Design Guide

for Wireless Device Antenna Systems

CENTURION™

WIRELESS TECHNOLOGIES, INC.

Design Guide
for Wireless Device Antenna Systems

Including: Bluetooth and 802.11 Applications

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This DESIGN GUIDE for WIRELESS DEVICE ANTENNA SYSTEMS, has been developed to answer RF data transmission application questions. This document covers topics of critical design parameters, antenna testing, and antenna selection.

These topics can be applied to applications involving:

Short Range		**Wide Area Network**	
Bluetooth	2.4GHz	Ardis	806MHz
802.11	2.4GHz	Ram	896MHz
WLAN	902MHz & 5.7GHz	Cellular	824MHz
		PCS	1.9GHz

The design guide provides information on internal and external antennas and their performance behavior. This guide is the first step in finding the right antenna solution. The next step is to contact an antenna designer/manufacturer who can complete the design process and provide an antenna solution that meets the customer's needs and expectations.

Centurion Wireless Technologies, Inc. is a leading technology company providing R&D and manufacturing services for wireless communications, holds multiple U.S. and international patents, and is an ISO 9001 registered company headquartered in Lincoln, Nebraska. More information on Centurion Wireless Technologies' products and services can be found at http://www.centurion.com.

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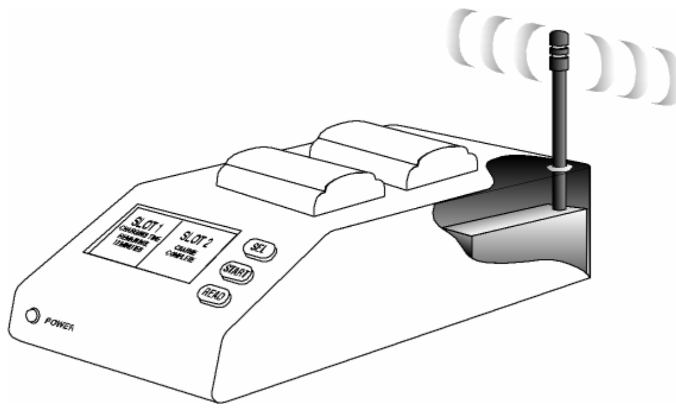
SECTION I: ANTENNAS

An antenna is an electrical conductor used in the transmission and reception of electromagnetic energy by converting radio waves into electrical signals and vice-versa. In normal circuits, electric energy either remains within the circuit and performs useful work or is converted into heat. When a resonant element (an antenna) is added to a RF circuit, it will redirect some of its power along the antenna, which will create an electromagnetic field. This energy is then radiated into space. This is basis for radio communications.



SECTION II: CRITICAL DESIGN PARAMETERS

The portable antenna environment is different than that of mobile or base station antennas. In general, the basic concepts of antenna tuning, gain, radiation pattern, VSWR, etc. are the same, but significant new variables are introduced:

- the size of the chassis (expressed as a function of wavelengths)
- the shape of the chassis (short and squat, long and thin, etc.)
- the construction of the chassis (plastic or metal)
- the environment in which it is used (surrounding objects, metal, etc.)
- the effects of the individual operating the product

All of the above have a significant effect upon the antenna system performance and therefore must be taken into consideration during the design stage.

ANTENNA TUNING

The frequency range of operation, simply put, is dictated by the application for which an antenna is to be used. Antenna performance within this range is designed to meet prescribed criteria. Outside of this range, performance will be degraded. Bluetooth operates in a frequency range of 2.4-2.5 GHz (ISM band).

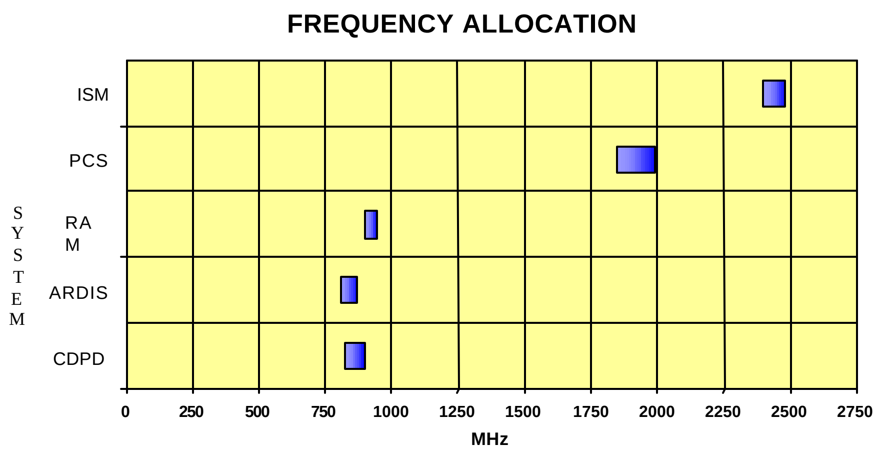


FIGURE 1

VSWR AND RETURN LOSS

VSWR and Return Loss are used as a performance parameter to quantify the percentage of power that will be reflected at the input to the antenna. When VSWR is evaluated, a value closer to 1.0:1 is more desirable than one that is higher (i.e. 1.5:1 is better than 2.5:1). Although a 2:1 VSWR implies a reflected voltage twice that of the forward voltage, the actual loss in radiation is 10% or .5 dB. A VSWR of 3.0:1 is considered the maximum acceptable and results in a 25% reduction of power or 1.2 dB loss. Therefore, it is very important to attain the best impedance match possible for maximum efficiency in the antenna system. Figure 2 shows a typical VSWR chart where the band edges are at 2:1 VSWR and the center frequency (2.45) is at 1:1.

Return loss is a measurement of the level of signal attenuation as it is reflected from the antenna. An open antenna has 0 dB return loss (i.e. all the power transmitted to the antenna is reflected), whereas a near perfect match has an extremely large negative value (typically -66 dB). A greater negative value is better than a smaller negative number (i.e. – 15 dB is more efficient than – 10 dB).

