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STIMULATED DIPOLE ANTENNA USING HFSS

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Abstract: The dipole antennas are commonly used for broadcasting, cellular phones, and wireless communications due to their omni directive property. Thus in this tutorial, a dipole antenna will be constructed and analyzed using the HFSS simulator. The example will illustrate both the simplicity and power of HFSS through construction and simulation of this antenna structure. HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator.

1. INTRODUCTION

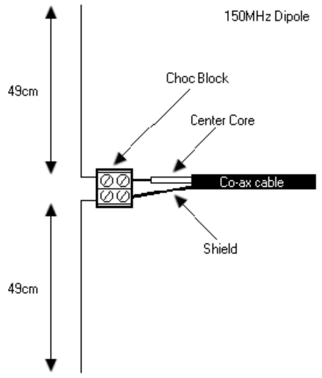
1.1 ABOUT HFSS – HIGH FREQUENCY STRUCTURAL SIMULATOR 13

HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University. Prof. Cendes and his brother Nicholas Csendes founded Ansoft and sold HFSS stand-alone under a 1989 marketing relationship with Hewlett-Packard, and bundled into Ansoft products.[1] After various business relationships over the period 1996-2006, H-P (which became Agilent EEsof EDA division) and Ansoft went their separate ways:[2] Agilent with the critically acclaimed[3] FEM Element and Ansoft with their HFSS products, respectively. Ansoft was later acquired by Ansys.

1.2 ABOUT DIPOLE ANTENNA

The monopole and dipole antennas are commonly used for broadcasting, cellular phones, and wireless communications due to their omnidirective property. Thus in this tutorial, a dipole antenna will be constructed and analyzed using the HFSS simulator. The example will illustrate both the simplicity and power of HFSS through construction and simulation of this antenna structure.

- General navigation of software menus, toolbars, and quick keys.
- Variable assignment.
- Overview of commands used to create structures.
- Proper design and implementation of boundaries.
- Analysis Setup.
- Report Creation and options.
- two rod elements is approximately 1/4 wavelength long, so the whole antenna is a half-wavelength long.



2.DESCRIPTON

2.1 DIPOLE CHARACTERISTICS

The directional characteristics are nothing but the radiation patterns of antennas. They indicate the distribution of radiation power in free space in different angular regions.
In other words, the radiation pattern of an antenna is a graphical representation of radiation as a function of direction. The radiation patterns of an antenna are of two types:

1. Field strength pattern
2. Power pattern.

The power pattern is proportional to the square of the field strength pattern. The patterns are plotted either in polar coordinates or in linear coordinates. The patterns represent far-field variation. They are presented in the form of the variation of absolute normalised field strength in dB as a function of θ.

2.2 FREQUENCY VERSUS LENGTH

Dipoles that are much smaller than the wavelength of the signal are called Hertzian, short, or infinitesimal dipoles. These have a very low radiation resistance and a high capacitive reactance, so they are inefficient antennas; though inefficient, they can be practical antennas for long wavelengths. Dipoles whose length is half the wavelength of the signal are called half-wave dipoles, and are more efficient. In general radio engineering, the term dipole usually means a half-wave dipole (center-fed).

A half-wave dipole is cut to length l for frequency f in hertz according to the formula

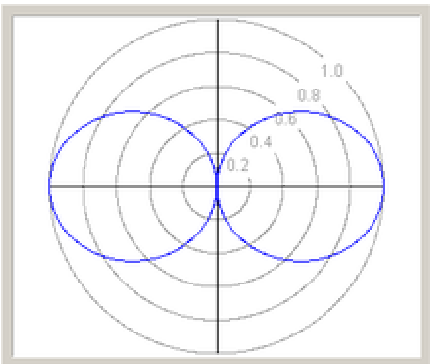
$$l = \frac{1}{2}\lambda_d = \frac{1}{2}k\lambda_0 = \frac{1}{2}k\frac{c}{f}$$

where λ_d is the wavelength on the dipole elements, λ_0 is the free-space wavelength, c is the speed of light in free space (299,792,458 metres per second (983,571,060 ft/s)), and k is an adjustment factor. The adjustment factor compensates for propagation speed being somewhat less than the speed of light. The dipole elements will have distributed inductance and capacitance. The value of k is typically 0.95. For thin wires (radius = 0.000001 wavelengths), k is approximately 0.981; for thick wires (radius = 0.01 wavelengths), k drops to about 0.915.

