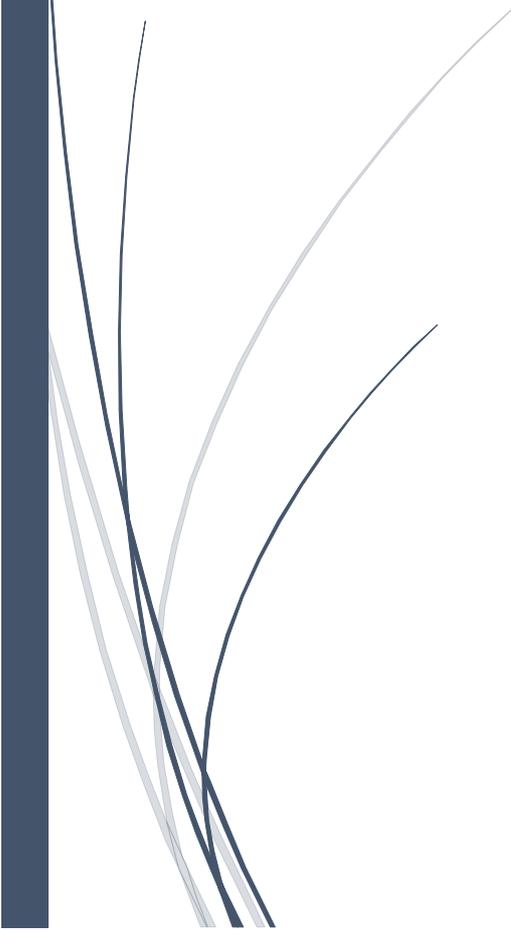


7th October 2020

Antenna Suspects



Alastair John Underwood, GW0AJU

Index

Page

1	Index
2	Introduction
3	RF signal power
4	Stub Antenna's
6	Half wave dipoles
8	Antenna inductances
9	Antenna load coils
10	300ohm Dipole
12	Antenna loading coil for a 300ohm ribbon fed dipole
14	Lumped Component coiled vertical antenna
15	Antenna Path Ratios

Introduction

url: <http://www.radiohamtech.com/page27.html>

url: <http://www.radiohamtech.com/page20.html>

Ok, now I have mentioned that a 50ohm stub antenna has a -20dB gain figure, or a loss of 20dB.

Now why so ?

First thought, we start by asking the question, “what is the inductance of one metre of wire”, fair question, but how does one find out so.

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

$$\text{Cable impedance} = \text{SQR}(\text{ inductance} / \text{ capacitance})$$

We know that the impedance is 50ohms, and the capacitance per metre is 120pF, thus the inductance per metre calculates out as :

$$50^2 * 120\text{pF} = 300\text{nH} / \text{metre}$$

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.

$$\text{Inductive reactance} = 2 * \text{PI} * \text{F} * \text{ inductance}$$

$$\text{XL} = 2 * \text{PI} * 300\text{MHz} * 300\text{nH}$$

$$\text{XL} = 565 \text{ ohms}$$

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.

$$\text{power} = \text{voltage}^2 / \text{resistance}$$

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

An alternative power equation is :- $\text{power} = \text{volts} * \text{current}$

First consider “ohms Law”, which equates to as :- $\text{Volts} = \text{current} * \text{resistance}$

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

$$\text{Current} = \text{volts} / \text{resistance}$$

Now place this into the equation :- $\text{power} = \text{volts} * \text{current}$,

The following results : $\text{power} = \text{volts} * (\text{volts} / \text{resistance})$

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

$$\text{power} = (\text{volts} * \text{volts}) / \text{resistance}$$

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

$$\text{power} = (5 * 5) / 50$$

$$\text{power} = \frac{1}{2} \text{ Watts, or } 0.5 \text{ Watts}$$

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.

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 565 ohms, also there are 100cm in one metre length.

Thus, to find out :- $(50/565) * 100\text{cm} = 8.85\text{cm}$

Now the 8.85cm 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 88.5cm. For the 2m band, then the length is 17.7cm for the 50ohm stub, while for the 70cm band, the 50ohm stub antenna is 6.2cm 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 565ohm 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.

However, how much of the RF signal is induced into or from an 50ohm stub antenna, that is now only 8.85% of the length of the original full wave antenna wire or element.

