Technical Sales Training

Multilayer Chip Antenna
LDA8220D Series

Purpose:

This document is intended for the purpose of internal technical training for the Murata sales force regarding the LDA series chip antenna. Any and all information in this document is subject to change without notice.

This document is not intended as an applications manual for distribution to customers; however, it may be used as a sales promotion tool to answer questions and concerns. This document may be supplied to customers with the understanding that any specific technical questions should be directed to PMMW. This ensures the latest information is provided to avoid potential problems during the design phase.

Prepared by S. Klettke (PMMW)

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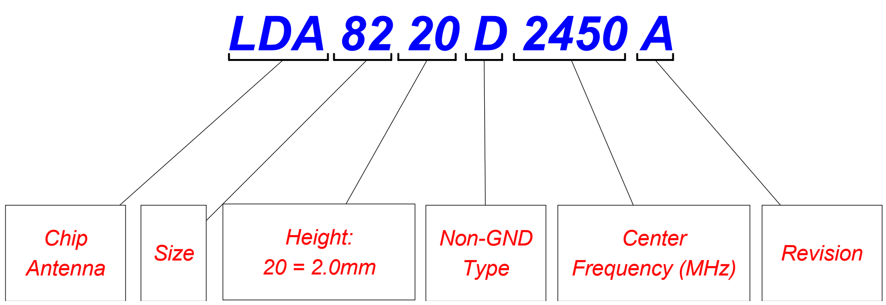
1 - Chip Antenna Basics

Background: The LDA8220D series chip antenna is the current front runner in the chip antenna line-up. Previous versions included LDA46D, LDA40D, LDA36D, and LDA42. The only product currently available in the US Market is the LDA8220D Series. Please see the promotion criteria for determining target markets, customers, and application. This product is not a standard component that can be promoted to every customer.

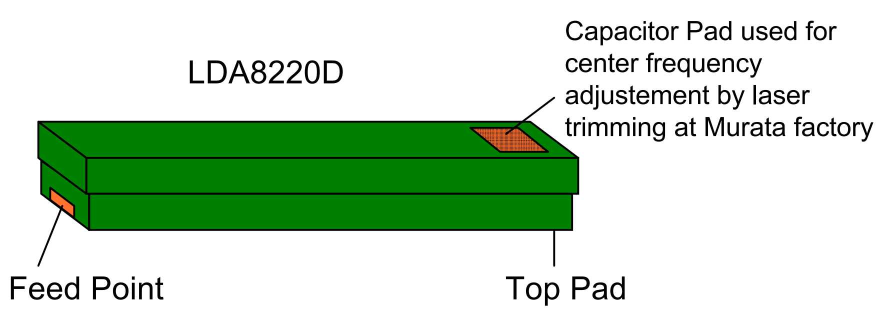
History: This product was designed for use in Japan's PDC (Personal Digital Cellular) handsets. Japan's Regulatory Agency requires two antennas in every handset. One is the main antenna. This is usually a standard whip antenna or a helical that you'd see in any cell phone. The second has to be different from the main antenna in order to get reception in a case that the main antenna is not getting good reception. The second antenna is usually an inverted-F or a chip antenna. Murata has had much success in supplying chip antennas for this purpose (secondary, diversity antenna for PDC).

Now, there may be some markets in North America that can use this technology. It doesn't have the same performance as a standard whip and it is more expensive. The reason it would be used is when a small-sized antenna is needed. The designer can trade off is lower performance and higher cost for a small, non-breaking solution. Advantages also include a surface mountable and adjustment free component. Many whip style antennas must be manually fastened to the PCB and adjusted before they can be packaged and shipped. This antenna is not a good main antenna for AMPS, PCS, GSM or DCS cellular phones because the bandwidth is too narrow to cover the necessary bands.



SOI:	1k pcs
Size:	9.5mm (L) x 2mm (W) x 2mm (H)
Frequency:	Current design has technical capability in bands from 1000MHz to 3GHz (not in one chip)
Type:	Helical
Polarization:	Linear
Bandwidth:	60-70 MHz @ 900 MHz typical 110-150 MHz @ 2.45 GHz typical

<u>Finding Your Away Around the Chip</u>



How it Works (basics)

The LDA series chip antennas derive their performance from a close proximity ground plane much like a standard 1/4 wavelength helical. Antennas transmit and receive energy by radiation resistance. Typically, the larger the antenna, the larger the radiation resistance, the greater the gain. In the chip antenna, there is small radiation resistance from the chip itself. Therefore, the antenna system relies on currents that run on the ground plane to derive big radiation resistance. Typically, the length and width of the ground plane should be on the order of 1/2 wavelength at the operation frequency for best bandwidth performance. For best gain, the length itself should be a quarter wavelength at the frequency of use. As the width increases, so does the cross polarization.

In summary:

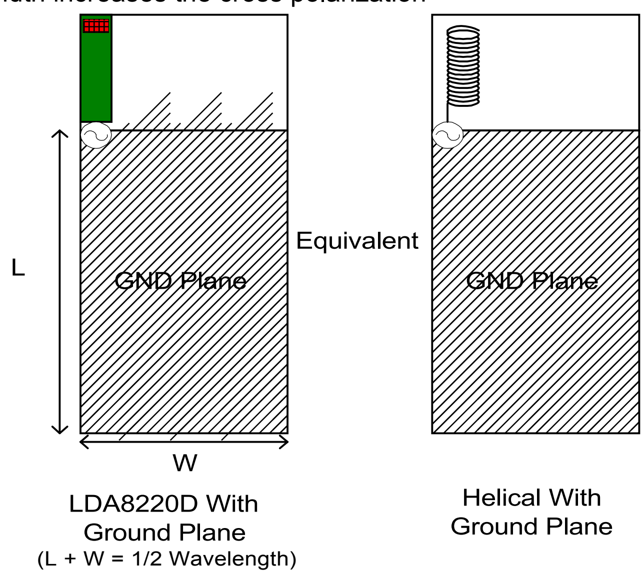
$$\lambda(meters) = 1 \cdot wavelength = \frac{c}{f}$$

Where:

c = Speed of Light in Free Space = 3x10^8 m/s

f = Frequency in Hertz (915 MHz = 915 x 10^6 Hertz)

