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Manufacturer: Schlumberger Electricity, Inc.
Equipment Type: Electricity Meter With Dual RF Transmitters
Model: CENTRON ™ ICARe

Theory of Operation

ICARe Project Functional Specification

CDP Requirement 3.1

This document describes the hardware and firmware functional specifications for the project.

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REVISION CHART

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Draft	DP McConnell	Initial draft	9/23/2002
Draft	DP McConnell	Incorporated comments from Jerome Bartier, Eric Deschamps and Vladimir Borisov	9/25/2002
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Preliminary	DP McConnell	Cleaned up format and made final changes from previous spec	1/15/2004

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1 INTRODUCTION

This document will describe the functional design specification for the ICARe RF electricity meter. The purpose of this project is to provide a meter module based on the COSMOS RFASIC developed in Montrouge, France and produced by Atmel. The design will allow the Centron meter to communicate in both the mobile and fixed network environments without hardware or programming modifications. The new module will be a lower cost over the existing CENTRON C1SC module in production.

1.1 Description

The ICARe will be a transmit-only meter module that collects and transmits metering data over the 902 - 928 MHz Industrial, Scientific and Medical (ISM) RF band. The unit will contain both a Direct Sequence Spread Spectrum (DSSS) transmitter and a Frequency Hopping (FSK) transmitter.

1.2 Endpoint Function

The ICARe functions as a RF transmitter that will support remote meter reading using both the mobile and the fixed network protocols. The mobile network functions will be the R300 (ITRON™ protocol) or the R900 (SURF© protocol). The fixed network function will be the CellNet© electricity endpoint protocol (PID2) to maintain legacy functionality.

The endpoint will be installed in the CENTRON meter as the register board. The metrology board will provide power and energy data to the endpoint in the same manner as a normal register board.

The endpoint will provide the following data depending on configuration:

- Cumulative energy readings using the ITRON protocol
- Cumulative energy readings using the Schlumberger SURF protocol
- Cumulative and interval readings using the SchlumbergerSema CellNet protocol

The endpoint will be able to transmit a combination of the fixed and one of the two mobile protocols in a deployment to support the ‘Agile’ network or any single protocol above based on the configuration loaded.

The endpoint will determine electrical energy data by counting pulses from the metrology board and then converting them to energy values for display and transmission. The endpoint will use a constant loaded during configuration to provide the correct energy values for the network being supported.

The endpoint will also use a serial protocol for configuration and testing using the register serial port.

It is also necessary for the endpoint to be able to be installed on previous meter bases with no modifications to the base to maintain the modularity requirement of the CENTRON meter.

References:

COSMOS RFASIC Requirements, by Gilles Picard
Schlumberger Qualification Test Specification for Solid-State Electricity Metering Products, SLB-QTS 5.0
SURF protocol Schlumberger Unlicensed Radio Frequency Protocol specifications, Version 1.0 dated June 9, 1998
Electric Interval Packet Transmission Randomization, White Paper, by Susan Stulz dated 24 June 2002
ICARe RF Protocols Specification
ICARe Product Vision
ICARe Business Case

2 RF Network Services

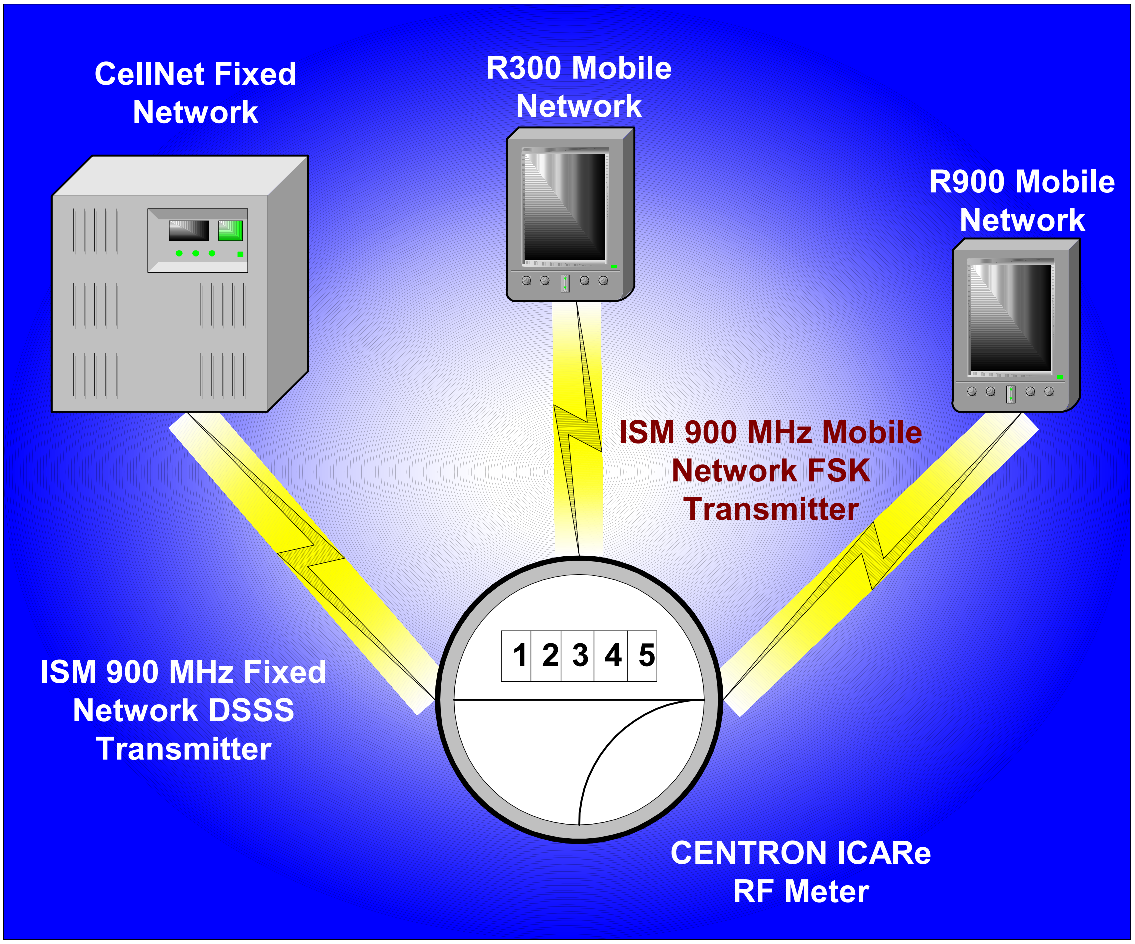

Figure 1 RF Network Interfaces

2.1 SchlumbergerSema CellNet Network System Services

The ICARe RF module will transmit a single channel of data at the 917 MHz using a Binary Phase Shift Keying (BPSK) spread spectrum transmitter. The transmitter is capable of transmitting both the On-Off-Keying (OOK) and the Cyclic Code Shift Keying (CCSK) chipping methods. The fixed network transmitter is capable of providing output power of 25 $\pm$1 dBm to the antenna. The fixed network module transmits standard CellNet Protocol Identification 2 (PID2) packets to the network. Refer to the ICARe RF Protocols Specification for message format and details.

2.1.1 Information Provided

The ICARe will provide the following information to the CellNet fixed network:

- Local Area Network Identifier (LAN ID)
- Meter ID
- Register Configuration
- Cumulative Active Energy delivered daily
- 10 or 18 Active consumption data intervals
- Power fail notification
- Reverse power flow notification
- Magnet switch activation flag

2.1.2 FCC Regulation

The fixed network transmitter operates and meets the requirements in the US code of federal regulations (CFR) Title 47, part 15, subpart C, paragraph 247 of the FCC rules.

2.1.3 RF Characteristics for Fixed Network

Function	Requirement
RF Frequency	917.58 MHz
Spreading Modulation	BPSK
Conducted Power Output	23 dBm ±3 dB (into 50 ohm load at 25° C)
Power Output Temperature Variation	23 dBm ±3 dB from –40/+85°C
Effective Radiated Power (ERP)	+20 dBm minimum peak averaged over 180° azimuth angle
Carrier Suppression	-6 ±6 dB in 3 kHz RBW to adjacent spectral components
Side Lobe Suppression	-13 dB to main lobe
Data Modulation	OOK and CCSK
Symbol Data Rate	19.27 kBPS for OOK and CCSK
Chipping Rate	1.22 MC/S for OOK and CCSK
Chipping Code Length	63 bits for OOK and CCSK
Preamble Length	92 bits (Continuous BPSK SS)
Transmit Duration	11.0 msec to 23.5 msec
Fming	<5kHz @ 1.22 MHz RBW
PLL Stability	±60 kHz from –40/+85°C over 15 years
FCC Certification	Per Part 15.107 and 15.247

Table 1 Fixed Network (CellNet) RF Transmitter Characteristics

2.2 R300 Mobile Network System

The R300 is a frequency-hopping RF transmitter that operates in the 910 to 920 MHz band. It transmits on an average of once per second with a randomized time interval to reduce interference and collisions. The R300 will operate at 0 dBm ±3 dBm to the antenna. The R300 module transmits an Itron standard consumption message (SCM) protocol composed of 96-bits of data. Refer to the ICARe RF Protocols Specification for message format and details.

2.2.1 Information Provided

The ICARe will provide the following services to the Itron Mobile network:

- Module ID
- Meter Type
- Cumulative Active Energy
- Tamper Information

2.2.2 FCC Regulation

The fixed network transmitter operates and meets the requirements in the US code of federal regulations (CFR) Title 47, part 15, subpart C, paragraph 249 of the FCC rules.

2.2.3 RF Characteristics for Mobile Network

Function	Requirement
RF Frequency	910 to 920 MHz
Spreading Modulation	FSK
Conducted Power Output	-1.25 dBm conducted or 94 dBuV @ 3 Meters
Power Output Variation over Temperature	
Effective Radiated Output Power (ERP)	-3 to 0 dBm peak, 94 dBuV/m @ 3 Meters
On Air Transmission Time	6.71 milliseconds (ITRON), 7.4 milliseconds (SURF)
Data Modulation	OOK
Data Rate	16.384 kBPS (32 KHz clock, Manchester coded data)
Data Pacing	1 Packet per second typical (125 milliseconds minimum)
Transmit Duration	6.71 msec
Number of Channels	32 Utilized (previous design), 48 Receiver channels
Channel Bandwidth	200 KHz transmitter, 208 KHz receiver
Frequency Stability	<750 KHz/ Packet
Frequency Accuracy	±3.75 MHz Max over Temperature
FCC Certification	Per Part 15.249

Table 2 Mobile Network (R300/R900) RF Transmitter Characteristics

2.3 Schlumberger R900 Mobile Network System

The R900 is a frequency-hopping RF transmitter that operates in the 910 to 920 MHz band. It transmits on an average of once every 2 to 4 seconds with a randomized time interval to reduce interference and collisions. The R900 will operate at 0 dBm ±3 dBm to the antenna. The R900 module transmits an Schlumberger SURF consumption message protocol composed of 116-bits of data. Refer to the ICARe RF Protocols Specification for message format and details.