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

$$(50/565) * 5 = 442\text{mV}$$

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:

$$\text{power} = (442\text{mV} * 442\text{mV}) / 50$$

$$\text{power} = 4\text{mW}$$

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

$$\text{dB} = 10 * \text{Log}(4\text{mW} / 0.5 \text{ Watt})$$

$$\text{dB} = -20.9$$

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, so 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 :

$$(100/565) * 5 = 884\text{mV}$$

The 100ohm stub signal power equates to:

$$\text{power} = (884\text{mV} * 884\text{mV}) / 50$$

$$\text{power} = 14.9 \text{ mW}$$

The equate the 100ohm stub antenna design signal performance:

$$\text{dB} = 10 * \text{Log}(14.9 \text{ mW} / 0.5 \text{ Watt})$$

$$\text{dB} = -15.2 \text{ dB}$$

Half wave dipole

A half wave dipole is made from two quarter wave sections. A full wave wire is 565ohms, so a quarter wave section would be :

$$\text{quarter wave section "XL"} = 565 / 4 = 141 \text{ ohms}$$

As each radiating element on each side of a coax, as a dipole would be, is effectively in parallel.

If both quarter wave sections were attached to a coax, then each side would be 141ohms. The coax would then see:

$$\text{coax load} = 141 / 2 = 70 \text{ ohms,}$$

Which would then equate to the 70ohms (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 141ohms, so the trim for a 50ohm dipole quarter wave would then be as such:

$$50\text{ohm dipole quarter wave trim to length} = 100 / 141 = 70\% \text{ overall.}$$

The knocking off 5%, just became a 30% 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 two 50ohm stub antennas on top of each other.

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:

$$\text{signal pickup of the 50ohm dipole} = (200 / 565) * 5 = 1.7 \text{ Volts.}$$

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

$$\text{thus, the power dipole (50ohms)} = (1.7 * 1.7) / 50 = 58\text{mW}$$

$$\text{dB gain} = 10 * \text{Log} (58\text{mW} / 0.5 \text{ Watts})$$

$$\text{dB gain} = -9.4\text{dB}$$

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.

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

Signal pickup of a cross 50ohm dipole = (800 / 565) * 5 = 7Volts.

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

$$\text{power} = (7 * 7) / 50 = 980\text{mW or } 0.98 \text{ Watts}$$

$$\text{dB gain} = 10 * \text{Log} (0.98\text{Watts} / 0.5 \text{ Watts})$$

$$\text{dB gain} = 2.9\text{dB in round numbers}$$

Between the standard 50ohm dipole and the 50ohm cross dipole, there is a 12dB difference.

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 9dB calculation loss, the beam could be a 1.5dB gain over a full wave vertical.

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 + 2.9dB “cross dipole”, equating to a near 13.4dB gain over a full wave vertical.

This equates to a 22 times gain boost, over the transmitter output or the receivers signal reception.

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.

Antenna inductance

You may perhaps remember from the start of the article, that the length of a one metre was around the 300nH mark, or 0.3uH overall.

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

The length of the 10m 50ohm stub was 88.5cm, also there are 100cm to one metre of wire antenna.

therefore, the inductance of the 10m 50ohm stub antenna is:

$$(88.5 / 100) * 300\text{nH} = 265\text{nH} \text{ or } 0.265\text{uH}$$

Now if one is building one's own 10m “walkie talkie”, then replace the 88.5cm wire whip for a 265nH inductor.

Now the thought of how this, 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 radiation current being spread over the 88.5cm antenna whip.

As the inductor is a compressed magnetic field in any case, this may well be the answer to why I think that the inductor sized 50ohm stub antenna would still function, being in mind that the 88.5cm wire whip, is a long wire inductor.

Antenna load coils

Now here is one trick to think off.

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

Should one wish to construct an 80m dipole, each side would then be 14.2m in length, or 28.4m overall, or a 4.2uH of inductance for each side element of the dipole, remembering that the inductive reactance of each element of a 50ohm dipole equals 100ohms:

$$(100 / 565) * 80m * 0.3uH/m = 4.2uH$$

For the 80m band 50ohm dipole, each element equates to 4.2uH in value.

If the loft has only 6metres of space to hand, then replacing some of the dipole wire with an inductance would be helpful.

