1 STATEMENTS

1.1 GENERAL NOTICE

It is hoped that this document will be useful in understanding and using the PureWave System. Please note that the information provided herein is subject to change without notice.

Always refer to the current set of Release Notes for the most up to date information and a description of the current features as they relate to the PureWave system. These may be different to the information contained within this User Guide.

1.2 REGULATORY NOTICE

It is the intention of PureWave Networks to ensure that this equipment is tested 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:

- Re-orient or relocate the receiving antenna/s.
- Increase the separation between the equipment and other receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Shielded cables and I/O cords must be used for this equipment to comply with the relevant FCC regulations.

Changes or modifications not expressly approved in writing by PureWave Networks may void the user's authority to operate this equipment.

> **!** **Note: This device must be professionally installed, and the responsibility to comply with the FCC regulations is of the user.**

1.3 PROPRIETARY STATEMENT

1.4 WARRANTY STATEMENT

1.4.1 **Hardware**

PureWave Inc ("PureWave" or the "Company") warrants to the end-user ("Customer") that this hardware product will conform in all material respects to the specifications provided with the hardware and will be free from defects in workmanship and materials, under normal use and service, for a period of 365 days from the date of original shipment by PureWave.

PureWave's sole obligation under this limited warranty shall be, at PureWave's option, to repair the defective product or part, deliver to Customer an equivalent product or part to replace the defective item, or if neither of the two foregoing options is reasonably possible, refund to Customer the purchase price paid for the defective product. All products that are replaced will become the property of PureWave. Replacement products may be new or reconditioned. PureWave's obligations hereunder are conditioned upon the returned of affected articles in accordance with PureWave's Return Material Authorization (RMA) procedures.

Subject to the limitations and conditions herein and in the Supply Agreement, after Customer has completed the steps outlined below in Section 2, PureWave will evaluate each returned Product and will use reasonable commercial efforts to either, in its discretion, repair or replace products confirmed by PureWave as non-conforming that are covered under the warranty provided in the Supply Agreement. PureWave shall be responsible for shipping the repaired or replaced Product to Customer. PureWave will use reasonable commercial efforts to ship repaired or replacement Product within thirty (30) business days of its receipt, however, the allegedly non-conforming Product must be received by PureWave before any replacement unit will be shipped.

The above warranty will also apply to any replaced or repaired product for 90 days from the date of shipment from PureWave of the replaced or repaired product, or the remainder of the initial warranty period, whichever is longer.

1.4.2 Software

PureWave warrants to the Customer that for a period of ninety (90) days from your receipt of the Product (the "Warranty Period") the Software will perform substantially in accordance with the Documentation.

If the Software fails to comply with the warranty set forth above, your exclusive remedy will be, at the option of PureWave (i) a reasonable effort by PureWave to make the Software perform substantially in accordance with the Documentation, or (ii) return of the purchase price. This limited warranty applies only if you return all copies of the Product, together with proof of purchase, to PureWave during the Warranty Period.

This limited warranty is VOID if failure of the Software is due to modification of the Software not made by PureWave, or the abuse or misapplication of the Software. PureWave does not warrant that the Software is error free, that the Customer will be able to operate the Software without problems or interruptions or that the Software or any equipment, system or network on which the Software is used will be free of vulnerability to intrusion or attack.

For further details of the terms and conditions of PureWave's obligations from a software perspective please refer to "PureWave Software Maintenance Program" (document not found).

1.4.3 Additional Conditions

Notwithstanding anything else herein or otherwise, PureWave reserves the right to establish amendments to this RMA Policy from time to time. Further, PureWave Technical Support may prefer to troubleshoot the wireless link with an onsite Customer technician while the Products are in their original non-conforming state. This process might assist Customer in understanding and troubleshooting the issue. If PureWave was not afforded the opportunity to troubleshoot an allegedly non-conforming Product in original non-conforming state, PureWave may approve or reject the RMA request in its sole discretion, and such Products are not eligible for advance replacement.

1.4.4 No Fault Found

Notwithstanding Sections above, if PureWave cannot duplicate any alleged non-conformity, the Product will be returned to the Customer as "No Fault Found." PureWave reserves the right to charge a testing fee in connection with a returned product that PureWave determines as "No Fault Found," and any such payment must be received by PureWave prior to return shipment of the applicable Product to Customer.

1.4.5 Warranty Limitations

PureWave's warranties do not apply to any product (hardware or software) which has (a) been subjected to abuse, misuse, neglect, accident, or mishandling, (b) been opened, repaired, modified, or altered by anyone other than PureWave, (c) been used for or subjected to applications, environments, or physical or electrical stress or conditions other than as intended

and recommended by PureWave, (d) been improperly stored, transported, installed, or used, or (e) had its serial number or other identification markings altered or removed.

1.4.6 **Warranty Disclaimer**

PURWAVE'S SPECIFIC WARRANTIES SUMMARIZED ABOVE ARE THE ONLY WARRANTIES GIVEN BY PUREWAVE WITH RESPECT TO ITS PRODUCTS (HARDWARE AND SOFTWARE) AND ARE GIVEN IN LIEU OF ANY AND ALL OTHER WARRANTIES, WHETHER EXPRESS, IMPLIED, STATUTORY, OR ARISING BY CUSTOM, TRADE USAGE, OR COURSE OF DEALING, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, AND PUREWAVE DISCLAIMS ANY AND ALL OTHER WARRANTIES TO THE MAXIMUM EXTENT PERMITTED BY LAW. Without limiting the generality of the foregoing sentence, PureWave makes no warranty or representation, either expressed or implied, as to, and disclaims all liability and responsibility for, (a) the operation, compliance, labeling, or packaging of any of its products under the laws of any jurisdiction outside of the United States of America and (b) the regulatory compliance of any products in any jurisdiction in which it has not specifically identified compliance or the use of any product in any jurisdiction in any manner other than as contemplated in the regulatory certifications and approvals for that product in that jurisdiction. To the extent an implied warranty cannot be excluded, such warranty is limited in duration to the warranty period. The disclaimer and exclusion applies even if the express warranty fails of its essential purpose.

