

Antenna Modelling For Radio Amateurs Made Easier -Part 2

G8ODE RSARS 1619

Even the simple formula for the quarter wave element hides some daunting complex science and mathematics that most of us are unaware. In fact, if a multi-element antenna is considered, matters get even more complicated because of interactions between the elements. However we no longer have to be put off trying to model our antennas, as explained in the first part of this article the science behind antenna modelling goes back a long way and involved many great people. One such person was James Clerk Maxwell who in 1864 heralded the beginning of the age of radio with his four very simple looking equations that explain the way electric and magnetic fields behave.

$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times H &= J + \frac{\partial D}{\partial t} \\ \nabla \times E &= -\frac{\partial B}{\partial t}\end{aligned}$$

Maxwells Equations.

Maxwell's equations should really be seen as the start of the technological revolution that has lead to the development of radio communication in all its forms we use today, and even for opening the window to look at the fundamental secrets of the universe using radio astronomy. These equations just don't give the scientist or engineer insight; they are literally the answer to everything RF.

The major problem is that the equations can be baffling to work with. Solving Maxwell's Equations even for simple structures like dipole antennas is no easy task especially when real life situations are factored in. But thanks to clever programmers and the development of the fast home computers all is not lost to the mathematically challenged radio amateur.

As mentioned in part 1 the US Government Laboratories program called Numerical Electromagnetics Code (NEC) for solving general electromagnetic radiation problems, was cut down and was able to run on home computers as the Mini-NEC versions. The majority of antenna analysis programs used today are derived from the same NEC program and uses a "Method of Moments" algorithm. However the necessary hundreds if not thousands of computations if they had to be done manually would most probably discourage most radio amateurs. Fortunately programs such as the freeware MMANA-GAL(basic) provide the means for radio amateurs and other interested in antenna design an easy to use tool to model even complex stacked Uda-Yagi arrays. Moreover it comes with an extensive library of antennas that beginners can play with so that the main functions of the program can be tried out.

Since discovering MMANA-GAL a few years ago that was originally written and made freeware by Makoto Mori - JE3HHT in 1999, later evolved into a multi-language Version 2.01 in 2005 and co-written by Schewelew Alexander DL1PDB and Igor Gontcharenko - DL2KQ. The latest version is 3.0.0.31 is available on the web. I was amazed at its capabilities, which gave me a much better insight into the operation of many common antennas W3DZZ, G5RV, Doublet, G7FEK to name a few. I decided to use screen shots from the program for my RSARS eLibrary antenna articles.

It's perhaps not that well known that RSARS members have contributed to the development of this program in beta testing new versions and suggesting improvements to the program. Most significant was perhaps my nine month involvement to produce the new revised English Help File with considerable help from Alastair Couper NH7O and Barry Short G3YEU. Barry in fact had to compare English, Russian and German versions of earlier help files to ensure that nothing was missed in translation. Alastair NH7O was also responsible for producing the much improved section on antenna optimisation and who also produced a three part article now published on the Yahoo MMANA user group library. So it will be no surprise that the remaining part of this article will be dedicated explaining some of the main features of the program.

