Pruf Energy Controls

Pruf Energy Control (PEC) Single Modular Radio Device

PEC915V10 Users Manual

Release Date 05/28/2014

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1. Overview

The PEC915V10 is a high performance low power long range high frequency transceiver containing the embedded Texas Instrument CC1110 System-on-Chip (SOC) and a power amplifier. It is FCC and IC compliant using the radio register settings in Section 7.1. As a result, expensive certification testing is not required. Customized applications can be quickly designed and implemented within the USA and Canada such as wireless sensing, monitoring, and controls. The CC1110 MCU data sheet located on the TI website explains detailed operation and register settings for programming [1]. The use of the power amplifier is explained in Section 2.3.

1.1 Radio

The PEC915V10 operates in the 902-928MHz US ISM band and has either a permanently attached helical antenna or a permanently attached IPEX antenna. The module meets all FCC and IC requirements for single modular transmitter device approval, eliminating time otherwise spent in RF design meeting regulatory requirements. Section 4 has information on the requirements the end user must fulfill to use the modules without intentional radiator regulatory testing. The device can be used in applications such as fixed point-to-point and point-to-multipoint networks.

-Modulation type: GFSK
-Data rate: 250 kBaud
-Receiver sensitivity of -108 dBm
-Digital RSSI / LQI support
-Maximum Programmable Output Power: 14.32 dBm
-Transmit Current: Ò100 mA at 14.32 dBm
-Receive Current: Ò22 mA at 250 kBaud data rate
-Standby Current: 5 mA
-Sleep Current: Ò1 µA

1.2 MCU, Memory, Peripherals, General

-High performance 8051 microcontroller
-Powerful Direct Memory Access functionality
-32 kB Flash Memory and 4 kB RAM
-128-bit AES security coprocessor
-Eight 7-12 bit ADC inputs
-Two USARTS and one I2S
-Three 8 bit timers
-Seventeen general purpose input output ports
-Hardware debug support
-Supply range: 2.2 V - 3.6 V

1.3 Applications

-Low power wireless SOC applications
-Wireless alarm and security systems
-Industrial Monitoring and Control
-Wireless Sensor Networks
-AMR-Automatic Meter Reading
-Home and Building Automation

2. Theory of Operation

The PEC915V10 module includes the Texas Instrument CC1110 SOC. The block diagram in Figure 1 lists some of the MCU components of the CC1110 including oscillators, ADC, flash memory, UART, and wireless data transmission. Figure 2 and Table 1 show the pin outs and their descriptions.

