User's Manual

Ultra wideband

Perimeter Surveillance Pole

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Draft
October 23, 2014

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Parties operating under the provisions of Title 47, Part 15, Subpart F, paragraph 15.511 must be eligible for licensing under the provisions of part 90.

Changes or modifications not expressly approved by the manufacturer could void the user’s authority to operate the equipment

Time Domain as manufacturer is in charge of all marketing. Any purchasers (non-government) by commercial clients will be informed of their responsibility under FCC rules by receiving a copy of Section 15.525 which requires them to co-ordinate their activities and inform the FCC at the following address preferable via certified mail.

Frequency Coordination Branch, OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
Attn: UWB Coordination

Overview

This document is a User's Manual for the Time Domain Ultra Wideband (UWB) Perimeter Surveillance Pole (PSP400). The document is divided into the following sections.

Section 1	***System Introduction & Theory of Operation***
Section 2	***Pole Overview***
Section 3	***P400 Radar***
Section 4	***Broadspec Antenna***
Section 5	***FCC Compliance***

The user will note we have not included a Section on installation and system bringup. After reviewing Section 1 the reader will appreciate that the PSP400 is one element of an overall system that will be integrated with existing elements of an installations fixed infrastructure. For this reason each installation is unique; system turn-on and setup instructions will be developed in conjunction the receiving facility.

1 System Introduction & Theory of Operation

This document addresses the Ultra Wideband (UWB) surveillance radar pole which is the sensor component of an integrated surveillance system. In order to introduce and provide operational context for the pole the overall system is discussed in this Section.

1.1 System Overview

The UWB Surveillance System (USS) creates a virtual fence along or around the perimeter of an area to be protected. It consists of a staggered fence line of distributed short range radars contained in poles. These poles work together to detect, track, and distinguish between people and animals moving along or through the perimeter area. The ability to distinguish between different types of targets also known as Items Of Interest (IOIs) is often referred to as classification. Because the USS does not create a physical barrier it can be deployed in areas where an actual fence would be detrimental to the environment such as along a shore line or across a wildlife migratory path.

UWB is the enabling technology that allows the USSUSS to offer the following capabilities:

- All weather, day/night operation
- High Probability of Detection coupled with a Low Probability of False Alarms
- Deployment in cluttered RF environments (near fences, buildings, moderate foliage)
- Classification/Identification

Numerous agencies eligible for licensing under the provisions of part 90 have identified an unmet need for a security system with the above characteristics.

Figure 1 is a conceptual depiction of the USS. As suggested in the figure the USS can track and independently classify multiple people and animals using its system of radars. A server processes data from the radars and provides outputs to external users of the data. A network connects the radars to each other and the server. The lower level components that make up the poles, server, and network and the USS interfaces will be described in subsequent paragraphs.

USS requires supporting infrastructure including power, a wired network, pole footings, and a central server. The cost of this infrastructure suggests USS will be deployed around high value assets or infrastructure typically found at many Government installations.

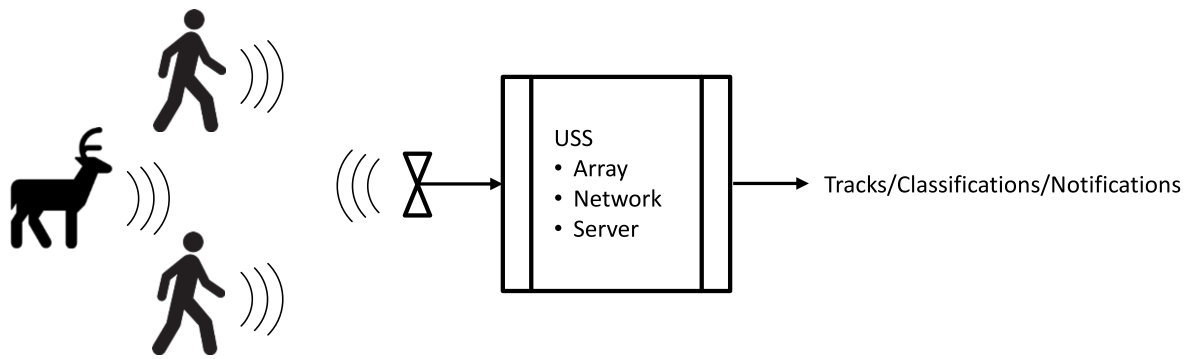

Figure 1 USS System Concept

As illustrated in **Figure 2** USS consists of a staggered line of poles, a wired network and a server. The server processes data from the poles and controls radar operation through the network.