2.3.1 Information Provided

The ICARe will provide the following standard services to the CellNet fixed network:

- Module ID
- Meter Type
- Cumulative Active Energy
- Tamper Information

2.3.2 FCC Regulation

The fixed network transmitter operates and meets the requirements in the US code of federal regulations (CFR) Title 47, part 15, subpart C, paragraph 249 of the FCC rules.

2.3.3 RF Characteristics for Mobile Network

Same as defined by the R300 in section 2.2.3.

3 SYSTEM HARDWARE REQUIREMENTS

The ICARe will function as a transmit-only meter module that will be installed in the register board slot in the CENTRON electricity meter. It will be configurable to provide a single channel of data to the CellNet fixed network, a single channel of data to the R300/R900 mobile networks, or a combination of fixed and mobile network data. The new design will maintain the present slot antenna design in use on the CENTRON C1SC.

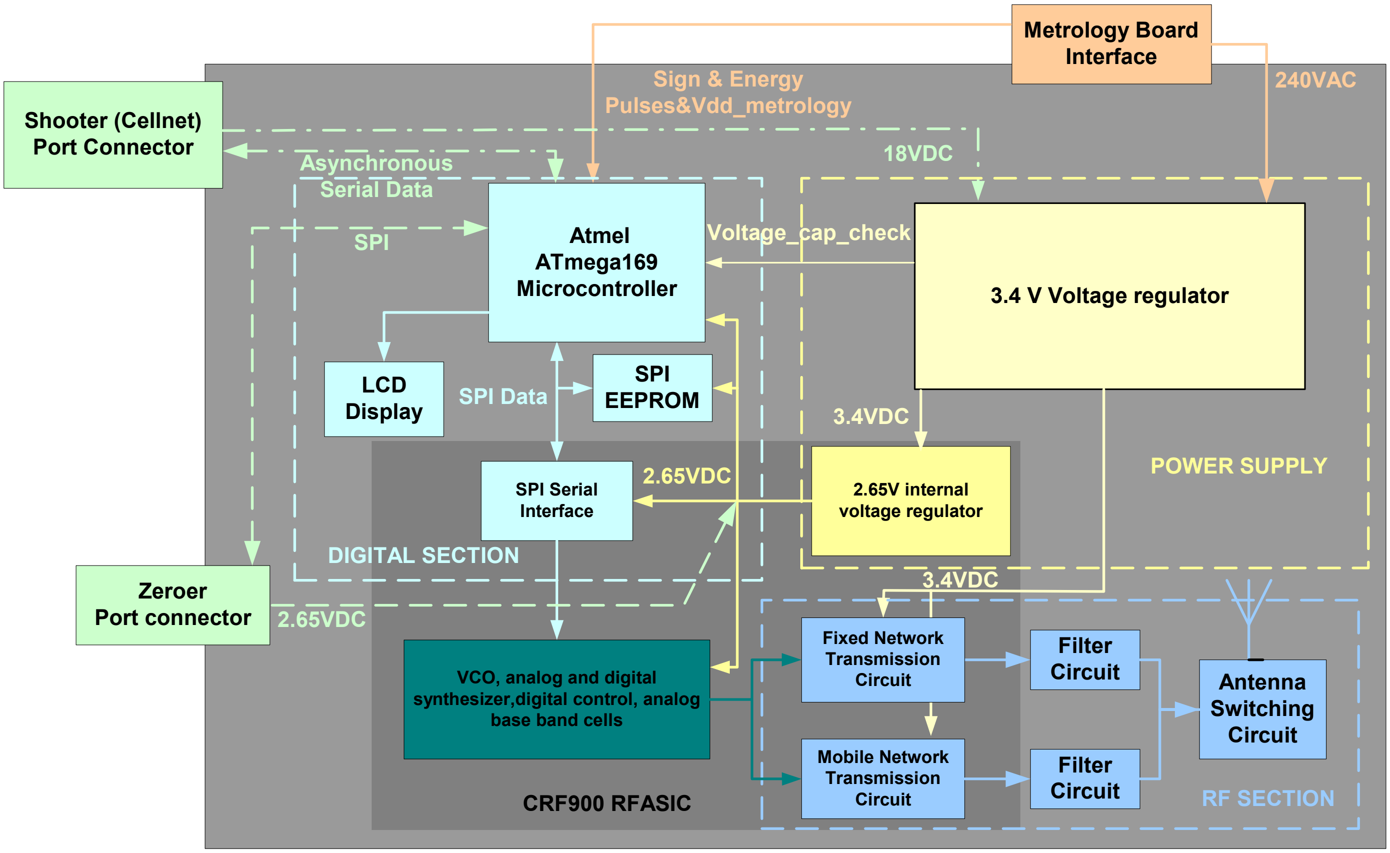

Figure 2 ICARe Block Diagram

The CENTRON meter is composed of the base, the register board and the meter cover. The base contains the metrology board and provides energy pulses and voltage via the interface connector to the register board. This section will deal with the signals coming to the register board via the interface as well as the register board.

3.1 Power Supply Specification

The power supply will be designed to meet the requirements of cost (PCB, component count, component cost), voltage regulation (normal processing, power fail detection) and current consumption (RF transmission, digital processing and voltage regulation)

3.1.1 Power supply inputs and outputs description

The power supply will use external discrete components to get a regulated 3.4V from the 240VAC/120VAC main. This 3.4V will then be supplied to both the internal CRF voltage regulator and the internal CRF RF Power Amplifiers. The internal CRF voltage regulator will then provide a regulated 2.65V voltage to the micro-controller, EEPROM, CRF VCO, CRF analog and digital synthesizer, CRF digital control and the analog base band cell.

Inputs:
- 120 VAC or 240 VAC from the Metrology Board Interface when the meter is plug into a base
- 18 VDC unregulated from the Serial Port Interface when it is connected

Outputs:
- Regulated 3.4 VDC for the internal CRF power amplifier and voltage regulator
- Regulated 2.65 VDC for the Digital section and the CRF internal digital and analog cells

3.1.2 Specification on inputs and outputs

3.1.2.1 Power grid input specification

The power supply is required to be capable of drawing power from both 120VAC and 240VAC-power line with minor changes. The power supply operational conditions are:

- The power line could have a 20% voltage variation
  - 120 VAC: 96 VAC< Power line < 144 VAC
  - 240 VAC: 192 VAC< Power line < 288 VAC
- The power supply will be capable of handling a 0 VAC potential for up to 100ms without triggering a power fail
- Power fail detection should be triggered when:
  - 120 VAC: power line voltage< 72 VAC for >100 mS
  - 240 VAC: power line voltage<144 VAC for >100 mS

3.1.2.2 Serial Port interface power input specification

The power supply will have an additional requirement of being capable to accept an unregulated 18 VDC via the serial port.

3.1.2.3 3.4V regulated output specification

The 3.4V regulated will have to meet the specification for the COSMOS internal voltage regulator as well for the COSMOS internal Power amplifier supply voltage:

Device	Minimum Voltage	Typical Voltage	Maximum Voltage
CRF Power Amplifier	2.4 VDC		3.75 VDC
CRF Voltage Regulator	3.2 VDC	3.3 VDC	3.6 VDC
Supply Ripple			20 mVpp

Table 3 COSMOS Voltage Specifications

3.1.2.4 2.65V regulated output specification

The 2.65 VDC regulated outputs from the COSMOS are the preferable voltage sources for this design since they were designed specifically for the COSMOS voltage requirements and they will reduce the overall component costs. The CRF internal voltage regulators provide:

- One source for the internal features of the CRF controllable by the MCU.
- One source for the Digital circuitry on the board that is constantly on as long as 3.4 VDC is supplied.

The 2.65V digital source meets the specification for all the major digital components in the design.

Device	Minimum Voltage	Maximum Voltage
Atmega169V Microcontroller	1.8 VDC	5.5 VDC
MicroChip 8kbit EEPROM	1.8 VDC	5.5 VDC
CRF Internal Devices	1.8 VDC	3.15 VDC

Table 4 Digital Circuit Voltage Requirements

3.1.3 Power Supply output current specification

Part	Descriptions	Maximum Current Value
Micro-controller Atmega169V	**16K ROM part**	
CPU	No sleep mode, run at 1Mhz on internal RC oscillator	0.7mA
Analog Digital Converter (ADC)	standby when it is not used (200uS max conversion time~40 ADC clock)(200Khz clock)	300uA active/5uA standby
EEPROM	**8Kbit part**	
	Standby mode	0.5uA
	Write 16-Byte page sequence in 5ms max	3mA
	Read sequence at 2Mhz clock	0.5mA
COSMOS RFASIC	**RF Transmitter**	
	Shutdown mode	10uA
	Serial Communication 1Mhz max	0.5mA
	Crystal and PLL stabilization in 10ms max	1.5mA
	Fix Transmission 25ms max at 23dBm	350mA
	Mobile Transmission 10ms at 8dBm	30mA
Metrology Board Interface	**Pull up to convert a +/-2.5V in 0V-2.5V logic**	**130uA low/0uA high**
	Watt hour pulse duration 10ms	130uA
	Lsync pulse	65uA
	Energy sign	130uA positive/0uA negative
Power Supply	**Power supply regulation**	
	Voltage capacitor detector	70uA
	Quiescent current in the LDO	100uA

Table 5 Component Current Requirements

From the above table the following charge quantities will be needed for each operation as well as the DC current that the Power Supply will have to provide.