- The ground plane is crucial for the antenna system to operate properly
- The ground plane cannot be above or below the antenna itself, but should be located adjacent to it.
- The antenna itself is never connected to ground electrically
- The ground plane should be = L + W = 1/2 λ for wide bandwidth performance
- The ground plane should be L = 1/4 λ for high gain
- Increasing the ground plane width increases the cross polarization



2 - Frequency Shifting

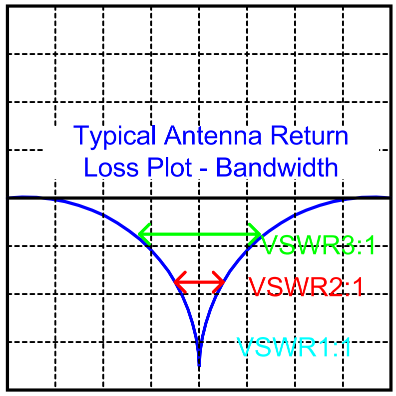
Test PCB

Murata uses a standard PCB that is supplied from an outside vendor for test purposes. This PCB is used on our mass production line to verify the following parameters:

2.1 Bandwidth/Return Loss/ VSWR (Not used to measure Gain)

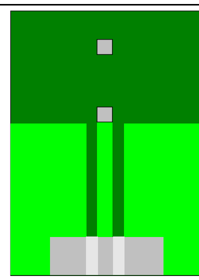
Bandwidth is the measure of a series of frequencies in which the antenna is operational. The blue curve below shows a typical antenna resonance as an S1 return loss plot.

Bandwidth is measured, typically, at VSWR2:1 (Voltage Standing Wave Ratio 2:1)
- This means the bandwidth in which the energy is transmitted or received
- At VSWR1:1, all energy is transmitted (light blue)
- As VSWR becomes bigger, more energy is reflected
- Many antenna user's look for a VSWR of 2:1 (red) or better (lower) over their intended band
- Sometimes VSWR3:1 (green) is useable in some applications



VSWR1:1 = 52.06 dB Return Loss
VSWR2:1 = 9.542 dB Return Loss
VSWR3:1 = 6.021 dB Return Loss

Murata measures these parameters and specs them using the standard PCB shown here
This PCB is not optimized for good gain performance.



Parameter	Value
ε_r:	2.6
Thickness of board:	0.6 mm
Thickness of Cu:	18 µm
Length:	35 mm
Width:	25 mm

2.2 Customer's Unit

When the customer applies the chip to his or her PCB, there will be a frequency shift. This shift is due to the loading effects of the environment around the antenna. Typical loading causes are:

- PCB's dielectric constant
- Casing material - proximity, thickness, and material properties
- Near dielectric components
- The human body near the antenna
- Large objects near the antenna in the environment of use (i.e. wall, metal desk, etc.)
- Size and shape of ground plane

These factors all serve to shift the center frequency. Typically, the frequency shifts down as much as 100 MHz or more. This is why an LDA8220D0915A chip antenna on Murata's PCB will not work as a 915MHz antenna on the customer's unit. The frequency is chosen higher so that when loaded, it shifts down to the useable range. You can imagine this is quite a process to determine which chip antenna frequency will be needed for each customer.

2.3 Frequency selection for samples

The question becomes, how do we go about getting a product that our customers can use? The design cycle looks something like this:

1. Provide samples that are higher in frequency than needed
2. Ask the customer to apply it to his or her PCB with all components and casing material in place
3. Feedback the measured frequency to Murata PM
4. Murata provides compensated samples to the customer to evaluate based on prior feedback
5. Collect customer feedback of the final results

Example:

XYZ is designing a 915 MHz wireless speaker. Murata provides the LDA8220D1000A, which is 1000 MHz on our test PCB. The customer can verify this. They apply it to their PCB following suggested layouts from application notes. Customer feedback shows a measured frequency of 895 MHz on their unit. Murata laser trims a new chip antenna sample to have a frequency of:

Original Frequency + (Desired Frequency - Measured Frequency)

In this case:

1000 MHz + (915 MHz - 895 MHz) = 1020 MHz which would be LDA8220D1020A.

Theoretically, this will shift to 915MHz when applied to the customer's unit.

3 - Gain and Radiation Pattern

3.1 Definitions

Gain is a primary measurement parameter for antennas. Gain is basically the ratio of the power gain (or loss) in a given direction to the power gain (or loss) of a reference antenna in its referenced direction. The reference antennas are typically either dipoles or ideal isotropic radiators (radiates equally in all directions).

Antenna gain is typically specified in dBd or dBi. dBd is the gain as compared to a reference dipole. Gain in dBi is the gain as compared to a fictional, ideal isotropic radiator. Murata used dBd <see 3.2 below>; however, dBd can be roughly converted to dBi by the following:

$$dBd = 2.15dBi$$

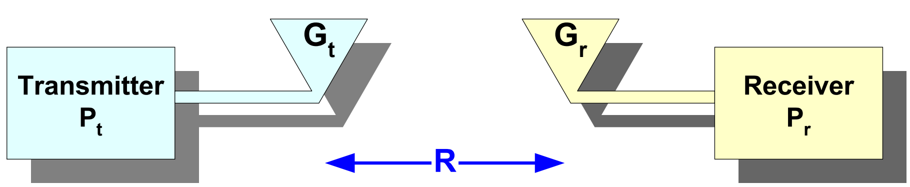
Example: -1 dBd expressed in dBi

-1 dBd + 2.15 = 1.15 dBi

Gain tells the designer how much of the power from the transmitter will actually be transmitted into the air. Conversely, it tells the designer how much of a transmitted signal of known power, will be received into the receive path of the transceiver. Note: Small antenna "gain" is usually a loss such as -2 dBd. This means that you will lose some of the power of your transmission to heat and other factors.

To illustrate the importance of gain for transmitting and receiving antennas, let's look at Friis Transmission equation.

$$\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi R}\right)^2 G_t G_r$$



In words, the ratio of the received power to the power that was transmitted is equal to the loss in air multiplied by the gain of the transmitting antenna multiplied by the gain of the receiving antenna.