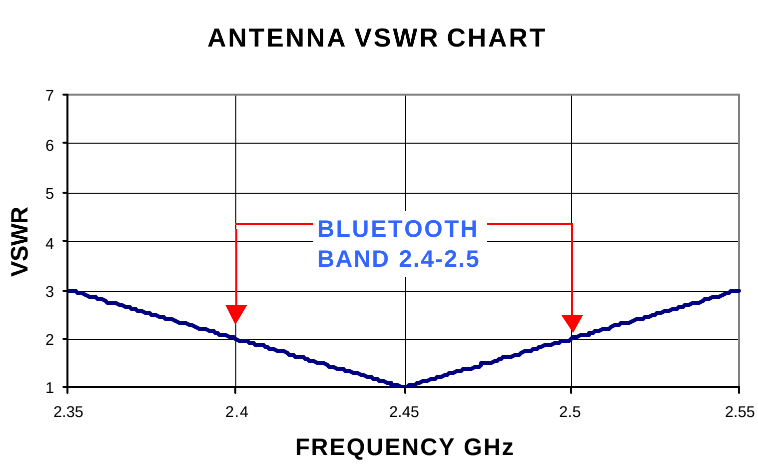


FIGURE 2

RADIATED ENERGY

The purpose of the antenna is to radiate electromagnetic energy. For a given amount of input power, the antenna will radiate a percentage of that power in the form of radio signals. A well designed antenna system will radiate a high percentage of energy whereas a poor system will lose efficiency by transforming energy into heat or reflecting it back into the wireless device. If the radiated energy from an isotropic source were visible, it would look like a sphere. Figure 3 shows a typical 3D-radiation pattern of a typical cellular telephone handset.

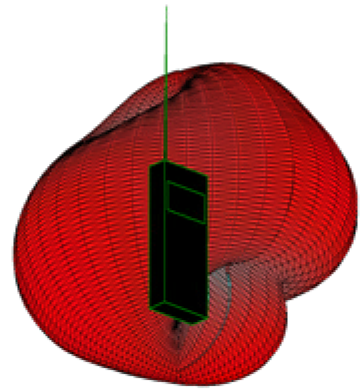


FIGURE 3

GAIN AND DIRECTIVITY

A critical factor when designing an antenna system is directing radiated energy towards the receiver antenna. Think of an antenna as a light bulb. An isotropic source has radiated energy that is spherical and provides equal intensity radiation in all directions. This is very similar to the light given by a single bulb without any fixture, lens, etc. to direct the pattern. When the light bulb is placed into a housing that provides a reflector (like a flashlight) and the bulb is illuminated, the light is emitted in a direction that is controlled by the reflector and focused at some point. This is similar to the concept of adding gain to an antenna. The power consumed by the bulb (antenna) is not any greater than the input power to the isotropic antenna, but the signal is directed and shaped to provide a higher intensity of illumination at a desired location and a lower intensity of illumination at a point that is not desired.

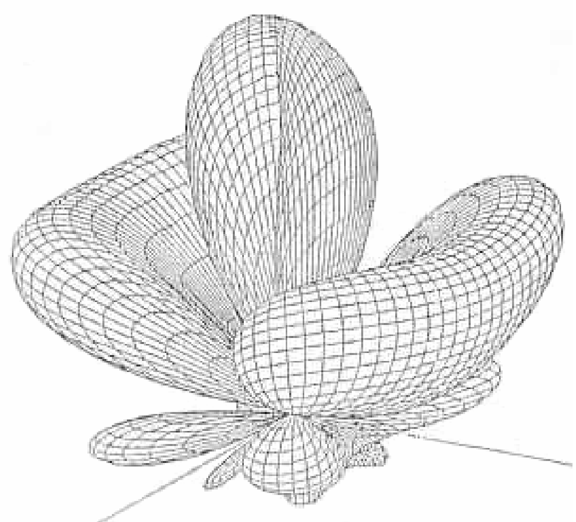


FIGURE 4

Gain is determined by many factors. Type of antenna, electrical length, antenna placement and antenna orientation all contribute to pattern shape and subsequently gain.

Gain and directivity can be controlled to a certain extent. For instance, in some applications, it is beneficial to direct radiated power towards the horizon for increased range. One method to do this is by changing the electrical length of an antenna so that the high angle of the radiation component is redirected and added to the lower angle radiation component. Figure 4 shows a radiation pattern for a very directive antenna.

LOCATION AND ORIENTATION OF THE ANTENNA

Another important factor when designing an antenna system is the location and orientation of the antenna on the wireless device.

Propagation within buildings is governed by the following factors: attenuation due to walls, reflection from walls, ceiling, floor, etc. and diffraction from obstacles within a building. With this in mind, it is best to mount the antenna higher than any obstacle between the transmitter and receiver and to orient it in the same electrical direction (polarity) as the receiver antenna. Unfortunately, this is usually not possible in most portable applications.

Two important things to consider when placing the antenna are:

1. Any metal surfaces that surround or partially surround the antenna will distort the radiation pattern. This distortion will impair the quality of transmission. Therefore, the antenna must be placed outside of the shielded housing of the device. Also, it should be placed as far away horizontally from any surface that would block “the line of sight” of the receiver antenna. For instance, if the antenna is to be placed adjacent to the screen it is better to move it as far as possible away from the screen. It is best to place the antenna under or over the screen.

2. Another consideration while locating an antenna on the appliance is the user effect. It is best to locate the antenna away from the user’s body. The interaction between user and the antenna can cause a de-tuning effect on the antenna and also the user can absorb energy that was to be transmitted into radio signals.

ATTACHING THE ANTENNA

There are many variables to consider when attaching the antenna to the wireless device. Electrically, the antenna is connected by a RF feed-line. A feed line is a method transferring RF energy from an exciting source (oscillator) to a terminal load (antenna). Two examples of feed lines are coaxial cables and the strip line method.

A coaxial cable is a two-conductor concentric unbalanced transmission line in which one conductor completely surrounds the other. The conductors are separated by a continuous dielectric. Such a line has minimal external RF field and is not susceptible to its surroundings. Advantages include good shielding characteristics and impedance not affected by circuitry or surroundings. Disadvantages include cost, difficult to orient within circuitry, and RF losses due to line length. For example, a common RG174 coaxial cable will lose .5 dB per foot at 2.4 GHz.

A strip-line or microstrip feed line is a planar, two-conductor transmission line mounted on a dielectric or PCB between or on top of a ground plane. Advantages include simple fabrication, easily applied to printed circuit board designs, and reasonable low losses for a selected band-pass. Disadvantages include minimal RF radiation suppression and RF loses due to line length. For example, RF loss for a common microstrip line is 1.0db per foot at 2.4 GHz.

There are many methods in which to connect the antenna to the RF feed line.