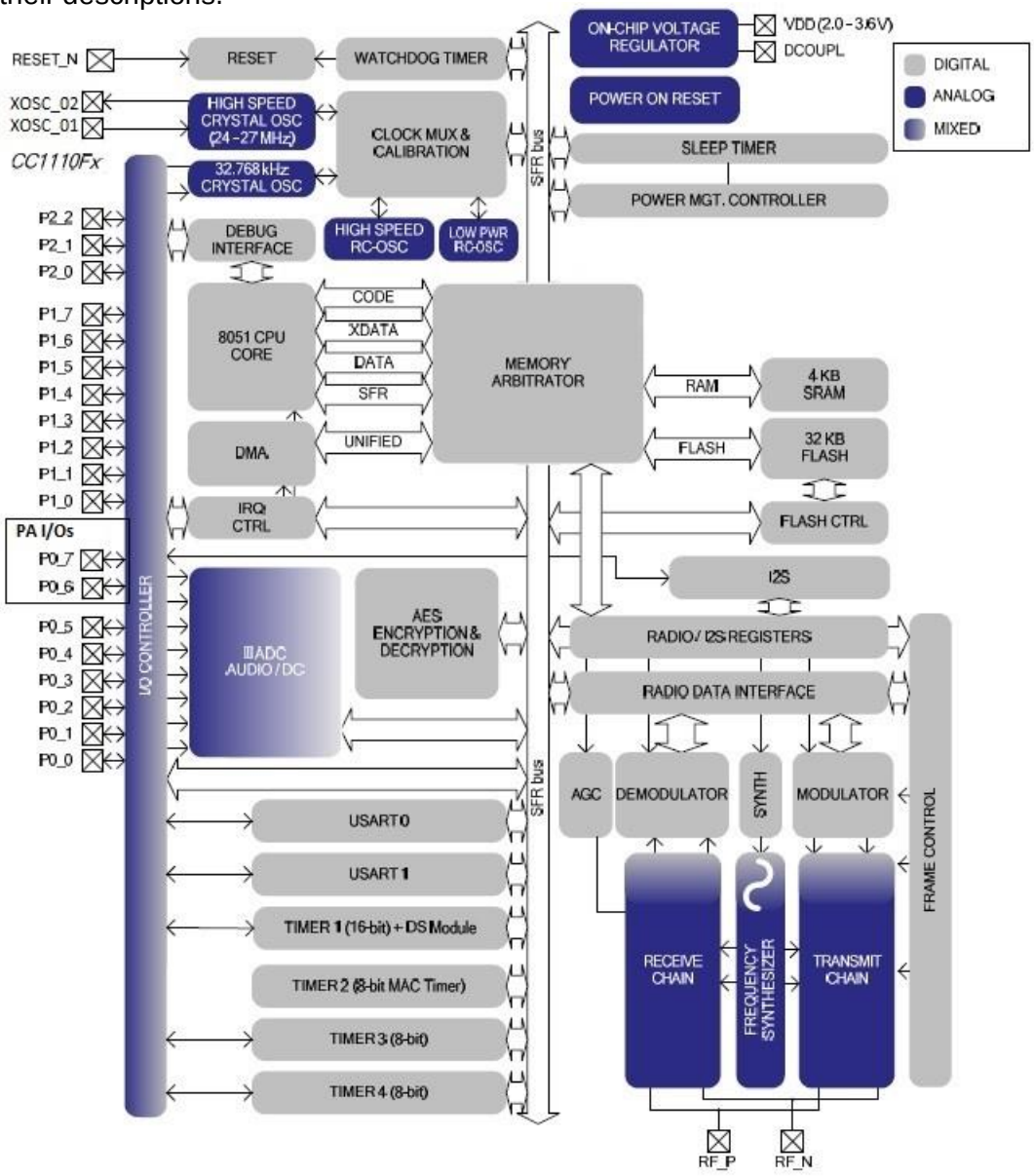

Figure 1: CC1110 System Block Diagram

2.1 Debug Interface

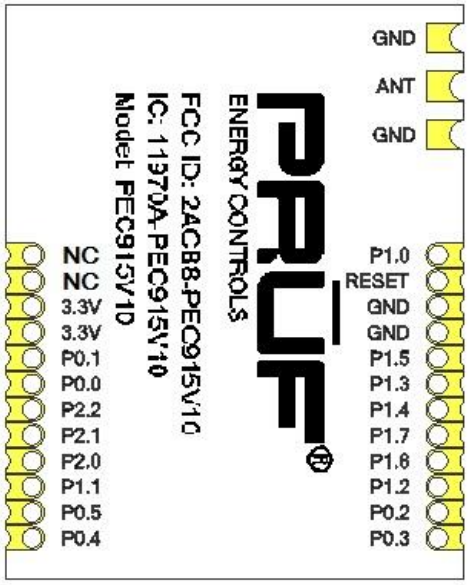

Figure 2: PEC915V10 Back

Pin Name	Pin Type	Description[1]
3.3 V	Power	DC 2.4 ï 3.6 V
GND	Ground	Ground
RESET	Reset Module	CC1110 RESET
P0_0	Digital I/O	CC1110 P0_0
P0_1	Digital I/O	CC1110 P0_1
P0_2	Digital I/O	CC1110 P0_2
P0_3	Digital I/O	CC1110 P0_3
P0_4	Digital I/O	CC1110 P0_4
P0_5	Digital I/O	CC1110 P0_5
P0_6	PA I/O	CC1110 P0_6
P0_7	PA I/O	CC1110 P0_7
P1_0	Digital I/O	CC1110 P1_0
P1_1	Digital I/O	CC1110 P1_1
P1_2	Digital I/O	CC1110 P1_2
P1_3	Digital I/O	CC1110 P1_3
P1_4	Digital I/O	CC1110 P1_4
P1_5	Digital I/O	CC1110 P1_5
P1_6	Digital I/O	CC1110 P1_6
P1_7	Digital I/O	CC1110 P1_7
P2_0	Digital I/O	CC1110 P2_0
P2_1	Digital I/O	CC1110 P2_1
P2_2	Digital I/O	CC1110 P2_2

Table 1: Pin Names and Descriptions. See CC1110 datasheet for details [1].

IAR Embedded Workbench 8051, SmartRF Flash Programmer [2], and SmartRF Studio [3] provide programming and debugging support for the module through pins GND, P2_2 (debug clock), P2_1 (debug data), RESET, and 3.3V. These pins are the needed connections for the Texas Instrument CC Debugger and SmartRF04EB.

The PEC915V10 is also compatible with the SmartRF Packet Sniffer [4] through pins P1_4, P1_5, P1_6, P1_7, P2_1, P2_2, GND, RESET, and 3.3 V. See TI CC Debugger Userôs Guide for more information. [5]

2.2 Typical Radio Flow

Figures 3, 4, and 5 illustrate the radio modes, settings, and block diagrams. Before operating the radio, register settings must be configured as set forth in Section 4 and the 26 MHz crystal oscillator must be stable. The frequency synthesizer on the PEC915V10 device needs to be calibrated before entering receive or transmit mode. After register initialization and frequency synthesizer calibration, the SRX strobe sets the radio to receive mode and the radio begins to listen for data packets. Once data is received, it is made available through the RFD register. The STX strobe sets the radio to transmit mode during which data is sent a byte at a time through the RFD register. It is recommended to transfer or receive bytes through direct memory access [6]. After all packets have been received or transmitted, the device can be set to recalibrate the frequency synthesizer, reenter TX or RX mode, or enter IDLE mode where the radio can transition to TX or RX mode promptly.