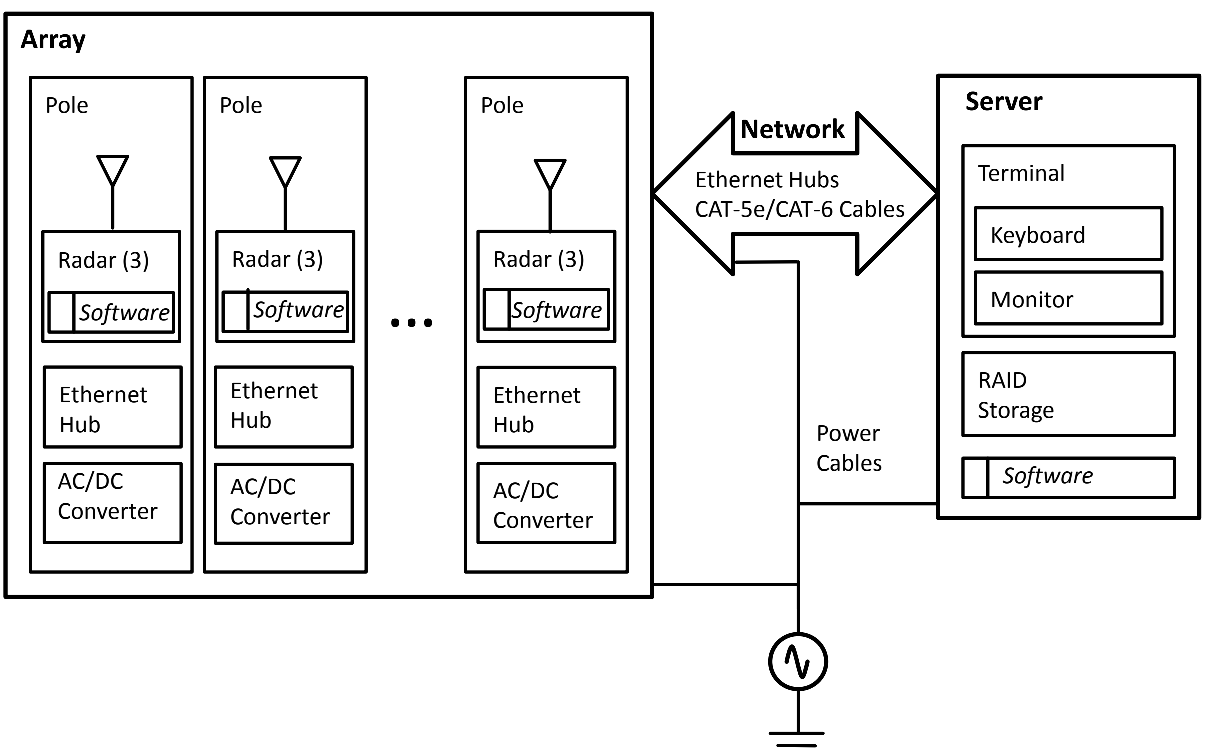

Figure 2 USS Hardware Components

The number of poles deployed at a given site depends on the length of the perimeter that requires monitoring. The poles are organized into groups of six poles referrred to as networking cells. As shown in **Figure 3** the physical footprint of a networking cell is a rectangle that is 100 meters long by 20 meters wide (note the radar coverage area extends up to 20 meters beyond the cells footprint in all directions).

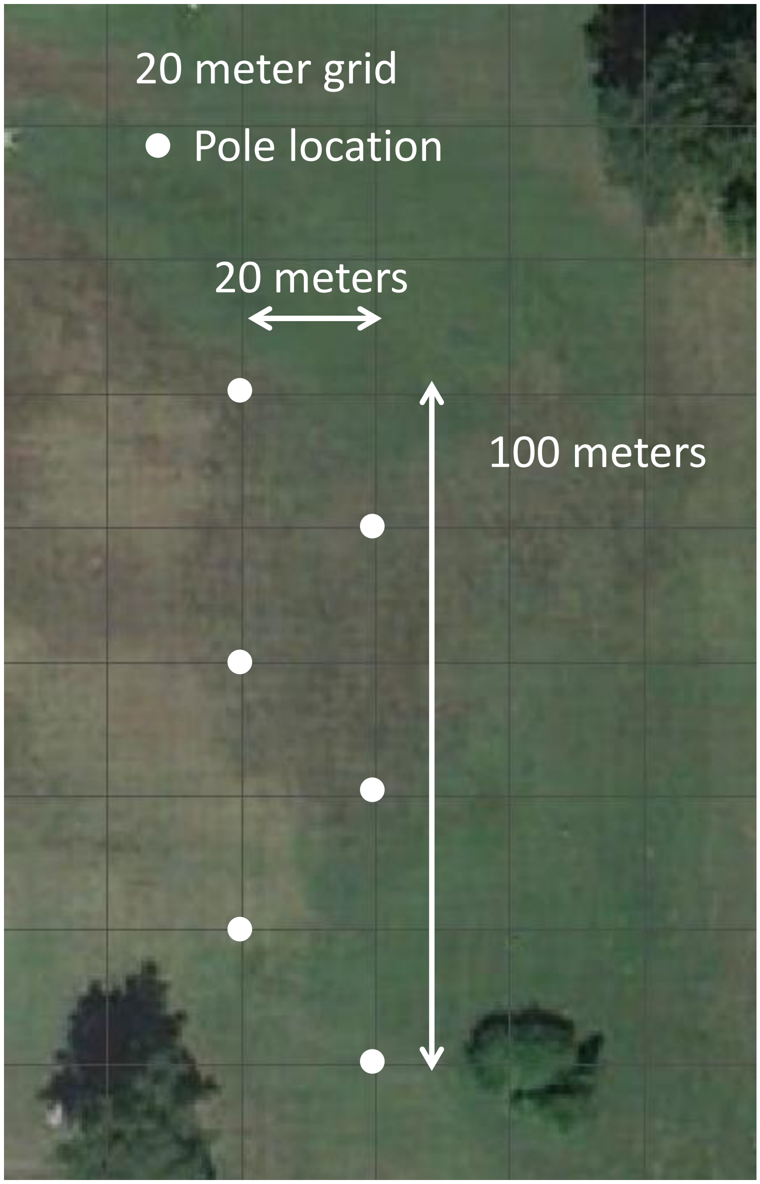

Figure 3: Footprint of six pole networking cell

As described in Section 1.2.2 a key feature of the networking cell concept is that only a single UWB radar (P400) within each cell is transmitting at any given time while the other radars within the same networking cell attempt to receive that transmission thus making very efficient use of the transmitted energy (air time). This has the benefit of reducing emissions from the overall system (1 transmitter within the space of a football field) thus reducing (and pratically speaking, eliminating) the system's interference potential.

The end user provided server should feature multicore processors and an operator terminal consisting of a keyboard and monitor. Such a server is needed to support the system's processing and interface operations. The operator terminal is for the purpose of configuring, controlling, and maintaining the system. **Figure 4** illustrates a typical server.

Figure 4: Typical end user provided server

The network consists of a number of Ethernet hubs and cables to provide data communication between the UWB Modules within the poles and the server.

1.2 System Theory of Operation

1.2.1 Software Architecture & Data Flow

Figure 5 shows the data flow on the network between the poles and the server, internal to the server, and external to the server. The P400s send TCP/IP packets containing radar scan data to the server where they are processed to detect, track, and classify targets. The server also sends TCP/IP packets to the poles as needed. Within the server, the outputs of the processing are TCP/IP packets containing tracks, classifications, configuration, status, notifications, and alarms. These are provided to the interface, which generates data and signals for consumption by an external user of the data. The TCP/IP packets allow this data to be processed or converted by another application, even one running at a separate location, without the need to modify the processing application itself.

