buddy Routing Address
8-9	C12.19 Table Number
10-12	Table Offset
13	# Bytes to Write (0-17)
14-31	Raw bytes to write

6.2.17 C&I Demand Reset

A command reset the Demands in the C&I Tables.

Byte (Bits)	Field
0	Repeat Level / Status
1	App Sequence
2	App Code: 7 – Command Message
3	Command Type: 17 – Demand Reset
4-7	Buddy Routing Address
8-31	(reserved)

6.3 Command Addressing

The Receiver will accept commtches its own Device Id and one using the Broadcast Address, which is all 1's or 0xFFFFFF. Broadcast messages are not acknowledged.

6.4 Receiver Miscellaneous

6.4.1 Miscellaneous

CSMA, RSSI listen before talk, which reduces collisions CSMA, allows coexistence if a channel in a shared FCC band.

6.4.2 Polling

A line power receiver enabled end point device may be polled by a tower or a specially equipped moving vehicle (Drive By). The poll may be a point address or broadcast. Broadcast causes all end point devices in listening range to delay for a pseudorandom time then report. The maximum delay is 60 seconds.

Appendix A FlexNet SmartPoint Radio Overview

The Sensus FlexNet SmartPoint module provides wireless communication capability to electric utility meters. The SmartPoint module interrogates the meter registers on a programmable interval from five minutes to daily readings. The SmartPoint module then transmits the meter consumption and status information at regular intervals.

The number of times the SmartPoint transmits is decoupled from the read setting, allowing for either greater number of transmissions per read, or fewer. In the case of a daily read, the SmartPoint can be programmed to transmit every six hours—providing the same information four times throughout the day.

A.1 SmartPoint Power Failure Detection and Alarm

The SmartPoint detects power failures at the meter location and sends an alarm message.

A.1.1 Power Fail Detection

The SmartPoint microprocessor (μC) monitors the power fail signal from the display board, and on power fail, the μC sleeps all hardware and waits the Outage Time Threshold amount of time plus a pseudo random interval of 0 to 152 seconds and then sends an Alarm power fail report message. The on-board power-supply capacitor stores enough energy for at least one Alarm power fail transmission. The board will continue to send additional Alarm power fail messages at 0 to 48 second pseudo random intervals until the capacitor is drained.

A.1.2 Power Restoration Notification

Upon power restoration, the SmartPoint μC waits the Power Restore Time Threshold amount of time and then sends 6 pseudo randomly timed Alarm Power Restore messages, followed by a meter read message with the power restore flag set.

A.1.3 Brown-Out Detection

The alarm and voltage fields from the sensor board are monitored for brown-out (low voltage detect). The Brown-out voltage is set via the SmartPoint Minimum Voltage Alarm Threshold. If the AC voltage drops below this threshold, the Brown Out bit will be set in the next transmitted on-air message.

A.2 Operating Frequencies of SmartPoint/TGB Devices

The TGB receiver may operate over two frequency ranges (at its LNA input) dependent on the RF card hardware version installed in the TGB. The frequency range given is further constrained by the actual pass band of the duplexer/preselector filter used between the LNA and the TGB antenna.

- TGB Receiver Operating Frequency: 896 To 902 MHz (Range 1) **OR**
  928 To 935 MHz (Range 2)
- The operating frequency range is selected based on whether the TGB will be operating under FCC Part 24 NBPCS or Part 90 SMR (Range 1) or FCC Part 101 MAS (Range 2).

The TGB Transmitter may operate over the following frequency range independent of RF card Hardware Version.

- TGB Transmitter Operating Frequency: 930 to 960 MHz
- The transmitter operating frequency is further constrained based on the pass band of the duplexer filter which connects between the transmitter output and the antenna.

It is important to specify the actual operating frequency range of the TGB when it is ordered so the correct RF card frequency range is delivered to the installation.

