Walter Doberenz DL1JWD

Special Networkanalyser V3.0

This useful tool allows a detailed analysis of passive electrical networks especially for the needs of radio amateurs in the shortwave range.
It not only determines all operating parameters of a circuit but also allows a detailed loss analysis.

In addition to the obligatory generator resistor RG (internal resistance of the PA) and the load impedance ZA, the following components are available and can be placed freely:

- Ohmic resistance (R)
- Capacity (C)
- Inductance (L)
- single tapped inductor (La1)
- double tapped inductor (La2)
- Twin winding transformer (U2)
- Three-winding transformer (U3)
- Coaxial cable (CC)
- Ribbon cable (RC)
- Horizontal Dipole (DIP)
- Groundplane (GP)
- Voltmeter (VM)

Baluns can be modeled by pieces of coax or tape cable.

As an alternative to load impedance ZA the following components can be used:

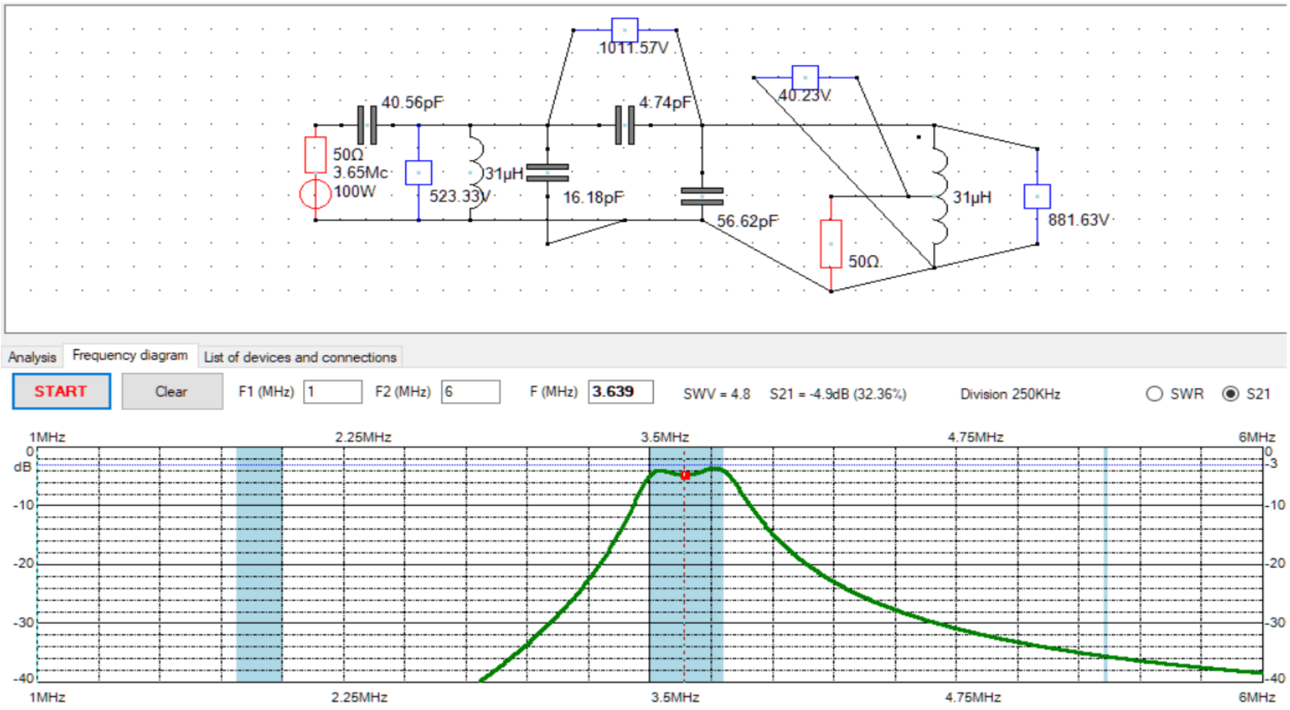
- Dipole (symmetrical or unbalanced) (DIP)
- Groundplane (GP)
- Input reflection (S11)

The program creates not only the sweep curves of LC-networks but also of an entire antenna system based on the geometric dimensions and the integrals of the antenna theory.
Thus, the analysis of antenna adjustments is no longer limited to a single frequency point, but can be extended to the entire KW range.

Example 1: **Bandpass for the 80m-band**

Load the file *Example 1.ama* via **File/Open**. The circuit diagram is drawn somewhat "chaotically" to show that the components can be rotated and placed freely as desired and, for example, line crossovers are possible.

Select the tab "Frequency diagram", click the option "S21" on the far right and then the START button.
Now you can move the frequency ruler in the diagram and display the current values for continuity loss and input SWR.



The sweep curve corresponds to that of a 2-port continuity measurement with a VNA.

If you click on the "Analysis" tab and then again on START you will see the various operating parameters of the circuit at the bottom of the data grid related to the main frequency mark (3.65MHz) entered in the window at the top left.

