

ANTENNA DESIGN FOR FREE USING MMANA-GAL SOFTWARE

1. AVAILABLE ANTENNA DESIGN SOFTWARE

EZNEC and **4nec2** are based upon the Numerical Electromagnetics Code, or NEC, which is a popular antenna modelling system for wire and surface antennas originally written in FORTRAN in the 1970s by Gerald Burke and Andrew Poggio of the Lawrence Livermore National Laboratory.

MMANA-GAL on the other hand is based upon MININEC which was written by John Rockway with support from Jim Logan.

These 3 programs are the most commonly used by radio amateurs.

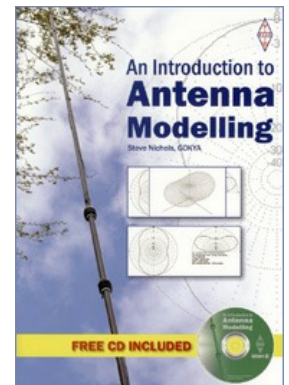
2. WHY CHOOSE MMANA-GAL

There is a free Demo version 6 of the program EZNEC but although it is the full program, it is restricted to only allowing upto 20 segments for any antenna design which can be quite restrictive.

The author experienced problems when trying to install 4nec2 and hence its use was abandoned.

As a Christmas present, the author received a copy of the RSGB Publication 'An Introduction to Antenna Modelling' by Steve Nichols (G0KYA) which includes a free CD containing the program together with sample antenna designs. This together with the program being a free download resulted in its choice! The free basic program (version 3.0.0.31) can be downloaded from :-

<http://hamsoft.ca/pages/mmana-gal.php>



3. WHY THE NAME MMANA-GAL

The name is derived from :- **Macoto Mori** (JE3HHT) who wrote the **AN**tenna **A**nalysers program - which was later modified by Igor **G**ontcharenko (DL2KQ) and **AL**ex Schewelew (DL1PBD)



4. WHAT CAN IT DO

MMANA-GAL has the following functions :-

- Enables an antenna to be defined in terms of straight wires (no loops) using xyz coordinates to specify the ends of each wire. Hence an antenna consists of one or more elements, where each element consists of one or more connected wires
- All wires must be of the same material but can have different diameters
- The design can be easily raised to a given height above ground (whose properties can be defined)
- One or more feed points (of definable characteristic impedance eg 50, 70, 300 etc) can be added at the centre/beginning/end or anywhere along any wire (eg dipole is single centre fed wire)
- Loading coils/tuned traps etc can also be added to any wire
- Antenna design analysis of impedance/SWR/Far field plots with graphical display
- Automatic antenna optimizer with respect to jX, SWR, Gain, F/B, Elevation, and Current
- Ability to compare designs and also to export spreadsheet type files

5. WHAT IT CANNOT DO

MMANA-GAL cannot model the effect of wire insulation upon the velocity factor of an electromagnetic wave which results in calculated wire lengths being longer than required in practice. The solution is to design the antenna for a working frequency which is proportionally higher than required in practice.

eg if pvc coated wire is used to construct the antenna then the velocity factor drops to approx 0.95 and the wavelength is 0.95 of that in free space. Consequently wire lengths would need to only be 0.95 of that predicted by MMANA-GAL. Alternatively, use a $1/0.95$ ie approx 5% higher design frequency to compensate.

It would also appear not possible to have different materials within any single design - eg it is not possible to have copper wires and an aluminium support pole within a given design.

MMANA-GAL cannot model buried radials

There are also limitations within the free basic version namely :-

Segments	8192
Wires (max.)	512
Sources (max.)	64
Loads (max.)	100

6. INITIAL PROGRAM SETUP

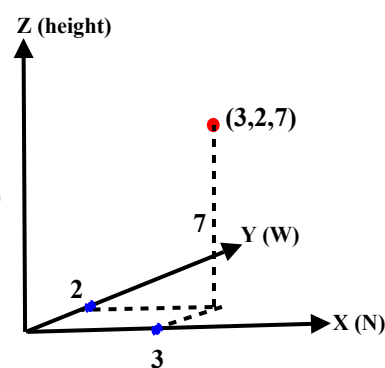
The program starts in the View window which initially just shows the xyz coordinate system. However, it is useful to check when using the program for the first time that SWR values will be based upon your preferred characteristic impedance eg 50 ohm. This is done by clicking on Setup (top left) and choosing Setup from the drop down menu and checking that in lower left of the Setup window that $R = 50$ and $jX = 0$ for Standard Z (SWR=1).

