DLM Antenna Technology

This Presentation Describes The Functioning and Advantages of DLM Antenna Technology

-

Robert Vincent

- University of Rhode Island
- Research Foundation

Shortened Antennas

- Low profile and shortened antennas all have a common denominator.
- When an antenna is decreased in size the radiation performance and bandwidth will be decreased. This is mostly due to the loading techniques used to reduce antenna size.

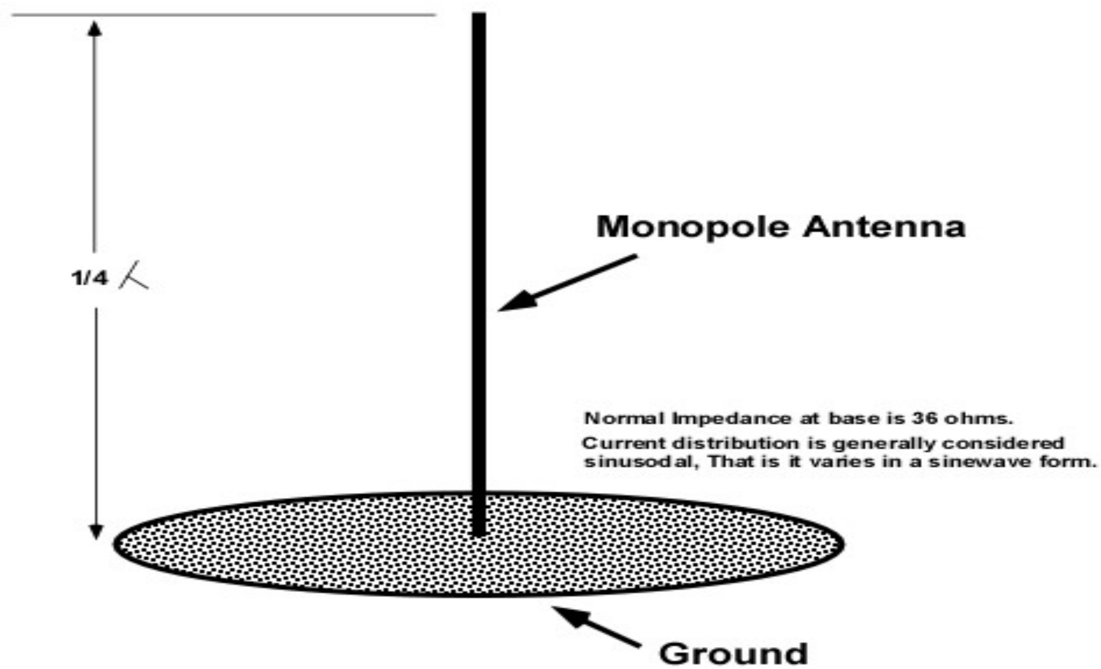
Some Typical Radiators

- The following describes some typical radiators and shows why antenna performance decreases when antennas are reduced in size

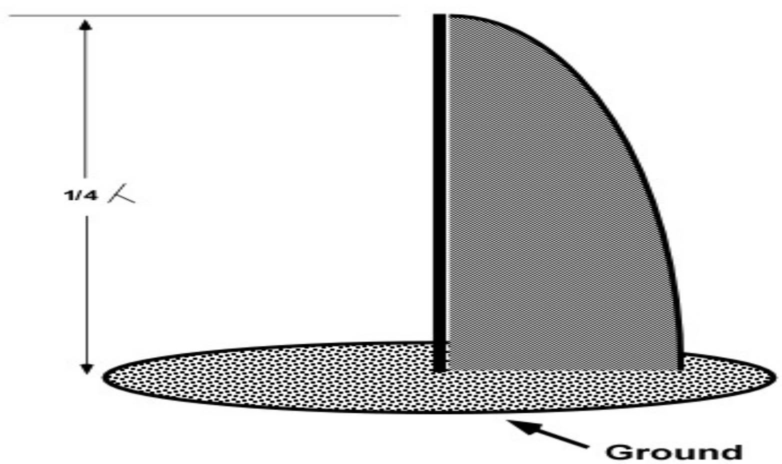
The Quarter Wave Monopole

- To begin we have to look at the performance of a standard quarter wave radiator.
- The quarter wave monopole antenna is a standard when comparing other antennas.

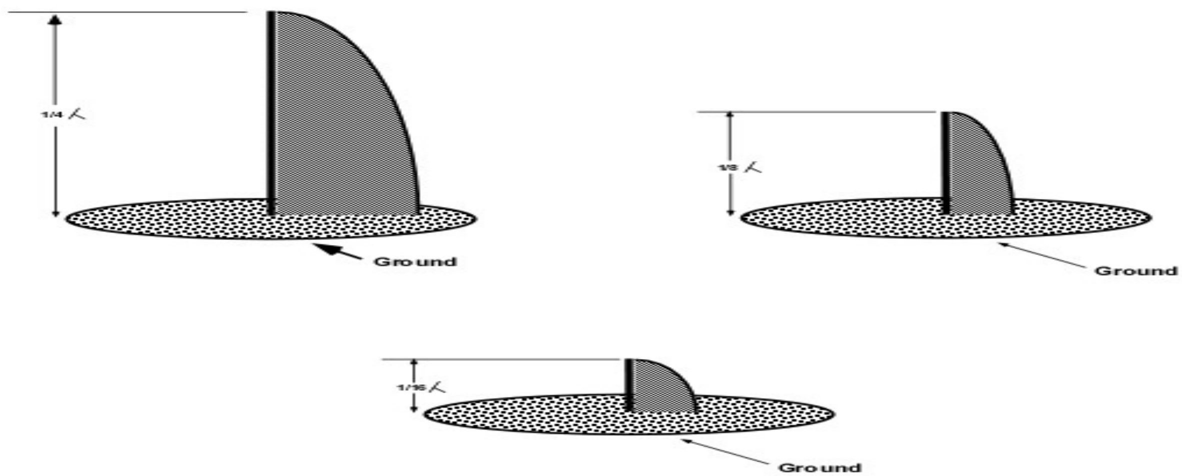
Quarter Wave Monopole Radiator



Quarter Wave Monopole Current Distribution



Shortened Antenna Current Distributions



As antenna size is reduced

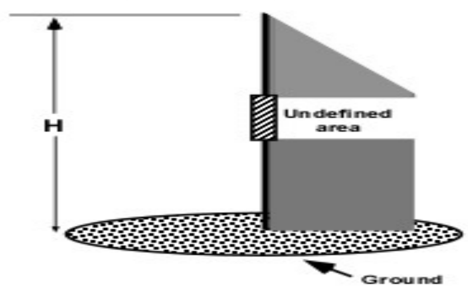
1. **Radiation area is also reduced**
2. **Base impedance is also reduced**
3. **Bandwidth is also reduced**

Increasing The Performance of Shortened Antennas

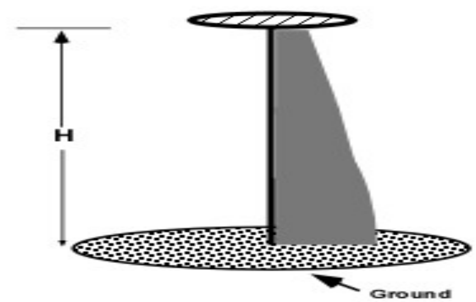
- To increase efficiency and thus the overall performance of shortened and low profile antennas, various forms of loading are used. These range from some form of capacity or inductance or a combination of both inserted within the antenna structure.
- These loading techniques will improve the current distribution or modify it so that the radiation efficiency will also be improved.
- All of these forms of loading are necessary to bring the antenna back into resonance.
- An antenna must be resonant at the operating frequency in order to accept any amount of driving power

Various Forms of Antenna Loading

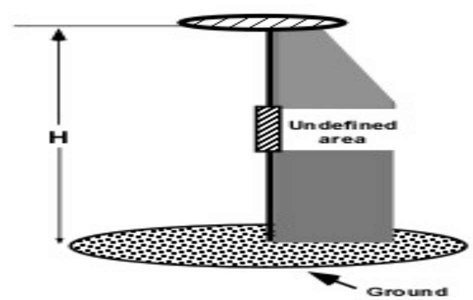
Inductive center loading



Capacitive Top loading



Inductive and capacitive loading



Increasing The Performance of Shortened Antennas

- None of these forms of loading will actually increase the amount of current from that which is initially achieved with the ¼ wave monopole.

All Antennas Have Inductance

Wire

Tubing

Pcb traces

An antenna must have a flow of current to create the EMF*

Am increase current creates more EMF and therefore more radiation

*EMF, Electro Magnetic Field. The creation of the EMF is detailed in Maxwells equations and is beyond the scope of this presentation.

Electromagnetic Potential Energy

- Electrical magnetic potential is defined as

$$E_m = \frac{1}{2}(LI^2)$$

This indicates that any inductance wherever present will posses this form of energy

A New Way of Looking at Antennas

- A quarter wave monople at any frequency will have a certain length or height. The antenna is made up from wire or metal tubing. It has been determined that the inductance of a straight length of wire or tubing* will have approximately .026uh of inductance per inch.

*tubing will have slightly less and large diameter tubing will have even less inductance per inch.

The Dipole Antenna

- A dipole antenna has twice the gain of a monopole antenna. This is because it has twice the length of the monopole. Therefore, because it also has twice the potential energy.

Energy Storage

- The storage of potential energy within an antenna can be lumped.* This is usually in the form of an inductor.

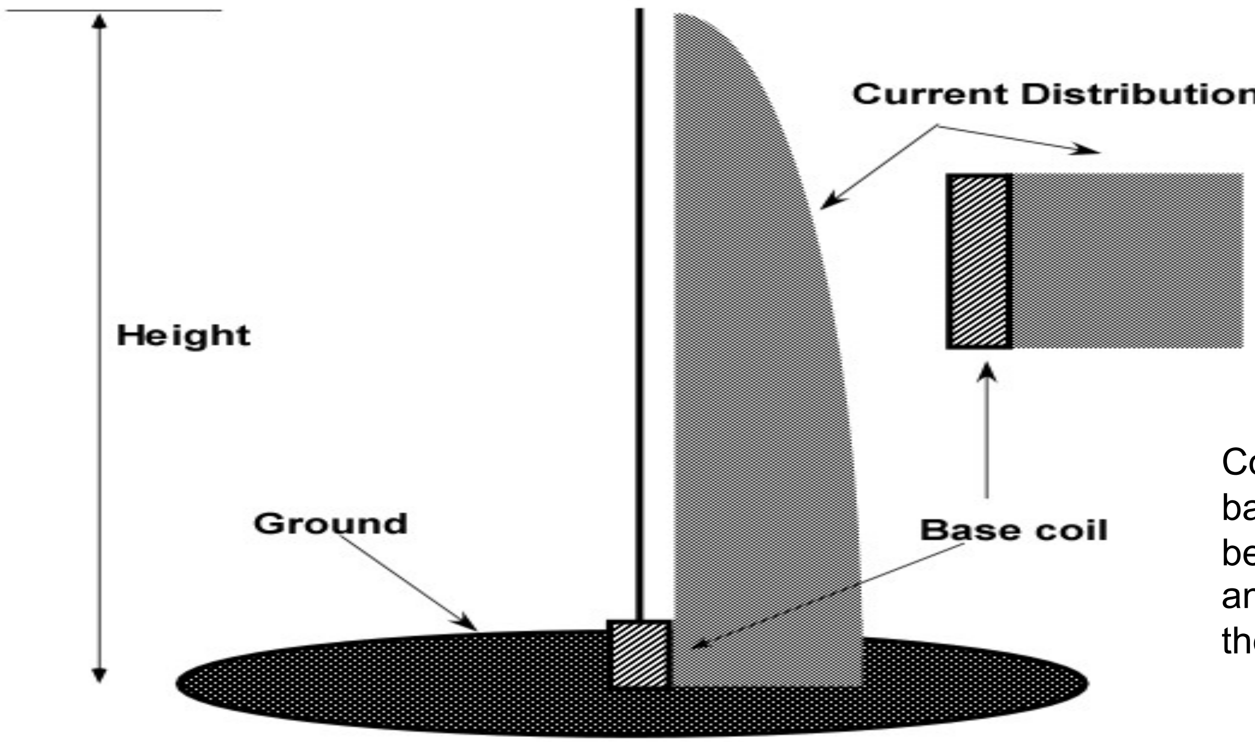
*This term is used to define the insertion of a coil or addition of fixed Capacitance within or on the antenna

The Base-Loaded Monopole

- Base loading an antenna allows a shortened antenna to become resonant at the operating frequency. This is accomplished in the form of a large inductor at the base of the antenna.