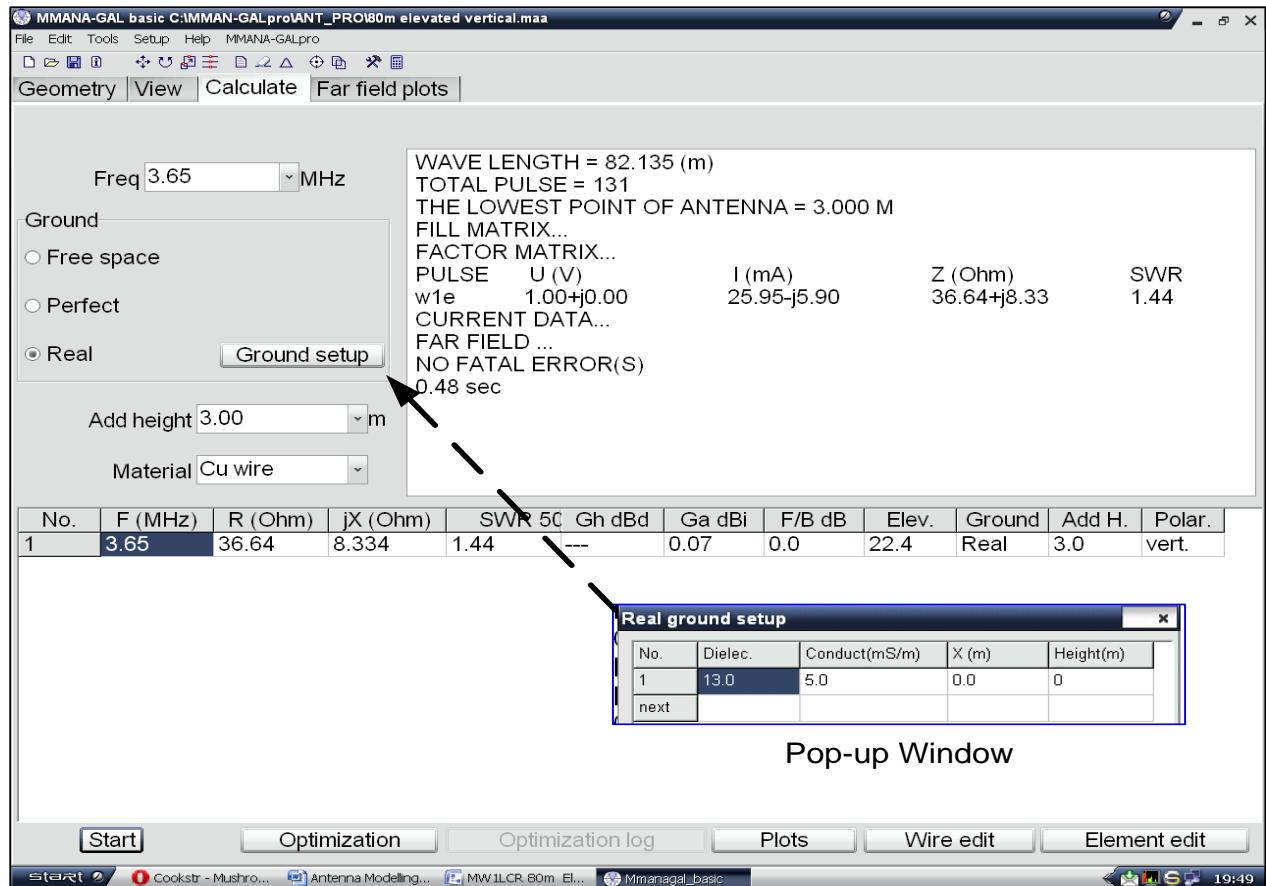
This week I saw a request from Adrian MW1LCR on the Yahoo RSGBTECH asking what value of capacitor he would require to tune his quarter wave 80m antenna elevated at 3m that he was building. So in the spirit of amateur radio I decided to take up the challenge and model the antenna for him. He explained that the radiating element was 20.5 m long and he would employ four horizontal radials. Radials that form a ground plane are usually longer, so as a starting point I assumed these to be 21m long and a Transmitter with 50 ohms output impedance.

Using MMANA-GAL the dimensions of the 5 wires elements have to be entered into the Geometry page using X,Y,Z co-ordinates for each wire. The antenna feed point, known as PULSE is 0,0,0 as towards the bottom left of the screen shot. The nominal RF voltage applied is 1.0v.