7. XYZ COORDINATES

The Geometry window defines the end points of each wire as XYZ coordinates.

MMANA prefers the Z Axis to define element heights agl, the X Axis to define element separation (eg Boom position for a Yagi) and the Y Axis for eg element lengths for horizontal elements ($Y=0$ for vertical elements)

Diagram shows a point (eg wire end) at a height of 7 units agl, positioned 3 units (eg along a Boom) and at a horizontal position of 2 units in the Y direction



However, if you find the coordinate system difficult, then the Wire Edit window option may be easier found by clicking on Edit at the top left of the View window and select Wire Edit from the drop down menu which will be explained later in the talk.

8. DESIGN STEPS

Design and analysis of an antenna is done in these stages :-

- Enter wires - position and radius
- Enter source point - ie where antenna fed
- Enter details of any point L/C loads
- Run Calculation and examine SWR & F/B
- Run (optional) Optimisation for eg SWR

To demonstrate the program, MMANA-GAL basic will be used to design and analyse a **simple 2m two element vertical Yagi** using 2mm diameter copper wire with the antenna base placed 1.5m above real ground at a design frequency of 145.5MHz.

9. ENTRY OF WIRES AND SOURCE (No Loads in this design)

There are two entry methods (Geometry & Wire Edit) but here we will use the **Geometry window**

Geometry Window Method

From the opening View window, click on the **Geometry tab** at the upper left

Enter **Name** for antenna design and change the **Freq** to 145.5MHz

Ensure DM1=800, DM2=80, SC=2, EC=2.

Assume that the Yagi has a Driven element initially approx half a wavelength long together with a 6% longer parasitic (undriven) Reflector element.

At 145.5MHz a half wavelength is $300/(2 \times 145.5)$ metres which is approx 1m. The Reflector will initially be 6% longer (1.06m) and placed a fifth of a wavelength (0.4m) from the Driven element. The antenna will be designed in the XZ plane and hence Y=0 for all points on the antenna, X defines position along the boom, and Z defines height above ground.

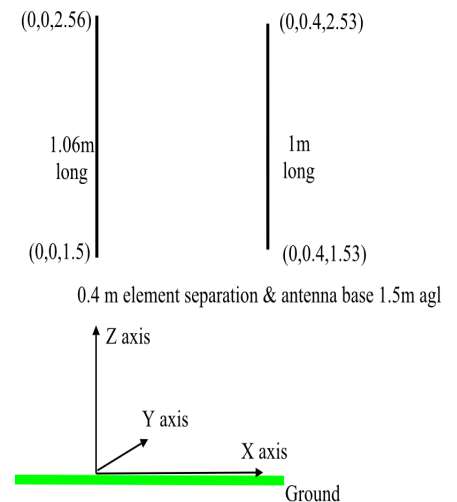
The antenna wire radius is 1mm.

Antenna wire end points are entered in meters and it is necessary to press Enter after entering each value. The Seg column should be kept at the default -1 value for optimum segmentation.

Start with the longer **Reflector (wire 1)** with its lower point at X=0, Y=0, Z=1.5 and upper end at X=0, Y=0 and Z=2.56.

The **Driven element (wire 2)** is positioned initially 0.4 m along the X axis. Since it is 0.06m shorter but centred on the Reflector, its lower end is at X=0.4, Y=0, Z=1.53 and its upper point is at X=0.4, Y=0, and Z = 2.53.