A.2.1 Systems Operating Under Part 24 of FCC Rules (Narrow-Band PCS)

US NBPCS Frequency:

- Inbound:901.125 MHz ±25 KHz
- Outbound:940.125 MHz ±25 KHz

A.2.2 Systems Operating Under RSS-134 in Canada (Narrow-Band PCS)

Canadian NBPCS Frequency:

- Inbound:901.625 MHz ±25 KHz
- Outbound:940.125 MHz ±25 KHz

The operating frequencies stated above are the center of the bandwidth in which Sensus is licensed to operate. For example, in the US, the operating bandwidth Sensus may use starts at 901.1 MHz and stops at 901.15 MHz. We define the center frequency of the licensed bandwidth as FCInbound and FCOutbound for the discussions below. For example, in the US for the NBPCS operating frequencies FCInbound would be 901.125 MHz and FCOutbound would be 940.125 MHz.

A.3 SmartPoint Radio Transmit Modes

The SmartPoint module can communicate to the TGB in three different modes:

- **Normal mode** allows for direct communication to the TGB,
- **Poll/Response mode** or clear channel for responses from tower commands,
- **mPass or “Buddy” mode** allows for indirect communication from the meter to the TGB via other meters.

The first two communication modes are direct, SmartPoint module to TGB, while the last provides the greatest flexibility in a two-way system.

A SmartPoint device may also transmit to other SmartPoint devices with mPass modulation, utilizing the channels described above. This mode allows a meter to repeat another meter (message pass, thus mPass) that is out-of-range of the TGB receiver due to installation constraints (i.e. transmitter is mounted in a basement or other environment that obstructs its signal path back to the TGB). It also allows the TGB to communicate with a blocked meter through another SmartPoint device.

Meters that receive mPass modulated messages from blocked meters repeat those messages to the TGB utilizing boost, ½ baudrate or normal modulation modes (and frequencies, i.e. the lower frequency of the frequency pair).

TGB communication to blocked meters through SmartPoint™ devices that are passing messages utilizes mPass modulation (and frequencies, i.e. the higher frequency of the frequency pair) from the TGB to the repeating SmartPoint™ meter and from the repeating SmartPoint™ meter to the blocked meter.

The mPass modulation is only utilized in the frequency channels that occupy the upper frequency of the frequency pair. The boost, ½ baudrate, and normal modes of modulation are only utilized on the frequency channels that occupy the lower frequency of the frequency pair.

The mPass modulation is also used by the TGB to communicate with all SmartPoint devices in the field.

A.3.1 Normal Mode

Normal mode, as its name implies, is the preferred mode of transmitter operation for the SmartPoint when the SmartPoint is operating in a 25 KHz channel (13.6 KHz if operating under FCC Part 90 Rules). Normal mode is utilized by the SmartPoint for the RF path from the SmartPoint to the TGB.

Three normal mode communication methods are used to collect SmartPoint™ meter data, Staggered Transmissions, Real-time, and Poll-respond, as described briefly below.

A.3.1.1 Staggered Transmissions

Hourly and daily meter read messages and bulk status information transit times are determined via time randomizations to cause the network to behave like an ALOHA-modeled network:

- Data required on a daily basis (Normal mode 111 ms), 20 tower receivers can read 1.4 million hourly meters.

> A single TGB can cover 70,000 SmartPoint devices, dependant upon meter and TGB configuration.

- Real-time, Report-by-exception, Status and Alarm Information
- Data generally required in seconds or minutes:
- If power available (240 VAC or battery):
- Alarms reported immediately;
- Alarms reported redundantly (1 to 32 times until Ack).
- If power not available (limited to capacative power supply):
- 3 to 6 redundant transmissions occur in dialated time intervals,
- 30 sec. average initial message report, and
- Faster reporting intervals can be selected (application dependent).

A.3.1.2 Poll-response Message Traffic

- Data generally required in real-time (Poll 158 ms and Respond 111 ms, 50 bytes):
- C&I meter traffic,
- Demand reads, and
- SCADA/Distribution Automation.

A.3.2 Poll/Response Mode

Poll/Response mode is the preferred mode of transmitter operation for the SmartPoint when the SmartPoint is operating in an authorized bandwidth narrower than 20 KHz.