In the simplest form, RF connection can be made by the following methods: soldering, mechanical fasteners such as rivets, screws, or spring pressure contacts. These types of connections are commonly used for ground dependent type antennas (¼ wave antenna).

For ground independent antennas such as the ½ wave dipole antenna, the connection to the RF feed line requires a RF coaxial connector. RF coaxial connectors are very common in the industry. They come in different sizes and shapes. Some thread on to the wireless device and others snap into place. There are many mechanical and electrical variables when deciding upon the right connector: frequency of operation, insertion loss, type of feed line, and how the device is being used are just to name a few. RF connectors that are commonly found on small portable wireless RF devices include SMA, SMB, SSMB, and OSMT.

SPECIFIC ABSORPTION RATE (SAR)

SAR is related to the heating of body tissues caused by the radio waves. It is highly dependent on the distance of the antenna from the body. It is also dependent on the type of device in which it is being used. SAR may not be a concern at the lower power levels utilized by the Bluetooth system, however, wireless manufacturers should be familiar with the applicable FCC rules and regulations. See part 1 and 2 of the FCC rules and regulations, 47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093.

SECTION III: ANTENNA TESTING

VSWR

VSWR is measured with a network analyzer. First, the Network Analyzer is calibrated using known standards. Next the Unit Under Test (UUT) is attached to the test port for measurements. Of course, the above measurement assumes that a coaxial port is available on the UUT. For those instances in which one is not, a coaxial transmission line is introduced at the input to the antenna. Using sound engineering techniques, errors associated with the introduction of this cable can be made negligible. Figure 5 shows a typical VSWR test set-up.

FIGURE 5

GAIN

Gain of the antenna is determined by measuring the co-polar radiation pattern of the antenna either in free space range or in an anechoic chamber. The absolute gain of Antenna Under Test (AUT) is obtained by comparing its radiation pattern with that of a reference antenna calibrated by a certified calibration company.

Gain is measured on an antenna range. There are two categories of antenna ranges: indoor and outdoor. All the indoor ranges use anechoic (literally 'no echo') material to suppress reflections of radio waves from the inside of the building. Indoor ranges, usually called anechoic chambers, also have metallic enclosures to block out radio waves from the outside world.

Anechoic material is foam that has resistive material such as carbon implanted within the fibers. The shape of the anechoic material also aids in suppressing radio wave reflections. Pyramidal absorber reflects leftover radio waves into adjacent pyramidal absorbers where the radio waves are further suppressed.

There are 4 types of anechoic chambers. All of them have what is called a "quiet zone." The quiet zone is a region within the chamber that has the lowest level of reflections from sidewalls. The quiet zone represents, as closely as possible, a radio wave traveling in space.

1. Rectangular chambers are large enough to allow radio waves to travel almost the same as if they were in a vacuum. Absorber reduces any reflections that do bounce off the walls. All types of antenna measurements can be performed in a rectangular chamber.

2. To save space, tapered anechoic chambers depend on reflections from the cone to form the quiet zone in a shorter distance. Not all types of measurements can be performed in a tapered chamber.

3. To save more space, compact ranges use a parabolic reflector to focus the radio waves and form the quiet zone in a much shorter distance. At lower frequencies, the size of parabolic reflector becomes larger than the space that is supposed to be saved. Not all types of measurements can be performed in a compact range.

4. Near-field anechoic chambers require the least amount of space. The near field occurs close to the antenna. The near field does not look like a radio wave in space. The radio wave in space is calculated from the near-field measurements.

Not only can all types of measurements be performed in a near-field chamber, but all types of measurements *must* be performed to successfully calculate the far-field (radio wave in space). This is a disadvantage when time is a critical factor.

There are two types of outdoor ranges. One is an elevated range, and the other is a ground reflection range.

1. An elevated range has elevated towers for the transmit antenna and the antenna under test. The reflections from the ground are reduced by having a transmit antenna with a narrow beam-width.

2. A ground reflection range abandons the possibility of eliminating reflections and actually enhances ground reflections by use of a metal plane. The amount of reflection from a very good conductor is well known and can be accounted for in the measurements.

Centurion has a tapered anechoic chamber with a 2' diameter quiet zone. The useful frequency range is 800 MHz to 3000 MHz. The size of the chamber is 8' x 8' x 25' (figures 6 & 7).

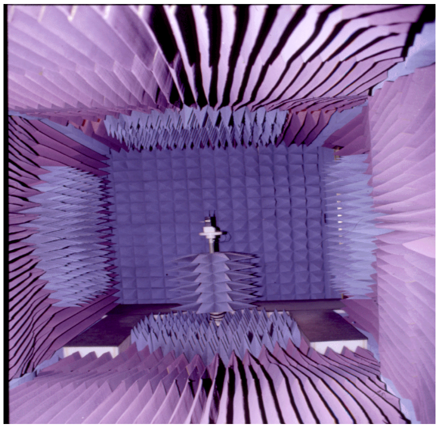


FIGURE 6

FIGURE 7

Centurion measures the antenna gain using the gain substitution method. An antenna with a known gain and the reference antenna, are placed in the chamber, and the power level is measured and recorded. We use a double-ridged horn with a relatively large gain to reduce errors from residual reflections. Then the antenna under test is placed in the chamber and the power level is recorded. The power of the antenna under test relative to the reference antenna power is the relative gain of the antenna under test. Because the gain of the reference antenna is known, the gain of antenna under test is calculated.

The antenna has different gain levels in different directions. To more accurately capture this data, power measurements are taken while the antenna is rotated 360 degrees in the three principal planes, azimuth, elevation PHI=0, and elevation PHI=90 (see Figure 8). The data is then represented graphically in the form of a gain plot (Figure 9).