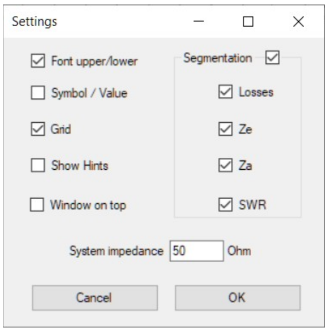
Analysis | Frequency diagram | List of devices and connections

START | Clear

	F(MHz)	Vp(dB)	Vu(dB)	RLoss(dB)	SWRin	Zin(Ohm)	SWRout	Zout(Ohm)	S11	S21
▸	3.65	-4.9 (32.37%)	-10.92 (176.94°)	3.66	4.82	228.08 - j52.64 (Cs = 828.31pF)	4.69	10.66 + j0.81 (Ls = 0.04µH)	-3.66dB 174.25°	-4.9dB 176.94°

Example 2: **Loss analysis of the 80m-Bandpass**

In order to subject the circuit of our 80m bandpass to a loss analysis, the components must be regrouped into a certain order.
Open the "Settings" menu and enable segmentation and other options:



A blue grid is now displayed in the designer.
By moving the components and connections, a rule-compliant circuit diagram must now be redrawn without of course changing the electrical behavior of the network.

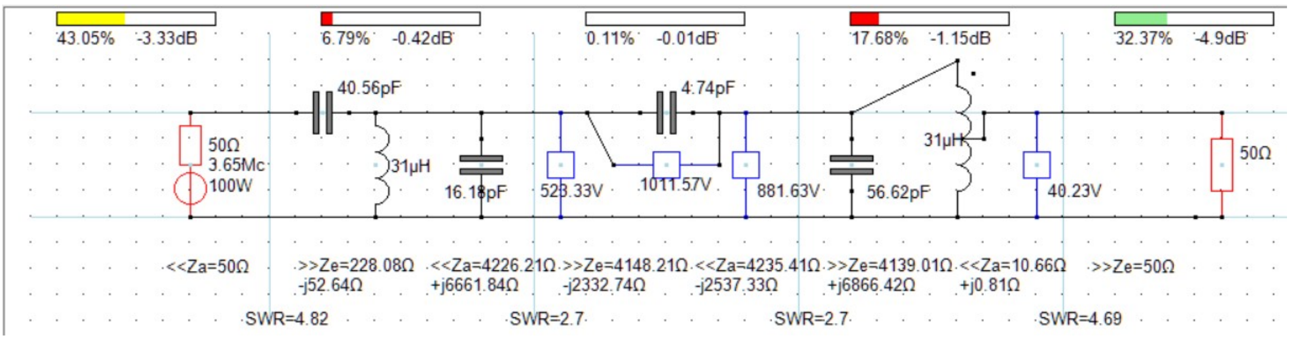
The following rules must be observed so that the loss bars display the correct values:

- The generator resistor (RG) must always be placed on the far left (in the first segment), the load impedance ZA on the far right (in the fifth segment).
- Only two connections (wires) are allowed between adjacent segments.
  These must be exactly at the height of the two horizontal lines of the blue grid.
- Avoid placing component connections directly on the intersection points of the grid.
- The connections of a component must not be located in different segments.

To move components or connections, drag a frame around them while holding down the right mouse button, then click left into it and move it to the new position while holding down the left mouse button.

If regrouping is too cumbersome for you, it is better to start from scratch (see example 3).

To perform the loss analysis for the following rule-compliant schematic of the 80m filter, activate the analysis tab and click the START button:



Below the circuit you can see the respective input and output impedances (Ze or Za) and the SWR at the interfaces of the segments.

What do the bars above the five segments mean?

The yellow bar (far left, 43.05%), shows the losses due to mismatch of the PA.
The bar is yellow because these are not heat losses.

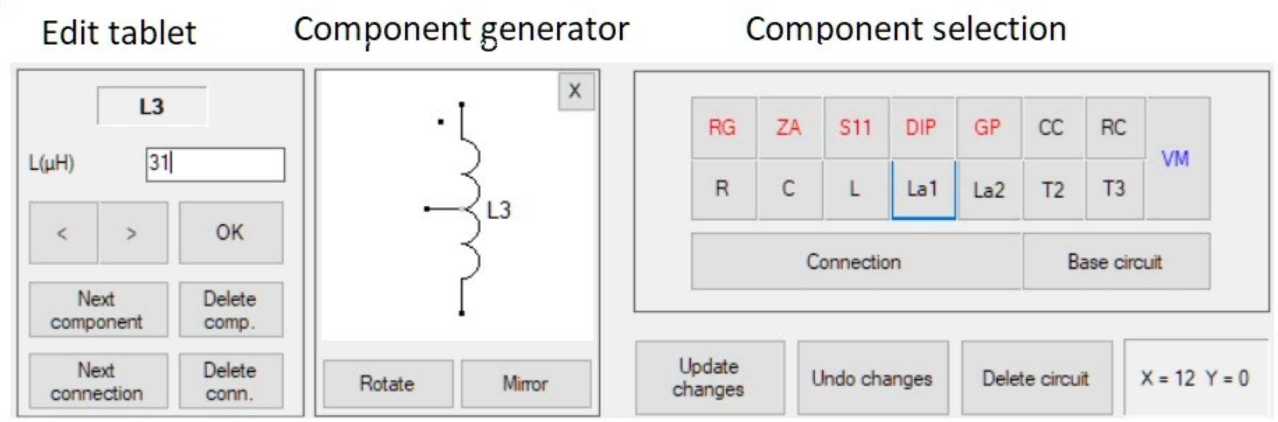
The 50Ohm internal resistance of the source "sees" the complex load Ze(Ohm) = 228-j52.6 which corresponds to a SWR = 4.82 or losses of 43%, so this is a clear mismatch.