Figure 3: Radio Operation States

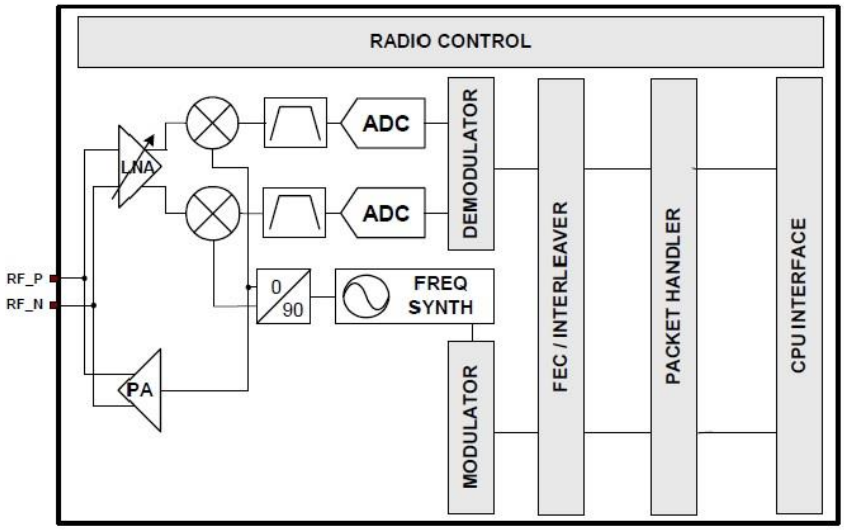

Figure 4: Radio Block Diagram

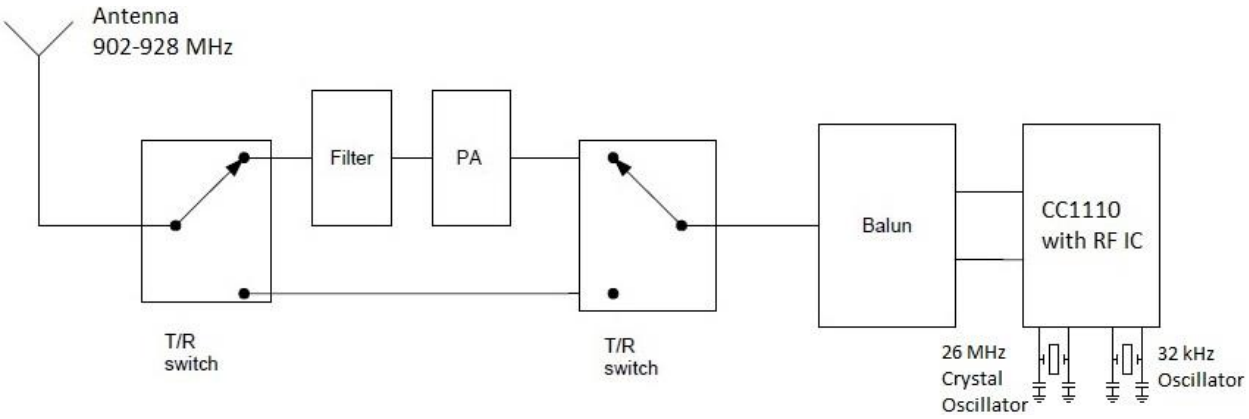

Figure 5: Block Diagram of PEC915V10 with Power Amplifier

2.3 Power Amplifier

The PEC915V10 has a power amplifier connected between the CC1110 and the antenna output. Power amplifier settings for transmit and receive mode are controlled by T/R switches using CC1110 pins P0_6 and P0_7. At the beginning of the software, the direction of these pins must be set to output.

Receive mode is entered by setting P0_6 = 0 and P0_7 = 1.
Transmit mode is entered by setting P0_6 = 1 and P0_7 = 0.
The amplifier is turned off by setting P0_6 = 0 and P0_7 = 0.

Power consumption is kept at a minimum by turning the power amplifier off.

2.4 Antennas and Ground Plane

The PEC915V10 comes with a choice of an attached helical antenna; a 200 mm Pulse IPEX antenna; or a PML dipole antenna. See the straight helical antenna [7], right angle helical antenna [8], Pulse antenna [9], and PML dipole antenna [10] data sheets for more information about the antennas including mounting options. The position at which the modular device is

placed inside a device as well as the direction the antenna is placed in a device can affect the performance of the radio. The helical antennas perform closest to an omnidirectional antenna when it is perpendicular to the PCB board (Figure 6), as opposed to when it is bent (Figure 7). Performance also depends on the ground plane, output power, radio pollution such as blocking RF, and the surrounding environment. Antennas that are placed parallel and next to a ground plane will have poorer performance due to the RF being absorbed in the plane. Obstructions, reflections, the material enclosing the device, and multipath fading also decrease the range of the radio. Line of sight will provide best results.

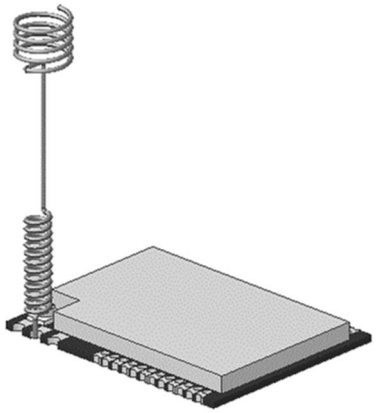

Figure 6: Helical perpendicular to SOC has best performance

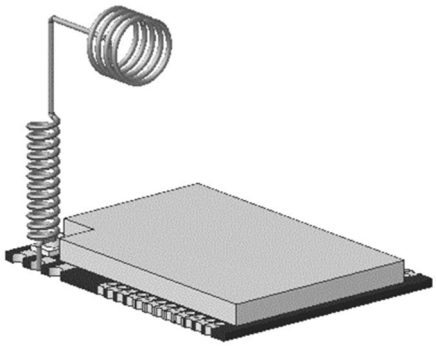

Figure 7: Helical perpendicular to SOC and bent has good performance

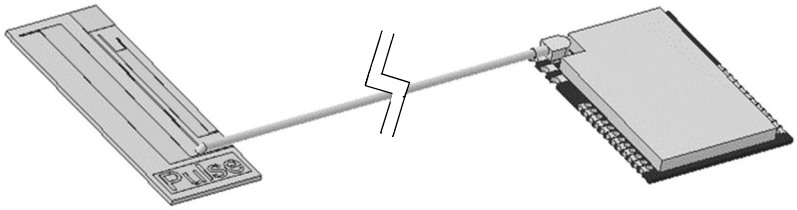

Figure 8: Pulse antenna has good performance regardless of position relative to the SOC

3. Regulatory Approval

3.1 FCC and IC Approval

The PEC915V10 has been tested for approval as a singular modular device according to FCC Part 15.212 [11] and Industry Canada (IC) RSS-Gen 3.2.2 [12].

In order to maintain this approval, operation is subject to the following conditions:

1) Proper labeling of the device must be displayed.
2) The register settings and rules listed in Section 4 must be followed.
3) The permanently attached helical antenna or permanently attached IPEX antenna must not be removed and replaced by a different antenna. Otherwise the device violates authorized approval as a single modular device and must not be used. If the antenna breaks, contact the manufacturer for replacement instructions.