| No. | X1(m) | Y1(m) | Z1(m) | X2(m) | Y2(m) | Z2(m) | R(mm) | Seg. |
|------|-------|-------|-------|-------|-------|-------|-------|------|
| 1 | 0.0 | 0.0 | 20.5 | 0.0 | 0.0 | 0.01 | 0.8 | -1 |
| 2 | 0.0 | 0.0 | 0.01 | 0.0 | 0.0 | 0.0 | 0.8 | -1 |
| 3 | 0.0 | 0.0 | 0.0 | -21.0 | 0.0 | 0.0 | 0.8 | -1 |
| 4 | 0.0 | -21.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | -1 |
| 5 | 0.0 | 0.0 | 0.0 | 21.0 | 0.0 | 0.0 | 0.8 | -1 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 21.0 | 0.0 | 0.8 | -1 |
| next | | | | | | | | |

| No. | PULSE | Volt. V | Phase dg |
|------|-------|---------|----------|
| 1 | w1e | 1.0 | 0.0 |
| next | | | |

The next step is to calculate the result, and this is done by going clicking on the CALCULATE Tab at the top of the GEOMETRY PAGE. The type of Ground as to be selected and you have to select Ground setup which brings up a pop-up window. By default the values are for average ground dielectric of 13 and a conductivity of 5mS/m. Close this window down and simply press START at the bottom Left.

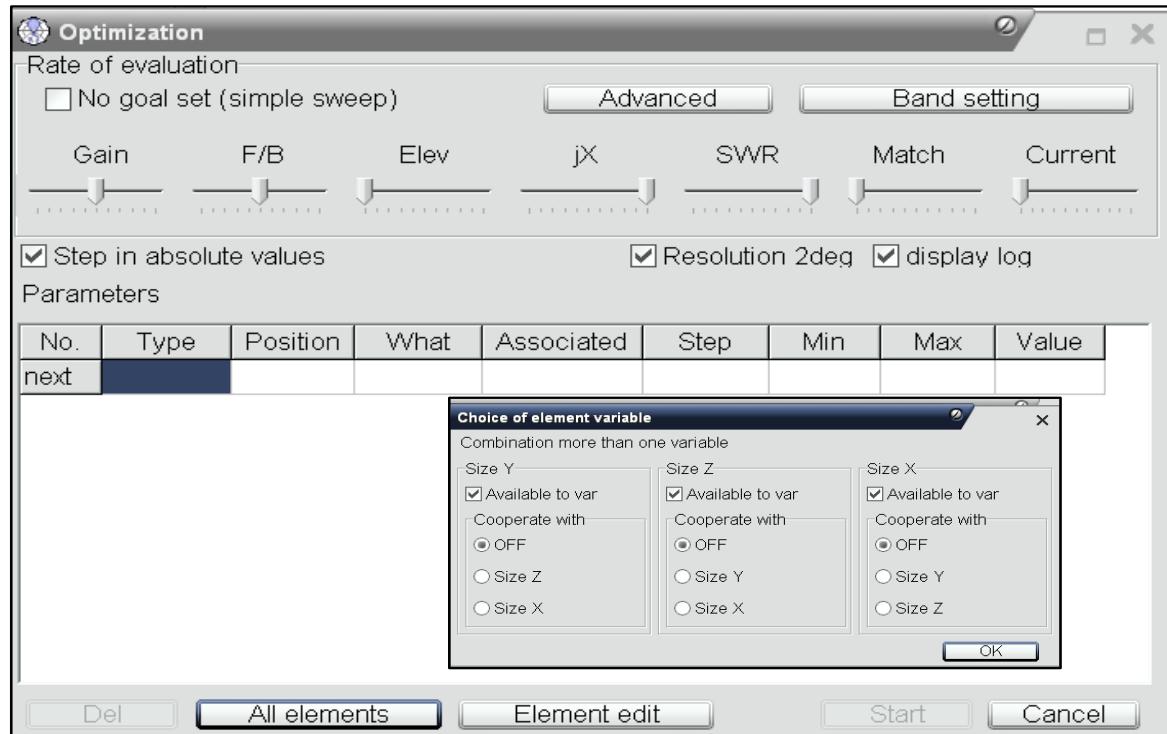


The results in this case appear in line 1 , as shown. The results show that the antenna is very close to resonance, since the" R ohms" value is 36.64 ohms very close to the theoretical value. The SWR is 1.44:1 reference 50 ohms of the transmitter. The this value can be changed if required i.e. to 75 ohms.