- There are certain advantages to placing the coil in locations other than the base, but the coil can be placed anywhere within the antenna

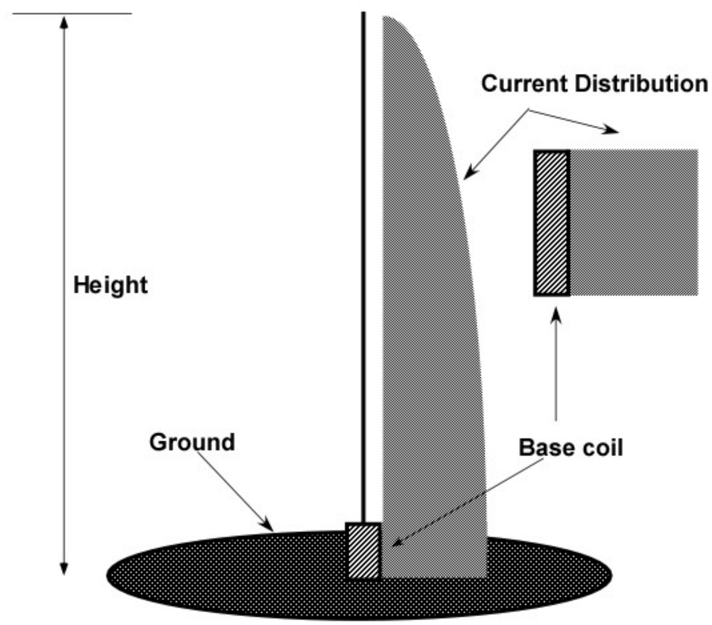
Base Loaded Monopole Antenna



BASE LOADED MONOPOLE ANTENNA

Coil shown in base but can be placed anywhere along the antenna length

- This antenna shown will be quite short in height depending on the amount of loading or inductance of the coil at the base. The current distribution will be somewhat modified. As shown the current distribution will be linear along the coil and taper off rapidly at the top of the antenna. However, this linear distribution along the coil will be a very small area as the base loading coil is very small in relation to the antenna size. This will not add significantly to the antenna radiation and in some cases will not add anything if the coil is enclosed in an enclosure

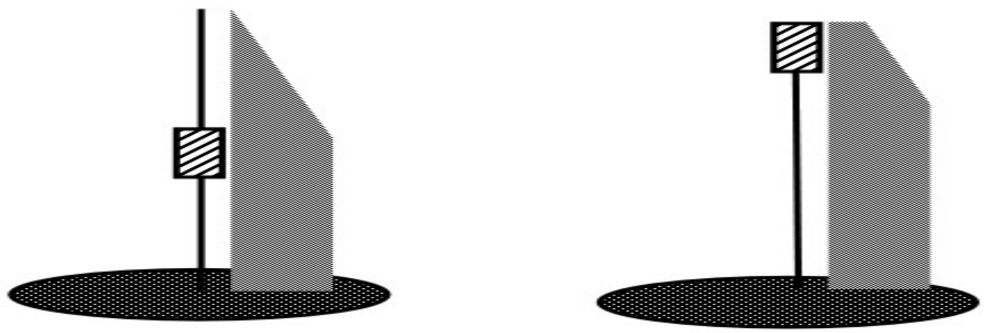


BASE LOADED MONOPOLE ANTENNA

- The base coil possesses a certain amount of electrical magnetic potential energy but this energy results in a very small area of radiation due to the fact that the physical size of the coil is a very small percentage of the overall antenna height or size. The same techniques can be used to shorten dipole antenna with similar results.

- Base loaded Monopole and Dipole antennas are generally very inefficient radiators

Coil Placement Other Than at the Bottom



Center Coil Placement

Top Coil Placement

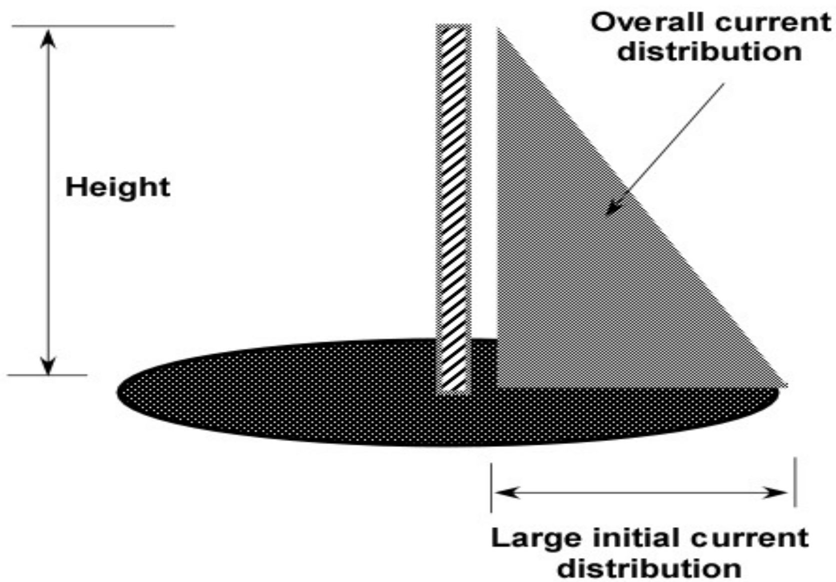
Placement of the load coil either in the middle or top of the antenna of the antenna will modify the current distribution as shown. However, There is no method of increasing the storage of potential energy other than what is available in the conductors (wire or tubing) which make up the antenna. Therefore there will be now additional storage of energy other that what can be stored in the relatively small area of the coil. These antennas will perform well below the performance of a full size monopole antenna.

The Helical Radiator

- The helical radiator or helix operated in the normal mode provides radiation perpendicular to the height or length of the helix. The helix can store an enormous amount of energy but has a trapezoidal current distribution and due to this fact the current distribution decrease rapidly along it's length. Additionally, the bandwidth of helix radiators is very narrow. Generally less than 1% of the operating frequency. Due to its poor current distribution, bandwidth and shortened height or length, the helix alone is a very poor radiator.

Helix Radiator and Current Profile

Helical radiator
Is very short in
length or height



Current along length of antenna decreases very rapidly from large initial level at base

Current level is nearly three times that of standard Quarter wave monopole for Same power into each antenna.

The helix radiator is made by winding wire around a long cylinder form. The amount of inductance of the helix and distributed capacitance resonates the helix at the operating frequency. Since energy has to be conserved, the voltage levels developed at the top of the helix become very large. Generally a small metal plate or wire/tubing extension is added to reduce this voltage buildup

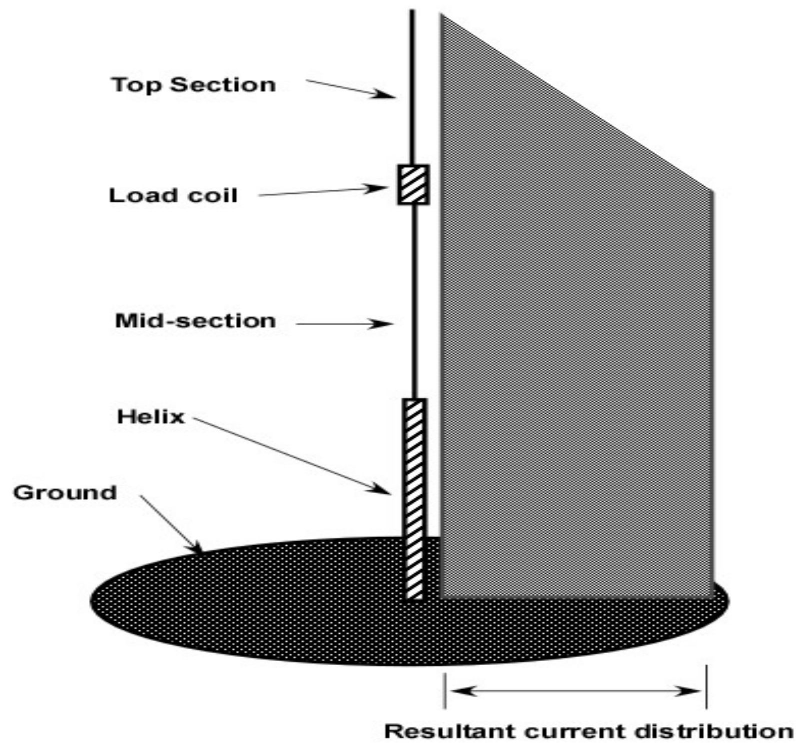
The Helix Does Have merits

- The initial large current distribution of the helix is due to the ability of the helix to store a large potential energy. This allows the helix to have an initial current distribution level at the base nearly three times that which can be achieved with a normal quarter wave monopole or dipole antenna for the same power input to the antenna.

The DLM Antenna

- Reducing the inductance of the helix and combining it with a load coil to resonate the antenna system at a pre-determined frequency allows for wider bandwidth and better overall radiation from a much shortened antenna. The addition of the load coil will enhance the initial large current distribution all the way from the base of the helix up through the antenna and through the load coil