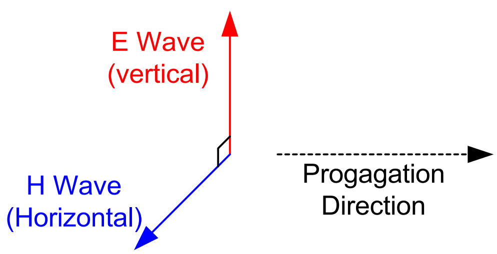
You can see that antenna gain is one of the most crucial specifications in a radio link. It determines the distance the signal can be radiated and also the amount of power that is gained or lost in a system. Gain becomes even more critical when the output power is fixed, such as in a cellular handset that is fixed to transmit no more than 600mW.

Antenna gain is typically specified in dBd or dBi. dBd is the gain as compared to a reference dipole. Gain in dBi is the gain as compared to a fictional, ideal isotropic radiator.

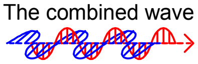
3.2 Measurement Set-Up

One of the most common methods to measure antenna gain is to use 2 antennas. The primary antenna is set-up to radiate a known amount of power. This antenna is typically a horn type antenna. It can be rotated to transmit either vertical waves or horizontal waves.

Sidebar: Electromagnetic radiation, the media in which the wireless communication information is encoded, is just that, electric and magnetic. The electric field is orthogonal (perpendicular) to the magnetic field in all electromagnetic waves. The wave propagates in the air as shown below.

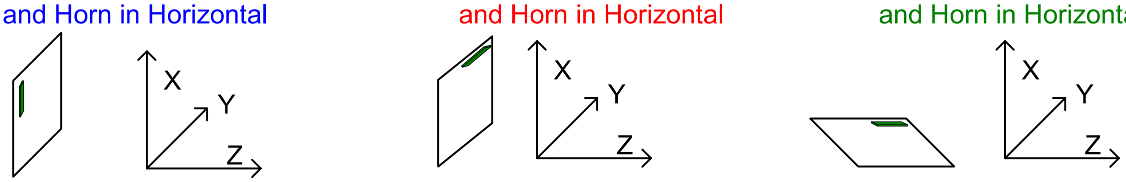


The combined wave would appear as follows:



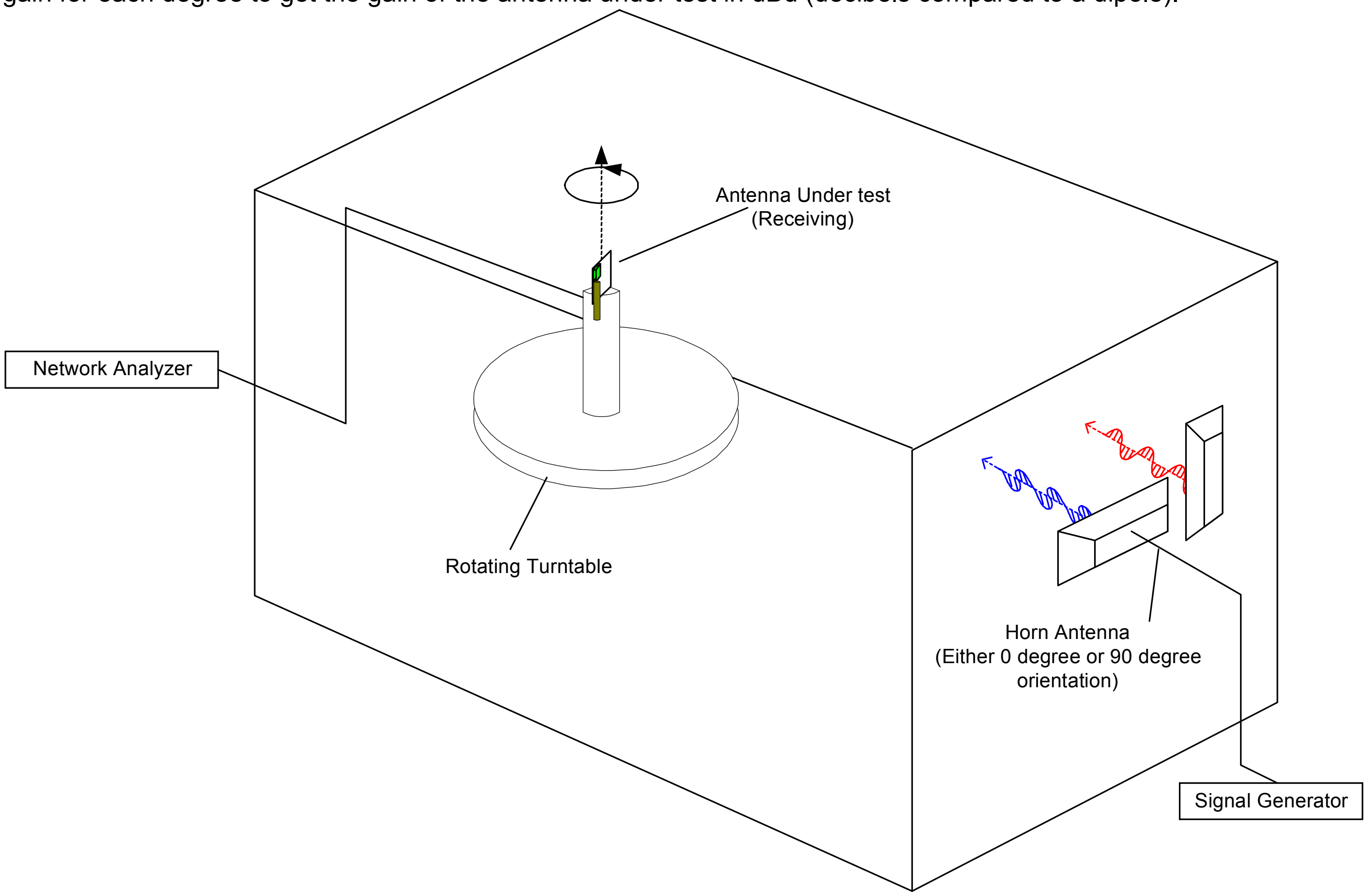
The primary horn antenna is set to radiate either E-polarized waves (Vertical) or H-polarized waves (Horizontal). The antenna under test is measured under 6 conditions.

