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Antenna Suspects

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Updated article version

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Introduction

url: http://www.radiohamtech.com/page27.html
url: http://www.radiohamtech.com/page20.html

First thought, we start by asking the question, "what is the inductance of one metre of wire", is a fair question, but how do we find this answer.

The trick here is to use the equation for the "characteristic impedance of a transmission line", namely:-

Cable impedance = SQR(inductance / capacitance)

We know that the impedance is 50ohms, and the capacitance per metre is 100pF / m, 'RG58C/U', the inductance per metre calculates out as :

50^2 * 100pF = 250nH / metre

The next question, as the wire is one metre in length, and the full wavelength of 300MHz is one metre, what is then the inductive reactance to the one metre wire to a 300MHz carrier.

Inductive reactance = 2 * PI * F * inductance

XL = 2 * PI * 300MHz * 250nH

XL = 471 ohms

If the full wave antenna induces into it a 5 Volt EMF signal, then what is the RF signal power.

The contents worded here, is my own handy work. To date I have not found any other periodical that has shown anything similar towards these contents, contained within this article type booklet.

The calculation methodology shown here, of antenna designs, is through my own understandings.

RF signal power

Our next question is how to do calculate the RF signal power induced into an antenna.

This can be achieved by measuring the voltage across the antenna load.

$$power = voltage ^2 / resistance$$

But first, how do you prove the power equation is correct.

An alternative power equation is :- power = volts * current

First consider "ohms Law", which equates to as :- Volts = current * resistance

However, measuring current in an RF signal is not so easy. By using "ohms Law", the current component can be replaced as follows:

$$Current = volts / resistance$$

Now place this into the equation :- power = volts * current,

The following results :   power = volts * (volts / resistance)

When the above equations are merged, the following given equation is

$$power = (volts * volts) / resistance$$

Looking back at our full wave wire antenna, the RF signal power of the induced 5 Volts can then be calculated.

$$power = (5 * 5) / 50$$

$$power = \tfrac{1}{2} \text{ Watts, or } 0{\cdot}5 \text{ Watts}$$

Using this above equation, the RF signal power can be calculated by just measuring the RF voltage and with a known terminal impedance of the RF loading, namely the Radio itself, or using a Nano Spectrum Analyser.

In order to determine the effectiveness of an antenna design, this article compares several antenna methods to a full wavelength antenna transmission or reception.

Stub Antenna's

Now this is fine so far, but then a 50ohm stub antenna would have a 50ohm inductive reactance, if so, then what is the length of a 50ohm stub at 300MHz.

Remember, referencing to the full wave wire antenna impedance of 471 ohms, also there are 100cm in one metre length.

Thus, to find out :- (50 / 471) * 100cm = 10·6cm

Now the 10·6cm long in length 50ohm stub antenna, what is the signal pick up, when compared to a full wavelength one metre 300MHz long wire, however it need not be a 300MHZ example shown here.

It could instead be 30MHz or the 10m band, thus then the 50ohm stub for the 10m band is 106cm. For the 2m band, then the length is 21·9cm (145MHz) for the 50ohm stub, while for the 70cm band, the 50ohm stub antenna is 7·3cm (435MHz) in length.

It may be perhaps that a smaller wire would pick up (or induce) a lesser signal, where as a longer wire may receive (or induce) a bigger signal, from the etha signal, the etha signal the induction voltage from electromagnetic field strength of the radio signal within the air, i.e. the etha.

Assuming that full wave 471ohm impedance is matched to a 50ohm load, then the induced RF voltage into the full wave antenna is 5 volts would be presented to the radio terminal input of 50ohms.

However, how much of the RF signal is induced into or from an 50ohm stub antenna, that is now only 10·6% of the length of the original full wave antenna wire or element.

By the same principle, the 50ohm stub received signal is :

(50/471) * 5 = 530mV

The 50ohm stub antenna as one can see here in this example, only picks up or send out 443mV of the signal, too and from the “etha” (the surrounding air). Remember, what happens to a Rx antenna, happens to an Tx antenna.