3.1.2 Radiofrequency Radiation Exposure

FCC OET Bulletin 65 [13] and IC RSS-102 [14] provide rules for compliance to RF exposure limits that transmitters must meet. The maximum permissible exposure (MPE) limits in FCC Section 1.1310 [13] and IC RSS-102 are applicable to all transmitters. Although the PEC915V10 is categorically excluded from *routine* environmental evaluation for RF exposure as a mobile or portable device prior to equipment authorization or use according to FCC Part 15 Section 1.1307 [11] and IC RSS-102 Section 2.5, it still must remain below the RF exposure limits. The end user of the PEC915V10 is responsible for coordinating and ensuring the implementation of the transmitter is compliant with any applicable RF exposure requirements in its final configuration by following the guidelines in this section.

If the OET or user desires to operate the transmitter at an output power and duty cycle outside of this sectionôs limits, Specific Absorption Rate (SAR) testing is required. However, SAR testing can be excluded if the configurations in Table 2 which are below the RF exposure limits are followed. Minimum distances between the transmitter and human bodies at 0.25%, 50%, and 100% duty rates as shown by the chart must be maintained. For each evaluation number, as long as care is taken that the field density is not increased, the transmitter meets the criteria for exclusion from SAR testing. For example, maintaining the same output power and duty cycle while decreasing the minimum distance between the body and the antenna would increase the field density and violate this sectionôs requirements and the end user would have further requirements as well as FCC and IC testing to perform. On the other hand, increasing the distance would decrease the field density and maintain the criteria for exclusion. It is recommended, when applications permit, to minimize the transmitter output power and maintain a distance between the antenna and the human body greater than or equal to 20 cm.

The RF Exposure Warning in Section 3.3 below must include the minimum distance in centimeters between the radiator and humans based on Table 2. If the end device will be greater than 20 cm away from the user, use 20 cm as the default value.

Maximum Permissible Exposure Evaluation #	1	2	3	4	5	6
Modulation Type and Baud Rate	GFSK (250 kBaud)					
Output Power (dBm)	14			10		
Duty Cycle (% of time radio is actually in transmit mode)**	0.25	50	100	0.25	50	100
Minimum Distance Between Antenna and Human Body to Remain Below SAR Exclusion Threshold (cm)	0.14	1.9	2.68	0.09	1.16	1.64

Maximum Permissible Exposure Evaluation #	7	8	9	10	11	12
Modulation Type and Baud Rate	GFSK (250 kBaud)					
Output Power (dBm)	8			0		
Duty Cycle (% of time radio is actually in transmit mode)**	0.25	50	100	0.25	50	100
Minimum Distance Between Antenna and Human Body to Remain Below SAR Exclusion Threshold (cm)	0.07	0.98	1.38	0.03	0.43	0.6
** For general population/uncontrolled exposure, the average time for the duty cycle is limited to 30 minutes for the FCC and 6 minutes for IC. As an example, a duty cycle of 50% could correspond to the radio operating in transmit mode 10 seconds out of a 20 second program cycle or up to 15 minutes out of 30 minutes for FCC and up to 3 minutes total out of 6 minutes for IC.						

Table 2: Maximum Permissible Exposure Evaluations

Lastly, in regards to RF exposure requirements, the module should not be co-located with other transmitters; otherwise, more requirements will need to be met by the end user according to FCC Part 15 Section 1.1307 [11] and IC RSS-102 Section 3.2 [14].

3.2 Labeling

3.2.1 FCC ID Labeling

NOTICE: For transmitter use in the U.S., the user or OEM must make sure that FCC labeling requirements are met. The PEC915V10 has an FCC ID label permanently affixed. If the module is installed into another device, then the outside of the device into which the module is installed should display a label referring to the enclosed module except when the device is so small or for such use that it is not practicable to place the statement, the label shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed.

This exterior label can use wording such as:
ñContains FCC ID: **2ACB8-PEC915V10**ò

Or
ñContains FCC ID: **2ACB8-PEC915V10**
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation.ò

3.2.2 Industry Canada (IC) ID Labeling
For transmitter use in Canada, the user or OEM must make sure that IC labeling requirements are met according to IC RSS-Gen Section 5.2 [12]. The PEC915V10 has an IC ID label permanently affixed and must be visible at all times in the host device; otherwise, an exterior label referring to the module shall be placed on the host device.

This exterior label can use wording like:
ñContains transmitter module IC: **11970A-PEC915V10**ò
Or
ñContains **11970A-PEC915V10**ò

The model number must also be written on the label like:
ñ**M/N PEC915V10**ò
Or
ñ**Model PEC915V10**ò

3.3 User Manual Notices
3.3.1 FCC Compliance Notices
Included in the userôs manual, the following must be written:

ñThis device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

FCC ID: 2ACB8-PEC915V10

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
ð Reorient or relocate the receiving antenna.
ð Increase the separation between the equipment and receiver.
ð Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
ð Consult the dealer or an experienced radio/TV technician for help.

WARNING: Changes or modifications not expressly approved by the party responsible for compliance could void the userôs authority to operate the equipment.

RF Exposure WARNING: This equipment complies with FCC radio frequency energy exposure limits set forth for an uncontrolled public environment. This equipment should be installed and

operated with minimum **[USE SECTION 3.1.2 TO INSERT THE APPROPRIATE DISTANCE IN CENTIMETERS HERE]** distance between the radiator and your body.ò

The OEM must include the above warnings with the appropriate distance for the RF Exposure Warning in the final configuration user manual plus comply with the marking and warning requirements shown elsewhere in this manual.

In cases where the user manual is provided only in a form other than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.

3.3.2 IC Compliance Notices

According to IC RSS-Gen Section 5.3 [12], the PEC915V10 radio apparatus shall comply with the requirements to include required notices or statements to the user of equipment with each unit of equipment model offered for sale.
The required notices are specified in the RSS documents (including RSS-Gen) applicable to the equipment model. These notices are required to be shown in a conspicuous location in the user manual for the equipment, or to be displayed on the equipment model. If more than one notice is required, the equipment model(s) to which each notice pertains should be identified. Suppliers of radio apparatus shall provide notices and user information in both English and French.