1.4.7   Obtaining Warranty Service

1.4.7.1 RMA

1.4.7.1.1 RMA Number

Customer must contact the Company, by sending an e-mail to support@pwnets.com to obtain warranty service authorization. When contacting PureWave for support, please be prepared to provide the product description and serial number and a description of the problem. The Customer will be expected to complete a "Return Material Authorization (RMA)" form to initiate the request. Full instructions as to how to complete and where to send the form are provided on the form. Date of proof of purchase from PureWave will be required.

Products returned to PureWave Inc must be pre-authorized by PureWave with a Return Material Authorization (RMA) number and sent prepaid and packaged appropriately for safe shipment. The Customer requesting the RMA will be the exporter. The exporter is responsible to ship RMA equipment to PureWave's address and has to bear the cost and risk involved in bringing the goods to PureWave's location.

Risk of loss in return shipment will be borne by Customer, and it is recommended that returned goods be insured and/or sent by a method that provides for tracking of the package. Responsibility for loss or damage does not transfer to PureWave until the returned item is

received by PureWave. Provided that PureWave determines that the item is actually defective, the repaired or replaced item will be shipped to Customer, at PureWave's expense, (1) not later than thirty (30) days after PureWave receives the defective product or (2) to the terms of a separate written agreement with PureWave.

If the allegedly non-conforming Product is not received by PureWave within thirty (30) days of Customer initiating the RMA request, the RMA process for that Product will be deemed cancelled.

1.4.7.1.2 RMA Status

Customer may also obtain the status of their RMA request(s) by sending an e-mail to support@pwnets.com referencing their assigned RMA Number(s).

1.4.7.2 Customer Obligations

No product will be accepted for repair or replacement by PureWave without a RMA number. The product must be returned to PureWave, properly packaged to prevent damage, shipping and handling charges prepaid, with *the RMA number prominently displayed on the outside of the container.* If PureWave determines that a returned product is not defective or is not covered by the terms of the warranty, the Customer will be charged a service charge and return shipping charges

The following table 1 is a summary of the conditions and charges that PureWave reserves the right to levy.

RMA Related	Under Warranty
Repair and return	No charge, PureWave pays
Shipment of unit to PureWave	Customer pays
Regular Shipment to Customer	No charge, PureWave pays
Expedited shipment to Customer	Customer pays the additional cost of the expedited shipping
No Fault Found	PureWave reserves the right to levy a charge
Warranty for repaired and or replaced product	Remainder of the original warranty or 90 days

Table 1 - Summary of PureWave RMA Conditions and Charges

1.4.8   Out of Box Failure (OBF) / Dead on Arrival (DOA)

In the event a product becomes entirely inoperable within the first forty-eight (48) hours of the initial installation of the product, and such installation takes place within ninety (90) days after

the date of shipment from PureWave, the Customer may request that the unit be considered as an "Out Box Failure (OBF) or "Dead on Arrival (DOA).

PureWave will consider an OBF or DOA as being eligible to be considered for an advance replacement request. The conditions for such a request are as outlined below in section **Error! Reference source not found.**.

1.4.9   Advanced Replacement

In some unique situations, PureWave may consider, at its sole discretion on a case-by-case basis, an advance replacement request for a non-conforming Product that is still covered under its warranty period.

1.4.9.1 Conditions
The following conditions apply to advance replacements:
(i)   PureWave has a suitable "equivalent" replacement unit available.
(ii)   Customer's network is experiencing a severe degradation or a complete outage.
(iii)   Customer has complied with the RMA procedures provided herein
(iv)   PureWave reserves the right to levy a charge for the processing and handling of the advance replacement request. To waive this charge will be the sole discretion of the Senior VP of Sales.
(v)   If expedited shipping is required then Customer pays for all expedited shipping and handling charges that are in excess of the regular shipment charges. To waive this charge will be the sole discretion of the Senior VP of Sales.
(vi)   When an advance replacement is provided and Customer fails to return the original product to PureWave within fifteen (15) days after shipment of the replacement, PureWave will charge the Customer for the replacement product, at list price.
(vii)   The shipment of advance replacement products is subject to local legal requirements and may not be available in all locations.

1.4.9.2 Replacement Timing
PureWave will use reasonable commercial efforts to ship advance replacement Products within five (5) business days after PureWave's confirmation that advance replacement is appropriate. PureWave shall not be responsible for shipping delays if any of conditions herein are not met.

1.4.9.3 Out of Warranty
For products that are out of warranty, the repair of such products will be subject to a repair fee. In addition, any request for the Advance Replacement of product that is out of warranty will be subject to not only the repair fee but additional fees as well. Please contact PureWave for further details.

PureWave does offer extended warranties and enhanced service options for its Customers who desire those enhanced features. Please contact PureWave for further information about these options

1.4.9.4 Assistance

For assistance, contact your nearest PureWave Networks Sales and Service office.
Additional information is available on the PureWave Networks website at http://www.pwnets.com.

For Customer Service call: 650-528-5200, or Email: support@pwnets.com.

1.5 SAFETY PRECAUTIONS

When installing this equipment, observe the following precautions to minimize the danger of personnel injury:

Danger:
- NEVER install equipment if there is a chance of lightning or other adverse weather conditions.
- NEVER install in a wet location unless the equipment is specifically designed for wet locations.
- NEVER touch uninsulated wires or terminals unless the wire has been disconnected at the Network interface.
- ALWAYS use caution when installing or modifying cables.

> **!** **ESD Warning:** Always assume that all components and assemblies are static sensitive and always follow local ESD-prevention guidelines to prevent equipment damage**.**

EXTERNAL POWER – SOURCE:

> **!** **Warning:** For any external power supply that provides the power source for the PureWave equipment, replace any power supply fuse with the same rating or equivalent, otherwise PureWave Networks will not be responsible for any subsequent damage to its equipment.

- Use normal caution when installing or modifying cables. Dangerous voltages may be present. It is also considered imprudent to install during a lightning storm.
- Always disconnect all lines and power connections before servicing or disassembling this equipment.