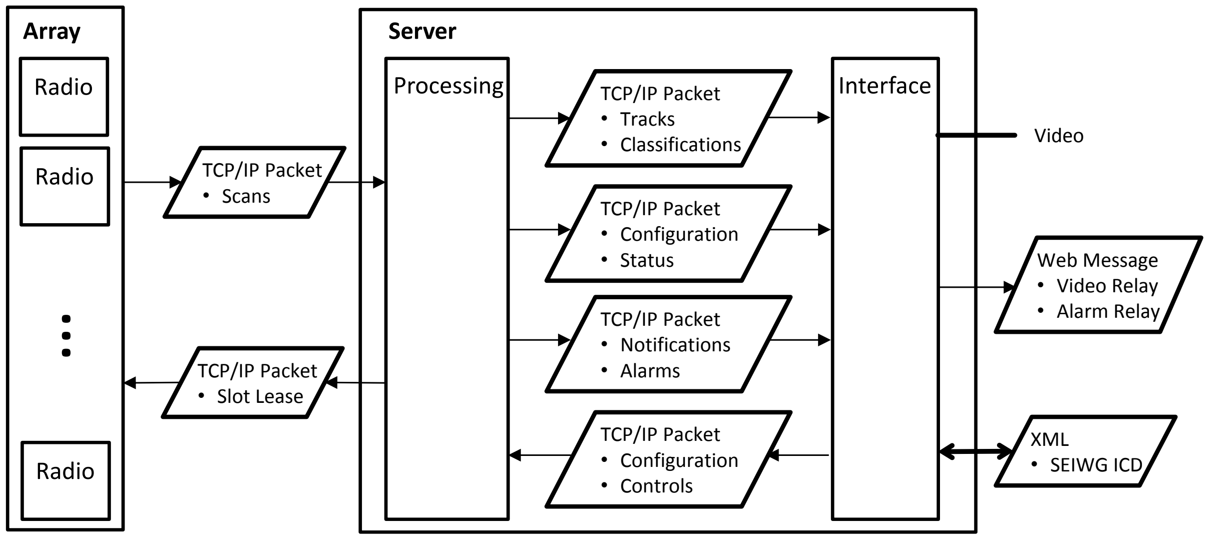

Figure 5: USS Data Flow

1.2.2 Network Cells

As introduced in Section 1.1 USS is organized into network cells consisting of six poles, covering ~100m x 20m (about the size of a football field). Networking cells are formed to ensure only one P400 radar in a cell is transmitting at any given time. For example (**Figure 6**), if a system is composed of three networking cells, of which only one radar per cell is transmitting at a time, then there would be three widely spaced P400s transmitting at any time. Because each of the three networking cells operates on a different code channel (different timing of when pulses are transmitted) and are a considerable distance from each other the transmitting P400s do not interfere with each other and also are not synchronous.

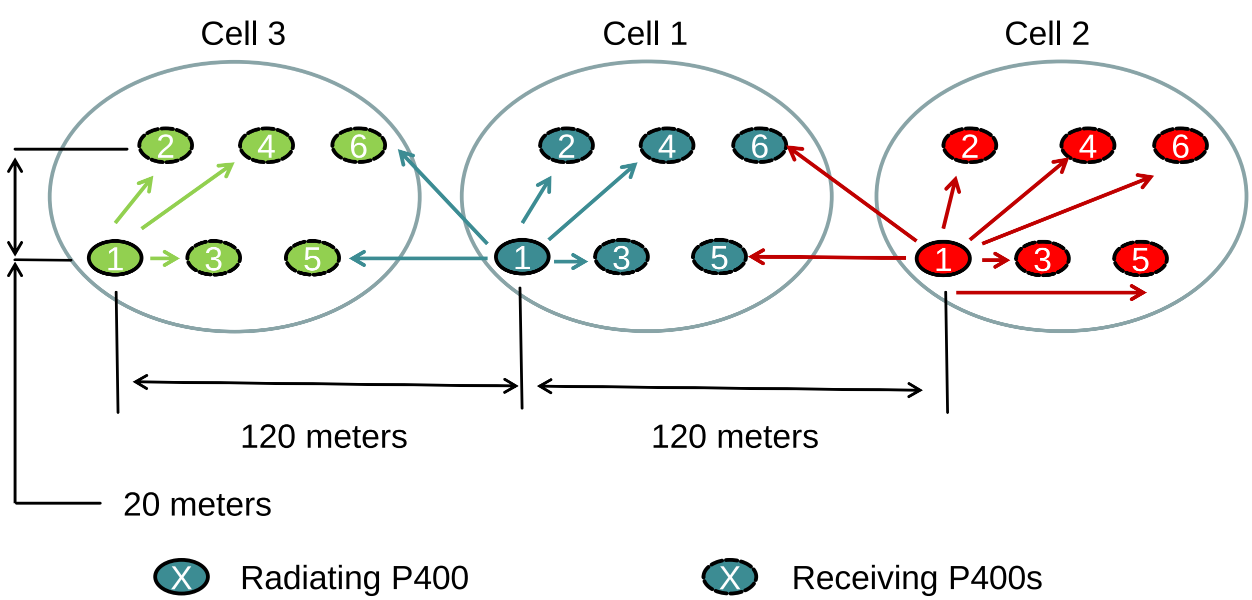

Figure 6: Map of TDMA slot 1

Each network cell is implemented as a fixed TDMA scheme that supports a 4 Hz update rate. This fixed TDMA cycle and timing information is available to each P400 and ensures only a single P400 (within each cell) is radiating at any given time. The TDMA network for each networking cell is 264ms in length and contains 8 time slots. The 264ms time period is called a superframe. For a single pole, only one time slot of a superframe is used to transmit for 24ms. Therefore per pole, the duty cycle for packet level transmissions is 9% (24ms/264ms). Additionally, the P400 radar technology is based on short pulse UWB technology. During this 24ms transmit time, the on-air duty cycle (pulses being sent) is <1%. Therefore the overall on-air time (pulse level) for a pole is <0.1%.

While there are three P400s per pole, only the P400 located in the middle of a pole radiates both the bottom and top P400s listen only. Moreover, all P400s in all networking cells always receive, even those that are transmitting act as monostatic radars. Each receiving P400 produces a waveform or a scan of the signal it received, which is sent via Ethernet to the signal processing application resident on the main computer. It's worth noting that the USS was designed to be efficient as it relates to transmit airtime (and power). For example, on average 18 different radars are designated to receive energy from one transmitter, thus making the most of each transmission for the purposes of detection, localization, tracking, and classification.

1.2.3 Processing

The processing flow consists primarily of signal processing, detection, localization, tracking, and classification/identification. The primary inputs to the processing are the radar scans generated by the P400s. The primary outputs of the processing are the tracks and classification. Secondary inputs are configuration and controls. Secondary outputs are configuration and status, and radar slot control.