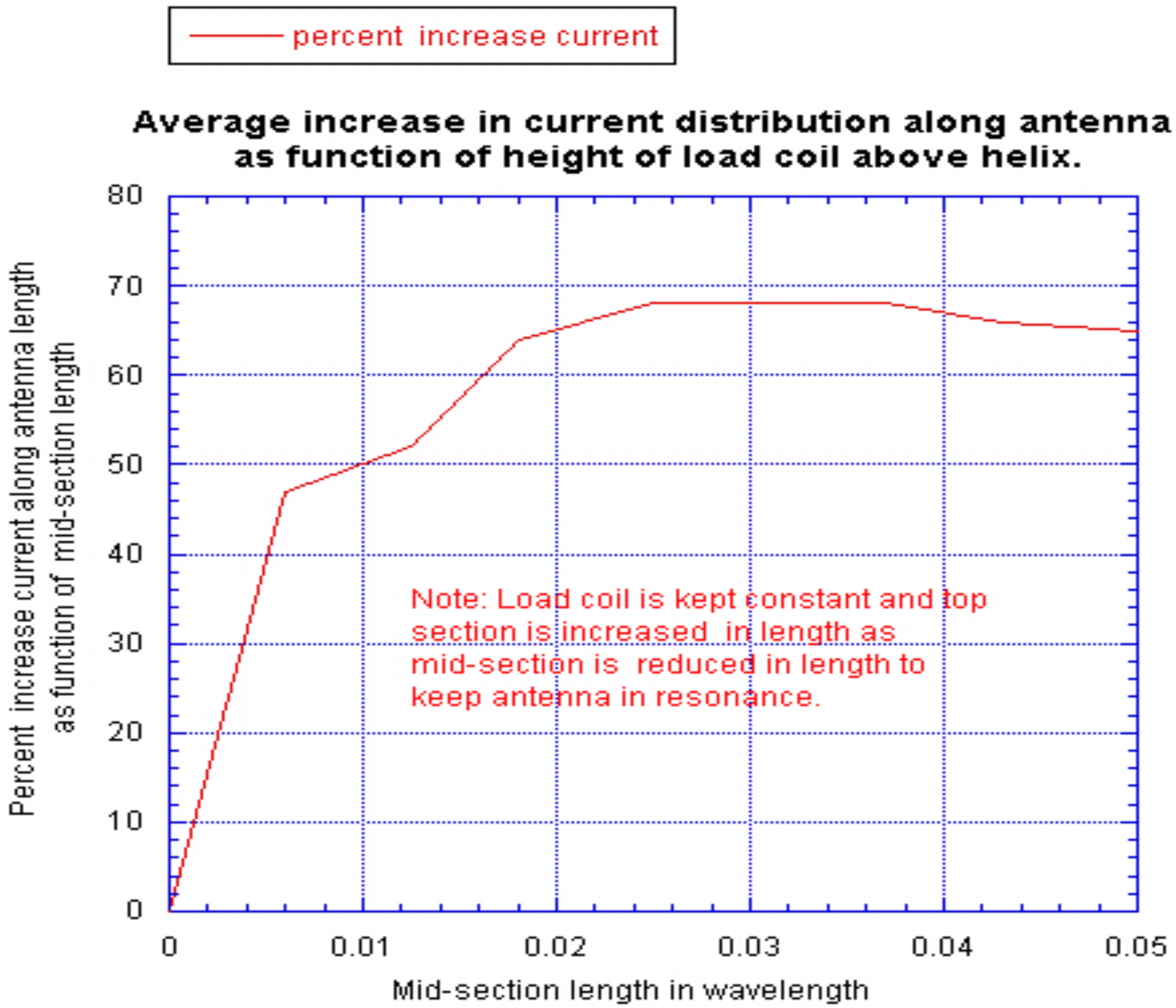
Load coil and Helix Combination

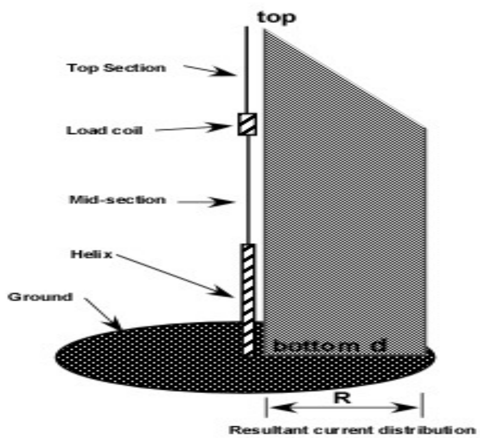


The DLM Antenna

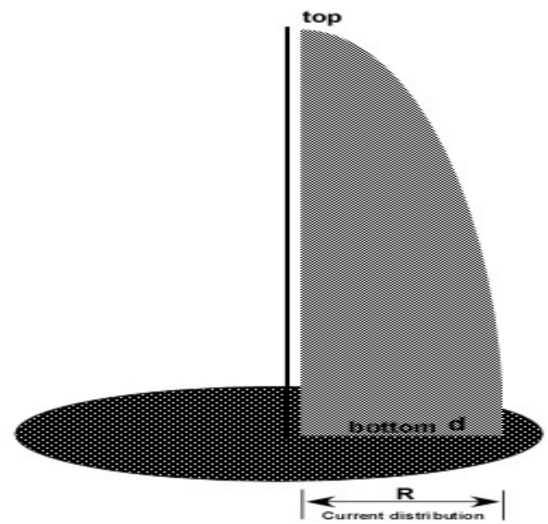
Large current level of
nearly three time larger
that what can be achieved
with the standard monopole
extended from the base
up through load coil

The Effect of the Load coil





The DLM Antenna



1/4 wave Monopole

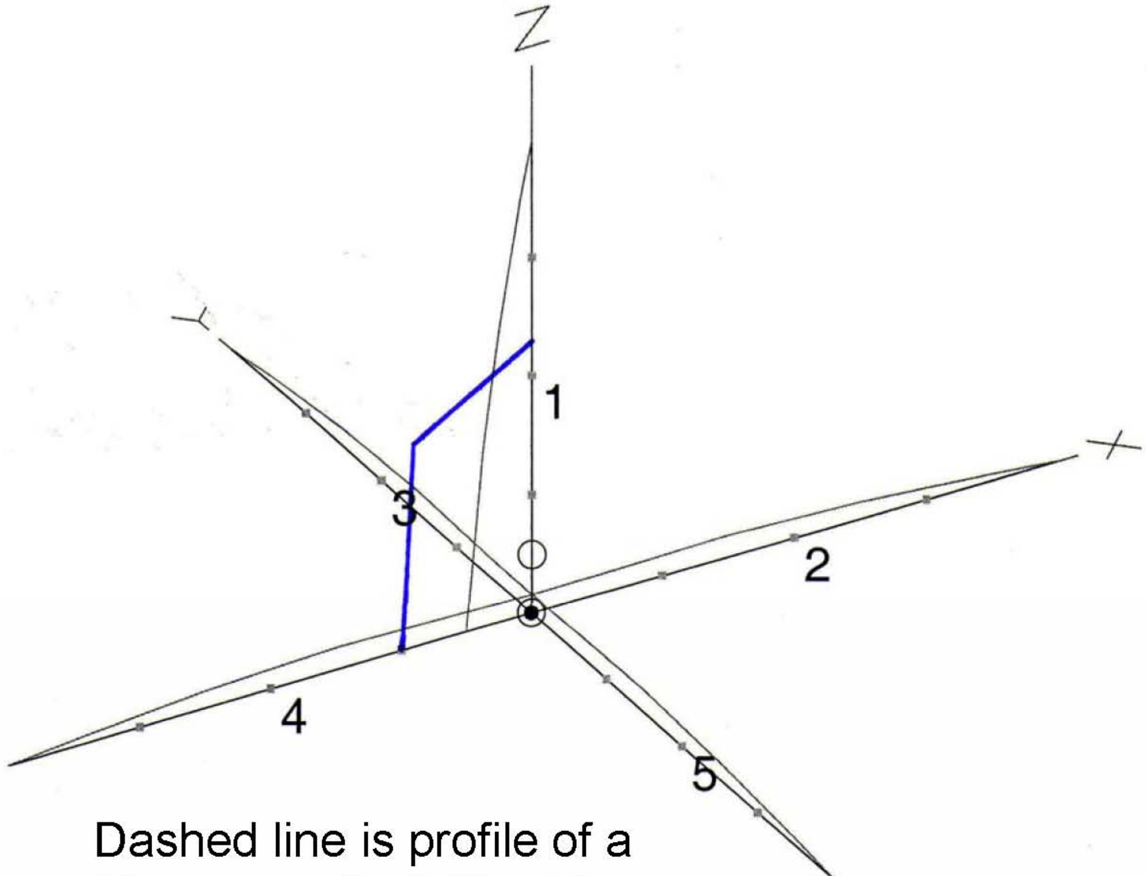
For the same power input to each antenna the initial current distribution for the DLM antenna will be nearly three times more than that that of the quarter wave monopole antenna. The DLM antenna despite it reduced size of of 60% in reference to the quarter wave monopole will after Integrating the area around both antennas result in a nearly equal volume of radiation.

$$\text{Radiation volume} = \int_{\text{bottom}}^{\text{top}} \pi R^2 \, dz$$

Basic Theory

- The radiation volume for each antenna will be nearly the same. This is a result of the potential energy stored in the helix. This initial current level is much larger than that which can be achieved with a normal full size radiator. This current profile is now extended up along the helix and mid-section along nearly the entire length of the antenna. The linearization of current along the DLM antenna is the result of adding the load. This also reduces the helix inductance which greatly expands the bandwidth of the antenna. The next slide shows this concept.

CURRENT PROFILE OF A ¼ WAVE COMPARED TO A DLM



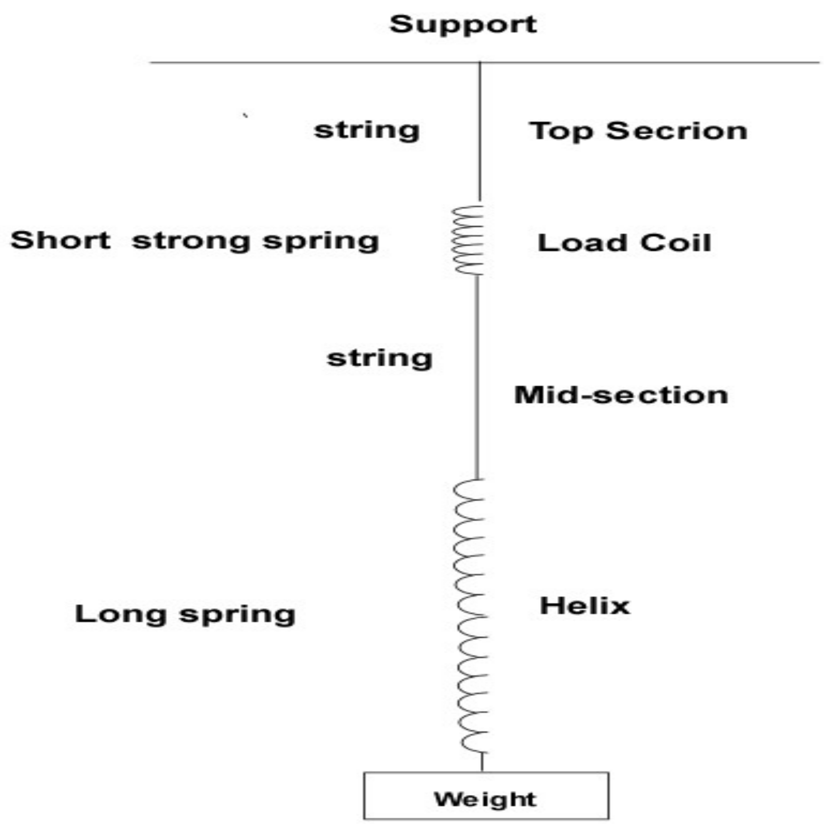
Dashed line is profile of a ¼ wave vertical. The blue profile is that of a DLM

This is a comparison of current profiles for a ¼ wave vertical radiator and that of a Distributed Loaded Monopole radiator.

The current profile of the DLM is larger and of unity level for a large portion of the radiator element. Integrating this area over the full 360 degrees around the antenna indicates a volume of radiation comparing one antenna to another. If the area of radiation is equal, both antennas are the same performance.

Mechanical Analogy

- A mechanical analogy of the DLM is explained in the following. A spring (The load coil) is hung from a support by a string (the top section) and from the bottom of this spring is hung another string (Mid-section) which is attached a much longer spring but with less strength (the helix) A weight is attached to the bottom of this spring. (the current or excitation)
- If the whole system is allowed to hang and reach equilibrium then pulling on the weight and exciting the system (applying an excitation current) will force the system into oscillation. The stronger spring supported from the top section, will absorb the helix oscillations (the lower spring) and will give up its energy forcing the larger spring to absorb all the energy of the helix spring. The whole system will try to oscillate out of control except that losses or damping of the springs will eventually force the system back into a steady state again. This will prevail until another excitation causes the system to again oscillate giving up its energy. In the DLM antenna this process forces the DLM to give up its potential energy (a large current) in the form of electromagnetic radiation. The next slide is a pictorial representation of this DLM antenna.



Mechanical Analogy of
DLM Antenna

- The process of oscillation is akin to various parts of the DLM antenna giving up it’s energy every time an excitation is applied. If you were to lightly tap the helix or load coil spring on it’s side it will also cause an oscillation (a very weak current will be induced.) This is what an arriving wave front of electromagnetic energy (a received signal) causes the system to do. Therefore the antenna will exhibit all the functions of the antenna whether it is being excited by a internal excitation (applying a current) or from an external excitation (a received passing wave of electromagnetic energy) This is called reciprocity and all antennas (If they are real antennas) exhibit this characteristic. The energy created in receiving is much smaller than in transmitting. Therefore the DLM will exhibit all the performance (gain and bandwidth) in either receiving or transmitting of energy.

Some 3D DLM Antennas

3D VHF DLM Antennas

160 meter (1.8Mhz) DLM

7MHz DLM

7MHz Cage Helix DLM

3.5MHz Spiral Top Hat “Super DLM”

Spiral Top Hat of 3.5MHz “Super DLM”

DLD made from 2 DLM antennas
Placed base to base.