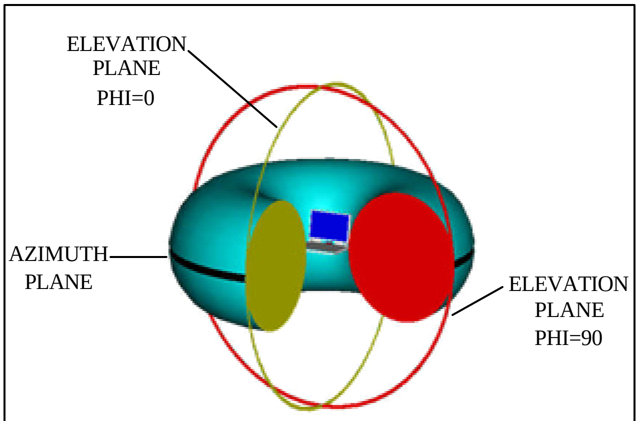


FIGURE 8

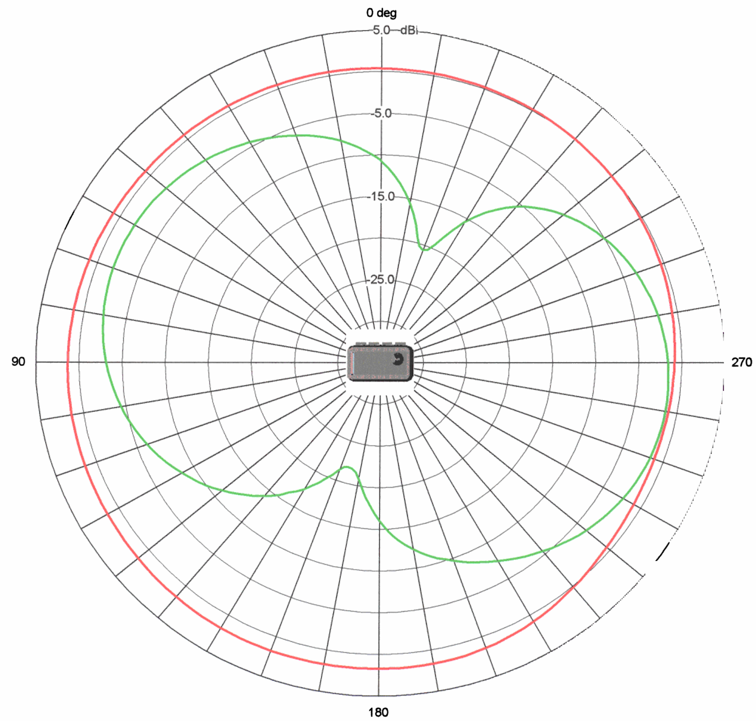


FIGURE 9

To further improve the accuracy of gain measurements, more data points must be taken around the radiation pattern. In this example (Figure 10), several elevation cut measurements are made that form a 3 dimensional pattern. Antenna efficiency measurements can be calculated from the 3-D pattern information.

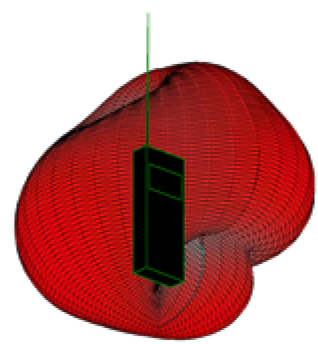


FIGURE 10

SAR TEST

There are two ways to measure SAR. One is to measure the temperature increase in different positions inside a head mockup filled with tissue simulating liquid.

The other is to measure the electric field in the tissue simulating liquid and calculate the amount of absorption based on the known properties of the liquid. Measuring the fields requires a highly specialized antenna probe that minimally disturbs the electric field (the bigger the antenna, the more it disturbs the fields being measured). Measuring the temperature rise is difficult because of heat convection. Two different SAR measurement vendors have reported accuracy of 25-30%.

SECTION IV: ANTENNA CHOICES

Antennas for this type of application may be broken into two main categories:

1. External (attached to the outside of the housing)
2. Internal (hidden within the housing)

Figure 11 shows different types of antennas mounted at different locations.

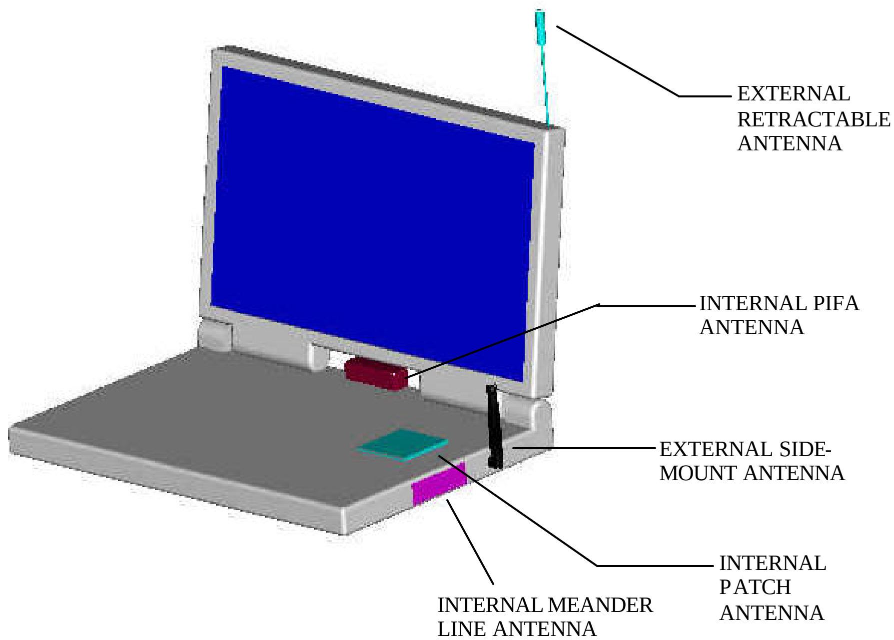
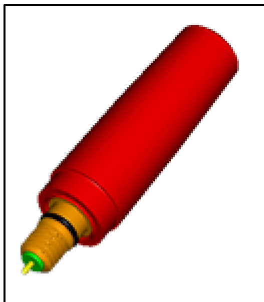


FIGURE 11

EXTERNAL ANTENNAS

External antennas commonly used in portable environments are typically constructed as a ¼ wave or a ½ wave antenna.

¼ WAVE EXTERNAL ANTENNAS



¼ wave Stubby

The ¼ wave helical stubby antenna has a radiation pattern that more closely approximates the radiation characteristics of an isotropic source. This provides an optimum condition for portable communications. In many cases, the helical stubby antenna will perform as well as the elongated ¼ wave antenna. The distributed capacity of the helical ¼ wave stubby antenna acts as an impedance matching section that is not present in the full size ¼ wave antenna. This minimizes the effect of the chassis.

Quarter wave antennas are ground dependent, that is, they must have a ground plane to work against (a chassis, metal plate, etc.).