The signal processing function operates on raw scans from the radar to filter and align scans to pass to the detection function. The detection function attempts to remove the background including clutter to report motion. The detections are then input to the localization function.

Up to this point all processing has been performed on scans from a single radar (monostatic) or a pair of separate radars (bistatic) independently. A transmit radar/receive radar pair (which for monostatic operation is the same device) is called a link. The localization function combines detections from all available links along with known coordinates of the radars to determine locations of potential targets.

The tracking function implements a tracker using the localization coordinates of potential targets. The goal of the tracker is to identify localizations that have spatial and temporal consistency and estimate their position over time. The outputs of this function are called tracks. Although the tracking function may initiate and maintain a number of tracks, only those with high confidence are provided as output to the classification function, visualization, or external output. The classification function determines whether the track is the result of a person or an animal.

1.2.4 Graphical User Interface (GUI)

The Graphical User Interface (GUI) function provides visual output to the operator terminal and controls to allow the operator to change configuration data, start and stop the system, enable or disable certain functions, etc. If remote connectivity is available, the GUI allows remote access to the operator terminal.

The visual output consists of tracks overlaid on a background image of the area. The tracks are color coded depending on their classification. The visual output also shows system status by color coding poles. Detailed information about system status is available using controls on the GUI.

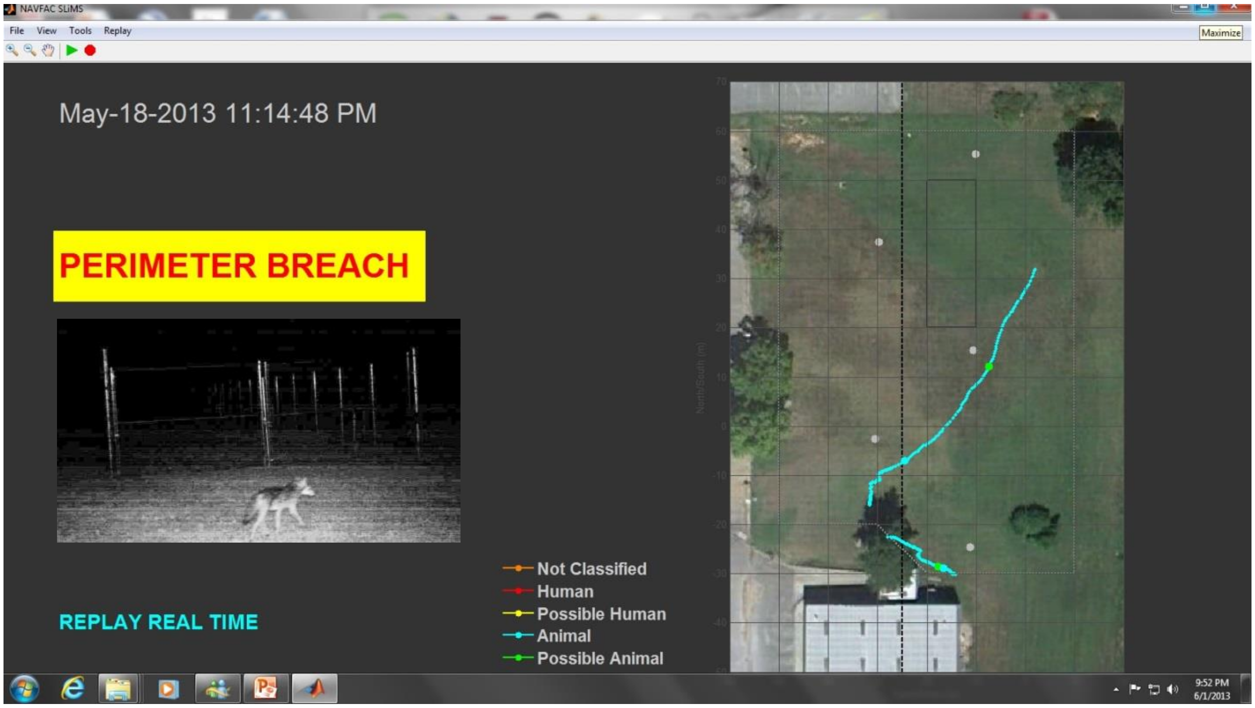

Figure 7: Coyote track in Huntsville, AL, (note: inset image of coyote NOT part of USS display)

2. Pole Overview

An assembled pole is approximately 6 inches in diameter and 10.5 feet tall (**Figure 8**). It is mounted on an end user provided concrete footing. The footing has four threaded studs that protrude above its top surface. The pole's base plate has four holes. The pole is erected by aligning the four holes in the base plate with the threaded studs and securing the base plate using nuts. The nuts can be adjusted to level the pole. The approach is the same as that used to install and level light poles. Ethernet and power cables are routed through the center of the footing into the pole. As shown in **Figure 8** there are three visible components:

- Anti-bird cap
- Radome (weather covering)
- Base Plate Cover

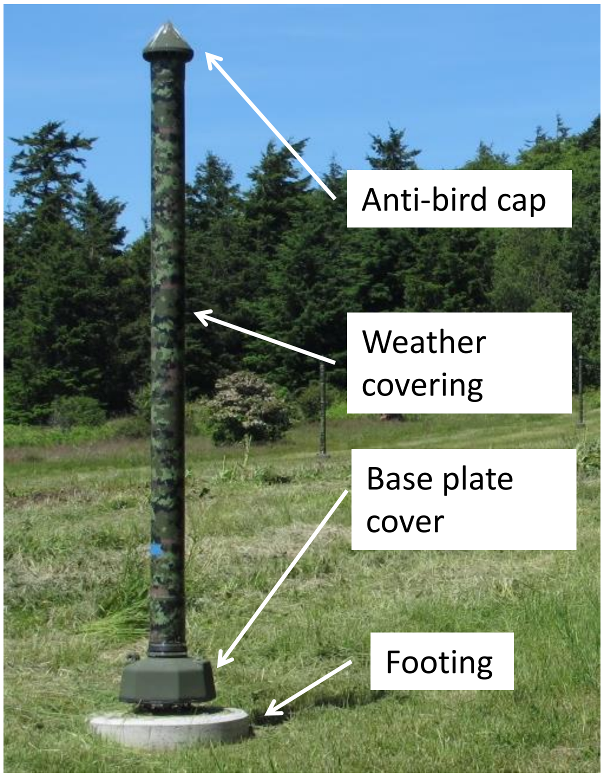

Figure 8: Exterior view of pole

As the name implies the Anti-bird cap prevents birds from roosting on the pole top. The interior of the Anti-bird cap features a short (~ 4”) pendulum suspended from its peak. This pendulum dampens pole vibration induced by severe wind gusts.