1. Antenna under test in X and Horn in Vertical
2. Antenna under test in X and Horn in Horizontal
3. Antenna under test in Y and Horn in Vertical
4. Antenna under test in Y and Horn in Horizontal
5. Antenna under test in Z and Horn in Vertical
6. Antenna under test in Z and Horn in Horizontal



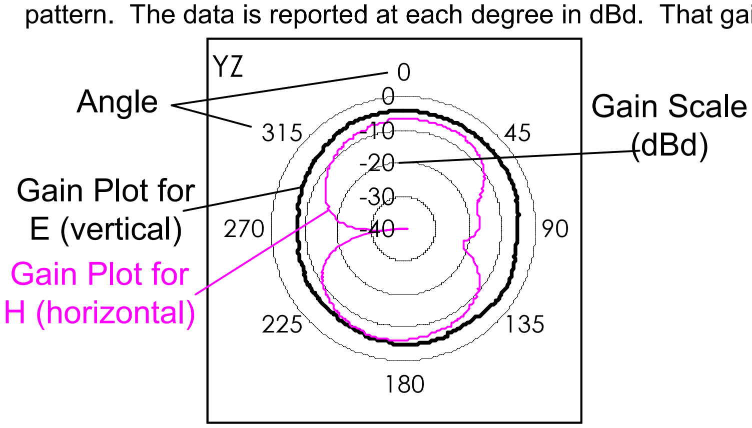
The first step in the test is to establish a reference gain from a known antenna. Typically, a standard dipole is used because an isotropic radiator does not exist. The anechoic chamber can be rectangular or tetrahedral. A rectangular chamber can be used to measure dBd. A tetrahedral chamber is needed along with complicated software to simulate and isotropic radiator that is needed to measure antennas in dBi.

Murata's setup is shown below. A dipole antenna is rotated through 360 degrees to establish a reference gain at the desired frequency. Next, the antenna under test (chip antenna in Murata's case) is rotated through 360 degrees for each orientation (X, Y, and Z) and for each polarization of the horn (E [vertical] and H [horizontal]). The data of received power is taken at each degree of measurement. This raw data is subtracted from the dipole reference gain for each degree to get the gain of the antenna under test in dBd (decibels compared to a dipole).



3.3 Radiation Patterns

The data taken in the above step is then analyzed and reported. The usual method of reporting gain is by radiation pattern. The data is reported at each degree in dBd. That gain is summarized in a polar plot as shown below.



The gain is usually summarized in the following metrics:

1. Max. Gain for Each direction and Polarization
2. Average Gain for each direction and Polarization
3. Total Average Gain

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4 - How It Works (Detailed)

Typically, the bigger the antenna, the bigger the gain and the wider the bandwidth. It would be great to have a giant antenna to match to a receiver or transmitter. You could greatly extend battery life and relax many of the specifications of the components making the overall cost of the device cheaper and still have excellent performance. However, many of the very small, handheld devices of today cannot afford such a big antenna. There exists a trade-off. The trade-off is the desire for a small, out of the way antenna against the need for good performance. So, the question becomes: How does a small 9x2x2mm chip antenna have adequate performance to be useful for handheld devices? To understand, let's go over the basic of radiation.

For an object to radiate electromagnetic waves, certain conditions have to be met. There either has to be time-varying current, or an acceleration or deceleration of electrical charge. If you connect a pulsed voltage source to a perfectly conducting wire, a charge will move down the length of the wire. At the feedpoint (where the voltage is applied), there will be acceleration as the charge propagates down the wire. This acceleration causes radiation. Since it's perfectly conducting, the velocity would be the speed of light. As that charge approaches the end of the wire, it slows down which also results in radiation. The charge would then return back towards the voltage source repeating the acceleration/deceleration process and thus radiating. Moving charge is called current. With the charges moving, electric and magnetic fields are created. These fields then radiate outward analogous to dropping a pebble in a pool of water and seeing the waves radiate from the source.

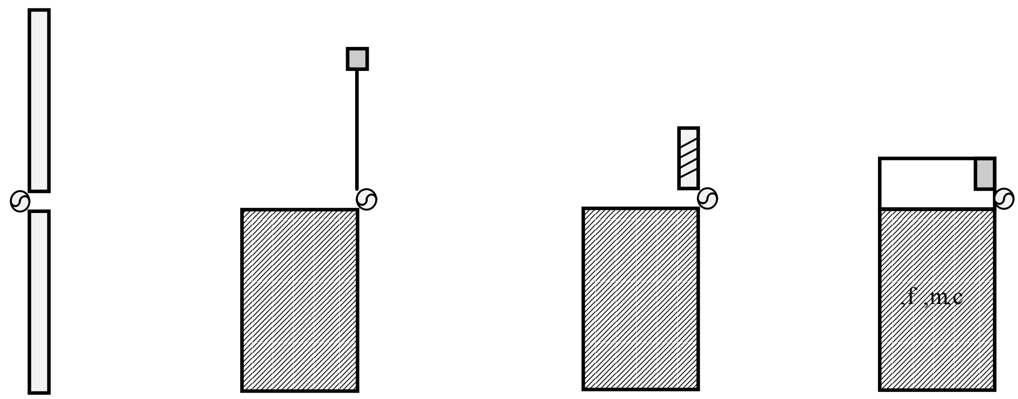
One of the main factors of radiation is radiation resistance. The radiation resistance in an antenna determines how much power is radiated into the air. The bigger the radiation resistance, the bigger the gain is for a given antenna. A large radiation resistance makes for a very efficient antenna.

Antenna Type	***Radiation Resistance***
Half Wave Dipole	73 Ohms
Small Loop	50 Ohms
Chip Antenna (Element Only)	< 1 Ohm

You can see that the chip antenna has very small radiation resistance. So how does it make for a useable antenna? That's where the effects of the ground plane come into effect. Please study the equivalency diagram below. It is shown that a half wave dipole antenna is equated to a 1/4-wave monopole (rod, whip, and rubber ducky) plus a ground plane. They are equated to a 1/4 wave helical with ground plane, which is what the chip antenna exactly is. The chip antenna is basically a helical antenna that is embedded in dielectric to reduce the size. With the 1/4 wave of chip antenna element combined with a 1/4 wave of ground, the radiation resistance approached that of a standard whip and helical with ground plane.