Reducing the 14.2m dipole element to just 1.4m would be nice to do. The load inductance for the dipole displacement coils, could then be calculated.

Load coil inductance, (displacement coil)

$$14.2m - 1.4m = 12.8m$$

Which then calculates the load coil inductance to as:

$$12.8m * 300nH$$

$$\text{Load coil inductance} = 3.84uH, \text{ or } 3.8uH \text{ to round up.}$$

By placing the load coil on both sides of the 80m dipole, the overall length of the 80m dipole could be kept down to 2.8m overall, to fit a 6m length loft area.

An interesting thought though, a switching relay circuit system could be used to switch from the 80m 3.8uH load coil, to a 1.7uH load coil for the 40m band.

300ohm Dipole

Likewise, if the design is for a 300ohm ribbon cable dipole, then each side of the 300ohm dipole would be 600ohms, for the very same reasons, in other words, each radiating element of a dipole antenna, would be 600ohm inductive reactance.

Thus, is being so, what would be the accumulated induced voltage compared to the full wave wire antenna. Effective change of accumulated induced RF signal voltage of a 300ohm ribbon dipole design:

$$600 / 565 = 106\%,$$

The induced RF signal voltage would just 6% greater than a full wave antenna wire, but also the dimensions of 300ohm dipole, each side of the 300ohm dipole is also just 6% greater than a full wave wire antenna.

However, as each side is 600 ohms, the total inductive reactance used is $600 * 2 = 1200$ ohms

The antenna performance equates to as :

$$(1200 / 565) * 5 = 10.6 \text{ Volts}$$

$$\text{power} = (10.6 * 10.6) / 50$$

$$\text{power} = 2.2 \text{ Watts}$$

Completing the antenna performance calculation:

$$\text{dB gain} = 10 * \text{Log} (2.2 \text{ Watts} / 0.5 \text{ Watts})$$

$$\text{dB gain} = 6.4\text{dB overall}$$

This means that a 300ohm dipole has basically a 6 dB advantage over a full wave long wire antenna. For a 100Watt transmitter, this is 430 Watts ERP, or there about and 4 times increase in the receiver's sensitivity.

If, however the dipole design was a 300ohm cross dipole design, then each element 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.

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

$$4800 / 565 = 8.5 \text{ times greater}$$

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

$$(4800 / 565) * 5 = 42 \text{ Volts}$$

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

$$\text{power} = (42 * 42) / 50$$

$$\text{power} = 35 \text{ Watts}$$

Completing the 300ohms cross dipole antenna performance calculation:

$$\text{dB gain} = 10 * \text{Log} (35\text{Watts} / 0.5 \text{ Watts})$$

$$\text{dB gain} = 18.5 \text{ dB overall}$$

Antenna loading coil for a 300ohm ribbon fed dipole

As mentioned previously, each side of a 300ohm, dipole is 600ohms of inductive reactance. Regarding the example above relating to a loaded coil 50ohm dipole, below is an example relating to a ribbon fed 300ohm dipole.

We will assume that our ribbon fed 300ohm dipole is to be no bigger than 3metres in length overall.

“80m / 40m band”

First, we will design the 80m band version of the 300ohm ribbon fed dipole.

Each side multiplier is:

$$(600 / 565) * 80m \text{ band} = 85\text{metres}$$

Inductance of each side of the dipole:

$$85m * 0.3\mu\text{H/m} = 25.5\mu\text{H}$$

Now, assuming that the 25uH is used as the end loading coil, in other words, each side of the 300ohm dipole, the loading coil placed at the very end of the dipole wire element.

In this regard, as the end fed loading coil is to be the 25uH loading coil, then the wire from the ribbon fed to the coil would then be the 0.5uH worth of the wire section.

This would then equate to the complete 25.5uH expected for the 80m band 300ohm dipole side element.

Each side length of the wire section for an inductance of 0.5uH, equates to as:

$$(0.5\mu\text{H} / 0.3\mu\text{H/m}) = 166\text{cm wire section overall}$$

To tune the 80m to a 40m band use, then we to a point, repeat the above calculations.