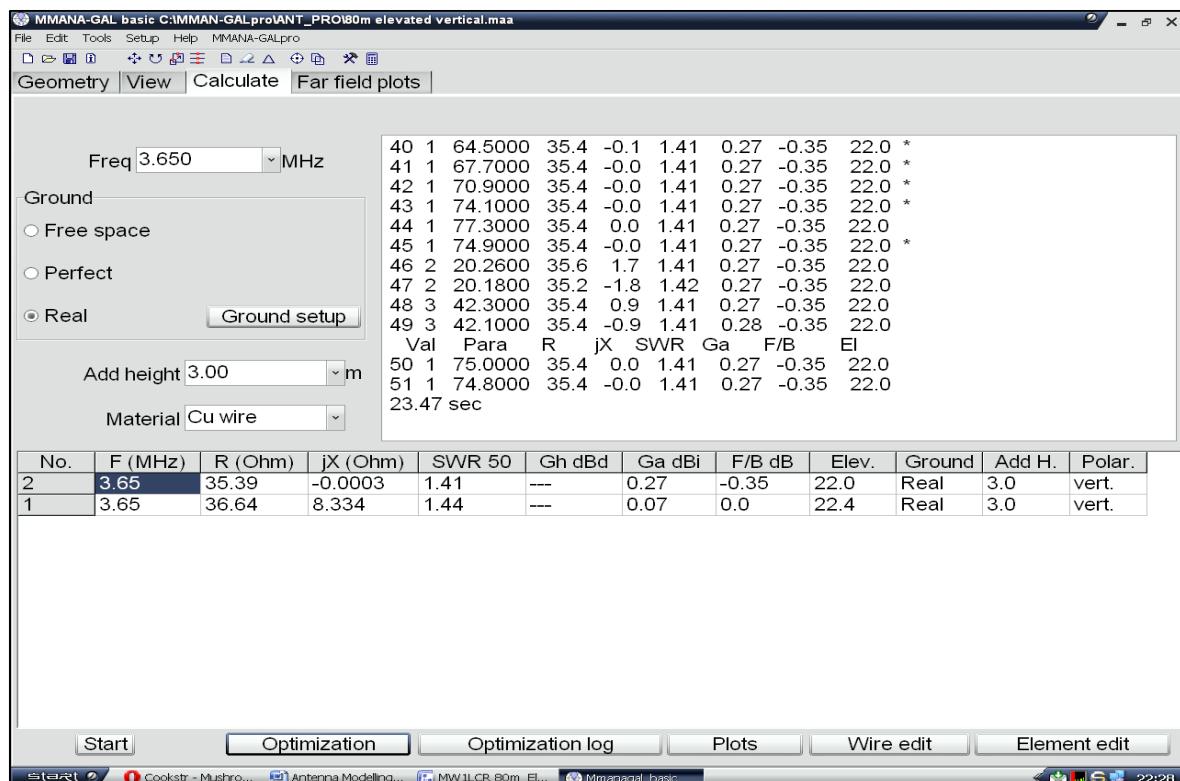
You can if you wish go back to the Geometry Tab change a length of a wire element, return to the Calculate Tab and press the START button to get a new set of results on a second line.

At the bottom of the screen there are also some extra useful self-explanatory buttons to use . The OPTIMISATION button is very useful to speed up "tuning" the antenna and getting the SWR down, or maximising the gain of the antenna. The main optimization controls are sliders that can be adjusted using the computer's mouse. The MMANA-GAL optimization routine checks the position of these control and uses the values to affect the way the optimisation will be done. Control to the left have minimum effect and maximum if they are to the right. Show below is the Optimization pop-up window that appear. The smaller pop-up window allow you to select the axis X, Y or Z that will be optimised . In this case all three were selected since the antenna is in three dimensions. Once this is

decided the “Start” button will become highlighted and can be used to start off the optimisation process.