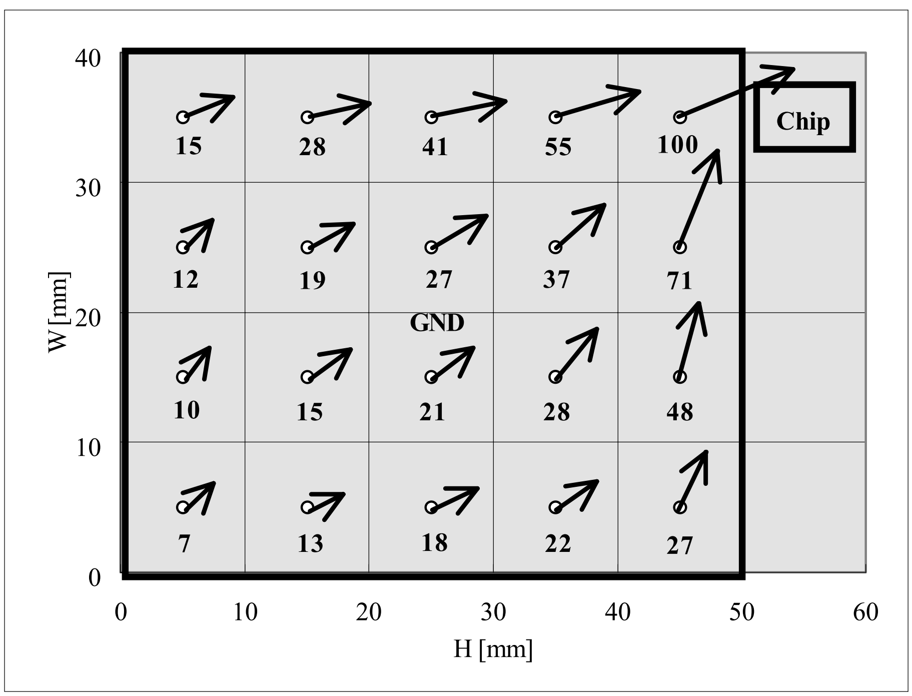
Utilizing unit's ground as a part of an antenna

Dipole antenna | Rod antenna + ground | Helical antenna + ground | LDA + ground

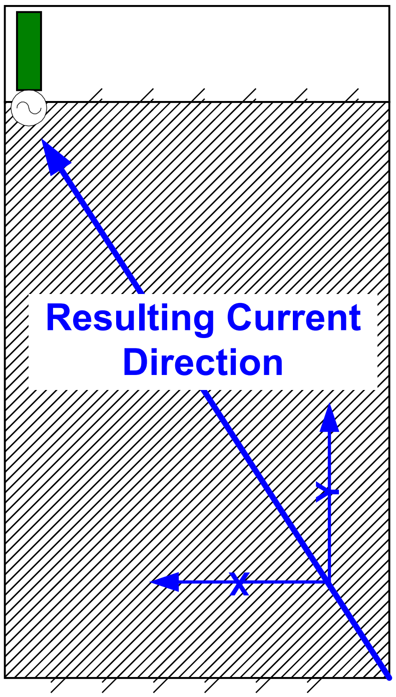


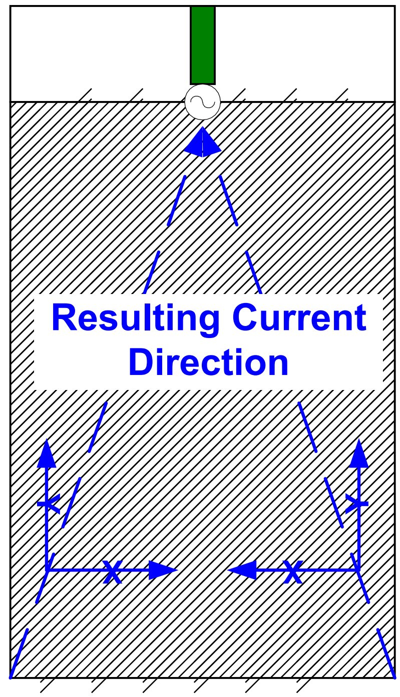
There are currents (moving charges) that run on the elements that cause the radiation as discussed previously. The picture below shows a simulation of the chip antenna and its ground plane. The current densities (current / unit area) and directions are shown.

Current distribution on the ground



It is shown that the high current areas are near the antenna's feedpoint. This explains why the chip antenna should be located on the edge of a PCB. Please see the pictures shown below for the reasoning.





When the antenna is in the corner, the current patch is corner to corner. The result is big gain and wide bandwidth. In the second picture, the current has two main paths that converge towards the chip. The X and Y components are shown. It is apparent that the X components will cancel one another and the resulting current and thus gain will be less than picture 1.

The size reduction comes from the fact that a designer can mount components on the PCB in which this ground plane is embedded. Typically, a customer will have a multilayer PCB with a given layer as solid ground plane.

In summary, the chip antenna by itself is a poor radiator. When that antenna, which is a 1/4 wave helical, is co-located with a 1/4 wave of ground, the performance approaches a standard monopole or helix. You can think of the systems as a center fed dipole with 1 pole made up of chip antenna and the other pole made up of ground plane. That, in a nutshell, is the reason why such a small antenna can be used as a replacement for whip and helical antennas in many handheld devices.

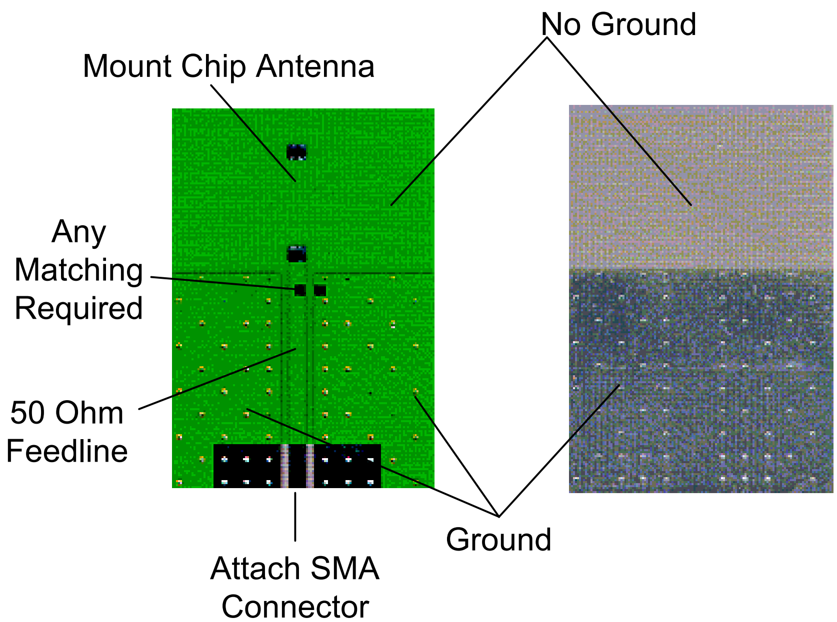
5 - Behind the Numbers

5.1 General Measurements:

A typical specification for an antenna includes the following measurement parameters. Previous topics have covered these parameters.