The weather covering is a PVC tube that protects the pole internals from the elements. Since the pole internals include three UWB radars the weather covering serves as a radome.

The Base Plate Cover protects the support electronics mounted on the pole's base plate as shown in **Figure 9** the support electronics consist of:

- An Ethernet switch
- An AC/DC converter
- A DC Power Terminal block

The Ethernet switch connects the radars in the pole to the network Ethernet cable. The AC/DC converter converts AC power into 12V DC power which is routed through the DC distribution block to the radars.

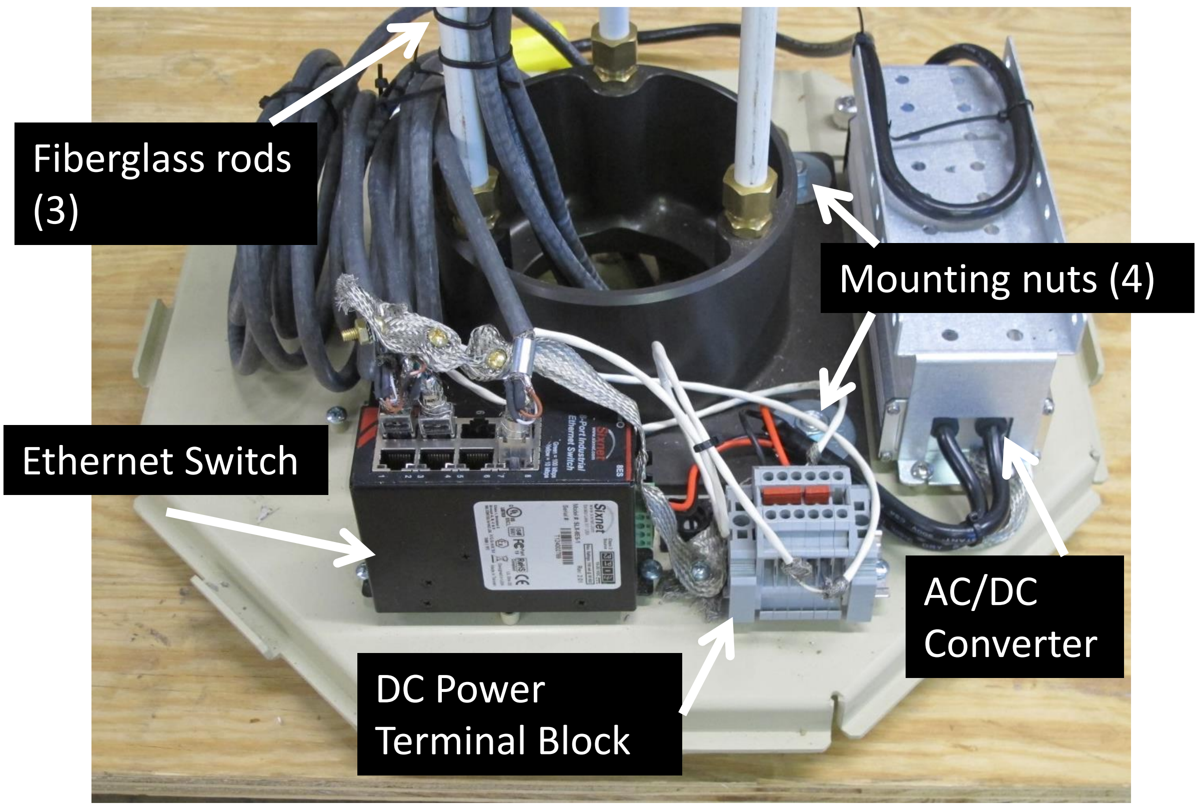

Figure 9: Pole support electronics

Figure 9 also depicts the three structural fiberglass rods that extend from the Base to the top of the pole. **Figure 10** illustrates one of the three UWB radars that are contained within the pole. Also note that the power and Ethernet feed to the UWB radar are provided in a single cable. **Figure 11** illustrates the P400 within its' housing. Note the UWB radars are discussed further in Section 3. **Figure 12** is a block diagram of the pole.

