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Written from memory 1/3/2024 edit. The concepts in this paper will not be found in any other text or paper.

Radiation resistance:

In resonant or anti-resonant antennas, the source is also the termination or load when the end is an open or shorted boundary. The power sent to the wire will be reflected and returned to the source using the same wire, where it will influence the apparent impedance.

Make a special note of the following resonant and anti resonant configurations:

In a <u>resonant</u> antenna, the return current is in phase with the applied current and accumulates until the loss due to radiation is equal to the applied power. The impedance decreases from the Zo of the wire, 437 Ohms for the radiation resistance of the ideal dipole, 73 Ohms at the steady state.

In an <u>anti-resonant</u> antenna, the return current is 180° out of phase with the source. <u>If the return is not impeded, it will block the current flow from the source entirely.</u> The loss due to radiation <u>limits</u> the <u>180° negative return</u>, effectively enabling current flow. This would be called negative resistance.

The absence of logical explanations regarding the similarities, differences, and properties of resonant and anti-resonant antenna concepts in textbooks is vague or nonexistent, resulting in confusion and poorly thought-out theories. This paper returns to an era of pencils, endless easers, and the slide rule. It may help to answer some contemporary conflicting and mistaken theories and opinions. There is no black magic; these concepts can be understood by the average amateur radio enthusiast using common mathematical concepts. The calculations and reasoning used in the following logic scripts will provide a comprehensive step-by-step set of calculations and explanations. The objective is to understand antenna and transmission line theory intuitively and calculate the properties of antennas without help from the software-based tool set.

The following material will be limited to antennas in free space undisturbed by environmental variables. This assures that the values rendered are consistent, accurate, verified, and unclouded by opinions. Environmental variables will be integrated after the fundamental concepts are made clear.

Building a foundation:

You have heard the expression "Angular acceleration" and tried to understand its meaning. It's much simpler than the black box theory that many assume we Hams will never understand. A good analogy would be inserting a satellite into orbit. Inserted at the right speed and angle, the acceleration toward the Earth due to gravity will equal the **angular acceleration** away from the Earth. It will accelerate toward Earth at precisely the same rate as it accelerates away from the planet. In the stable orbit, both have the same force. If either is varied, the orbit is compromised during the change. View the force of gravity as the electric potential and the force due to the rate of angular variation as the magnetic curl. A logical comparison in antenna theory would use the radian; the radius equals the angular acceleration of 57.29577951°. This value is used extensively throughout antenna and transmission line design and is called the wave number.

Radiation resistance:

Radiation Resistance is a fictitious and misleading definition based on what was once called common-law physics. The metric of Radiation Resistance is not resistance at all; it is a measure of the loss of voltage and current in a traveling wave per radian of angular acceleration. It presents no resistance to the Current or Voltage in the antenna wire; however, 2.60497297% of the current and voltage will be missing for each radian the linear wave travels from source to termination. This loss is also a measure of the *Displacement* *current,* the power that will appear in the ***Far Field.*** Measuring and calculating the displacement current can be done using a vintage experiment, which will be included later. The Poynting equations can determine how the power is distributed to the apertures.

QUICK CALCULATION OF RADIATION RESISTANCE for 1/4λ mono and 1/2λ CF antennas:
Resonant 1/4λ. Rr = (Z0/(1/2Bl))
Physical 1/4λ. Rr = (Z0/(1/2Bly)).
(1/2BLY) is Radiation Q.
(B = 1/6.283185307 = .159154549431) (2 • B = .3183098862) (l = Length/λ) (y = Scatter or VF of wire)
(1/2BL) is Radiation Q for resonant antennas
(1/2Bly) is the radiation Q for physical λ length.
Radiation resistance is = (Z0/Q).

PRECISE RADIATION Q:

The radiation Q for a 1/4λ resonant monopole is based on the number of radians the traveling wave passes from the source to the end and end to the source. This would total 3.14159265359 radians, 1.570796327rad outbound, and 1.570796327rad inbound returning to the source. The loss in voltage and current to radiation per radian per radian that occurs in a traveling wave is (1 - .9739502703 = .0260497297). The loss is not a resistance; it is simply power that never returns to the source. The loss is displacement current, which Maxwell defined to satisfy the current laws. The following logic script calculates the radiation Q for any length wire, including those shorter than 1/4λ.