1. Center Frequency
2. VSWR2 Bandwidth
3. Nominal Input Impedance

The above parameters are measured by using a PCB as shown below and a network analyzer.



*Note: This PCB is not optimized for good gain performance.

5.2 Gain Measurements:

Because gain performance is highly dependent on a customer's design, reference data is typically provided. The data is taken in a representative environment using a representative layout to a customer's actual use. Of course, Murata can not duplicate that layout; therefore, the data is a reference only.

Within the Murata supplied gain data are various calculated values. Such as is shown below.

Antenna Orientation

Polarization of Incident Wave from Horn Antenna

Maximum Gain for Each Orientation and Polarization

Average Gain for Each Orientation and Polarization

Plane	Polarization	Gain (dBd)	
		Max	Avg
X-Y	Vertical	-1.2	-2.3
X-Y	Horizontal	-9.3	-12.6
Z-X	Vertical	-9.1	-11.1
Z-X	Horizontal	-1.5	-5.2
Y-Z	Vertical	-16	-20.1
Y-Z	Horizontal	-1.7	-4.9
Efficiency (dB)		-1.3	

Total Average Gain

1. Antenna Orientation was described in the last section. It is the orientation of the antenna and PCB compared to the horn antenna. Possible orientations are X-Y, Z-X, and Y-Z.

2. The polarization of the incident wave is either horizontal or vertical depending on how the horn antenna is oriented.

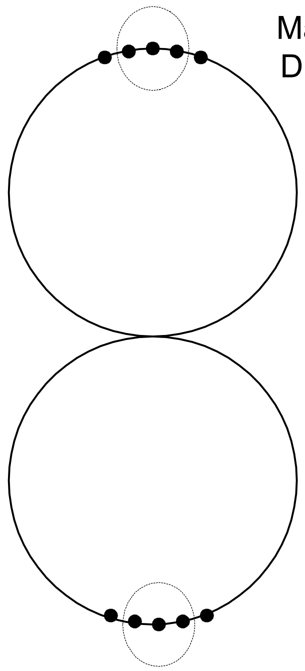
3. The maximum gain for each entry is just that, the maximum gain that was measured over a complete rotation.

4. The average gain is a calculation of the average of the gain measured for each angle for a complete rotation.

5. Total average gain is the overall average of the gain performance for the antenna in all directions.

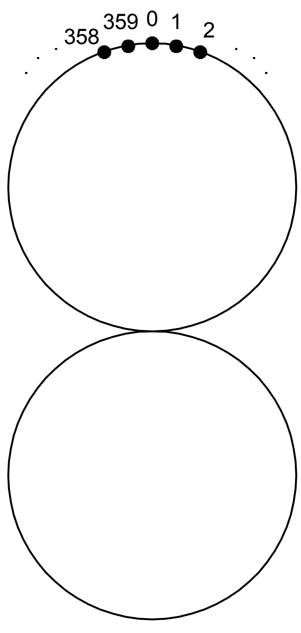
To explain in greater detail, the steps in a gain measurement should be discussed.

A. Determine the maximum gain of a reference dipole (G_d)
Done by measuring the maximum gain of a reference dipole for each main lobe of radiation and averaging the two points as shown in the diagram and equation below.



$$G_d[dB] = 10 \times LOG_{10} \frac{M1 + M2}{2}$$

B. Rotate the antenna under test in a given orientation with the horn in the vertical position through 360 degrees. The raw received power data will be recorded for each degree of rotation through all 360 degrees. The data is then converted to decibels from power and averaged. The Maximum of this data is recorded as Max Gain.



$$G_a[dB] = 10 \times LOG_{10} \frac{Sum(G_0, G_1, ..., G_{359}}{360}$$

$$G_{ad}[dBd] = G_a - G_d$$

C. This calculation is then competed for all combinations of antenna orientation and polarization to give the six items shown in the graph above.

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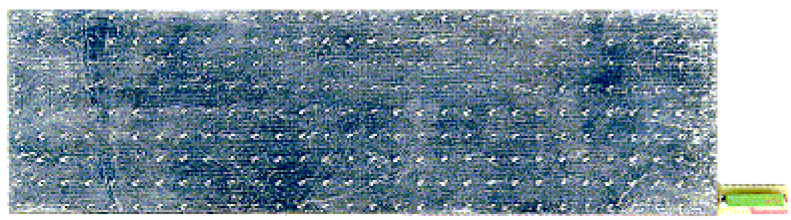
D. This gain data is compared to the reference dipole's maximum gain to get the gain for each orientation and polarization for the antenna under test (G_{ad} above). G_{ad} is the average gain of the antenna in dBd.

E. The efficiency, or total average gain, for the antenna is calculated by averaging all of the data for all orientations and polarizations. This is a measure of the overall performance of the antenna.