½ WAVE COAXIAL DIPOLE

A ½ wave coaxial dipole antenna is a method of constructing a dipole antenna where coaxial cable feeds the antenna. Radiation extends upwards from the feed point, approximately ¼ wave length, and a sleeve is connected at the feed point and extends down approximately ¼ wave.

Theoretically, this antenna provides 2.15 dBi gain. In application however, 1.0-2.0 dBi peak gain is expected. The coaxial cable construction method provides an antenna that is decoupled from the chassis of the portable device and provides excellent attenuation of RFI and unwanted signals from entering the phone that are common on shorter antennas and ¼ wave antennas. Another benefit of this method of construction is that the effects of the user holding the portable device are minimized greatly by getting the signal up and away from the wireless device.

½ WAVE COAXIAL DIPOLE ANTENNA

DESK TOP | RIGHT ANGLE SWIVEL | STRAIGHT

PRELIMINARY SPECIFICATION

½ WAVE COAXIAL DIPOLE ANTENNA (PROT9661)

ELECTRICAL

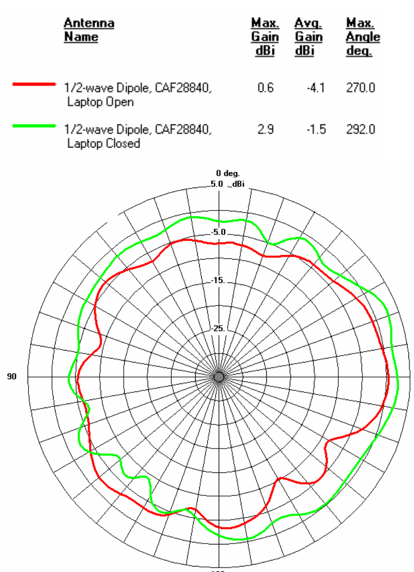
Frequency	2.4 - 2.5 GHz
Impedance	50 ohms nominal
Polarization	Linear
Peak Gain	3.4 dBi (Free Space)
VSWR	<2.5:1 Across band

MECHANICAL

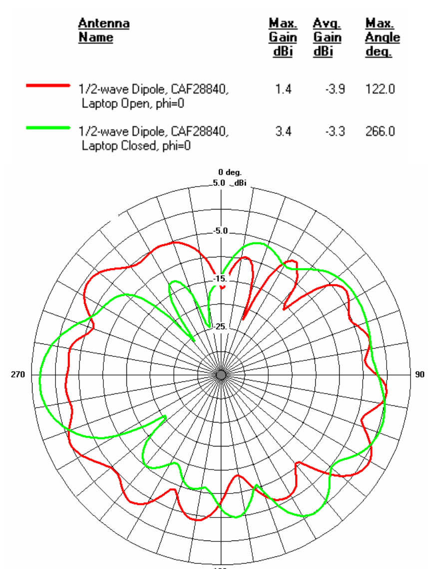
Dimensions	Length: 2.0” Diameter: .28”
Pull Test	20 lb. Linear pull
Temperature	-40°C to +85°C
Vibration	6G RMS (0.04g2/Hz) for 15 Minutes each in vertical and Horizontal axes.
Shock	Change after 4 repeated cycles Of 1 hr at +85°C and 1 hr at -40°C. Transfer time is 5 min.

CENTURION ANTENNA COMPARISON for ½ wave Coaxial Dipole
2450MHz Laptop in Free Space, Anechoic Chamber

AZIMUTH PLANE



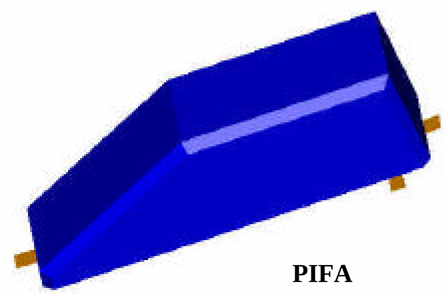
ELEVATION PHI=0



INTERNAL ANTENNAS

Many types of antenna technologies may be chosen for internal antennas. It depends upon size and the shape that the antenna must fit and the performance requirements of the antenna. For instance, a planar inverted F antenna will provide very good electrical performance but is taller than a microstrip patch antenna. A chip antenna is very small but requires a large ground plane. A meander line antenna performs well if it is kept away from the ground plane or other metallic surfaces. The bottom line is that the antenna must be chosen based upon system electrical requirements and then retrofitted to the wireless device.

PLANAR INVERTED F ANTENNA (PIFA)



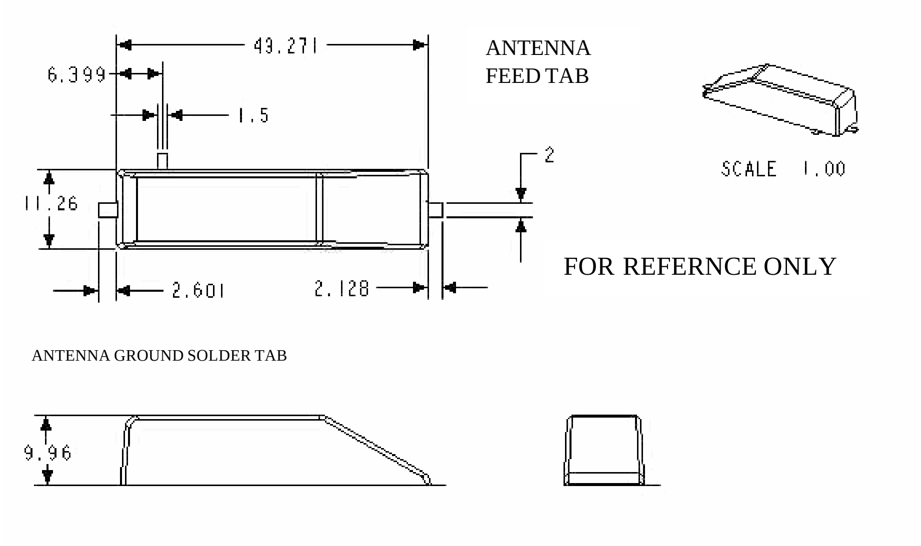
PIFA

Planar Inverted F antenna (PIFA) is of a planar configuration with low profile. PIFA can easily be mounted on portable communication devices. The PIFA typically consists of a rectangular planar element located above a ground plane, a short circuiting plate or pin, and a feeding mechanism for the planar element. On the one hand, PIFA can be considered as a kind of linear inverted F antenna (IFA) with the wire radiator element replaced by a plate to expand the bandwidth. On the other hand, PIFA can be considered as a type of rectangular microstrip antenna with a short circuit. PIFA is characterized by many distinguishing properties such as being relatively lightweight, ease of adaptation to the wireless device, moderate range of bandwidth and omni-directional radiation patterns in orthogonal principal planes for vertical polarization. In the present configuration of ISM band PIFA, the antenna has optimized for very large bandwidth with satisfactory gain performance without necessitating an external-matching network.