The three middle segments are involved in different ways, together with the first segment resulting in total losses of 67.63%.

The remaining remainder (32.37%) is indicated by the green bar above the last segment, it is the forward transmission S21 of the circuit (-4.9dB) or transmission loss (4.9dB), i.e. at a PA power of 100W 32.37W are converted in the load resistor.

Example 3: **Design of a circuit (80m-bandpass)**

The operation of the designer is not difficult and quickly becomes routine.



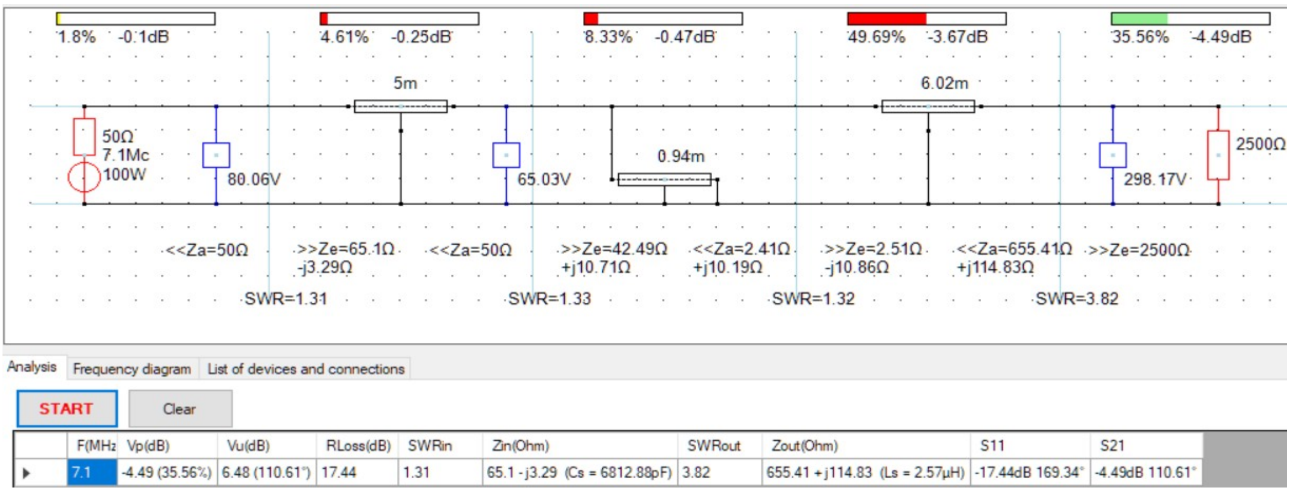
Here it should be shown step by step how you create a rule-compliant circuit for loss analysis from scratch:

- Open a new blank circuit file with **File/New.**
- Open the **Settings** menu, activate **Segmentation** and set the necessary checkmarks for the display options below the interfaces of the individual segments (Losses, Ze, Za, SWR).
- After you have closed the dialog with OK, click on the button **RG** in the **Component selection** (top right).
- The symbol for the internal resistance of the PA appears in the **Component generator** and must be rotated (**Rotate**) and mirrored (**Mirror**) as it should appear later at its final position.
- Click with the left mouse button in the first segment of the designer (to the left of the first blue line) and move the component (while holding down the mouse button) to its final position and only then release the mouse button.
  Note: A rotation or mirroring of the component is no longer possible here!
- Click on the **C** button in the **Component selection**, rotate the C symbol in the **Component creator** to the desired position and place it in the second segment.

- Proceed in an analogous way with the other components of the three middle segments.
- Click on the **ZA** (antenna impedance) button in the **Component selection** and place this component in the fifth segment (far right).
- Now establish the connection between the components by first clicking on the **Connection** button.
- Then click on a port and drag (while holding down the mouse button) the connecting line to the other port. Only then do you release the mouse button.
- Now make the remaining connections. You don't need to click the **Connection** button again, you simply proceed by clicking on the starting point of the next connection, dragging the connection, releasing the mouse, etc.
- Place **VM** (voltmeter) components where you want to measure the voltages.
- You can remove individual components by activating them first (click near the blue dot in the middle). The component now appears in red and is deleted when you click **Delete comp.** (or Delete key on the computer keyboard).
- As an alternative to clicking, you can also drag a frame around the circuit section to be deleted while holding down the **right** mouse button.
- At least now you should start with **File/Save as ...** save the circuit under a meaningful name.
- The electrical parameters are assigned by clicking on the component (it appears outlined in red) and assigning the values in the **Edit tablet**. You only need to click its **OK** button after all parameters of the component have been entered.

Example 4: End-feeded λ/2 coax antenna (J-antenna)

Load the file *Example 4.ama* via **File/Open**, select the **Analysis** tab (bottom left) and click on **START** next to it.