- For performance and safety reasons, only power supplies listed for use with telephone equipment by a Nationally Recognized Testing Laboratory (NRTL) should be used with equipment.
- Refer to the installation section of the appropriate instruction manual for the unit you are installing for:
    - Cabling information
    - Proper connections
    - Grounding information
- All wiring external to the product(s) should follow the provisions of the current edition of the National Electrical Code.

Warning: These units contain no user serviceable components. Only authorized Service Personnel should service or repair these units. "Use only isolated Class 2 Power Source, Rated 48V dc 5.0A Minimum."

2 SYSTEM AND PRODUCT OVERVIEW

2.1 INTRODUCTION - WHAT IS A COMPACT BASE STATION?

At PureWave, we believe that true broadband data networks must roll out in a completely different manner than the traditional, low-throughput cellular networks of yesterday. The traditional cellular network paradigm of colossal "macro" base stations and large cell radii developed from the need for high-coverage networks to carry low-bandwidth voice and messaging traffic. However, as the demand for data-based applications has grown, networks have quickly become congested, necessitating new wireless standards designed specifically for high-speed broadband data. Furthermore, as spectrum is always a scarce and expensive resource, the need for improved frequency re-use techniques has become more important than ever.

The clear solution to this is higher-efficiency wireless standards, such as IEEE 802.16e Mobile WiMAX, and more flexible cell sizes. Where medium and high population density exists, cell sizes should be small to enable increased spectral re-use, thereby ensuring that each subscriber enjoys a sufficient amount of throughput. In such cases it may be necessary to deploy base stations on utility poles, flag poles, rooftops, small buildings, and walls. This necessitates small, pleasant form-factor base stations that can accept a variety of antenna types, both omni-directional and directional. Such base stations are often referred to as "Pico". Because wired backhaul may not always be available in some such locations, it also suggests the need for wireless backhaul options.

On the other hand, in rural areas with lower population densities, it makes more economic sense to deploy fewer base stations on higher towers or buildings, and usually with higher transmit power. This is closer to the traditional cellular approach and typically involves large, expensive, and power-hungry "macro" or "micro" base stations, often with split designs requiring both indoor and tower-top electronics. Wherever indoor components are required an operator must obtain an air-conditioned shelter, which adds significantly to the continual operating expenditures of such a deployment, and limits the deployment location.

PureWave has taken a revolutionary approach in the development of exclusively "Compact" base stations. A compact base station shares the similar form-factor and cost of a Pico base station, but with the performance of a Macro base station. It is a zero-footprint device that can be fully co-located with its antennas. It is the best of all worlds, and can be flexibly deployed in Pico, Macro, and Micro type deployments.

Welcome to the Revolution!

2.2 PureWave Quantum At a Glance

The PureWave Quantum Family of Compact Mobile WiMAX Base Stations is PureWave's 3rd generation base station platform, and we believe it presents what is simply the most advanced and high-performing, yet cost-effective base station solution available.

The PureWave Quantum Family of base stations consists of the 2x4 (2 Transmit, 4 Receive) Quantum 1000, as well as the PureWave Quantum 2200 (2x2), 4400 (4x4), and 6600 (6x6) products.

This User's Guide covers the PureWave Quantum 2200, 4400, and 6600 products. These models are differentiated from each other only by the number of Transmit (Tx) and Receive (Rx) antennas they support. Otherwise they are functionally identical. In this User's Guide we will, without loss of generality, refer primarily to the Quantum 6600 product.

The PureWave Quantum Family of base station products is fully 802.16e (Mobile WiMAX) compliant and designed to interoperate seamlessly with standard, off-the-shelf, WiMAX-certified subscriber devices. All PureWave Quantum products feature a software-defined radio (SDR) architecture that allows them to continuously evolve and take on new features as they become available. Some of the key highlights of the PureWave Quantum Family of products include the following:

- Superior Range – An antenna array of up to 6 antennas operated in concert creates tightly focused radio beams that extend the range of each base station by up to 40% or boost capacity where required.

- Spectral Re-use – Sophisticated interference mitigation techniques coupled with advanced beamforming technology, both made possible by PureWave's multiple antenna architecture, allow for simple network deployments and for improved spectral re-use.

- Software Defined Radio – Protects your investment through support for over-the-air, field upgrades of existing networks as standards evolve and new features and capabilities are released.

- Completely Weatherproof – PureWave Quantum base stations do not require shelter and can be installed completely outdoors. This eliminates the capital cost of building a shelter and the recurring cost of leasing or running an air-conditioned site.

- Flexibly Mount Virtually Anywhere – PureWave Quantum base stations can be deployed on towers, utility poles, walls, rooftops, etc, without the need for remote RF heads.

- ASN-GW Optional – PureWave Quantum base stations can operate with or without an ASN-GW, making even small deployments affordable.

- Future Integrated Backhaul Options – Greatly simplifies deployments, eliminating the need for dedicated microwave backhaul links, and reduce the capital cost associated with base station deployment.

PureWave Quantum base stations can utilize virtually any off the shelf antennas, both omni-directional and sectored. However, PureWave recommends our own line of affordable, compact, multi-antenna panels designed specifically to complement the performance of our base stations.

Error! Reference source not found. shows a typical tower-top deployment of the Quantum 6600 and a PureWave 6-Antenna Panel.

Figure 1: PureWave Quantum 6600 with 6-Antenna Panel

PureWave's carrier-grade solution includes our full-featured and highly scalable PureView NMS Network Management System, which can effectively provision and manage all base station and subscriber stations in the access network.   PureView features include automatic discovery, fault management, inventory tables, configuration, and performance management. PureView utilizes full open standard SNMP on the access network side, and employs a full-featured northbound interface for connection to virtually any existing NMS.

In addition to the PureView NMS, all PureWave Quantum Base Stations support a full-featured Command Line Interface (CLI) and an integrated Web Interface. The CLI is covered in depth in **Error! Reference source not found.**. Please refer to the PureView NMS and Web Interface User Guide's for details on those applications.