The 50ohm stub signal power equates to:

power = (530mV * 530mV) / 50

power = 5·6mW

The equate the 50ohm stub antenna design into suspect numbers, using “LOG to the base of ten”,

$$dB = 10 * Log(5{\cdot}6mW / 0{\cdot}5 \text{ Watt})$$

$$dB = -19{\cdot}5$$

Now perhaps an idea to improve the 50ohm stub antenna design, would be to double up on the stub antenna design, say two 50ohm stubs, one on top of the other in a line.

The 50ohm stub antenna would thus become a 100ohm stub antenna, a double side stub antenna, what would this give us Radio Hams if a 100ohm stub design were used for an antenna with our radios.

By the same principle, the 100ohm stub received signal is :

$$(100/471) * 5 = 1V$$

The 100ohm stub signal power equates to:

$$power = (1V * 1V) / 50$$

$$power = 20mW$$

The equate the 100ohm stub antenna design signal performance:

$$dB = 10 * Log(20mW / 0{\cdot}5 \text{ Watt})$$

$$dB = -13{\cdot}9 \text{ dB, or a } 13{\cdot}9 \text{ dB loss}$$

Half wave dipole

A half wave dipole is constructed from two quarter wave sections. A full wave wire is 471ohms, so a quarter wave section would be :

quarter wave section "XL" = 471 /4 = 117·75 ohms

As each radiating element on each side of a coax, as a dipole would be, is effectively in parallel. The principle that both of the117·75ohm ¼ wave sections, are supplying a current source to the cable 50ohm terminal impedance.

If both quarter wave sections were attached to a coax, then each side would be 117·75ohms. The coax would then see:

coax load = 117·75 / 2 = 58 ohms,

Which would then equate to the 58ohms (or 75ohms) the books say.

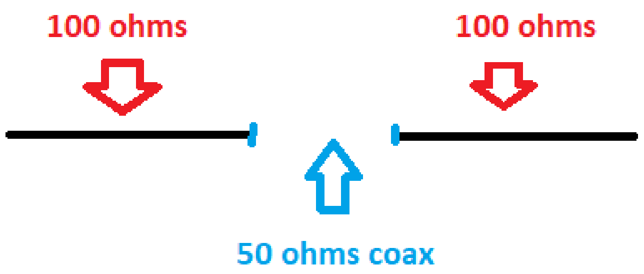
For a 50ohm coax load, each side of the dipole would need to 100ohms.

Now the true quarter wave is 117·75ohms, so the trim for a 50ohm dipole quarter wave would then be as such:

50ohm dipole quarter wavelength = 100 / 117·75 = 85% overall.

The knocking off 5%, just became a 15% trim off the true quarter wave wire.

As it happens, a 50ohm dipole each side has an inductive reactance of 100 ohms for each dipole element, which seems to equate in essence two 100ohm stub antennas on top of each other.



50 ohms dipole

As each side of the 50ohm dipole is 100ohms, the total inductive reactance is 200ohms, both sides added together.

Well things work as such, by the following:

signal pickup of the 50ohm dipole = (200 / 471) * 5 = 2·1Volts.

Now convert this into signal power of Watts, remember power = V^2 / R

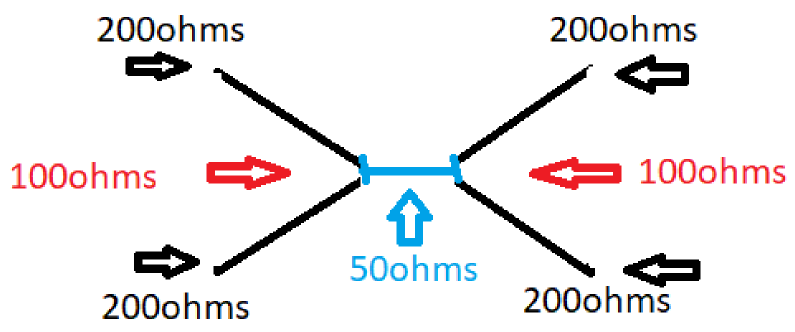
thus, the power dipole (50ohms) = (2·1 * 2·1) / 50 = 88mW

dB gain = 10 *Log (88mW / 0.5 Watts)

dB gain = -7·5dB, or a 7·5dB loss

Cross dipole

Now for a 50ohms cross dipole, each side element is 200ohms, thus each has two 200ohms elements positioned sideways in a "V" shape, effectively with each side a "V" shape antenna element, equalling out to 100ohms load each side to a cable connection of 50ohms.