EXAMPLE OF PRECISE RADIATION Q OF A RESONANT 1/4λ MONOPOLE:

.9739502703^3.14159265359 = .9204225284
1 - .9204225284 = .0795774716 This is the aggregated loss for 3.14159265359 radians.
(.0795774716 ÷ 3.14159265359 = .02533029593) The average loss per radian for 1/4λ resonant monopole.
(1 ÷ .0795774716 = 12.56637061) = Radiation Q for a resonant 1/4λ monopole.

ANCHOR MEDIA IMPEDANCE FOR ANTENNA THEORY:

The following calculation represents the media impedance of the anchor model used to calculate the Q and Rr for other wire diameters.

Diameter of 376.7303134r wire:
(157.48 ÷ .1389158617" diameter wire = 1133.635843
(Ln 1133.635843 = 7.033185307)
(7.033185307 - .75 = 6.283185307)
(6.283185307 • 59.95849161 = 376.7303135r) the surge impedance of the wire

NOTE: The contemporary 73r +j42 model is a derivative of the anchor values. It is simply a convenient, democratically selected derivative of the anchor model. It seems inappropriate to use a derivative for a base configuration to compare.
The equation for Radiation resistance is (Z0 ÷ Qr). The radiation resistance of the anchor 1/4λ resonant monopole. (376.7303135R ÷ 12.56637061Q = 29.9792458R +-j0). For the dipole, it would be 59.95849162R +-j0. 30 and 60 will be found in most or all other resonant or anti resonant antenna calculations. These anchor values are used for comparison calculations, not 73R, which is a derivative of the anchor; 73R was selected for convenience. If you are using software products to design antenna systems, model a dipole using a wire size of approximately .1389158617" in free space and compare the results with those in the above paragraph. It should become apparent that using 73r for an anchor model is an inappropriate common law selected value.

THE SURGE IMPEDANCE OF THE WIRE USED FOR THE IDEAL DIPOLE:

This value is not scientifically calculated. An influential group of advocates selected it as it is close to the wire size used by the telegraphers, .06". The wire used for the ideal dipole is #16 .0508".

Calculate the Zo of the ideal wire:

(Ln (4M/d) -75) • 59.95849159)

(4 Meters = 157.48") ÷ (The diameter of the wire.0508") = 3100

(Ln 3100 = 8.03915739) – .75 = 7.28915739 • 59.95849159 = 437r

CALCULATE THE Rr FOR THE RESONANT 1/4λ LENGTH MONOPOLE AND 1/2λ DIPOLE:

The calculation can be performed, and the concept can be understood with a meager electronic background. There is no mystery or black magic here.

.9739502703^3.14159265359 = .9204225284

1 - .9204225284 = .0795774716 This is the aggregated loss for 3.14159265359 radians.

(.0795774716 ÷ 3.14159265359 = .02533029593) The average loss per radian for 1/4λ resonant monopole.

Another average calculation method of proof (1 ÷ 6.283185307^2 = .02533029589).

(1 ÷ .0795774716 = 12.56637061) = Q

12.56637061 = The radiation Q for a resonant 1/4λ monopole

The radiation Q is used with the 437R *surge impedance* of the ideal antenna wire (437/12.56637061 = 34.77535508Rr) for the 1/4λ wire and x2, 69.55071016Rr for a 1/2wl resonant dipole.

This calculation method is used for any length antenna, including short antennas.

Shortcut calculation for the radiation resistance of a 1/2λ resonant dipole using a #16 wire:

(7.28915739 ÷ Rq 6.283185307 = 1.160105415)

1.160105415 • 59.95849159 = 69.60632492Rr

CALCULATE THE Rr FOR THE PHYSICAL 1/4λ LENGTH MONOPOLE AND 1/2λ DIPOLE:

(3.14159265359 • 1.0554 = 3.315636887) Add scatter or VF

(.9739502703^3.315636887 = .9162038936) Calculate the radiation Q

(1 - .9162038936 = .08379610639)

(1 ÷ .08379610639 = 11.9337287)

(437r ÷ 11.9337287 = 36.6188985r) Radiation resistance for #16 wire diameter .0508" monopole.

(36.6188985 • 2 =73.237797) Dipole.