Included in the userós manual, the following must be written:

ñThis device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.
Le présent appareil est conforme aux CNR dôIndustrie Canada applicables aux appareils radio exempts de licence. Lôexploitation est autorisée aux deux conditions suivantes : (1) lôappareil ne doit pas produire de brouillage, et (2) lôutilisateur de lôappareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible dôen compromettre le fonctionnement.

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.
Conformément à la réglementation dôIndustrie Canada, le présent émetteur radio peut fonctionner avec une antenne dôun type et dôun gain maximal (ou inférieur) approuvé pour lôémetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à lôintention des autres utilisateurs, il faut choisir le type dôantenne et son gain de sorte que la puissance isotrope rayonnée quivalente (p.i.r.e.) ne dépassepas lôintensité nécessaire à lôétablissement dôune communication satisfaisante.

The PEC915V10 has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Le présent émetteur radio (identifier le dispositif par son numéro de certification ou son numéro de modèle s'il fait partie du matériel de catégorie I) a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.»

Pulse Antenna – Operating Frequencies 902.9 MHz – 927.5 MHz Maximum Gain is 2.8 dBi.
PEC Helical Antenna – Operating Frequencies 902.9 MHz – 927.5 MHz Maximum Gain is 0 dBi

The user manual of devices intended for controlled use shall also include information relating to the operating characteristics of the device in Section 4; the operating instructions to ensure compliance with SAR and/or RF field strength limits from Section 3.1.2 with the warnings below; information on the installation and operation of accessories to ensure compliance with SAR and/or RF field strength limits. The user can obtain more Canadian information on RF exposure and compliance from IC RSS-102 on the internet [14].

«**WARNING**: Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

RF Exposure WARNING: This equipment complies with IC radio frequency energy exposure limits set forth for general public use. This equipment should be installed and operated with minimum **[USE SECTION 3.1.2 TO INSERT THE APPROPRIATE DISTANCE IN CENTIMETERS HERE]** distance between the radiator and your body.»

The OEM must include the above warnings with the appropriate distance for the RF Exposure Warning in the final configuration user manual plus comply with the marking and warning requirements shown elsewhere in this manual.

In cases where the user manual is provided only in a form other than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.

3.4 Potential Interference

Home weather stations, automated meter reading, industrial monitoring, home security as well as RFID technology operating in the 902-928 MHz band may potentially cause interference.

4. Permitted Usage

The PEC915V10 is limited by FCC Section 15.247 [11] and IC RSS-Gen 3.2.2 [12] which states that it should use a digital modulation technique with a minimum 500 kHz bandwidth measured 6 dB below the peak power and its maximum conducted output power must be below 1 W or +30 dBm. The power spectral density (PSD) must not be greater than 8 dBm in any 3 kHz band during any time interval during continuous transmission. The PSD is the limiting factor for the PEC915V10 and the below descriptions and register settings must be followed for these requirements to be met. Using the radio outside the settings below are prohibited and could void the user's authority to operate the modules.

The PEC915V10 transmitter is designed for single channel use only. Multi-channel systems including frequency hopping are not allowed.

4.1 General Settings

Approved Configuration
Modulation Format = GFSK
Data Rate = 250 kBaud
Deviation = 165 kHz
Maximum output power = 14.32 dBm
Minimum center frequency = 902.9 MHz
Maximum center frequency = 927.5 MHz

P0_6 and P0_7 general purpose input/output pins must be configured as output.

See Appendix Section 7.1 for the approved register settings.

4.2 PA Settings

Table 3 displays the PATABLE, power amplifier setting as discussed in Section 2.4, corresponding output power, and current for the module.

PATABLE	Power Amplifier Setting (On/Off)	Output Power (dBm)	Current (mA)
0x53	On	14.32	
0x39	On	13.93	81.7
0x2A	On	12.19	79.3
0x35	On	10.05	
0x27	On	9.69	76.1
0x26	On	8.56	
0x25	On	7.13	
0x33	On	6.24	75.1
0x1E	On	4.74	73.3
0x32	On	3.04	
0x1A	On	2.18	
0x19	On	1.33	73.4
0x0F	On	0.22	
0x16	On	-1.69	
0x31	On	-2.18	
0x15	On	-3.1	
0x14	On	-4.69	
0x13	On	-6.49	
0x12	On	-8.87	
0x03	On	-10.05	
0x11	On	-11.74	
0x20	On	-14.2	
0x6E	On	-27.5	
0x6F	On	-33.1	

Table 3: PA Table Register Settings and Output Power

5. Electrical Characteristics

5.1 Operating Conditions

Parameter	Min	Max	Units	Condition
Operating ambient termpature, T_A	-40	85	°C	
Operating Supply Voltage (VDD)	2	3.6	V	All supply pins must have the same voltage.

Table 4: Operating Conditions

5.2 Absolute Maximum Ratings

Caution! *ESD sensitive device. Precaution should be used when handling the device in order to prevent permanent damage.*

Parameter	Min	Max	Units	Condition
Supply Voltage (VDD)	-0.3	3.9	V	All supply pins must have the same voltage.
Voltage on any digital pin	-0.3	VDD + 0.3, max 3.9	V	
Voltage on the pins RF_P, RF_N and DCOUPL	-0.3	2	V	
Voltage ramp-up rate		120	kV/µs	
Input RF level		10	dBm	
Storage temperature range	-50	150	°C	Device not programmed
Solder reflow temperature		260	°C	According to IPC/JEDEC J-STD-020D
ESD CC1110Fx		1000	V	According to JEDEC STD 22, method A114, Human Body Model (HBM)
ESD CC1110Fx		750	V	According to JEDEC STD 22, C101C, Charged Device Model (CDM)

Table 5: Absolute Maximum Ratings [1]

5.3 Recommended Layout

The available antennas will have better performance if they do not lie under the ground plane. The modular device has seen no difference in performance if it is attached to a PCB using pins or surface mounted.