Poll/Response mode is identical to Normal mode with the exception that its data rate and its deviation is one-half of Normal mode, and is utilized by SmartPoint devices for the RF path from the SmartPoint to the TGB.

A.3.3 mPass or “Buddy” Transmit Mode

mPass (message pass) Transmit Mode allows a meter that cannot reach a TGB directly to use its neighboring two-way SmartPoint modules to repeat its message. Generally, communications between meters and FlexNet tower-mounted receivers is not a problem because of FlexNet tower heights. However, in some few installations, the meter-to-tower signal path may be obstructed by objects that significantly attenuate the SmartPoint transmitter signal.

In these locations, the mPass mode communications method is used.

The mPass mode also is the modulation type used by the TGB when it communicates with any SmartPoint device. These communications constitute (but are not limited to):

- Timekeeping chores (allowing the EMD to set its internal clock, correcting for EMD crystal aging by re-tuning the EMD RF frequency within 50 Hz, etc.),
- Polling tasks (gathering data from an individual EMD such as rate tables etc.), and
- Command execution (turning electricity off or on, etc.).

SmartPoint meters, capable of using Normal mode operation, ***receive*** using mPass modulation from the TGB and other meters which may not be able to communicate with the TGB, and ***transmit*** using 7FSK modulation back to the TGB. These units transmit on the same frequency the TGB uses for its receive operation.

SmartPoint meters that are relying on mPass mode to communicate to the TGB through another SmartPoint device, utilize mPass modulation for both receive ***and*** transmit operations. They transmit on the same frequency that the TGB utilizes for transmission.

A SmartPoint device that cannot communicate directly with a FlexNet tower is considered an **Out of Range Device (ORD)**. A SmartPoint device that can communicate directly with a FlexNet tower is considered a candidate to be configured as a “Buddy Device.”

Unlike other communications, no routing information is necessary for the Buddy message to be repeated. Any meter that hears the Buddy message will repeat using a pseudo random algorithm to minimize network loading. Upon reception at the TGB of a Buddy message, the TGB broadcasts a quench signal informing other meters still waiting to repeat the message that it has been received and they should no longer attempt to repeat the message.