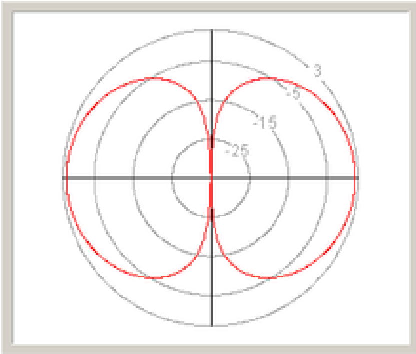
The above formula is often shortened to the length in metres = $143/f_{MHz}$ or the length in feet = $468/f_{MHz}$; f_{MHz} is the frequency in megahertz.

2.3 RADIATION PATTERN AND GAIN

Dipoles have a radiation pattern, shaped like a toroid (doughnut) symmetrical about the axis of the dipole. The radiation is maximum at right angles to the dipole, dropping off to zero on the antenna's axis. The theoretical maximum gain of a Hertzian dipole is 10 log 1.5 or 1.76 dBi. The maximum theoretical gain of a λ/2-dipole is 10 log 1.64 or 2.15 dBi.



Radiation pattern of a half-wave dipole antenna. The scale is linear.



Gain of a half-wave dipole (same as left). The scale is in dBi (decibels over isotropic).

3. FEEDING DIPOLE ANTENNA

A folded dipole has a central impedance of about 300 ohms. Therefore the simplest way of feeding a folded dipole antenna is using a 300-ohm ladder line. Ideally, a half-wave (λ/2) dipole should be fed with a balanced line matching the theoretical 73-ohm impedance of the antenna. A folded dipole uses a 300-ohm balanced feeder line. Many people have had success in feeding a dipole directly with a coaxial cable feed rather than a ladder-line[*citation needed*]. However, coax is not symmetrical and thus not a balanced feeder. It is unbalanced because the outer shield is connected to earth potential at the other end. When a balanced antenna such as a dipole is fed with an unbalanced feeder, common mode currents can cause the coax line to radiate in addition to the antenna itself,[10] and the radiation pattern may be asymmetrically distorted. This can be remedied with the use of a balun.

A dipole is a symmetrical antenna, as it is composed of two symmetrical ungrounded elements. Therefore it works best when fed by abalanced transmission line, such as a ladder line. This is because in that case the symmetry (one aspect of the impedance complex, which is a complex number) matches and therefore the power transfer is extremal.

When a dipole with an unbalanced feedline such as coaxial cable is used for transmitting, the shield side of the cable, in addition to the antenna, radiates.[10] This can induce RFcurrents into other electronic equipment near the radiating feedline, causing RF interference. Furthermore, the antenna is not as efficient as it could be because it is radiating closer to the ground and its radiation (and reception) pattern may be distorted asymmetrically. At higher frequencies, where the length of the dipole becomes significantly shorter than the diameter of the feeder coax, this becomes a more significant problem. To prevent this, dipoles fed by coaxial cables have a balun between the cable and the antenna, to convert the unbalanced signal provided by the coax to a balanced symmetrical signal for the antenna. Several types of baluns are commonly used to feed a dipole antenna: current baluns and coax baluns.