6. Mechanical and Process

6.1 Dimensions

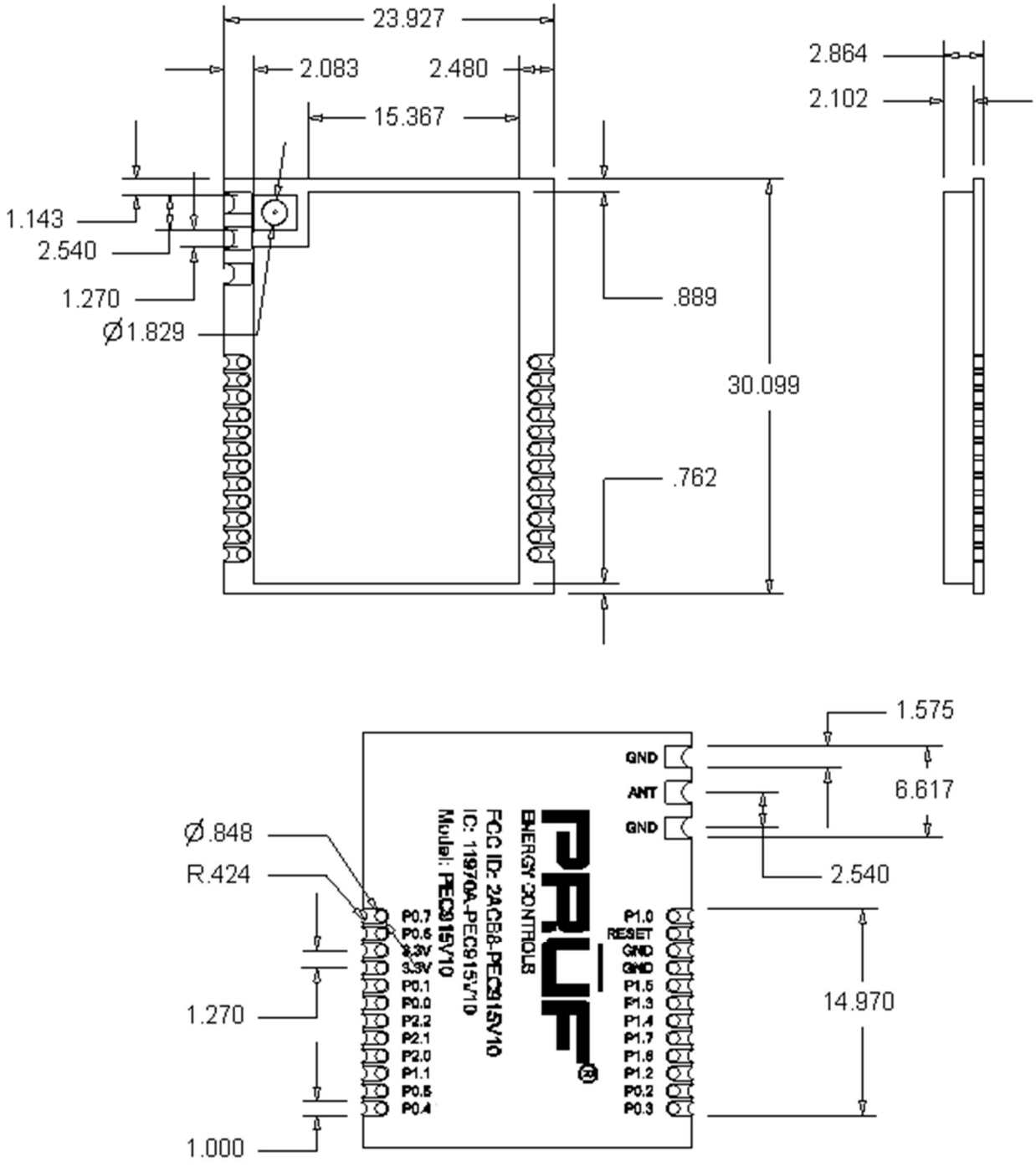

Figure 9: PEC915V10 Dimensions (all dimensions in mm; not to scale)

6.2 Packaging

To be determined.