Event Description	Total Charge Needed	Average Current
Each 150s-period, the algorithm will write and read (worse case) 250Khz=>250bit/ms~32byte/ms~2page/ms) 2 locations of 2 pages of the EEPROM.	Read:1.5uC Write:90uC Total:91.5uC	I_EEPROM=1.5uA @ 150s period
CRF transmission steps: COSMOS RFASIC Serial communication: 54-byte max for a CCSK plus ~10 bytes for CRF configuration and start of transmission (@250Khz~64Byte/2ms) 25.58Mhz Crystal + PLL stabilization Cellnet transmission every 300s period Mobile transmission every 1s period	Serial com:1uC Crystal+PLL:15uC Cellnet:8.75mC Mobile:300uC	I_CELLNET=(8.75+0.015+0.001)/300=30uA I_MOBILE=(0.3+0.015+0.001)/1=316uA
Analog/Digital Converter (ADC): Check the capacitor voltage every 9ms Check for Temperature Compensation every 9ms Check the metrology power supply(Vdd) every 9ms	ADC conversion:0.06uC	I_Check_Cap=15uA I_Check_RMS=15uA I_Check_Metro=15uA
Metrology board interface : 3 lines are coming from the metrology: Sign : when the energy is positive the line is at –2.5V Lsync: Squared signal between 2.5V and –2.5V @60hz Whpulse: -2.5V 10ms-pulse for one unity of 50Wh. Max frequency is 32Hz.		I_Lsync=65uA I_positive_sign=130uA I_32HzWhpulse=41.6uA

Table 6 Power Supply Current Requirements

In Normal mode without transmission, the power supply should handle the following current:

- MCU - 700uA
- Metrology Board Interface Circuitry – 240 uA (no input pulses present)
- MCU ADC – 50 uA
- COSMOS Standby Current – 500 uA
- Power Supply – 180 uA
- **Total of 1.7mA DC current**

Here are the criteria that the power supply is required to provide:

- **Handle 1.7mA DC current**
- **Handle 350mA-25ms transmission every 300s**
- **Handle 30mA-8ms transmission every 1s**
- **Handle 350mA 20ms power transmission**
- **All requirements are valid for 15 years product life time**
- **Power up the board and ready to transmit in less than 8.2s (see manufacturing specification)**

3.2 RF Section Specification

3.2.1 CRF ASIC part

CRF ASIC is handling the major functions required by the network:

- Receive data from microprocessor and modulate it following the Cellnet protocol
- Receive data from microprocessor and modulate it following the R300 or R900 or SURF protocol
- Each timing related to the RF data is handle by the CRF ASIC through a 25.48833MHz crystal

3.2.2 RF on board circuitry

The RF circuitry is divided in two sections:

- Antenna
- Matching between antenna and the CRF ASIC

The antenna is required to:

- Have a minimum 0dB gain at 917.58MHz for both horizontal and vertical polarization
- Be matched for 50ohms in the 910MHz-920MHz band

The matching circuit between the CRF ASIC and the antenna:

- Design a strip-line balun for both Cellnet and mobile Power amplifiers
- For cellnet, the Power amplifiers need to matched both at the fundamental (917.58MHz) and the second harmonic (1.835GHz)
- For Mobile, the power amplifier need to matched over the band 910MHz-920MHz
- Harmonics rejecter low pass filter to be design to have a minimum 40dB attenuation for harmonics 3,4 and 5
- For cellnet, balun and filter losses should be lower than 2dB
- For Mobile, balun and filter losses should be lower than 8dB

3.3 CENTRON Meter Metrology Interface specification

The endpoint will utilize the standard CENTRON interface for power and energy readings consisting of the following signals.

Pin Number	Signal
1	120/240 VAC
2	+2.5 VDC
3	LSYNC
4	Sign Pulse
5	Watthour Pulse
6	-2.5 VDC
7	GND

Table 7 CENTRON Interface Pinout

The two outputs of the metrology board from pins 4 and 5 are pulses that represent the watthours measured and the direction (sign) of the energy flow. The Watthour Pulse is a normally high signal with a 10 millisecond; low going pulse to represent the energy signal.

The sign pulse is either a high signal representing a negative energy flow or low signal representing a positive energy flow.

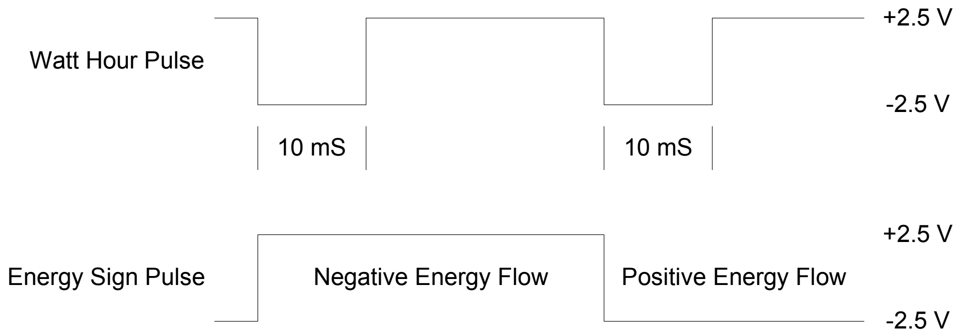

Figure 3 Metrology Energy Pulses

The LSYNC signal is a 60 Hz square wave that will be present as long as power is available on the main. This is the signal that should be monitored to calibrate in real time the internal RC oscillator of the microprocessor

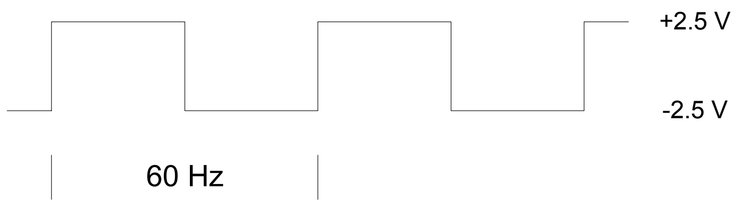

Figure 4 LSYNC Signal

For interfacing to the register board microcontroller, the signals from the metrology board will have to be level shifted to 2.65V-0V levels.

3.4 Manufacturing specification

3.4.1 Test Points

The module will contain test points to support manufacturing operations as well as providing necessary access to signals for debugging both the hardware and firmware. Each node of the circuit requires a test point. All the Test points will be used in ICT test whereas only some of the test points will be use to perform the FVT test. Manufacturing is specifying that the test points should be either all on the bottom layer of the board or on the top layer of the board. The number of test point per board should be limited to 102 test points (maximum of 2048 test points available on a fixture and panel of 20 boards). The test point should also be numerated from 0 to 101.

3.4.2 Manufacturability

- The component count cannot exceed 150 components on the design
- The unit must have test points for ICT and FVT testing
- Increase of the number of boards per panel from 16 to 20. Note: This will reduce the total board area and with the new LCD holder it will have an impact on the size of the onboard slot antenna.
- All components have to be surface mount to eliminate any through-hole processes.
- In order to meet the present burden and overhead costs of the RMR, the power supply will have to handle a transmission within 8.2s after power up while test in process.
- During the Meter Functional Test (MFT), the meter will be fully assembled with no external access to the board. A magnet to produce a magnet packet for the CellNet fixed network application will trigger the RF transmissions.

3.4.3 Mechanical guidelines

- The board material structure should follow the following optimum conditions:
    - 4 layers (layer1->14mils->layer2->28mils->layer3->14mils->layer4)
    - Material will be a FR4 (permitivity close to 4.6)
    - Inner layer should be 1oz thick (start and finish), external layer should start with 0.5oz thickness and finish with 1oz thickness
- Copper should stay at 20 mils from the edge of the board after scoring operation (manufacturing cutting operation requirement)
- Use of the new board-to-board connector pads (bigger pads for GND and 240VAC)
- Use of the newest LCD pads developed by mechanical Engineer to decrease problem in manufacturing
- Keep a space for the new bar code developed by manufacturing

3.5 Qualification

The module will be able to pass all standard qualification tests per the Schlumberger Electricity Qualification Test Specification listed in the references in section 5.

4 SYSTEM FIRMWARE REQUIREMENTS

The firmware will be located in the MCU ROM with a maximum of 16 kBytes of code space. The firmware will encompass the functionality of the CellNet and SURF protocols.

The firmware will be written in “C” for portability requirements. The code will be modular in nature with each unique function having it’s own module. This will enhance the reuse capability of the code for future projects. The code will be maintained using version control software at all times.

The firmware should attempt to maintain commonality with existing CENTRON products as much as possible. This will reduce the risk of introducing problems that have already been resolved back into the system. Both the CENTRON and RTEMS teams should review all firmware.

4.1 Firmware Description

The firmware will operate in several states shown in figure 2. These states will be used to validate ICARe power levels, support existing serial interfaces, verify and load the static and dynamic data, process metrology and power fail signals, update the LCD, save and verify dynamic data, and create and schedule RF messages for transmissions as needed. This diagram is the “large picture” with the details of the firmware to be presented in the firmware specification document.