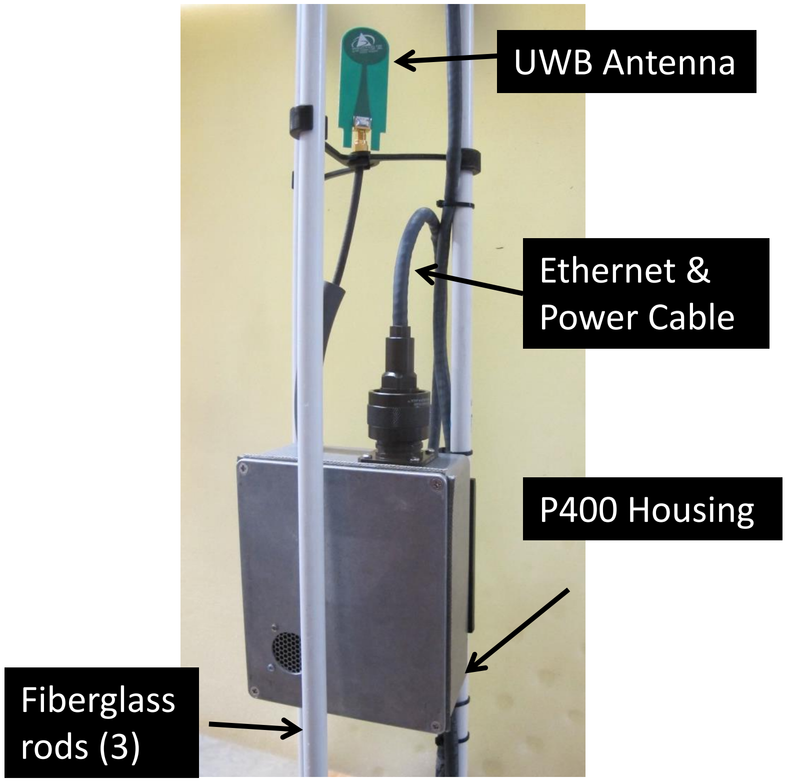

Figure 10: UWB Radar (P400) mounted to pole structure

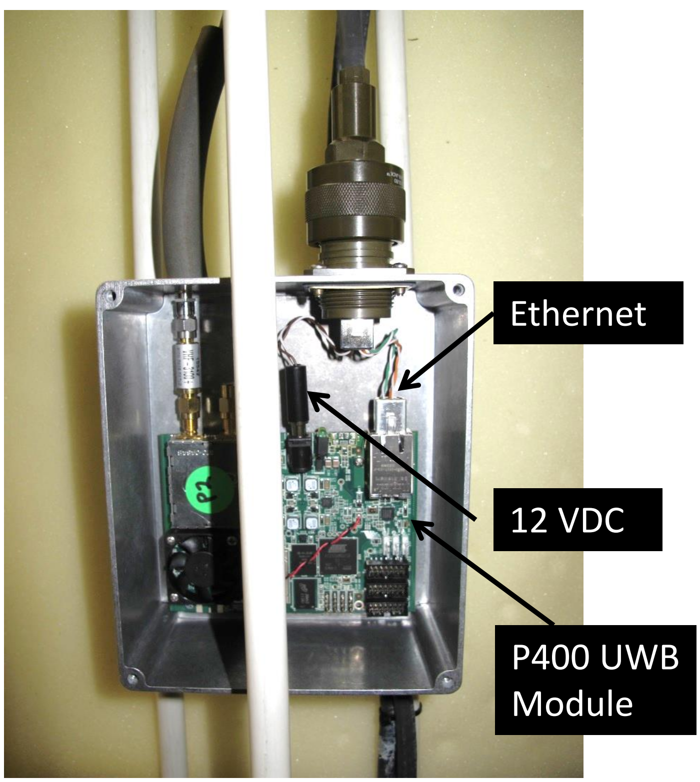

Figure 11: P400 within its housing

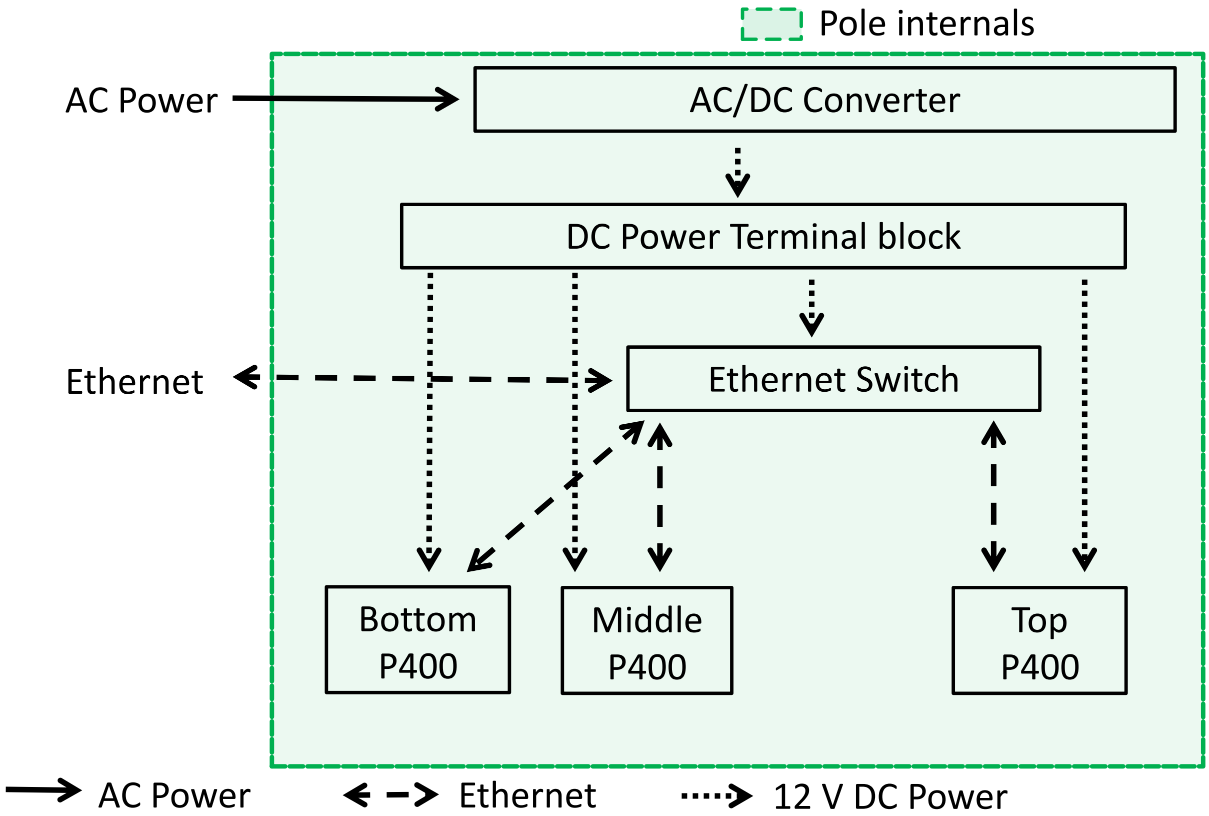

Figure 12: PSP Block Diagram

3. P400 Radar

The radar is Time Domain's P400 Ultra Wideband (UWB) module (**Figure 13**) configured to provide monostatic and bistatic radar operation. Monostatic radar operation is a single device receiving scans from its own transmitted pulses. In a bistatic mode one radar receives scans (pulses) transmitted from another radar. The receiving radar first acquires the transmitted energy and establishes a common time base with which to receive the scans.

Data communication for the P400 is over Ethernet. Each P400 is configured with a static IP address. Scan data is sent from the P400 over Ethernet to the server. The server also sends control and configuration data to the P400s over the Ethernet, either directly to a specific P400 (i.e. IP address) or by broadcasting to all P400s.