6.3 Solder pads

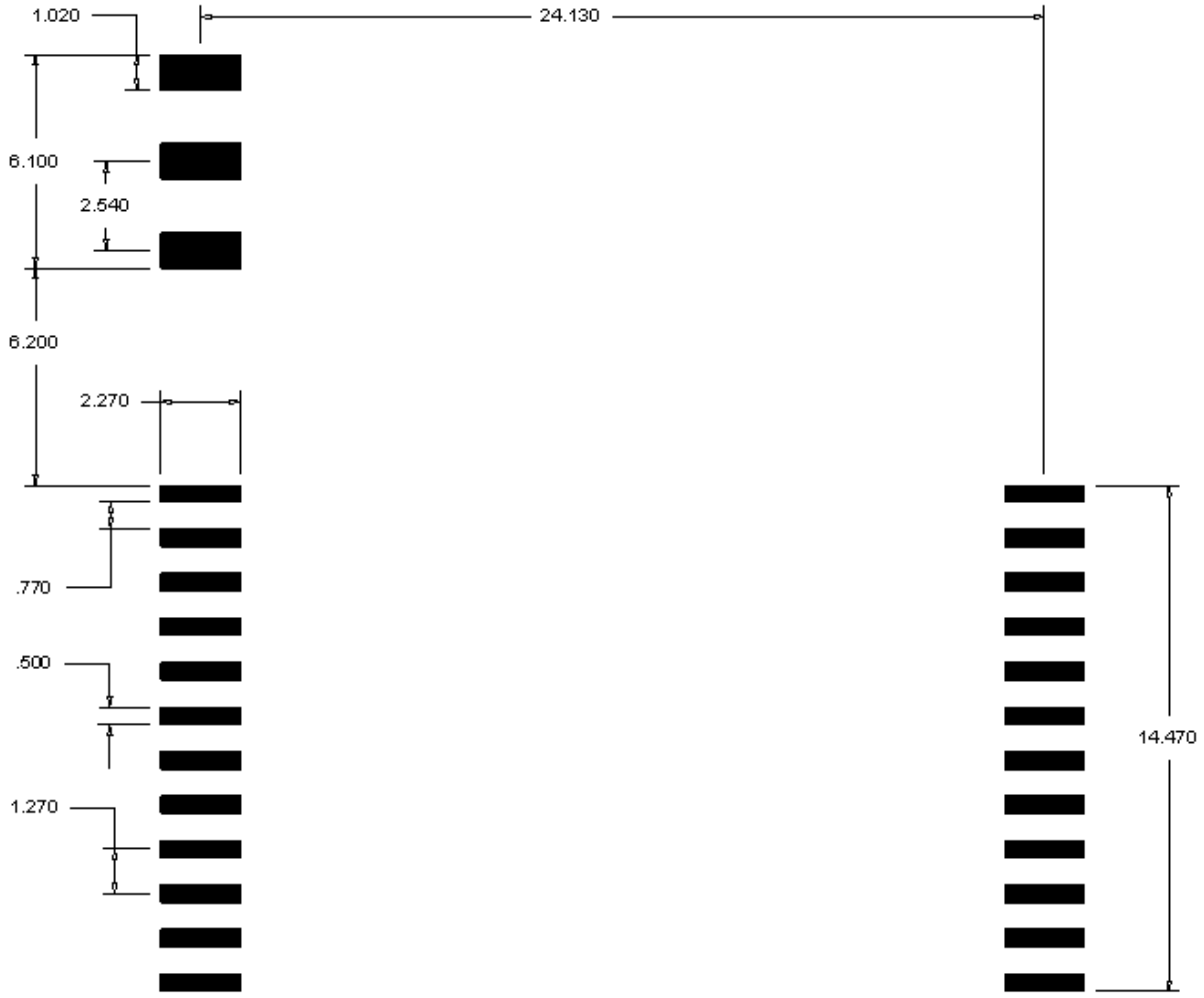

Figure 10: Solder Pads (all dimensions in mm; not to scale)

6.4 PCB Soldering

The reflow profile below is adapted from JEDEC Standard IPC/JEDEC J-STD-020D.1 [12] as applicable for the PEC915V10 transceiver.

Package Thickness	Volume mm^3	Volume mm^3
	<350	≥350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

Table 6: SnPb Eutectic Process – Classification Temperature (T_c) [12]

Package Thickness	Volume mm^3	Volume mm^3	Volume mm^3
	<350	350-2000	≥350
<1.6 mm	235 °C	220 °C	220 °C
1.6 mm - 2.5 mm	220 °C	220 °C	220 °C
≥2.5 mm	220 °C	220 °C	220 °C

Table 7: Pb-Free Process – Classification Temperature (T_c) [12]

Profile Features	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat/Soak		
Temperature Min (T_{smin})	100 °C	150 °C
Temperature Max (T_{smax})	150 °C	200 °C
Time (t_s) from Tsmin to Tsmax	60-120 seconds	60-120 seconds
Ramp-up rate (T_L to T_P)	3 °C/second max.	3 °C/second max.
Liquidous temperature (T_L)	183 °C	217 °C
Time (tL) maintained above T_L	60-150 seconds	60-150 seconds
Peak package body temperature (T_P)	See Table 6.	See Table 7.
Time (t_P)* within 5 °C of the specified classification temperature (T_C)	20* seconds	30* seconds
Ramp-down rate (T_p to T_L)	6 °C/second max.	6 °C/second max.
Time 25 °C to peak temperature	6 minutes max.	8 minutes max.

Table 8: Reflow Profile. Adapted from [12].