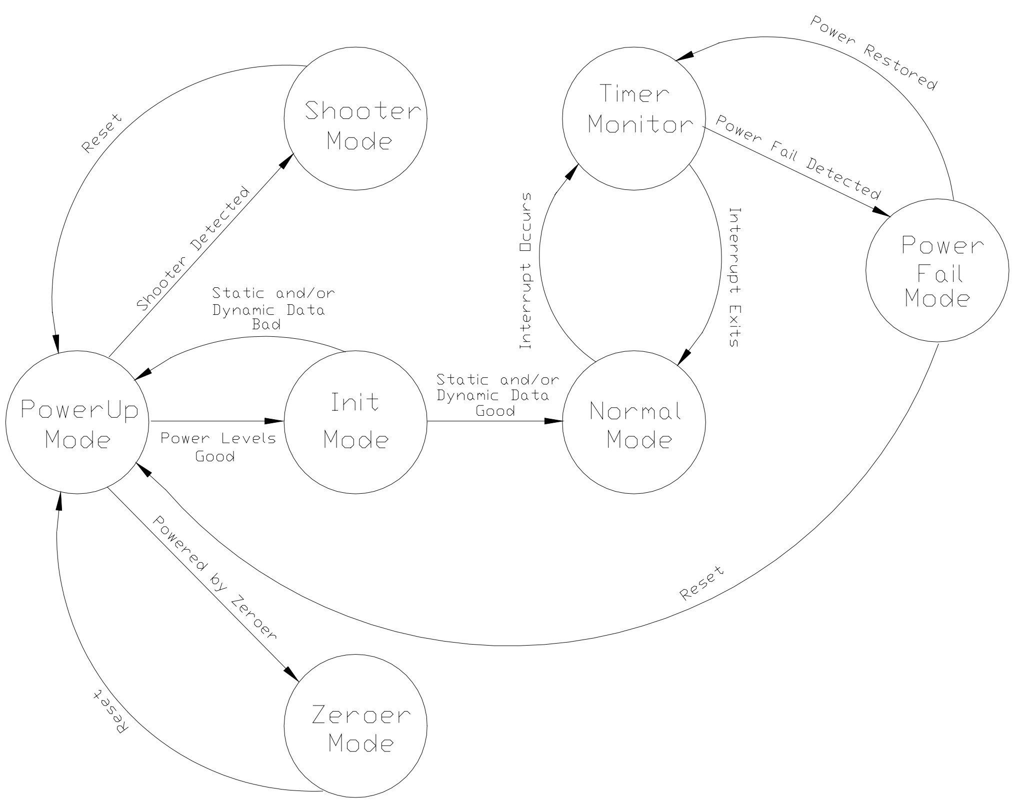

Figure 5 ICARe Modes of Operation

Mode	Description
Power Up	The Power Up mode will be the initial state of the module. It will enter this state upon a power on or watchdog reset. This mode will initialize the MCU's peripherals and then determine when the power levels are sufficient to progress to move onto the initialization mode. This state is exited when: • Shooter detected → Shooter Mode • Powered by Zeroer → Zeroer Mode • Power Levels good → Initialization Mode
Initialization	Once the module has verified that reliable supply power is present, the configuration data will be read from the nonvolatile memory and the module will initialize itself. This state is exited when one of the following conditions are met: • Invalid configuration → PowerUp Mode • Initialization successful → Normal Mode
Normal	This will be the main operating state for the module. In this state the module will update the LCD with the cumulative consumption value determine, implement the EEPROM data saving algorithm, and call functions to schedule and create RF messages for both Mobile and Fixed technologies. A pet of the watchdog is also performed in this normal mode loop. This mode is exited when: • Interruption from Timer Monitor → Timer Monitor Mode This mode is entered when: • Configuration is validated and loaded from Initialization Mode • Timer Monitor interrupt is complete
Shooter	Shooter mode is entered when it is determined that the shooter is connected to the ICARe board. This mode will be used to configure the Fixed configuration parameters as well as other test utilities to support the Fixed network. This state is exited when: • Shooter RxD low for > 1.5 msec forces watchdog reset → PowerUp Mode
Zeroer	Zeroer mode was designed to support RMR using the I2C protocol. After power is determined to come from the Zeroer device, the firmware gathers data and awaits either a read or reset energy command from the user. This state is exited when: • Zeroer voltage is removed and forces reset → Power Up mode
Timer Monitor	The mode is entered via a timed internal interrupt. This interrupt when entered will conduct all metrology signal processing and check signal levels for possible power fail mode entry. This mode also operates as the firmware's freerun timer. This state is exited when: • Power Fail Detected → Power Fail Mode • Completion of tasks → Normal Mode
Power Fail	Power fail mode commences when the Timer Monitor mode detects a possible power fail by evaluating several signals on board the ICARe. This mode is exit when: • Power Fail Detection Confirmed → Resets • Power Restored → Timer Monitor

Table 8 ICARe Firmware Modes

4.2 Firmware Requirements

The ICARe firmware will perform the following functions:

- Count energy pulses from the metrology board
- Monitor the sign line from the metrology board for energy flow and open bond detection
- Maintain module CellNet and R300/R900 configuration data in EEPROM
- Maintain module cumulative and interval counts in EEPROM
- Monitor Power Fail and Power Recovery operations
- Update LCD with cumulative consumption and perform temperature compensation
- Load and validate static configuration and dynamic data
- Schedule RF Transmissions

Interface with Serial port

- ESP serial interface capability
- Use standard Shooter interface
- Maintain MMLIB functionality as much as possible
- Support the Zeroer and I^2C functionality for the RMR version

Interface with COSMOS CRF

- SPI serial interface capability
- Provide RF configuration data to CRF
- Confirm RF messages sent

Transmit PID 2 Message Packets to CellNet fixed network

- Nominally transmitted every two native intervals (2.5 minute native interval) with a randomization period of one native interval. Packets could be transmitted from anywhere between 0 to 5 minutes minus one second.
- Consumption data packets, both CUMINT2 and CUMINT3
- Administrative packets, ADMIN3 only
- PowerFail and PowerUp packets
- Magnet Packets

Transmit R300/R900 Message Packets to mobile network

- Consumption data packet
- Nominally transmitted every 2 to 4 seconds randomized

Utilize present CENTRON algorithms in RTEMS applications

- Monitor the energy accumulation to detect the metrology bond wire failure
- Monitor the LSYNC line from the metrology board to aid in power fail detection
- Perform EEPROM backup every interval period and X Whr

5 SYSTEM RF OPERATION

5.1 RF Characteristics

The COSMOS RFASIC is designed to provide both direct sequence spread spectrum (DSSS) and frequency shift keying (FSK) transmissions in the 902 – 928 MHz ISM band. The characteristics of the transmitters for both the fixed (DSSS) and mobile (FSK) network transmitters are detailed in section 3 of the COSMOS RF ASIC Requirements Specification.

5.2 Fixed Network Description

The fixed network RF transmitter is designed for integration with the SchlumbergerSema CellNet Fixed RF Network. The RF transmitter specifically works within the CellNet RF local area network (LAN) in the unlicensed 900 MHz ISM band. The transmitter complies with title 47, part 15, section 247 of the FCC rules for radio frequency devices.

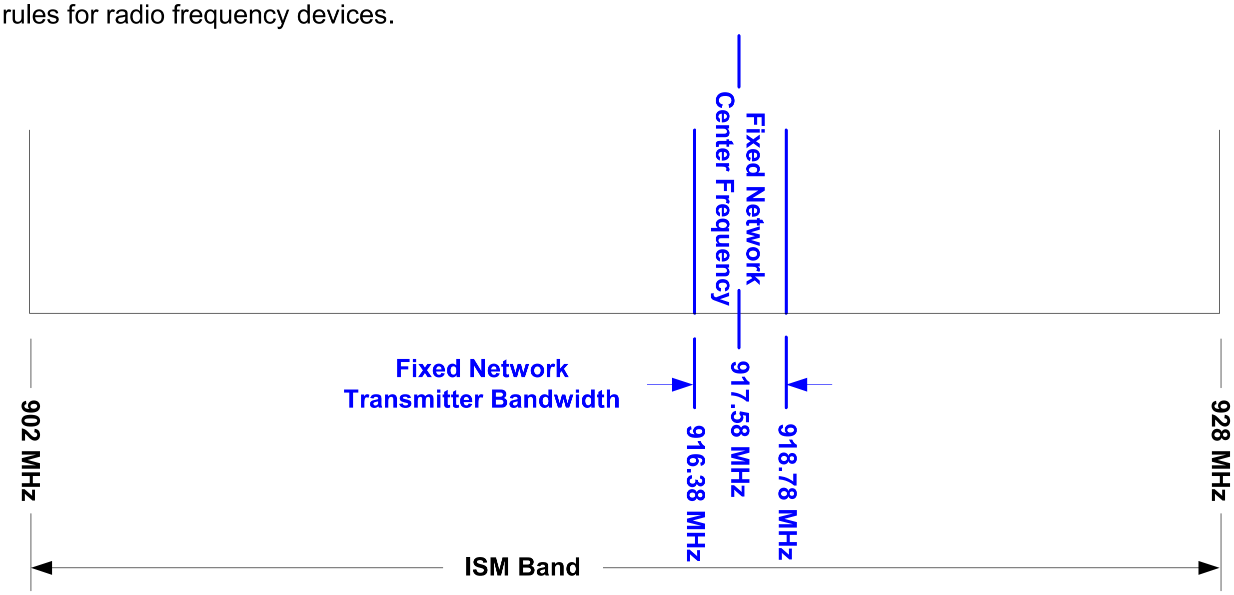

Figure 6 Fixed Network Bandwidth

5.2.1 Spreading Code

The COSMOS RFASIC is capable of both On-Off Keying (OOK) and Cyclic Code Shift Keying (CCSK) for RF data transmission based on the requirements of the network. The 917.58 MHz carrier is Binary Phase Shift Keying (BPSK) modulated with a 63-bit pseudorandom code sequence. This COSMOS RFASIC design contains only one DSSS RF channel. For details about the OOK and CCSK messages refer to the ICARe RF Protocols Specification.

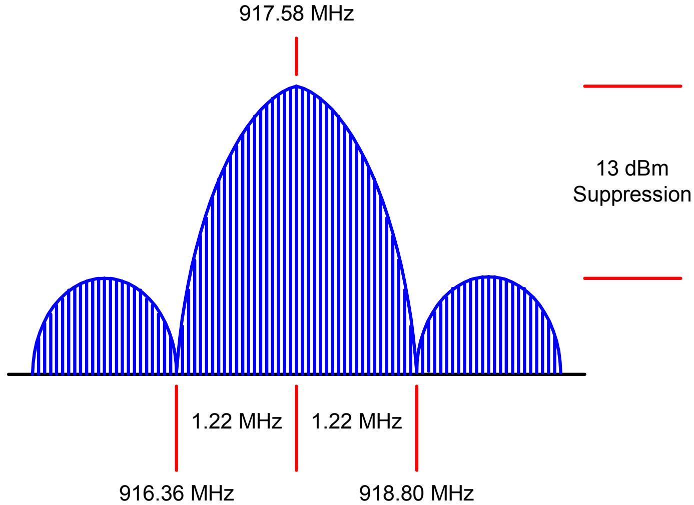

Figure 7 Fixed Network DSSS Pattern

5.3 Mobile Network Description

The mobile network works within the 900 MHz ISM band using a FSK transmitter. The system works within the range of 910 to 920 MHz using 77 receiver channels on the drive-by unit and one scanning channel on the handheld unit. The COSMOS RF is capable of providing either 64 channels with 131.072 kHz channel spacing or 128 channels with 65.536 kHz channel spacing.