The 64.44W lost on the way to the antenna are therefore composed as follows:

- 1.8W losses due to mismatch
- 4.61W heat losses in the 5m long RG58 power cable
- 8.33W heat losses in the 0.94m long RG58 branch line
- 49.69W heat losses in the 6.02m long RG58 transformation line

The interpolation of the cable attenuation a(dB) for the working frequency f is carried out as usual according to the known root method:

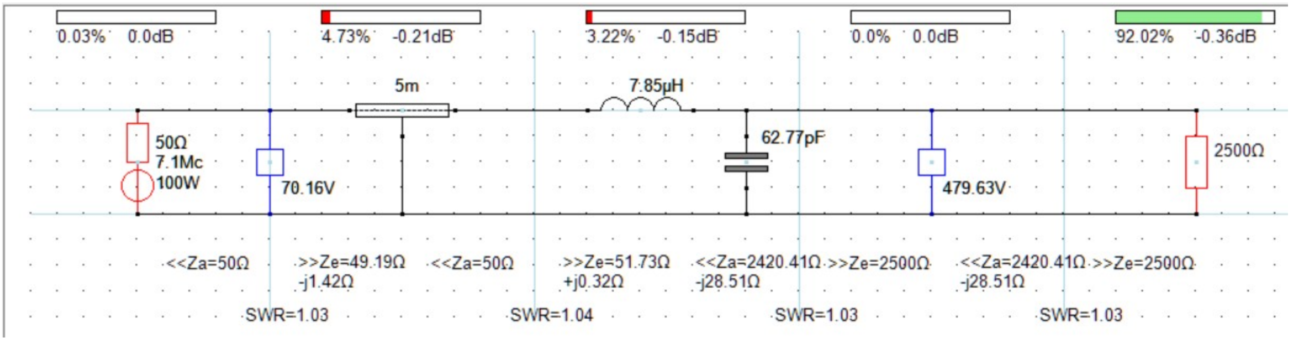
$$a(dB)_f \;=\; a(dB)_{fb}\sqrt{\frac{f}{fb}}$$

To edit the cable parameters, click in the middle of the cable (it will then appear outlined in red). Now you can navigate between the parameters in the edit tablet (top left) with the arrow keys and see that the cable attenuation of the RG58 is entered with 4dB at 7MHz.
According to the root approximation, this is about 4.03dB at 7.1MHz.

If you change the main frequency mark (input field at the top left) and click on START, the result list at the bottom of the main window will be supplemented by another line (similar to the well-known antenna simulation program MMANA-GAL).

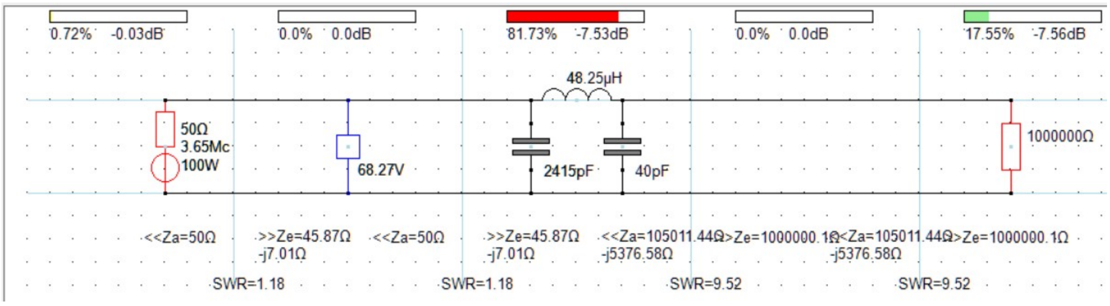
Example 5: λ/2-Antenna with LC-Adjustment

The file *Example 5.ama* contains the much less lossy alternative to the above, still very popular, coax antenna.



Beispiel 6: Kamikaze of an automatic ATU

The circuit in *Example 6.ama* demonstrates the self-destruction of an SG-230 due to the unconnected antenna cable:

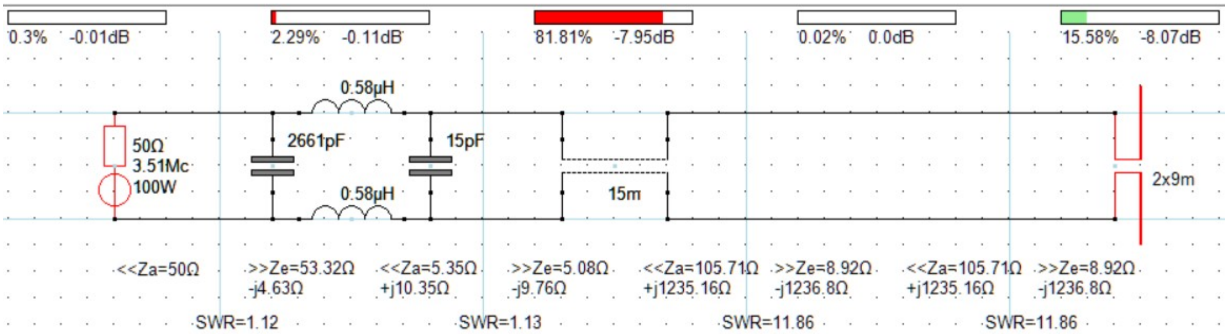


The "forgotten" antenna cable is simulated here by a very high-impedance load resistor (1MOhm).