This is shown on the XYZ coordinate diagram opposite :-



Having entered the end points of the wires, the source (ie point on a wire where the antenna is fed) is added next. The feed point is at the centre of the Driven element, wire 2 and is entered as w2c in the Source Pulse box as shown in the diagram below. Other options are w2b to feed at the beginning of wire 2, and w2e to feed at the end of wire 2.

MMANA-GAL basic c:\mmana-gal_basic\talk\2m 2el vertical yagi\final version x axis\2m 2el vertical yagi at 1.5m initial 0.4m gap values.maa

File Edit Tools Setup Help MMANA-GALpro

Geometry View Calculate Far field plots

Name Freq MHz ☐ lambda

Wires 2 Auto segmentation: DM1 DM2 SC EC ☐ Keep connect.

No.	X1(m)	Y1(m)	Z1(m)	X2(m)	Y2(m)	Z2(m)	R(mm)	Seg.
1	0.0	0.0	1.5	0.0	0.0	2.56	1.0	-1
2	0.4	0.0	1.53	0.4	0.0	2.53	1.0	-1
next								

Sources 1

No.	PULSE	Volt. V	Phase dg
1	w2c	1.0	0.0
next			

Loads 0 (L - uH; C - pF; R/jX - Ohm) ☐ Use loads

No.	PULSE	Type	L/R/A0	C/jX/B0	Q/A1	F/B1
next						

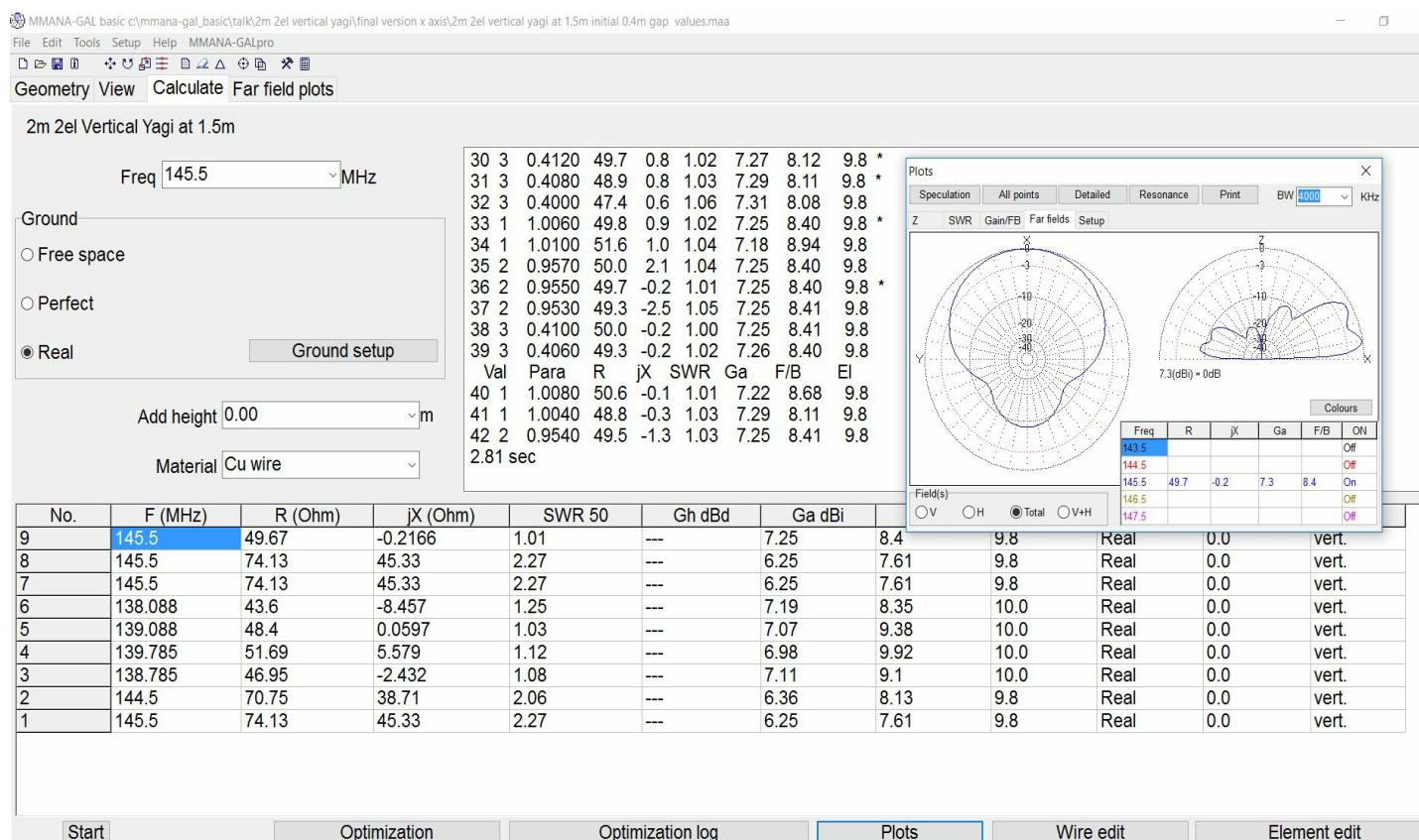
10. ANTENNA PERFORMANCE CALCULATION

Now that the wire and source details have been entered, the antenna performance eg SWR etc can be calculated. This is done by clicking the **CALCULATE** tab in the upper left and in the Calculate window which opens, select the **GROUND** type as **REAL** and leave **ADD HEIGHT** at 0. Finally, select **Cu wire** as the **MATERIAL**.

Click **START** and the first line of the table gives the antenna's initial design performance namely

SWR is 2.27, Gain is 6.25 dBi and the F/B is 7.61 dB

Click on **PLOTS** which opens a window to show initially the Far Fields plots of Directivity (left plot) and Take Off (right plot).



The resonant frequency of the antenna (ie when $jX=0$) can be found by clicking on **RESONANCE** and **YES** to write to tables then select the **Z** tab and note the frequency where $jX=0$ which gives a resonant frequency of **139 MHz** indicating that the antenna element lengths are too long.

However, clicking on **Plots/** and **Far Fields tab** shows a useful low angle lobe at **10 deg**.