Cross dipole elements reactances

As each side of the "V" shape element has two 200ohms elements, equating with both sides to any overall 4 elements, each element of 200 ohms, then totals to an overall 800ohms inductive reactance used for the cross-dipole design.

Signal pickup of a cross 50ohm dipole = (800 / 471) * 5 = 8·5Volts.

Thus, the RF signal power from the 50ohm cross dipole design:

power = (8·5 * 8·5) / 50 = 1·4 Watts

dB gain = 10 *Log (1·4 Watts / 0·5 Watts) dB gain = 4·5dB for a cross element dipole

Between the standard 50ohm standard dipole (7·5dB loss) and the 50ohm cross dipole (4·5dB gain), there is a 12dB difference.

12dB overall difference = 7·5dB loss + 4·5dB gain

Now this bit of the article booklet is just theoretical, but, if your beam has a 10·5dB gain over a dipole, with the dipole 7·5dB calculation loss, the beam could be a 3dB gain over a full wave vertical or wire.

However, the dipole still has a 10·5dB gain, but this signal gain is over and above the standard dipole design, hence than the beam antenna is a reference gain of 10·5dB(dipole).

Replace the 50ohm dipole with a 50ohm cross dipole, the beam of a 10·5dB over a dipole, despite the dipole losses, would then be a 10·5dB + 4·5dB of the "cross dipole", equating to a near 15dB gain over a full wave vertical, as an emf voltage within the etha.

Equates as : 10^(15/10) = 31 times power improvement of concentrated signal, or as a signal voltage improvement, 10^(15/20) = 5·6 times voltage :

equates to as V^2/R = (5.6 * 5.6) / 1 = 31 times.

(the "1" is a normalised magnitude value of 50hms)

In essence, a 15dB signal improvement upon the receiver input from the antenna, or a near 2 - 3 "S points" improvement.

One could try swapping their 50ohm dipole on their beam antenna for a 50ohm cross dipole version

To be sure to here, one must go by one's own experience regarding beam antennas.

By the way, a 31 times direction concentration is 10Watts radio, equates the antenna signal of 310 Watts ERP.

A 100Watt radio would elevate this to 3100 Watts ERP.

Beware please !.

Antenna design inductances

You may perhaps remember from the start of the article, that the length of a one metre was around 0·25uH (250nH) overall.

To calculate the antenna elements inductance, follow the below example.

For an example, the length of the 10m 50ohm telescopic stub antenna was 106cm, also there are 100cm to one metre of wire antenna.

The inductance of the 10m 50ohm telescopic stub antenna is:

$$(106 / 100) * 250\text{nH} = 265\text{nH} \text{ or } 0{\cdot}265\text{uH}$$

Now if one is building one's own 10m “walkie talkie”, then it could perhaps be possible to replace the 106cm wire whip for a 265nH inductor.

Now the thought of how this is, is a fair question, monitoring the bands I have noticed some asking the same question to fellow hams. The best answer I can offer, is the following.

The antenna radiation, of the current lobe, is compressed into the length of the coiled 265nH inductor, instead of the current lobe radiation current being spread over the 106cm antenna whip.

As the inductor is a compressed magnetic field, thus a concentrated magnetic field, so this may well be the answer to why I think that the inductor sized 50ohm stub antenna would still function, bearing in mind that the 106cm wire whip, is a long wire inductor by comparison.

Also bear in mind that a medium or long wave radio, uses a pickup coil that is wound around a ferrite rod, the ferrite rod to boost the coil inductance value of the pickup coil, then the coil inductance tuned by a variable capacitor, for medium and long wave broadcast reception.

An air spaced coil would do similar, both for reception and transmission.

In question, the tuned medium wave coil for medium wave reception, is in essence a parallel tuned LC circuit. This with one end of the LC circuit grounded, while the top live end has a high impedance at resonance.

Although the live top end high impedance this is dependent upon the dynamic resistance of the LC tuned circuit, the parallel tuned LC circuit is in essence a ¼ wave coax cable section in lumped component form.

Dipole antenna load coils for 80m / 40m band operation.

Now here is one trick to think off.

If one were to replace the dipole elements with an inductor, what would occur.