A.3.3.1 Buddy Mode Using mPass Transmissions

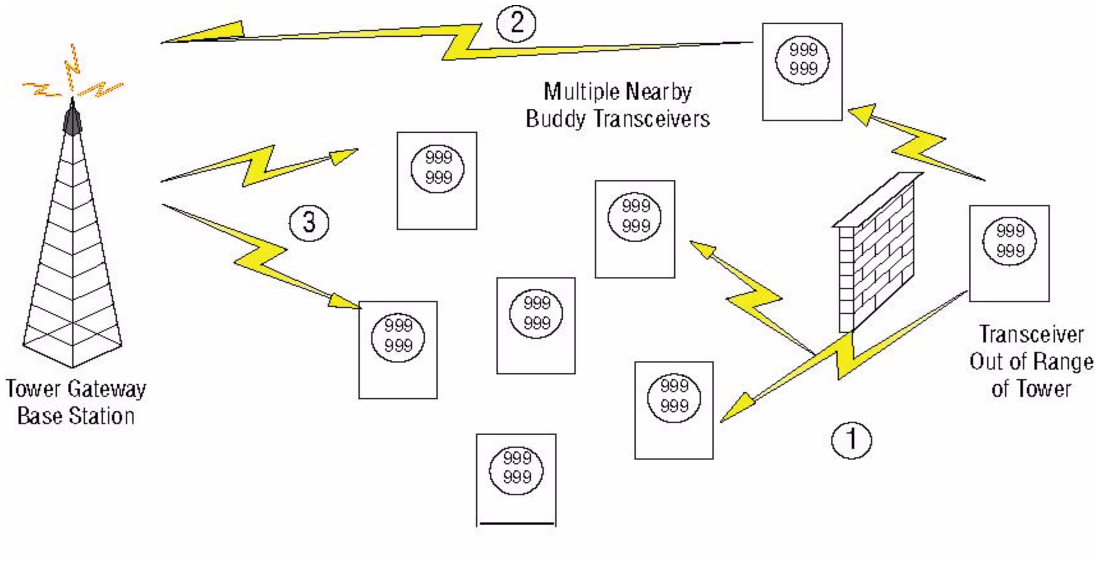

Figure A-1: Remote SmartPoint to Tower mPass Buddy Mode Schematic

Figure A-1shows how a remote SmartPoint device out-of-range of any tower, an ORD, can send messages in mPass mode to other Buddy transceivers, which then relay the ORD messages on to the tower.

1. The out-of-range transceiver (or transmit only device) sends an mPass modulated message which is received by multiple Buddy transceivers. Each Buddy queues the message to be repeated with a timeout inversely proportional to the signal-to-noise ratio (SNR) of the message it received, plus a small pseudo random amount. Closer Buddy transceivers will have a shorter timeout.
2. The first Buddy to timeout and repeat the message sends it directly to the tower on the Normal mode channel. If the tower does not hear the repeated message, nothing happens until the next Buddy timeout occurs and the next buddy repeats the message.
3. Once the tower hears a repeated message from a Buddy, it sends an acknowledge (Ack) message with the ID of the repeated message, which causes all Buddy devices with a message still queued from that ID to eliminate that message from their queue. This minimizes the number of times the message is repeated on air.

A.3.3.2 Tower mPass Buddy Mode to ORD Command Transmissions

Figure A-2 exhibits how a remote SmartPoint device that is out-of-range of commands from a tower can receive those commands via a Buddy relay of the message.

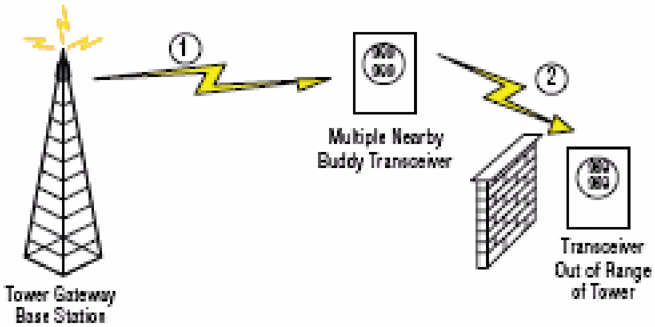

Figure A-2: Remote Tower to SmartPoint mPass Buddy Mode Schematic

1. The tower sends an mPass-modulated message with the address of the out-of-range transceiver as the primary address, and the address of the desired relaying Buddy as the Buddy Routing Address. The Buddy receives the message and identifies it as one the Buddy is commanded to relay.
2. The Buddy transmits the repeated message in the mPass channel to the out-of-range transceiver.

A.4 SmartPoint Data Security

The FlexNet system is designed with total data security in mind. Sensus is acutely aware that meter reads, customer data, and telemetry data is highly confidential, and extends every effort to ensure the protection and integrity of that data. For the protection of customer meter-read data, all meter data can be encrypted at the meter and remains encrypted throughout the entire communications path until it is inserted into the utility database, safely inside the utility customer firewall.

A.4.1 SmartPoint Radio Data Security

The SmartPoint radio module is designed to integrate directly into the registers of the host meter. Register values are read from the meter and encoded into a message inside the SmartPoint radio module. This message is then mangled in a convolution algorithm, and then encrypted with the system WEP key, 128 bit, for transmission. In addition, each RF packet is tagged with a sequence number that allows detection of attempted tampering.

Lastly, the proprietary SmartPoint 7-FSK modulation is not public domain. It is not recognizable by a spectrum analyzer and no off-the-shelf equipment can be purchased to demodulate it.

A.4.2 TGB Data Security

Once data has arrived at the TGB, additional security measures are added. Data is stored only for the period of time needed to ensure accurate transmission over the backhaul link to the RNI. Data stored in the TGB remains encrypted, and the encryption keys are never stored on the same device as the data.