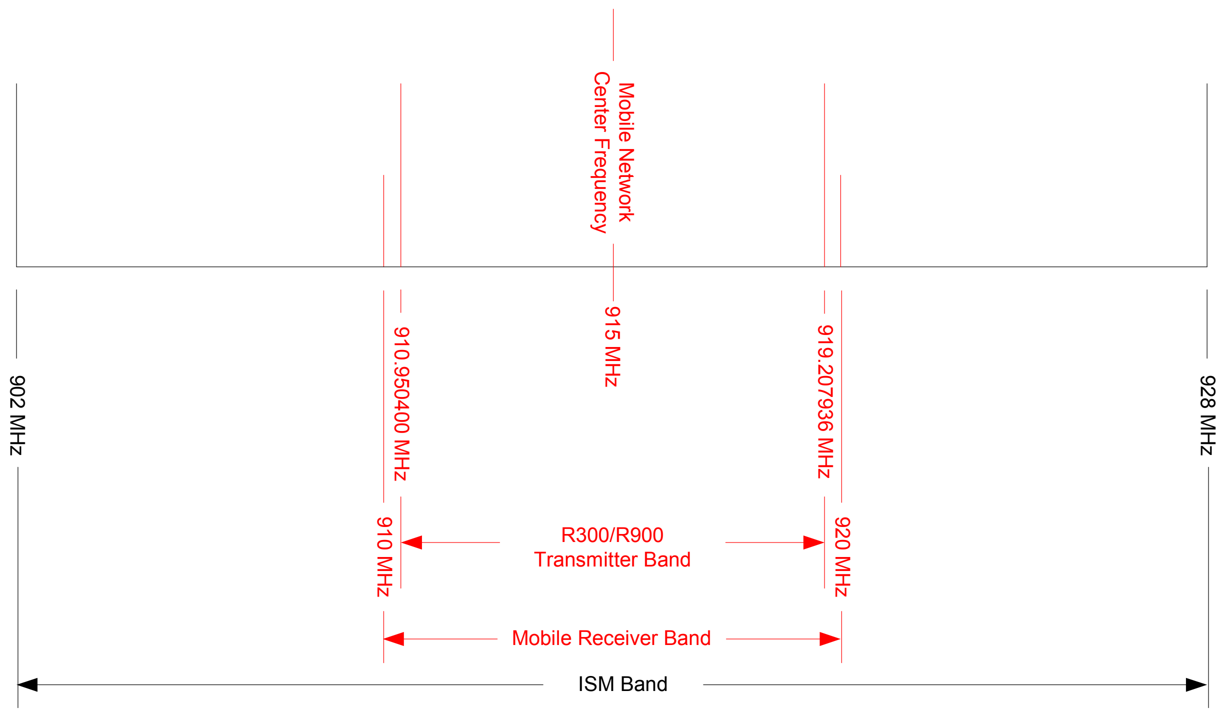

Figure 8 Mobile Network Transmission Bandwidth

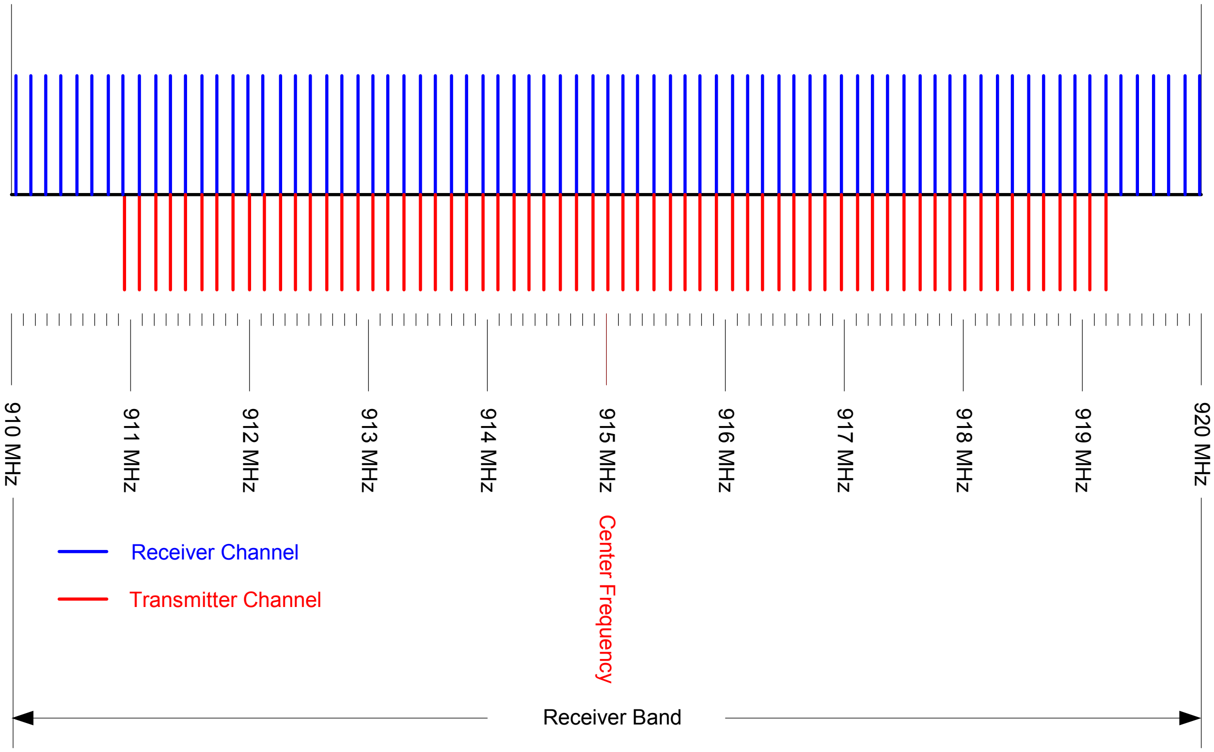

Figure 9 Mobile Transmitter 64 Channels

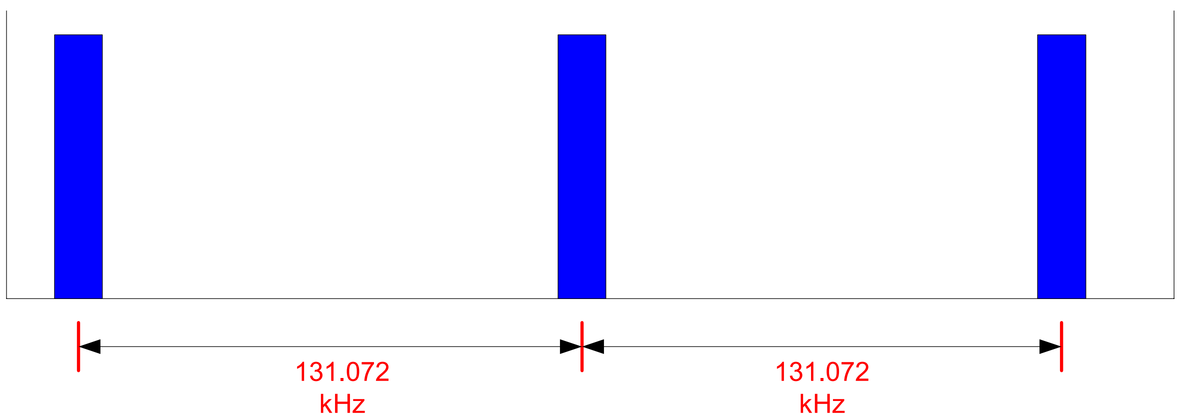

Figure 10 64 Channel Frequency Spacing

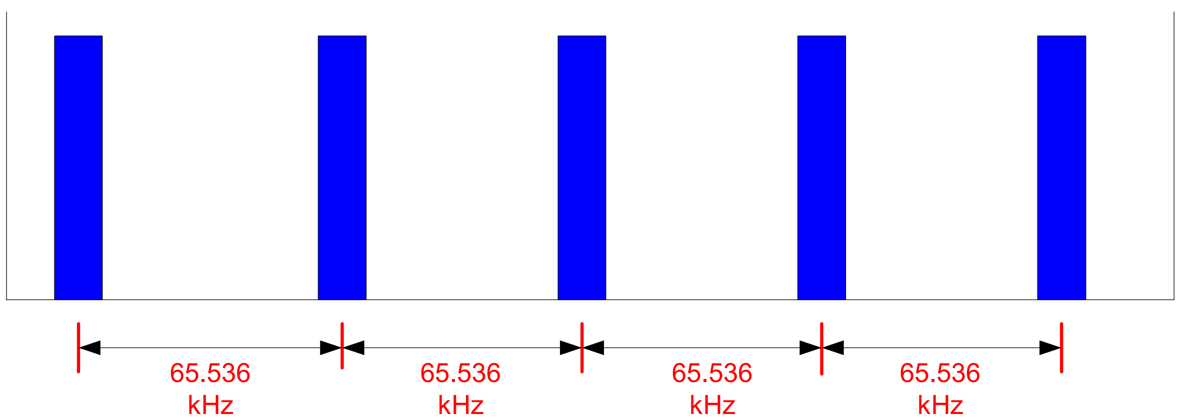

Figure 11 128 Channel Frequency Spacing

5.4 R300 / R900 Transmissions

The R300 and R900 use two different transmission methods that should be noted. The R900 transmissions are standard On-Off-Keying (OOK) while the R300 is a Manchester encoded signal. The R900 transmitter basically turns the amplifier on and off to represent a 1 and a 0 respectively for the OOK. The R300 Manchester encoded signal actually is a double chipset that has a 1 to 0 transition to represent a 1 and a 0 to 1 transition to represent a 0.