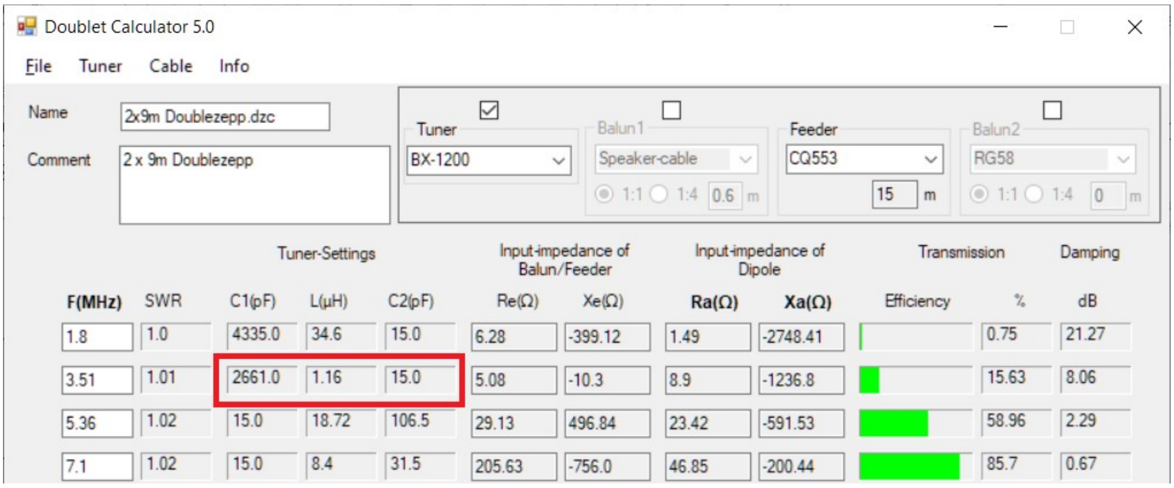
Beispiel 7: Short Doublezepp 2x9m

The file *Example 7.ama* shows a short Doublezepp which is feeded by 15m 450Ohm Wireman cable CQ553.
However, the exact values of the CQ553 differ from the inaccurate catalog specifications and are: Zw = 392Ohm, VF = 0.89, a = 0.63dB/100m at 3.5 MHz.
The balanced antenna coupler is a BX-1200.

As you can see, this double zepp has only a very low efficiency (15.6%) on the 80m band despite good SWR, as almost all the power is lost in the 15m long feeder.



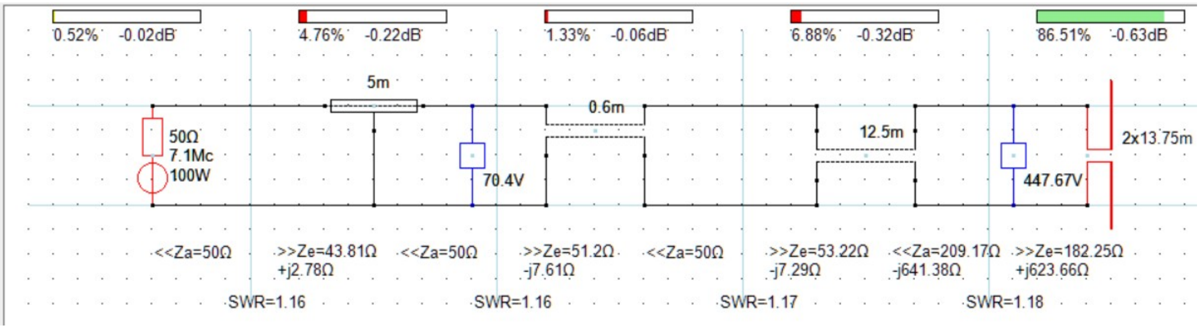
The LC values of the ATU required for tuning were determined bevorehand with the double-zepp calculator:



Example 8: ZS6BKW-"Miracle antenna"