2.3 PRODUCT SPECIFICATIONS

PureWave Quantum products employ a sophisticated and flexible hardware architecture that combines multiple digital signal processors (DSPs), general purpose processors, and application-

specific hardware. Together these components deliver the processing power required to realize the high-performance required by today's demanding applications, while yielding the flexibility to support future functionality as the needs arise.

2.3.1 Physical Interfaces

The PureWave Quantum 6600 is shown in Figure 2. The PureWave Quantum product's flexible architecture allows for a number of product variants to suite almost limitless deployment needs. The model shown includes six antenna ports, two additional ports for future wireless backhaul options, Gigabit Ethernet backhaul ports, and a DC power connector. Single or Multi-Mode Fiber backhaul and AC power options are also available. As the configuration of individual base station models vary, so will the appearance of the connector panel. All PureWave Quantum base stations include an RS-232 console port, a GPS antenna connector, a ground screw, and three high-intensity LEDs. They are described in 2 and Table 3.

Note that Installation and weatherproofing must be completed by a professional installer. Please refer to the PureWave Quantum Base Station Installation Manual for detailed instructions.

Figure 2: PureWave Quantum 6600

Connector	Function
PWR	-48VDC or 110/220V AC power source inputs for the unit. DC power connector: LTW BB-04PMMS-LC7001 (chassis), LTW BB-04BFFA-LL7001 (mate) AC power connector: LTW BB-03PMMS-LC7001 (chassis), LTW BB-03BFFA-LL7001 (mate)

GND	This M5 screw provides a ground connection point to the base station. It is the installer's responsibility to ensure that the unit is professionally grounded and complies with all relevant local codes.
GPS	N-type connector for mandatory external GPS antenna. 3.3V power on center pin.
ETH-1	This Gigabit Ethernet port serves as the data traffic backhaul Interface and also provides for in-band management of the base station. Note that this port may be physically routed directly to the operator's network equipment, or it may be daisy-chained through additional PureWave Quantum sectors by routing it to another unit's ETH-2 port. Cat-5 (RJ-45), Single-Mode Fiber (HartingPull/Han 3 A), and Multi-Mode (LC duplex) Fiber options are available for the ETH-1 port.
ETH-2	This Gigabit Ethernet port serves as an incoming daisy-chain port from a neighboring sector, and may be used for out-of-band management of the base station. It may also be used to connect to an external device, such as a web camera. Daisy-chained traffic is aggregated and passed through the ETH-1 port. Cat-5 (RJ-45), Single-Mode Fiber (HartingPull/Han 3 A), and Multi-Mode (LC duplex) Fiber options are available for the ETH-2 port.
CONSOLE	RJ-45 based RS-232 port for CLI control via a console. Defaults settings are 38400, 8, None, 1, Xon/Xoff.
ANT 1-6	N-type Tx / Rx Antenna Ports. Note that different models have differing numbers of antenna ports.
BH 1-2	N-type Tx / Rx Wireless Backhaul Antenna Ports. These ports are reserved for future use and, if present, should be tightly capped and weather-proofed.

Table 2: Description of Connectors

LED	Function
STATUS	**Green** - BS is up and running normally. No faults detected. **Blinking Red** – System booting up, or system is temporarily down. **Solid Red** - Fault detected. **Off** – LEDs disabled or Power is off. Fault detected if POWER LED is Green, but STATUS LED is Off.
LINK/ACT	**Solid Green** – Connected to an Ethernet switch. **Blinking Green** – Ethernet packet activity. **Off** – LEDs disabled or no Ethernet activity detected.
POWER	**Green** – Power is being supplied to the BS. **Off** – LEDs disabled or no power is being supplied to the BS.

Table 3: Description of LEDs

2.3.2 Radio and Physical Layer Specifications

The PureWave Quantum Family of base stations is available in several model variants that support a variety of frequency bands in accordance with the regulatory requirements of a number of countries. Because several deployment-specific variables (e.g., antenna type, cable type and length, EMS settings, etc) can affect the effective power output and other characteristics of the system, it is the customer's responsibility to assure that each deployment of this product meets applicable regulations. Guidelines and rules are provided as a supplement to this manual, specific to each region and model. In addition, the PureView NMS, the Web UI, and the CLI all provide guidelines and feedback to ensure an appropriate installation.

Table 4 lists key radio-related specifications of PureWave Quantum base stations. Note that some features may not be currently available, but are planned for future software releases.

Parameter	Specification
Frequency Bands	XX23: 2.3-2.4GHz XX25: 2.496-2.69GHz XX33: 3.3-3.4GHz XX35: 3.4-3.6GHz XX36: 3.6-3.8GHz, including 3.65GHz US
Channel Sizes	3*, 5, 7*, 10 MHz (* future)
Duplex Method	TDD
DL:UL Ratios	35:12, 29:18, 32:15, 26:21 Note: Includes 5 and 10 MHz only. Additional ratios for 5 and 10MHz, as well as for 3.5 and 7 MHz supported via future software updates.
Number of Tx/Rx Antennas	22XX: 2 Tx, 2 Rx 44XX: 4 Tx, 4 Rx 66XX: 6 Tx, 6 Rx
Tx Power per Antenna	33dBm (RMS data power at maximum MCS level, measured at each external antenna connector of the base station)
Permutation	PUSC, AMC 2x3* (* future)
Modulation	QPSK-1/2, QPSK-3/4 16QAM-1/2, 16QAM-3/4 64QAM-1/2, 64QAM-2/3, 64QAM-3/4, 54QAM-5/6
Data Repetition Coding*	QPSK-1/2 Repetition 2, 4, 6 (*future)
MAP Repetition	1, 2, 4, 6
Smart Antenna Capabilities	Beamforming, MIMO Matrix A, MIMO Matrix B, Cyclic Delay Diversity, MRC,

	UL Collaborative Spatial Multiplexing*, UL SDMA* (* future)
Air Link Optimization	HARQ, CTC

Table 4: Radio and PHY Specifications

2.3.2.1 Receiver Sensitivity

Table 5 presents typical receiver sensitivity specs of the Quantum 6600 base station. Note that sensitivity will be correspondingly less on models with fewer than 6 antennas. Note that the values presented are measured over the entire channel bandwidth, as opposed to WiMAX Radio Conformance Test (RCT) type measurements, which are measured over only a fraction of the channel bandwidth.