To construct an 80m dipole, remembering that each side section of a 50ohm dipole is 100ohms reactance:

$$(100 / 471) \quad * \quad 80m \quad * \quad 0{\cdot}25uH/m \quad = \quad 17uH$$

For the 80m band 50ohm dipole, each element equates to 17uH in value.

An interesting thought though, a switching relay circuit system could be used to switch from the 80m (17uH load coil) to the 40m band (8·5uH load coil), using band switching relays.

If the loft (attic), has only limited space to hand, then even replacing some of the dipole wire with a coil inductance, would be helpful.

300ohm coax Dipole

Likewise, if the design is for a 300ohm ribbon cable dipole, then each side of the 300ohm dipole would be a 600ohms inductive reactance, a total of 1200 ohms.

Over a full wave wire,

$$1200 / 471 = 255\%,$$

The 300ohm coax cable dipole is 255% greater than a full wave wire within its signal capability.

Referring for a check, as each side is 600 ohms, the total inductive reactance used is 600 * 2 = 1200 ohms

The antenna performance equates as :

$$(1200 / 471) * 5 = 12{\cdot}7 \text{ Volts}$$

$$\text{power} = (12{\cdot}7 * 12{\cdot}7) / 50$$

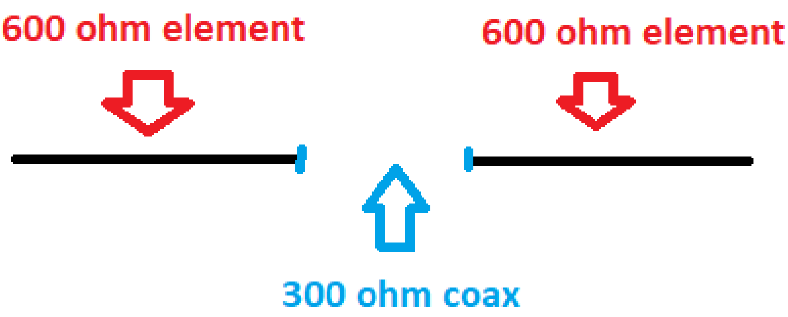
$$\text{power} = 3{\cdot}2 \text{ Watts}$$

Completing the antenna performance calculation:

$$\text{dB gain} = 10 * \text{Log} (3{\cdot}2 \text{ Watts} / 0{\cdot}5 \text{ Watts})$$

$$\text{dB gain} = 8\text{dB overall}$$

This means that a 300ohm coax dipole has basically a 8dB advantage over a full wave long wire antenna. For a 100Watt transmitter, this is 630 Watts, or there about and 8dBm increase in the receiver's sensitivity, equates to as one and bit ‘s’ points.



300 ohm dipole

For a lumped component 300ohm coax standard dipole design, with each side of the 300ohm dipole just an inductance coil, at an antenna boost of 8dB overall, or 6 times Tx power.

A 100 Watt Tx would seem as a 600Watt Tx overall output.

Dipole : band wavelength * (600 ohms / 471 ohms) * 250nH = load coil for 300ohms dipole lump component element

160m dipole load coil element = 51uH

80m dipole load coil element = 25·5uH

60m dipole load coil element = 19uH

40m dipole load coil element = 12·7uH

17m dipole load coil element = 5·4uH

15m dipole load coil element = 4·8uH

12m dipole load coil element = 3·8uH

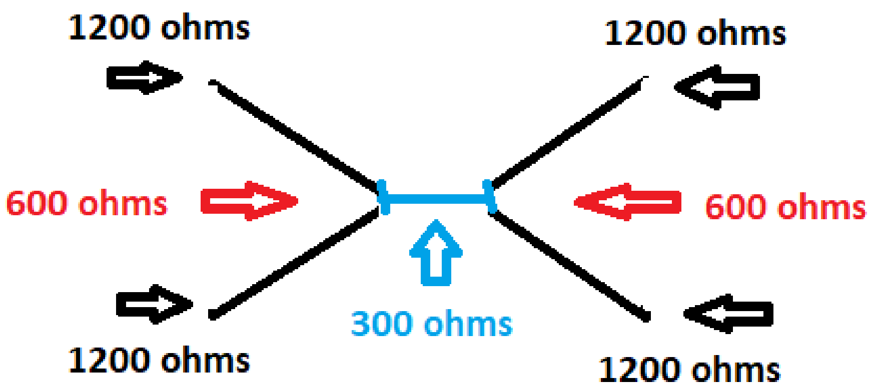
10m dipole load coil element = 3·2uH

6m dipole load coil element = 1·9uH

4m dipole load coil element = 1·3uH

With the feed point at 300ohms, then a 300ohm to 50ohm balun could be used to impedance match a 50ohm coax cable. For multi band use, remote switch the loading coils.