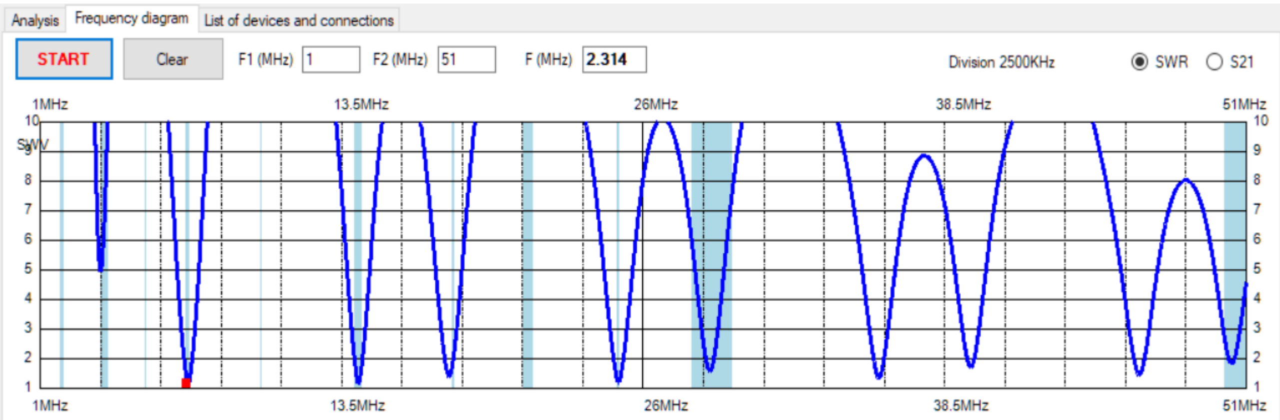
- Open the file *Example 8.ama* to load this famous antenna.
- The balun consists of 1m two-wire cable (Zw=102Ohm) and the feeder made of 12.5m Wireman tape cable CQ553 (used correctly, this cable is far better than its reputation!).
- Click on the red symbol of the dipole in the schematic on the right. As with all other components, you can navigate between the dipole parameters in the **Edit tablet** with the arrow keys (length = 27.5m; OCF tapping = 50%, i.e. symmetrical supply; Wire thickness d = 2mm) and change them if necessary.
- In the **Settings** menu, check the boxes for **Loss analysis**.

- Click START for a loss analysis (without antenna tuner!) e.g. for 7.1MHz:

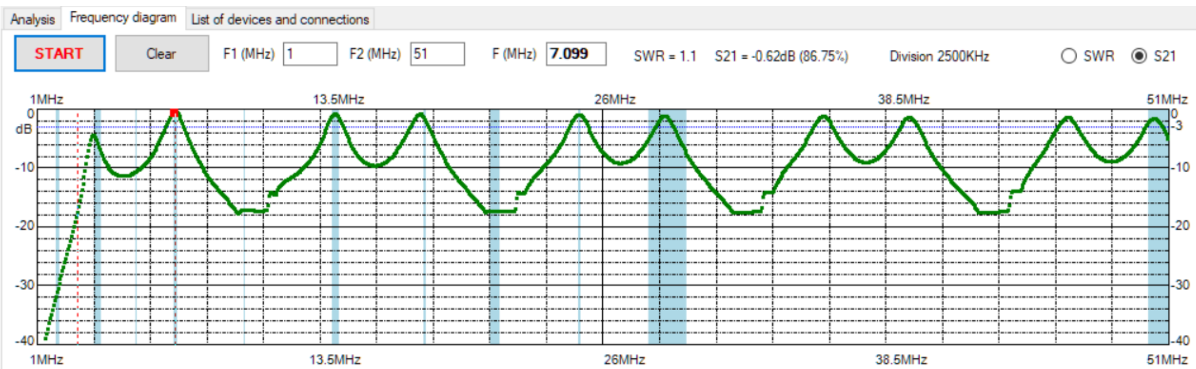


- Select **Frequency diagram** tab, enter the start and end frequency of the sweep-area (1...51MHz) and click START.

- The SWR curve confirms the 5 resonances, i.e. the SWR on the bands 40m, 20m, 12m, 10m and 6m is smaller than 2 (the 11 AFU bands are marked by light blue bars):



- You can also display the curve of the forward transmission (S21):

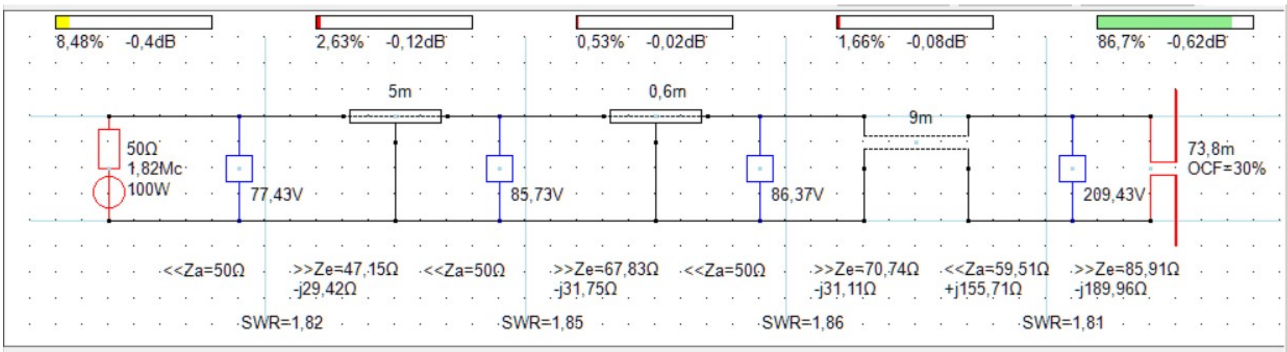


- With the mouse you move a vertical red frequency ruler over the diagram to continuously read SWR and forward transmission (above the diagram).
  You can also enter the frequency directly and complete with ENTER.