It is useful at this stage to save the initial antenna dimensions using **File/Save As**

The resonant frequency must now be optimised to **145.5 MHz** and the element spacing of **0.4m** optimised for the best **Gain and F/B**

Click on the **Optimization button** at the bottom of the **Calculate** window.

Select **All Elements** (Table should show 3 lines of entry - element 1 adjusted for Z (length) , element 2 also adjusted for Z (Length), and a third row for element 2 adjusted for Interval (Boom spacing)

If there is no 3rd row, click **Type** and select **Element**, double click the **1** under **Position** and edit to **2**, and ensure **Int** (Interval) is shown under **What**

Set the **Gain, F/B, and SWR sliders fully right, and all others fully left**

Click **Start** and select **No** to saving the results

This results in optimised results of :-

SWR of 1.01, Gain of 7.25 dBi (5.1 dB), F/B of 8.4 dB

Now return to the View tab and note the new element lengths and separation (obtained from the X values)

Reflector 100.6 cm, Driven 95.4 cm Separation 40.8 cm

Plots/Far Fields shows the radiation pattern

Plots/SWR/Detailed gives the SWR plot as shown opposite.



11. BUILD, TEST AND FINE TUNE

To help evaluate the effectiveness of MMANA-GAL to model the effects of wire insulation (enamel in our case) and wire end effects, it is useful to compare the predicted and measured values of resonant frequency for the **Driven element alone** with the Reflector removed.

The MMANA-GAL predicted resonant frequency is obtained by switching to the **Geometry** window, select any value for **wire 2 (Reflector)**, right click and select **Del** from the drop down menu to remove **wire 1**.

Use **Calculate/Start** (but do **not** optimise) to find a predicted resonant frequency of **150 MHz**.

The antenna (**Driven element only - 95.4 cm tip to tip**) was then built and fed with RG58 via a **10T choke** balun near to the feed point (necessary since feeding a balanced antenna with unbalanced coax).