Discussion

- The presentation thus far has involved the DLM antenna in a three dimensional geometry. Before we proceed to the two dimensional geometry and the Plano Spiral DLM the presentation is open to discussion of what has been thus far presented.

2D PlanoSpiral DLM Antennas

The following slides Jump from 3D to 2D DLM/DLD Antennas and their characteristics.

The Plano Spiral 2 Dimensional DLM Antenna

.

As frequency of application moved up from the high frequency to the lower and higher VHF frequency range, it became very difficult to fabricate DLM antennas using three dimensional fabrication methods

To solve this problem another helix form had to be invented that could readily be adapted and capable of storing energy like its 3D predecessor.

A 3 Dimensional DLM Antenna for 500MHz

- Helix length 0.6720 inches
- Helix Dia. 0.0175 inches
- Helix Winding 96 turns of .0035 copper strap 0.0008 inches thick
- Mid Section Length 0.670 inches
- Load Coil)0.034 dia. by 0.136 inches long
- Top Section 0.442 inches

A 500 MHz 3D DLM Antenna

The previous slide makes It readily apparent that this antenna cannot be made using the three dimensional geometry and method of fabrication .

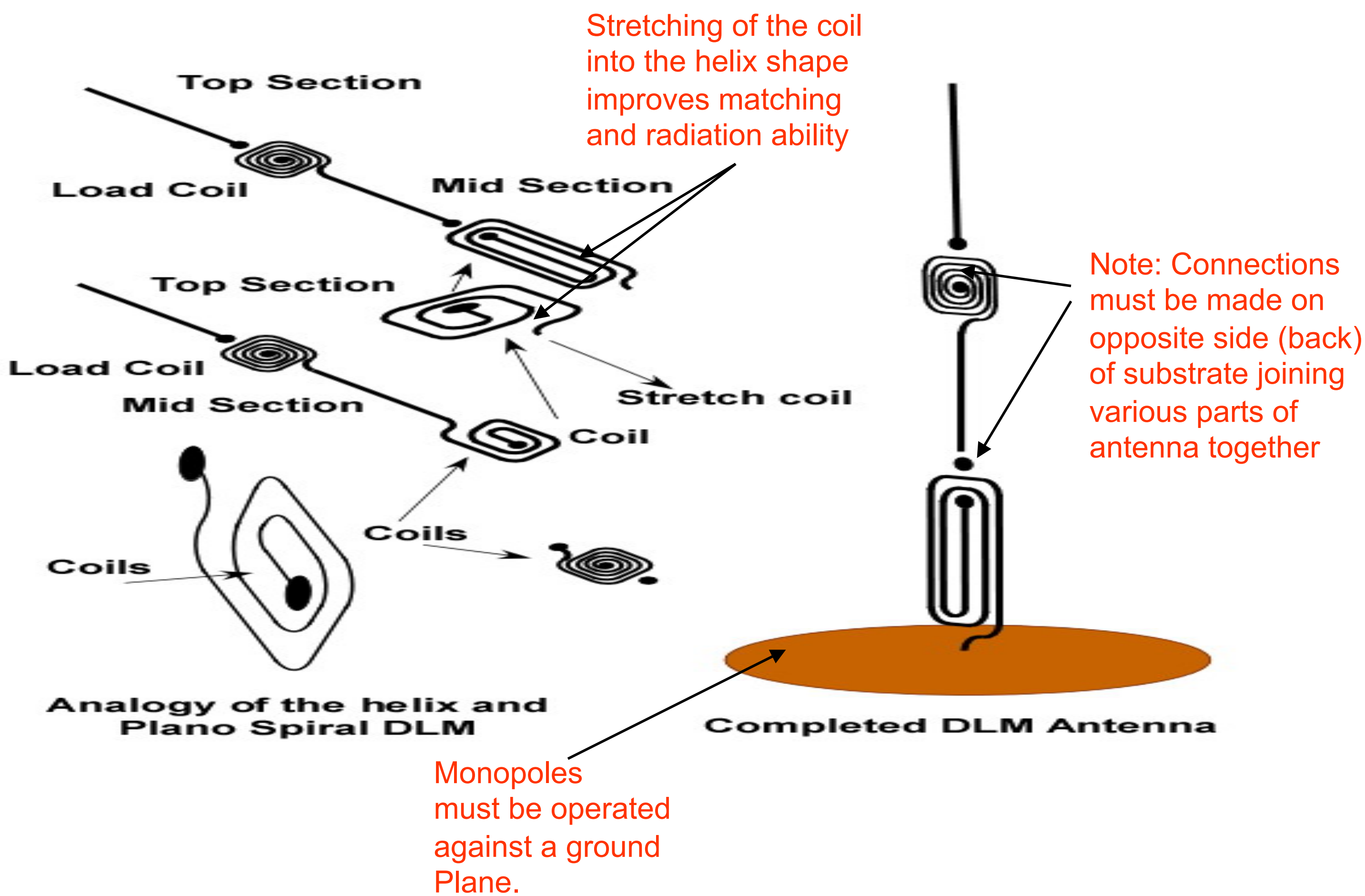
The Flat Helix

- When looking for something to store electromagnetic potential energy there are not all that many options.
- The only thing that really can be used, has to be a coil which pretty much limits the "what it has to be". However, how do you make something in the form of a flat coil that is easy to fabricate and also radiates as well as the 3D counterpart.

The Plano Spiral Helix

- The plano spiral helix for the most part is two dimensional. It has width, length but is very thin. This form of helix was inspired by early test done using two coils connected together by a wire and the addition of a wire on top. The coils were eventually would flat like a pancake spiral
- After further testing it was found that if you stretched out the coil it would radiate and behave just like a normal mode three dimensional helix.

The Analogy of the Plano Spiral Helix and DLM



Reciprocity

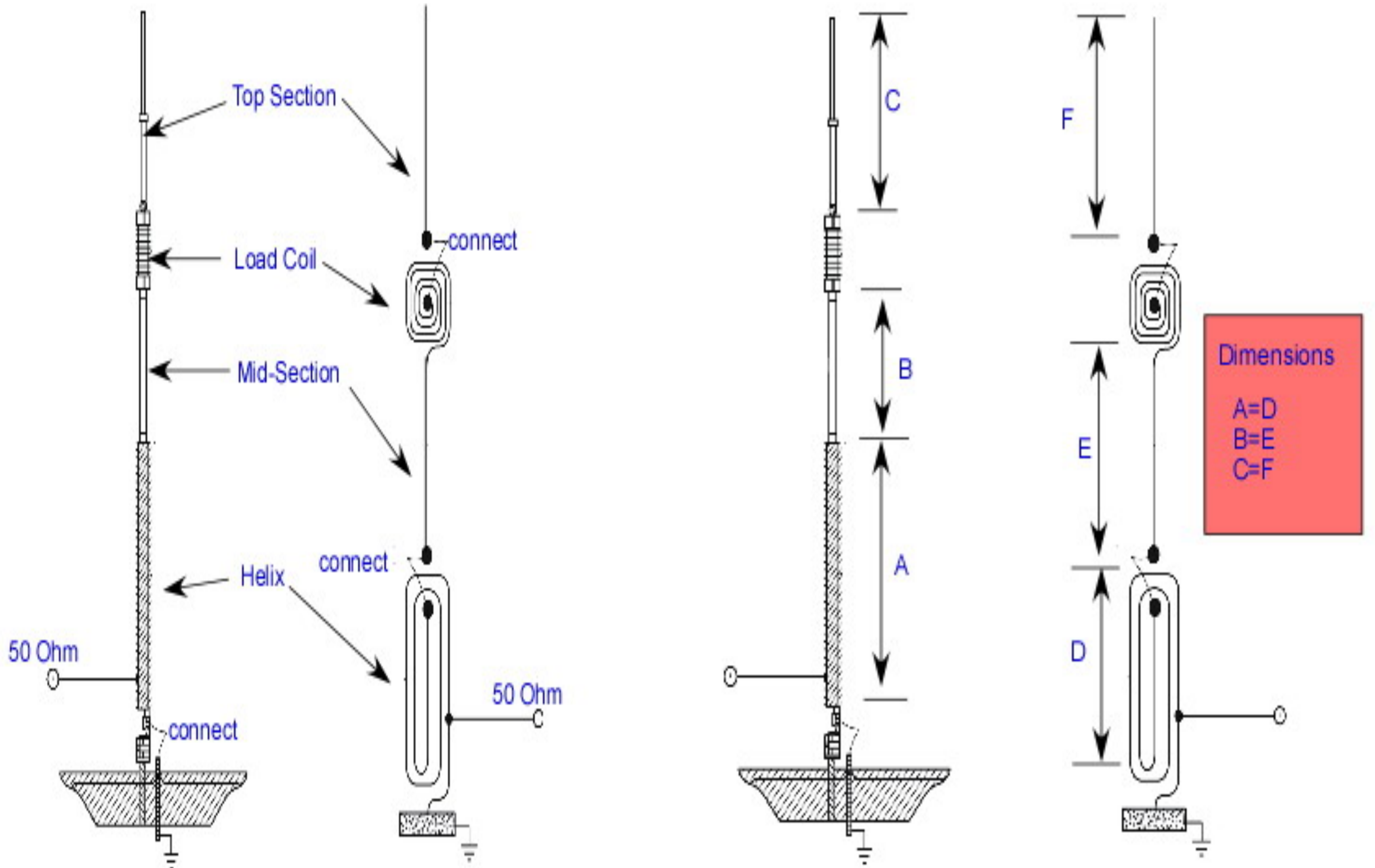
- Two dimensional equivalents* of three dimensional antennas have been constructed and tested.
- Evaluation of all the data, Frequency of operation, bandwidth, efficiency, size and performance are identical to their three dimensional counterparts.

*Note: two dimensional equivalents

- While it is possible to make a two dimensional equivalent of any three dimensional DLM antenna, it is not always possible to make three dimensional DLM equivalent of a two dimensional DLM antenna as explained in a previous slide.

Operation and Performance

- The operation of 2D DLM antennas is exactly like 3D counterparts.
- All the theory of operation of 3D DLM antennas pertains to 2D DLM antennas



3D to 2D DLM Equivalents

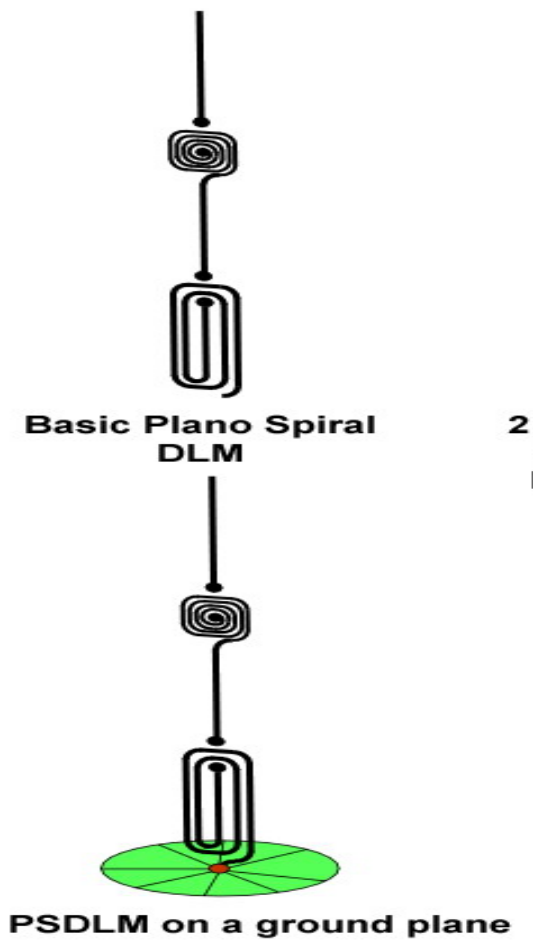
All the mechanical and electrical values of a two dimensional DLM are exactly equal to those of a three dimensional counterpart.

Helix inductance and load coil inductance as well as all ratios of various mechanical parts will be identical such as helix length, Mid-section length and top section length

The exception to this is helix form and diameter and load coil geometry.