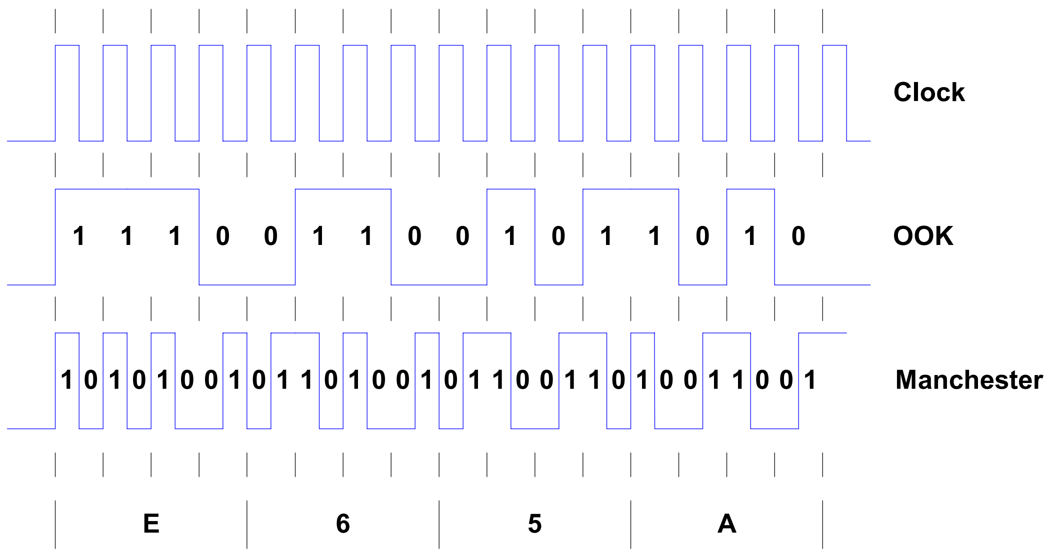

Figure 12 Mobile OOK versus Manchester Encoding

5.5 Interleaved Network Transmission Bandwidth

This first example shows the bands of operation based on the standard transmission bandwidths of both the fixed network and the mobile network transmitters.

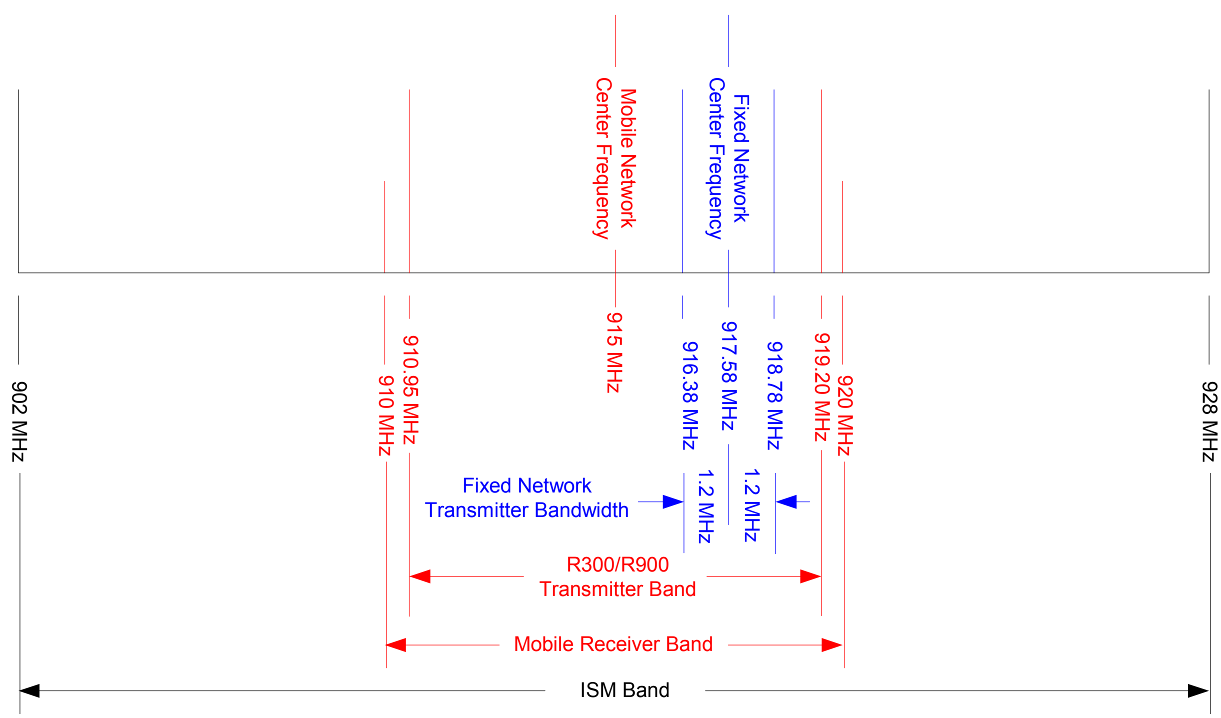

Figure 13 Interleaved Network RF Bands

If the mobile transmitter acts as a “jammer” and reduces the PSR of the fixed network operations, a possible second solution for the RF bands is shown below.

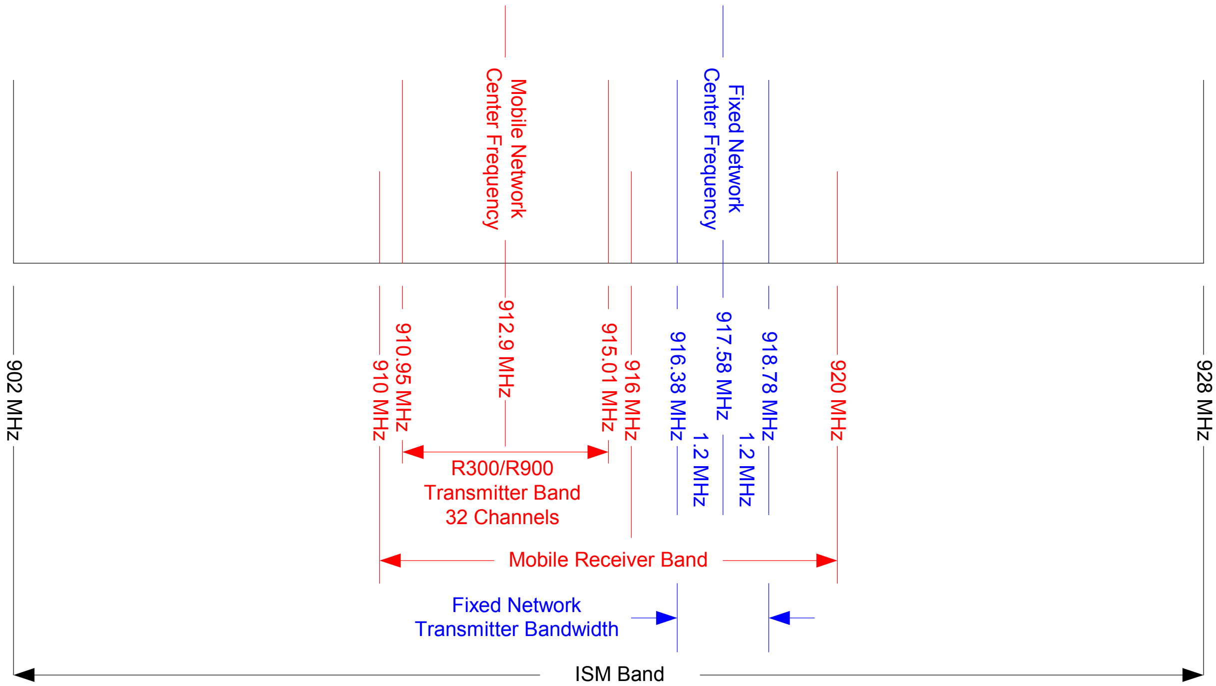

Figure 14 Alternate Interleaved Network RF Bands

5.6 Transmission Randomization

The ICARe will have the ability to transmit multiple data protocols from the same meter. The interleaving and transmitter selection will be controlled by the microcontroller, which will also maintain a common energy count for both systems. The data will be converted to the proper protocol and then transmitted on an interval period loaded during configuration.

The mobile data will be transmitted every 2 seconds randomized from 0.125 to 2 seconds when operated in R300/R900 mode only. This allows the unit to operate in existing mobile networks with no impact to operation.

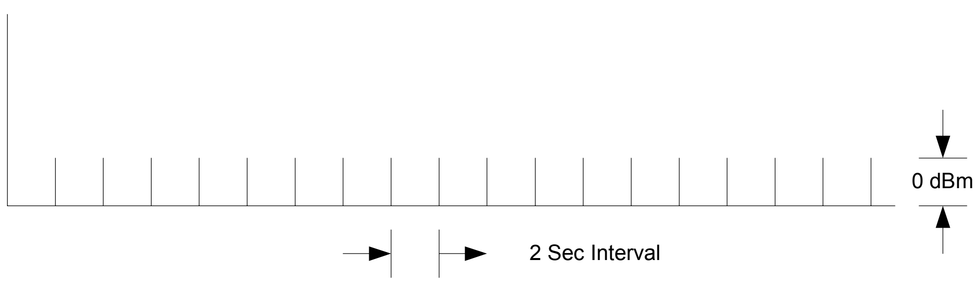

Figure 15 Mobile Transmitter Only Timing

If operated as an interleaved transmitter with the fixed network data a transmission time of 2 – 4 seconds will be the data rate for the mobile transmitter. The fixed network transmitter will operate based on a native interval of 2.5 minutes (150 seconds) with a transmission rate of 2 native intervals or 5 minutes (300 seconds). This maintains a common legacy with existing residential electricity meters already in existence in fixed networks. While the two transmission mediums are integrated they will operate independently of each other.

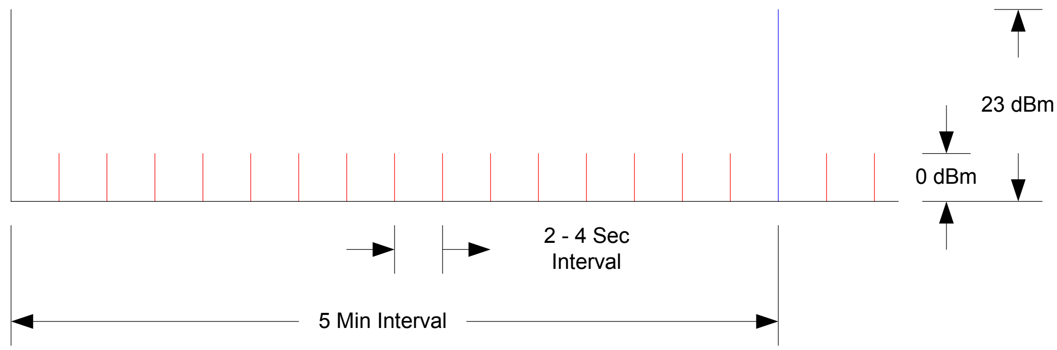

Figure 16 RF Mobile and Fixed Interleaved Transmission Timing

5.6.1 Fixed Network Randomization

The randomization of the fixed network takes place over a 150 second native interval from the EOI which is the default setup. The normal operation for most deployed residential fixed network endpoints are two native intervals of data per transmission. That means that while 150 seconds of interval data is collected, transmissions occur every 300 seconds. The randomization values will be between minimum of 1 second and a maximum of 140 seconds to allow for an additional clearance time of the message transmission.