The resonant frequency was measured using an **MFJ Antenna Analyser** and compared with the **150 MHz predicted value**. My measured value was **actually 145 MHz** ie lower indicating that the elements are too long due to wire insulation and end effects by approx **3%**.

The MMANA-GAL analysis was then repeated at a **3% higher frequency** of **150 MHz** to compensate for the analysis not correctly allowing for enamel insulation and wire end effects.

To do this, reload the initial antenna dimensions file saved earlier and in the **Geometry** window, ensure that the **Frequency** is now set to **150 MHz**.

Repeat the analysis and optimisation as before to give an **SWR of 1, Gain of 7.25 dBi (5 dBd giving a power gain of almost 3.2) and F/B of 9.41dB**.

The final practical element lengths obtained from the View window are now :-

Reflector 98.4 cm Driven 92.6 cm Gap 37.6 cm

which when constructed should have a minimum SWR at 145.5MHz

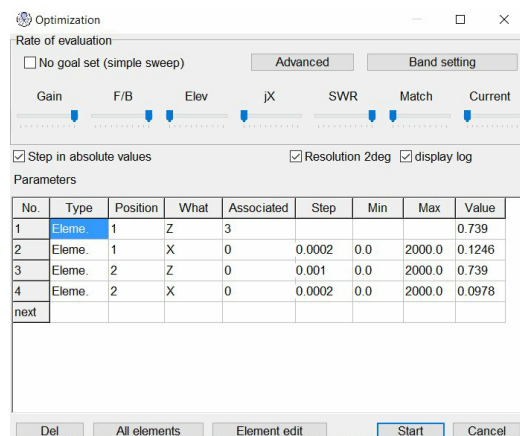
12. USE OF MMANA-GAL TO DESIGN A 2m MOXON BEAM

Best starting point is to download a copy of MoxGen from <http://www.moxonantennaproject.com/design.htm> and enter **145.5 MHz** as the design frequency. The antenna dimensions (6 wires) produced by MoxGen have been entered into MMANA-GAL and the antenna file can be downloaded from the Club Website.

Load this file into MMANA-GAL and use **Calculate/Start** to obtain the antenna performance.

The results can be optimised as per the previous 2el 2m Vertical Yagi example ie using **Optimization/All elements/OK** in window that opens. However, edit the **Association** in **line 1** from **0** to **3** in order that any changes in the Reflector vertical height are also applied equally to the Driven element in order to retain the rectangular shape of the design. As before set the **Gain, F/B and SWR sliders fully right** with **all others left** to achieve optimum Gain, F/B and SWR. Finally, rerun the analysis at eg **150 MHz** to compensate for wire end effects etc.

A copy of the optimised antenna design file (at 150 MHz) is available from the Club's website.



13. USE OF MMANA-GAL TO DESIGN A 40/20m TRAPPED DIPOLE

This final section has been added to show how the **Graphical Wire Edit** mode can be used to define the wires rather than having to work out the xyz coordinates as done in the 2m 2el Vertical Yagi example.

The antenna will be assumed to be at **10m** above **Real Ground** and constructed from **0.8 mm Cu wire** and consist of 3 wires - a central **10m** long wire with two **3m** long wires attached at each end.

Open MMANA-GAL which will be in the **View** mode and click from the top bar **Edit/Wire Edit** to open the **Wire Edit** window.