PRELIMINARY SPECIFICATION

PLANAR INVERTED F ANTENNA (PIFA)
(PROT9318)

ELECTRICAL		MECHANICAL	
Frequency	2.4 – 2.5 GHz	**Dimensions**	43.5 x 11.3 x 10mm (L x W x H)
Impedance	50 ohms nominal	**Pull Test**	NA
Polarization	Linear	**Temperature**	-40°C to +85°C
Peak Gain	3.9 dBi	**Vibration**	6G RMS (0.04g^2/Hz) for 15 Minutes each in vertical and Horizontal axes.
VSWR	<2.5:1 Across band	**Thermal Shock**	No appearance or functional change after 4 repeated cycles Of 1 hr at +85°C and 1 hr at -40°C. Transfer time is 5 min.

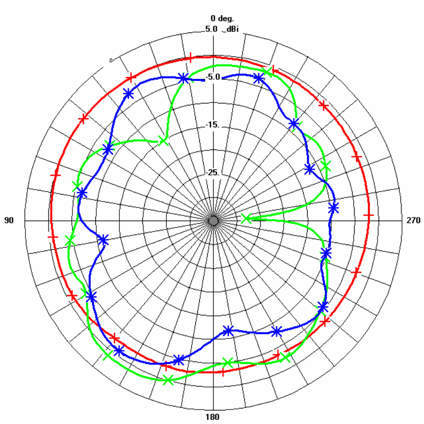


Drawing of PIFA Antenna (PROT9318)

CENTURION ANTENNA COMPARISON for PIFA
2450.0MHz, 43x43 MM GROUND PLANE in Free Space, Anechoic Chamber

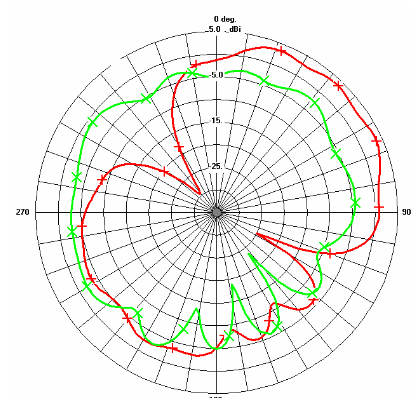
AZIMUTH PLANE

Antenna Name	Max. Gain dBi	Avg. Gain dBi	Max. Angle deg.
PIFA (FREE SPACE)	0.1	-1.4	58.0
(DISPLAY CLOSED)	1.3	-3.9	150.0
(DISPLAY OPEN)	-0.9	-5.7	144.0



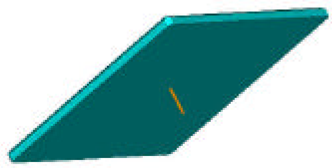
ELEVATION PHI=0

Antenna Name	Max. Gain dBi	Avg. Gain dBi	Max. Angle deg.
(DISPLAY OPEN)	3.9	-1.6	44.0
(DISPLAY CLOSED)	-1.0	-4.3	306.0

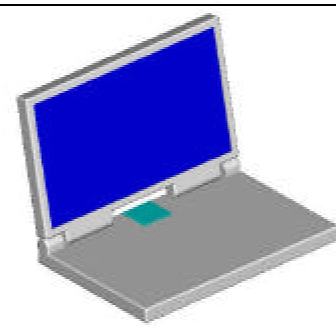


MICROSTRIP ANTENNA

Microstrip antenna is a low profile planar structure easily adaptable for planar integration. The present configuration of a microstrip antenna for ISM band consists of a nearly square patch with shorting pins and dual slots. The concept of dual resonance in a single band is invoked to widen the bandwidth of a single band microstrip antenna. The closely spaced adjacent resonant bands have been combined to result in a wider bandwidth. The broadening of bandwidth of the microstrip antenna is accomplished without the external matching circuit as well as without the increase of height or the linear dimensions of the antenna. Benefits include low profile, wide bandwidth, configuration simplicity, lightweight and compact size.



Microstrip Patch Antenna

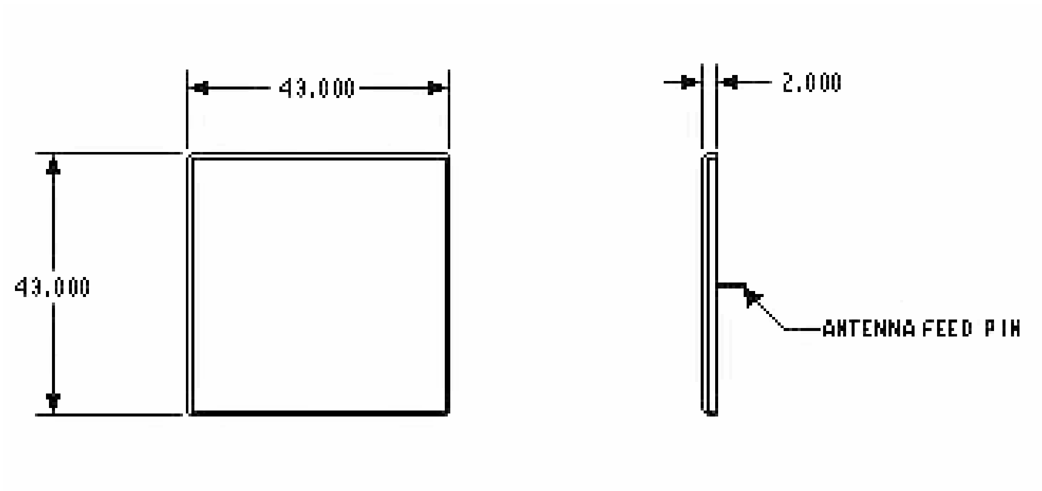


Placement of Patch Antenna

PRELIMINARY SPECIFICATION

MICROSTRIP PATCH ANTENNA

ELECTRICAL		MECHANICAL	
Frequency	2.4 – 2.5 GHz	**Dimensions**	43 x 43 x 1.65mm
Impedance	50 ohms nominal	**Pull Test**	NA
Polarization	Linear	**Temperature**	-40°C to +85°C
Peak Gain	5.0 dBi (free space)	**Vibration**	6G RMS (0.04g^2/Hz) for 15 Minutes each in vertical and Horizontal axes.
VSWR	<2.5:1 across band	**Thermal Shock**	No appearance or functional change after 4 repeated cycles Of 1 hr at +85°C and 1 hr at -40°C. Transfer time is 5 min.