Plano Spiral DLM antennas can be placed back to back just like 3D DLM antennas to form a Plano Spiral DLD

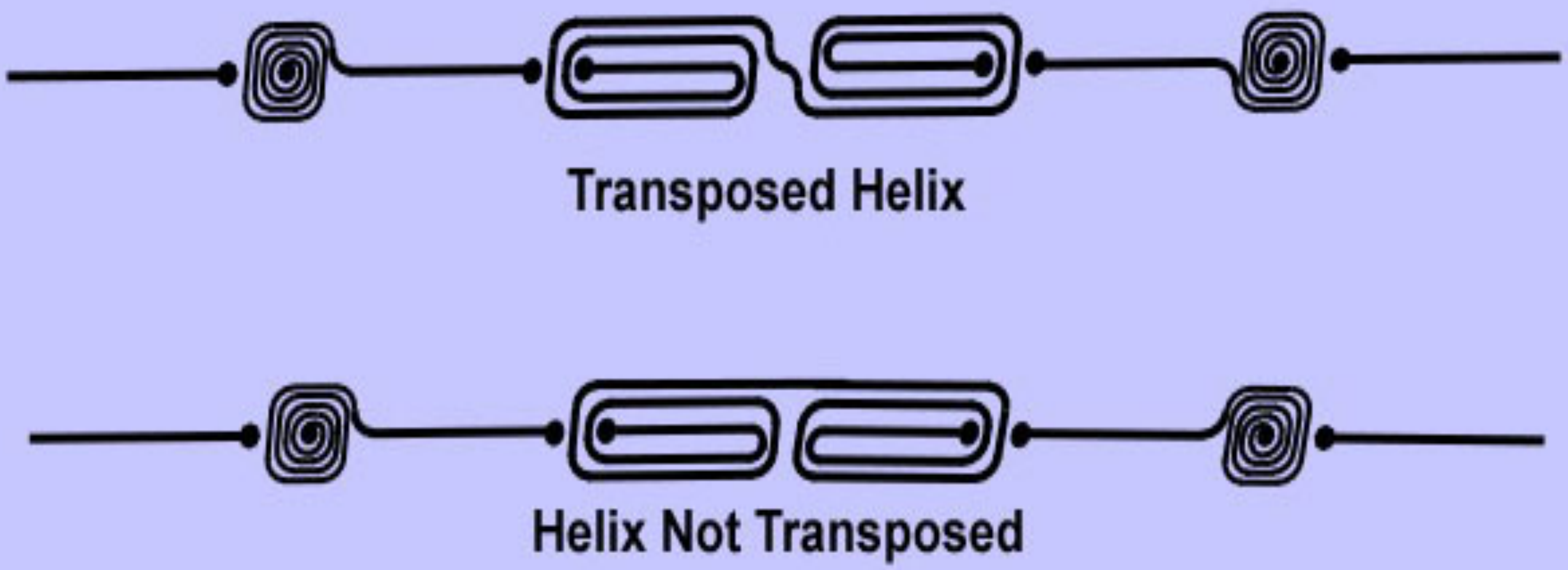
Evolution of Various 2D Plano-Spiral DLM to DLD Antennas



Plano Spiral DLD Helix

- Transposition of helix.
- Plano Spiral DLD can have either a transposed or non-transposed helix depending on the application.
- If the DLD is to be placed against a large metal surface then the helix may not want to be transposed

DLD Helix Transposition

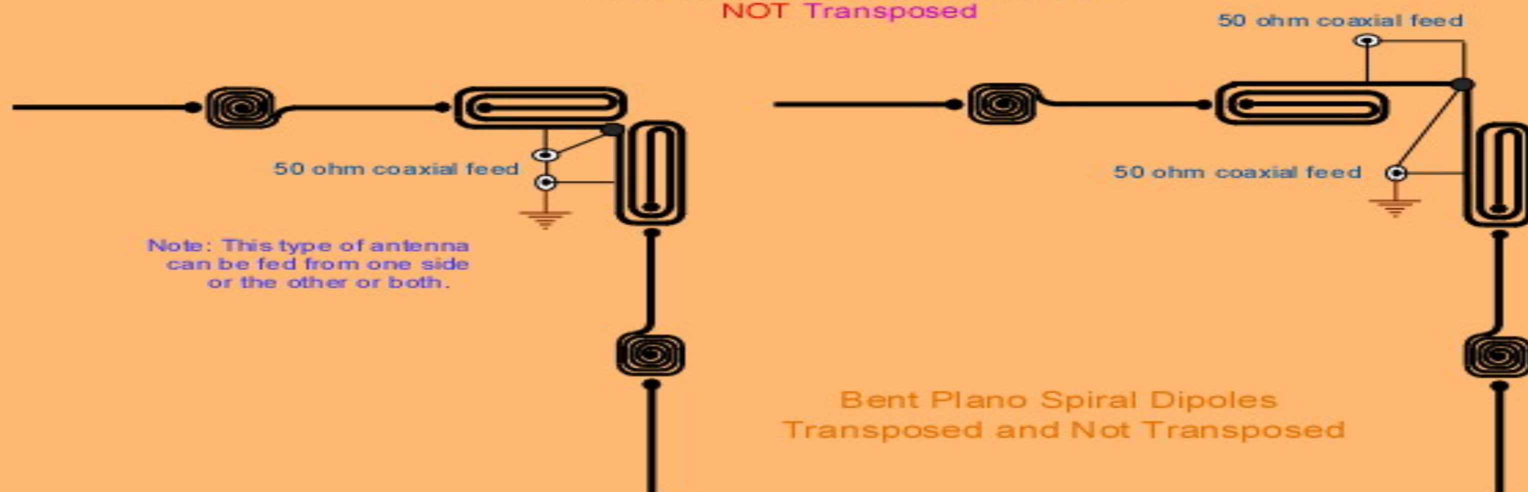


Plano Spiral Distributed Load Dipoles
PS-DLD

Plano Spiral Distributed Load Dipole
Transposed

The ⏚ Means Virtual Ground. You can connect this point to ground or not and you can connect anything you want to this point and it will not affect the operation of the antenna.

Plano Spiral Distributed Load Dipole
NOT Transposed



Bent Plano Spiral Dipoles
Transposed and Not Transposed

Why Transpose Helix

Transposing the helix changes the phase relationship along the helix and when placing the entire DLD against a large metal or conductive substrate will sometimes allow better matching and antenna radiation.

Substrate Tolerance

- Plano Spiral 2D DLM and DLD antennas are fabricated on a variety of substrates.
- The include FR4 PCB material as well as a variety of other substrate materials.
- These antennas have a high tolerance to substrate characteristics such as dielectric variations and loss tangent.

Performance

- The performance of both 3D and 2D DLM and DLD antennas with standard tapped helix connection of transmission line was pretty much similar. The following are in comparison to either standard ¼ wave monopole or ½ wave dipole using same groundplane or height above ground.

Performance

DLM monopole and Dipole

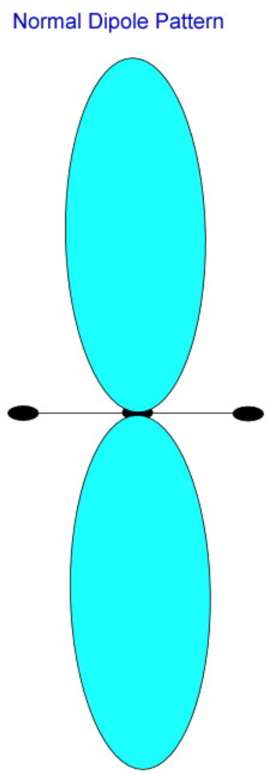
Gain	-2 to +1db
Bandwidth	Typically 3-5%
Overall height (Monopole)	1/3 size of ¼ Wave
Overall length (Dipole)	1/3 size of ½ Wave

However in the case of the dipole antennas in either 3D or 2D geometry

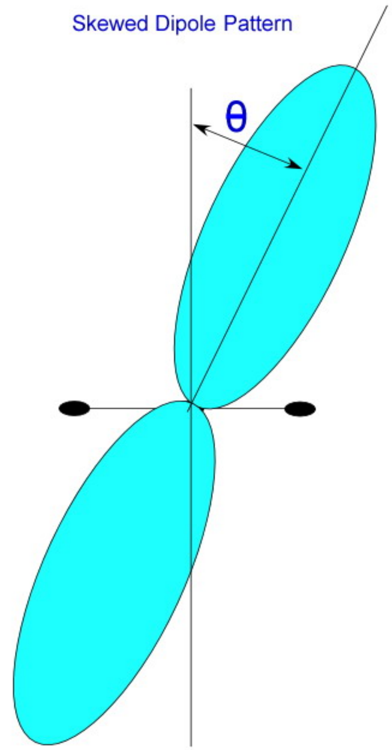
the pattern skew of either antenna was normal. This is indicated in the following slide.

To overcome this operational defect in the dipole configuration a new coupling system had to be developed.