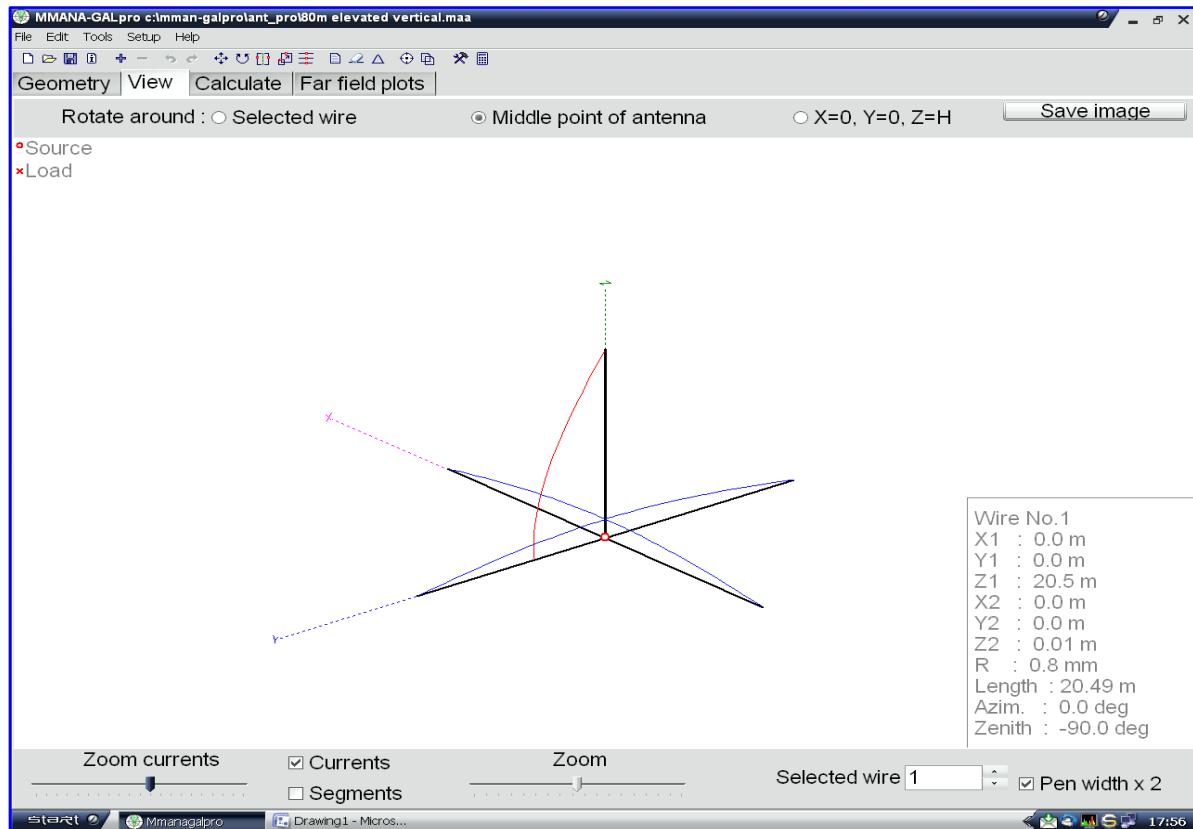


The many iterations of the optimization will appear on the CALCULATE Screen’s scratch pad area.



The final result of the optimization is shown in line 2. The antenna has now been made to resonate at 3.65MHz and the reactance has been reduced close to zero, but the SWR is still 1.41:1 since the