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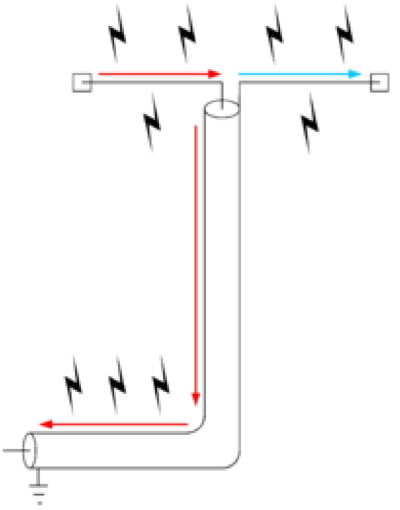
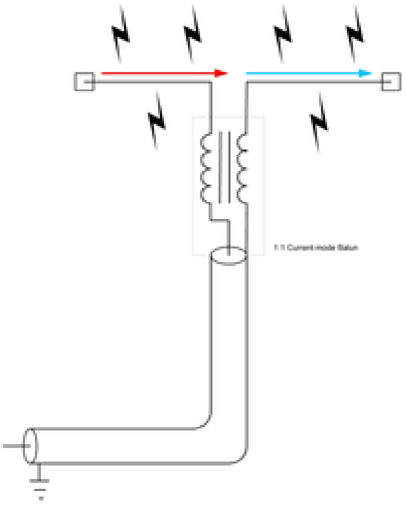
Baluns can be made using ferrite toroid cores or even from the coax feedline itself. The choice of the toroid core is crucial. A rule of thumb is: the more power the bigger the core.

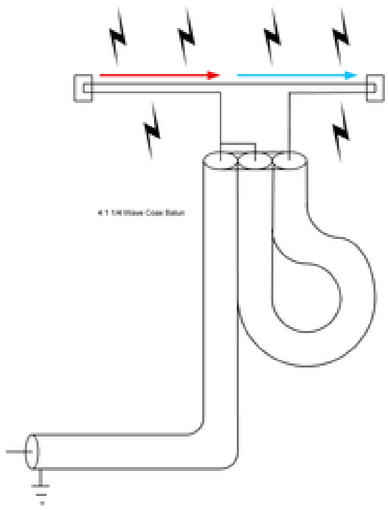
Feeding a Dipole Antenna with Coax Cable



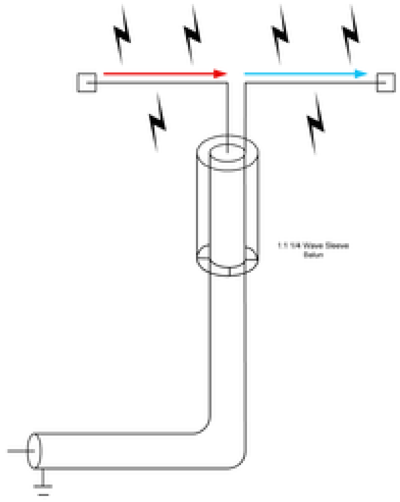
Coax and antenna both acting as radiators instead of only the antenna.



Dipole with a current balun.



A folded dipole (300Ω) to coax (75Ω) 4:1 balun.



Dipole using a sleeve balun.

3.1 CURRENT BALUN

A current balun consists of two windings that are closely coupled.

3.2 COAX BALUN

- A coax balun is a cost-effective method of eliminating feeder radiation, but is limited to a narrow set of operating frequencies.
- One easy way to make a balun is a ($\lambda/2$) length of coaxial cable. The inner core of the cable is linked at each end to one of the balanced connections for a feeder or dipole. One of these terminals should be connected to the inner core of the coaxial feeder. All three braids should be connected together. This then forms a 4:1 balun which works correctly at only a narrow band of frequencies.

3.3 SLEEVE BALUN

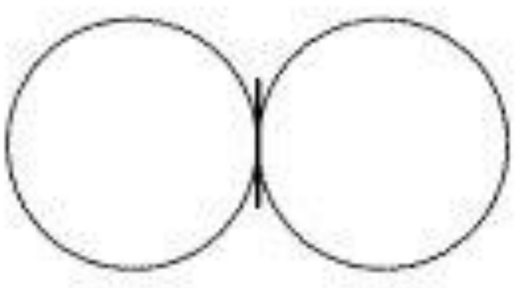
- At VHF frequencies, a sleeve balun can also be built to remove feeder radiation.[14]
- Another narrow band design is to use a $\lambda/4$ length of metal pipe. The coaxial cable is placed inside the pipe; at one end the braid is wired to the pipe while at the other end no connection is made to the pipe. The balanced end of this balun is at the end where the pipe is wired to the braid. The $\lambda/4$ conductor acts as a transformer converting the infinite impedance at the unconnected end into a zero impedance at the end connected to the braid. Hence any current entering the balun through the connection, which goes to the braid at the end with the connection to the pipe, will flow into the pipe. This balun design is impractical for low frequencies because of the long length of pipe that will be needed.