If should the dipole design be a **300ohm cross dipole design,** then each element of the cross section would be 1200 ohms. The overall total inductive reactance used for a 300ohm cross dipole, would be 4 * 1200 ohms, equating thus to 4800 ohms overall.



300ohm cross dipole emelents

Effective change of accumulated induced RF signal voltage of a 300ohm ribbon cross dipole design:

4800 / 471 = 10·2 times greater

The induced voltage reference to the full wave 5 Volts, equates to :

(4800 / 471) * 5 = 51 Volts

The RF signal power of the 300ohm cross dipole reception is thus :

power = (51 * 51) / 50

power = 52 Watts

Completing the 300ohms cross dipole antenna performance calculation:

dB gain = 10 * Log (52Watts / 0·5 Watts)

dB gain = 20·2 dB overall

This equates also to a 20dB signal improvement upon the receiver, or a near ‘3 – 4’ “S point” improvement of the radio performance both Tx and Rx wise.

Cross : band wavelength * (1200 / 471) * 250nH = load coil dipole lump element

160m dipole load coil element = 101uH

80m dipole load coil element = 51uH

60m dipole load coil element = 38uH

40m dipole load coil element = 25·4uH

17m dipole load coil element = 10·8uH

15m dipole load coil element = 9·6uH

12m dipole load coil element = 7·6uH

10m dipole load coil element = 6·4uH

6m dipole load coil element = 3·8uH

4m dipole load coil element = 2·5uH

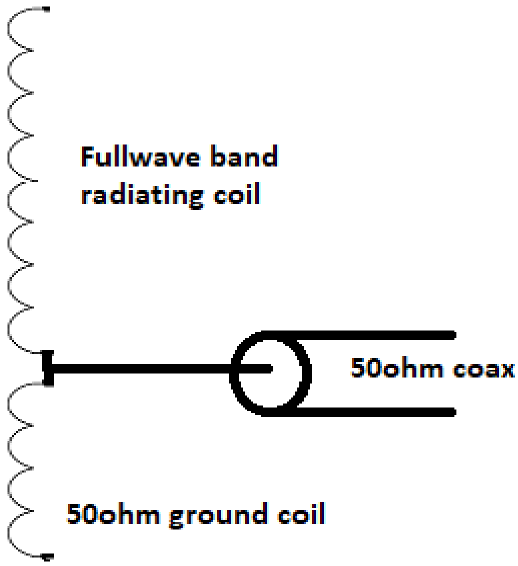
A 10Watt qrp radio with a 300ohm cross dipole, would seem as 1KW transmitter output.

A 100Watt radio, running as they say as “bare foot”, with a 300ohm cross dipole, would seem as 10KW transmitter output.

Be careful as to the band plan ERP limits for your ham radio licence.

Lumped Component coiled vertical antenna

View the below diagram:



The top coil used as the radiating element, inductance reactance of 471ohms, but may be a multiple of wavelengths of extra signal gain. The grounding coil is used to impedance match the radiating coil to the 50ohm coax, as well as the radio itself.

For the 80m band, the full wave load coil inductance :

80m * 0·25uH/m = 20uH "40m band, 40uH load coil"

The 80m 50ohm ground loading coil inductance :

(50 / 471) * 20uH = 2·1uH "40m band, 4·2uH ground coil"

The principle here, the vertical antenna is full wavelength, thus the radiating coil would have a full electromagnetic connection to the surrounding etha. The full wave coil would in thought have a purposeful "1:1" turns ratio connection to the etha.

However, the insertion loss between the antenna and the etha, is based on the idea of a weak "B/H" magnetic curve of the etha environment. The "B/H" curve losses, magnetic saturation of the ferrite core, would be on top of any other propagation losses.

The antenna design is essentially off-centred dipole, replacing a wire inductance radiating element, by coiled inductance radiating elements.