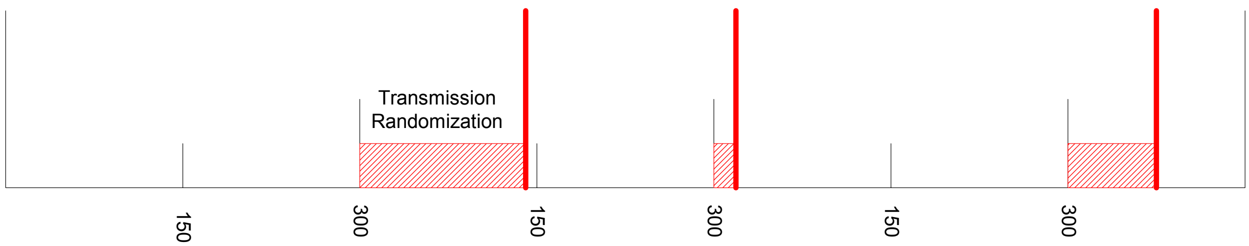

Figure 17 Fixed Network Interval Randomization

5.6.2 R300 / R900 Mobile Network Randomization

The randomization of the R300 / R900 mobile network takes place over a 2 second native interval. The normal operation for the mobile network is one transmission per second randomized. The mobile transmitter will transmit the cumulative data as it is updated as opposed to the native interval method of the fixed network.

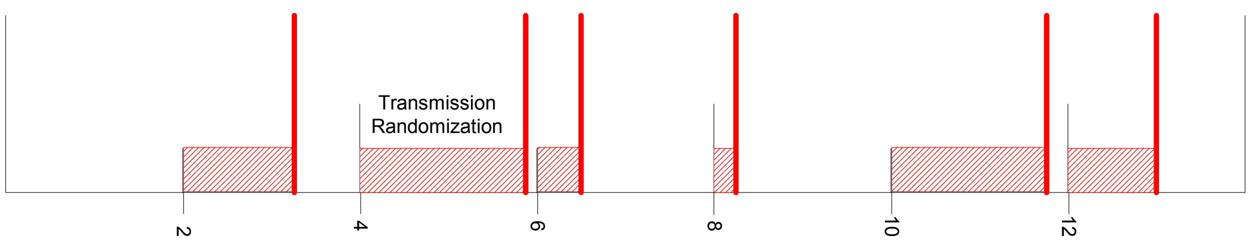

Figure 18 Mobile Network Randomization

5.6.3 Agile Mobile Network Transmitter Randomization

The randomization of the agile mobile network takes place over a 2 second native interval. The normal operation for the agile network is one transmission every 2 seconds randomized. The agile transmitter will transmit the R300 cumulative data followed immediately by the R900 as soon as sufficient power is available for the transmission.

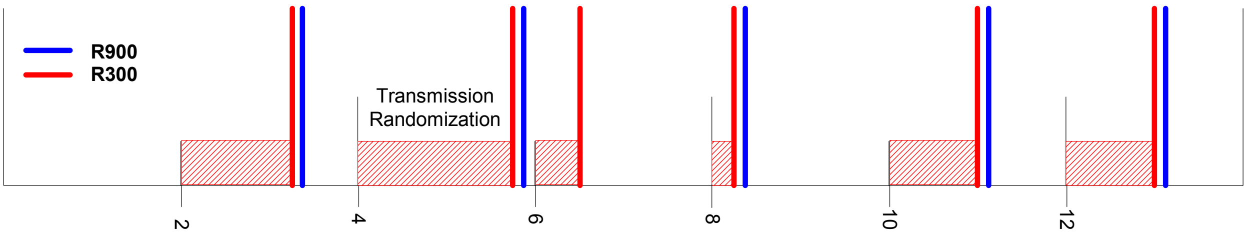

Figure 19 Agile Network Mobile Randomization

5.6.4 Fixed Network Intervals

The fixed network transmissions include cumulative and interval data. There are two formats for the messages that can be transmitted. The first format is a Cumulative 2 (CumInt2) message that has 18 bytes of interval data that is transmitted along with the total energy cumulative count. Since the normal setup for the residential transmitter is to transmit every other native interval each transmission will include 2 intervals (300 seconds) of data. For the residential meter the data is the total energy accumulated during the interval.

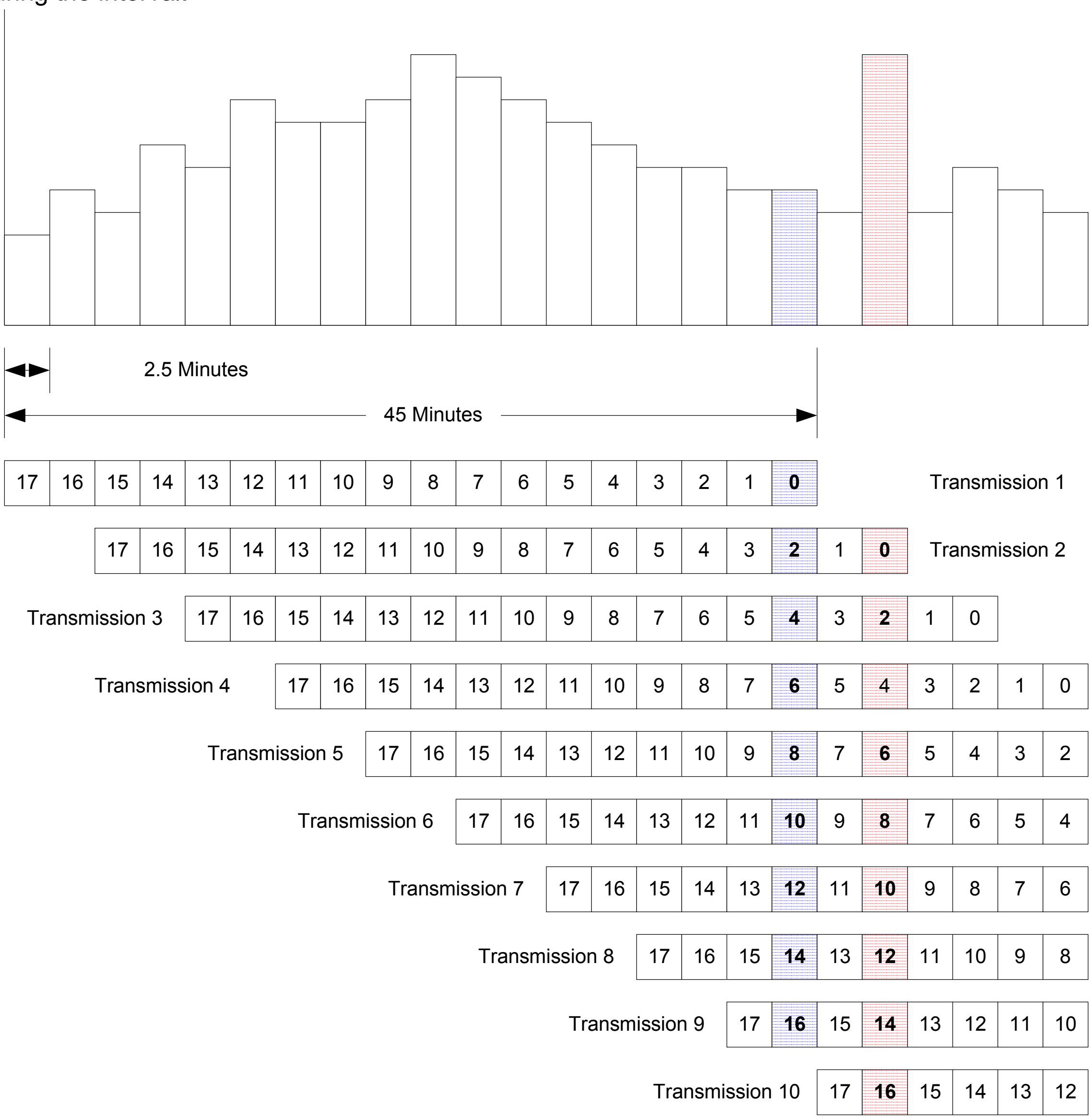

Figure 20 Cumulative 2 with 18 Intervals

The second format is a Cumulative 3 (CumInt3) message that has 10 15-bit intervals of data that is transmitted along with the total energy cumulative count. This message operates in a similar fashion to the cumulative 2 message.