Dipole Patterns



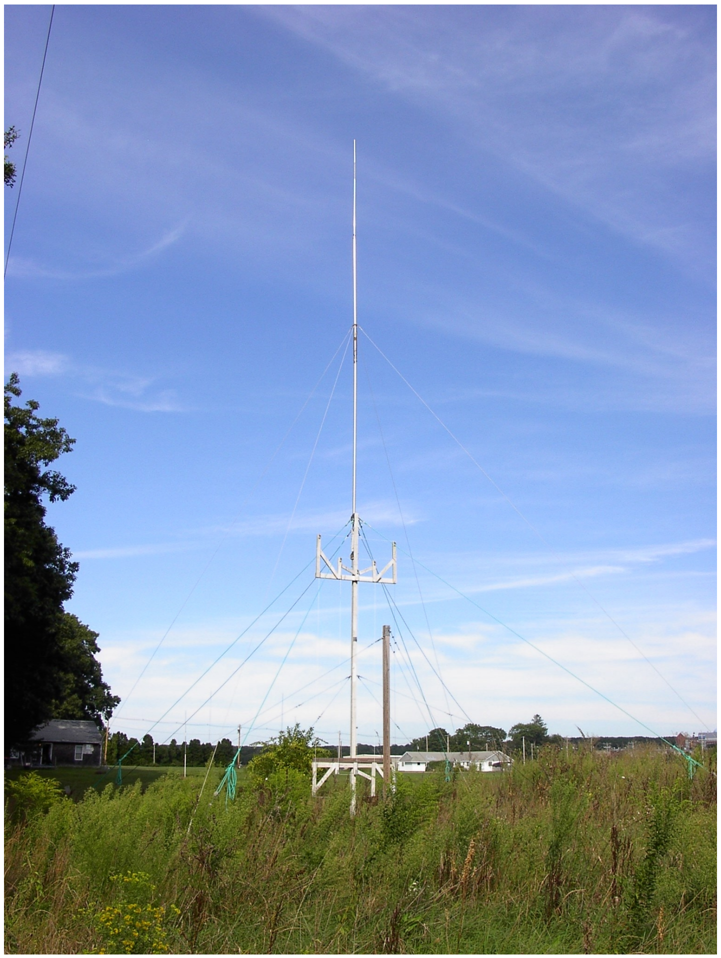
Normal Dipole Pattern

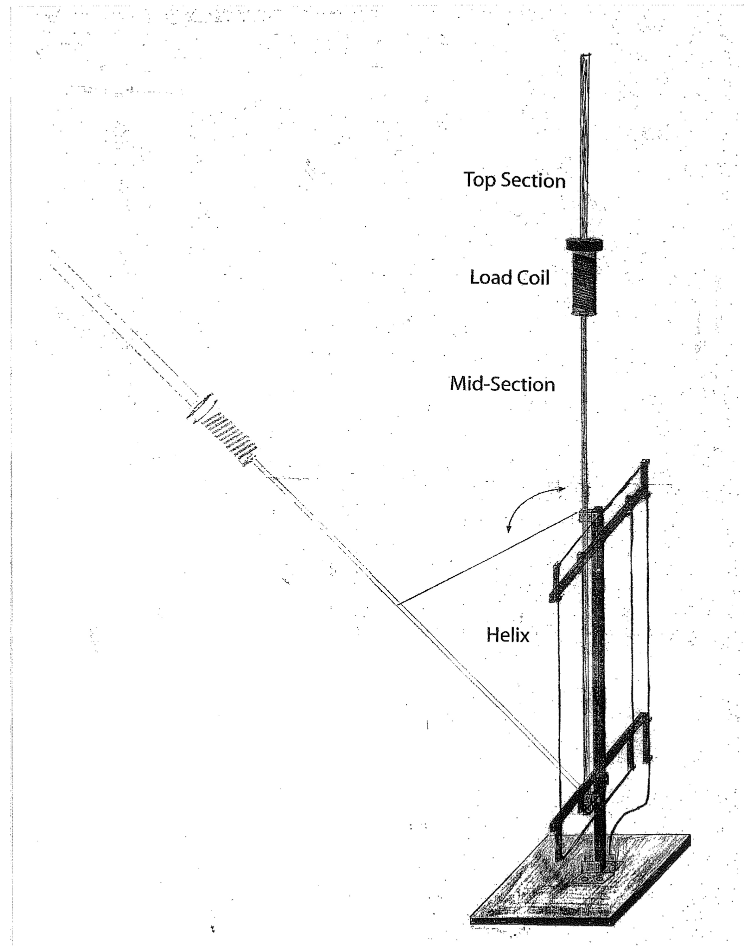


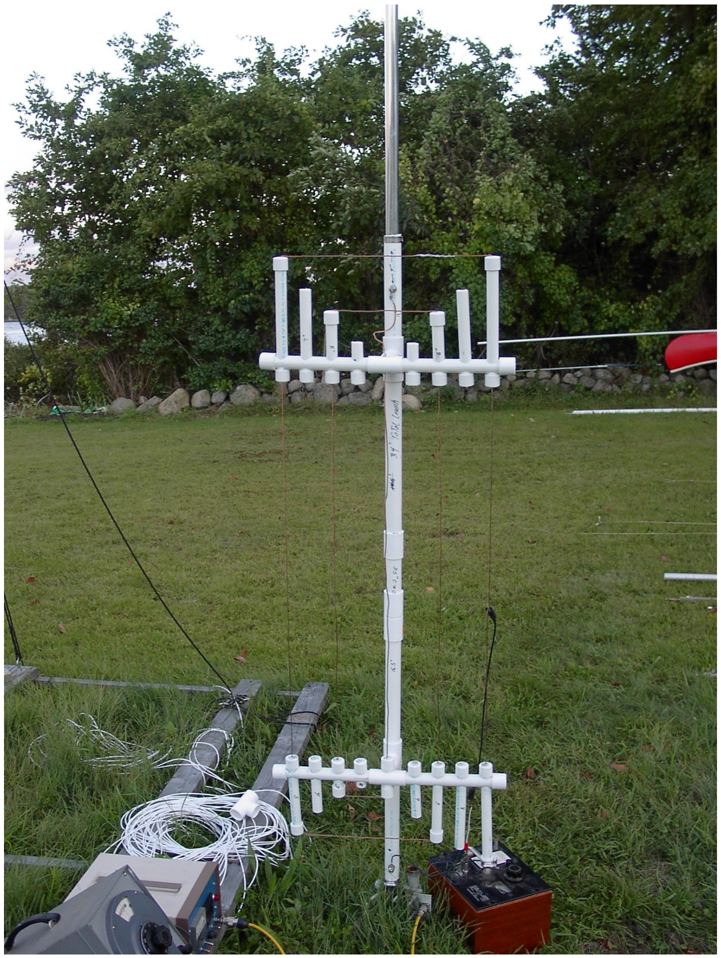
Skewed Dipole Pattern

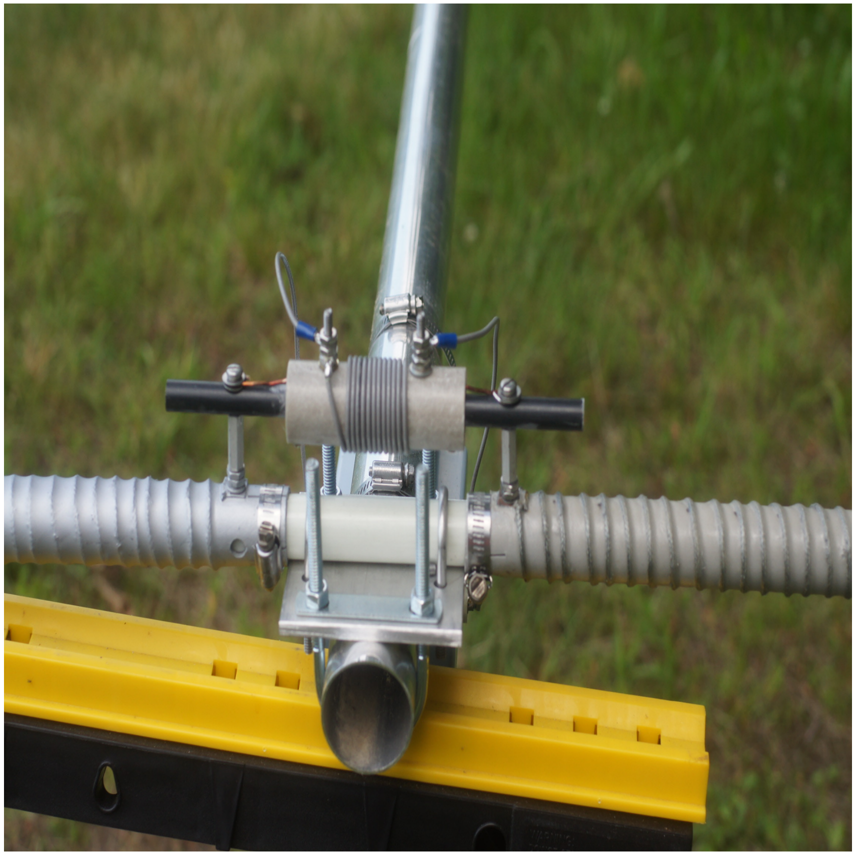
To overcome these dipole pattern distortions a new coupling system had to be developed. These coupling deficiencies became very apparent when DLD dipoles were formed into phased arrays or arrays of parasitic elements. The pattern skews caused the overall array pattern to be skewed in different directions.

2D DLM and DLD Antennas

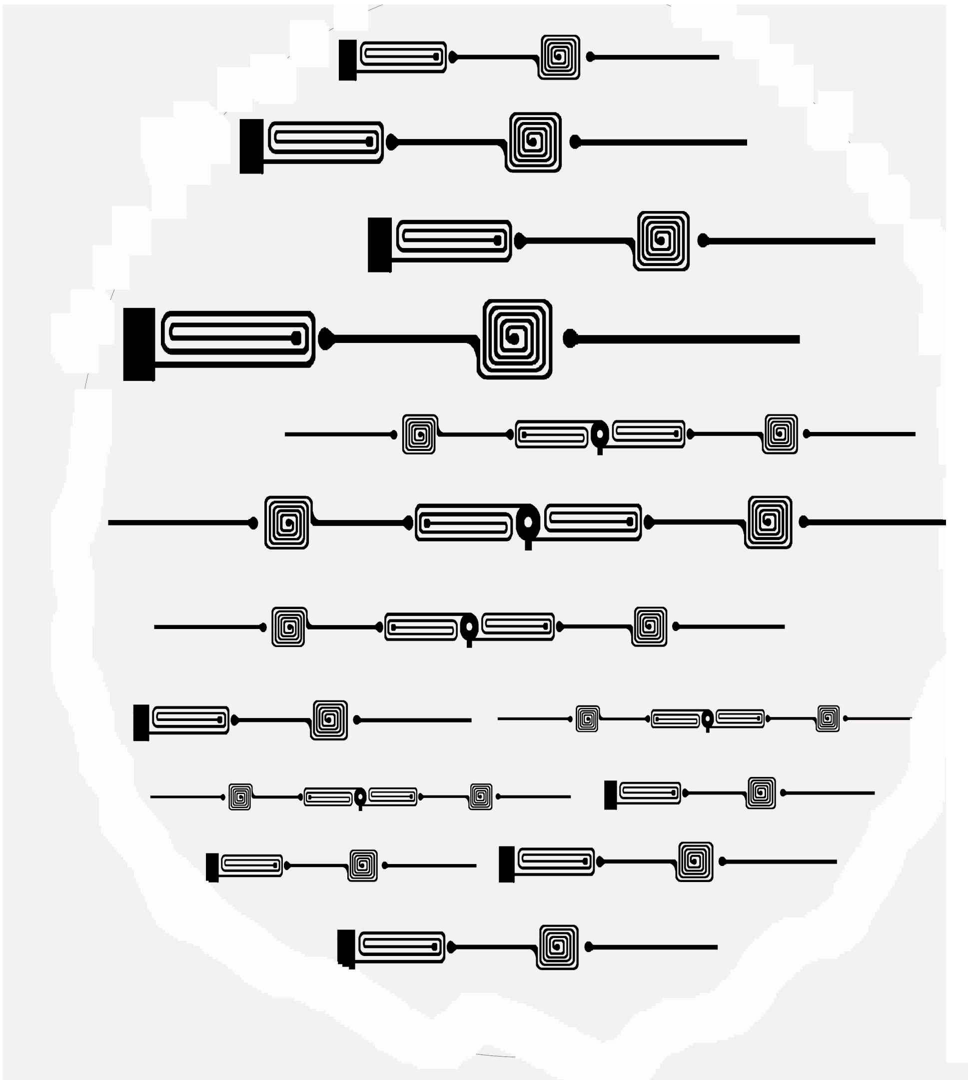


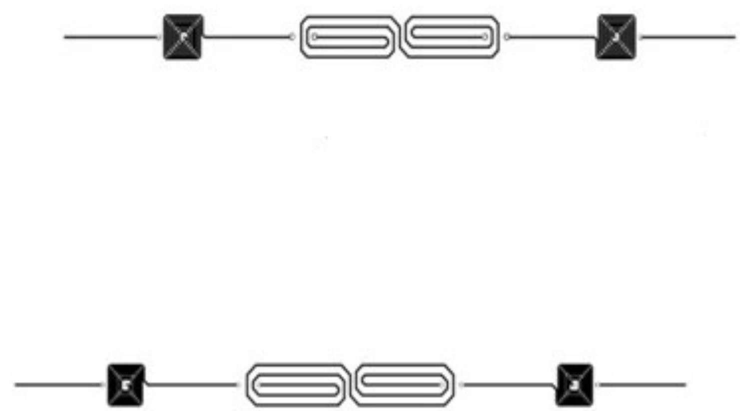






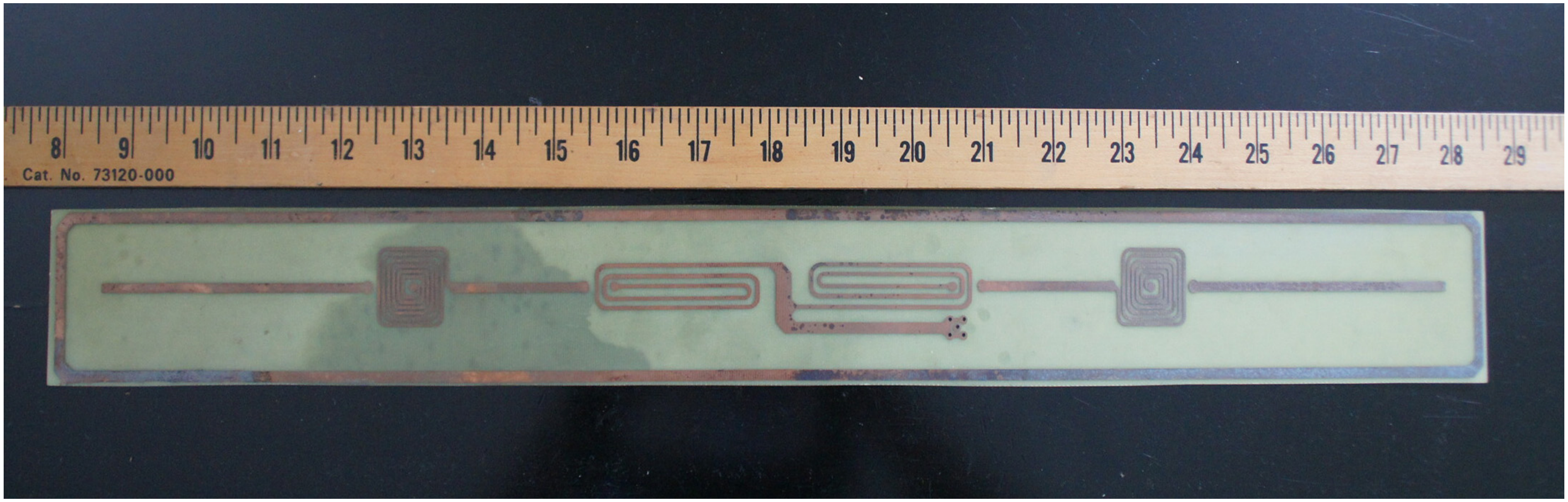
A 30 Meter 2 element Yagi. Yagis of 2 and 3 elements have been built for 40, 20 and 15 meters as well as the one shown here. Shown is part of a variation of the New coupling system but not the latest being used.