Each side multiplier is:

$$(600 / 565) * 40m \text{ band} = 42.5 \text{ metres}$$

$$42.5m * 0.3\mu\text{H/m} = 12.75\mu\text{H}$$

Now reducing the loading coil by 0.5uH, to allow for the wire element section,

$$12.75\mu\text{H} - 0.5\mu\text{H} = 12.25\mu\text{H} \text{ loading coil each side}$$

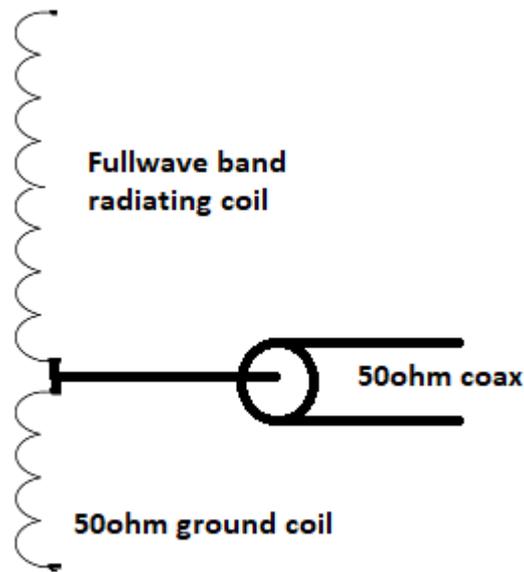
$$(0.5\mu\text{H} / 0.3\mu\text{H/m}) = 166\text{cm wire section each side}$$

the inductance of the loading coil for each side of the dipole is thus 12.25 μ H, and the remaining 0.5 μ H used for the 166cm of wire section. To install such a twin band 300ohm dipole, use a two way switch relay, to switch between the two different end wire connected loading coils.

For other bands on the HF spectrum, just repeat the above process, or to increase the number of bands of use for the 300ohm dipole, just added more relay switched end loading coils to the antenna design.

Lumped Component coiled vertical antenna

View the below diagram:



The top coil is used as the radiating element, inductance reactance of 565ohms, 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 :

$$80\text{m} * 0.3\mu\text{H}/\text{m} = 24\mu\text{H} \quad \text{“or } 48\mu\text{H} \text{ for two wavelengths etc”}$$

The 80m 50ohm ground loading coil inductance :

$$(50/565) * 80\text{m} = 7\mu\text{H} \quad \text{“remains a 80m band constant”}$$

The principle here, the vertical antenna is full wavelength, thus the radiating coil would have a full electromagnetic connection to the surrounding etha. This based on the idea that a full wave 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, would be on top of any other propagation losses.

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

Hope folks, this helps.

Antenna Path Ratios

Much over the airwaves has been mentioned or talked about, relating to the benefits of one's own application of an antenna system.

Over the last few years, I have been attempting to derive a propagation program to at least try to un-tangle the physics behind just the "Inverse Square Law of signal decay", relative to the transmitter power output, the antenna system used, and the RF bandwidth of the receivers front end design.

I started the quest with a degree of log notes related to the local 70cm repeater, and then onto a HF contact some 3000Km away towards Europe. The QSO occurred on the 40m band, while using a bitx40 operating through a 40m wire via a 9:1 balun. The radio ham some 3000Km away, was using a dipole and a transmitter power output of some 350Watts. Please note also the front-end bandwidth change the radio receivers performance, as relating to the radio in hand, the bitx40 and the QSO end.

I found that while developing the Inverse Square Law application, an additional factor variable had to be taken into the equations. The signal values recorded in my logbook, did not match the prediction, so an "additional signal path loss" was added. This then gave the ability to change the path loss variable for bad days and good days of a signal lift.

On the whole, the "additional signal path loss" averages to a 70dB increase in signal path losses. Whether this changes from HF to Microwaves is unknown, but it did seem otherwise to be the insertion loss connection of the antenna system, between the two stations. The "Inverse Square Law" equation itself, did not go fully to explain the communications pathway physics figures.

The first image, page 16, relates to the bitx40 both sides, with the 40m wire antenna, obtaining a QSO distance of some 3000Km.

The second image, page 17, relates to a European return station, using a dipole, please note the transmitter power that was used to make the return path. This is some 350Watts to bridge the 3000Km distance. The third image, page 18, shows the transmitter requirements for a 50ohm stub antenna used by the European station, some 3000Km away. Do please note the return path transmitter prediction of some 4500Watts. Both cases assuming a front-end bandwidth of 4MHz

The fourth image, page 19, shows the bitx40 both sides using a 50ohm dipole. The effective QSO distance then drops down to some 375 miles maximum of distance, the contact also using a 50ohm dipole.