All communications between the TGB and the RNI occurs over encrypted channels. No data is ever sent over any network, public or private, in clear text. All backhaul network interactions are conducted over SSL tunnels using AES-256 encryption.

A.4.3 RNI Data Security

The meter data stream is terminated at the RNI, where it is received via a secure, encrypted tunnel from the TGB. The actual meter readings are decrypted at this point using the WEP keys, and inserted into the utility customer-controlled meter-read database.

A.4.4 Separation of Customer Data

Another unique feature of the FlexNet system is the separation of customer data from network telemetry. This separation, which occurs at the RNI, ensures that customer data is directed to the utility database, and network telemetry and housekeeping data is directed to the network operations database. Personal customer data, such as names and street addresses, are never mixed into the network operations database, ensuring that utilities control the access to information that can personally identify customers.

Appendix B Specifications

B.1 External AC Line Power

- **DC Supply A**: 13 VDC +/- 1V, 150mA max
- **Maximum Message Duration**: Supported by supply capacitor, 200 ms

B.2 Current Consumption

The end point device shall have three modes of operation and a different current requirement for each.

- **Quiescent Mode**: Normal quiescent state. Entered during periods of no input or reading activity to charge capacitor, microprocessor and local high speed crystal always running. The TCXO and other peripherals are off in this state. In this state an additional 9 mA is available for charging the transmit capacitor. $I_{Charge} \leq 6$ mA @ the 36 V rectified voltage source.
- **Receive Mode**: (Optional) A duty cycled state entered to detect if an incoming message is occurring, and, if so, to receive that message. $I_{Receive} \leq 25$ mA @ the 3.3 V supply.
- **Pre-Transmit Mode**: Before transmission, the uC powers up TCXO, Synthesizer, VCO, and other RF circuitry before actively transmitting. The current consumption in this mode will be $I_{Pre\text{-}Transmit} \leq 30$ mA @ the 3.3 V supply.
- **Transmit Mode**: Entered when on air transmission is required. $I_{Transmit} \leq 850$ mA @ the 3.6 V switching regulator.

B.3 Power Failure

- **Power Fail Transmission:** Following power failure, as detected by a Power Failure IRQ signal from the iCon display board, the processor shall place the endpoint device into a low power mode until a programmable time limit up to 120 seconds (Outage Time Threshold). During this time, the device shall count the number of pulses on the Power Failure IRQ line and keep this information to report in an Alarm Message to report the outage. Once the Outage Time limit has been reached, the device shall wait an additional pseudo-random time (up to 152 seconds), at which time it shall transmit an Alarm Message.
- **Power Restored Detection:** Once power has been restored (as determined by no Power Fail IRQ signals being sent by the iCon and the Minimum Voltage Level being exceeded) for longer than the Power Restored Time Threshold, the device shall wait an additional pseudo-random time (up to 160 seconds) at which time it shall send an Alarm Message indicating Power Restored.

B.4 Internal Power Supplies

B.4.1 Micro Power Regulator

Always on, supplies power to CPU, VCO, Buffer Amplifier, Synthesizer, TCXO, and Receiver (if implemented).

- **Drop Out**: 60mV @ 50 mA load
- **Minimum Voltage Input**: 3.4V
- **Maximum Voltage Input**: 3.8V
- **Voltage Output**: 3.3V

B.4.2 DC to DC Converter

Enabled during transmit operation.

- **Efficiency**: 65% Minimum (70% typical)
- **Drop Out**: 2 V maximum under 850 mA load
- **Converter Ripple**: ≤ 100mV
- **Converter Impulse Response**: 750 mA causes ≤ 20 mV spike (TBD)
- **Voltage Output**: 3.6V +/- 5%

B.5 Start Up Timing Requirements

After changing from Charge Mode to other modes, the device takes the following amounts of time for different components to be operational.

- **DC-DC Converter Stabilization:** 10 msec
- **TCXO Stabilization:** 10 msec
- **VCO Frequency Lock:** 1.0 msec
- **Transmit RF Data:** 1.0 msec

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