5. DIPOLE TYPES

5.1 SHORT DIPOLE

A short dipole is a physically feasible dipole formed by two conductors with a total length L very small compared with the wavelength λ. The two elements are fed at the center of the dipole. The current profile in each element, actually the tail end of a sinusoidal standing wave, is approximately a triangular distribution, declining linearly from a maximum at the center feed point to zero at the ends. At any instant the direction of the current is the same in both the dipole branches: to the right in both or to the left in both. The far field E_θ of the electromagnetic wave radiated by this dipole is

$$R_{\text{series}} = \frac{\pi}{6} Z_0 \left(\frac{L}{\lambda}\right)^2 \qquad \text{for } L \ll \lambda,$$



Radiation pattern of an elementary doublet, shown in profile.
Three-dimensional perspective of the radiation pattern of an elementary doublet.

Field strength is maximal in the plane perpendicular to the dipole axis, declining monotonically to zero on the antenna's axis. The 3 dimensional radiation pattern (right) of a vertical dipole is torus-shaped, with equal radiation in all horizontal directions.

Knowing the radiated electric field, we can compute the total emitted power and then compute the resistive part of the series impedance of this dipole due to the radiated field, known as the radiation resistance:

$$R_{\text{series}} \approx 20\pi^2 \left(\frac{L}{\lambda}\right)^2 \qquad \text{(in ohms).}$$

where is the impedance of free space. Using a common

approximation of ohms, we get

$$E_\theta = \frac{-iI_0 \sin\theta}{4\varepsilon_0 c r} \frac{L}{\lambda} e^{i(\omega t - kr)}.$$

Antenna gain

Gain of dipole antennas		
length **L** in	Gain	Gain(dBi)
0.1	1.50	1.76
0.5	**1.64**	**2.15**

Antenna gain, G, is the ratio of surface power radiated by the antenna to the surface power radiated by a hypothetical isotropic antenna:

$$G = \frac{(P/S)_{\text{ant}}}{(P/S)_{\text{iso}}}.$$

The surface power carried by an electromagnetic wave is

$$\left(\frac{P}{S}\right)_{\text{ant}} = \frac{1}{2} c \varepsilon_0 E_\theta^2 \simeq \frac{E_\theta^2}{240\pi},$$

while the surface power radiated by an isotropic antenna feed with the same power is

$$\left(\frac{P}{S}\right)_{\text{iso}} = \frac{\frac{1}{2}R_{\text{series}}I_0^2}{4\pi r^2}.$$

Combining these expressions with the far-field expression for E_θ for a short dipole gives

$$G = \frac{3}{2} = 1.76 \text{ dBi},$$

where dBi means decibels gain relative to an isotropic antenna.

5.2 HALF-WAVE DIPOLE

Typically a dipole antenna is formed by two quarter-wavelength conductors or elements placed back to back for a total length of L = λ/2. A standing wave on an element of length approximately λ/2 yields the greatest voltage differential, as one end of the element is at a node while the other is at an antinode of the wave. The larger the differential voltage, the greater the current between the elements.

The current distribution is assumed to be approximately sinusoidal along the length of the dipole, with a node at each end and an antinode in the center:

Gain of dipole antennas		
length **L** in	Gain	Gain(dBi)
0.1	1.50	1.76
0.5	**1.64**	**2.15**

5.3 IDEAL HALF – WAVE DIPOLE

This type of antenna is a special case where each wire is exactly one quarter of the wavelength, for a total of a half wavelength. The radiation resistance is about 73 ohms if wire diameter is ignored, making it easily matched to a coaxial transmission line. The directivity is a constant 1.64, or 2.15 dB. Actual gain will be slightly lower due to ohmic losses.

If the dipole is not driven at the center, then the feed point resistance will be higher. If the feed point is distance x from one end of a half wave (λ/2) dipole, the resistance will be described by the following equation.