Typical 6-Ant Rx Sensitivity		
AWGN, 10^{-6} BER, Full Band, in dBm		
UL MCS (CTC)	5MHz	10MHz
QPSK-1/2	-105.0	-102.0
QPSK-3/4	-102.0	-99.0
16QAM-1/2	-99.8	-96.8
16QAM-3/4	-96.1	-93.1
64QAM-1/2	-95.1	-92.1
64QAM-2/3	-90.9	-87.9
64QAM-3/4	-90.2	-87.2
64QAM-5/6	-87.0	-84.0

Table 5: Typical Rx Sensitivity

2.3.2.2 Computing EIRP Power

Effective Isotropic Radiated Power (EIRP) refers to the transmit power radiating out of the antenna. The accurate computation of EIRP is essential to proper network planning and to ensuring that the system meets local and regional maximum power regulations.

As indicated in Table 4, the average Tx power output at each base station antenna connector is 33dBm. The average EIRP per antenna is computed as follows:

Ave EIRP per Ant (in dBm) = Ave Tx Pwr per Ant + Ant Gain – Cable and Connector Loss

For example, if deployed with a 14dBi antenna connected to the base station with only a few feet of cable, the average EIRP per Antenna might be 33dBm + 14dBi – 1dB = 46dBm.

The total average EIRP of the base station with all antennas combined can then be computed as follows:

Total Ave EIRP (in dBm) = Ave EIRP per Ant + 10log(Number of Antennas)

For a 6-ant base station, the example above yields Total Ave EIRP = 46dBm + 7.78dB = 53.78dBm.

Note that most regulations refer to Peak power, which in a WiMAX system is normally as much as 10dB higher than average power. In the case of the PureWave Quantum products the peak power can be assumed to be around 9dB higher than average. Therefore, peak EIRP may be computed as follows:

Peak EIRP per Ant (in dBm) = Ave EIRP per Ant + 9dB.

Total Peak EIRP (in dBm) = Total Ave EIRP + 9dB.

For the above example, Peak EIRP per Ant = 46dBm + 9dB = 54dBm and Total Peak EIRP = 53.78dBm + 9dB = 62.78dBm.

These equations are summarized in Table 6.

EIRP Metric	Formula
Ave EIRP per Ant (in dBm)	= Ave Tx Pwr per Ant + Ant Gain – Cable and Connector Loss
Total Ave EIRP per ant (in dBm)	= Ave EIRP per Ant + 10log(Number of Antennas)
Peak EIRP per ant (in dBm)	= Ave EIRP per Ant + 9dB
Total Peak EIRP (in dBm)	= Total Ave EIRP + 9dB

Table 6: EIRP Calculations

Note that some regulations are specified for particular channel bandwidths and/or antenna beamwidths and in such cases the allowable power should be scaled accordingly. As with the previous calculations, each case is often unique. Again, the PureView NMS provides guidance when deployed in markets where such regional regulations apply.

2.3.2.3 Smart Antenna Capabilities

Beamforming is a technique that combines and focuses signals to and from multiple antennas to improve both downlink and uplink performance.

On the uplink, the base station combines signals received on its multiple antennas, resulting in substantial link budget gains that improve range and throughput. **MRC** is the basic technique

from which more sophisticated uplink processing techniques (such as interference mitigation) are built.

On the downlink (Base Station to Subscriber Station), sophisticated digital signal processing algorithms exploit information gathered during the uplink beamforming process to concentrate the transmitted RF energy from the antenna array to the exact subscriber stations locations, improving gain, efficiency, and signal to noise ratio (SNR), resulting in greater range and throughput.

MIMO Matrix A utilizes a technique called space-time coding (STC), which exploits the spatial diversity of the channel to improve downlink performance. By improving data reception, it can increase range and maximize the utilization of available sector capacity.

MIMO Matrix B utilizes a technique called spatial multiplexing (SM), in which multiple streams of data are simultaneously transmitted through multiple antennas and effectively separated by the receiving device. This technique can actually increase the spectral efficiency and, hence, the capacity of a system.

The effectiveness of MIMO relies upon the spatial diversity inherent within the channel as well as other factors, and therefore a given technique may be more appropriate for certain users or deployments. Fortunately, PureWave Quantum Base Stations make these decisions automatically, maximizing the efficiency of your valuable spectrum.

Cyclic Delay Diversity (CDD) is a technique employed by PureWave Quantum base stations to allow the power of multiple antennas to be combined in transmitting a single stream of data even when MIMO or beamforming cannot be supported (e.g., when transmitting the MAP).

Spatial Division Multiple Access (SDMA) is SDMA is an advanced form of beam-forming in which multiple distinct beams are transmitted (or received) at the same time on the same frequency to (or from) multiple users. Whereas FDMA separates users in frequency (e.g., sub-channelization) and TDMA separates users in time, SDMA separates users in space. With SDMA different signals are simultaneously sent on the same frequency to different physical locations.

Collaborative MIMO, also known as **Collaborative Spatial Multiplexing (CSM)**, is a technique that, similar to uplink SDMA, allows multiple subscriber stations to transmit at the same time on the same frequency.

A key difference between CSM and SDMA is, however, that CSM transmissions are specially coded and require specific support in the subscriber stations. In contrast, SDMA does not require specific support from the subscriber station.

2.3.3 Capacity and Performance Characteristics

Table 7 summarizes key upper layer and overall performance characteristics of PureWave Quantum base stations. Note that some features may not be currently available, but are planned for future software releases. In addition, detailed throughput tables for each DL:UL ratios is presented in Appendix B.