My own radio has a 4MHz front-end bandwidth on the 40m band, as I found most manufacturer radio do so, although I understand the bitx40 is a 500KHz bandwidth.

radio base to propagation distance:bbc

-104.397431dBW = 42.62uW
-149.6309dBW = 0.25uW
-103.0103dBW = 50uW
-151.189008dBW = 0.195uW

Rx Radio noise figure = 4.8 dB
Rx Audio signal to noise = 10 dB
Rx test bw Bw = 2700 Hz
Radio base line = 0.25 uW

Radio front-end Bw = 0.5 MHz
Tx power watts = 5 Watts
Frequency of signal = 7 MHz

antenna radio 'Tx' set 1 = 100 % eff. 0 dB 'Tx antenna'
antenna radio 'Rx' set 2 = 100 % eff. 0 dB 'Rx antenna'

additional signal path loss dB = 70dB

Reach RF Tx budget watts = 499 mW
Reach RF Tx budget dBW = -63.02 dBW

```
[----- Comm's channel -----] [----- radio unit -----]
```

Rx signal	com's range	ERP Watts	EMF uW	EMF 'S'	RX 'S'	Rx dBW	Rx uW	
-126.17 dBW	4905 Km 3065.6 miles	5	3.47	4.65	4.65	-126.17	3.47	10 dB s/n
-123.17 dBW	3473.7 Km 2171 miles	5	4.9	5.22	5.22	-123.17	4.91	13 dB s/n
-120.17 dBW	2459.2 Km 1537 miles	5	6.93	5.78	5.78	-120.17	6.93	16 dB s/n
-117.17 dBW	1740.9 Km 1088.1 miles	5	9.79	6.34	6.34	-117.17	9.79	19 dB s/n
-114.17 dBW	1282.5 Km 770.3 miles	5	13.83	6.9	6.9	-114.17	13.84	22 dB s/n
-111.17 dBW	872.5 Km 545.3 miles	5	19.54	7.47	7.47	-111.17	19.54	25 dB s/n
-108.17 dBW	617.7 Km 386 miles	5	27.6	8.03	8.03	-108.17	27.61	28 dB s/n

radio base to propagation distance:bbc

-104.397431dBW = 42.62uW
 -149.0309dBW = 0.25uW
 -103.0103dBW = 50uW
 -151.189008dBW = 0.195uW

Rx Radio noise figure = 4.8 dB
 Rx Audio signal to noise = 10 dB
 Rx test bw Bw = 2700 Hz
 Radio base line = 0.25 uW

Radio front-end Bw = 4 MHz
 Tx power wats = 350 Wats
 Frequency of signal = 7 MHz

antenna radio 'Tx' set 1 = 35.39 % eff. -9.1 dB 'Tx antenna'
 antenna radio 'Rx' set 2 = 100 % eff. 0 dB 'Rx antenna'

additional signal path loss dB = 70dB

Reach RF Tx budget wats = 4305 nW
 Reach RF Tx budget dBW = -53.66 dBW

```

[----- Comm's channel -----] [----- radio unit -----]
Rx signal      com's range      ERP Wats      EMF uW      EMF 'S'      RX 'S'      RX dBW      Rx uW
-117.14 dBW    5089.1 km    3180.7 miles  43.05      9.82      6.35      6.35      -117.14      9.83      10 dB S/n
-114.14 dBW    3604.5 km    2252.8 miles  43.05      13.88     6.91      6.91      -114.14     13.88     13 dB S/n
-111.14 dBW    2551.8 km    1594.8 miles  43.05      19.61     7.47      7.47      -111.14     19.61     16 dB S/n
-108.14 dBW    1806.5 km    1129 miles    43.05      27.7      8.04      8.04      -108.14     27.71     19 dB S/n
-105.14 dBW    1278.9 km    799.3 miles   43.05      39.12     8.6       8.6       -105.14     39.14     22 dB S/n
-102.14 dBW    905.4 km     565.8 miles   43.05      55.26     9.16      9.16      -102.14     55.29     25 dB S/n
-99.14 dBW     640.9 km     400.6 miles   43.05      78.07     9.72      9.72      -99.14      78.1      28 dB S/n
  