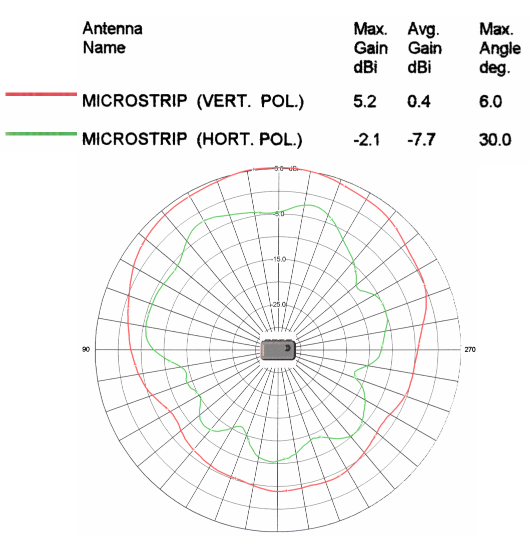


FOR REFERENCE ONLY

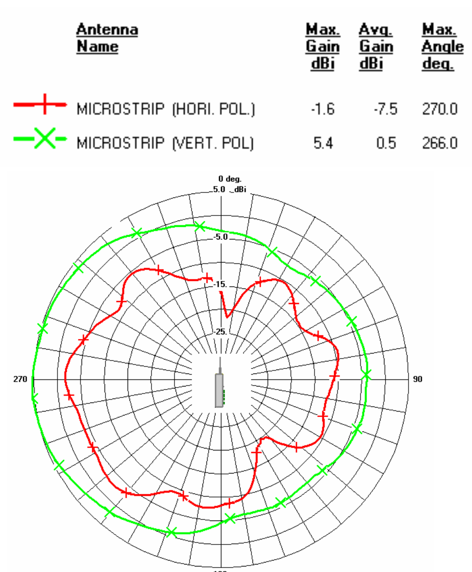
Microstrip Patch Antenna
(PROT7704)

CENTURION ANTENNA COMPARISON for MICROSTRIP PATCH
2450.0MHz, in Free Space, Anechoic Chamber (PROT7704)

AZIMUTH PLANE



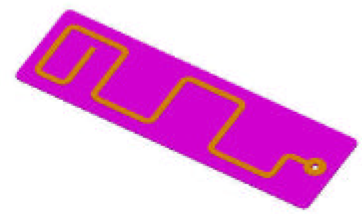
ELEVATION PHI=0



MISCELLANEOUS

MEANDER LINE ANTENNA

This meander line antenna is a type of printed antenna that achieves miniaturization in size of a conventional wire antenna. The miniaturization in size is accomplished by embedding the wire structure on a dielectric substrate. In basic form, meander line antenna is a combination of conventional wire and planar strip line. Benefits include configuration simplicity, compact in size, easy integration to a wireless device, inexpensive and potential for low SAR features.



Meander Line Antenna

SECTION V: GLOSSARY OF TERMS

Antenna - An electrical conductor or array of conductors that radiates signal (transmitting) or collects signal (receiving).

Base loading - A lumped reactance that is inserted at the base (ground end) of a vertical antenna to resonate the antenna.

Bridge - A circuit with two or more ports that is used in measurements of impedance, resistance or standing waves in an antenna system. When the bridge is adjusted for a balanced condition, the unknown factor can be determined by reading its value on calibrated scale or meter.

Capacitance hat - A conductor of large surface area that is connected at the high-impedance end of an antenna to effectively increase the electrical length. It is sometimes mounted directly above a loading coil to reduce the required inductance for established resonance. It usually takes the form of a series of wheel spokes or a solid circular disc. Sometimes referred to as a 'top hat.' The antenna with 'top hat' more closely approximates the uniform current ideal dipole with larger radiation resistance.

Center fed - Transmission-line connection at the electrical center of an antenna radiator.

Coaxial cable - Any of the coaxial transmission lines that have the outer shield (solid or braided) on the same axis as the inner or center conductor. The insulating material can be air, helium or solid-dielectric compounds.

Conductor - A metal body such as tubing, rod or wire that permits current to travel continuously along its length.

Counterpoise - A wire or group of wires mounted close to ground, but insulated from ground, to form a low-impedance, high-capacitance path to ground. Used at MF (Medium Frequency) and HF (High Frequency) to provide an RF (Radio Frequency) ground for an antenna. Also see ground plane.

Decibel - A logarithmic power ratio, abbreviated dB. May also represent a voltage or current ratio if the voltages or currents are measured across (or through) identical impedance. Suffixes to the abbreviation indicate references: dBi, isotropic radiator; dBic, isotropic radiator circular; dBm, milliwatt; dBW, watt.

Dielectrics - Various insulating materials used in antenna systems, such as found in insulators and transmission lines.

Dipole - An antenna that is split at the exact center for connection to a feed line, usually a half wavelength long.

Directivity - The property of an antenna that concentrates the radiated energy to form one or more major lobes.

Driven element - A radiating element of an antenna system to which the transmissions line is connected.

E plane - Related to a linearly polarized antenna. The plane contains the electric field vector of the antenna and its direction of maximum radiation. For terrestrial antenna systems, the direction of the E plane is also taken as the polarization of the antenna. The E plane is at right angles to the H plane.

EIRP - Effective isotropic radiated power. The power radiated by an antenna in its favored direction, taking the gain of the antenna into account as referenced to isotropic.

Elements - The conductive parts of an antenna system that determine the antenna characteristics. For example, the reflector, driven element and directors of a Yagi antenna.

End effect - A condition caused by capacitance at the ends of an antenna element. Insulators and related support wires contribute to this capacitance and lower the resonant frequency of the antennas. The effect increases with conductor diameter and must be considered when cutting an antenna element to length.

End fed - An end-fed antenna is one to which power is applied at one end, rather that at some point between the ends.