Parameter	Specification
Active Users	256
Service Flows Per User	16
Idle-Mode Users	2048
Peak Throughput	Aggregate: Up to 50Mbps DL: Up to 43Mbps UL: Up to 20Mbps
QoS	BE, UGS, rtPS, ErtPS, nrtPS
Convergence Sublayer	IP-CS, Eth-CS, PHS*, IPv4, IPv6*, IPv6 Pass-Through (*Future)
Security	AES-128, EAP-TLS, EAP-TTLS, PKMv2
Management	PureView NMS / EMS, Remote CLI, Web Interface, SNMP v2c, SNMPv3
Core Network Interface	R6 (NWG 1.2.2, NWG 1.3.1), Radius

Table 7: Performance Characteristics

2.3.4 Electro-Mechanical and Environmental Specifications

All PureWave Quantum Family Base Stations consist of a single, all-in-one, fully weatherproof unit that may be installed entirely outdoors (or indoors, as a deployment dictates). Please refer to the PureWave Quantum Base Station Installation Manual for detailed installation instructions and guidelines.

Table 2 lists the mechanical, electrical, and environmental properties of the PureWave Quantum 22XX, 44XX, and 66XX Base Stations.

Parameter	Specification
Dimensions	17.5" (H) x 16.7" (W) x 5.3" (D) 44cm (H) x 42cm (W) x 13cm (D)
Weight	Base Station: 32 pounds (14.5kg) Mounting Bracket: XX pounds (xxkg)
Power	-48VDC or 110/220 VAC, 180 Watts Max
Temperature	-45 to +55 degrees C (ETSI EN 300 019-1.4 Class 4.1E)

	Note: An available solar shield is required for ambient temperatures exceeding +45C with full sun exposure.
Humidity	5 to 100% non-condensing
Altitude	To 10,000 ft. above sea level
Surge Protection	UL497B
Lightning Protection	10kA IEC 6100-4-5 (optional via external kit)
Weatherproofing	IEC IP67
Wind Loading	160Km/hr operation, 200Km/hr survival
Safety and IEC IP	EN 300 019-2-2, GR487, IEC 60529
Vibration and dust	ETSI EN 300 019-1-4 Class 4.1E

Table 8 – Electro-Mechanical, and Environmental Specifications

Figure 3 shows the PureWave Quantum 6600 with its pole mounting bracket. Note that there are 2 pieces to the mounting bracket assembly – one that mounts to the base station (Figure 3) and one that mounts to a wall or pole (Figure 4). Details can be found in the PureWave Quantum Base Station Installation Manual.
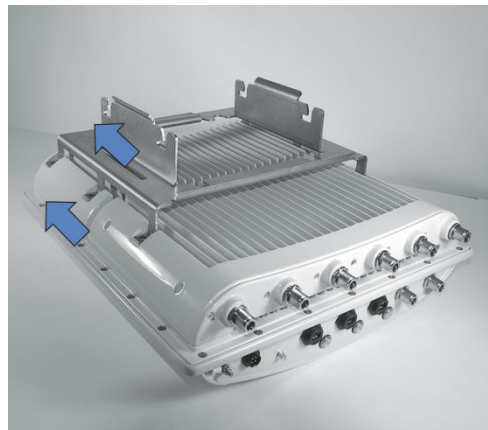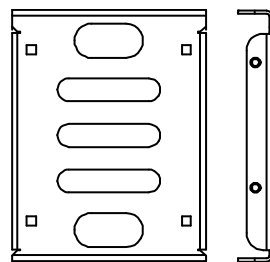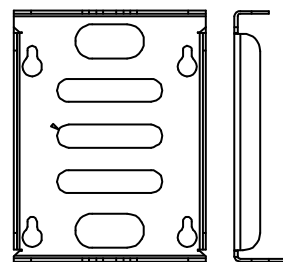

Figure 3: PureWave Quantum 6600 with its Pole Mounting Bracket

Front Mounting Plate   Rear Mounting Plate

Figure 4: Front and Real Mounting Plates

For temperatures above +45 degrees C in direct sunlight it is necessary to deploy the base station with the available solar shield, shown in Figure 5. Again, details can be found in the PureWave Quantum Base Station Installation Manual.
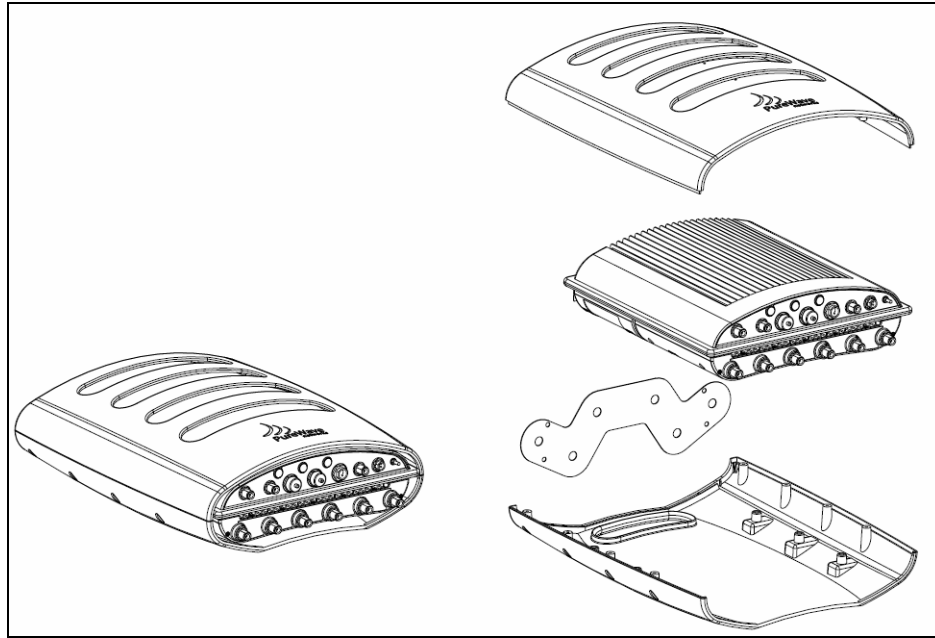

Figure 5: Quantum 6600 with Available Solar Shield

## 2.4   THE BROADER WIMAX 802.16E ECO-SYSTEM

The 4th generation of wireless mobile networks, WiMAX 802.16e, is creating high speed internet connectivity anywhere, providing for broadband connectivity while supporting Authentication, Billing, and Management of mobile users.   For that purpose it requires a full eco-system involving multiple vendors and a number of components:

- o **Radio Access Network (RAN)** - Wireless BTS and Subscriber Devices (also known as the Access Service Network or ASN)
- o **Access Service Network Gateway (ASN-GW)**
- o **Core Network** - Management, AAA, TR-69, etc
- o **Applications** – To run on or connect to subscriber devices

In this section we describe at a high level the different elements and their roles in the network.