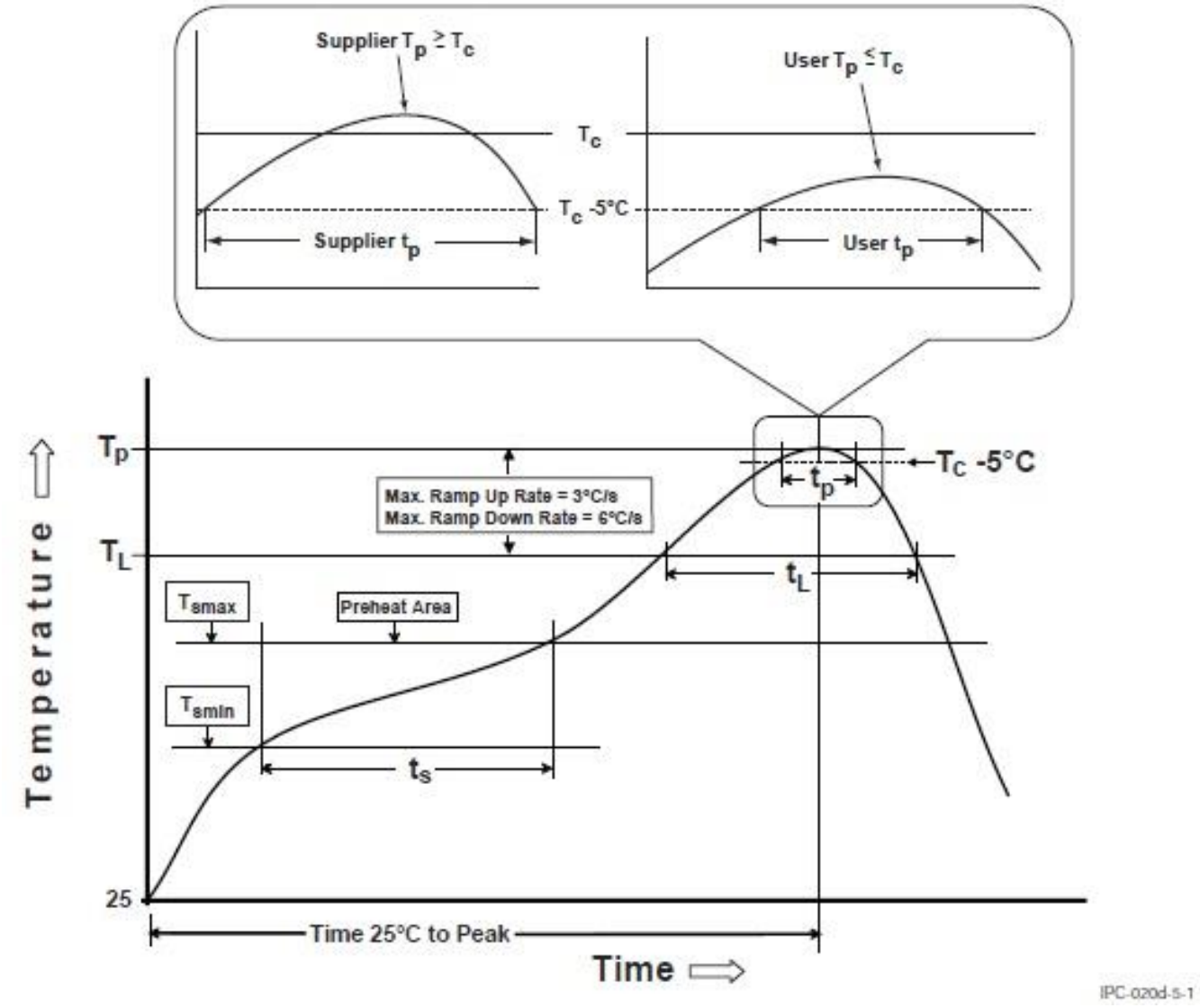

Figure 11: Classification Reflow Profile (not to scale) [15]

7. Appendix

7.1 Approved Register Settings

```
P0SEL = 0xC0;
P0DIR = 0xC0;
IOCFG2 = 0x00;
IOCFG1 = 0x00;
IOCFG0 = 0x00;
SYNC1 = 0xD3;
SYNC0 = 0x91;
PKTCTRL1 = 0x04;
ADDR    = 0x00;
CHANNR  = 0x00;
FSCTRL1 = 0x0C;
FSCTRL0 = 0x00;
MDMCFG0 = 0xF8;
MDMCFG4 = 0x2D;
MDMCFG3 = 0x3B;
PKTCTRL0  = 0x04;
PKTLEN = 0xFF;
MDMCFG2 = 0x13
DEVIATN = 0x65;
MCSM2   = 0x07;
MCSM1   = 0x30;
MCSM0   = 0x18;
FOCCFG  = 0x1D;
BSCFG   = 0x1C;
AGCCTRL2 = 0xC7;
AGCCTRL1 = 0x00;
AGCCTRL0 = 0xB0;
FREND1  = 0xB6;
FREND0  = 0x10;
FSCAL3 = 0xEA;
FSCAL2 = 0x2A;
FSCAL1 = 0x00;
FSCAL0 = 0x1F;
TEST2 = 0x88;
TEST1 = 0x31;
TEST0 = 0x09;
FREQ2 = 0x23;
FREQ1 = 0x31;
FREQ0 = 0x3B;
PA_TABLE0 = 0x53;
```

8. References

[1] CC1110F32 (SWRS033H)
http://www.ti.com/product/CC1110F32/technicaldocuments

[2] SmartRF Flash Programmer
http://focus.ti.com/docs/toolsw/folders/print/flash-programmer.html

[3] SmartRF Studio
http://www.ti.com/smartrfstudio

[4] SmartRF Packet Sniffer
http://focus.ti.com/docs/toolsw/folders/print/packet-sniffer.html

[5] CC Debugger Userõs Guide
http://www.ti.com/lit/swru197

[6] DN017 ï DMA and Radio Configuration
http://www.ti.com/lit/an/swra164a/swra164a.pdf

[7] Antenna, Helical 915 MHz, available by request from Pruf Energy Controls.

[8] Right Angle Antenna, Helical 915 MHz, available by request from Pruf Energy Controls.

[9] Pulse Antenna Data Sheet
http://productfinder.pulseeng.com/product/W3538B0200

[10] Linx Technologies ANT-916-PML Data Sheet
http://www.linxtechnologies.com/resources/data-guides/ant-916-pml.pdf

[11] "ECFR ð Code of Federal Regulations." *ECFR — Code of Federal Regulations*. N.p., 25 Apr. 1989. Web. 28 May 2014.

[12] "RSS Gen - General Requirements and Information for the Certification of Radio Apparatus." *Government of Canada, Industry Canada, National Capital Region, Office of the Deputy Minister, Spectrum, Information Technologies and Telecommunications*. N.p., Dec. 2010. Web. 28 May 2014.

[13] Commission, Federal Communications. "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields." *OET Bulletin 65* (n.d.): n. pag. Aug. 1997. Web. 28 May 2014.

[14] "RSS-102 ð Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)." *Government of Canada, Industry Canada, National Capital Region, Office of the Deputy Minister, Spectrum, Information Technologies and Telecommunications*. N.p., Mar. 2010. Web. 27 May 2014.

[15] Joint Industry Standard, ñMoisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices.ò IPC/JEDEC J-STD-020D.1. March 2008. Web. 28 May 2014.

History

Date	Author	Notes
5/28/2014	Holland	Initial Release
6/19/2014	Holland	Corrected Pulse Ant. Gain
7/10/2014	Holland	Updated Deviation Rate
5/6/2015	Holland	Updated Address
12/7/2015	Holland	Added antennas

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