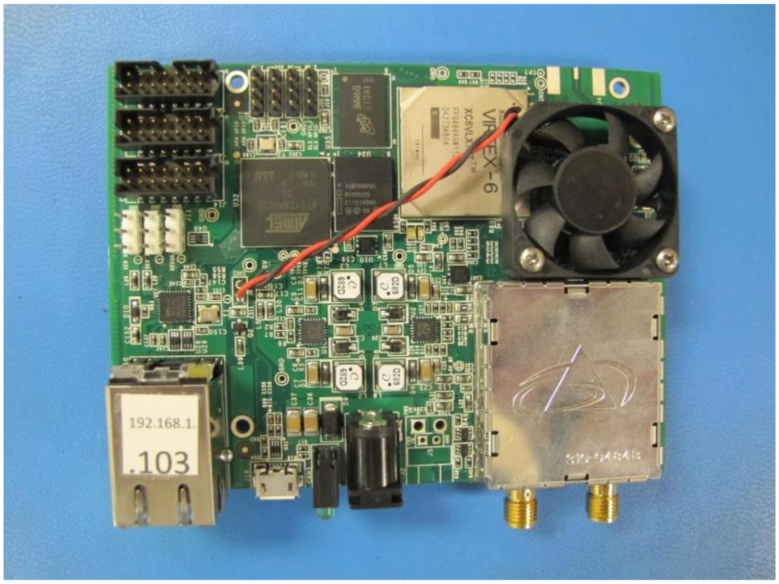

Figure 13: P400 UWB Module

3.1 P400 Radar Theory of Operation

The P400 UWB radar transmits high bandwidth (narrow) Gaussian pulses. With a center frequency of 4 GHz and a bandwidth of 2 GHz (see **Figure 14**) the waveform supports a resolution of a few centimeters. The UWB radars receive the pulse response in either a mono-static mode or bi-static mode. Each radar's precision on-board timing allows it to operate as a mono-static device where it first transmits a pulse and subsequently receives the pulse response. In the bi-static mode, one radio transmits the pulse and another radio receives the response. In order to enable bi-static operation the transmitted waveform includes an acquire sequence that allows the receiving radio to "find" the transmitted pulses in time. Once found, a code embedded in the polarity of the transmitted pulses allows the receiving radios to synchronize with the transmitter. When multiple receivers receive the same transmitted pulse response this is termed the multi-static mode; this mode is fundamental to the system. Within the system a complete pulse response is known as a scan. The sequence of scans between a specific transmitter and receiver pair is a link. As discussed in Paragraph

1.2.3 scans generated by the P400s are processed by software in order to realize the detection, tracking, and classification capabilities of the system.

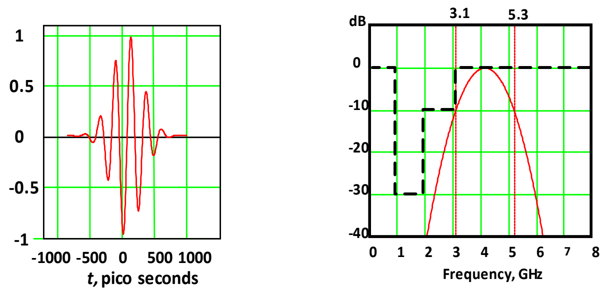

Figure 14: Time and frequency measurements of the fundamental pulsed signaling strategy of the P400 radio module

3.2 P400 Block Diagram

This section provides and discusses at a high level the P400 functional hardware block diagram, as shown in **Figure 15**.

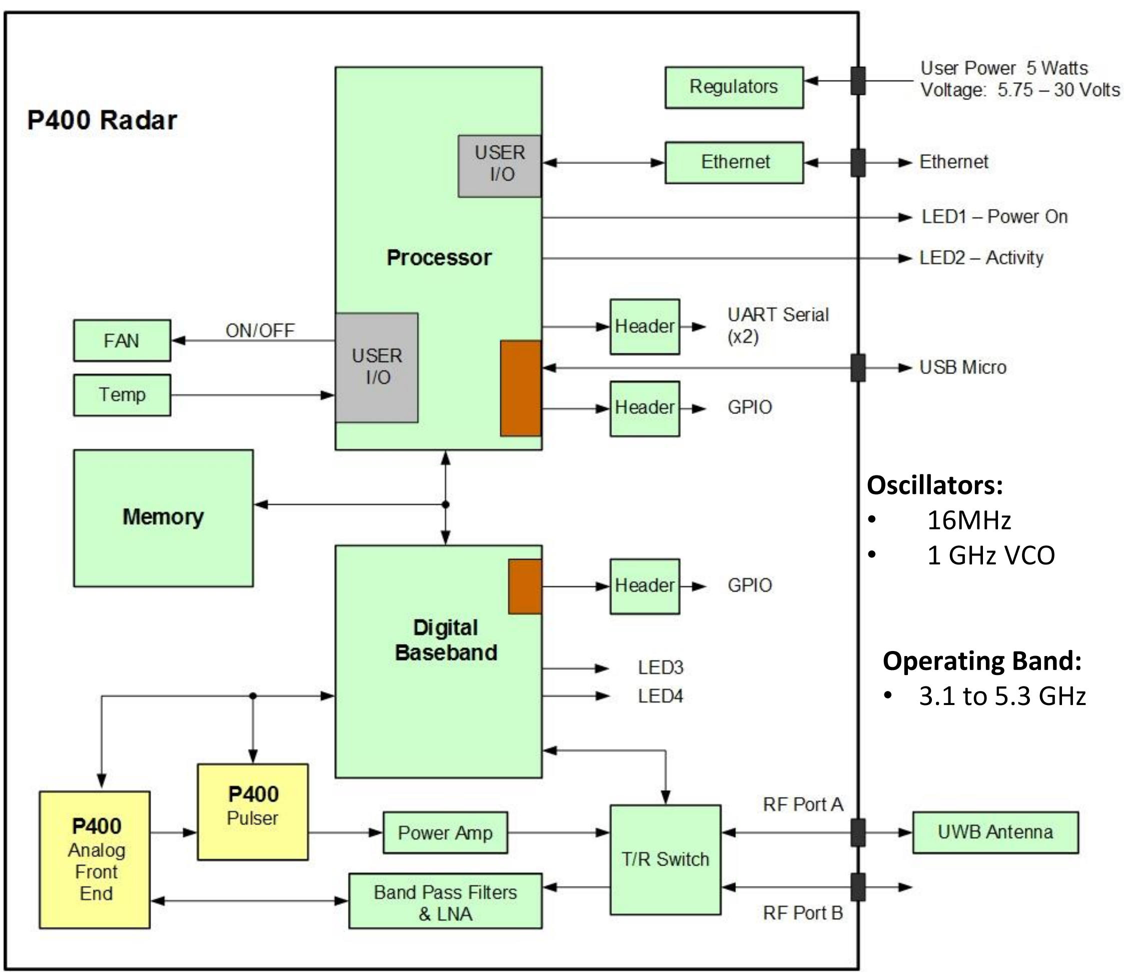

Figure 15: P400 hardware functional block diagram

To power the board, the user must supply a maximum of 5 Watts at any voltage between 5.75-30V. **Indicating lights provide operating status information.**

The user can interface to the P400 through either USB (standard USB Micro B connector), Serial connection, or Ethernet. Power is provided via a barrel connector. In addition, the user can request the P400 to report the board temperature and can command the fan to turn on or off.