The architecture reference model in Figure 6 illustrates the interconnections between the various system components. PureWave maintains a catalogue of network elements that have

been tested against each other. To ensure interoperability between components, we strongly recommend that an operator choose from that list.
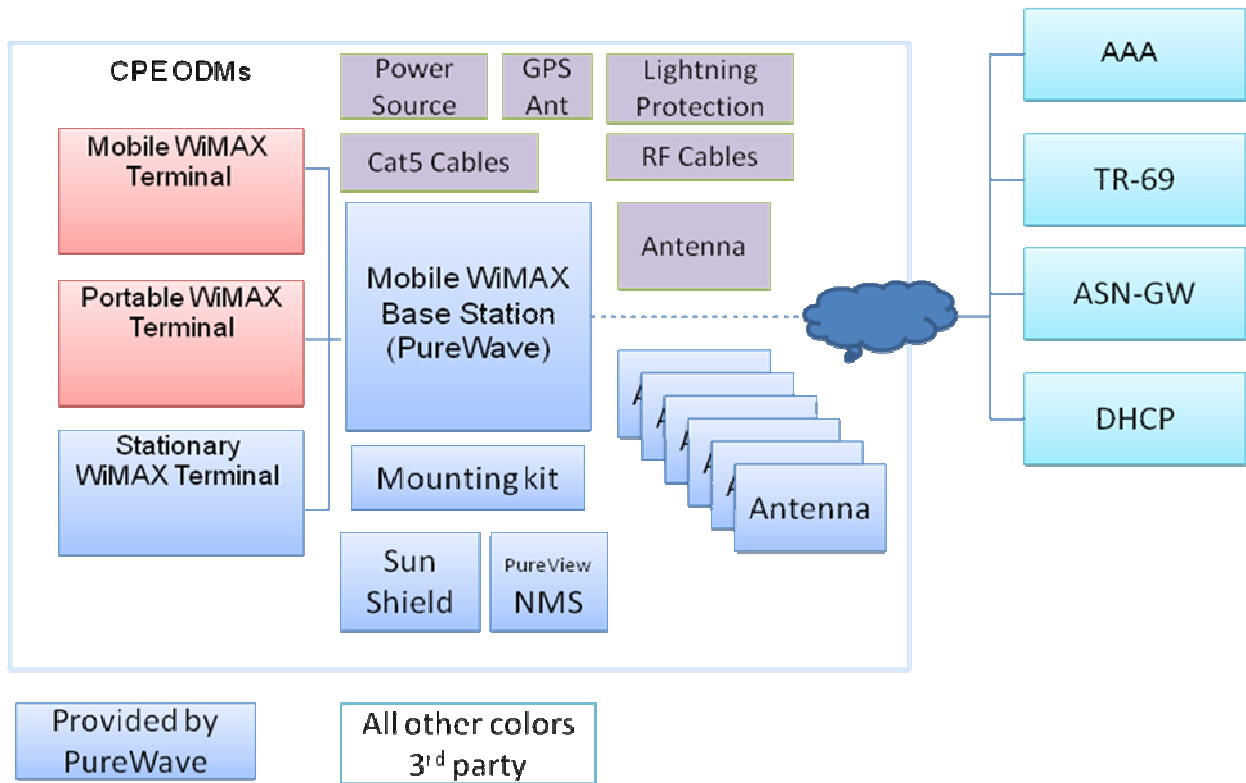
Figure 6 - Architecture Reference Model.

Combining these devices into a network, as shown in Figure 7, an operator can offer fixed and mobile data, voice, video, and countless applications to users wherever they may be.

Figure 7 - 802.16e system implementation

2.4.1 The RAN - Radio Access Network

The Radio Access Network is simply composed of one or more Base Stations with attached Antennas (or antenna array) that connect wirelessly to subscriber devices (e.g., Customer Premise Equipment (CPE), Mobile Stations (MS), etc.

Depending upon its type and characteristics, a subscriber device may be self-contained (e.g., a handset) or may connect to a router or computer via its "subscriber interface".

A base station connects to the core network by means of its backhaul interface, which is fundamentally a wired interface but may itself be carried by means of a wireless link or network. The backhaul interface may connect to the core network directly, or through an Access Service Network Gateway (ASN-GW).

2.4.1.1 RAN – Base Station

A Base Station has hardware, software, and mechanical characteristics that support its functional and performance requirements. Base Stations and Subscriber Stations interconnect with each other and their respective networks via sets of network, MAC, and PHY protocols.

PureWave Quantum base stations employ up to 6 transmitters and 6 receivers (depending upon the specific model) that work together to achieve unprecedented results in terms of its ability to connect to subscriber devices at greater distances and higher throughputs.

All PureWave Quantum Base Stations utilize the IEEE 802.16e Mobile WiMAX standard for wireless communication with subscriber devices. Mobile WiMAX supports time division duplex (TDD) communication between a base station and multiple subscriber devices on a given channel of spectrum. In a WiMAX system the direction from base station to subscriber station is known as the Downlink (DL) and the direction from subscriber station to base station is known as the Uplink (UL). The ratio of time devoted to the DL to that of the UL is referred to as the DL:UL Ratio.

WiMAX base stations utilize GPS (the Global Positioning System) to maintain tight synchronization and coordination among themselves in a network. This assures that all base stations in the network transmit and receive in harmony, as they must all utilize the same DL:UL Ratio.

All PureWave Quantum Base Stations incorporate an integrated GPS receiver which must be connected to an external GPS antenna in view of a number of GPS satellites.