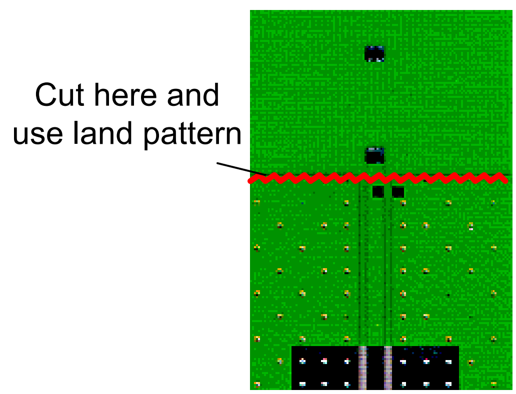
$$E = \frac{Sum\left|G_{ad}(vertical) + G_{ad}(horizontal)_{XY,YZ,ZX}\right|}{3}$$

6 - Setting Up For Testing

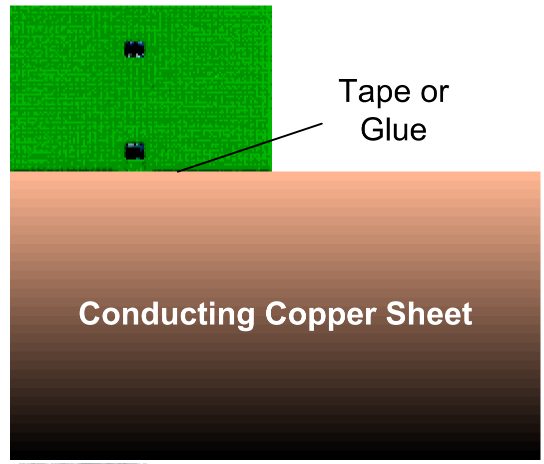
The first step in testing the LDA series chip antenna is to develop a suitable PCB. The PCB supplied with the antenna is suitable for testing center frequency and return loss, but it's not optimized for gain; Therefore, a suitable PCB should be fabricated for testing ideal gain. As a rule of thumb, a mock-up PCB can be made using the dimensions of the PCB from the actual unit. Murata typically uses a blank PCB as shown to the right. This is a 2-sided PCB with vias connecting each side of the PCB. A land pattern for the LDA82 series is printed on this PCB.



If an ideal PCB is not available, any solid conducting PCB will suffice. The land pattern from the PCB supplied with the samples can be cut and incorporated to form a suitable PCB.

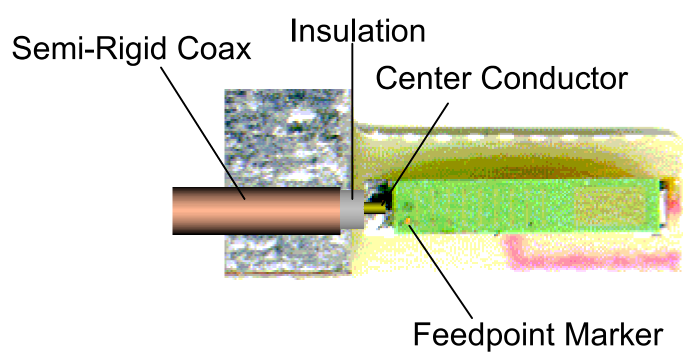


It can be glued or taped to the end of a conducting ground plane because there is no electrical connection to ground required by the antenna.

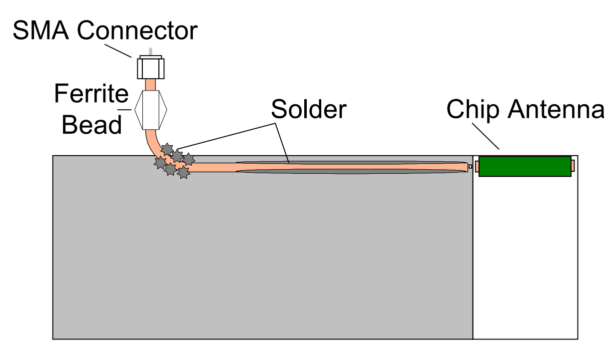


After a PCB is ready, solder the antenna to the PCB with the end of the antenna with a circular, copper dot as the feedpoint end. The opposing end should be soldiered to the floating pad for mechanical strength.

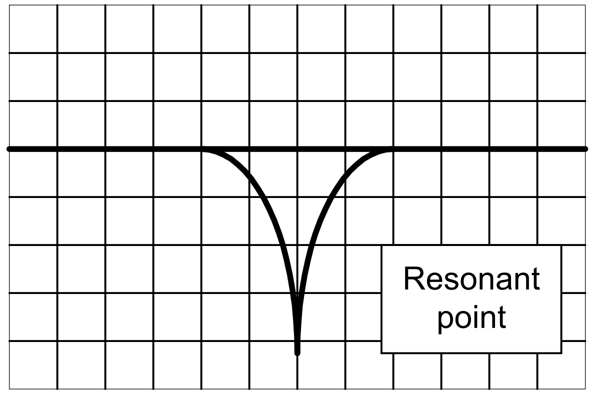
The next step is to attach an interface to the outside world. Typically, a semi-rigid cable is soldered to the PCB. The center conductor is soldered to the feedline leading to the antenna.



The outer casing of the cable is soldered to ground as much as possible. This is very important. The semi-rigid cable should be soldered to ground for at least 1/4 wavelength of the frequency of operation to avoid stray currents on the cable. This would result in incorrect data. Typically, ferrite beads are affixed to the part of the cable that extends away from the PCB.



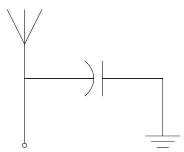
Return Loss



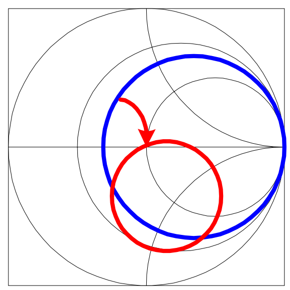
Next, the antenna system can be tested on a calibrated network analyzer. (For more exact measurements, the center conductor can be unsoldered from the feedline and the electrical delay set on the analyzer). The S1 plot will show the return loss plot of the antenna system. The dip shown will be the resonant point of the antenna.

The Smith Chart view can be used to match the antenna to the conditions of the layout.

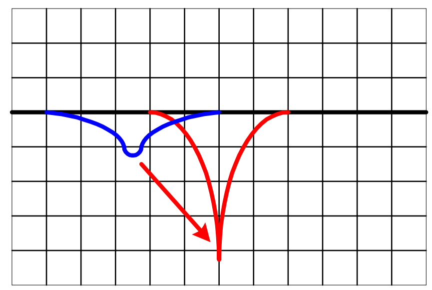
1. Frequency too low
The antenna can be matched using a shunt capacitor to bring the desired resonant point to a 50 ohm match when the return loss is poor and the frequency is lower than desired.