Click on the **XZ Projection** and **New Wire** buttons

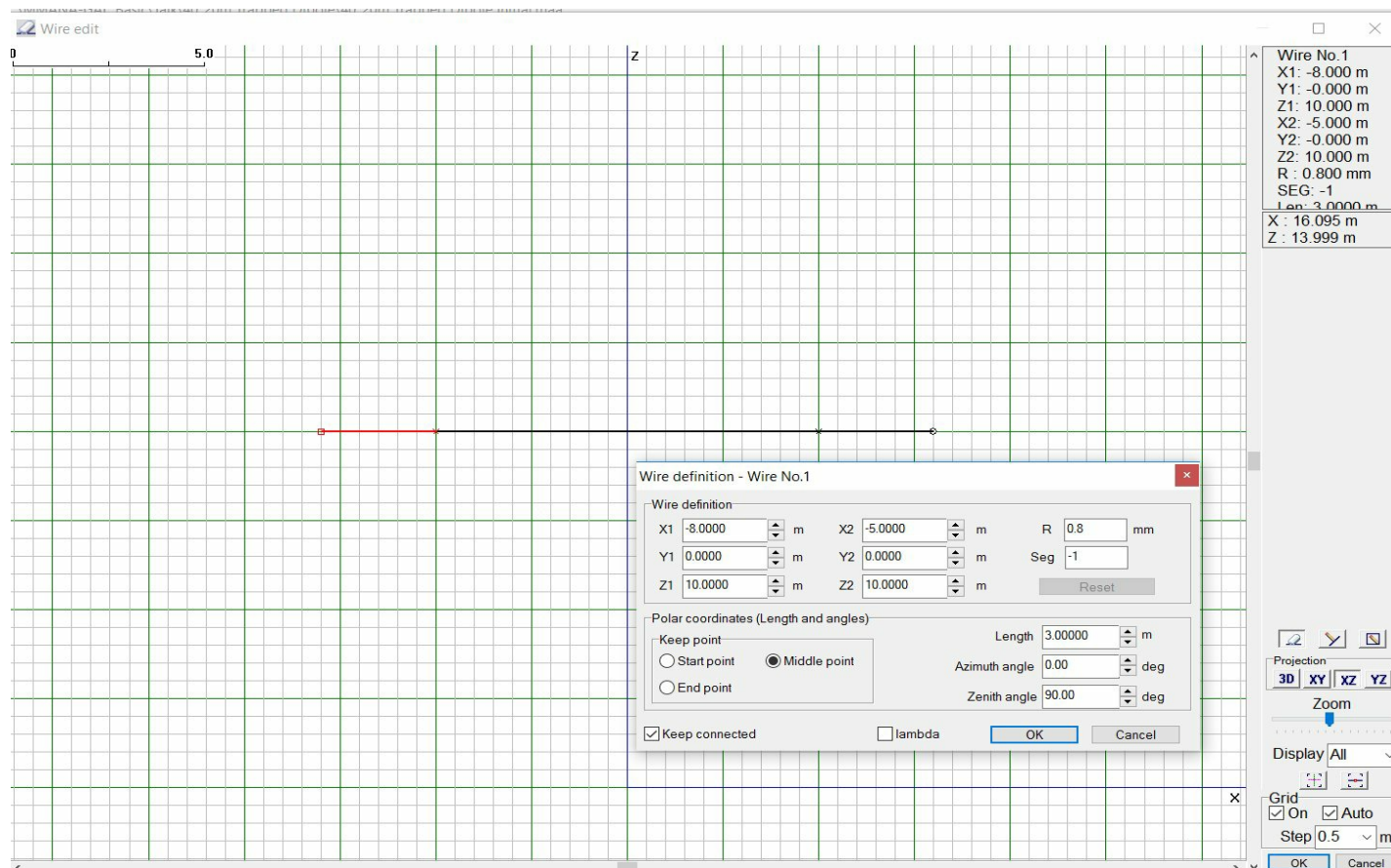
In the upper half of the window hold down the **Left Mouse button** and draw a single horizontal line (in red) symmetrically about the vertical Z axis.

Click in top right **wire details box** to open **Wire Definition window**.

Keeping the **Mid Point**, check and alter if needed that **Z1=Z2=10m** and also that **X1 & X2** are **symmetrical** but do **NOT** press Enter yet

Then alter the **Length** to **10+3+3=16m** and press **OK**

Select **Wire Edit** button and Right click on the single wire and select **Divide Wire** into **3 pieces**



Still in **Wire Edit** mode, select **central wire 2** and open **Wire Definition window** and **Keeping the Mid Point**, edit wire length to **10m** and **OK**. **Wires 1 and 3** are now automatically each **3m** long. Finally click on the lower right **OK** and then select the **Geometry** tab. Should now give 3 wires as required.