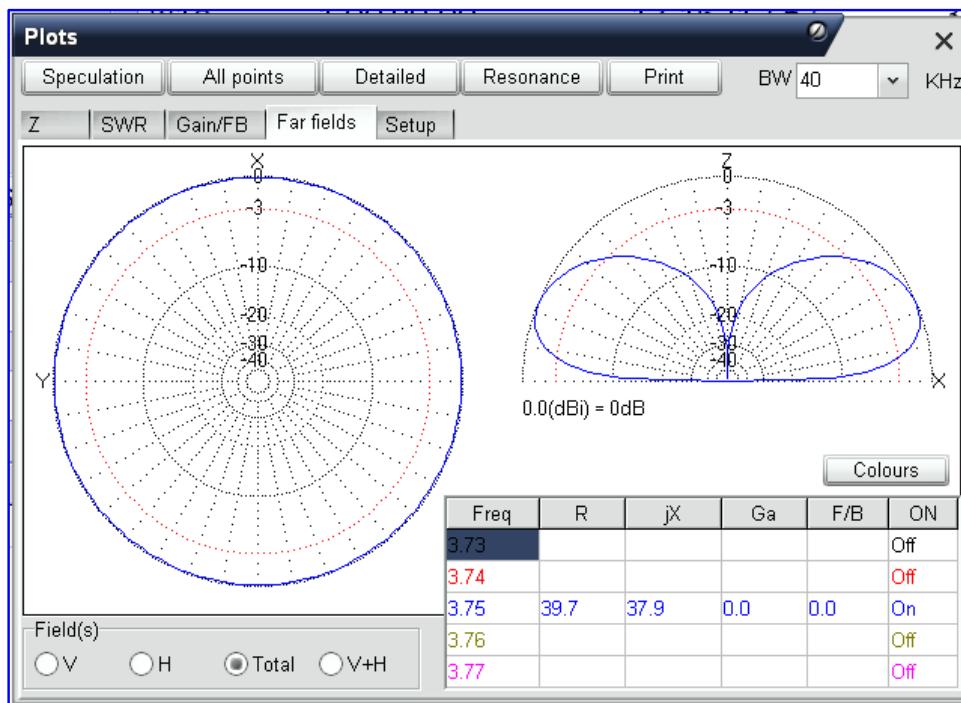
transmitter output is 50 ohms. But there is more to see. Clicking on the VIEW button at the top of the screen enables you to see the magnitude of the currents in the 5 wire elements, and using the mouse you can rotate the antenna to look at these from different viewing angles. This is more useful on large Uda-Yagi arrays than in this simple example.



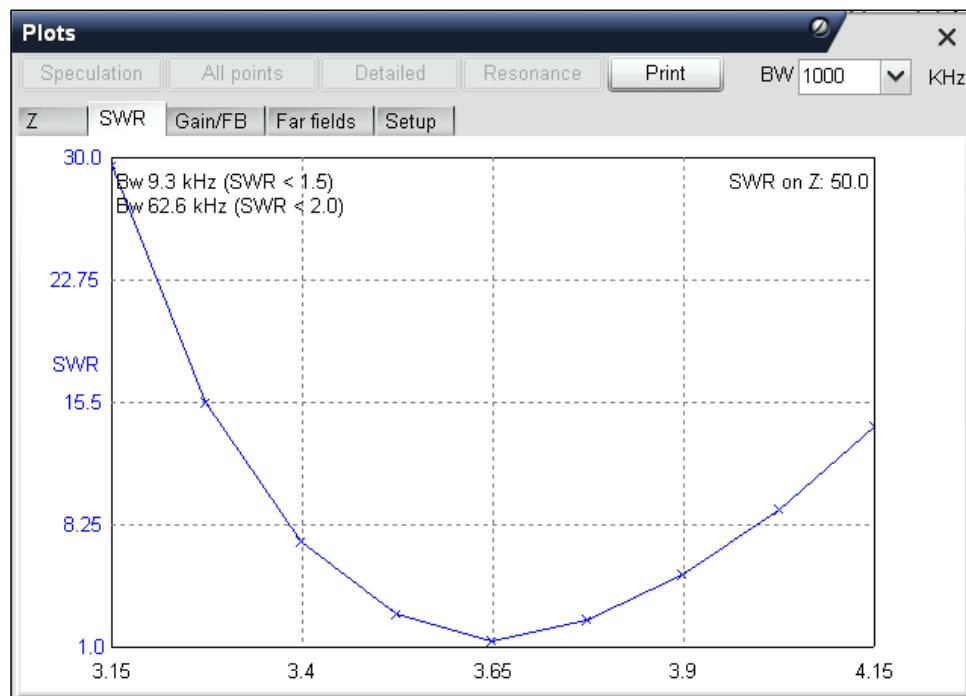
The slide controls at the bottom of the screen enable you to magnify the currents so that they can be seen more clearly. This can be useful when a wire element does not have much current flowing in it as can be the case sometimes. The Zoom in the middle of the screen can be used to make the antenna fill the screen for easier viewing. The Selected wire control on the right enable you to select a wire and the XYZ start and finish values will be shown in the small window on the bottom right.