If taken to the extreme then the feed point resistance of a λ/2 long rod is infinite, but it is possible to use a λ/2 pole as an aerial; the right way to drive it is to connect it to one terminal of a parallel LC resonant circuit. The other side of the circuit must be connected to the braid of a coaxial cable lead and the core of the coaxial cable can be connected part-way up the coil from the RF ground side. An alternative means of feeding this system is to use a second coil that is magnetically coupled to the coil attached to the aerial.

5.4 QUARTER WAVE MONOPOLE ANTENNA

The quarter-wave monopole antenna is a single-element antenna fed at one end, that behaves as a dipole antenna. It is formed by a conductor in length, fed in the lower end, which is near a conductive surface which works as a reflector (see effect of ground) and is an example of a Marconi antenna. The current in the reflected image has the same direction and phase as the current in the real antenna. The quarter-wave conductor and its image together form a half-wave dipole that radiates only in the upper half of space.

In this upper side of space, the emitted field has the same amplitude of the field radiated by a half-wave dipole fed with the same current. Therefore, the total emitted power is half the emitted power of a half-wave dipole fed with the same current. As the current is the same, the radiation resistance (real part of series impedance) will be half of the series impedance of a half-wave dipole. As the reactive part is also divided by 2, the impedance of a quarter-wave antenna is ohms. Since the fields above ground are the same as for the dipole, but only half the power is applied, the gain is twice (3dB over) that of a half-wave dipole ( ), that is, 5.14 dBi.

The earth can be used as ground plane, but it is a poor conductor. The reflected antenna image is only clear at glancing angles (far from the antenna). At these glancing angles, electromagnetic fields and radiation patterns are the same as for a half-wave dipole.

Naturally, the impedance of the earth is far inferior to that of a good conductor ground plane. This can be improved (at cost) by laying a copper mesh.

When ground is not available (such as in a vehicle) other metallic surfaces can serve as a ground plane (typically the vehicle's roof). Alternatively, radial wires placed at the base of the antenna can simulate a ground plane. For VHF bands, the radiating and ground plane elements can be constructed from rigid rods or tubes.

5.5 OTHER DIPOLE

- There is a variety of other important dipole antennas.
- The bow-tie antenna is a dipole with flaring, triangular shaped arms. The shape gives it a much wider bandwidth than an ordinary dipole. It is widely used in UHF television antennas.
- The G5RV Antenna is a dipole antenna with a symmetric feeder line, which also serves as a 1:1 impedance transformer allowing the transceiver to see the impedance of the antenna (it does not match the antenna to the 50-ohm transceiver. In fact the impedance will be somewhere around 90 ohms at the resonant frequency but significantly different at other frequencies).
- The Doublet Antenna is a dipole antenna with a resonant symmetric feeder line.
- The Sloper antenna is a slanted dipole antenna used for long-range communications or in limited space.
- The AS-2259 Antenna is an inverted-V dipole antenna used for NVIS communications.

8.1 ADVANTAGES

- A dipole antenna is a basic antenna that receives radio frequency, or RF, signals. It has the basic two-pole design that meets in the middle. According to Search Mobile Computing, it is balanced due to the antenna's symmetry, which is bilateral. Antennas are used in a variety of devices such as a radio, TV or cell phone. A dipole antenna is one of the antenna options available to pick up signals.
- Dipole antennas are naturally balanced antennas because they have a two-pole design. The balance allows the antenna to pick up signals from a variety of frequency types and minimizes problems relating to unbalanced signals or conflicting signals.
- Dipole antennas can move, which allows antennas to pick up more signals. Any dipole antenna can move horizontally, vertically and at a slant to pick up a wide variety of radio signals, which provides more options. For example, if listening to a radio, being able to change the antenna can help pick up signals that a stationary antenna cannot pick up.
- The basic dipole antenna has two equal metal poles which can move and adjust. There are also folded dipole antennas, which can adjust the lengths of the antenna poles so that they pick up more signals or stronger signal strength. The folded design allows the user to make further adjustments than the basic movements of the original dipole. Having more than one design allows for more options.

CONCLUSION

The progress in science & technology is a non-stop process. New things and new technology are being invented. As the technology grows day by day, we can imagine about the future in which thing we may occupy every place. The results show that simulation can be virtual and cost effective. Using this software accuracy of simulation and less processing time can be obtained.

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