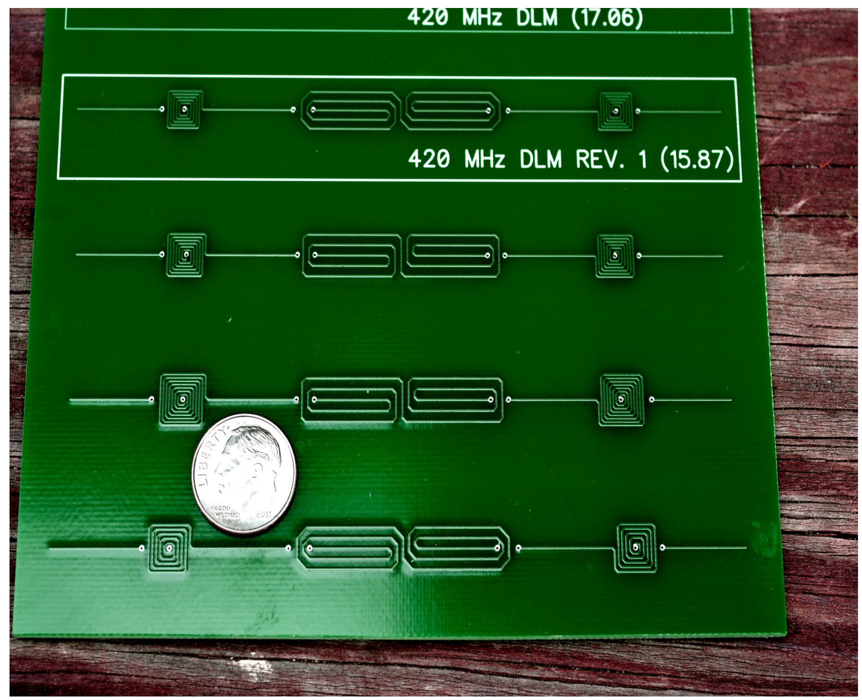


420 MHz DLM REV. 1 (15.87)

420 MHz DLM Rev. 2 (16.33)


8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Cat. No. 73120-000


LIBERTY
IN GOD WE TRUST
2000
P


420 MHz DLM (17.06)
420 MHz DLM REV. 1 (15.87)

New Coupling system

- Improve user interface
- Better performance
- Increase in antenna current for same power
- Improved bandwidth
- Easier application
- Predictable antenna patterns

Designing DLM antennas

- A computer CAD program is being developed that aids in the design and development of DLM and DLD antennas.
- This CAD program allows the user to input frequency and substrate to be used.
- The program list all dimensions in a spread sheet and describes the outline of the antenna.
- In addition the program will design 3D as well as 2d DLM and DLD antennas.
- The program is still being improved and under development.

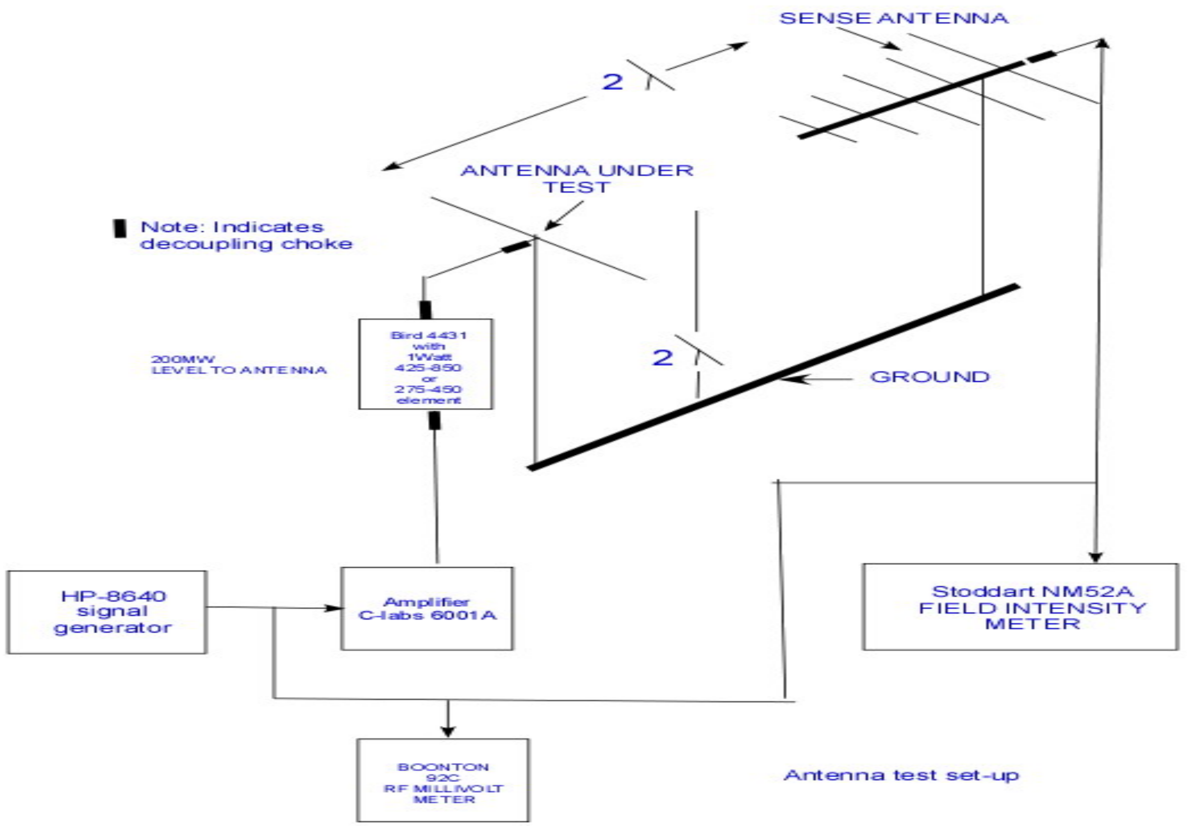
New Antenna Performance

- DLM and DLD antennas utilizing the new coupling system have added new performance levels to these antennas.
- Typical antenna performance levels with either 2D or 3D geometry are outlined in the next slides.
- These performance levels have been carefully measured. However, they have not been independently verified.

Measured Performance

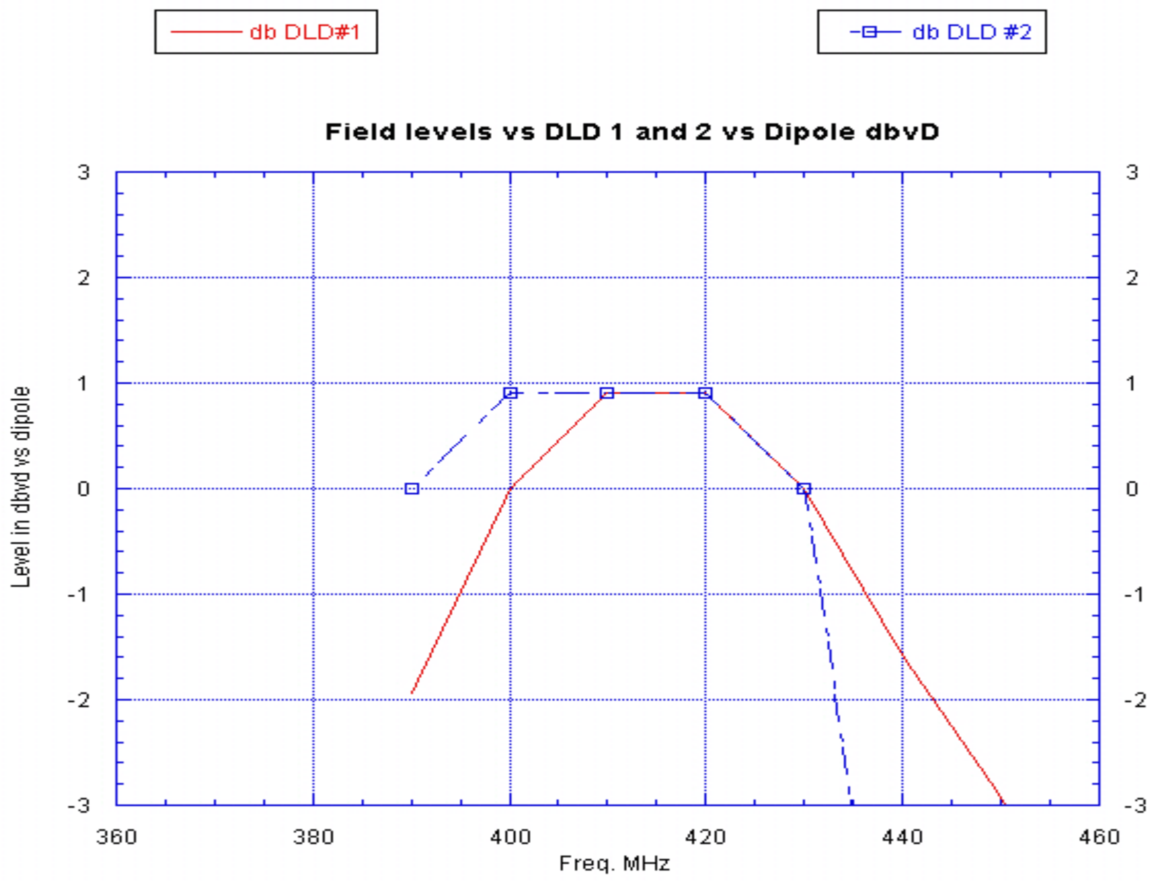
- All measurements have been made in comparison to a standard dipole of known performance matched and tuned to the frequency of measurements.
- To reduce multipath distortion levels from reflections a highly directional wide band antenna was used as the sense antenna for receiving.
- A diagram of the test setup is shown.