Returning to the Calculate screen, the other useful button at the bottom is Plots. This brings up another pop-up window with some more useful options shown at the top. These are Z for an impedance plot, SWR, Gain /FB and Far Fields. These are used in conjunction with BW (bandwidth) control the top right which is shown set to 40KHz. This can be set from 40 -80,000KHz. To obtain the results you have to use the computer mouse to select either "All points" or "Detailed".

The screen shot shows that the 80m vertical ground plane antenna is omni-directional with a fairly low angle of radiation at 22 degrees, and the gain is 0db (n.b. a dipole is 3dB).

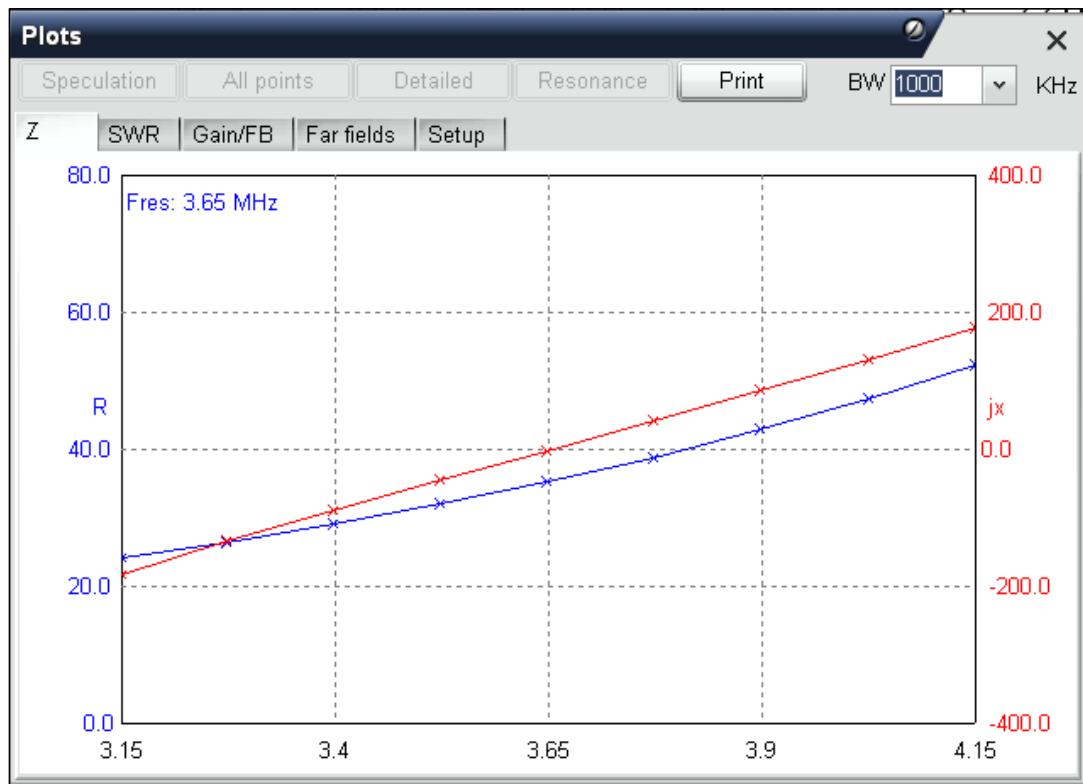


Selecting the SWR tab brings up another pop-up window, and if the BW is set to 1000KHz, in this case after selecting “Detailed” the results at the top left show that the bandwidth of the antenna to the 2:1 SWR point is 62.6KHz



The Z (impedance) plot can be useful when looking to see how far off resonance the antenna might be . At the resonance frequency the reactance will be zero .