The processor controls the UWB front end through a Digital Baseband FPGA interface. More specifically, the FPGA configures the Time Doman P400 Pulser chip (UWB transmitter) and P400 Analog Front End (AFE) chip (UWB receiver), provides timing signals and out-going data, receives incoming data and controls the position of the transmit/receive (T/R) switch.

There are three RF sections:

- A variable transmit power amplifier is provided in the Pulser chip. This allows the user to adjust the transmit power over approximately a 19 dB range. At its maximum setting (and when using the standard P200 antenna) these transmissions are compliant with FCC Part 15 levels
- Receive chain consists of gain stages and band pass filter; and
- T/R switch supports two configurations: Transmit/Receive on Port A and Transmit on A, Receive on B.

4. Broadspec Antenna

The P400 is designed to operate with the Broadspec antenna shown in **Figure 16**. Use with *ANY* other antenna invalidates the FCC certification. Per FCC 15.203, the Broadspec antenna must be professionally installed and the installer has the responsibility to insure that the Broadspec antenna is used.

The P400 can be operated with a single antenna (used for transmit and receive) or with two antennas (where one is dedicated for transmit and the second for receive).

The Broadspec antenna (~3dBi) provides an omni-directional transmit/receive pattern supporting a frequency range of 3.1-5.3 GHz. It has a standard SMA female connector and measures 1" x 2.5" x 0.125". Specifications are available on the web at:

http://www.timedomain.com/datasheets/TD_Broadspec_Antenna.pdf

Figure 16: Broadspec Antenna

5 FCC Compliance

The PSP400 has been designed to be in compliance with the FCC regulations governing UWB Surveillance Systems (Part 15.511).

Time Domain as manufacturer is in charge of all marketing. Any purchasers (non-government) by commercial clients will be informed of their responsibility under FCC rules by receiving a copy of Section 15.525 which requires them to co-ordinate their activities and inform the FCC at the following address preferable via certified mail.

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Federal Communications Commission
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Washington, D.C. 20554
Attn: UWB Coordination

In compliance with FCC requirements the label depicted in **Figure 17** is affixed to the Base Plate Cover of each pole at the location shown in **Figure 18**.

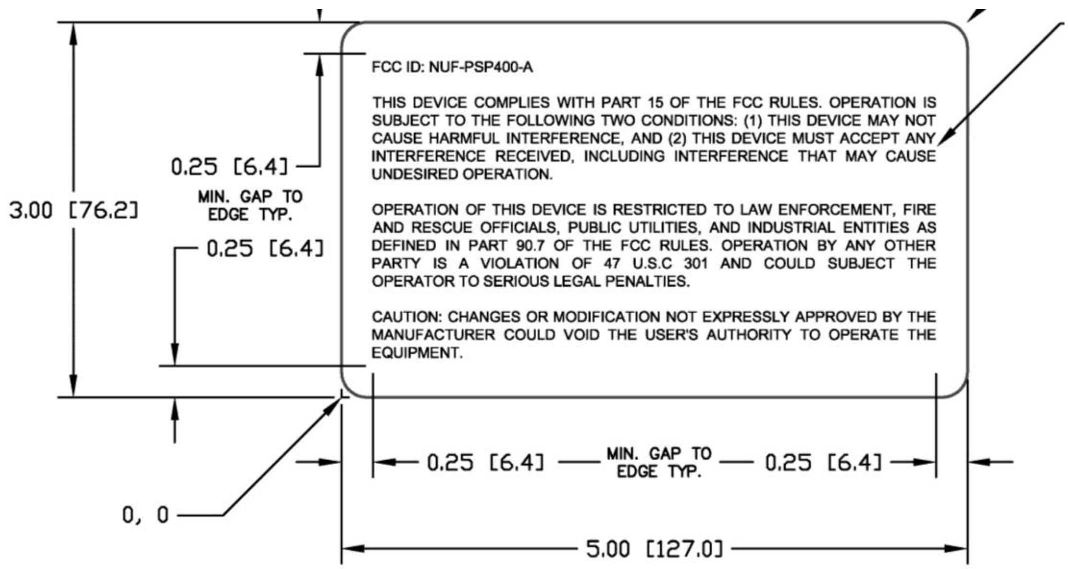

Fig. 16: Label with FCC ID number

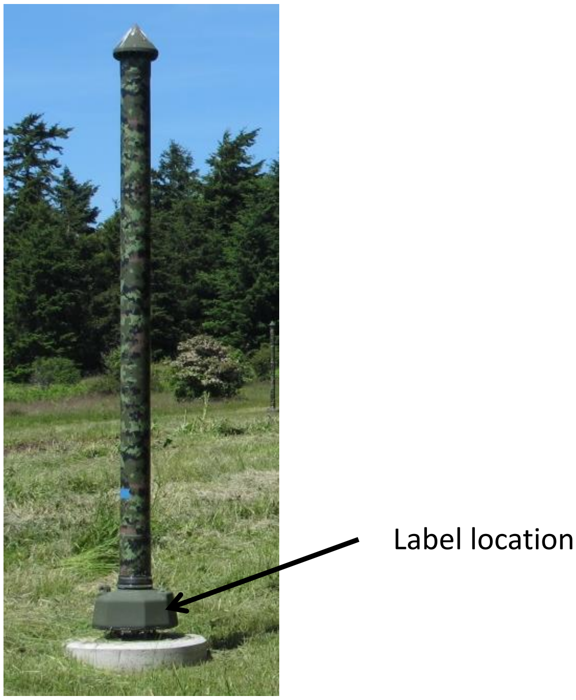

Figure 18: PSP400 label location