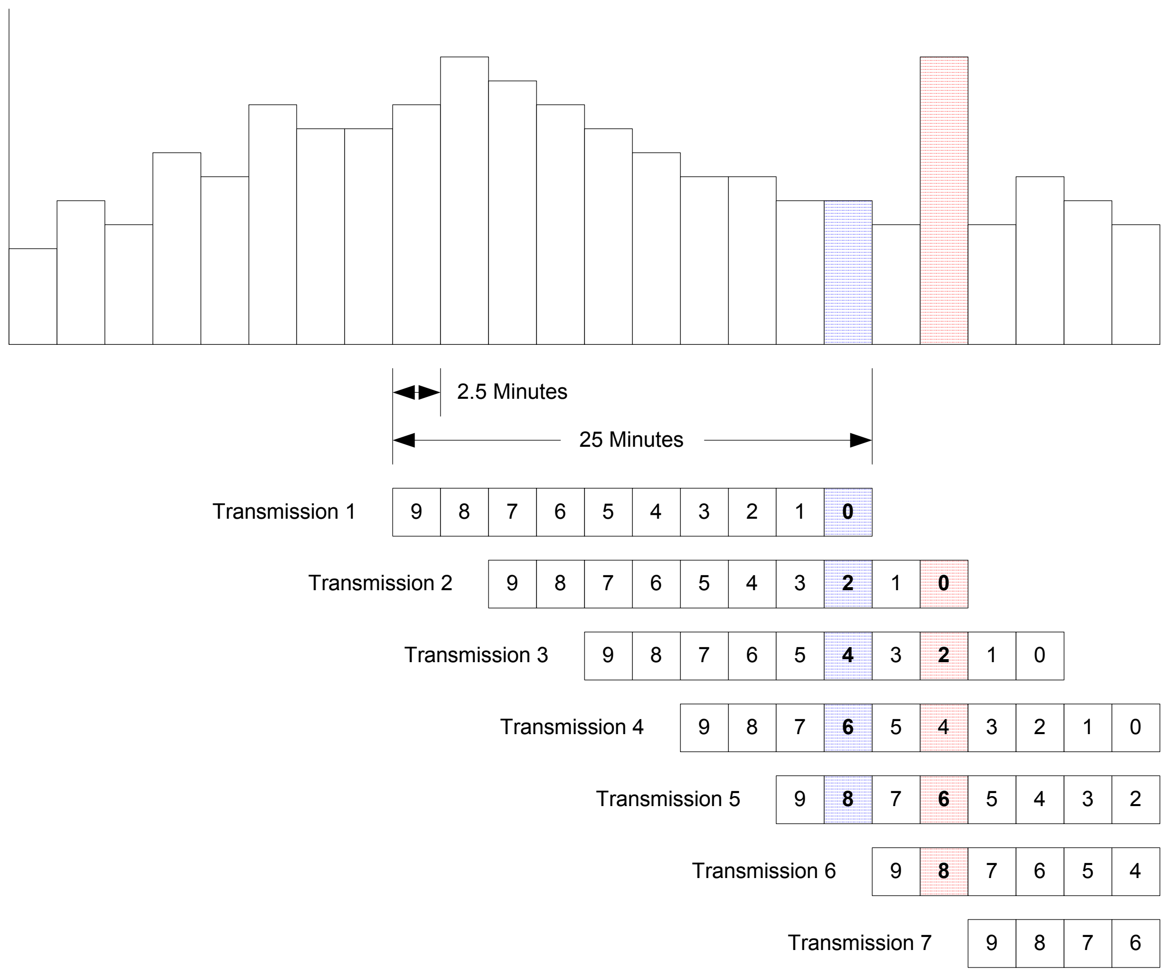

Figure 21 Cumulative 3 with 10 Intervals

5.6.5 Mobile Channel Selection

Based on the equation given in the COSMOS RF specification version 2.4 the following table should give the correct N & M values to correspond with one of the allocated frequencies.

Schlumberger

N	M	Channel Frequency	Channel No.	N	M	Channel Frequency	Channel No.	N	M	Channel Frequency	Channel No.
				51	26	913769812		53	6	916652780	
50	15	910952366	1	51	27	913835334	23	53	7	916718302	45
50	16	911017888		51	28	913900856		53	8	916783824	
50	17	911083410	2	51	29	913966378	24	53	9	916849346	46
50	18	911148932		51	30	914031900		53	10	916914868	
50	19	911214454	3	51	31	914097422	25	53	11	916980390	47
50	20	911279976		52	0	914162944		53	12	917045912	
50	21	911345498	4	52	1	914228466	26	53	13	917111434	48
50	22	911411020		52	2	914293988		53	14	917176956	
50	23	911476542	5	52	3	914359510	27	53	15	917242478	49
50	24	911542064		52	4	914425032		53	16	917308000	
50	25	911607586	6	52	5	914490554	28	53	17	917373522	50
50	26	911673108		52	6	914556076		53	18	917439044	
50	27	911738630	7	52	7	914621598	29	53	19	917504566	51
50	28	911804152		52	8	914687120		53	20	917570088	
50	29	911869674	8	52	9	914752642	30	53	21	917635610	52
50	30	911935196		52	10	914818164		53	22	917701132	
50	31	912000718	9	52	11	914883686	31	53	23	917766654	53
51	0	912066240		52	12	914949208		53	24	917832176	
51	1	912131762	10	52	13	915014730	32	53	25	917897698	54
51	2	912197284		52	14	915080252		53	26	917963220	
51	3	912262806	11	52	15	915145774	33	53	27	918028742	55
51	4	912328328		52	16	915211296		53	28	918094264	
51	5	912393850	12	52	17	915276818	34	53	29	918159786	56
51	6	912459372		52	18	915342340		53	30	918225308	
51	7	912524894	13	52	19	915407862	35	53	31	918290830	57
51	8	912590416		52	20	915473384		54	0	918356352	
51	9	912655938	14	52	21	915538906	36	54	1	918421874	58
51	10	912721460		52	22	915604428		54	2	918487396	
51	11	912786982	15	52	23	915669950	37	54	3	918552918	59
51	12	912852504		52	24	915735472		54	4	918618440	
51	13	912918026	16	52	25	915800994	38	54	5	918683962	60
51	14	912983548		52	26	915866516		54	6	918749484	
51	15	913049070	17	52	27	915932038	39	54	7	918815006	61
51	16	913114592		52	28	915997560		54	8	918880528	
51	17	913180114	18	52	29	916063082	40	54	9	918946050	62
51	18	913245636		52	30	916128604		54	10	919011572	
51	19	913311158	19	52	31	916194126	41	54	11	919077094	63
51	20	913376680		53	0	916259648		54	12	919142616	
51	21	913442202	20	53	1	916325170	42	54	13	919208138	64
51	22	913507724		53	2	916390692		54	14	919273660	
51	23	913573246	21	53	3	916456214	43				
51	24	913638768		53	4	916521736					
51	25	913704290	22	53	5	916587258	44				

Table 9 Mobile Channel Selections

Xmtr Chan	Xmtr Chan Frequency	Rcvr Chan	Rcvr Chan Frequency	Xmtr Chan	Xmtr Chan Frequency	Rcvr Chan	Rcvr Chan Frequency
1	910952366	95	910949978	33	915145774	63	915144282
2	911083410	94	911081050	34	915276818	62	915275354
3	911214454	93	911212122	35	915407862	61	915406426
4	911345498	92	911343194	36	915538906	60	915537498
5	911476542	91	911474266	37	915669950	59	915668570
6	911607586	90	911605338	38	915800994	58	915799642
7	911738630	89	911736410	39	915932038	57	915930714
8	911869674	88	911867482	40	916063082	56	916061786
9	912000718	87	911998554	41	916194126	55	916192858
10	912131762	86	912129626	42	916325170	54	916323930
11	912262806	85	912260698	43	916456214	53	916455002
12	912393850	84	912391770	44	916587258	52	916586074
13	912524894	83	912522842	45	916718302	51	916717146
14	912655938	82	912653914	46	916849346	50	916848218
15	912786982	81	912784986	47	916980390	49	916979290
16	912918026	80	912916058	48	917111434	48	917110362
17	913049070	79	913047130	49	917242478	47	917241434
18	913180114	78	913178202	50	917373522	46	917372506
19	913311158	77	913309274	51	917504566	45	917503578
20	913442202	76	913440346	52	917635610	44	917634650
21	913573246	75	913571418	53	917766654	43	917765722
22	913704290	74	913702490	54	917897698	42	917896794
23	913835334	73	913833562	55	918028742	41	918027866
24	913966378	72	913964634	56	918159786	40	918158938
25	914097422	71	914095706	57	918290830	39	918290010
26	914228466	70	914226778	58	918421874	38	918421082
27	914359510	69	914357850	59	918552918	37	918552154
28	914490554	68	914488922	60	918683962	36	918683226
29	914621598	67	914619994	61	918815006	35	918814298
30	914752642	66	914751066	62	918946050	34	918945370
31	914883686	65	914882138	63	919077094	33	919076442
32	915014730	64	915013210	64	919208138	32	919207514

Table 10 Transmitter & Receiver Channels

6 SPECIFICATIONS & STANDARDS

6.1 Specifications

6.1.1 Electrical

Voltage Ratings: 120V & 240V ± 20%

- Frequency: 60 Hz ± 5%

6.1.2 Operating Environment

- Temperature: -40° C to +85° C
- Humidity: 0 to 95% relative humidity, noncondensing
- Accuracy: ± 0.5%
- Transient/Surge Suppression: ANSI C37.90.1-1994
  IEC 61000-4-4
  ANSI C62.45-1992
- High Voltage Surge: ANSI C62.41
- Electrostatic Discharge (ESD): ANSI C12.1-2001,
  10 pulses of 15kV direct contact to meter enclosure per IEC 61000-4-2
- Radio Frequency Interference (RFI): EMI/RFI fields of between 15 V/m for all frequency ranges between 14 kHz and 10 GHz.

6.2 Meter Base Requirements

The ICARe will be required to work in CENTRON meter with the following form, class, and voltage ratings:

Class	Volts	Form
20	120	3S
20	240	3S
20	240	4S
100	120	1S
200	120	12S
200	120	25S
200	240	2S
320	240	2S

Table 11 Meter Specification Types

6.3 External Standards

6.3.1 ANSI Standards

The system will be required to meet the following standards.

- ANSI C12.1 - 2001
- ANSI C12.20 (Class 0.5) – 1998 as a minimum requirement since the present metrology/base unit was certified under this standard. If at all possible, the meter should strive to qualify under the newer ANSI C12.20 (Class 0.5) –2002 specification where possible.

6.3.2 FCC Regulations

These regulations will be required to be verified using the in-house RF test facility for verification and a FCC certified RF OATS test facility for certification.

6.3.2.1 CFR Title 47,Part 15, Subpart C, Paragraph 247

Applicable section for 902-928 MHz include:

Field strength of fundamental: **500 mV/m @ 3m**
Field strength of harmonics: **1.6 mV/m @ 3m**

"Frequency hopping systems shall have channel frequencies separated by a minimum of 25 KHz or 20 dB bandwidth of the hopping channel whichever is greater. Hopping channels are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter."

"If the 20 dB bandwidth of the hopping channel is less that 250 KHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth is 250 KHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater that 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 KHz."

"The maximum peak output power of the intentional radiator shall not exceed 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels."

"If transmitting antennas of directional gain greater that 6 dBi are used the peak output power from the intentional radiator shall be reduced below the stated values above as appropriate, by the amount in dB gain of the antenna exceeds 6 dBi."

6.3.2.2 CFR Title 47,Part 15, Subpart C, Paragraph 249

Applicable sections include:

Field strength of fundamental: **50 mV/m @ 3m**
Field strength of harmonics: **500 uV/m @ 3m**

"Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits whichever is the lesser attenuation."

6.4 Internal Standards

The following internal quality standards will apply to this project.

- N-Q001 : Quality Manual
- N-Q017 : Documentation & Control of Changes
- N-Q034 : ECN
- N-Q043 : Calibration, Traceability of Electronic Measuring Equipment
- N-Q050 : ESD Control
- N-Q057 : Identifying the Latest Revision of Engineering Drawings
- N-Q071 : Initiating & Releasing New Engineering Drawings
- N-Q075 : Control of Software
- N-B010 : IPO Management