Enter source centrally on **wire 2 - w2c**

Enter Loads (click **Use Loads**) and enter **w1e/LC/22pF/100(Q)/14.2 MHz**

Similarly enter **w3b/LC/22pF/100/14.2**

Calculate and check **14.2 MHz** and **No height** and **Cu wire**.

Start gives **SWR 2.38** and **Resonant** freq **14.42MHz**

Need to get better SWR thus :-

Select **Optimization** with **SWR** slider fully **right**, all others fully **left**

Line 1 should entered as **Wire/2/Y1/-2** (-2 Association ensures that ends are symmetrical) and **Line 2** as **Wire/2/Y2**

Start/ and **No** to option to Save

Gives SWR of **1.75** and check SWR Plot using **Plots/SWR/Detailed**.

Now look at 7.15MHz

Geometry 7.15 MHz, **Calc/Start** gives SWR 9.8 and **Resonant** at **7.6 MHz**

Optimise wires 1 and 3 for best SWR thus :-

Optimization/Wire 1/Y1/-2 plus a second line with **Wire 3/Y2** and with the **SWR** slider fully **right**, all others fully **left/Start/** and **No** to option to Save

Gives SWR of **1.45** and check **SWR Plot** using **Plots/SWR/Detailed**.

Finally it is useful to recheck 14.2 MHz using **Geometry 14.2 MHz** **Calc/Start** to get SWR **1.76**

Best to now build the antenna and trim the centre section for best SWR at 14.2 MHz and then finally trim the outer sections for best SWR at 7.15 MHz

To determine coil construction go to **Tools/HF Components/Coil** and enter required inductance of **5.71uH** and opt for **calculate by coil diameter**. Enter **2.5cm** for coil diameter and wire dia of **1mm** and **1mm** separation

Results in a **23 turn coil, 4.62cm long with 2.5cm diameter**

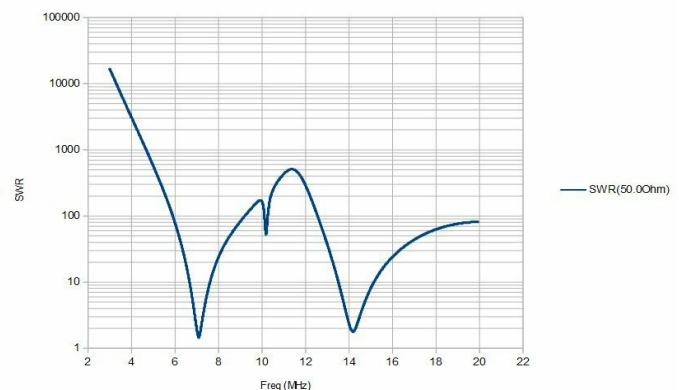
To get an Excel plot of SWR v Frequency - go to **File** & select **Table F/SWR/Gain/Z * csv**

In new window set **Fmin** to **3MHz** and **Fmax** to **20 MHz** with a **50 kHz** step. Ensure **Not Match** is selected.

OK and select file location and **WAIT!** window disappears when done.

To display, open this file in a Spreadsheet program eg Excel, OpenOffice or LibreOffice.

Select **XY Scatter graph**, **smooth lines** only, and ensure that the vertical **SWR** axis is **logarithmic**.



Now have a 40/20m trapped dipole approx **17m (56 feet)** in length with a min SWR of **1.45** at **7.15 MHz** (under 2 over most of the band) and **1.76** at **14.2 MHz** (under 2 over the SSB part of the band) when mounted at a height of **10m**.

However as before, the built antenna may need some trimming due to any wire insulation/end effects not modelled by MMANA-GAL. The reader may need to edit the wire radius to suit what is available.

Hopefully the reader has found this article sufficiently stimulating that you now will give MMANA-GAL a go.

Enjoy and please contact me if however you find anything in this article which needs correcting.

Terry (G4CHD)