CALCULATE THE REACTANCE OF PHYSICAL 1/4λ MONOPOLE and 1/2λ Dipole:

Tan – 92.77 = 20.66827922

437 ÷ 20.66827922 = +j21.14351153 Monopole

+j21.14351153 • 2 = +j42.28702306 Dipole

CALCULATE THE ANGLE:

42.28702306 ÷ 73.237797 = .5773934333

$\tan^{-1}$ .5773934333 = 30.00185481°

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VOLTAGE AND CURRENT CALCULATION METHOD FOR RADIATION RESISTANCE:

The wire used will be as for the ideal 1/2λ resonant center fed dipole in free space which has a diameter of .0508" and surge impedance of 437r.

The 1/2λ resonant dipole is a collinear array composed of two independent monopoles. The parameters of each monopole are calculated independently and then combined. 100 watts will be applied to this model, 50 watts to each.

Calculate the voltage and current applied to the wire to equal 50 watts:
(50v ÷ 437r = .114416476) ($.114416476^{.5}$ = .3382550458a) (.3382550458a • 437r = 147.817455v) (147.817455v • .3382550458a =50.000) watts.

Calculate the radiation Q:
The traveling wave from the source to the end and return to the source for an electrical 1/4λ will be 1.570796327 radians outbound and 1.570796327 inbound for 3.14159265359 radians.

(.9739502703^3.14159265359 = .9204225284)
(1 - .9204225284 = .0795774716)
(1 ÷ .0795774716 = 12.56637061) The radiation Q
($12.56637061^{.5}$ = 3.544907701) The square root of the radiation Q

Calculate the voltages and currents for each monopole:
(147.817455v ÷ 3.544907701 = 41.6985342v)
(.3382550458a • 3.544907701 = 1.199082917a)
(41.6985342v • 1.199082917a = 50.000000 watts
(41.6985342v ÷ 1.199082917a = 34.77535507r)

Calculate the voltages and currents for the dipole:
(34.77535507r • 2 = 69.55071014r)
(69.55071014r • 1.199082917a = 83.3970684v)
(83.3970684v • 1.199082917a = 100w)

The voltage at the end of each leg.
(147.817455v • 3.544907701 = 523.9992346v

THE 1/2λ END FED ANTI RESONANT ANTENNA:

(6.283185307 • 1.052421542 = 6.612559431)
(.97395027031^6.612559431 = .8398443265)
(1 - .8398443265 = .1601556735)
(1 ÷ .1601556735 = 6.243924915) TheRadiation Q

(437 ÷ 6.243924915 = 69.98802932) Rr
(437 • 6.243924915 =2728) -Rr Anti resistant.
Tan 185.242152 = .09192496841

(.09192496841 • 6.243924915 = .5739726006) Eulers constant.
($\tan^{-1}$ .5739726006 = 29.8546431°
(tan 185.242152 = .09174896347)
(437 ÷ .09174896347 = -j4762)
(2728 ÷-j4762 = .5728685426) again Eulers constant.
($\tan^{-1}$ .5728685426 = 29.80703824°)

CONCLUSION: The 1/2λ end fed monopole properties in free space and ignoring wire resistance are 2728 Rr, -j4762, 29.8°. This represents the power provided to the antenna.
100 Watts will require 522.3v @.1914598953a.

THE TERMINATED NON-RESONANT ANTENNA:

The power handling parameters for the terminating resistors are calculated as follows.
Calculate the number of radians the traveling wave will travel to the terminators. (4λ • 6.283185307 = 25.1327423 radians)
(.9739502703^25.13274123 = .5151075566) This is 51.51075566% of the applied voltage and current that will reach the terminating resistor, and (1 - .5151075552 = .4848924448) will be the loss of the applied voltage and current due to radiation, representing displacement current. Using these percentages, the power handling value of the terminator can be calculated. 51.5107552% of the applied power will reach the terminating resistors.

In a 1/4λ resonant monopole, the source connection is the destination or load point using the same wire for both. The outbound and returning traveling waves radiate. They are linear waves that pass each other, exerting no influence on the ability of either to radiate. Standing waves are present but have nothing to do with radiation; they are stationary and represent the sum of the outbound and inbound voltage and current at points along the wire.