```

radio base to propagation distance.bbc

-104.397431dBW = 42.62uW
-149.0309dBW = 0.25uW
-103.0103dBW = 50uW
-151.189008dBW = 0.195uW

Rx Radio noise figure = 4.8 dB
Rx Audio signal to noise = 10 dB
Rx test bw Bw = 2700 Hz
Radio base line = 0.25 uW

Radio front-end Bw = 4 MHz
Tx power watts = 4500 Watts
Frequency of signal = 7 MHz

antenna 'Tx' set 1 = 8.84 % eff. -21.1 dB 'Tx antenna'
antenna 'Rx' set 2 = 100 % eff. 0 dB 'Rx antenna'
additional signal path loss dB = 70dB

Reach RF Tx budget watts = 3493 mW
Reach RF Tx budget dBW = -54.57 dBW

```
[----- Comm's channel -----] [----- radio unit -----]
Rx signal      com's range      ERP Watts      EMF uW      EMF 'S'      Rx 'S'      Rx dBW      Rx uW      dB S/n
-117.14 dBW    4583.7 Km    2864.8 miles    34.93      9.82      6.35      6.35      -117.14      9.83      10 dB S/n
-114.14 dBW    3246.5 Km    2029 miles      34.93      13.88      6.91      6.91      -114.14      13.88      13 dB S/n
-111.14 dBW    2298.3 Km    1436.4 miles     34.93      19.61      7.47      7.47      -111.14      19.61      16 dB S/n
-108.14 dBW    1627.1 Km    1016.9 miles     34.93      27.7      8.04      8.04      -108.14      27.71      19 dB S/n
-105.14 dBW    1151.9 Km    719.9 miles      34.93      39.12      8.6      8.6      -105.14      39.14      22 dB S/n
-102.14 dBW    815.4 Km     509.6 miles      34.93      55.26      9.16      9.16      -102.14      55.29      25 dB S/n
-99.14 dBW     577.3 Km     360.8 miles      34.93      78.07      9.72      9.72      -99.14      78.1      28 dB S/n
```

>

radio base to propagation distance:bbc
 -104.397431dBW = 42.62uW
 -149.0309dBW = 0.25uW
 -103.0103dBW = 50uW
 -151.189008dBW = 0.195uW

Rx Radio noise figure = 4.8 dB
 Rx Audio signal to noise = 10 dB
 Rx test bw Bw = 2700 Hz
 Radio base line = 0.25 uW

Radio front-end Bw = 0.5 MHz
 Tx power watts = 5 Watts
 Frequency of signal = 7 MHz

antenna radio 'Tx' set 1 = 35.39 % eff. -9.1 dB 'Tx antenna'
 antenna radio 'Rx' set 2 = 35.39 % eff. -9.1 dB 'Rx antenna'
 additional signal path loss dB = 70dB

Reach RF Tx budget watts = 61 mW
 Reach RF Tx budget dBW = -72.12 dBW

```

[-----] Comm's channel [-----] radio unit [-----]
Rx signal      com's range      ERP Watts      EMF uW      EMF 'S'      Rx 'S'      Rx dBW      Rx uW      dB S/n
-117.07 dBW    603.4 Km      377.1 miles    0.61        9.9          6.36        4.65        -126.17    3.47      10 dB S/n
-114.07 dBW    427.3 Km      267.1 miles    0.61        13.99       6.92        5.22        -123.17    4.91      13 dB S/n
-111.07 dBW    302.5 Km      189 miles      0.61        19.76       7.49        5.78        -120.17    6.93      16 dB S/n
-108.07 dBW    214.1 Km      133.8 miles    0.61        27.92       8.05        6.34        -117.17    9.79      19 dB S/n
-105.07 dBW    151.6 Km      94.7 miles     0.61        39.44       8.61        6.9         -114.17    13.84     22 dB S/n
-102.07 dBW    107.3 Km      67 miles       0.61        55.71       9.18        7.47        -111.17    19.54     25 dB S/n
-99.07 dBW     75.9 Km       47.4 miles     0.61        78.7        9.74        8.03        -108.17    27.61     28 dB S/n
  
```