Feeders - Transmission lines of assorted types that are used to route RF power from a transmitter to an antenna, or from an antenna to a receiver.

Field strength - The intensity of a radio wave as measured at a point some distance from the antenna. This measurement is usually made in microvolts per meter.

Gain - The increase in effective radiated power in the desired direction of the major lobe.

Ground plane - A system of conductors placed beneath an elevated antenna to serve as an earth ground. Also see counterpoise.

H plane - Related to a linearly polarized antenna. The plane contains the magnetic field vector of an antenna and its direction of maximum radiation. The H plane is at right angles to the E plane.

Helical - A helical wound antenna, one that consists of a spiral conductor. If it has a very large winding length to diameter ratio it provides broadside radiation. If the length-to-diameter ratio is small, it will operate in the axial mode and radiate off the end opposite the feed point. The polarization will be circular for the axial mode, with left or right circularity, depending on whether the helix is wound clockwise or counterclockwise.

Image antenna - The imaginary counterpart of an actual antenna. It is assumed for mathematical purposes to be located below the earth's surface beneath the antenna, and is considered symmetrical with the antenna above ground.

Impedance - The ohmic value of an antenna feed point, matching section or transmission line. An impedance may contain a reactance as well as a resistance component.

Isotropic - An imaginary or hypothetical point-source antenna that radiates equal power in all directions. It is used as a reference for the directive characteristics of actual antennas.

Lambda - Greek symbol (^) used to represent a wavelength with reference to electrical dimensions in antenna work.

Loading - The process of a transferring power from its source to a load. The loading has an effect on a power source.

Log periodic antenna - A broadband directive antenna that has a structural format causing its impedance and radiation characteristics to repeat periodically as the logarithm of frequency.

Matching - The process of effecting impedance match between two electrical circuits of different impedance. One example is matching a transmission line to the feed point of an antenna. Maximum power transfer to the load (antenna system) will occur when a matched condition exists.

Monopole - Literally, one pole, such as a vertical radiator operated against the earth or a counterpoise.

Multi-path signals - In addition to the direct radio signal from the transmit antenna other signals that have been bouncing around and reflecting around objects like buildings trees, and the earth will reach the receive antenna. These are call multi-path signals. Multi-path signals cause fading fluctuations. Fading fluctuations are caused by constructive and destructive interference between signal and multi-path reflected signal. If direct and multi-path signals are in phase, total signal is higher. If direct and multi-path signals are out of phase, total signal is lower. Possible solutions for multi-path reduction are diversity antenna techniques; repeaters, active and passive, additional base stations, and directional antennas.

Null - A condition during which an electrical unit is at a minimum. The null in an antenna radiation pattern is that point where a minimum field intensity is observed.

Polarization - The sense of the wave radiated by an antenna. This can be horizontal, vertical, elliptical or circular (left or right hand circularity), depending on the design and application. (See H plane) The sense of the wave radiated by an antenna. The polarization of the antenna is based on the orientation within the sphere of the electric or E field component. Polarization must be matched to the orientation of the radiated field to receive the maximum field intensity of the electromagnetic wave. If it is not oriented properly, we lose a portion of the signal. Dependent on the antenna type, it is possible to radiate linear, elliptical, and circular signals.

Radiation pattern - The radiation characteristics of an antenna as a function of space coordinates. Normally, the pattern is measured in the far-field region and is represented graphically.

Radiator - A discrete conductor in an antenna system that radiates RF energy.

SAR (Specific Absorption Rate, P_g) - Gives the ratio between the infinitesimal amount of RF power 'dW' absorbed in the infinitesimal mass 'dm' of tissue surrounding a specific point. $P_g = dW/dm$;

Shunt feed - A method of feeding an antenna driven element with a parallel conductor mounted adjacent to a low-impedance point on the radiator. Frequently used with grounded quarter-wave vertical antennas to provide an impedance match to the feeder. Series feed is used when the base of the vertical is insulated from ground.

Stub - A section of transmission line used to tune an antenna element to resonance or to aid in obtaining an impedance match.

SWR - Standing-wave ratio on a transmission line in an antenna system. More correctly, VSWR, or voltage standing-wave ratio. The ratio of the forward to reflected voltage on the line, and not a power ratio. A VSWR of 1:1 occurs when all parts of the antenna system are matched correctly to one another.

Top loading - Addition of a reactance (usually a capacitance hat) at the end of an antenna element opposite the feed point to increase the electrical length of the radiator.

Trap - Parallel L-C network inserted in an antenna element to provide multi-band operation with a single conductor.

Velocity factor - The ratio of the velocity of radio wave propagation in a dielectric medium to that in free space. When cutting a transmission line to a specific electrical length, the velocity factor of the particular line must be taken into account.

VSWR - Voltage standing-wave ratio. See SWR.

Wave front - A surface that is a locus of all the points having the same phase at a given instant in time.

Yagi - A directive, gain type of antenna that utilizes a number of parasitic directors and a reflector. Named after one of the two Japanese inventors (Yagi and Uda).

SECTION VI: ABOUT CENTURION WIRELESS TECHNOLOGIES (www.centurion.com)

For more than 20 years, Centurion Wireless Technologies has set the industry standard of excellence in turning customer ideas into functional, manufacturable products. Our goal from the beginning has been to establish a measurable standard for quality that the wireless communications industry can depend on – and confidently expects. We have positioned ourselves as a reliable world class supplier with unparalleled expertise in the development of wireless communications components.

By integrating R & D, design, tooling and molding, assembly and testing in the US and UK facilities, Centurion continues to grow and change with industry demands. Using the latest technology, including robotics and automation, we reduce cycle time, increase consistency and improve overall quality. All of which keeps Centurion ahead with the best in technology.

Centurion is dedicated to providing our customers with the highest quality products and services, in a timely manner at a competitive price. Quality assurance programs are in place in all phases of design and development. The Lincoln, Nebraska facilities are ISO 9001 registered and the manufacturing facilities in Shanghai, P.R.C. and the United Kingdom are both ISO 9002 registered. Our manufacturing facility in Tijuana, Mexico, will be ISO 9002 registered in 2000.

Centurion is the only company you need. Quick turnaround, rapid ramp-up, additional burst capacity, and shorter cycle times are all Centurion trademarks. Through global facilities, in-house tooling and machining, total engineering support and numerous electronic communications avenues, Centurion is the industry leader in responding to customer's needs.