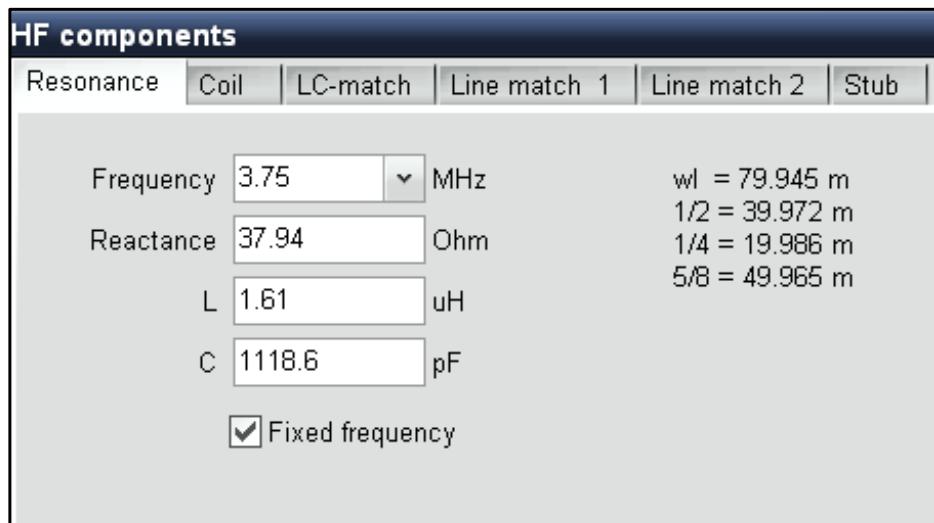
On the Z –Plot the left vertical axis is resistance value and the right hand side is the reactive value and this is the upper line of the two and this cross the zero line at a frequency of 3.65MHz as you would expect for an optimization concentrating of minimising the SWR and reactance.



However Adrian's original question related to the antenna being slightly longer than a quarter wave and would need a capacitor to cancel out the inductive reactance. This answer is easily provided after the Line 1 calculation was made. At the top of the Screen there is an extra menu selection provided by several icons.



The crossed spanner and hammer brings up another pop-up window shown below. This shows that the antenna if used on 3.75MHz will have a reactance of 37.94ohms and would need a 1118.6pF capacitor to cancel the 1.61uH inductance. In by drooping the radials Adrian will be able to improve the SWR as this will move the radiation resistance closer to 50 ohms.



Hopefully this simple example will have demonstrated how easy it is to model simple antennas. There is far more that the MMANA-GAL (Basic) program that can be written in a very short article e.g. such as features to export data as comma separated variables file (CSV) into a spreadsheet program like Microsoft's Excel, enabling you to manipulate the data plot graphs.

However software modelling may only be a guide, and programs like MMANA-GAL which have traded off the such things as ability to model insulation of wire, take into account the affect of the ground when the antenna is very low and objects in the environment, means the model will never be as accurate as expensive commercial program, but then this program is free after all and the results that it produces are generally pretty good if you take care and follow the MMANA Help guide that's available. It's worth downloading just to have play with the existing models that come in the MMANA-Gal library. All you have to do is open the file from the CALCULATE screen as you would with a Windows file and then click Start then click around a few of the buttons to discover a few things I have not mentioned.

Acknowledgments

My special thanks to the developers of this antenna modelling program for making this Freeware.

Original code by JE3HHT - Makoto Mori,

MMANA-GAL basic & MMANA-GAL Pro by DL1PBD - Alex Schewelew & DL2KQ - Igor Gontcharenko

The program can be downloaded from

The program **mmanabasic.zip** - (v. 3.0.0.31 - 2.6 MB) can be downloaded from
<http://hamsoft.ca/pages/mmana-gal.php>

It will be installed as C:\MMANA-GAL_Basic\MMANAGAL_Basic.exe. This is because of the security restrictions of Microsoft Windows.