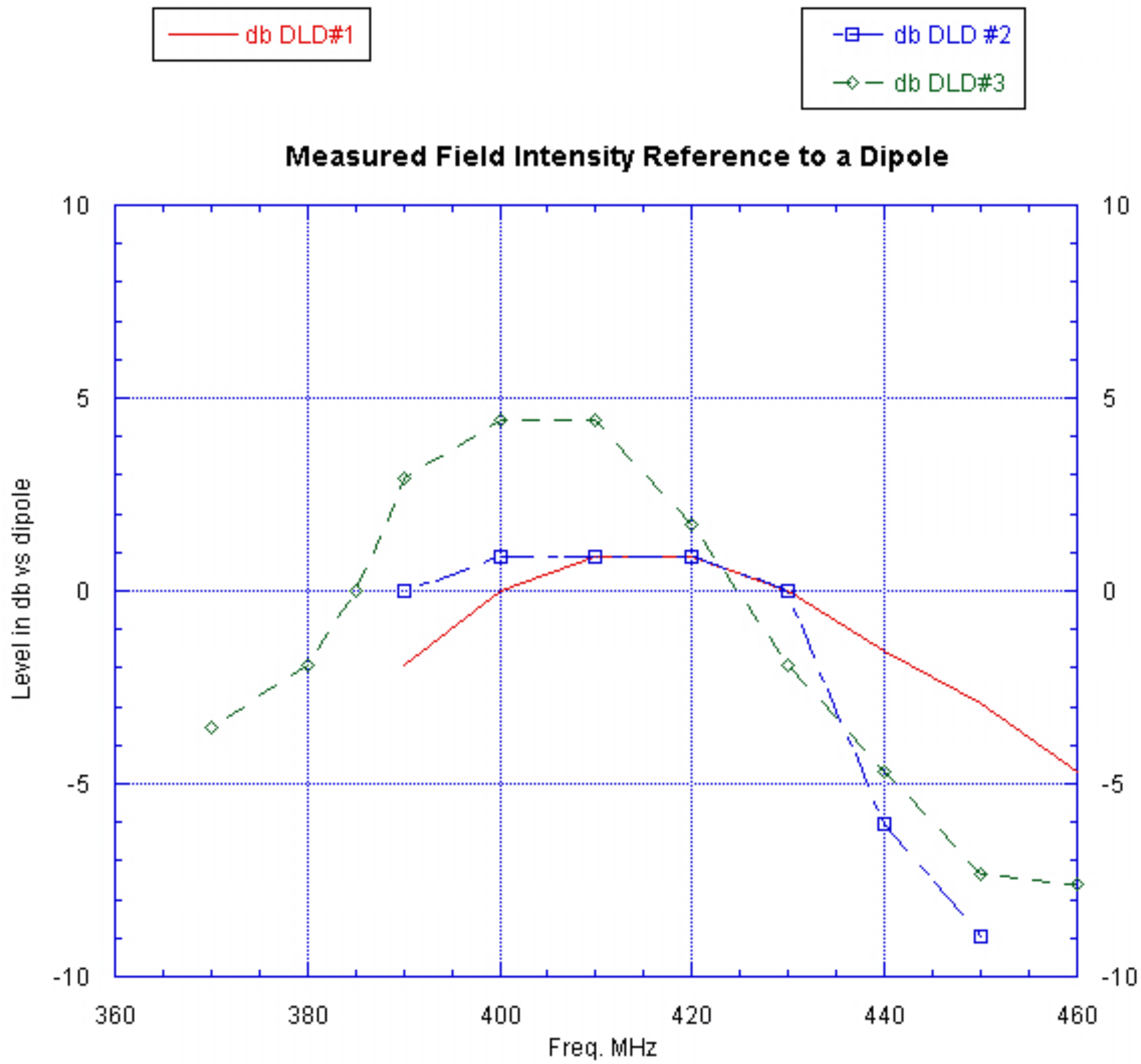
Measurement Test Setup

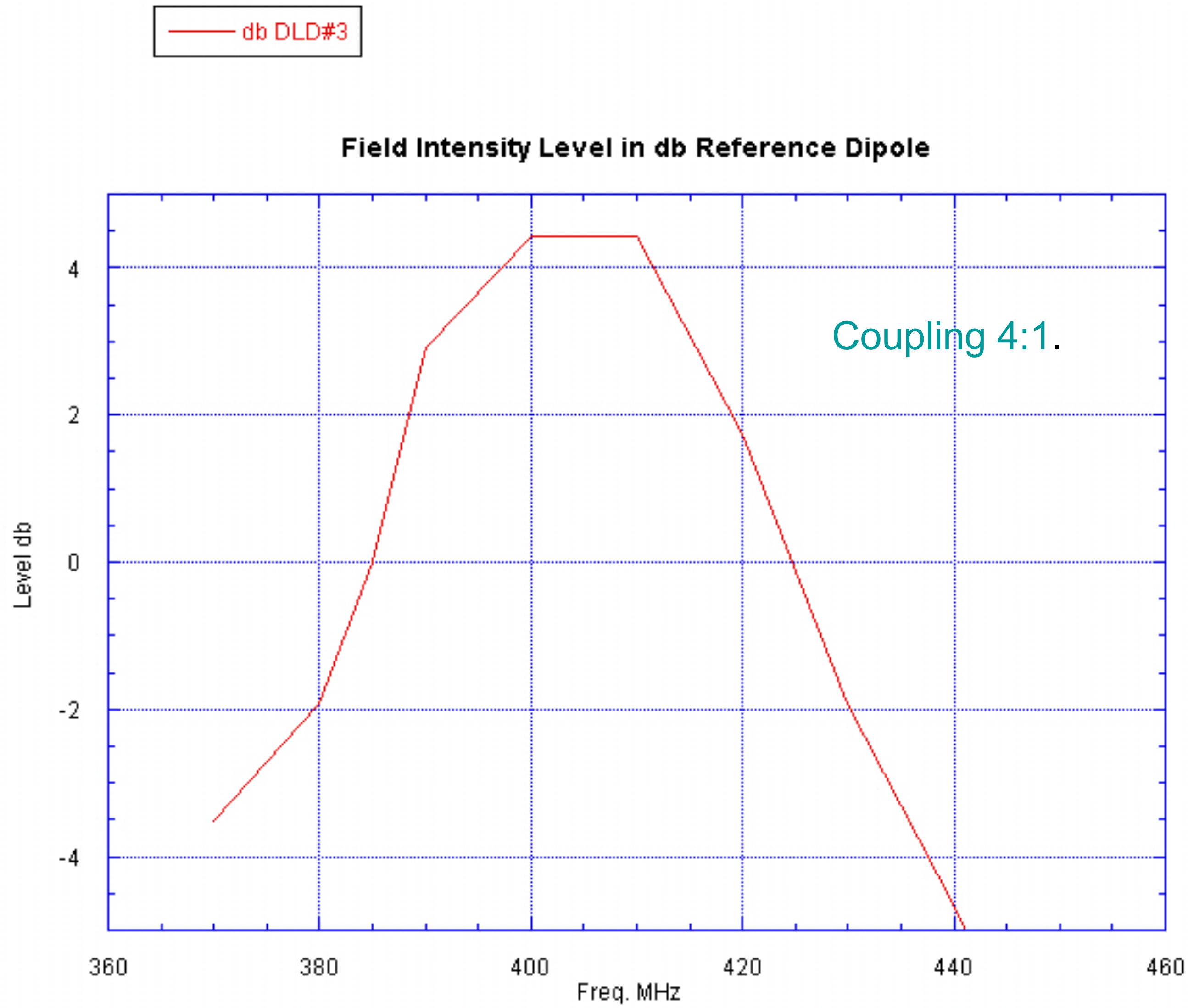


Antenna test set-up

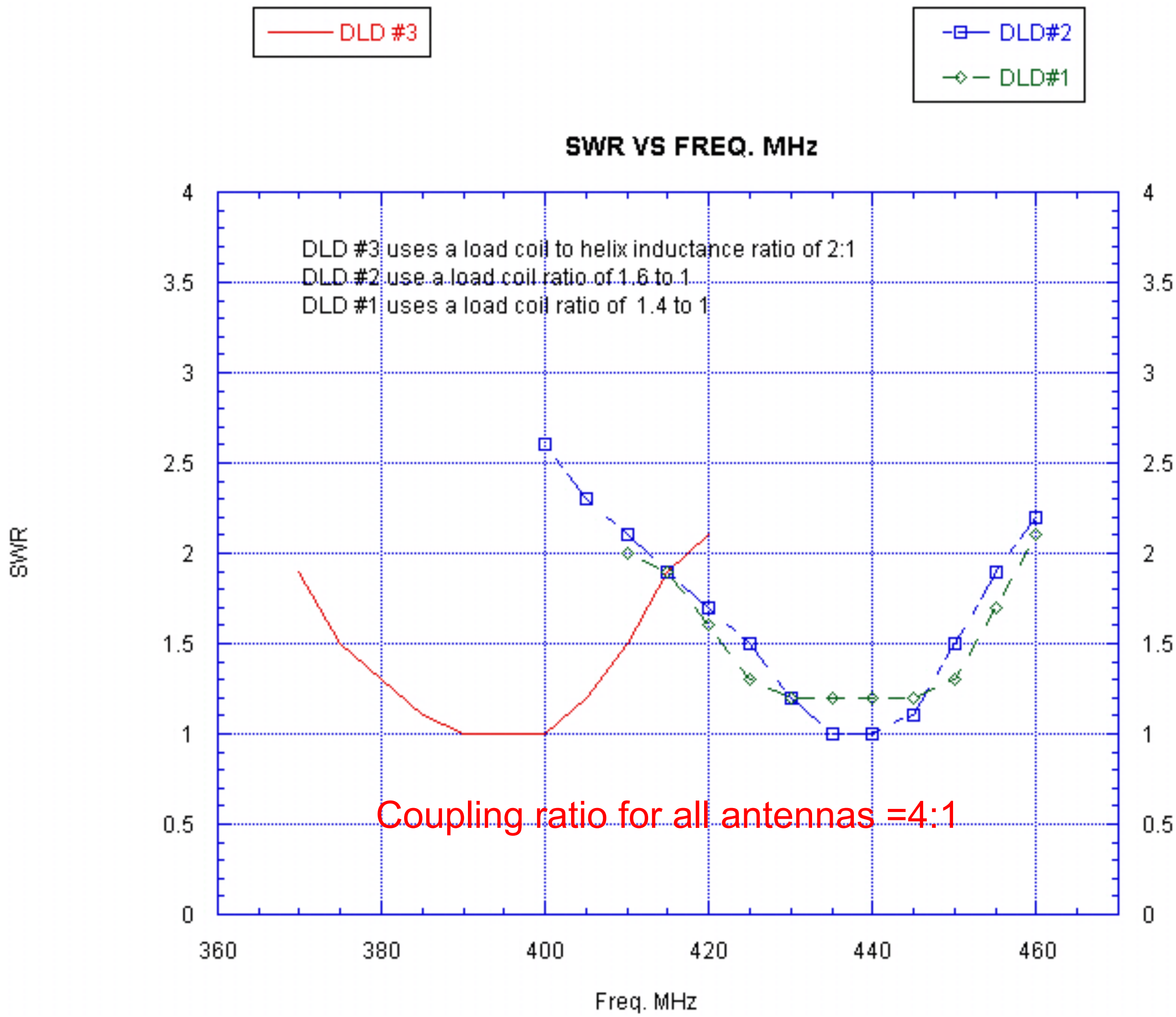
Measured Levels of selected Antennas




db DLD#1
db DLD #2
db DLD#3
Measured Field Intensity Reference to a Dipole
Level in db vs dipole
Freq. MHz
10
5
0
-5
-10
360
380
400
420
440
460



Field levels measured in respect to a full size standard dipole. This antenna Utilized slightly larger load coils with the new coupling system.


DLD #3
DLD#2
DLD#1
SWR VS FREQ. MHz
DLD #3 uses a load coil to helix inductance ratio of 2:1
DLD #2 use a load coil ratio of 1.6 to 1
DLD #1 uses a load coil ratio of 1.4 to 1
Coupling ratio for all antennas =4:1
SWR
Freq. MHz
0
0.5
1
1.5
2
2.5
3
3.5
4
360
380
400
420
440
460

Further Improvements

- Recent improvements to the coupling system have shown additional performance improvement.
- The improvements have been as outlined below.

• Radiation level.	+6 to 8dbv
• Bandwidth (2:1 SWR)	20 % of CF
• Size:	33% of FSD.
• Feed impedance	50 ohm coax.

New Coupling system with Monopoles

- Testing and development is currently underway for monopole DLM elements in both ground mounted over a radial system and elevated mounting with elevated radials.
- Results this far have been encouraging but continued testing and evaluation is underway.

Thank You

END OF PRESENTATION