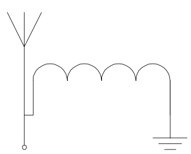
Smith Chart



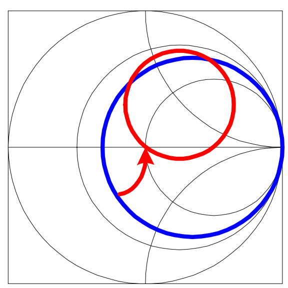
Return Loss



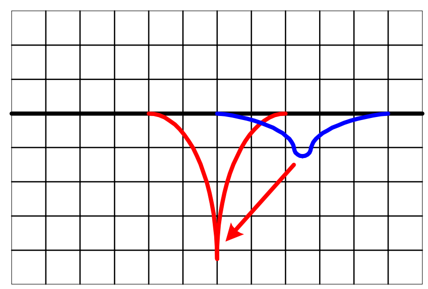
2. frequency too high
The antenna can be matched using a shunt inductor to bring the desired resonant point to a 50 ohm match when the return loss is poor and the frequency is higher than desired.



Smith Chart



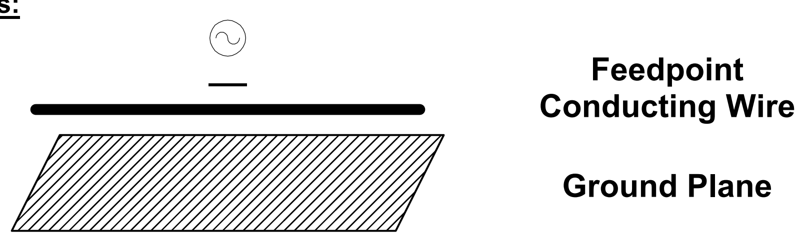
Return Loss

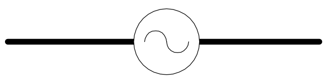


Once the resonant point of the antenna is located at the frequency of operation and properly matched to give good return loss and bandwidth, the antenna can be measured for gain performance using an anechoic chamber set-up.

7 - Antenna Types

Key for the Pictures:

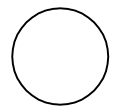




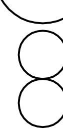
Half-wave Dipole Antenna

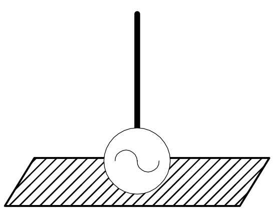
A halfwave dipole is a typically not used in mobile communications because it is twice as big as a 1/4 wave helical or monopole, but it's performance is good and it's not susceptible to outside interference.

Horizontal Pattern



Vertical Pattern

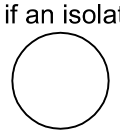




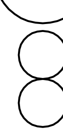
Monopole Antenna (Whip, Rod, Rubber Ducky)

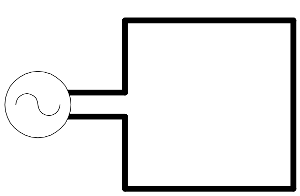
A monopole antenna is very common on mobile handsets because of it's good performance, low cost, and ease of use. It requires some additional manufacturing costs because it usually has to be hand assembled and typically requires adjustment in MFG. Typically, an isolator is required in a circuit when a monopole is used because the impedance is changed when the antenna is extended or retracted. A reflected wave can damage the power amplifier if an isolator is not used.

Horizontal Pattern



Vertical Pattern

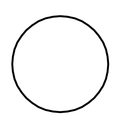




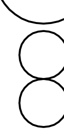
Loop Antenna

A loop antenna is usually used in on-body devices like pagers. It is a magnetic type antenna meaning it has good reception of magnetic waves. Magnetic antennas performance is improved when close to the body. Loop antennas are good receiving antennas. They can be circular or square.

Horizontal Pattern

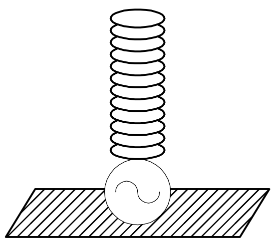


Vertical Pattern



 Prepared by S. Klettke (PMMW)

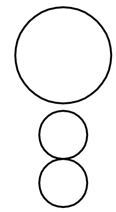
1/4 Wave Helical Antenna



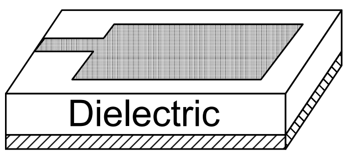
A helical antenna is basically a 1/4 monopole antenna wound into a coil. It is commonly referred to a stub antenna. This is the same technology as the LDA8220 series antennas from Murata. A helical has not only a vertical component but also a small horizontal component; therefore, it can be used to receive some circularly polarized signals such as from satellites (GPS). Typically, it is used as a linear type such as a monopole.

Horizontal Pattern

Vertical Pattern



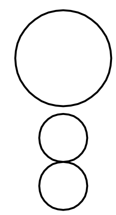
Patch Antenna



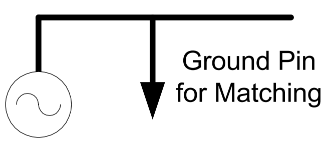
Patch antennas are good performers and can be design easily on a printed PCB. Size is usually big especially at lower frequencies. Patch antennas can be used to receive circularly polarized waves such as GPS. Murata's GPS patch is this type. Murata's ANC family is also a similar technology to a patch. Bandwidth is usually narrow for patch antennas.

Horizontal Pattern

Vertical Pattern



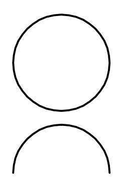
Inverted F Antenna



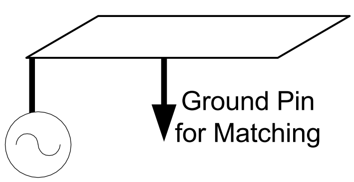
Inverted F antennas are typically used as a secondary antenna in many systems. The pin can be adjusted to change the matching and impedance. These typically are larger in size especially at the lower frequencies. This type of antenna is similar to the patch antenna with air as the dielectric.

Horizontal Pattern

Vertical Pattern



Plane Inverted F Antenna



Same as the inverted F, but with better performance due to the bigger size.

Horizontal Pattern

Vertical Pattern