The PureWave Quantum family of products is mobile WiMAX (802.16e) Profile C compliant and offers models that cover frequency bands from 2.3-2.7GHz and 3.3-3.8GHz. Products are available also in a Stand-Alone mode and can be operated without an Access Service Network Gateway (ASN-GW) to further reduce network costs. By maintaining strict compliance with the standards, PureWave Quantum base stations allow the maximum compatibility with a wide variety of 3rd party network elements.

> **!**
>
> **Warning:** When choosing a GPS antenna, choose carefully, as there are many models in the market. Some are very cheap but also low gain and/or low quality and can easily become the point of failure of your system. PureWave recommends a high-quality GPS antenna from our product catalog.

2.4.1.2 RAN – Subscriber Devices

A large variety of WiMAX subscriber devices are available today, including outdoor-mounted CPEs, indoor desktop units (IDUs), USB dongles, and mobile handsets. Some devices have built-in VoIP-based POTS ("plain old telephone service") ports, and some even have built-in WiFi access points.

We strongly recommend that operators select subscriber devices from PureWave's catalog of recommended devices. That is the best way to assure compatibility and the highest possible performance.

Outdoor Fixed Subscriber Devices:

Outdoor Customer Premises Equipment (CPE) must usually be professionally installed on a house, building, pole, or other elevated location. They are used for fixed communications and usually integrate a set of high-gain directional antennas. A typical outdoor CPE is shown in Figure 8.

Figure 8: Typical Outdoor CPE

Indoor Fixed Subscriber Devices:

Indoor CPE, also referred to as Indoor Access Devices (IADs) are rated for indoor use only and may have omni-directional antennas, directional antennas, or both. Either way, their antenna gain is normally significantly less than that of an outdoor unit. Although used for fixed communications, it has the advantage that its location may be easily adjusted for better reception. However, it is also subject to very significant building penetration loss which is avoided by an outdoor installation. Indoor subscriber devices are popular with operators since they can be shipped to (or purchased by) and installed by a customer, avoiding the need for professional installation. A typical indoor CPE is shown in Figure 9.

Figure 9: Typical Indoor CPE

USB and Integrated Laptop Portable Subscriber Devices:

A USB-based subscriber device or a device built-into a laptop computer offers all the flexibility that users enjoy today with WiFi, but with the data rates and ranges offered by WiMAX. Due to their very low antenna gain, such a device will offer a lower range than fixed devices, particularly when used indoors, but they offer the advantage of portability. Some such devices even have integrated WiFi access points, creating a portable "Hot Spot". A typical USB subscriber device is shown in Figure 10.

Figure 10: Typical USB Subscriber Device

Mobile Handsets

With the announced and soon-upcoming volume availability of mobile WiMAX handsets, users will have the ability to enjoy full broadband data services with the seamless mobility they are used to on today's voice-centric cellular networks.

2.4.2 Core network

The core network plays an important role in the 802.16e eco-system. Several elements are located in the Network Operation Center (NOC) and we briefly describe each here.

2.4.2.1 Management

A Network Management System (NMS) and/or an Element Management System (EMS) provides for configuration, provisioning, and management of the base station and subscriber stations. It provides alarms, traps, statistics, and more. The PureView NMS (Figure 11) is a carrier-grade multi-platform NMS/EMS that provides all of these capabilities.
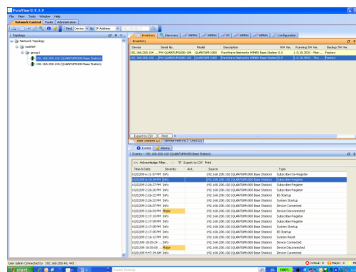

Figure 11: PureView NMS

2.4.2.2 AAA

An Authentication, Authorization and Accounting System (AAA) is required by 802.16e to authenticate and track subscriber devices within the network. PureWave Base Stations are tested for interoperability with several options of AAA servers:

- Free Radius AAA
    - Version 2.1.7 Linux
    - Version 1.1.7 Windows
- Cisco AAA (CAR-4.2)

2.4.2.3 ASN-GW

An Access Service Network Gateway (ASN-GW) is designed to support connection management and mobility across sectors, cell sites, and even across service provider network boundaries (roaming capabilities). An ASN-GW can coordinate inter-base station traffic, as well as traffic between base stations and the core network. Simply, the ASN-GW is the gateway between the Radio Access Network and the Core Network.

PureWave Quantum base stations support the standard WiMAX R6 (Profile C) and, at the time of writing, have been interoperability tested with the following ASN-GWs:

- WiChorus ASN-GW: Master Intelligent Packet Processor (IPP) SW version 2.1.1-193 (With Built-In Radius Server)
- Cisco ASN-GW: Cisco Broadband Wireless Gateway (BWG) Release 2.0 for Cisco IOS. Version Release 12.4 (20091215:091801)

PureWave Quantum Base Stations also incorporate internal ASN-GW functionality that allows them to alternatively be deployed without an external ASN-GW in small to mid-sized deployments.

2.4.2.4 DHCP

A DHCP server is used to provide IP Address Assignment to subscriber stations. There are a number of ways this can be set up, depending upon the network elements in use. This topic is discussed in depth later in this manual.

2.4.2.5 TR-69 (Technical Report 069)

TR-69 is a bidirectional SOAP/HTTP based protocol that is used for Over-The-Air (OTA) provisioning and software upgrade of subscriber devices. Communication takes place between subscriber devices and an Auto Configuration Server (ACS) and is transparent to the base station.

2.4.3   Applications

The performance offered by WiMAX enables such a vast set of possible applications that a discussion of them here could not possibly do them justice. Categories include personal mobile broadband for data and video, VoIP, video surveillance, public safety, utilities, Smart-Grid, oil & gas, education, mining, backhaul needs, etc. The possibilites are endless.

As every application is different, each requires a unique network and configuration settings to assure optimal spectral utilization and performance. In this guide as well as the PureView NMS User's Manual we show how to bring up and configure the system under particular sets of assumptions, and we explain all the settings at one's disposal in optimizing the network for any arbitrary application.