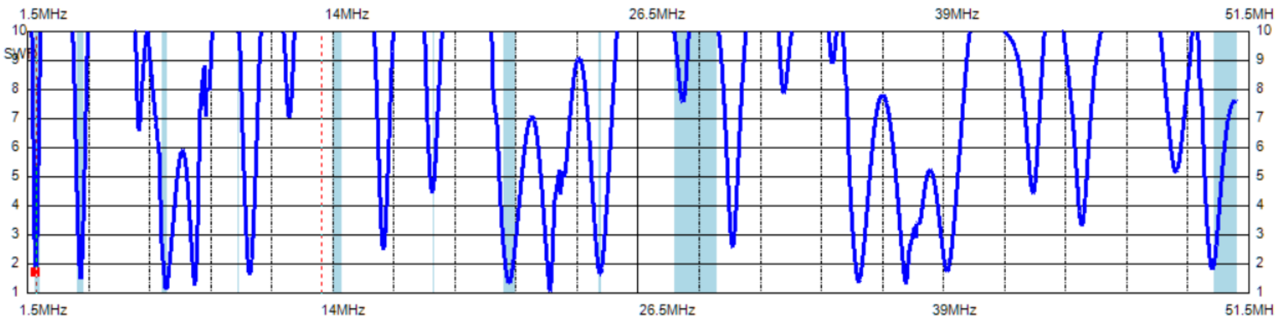
Note: After switching from the "Analysis" mode to the "Frequency diagram" (and vice versa), always click START again!

Example 9: **JWD-Allband-Doublezepp**

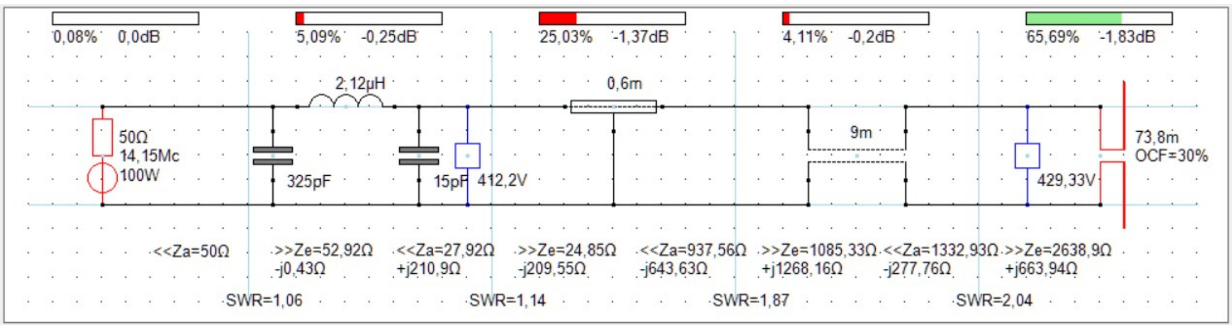
This antenna I discovered with the *MultiResonanceFinder*. Compared to the ZS6BKW, it can be used on all(!) 11 AFU bands (incl. 160m), but reaches considerable dimensions with 73.8m.
Here is the loss analysis for the 160m band (*Example 9.ama*):



The PA is connected via 5m RG58 to a 1:1 balun made of 0.6m RG316U (on FT140-43 toroidal core).
This is followed by a 9m feeder made of CQ553 ribbon line, which leads to a 73.8m long OCF dipole fed in at 30%.
The SWR diagram shows resonances on 6 bands (160m, 80m, 40m, 15m, 12m and 6m):

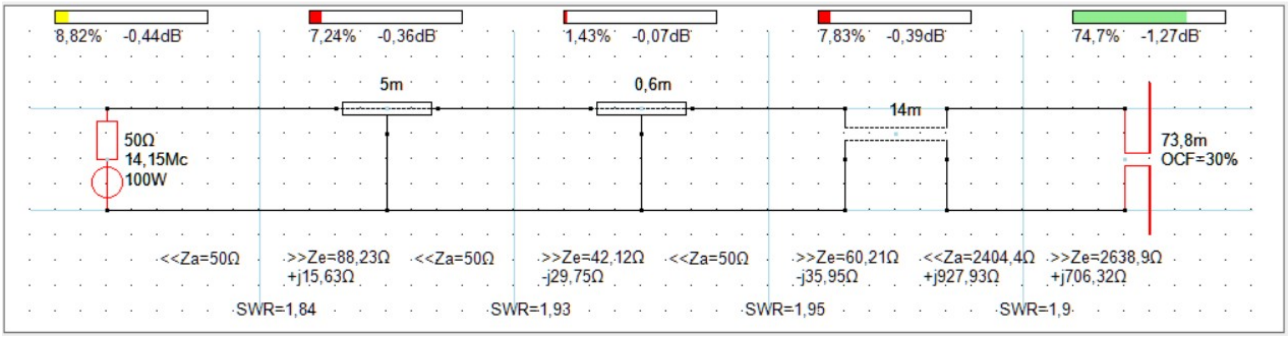


As the *Doublezepp Calculator* confirms, all other bands can also be brought to life with an antenna tuner (SWR < 2).
Here, however, it can lead to an overheating of the balun during prolonged broadcasting, e.g. on the 20m band:



The example illustrates that at 14.15MHz and 100Watt output the balun is "heated" with just under 25 watts (see *Example 9_14Mc.ama*).
However, with an extension of the feeder from 9 to 14m, the 20m band can also be operated without ATU.[1]:

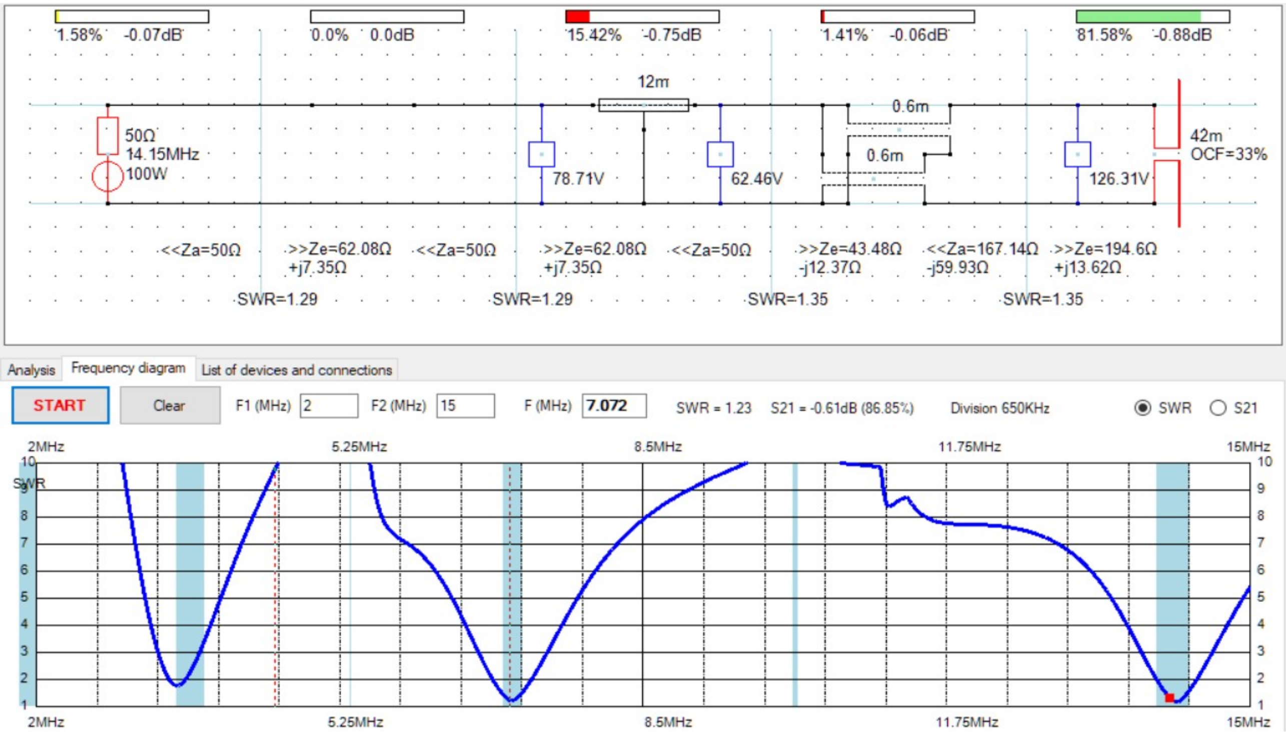
1 Tnx Mark (2E0VSS) who figured this out.



Attention: The feeder extension will partially destroy other resonances!

Example 10: **Windom-Antenna**

This 42m Windom is fed over 12m RG58 and a 4:1 balun manages on the bands 80/40 and 20m without ATU (*Example 10.ama*):

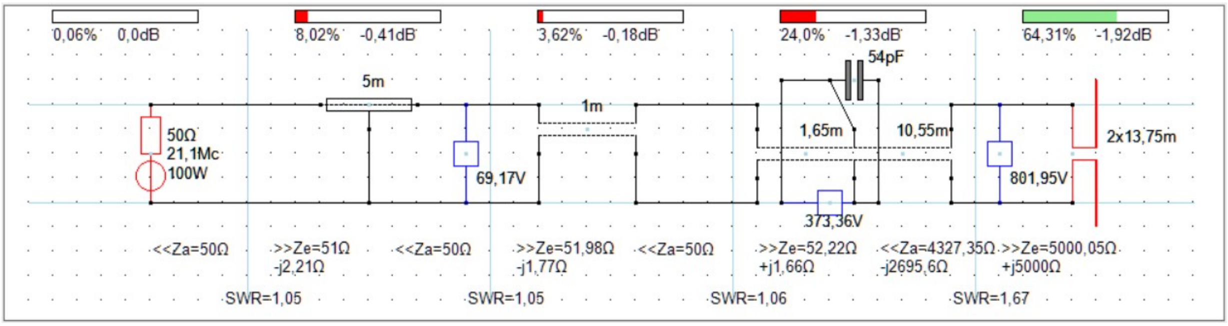


Example 11: **Additional band with parallel-C in the feeder**

If the feeder of a dipole is bridged at a certain point with a switchable capacitance, an additional resonance can be generated.

The *CFinder*-*Tool* can be used to calculate whether and at which position a certain C must be connected in order to achieve the desired result.

In *Example 11.ama*, the ZS6BKW is adapted to the 15m band by bridging the feeder with 54pF at a distance of 1.65m from the balun output.
The capacitor has about 373Vrms, so it should be loadable with about 1kV.



Example 12: **Antenna-Analysis with NanoVNA**

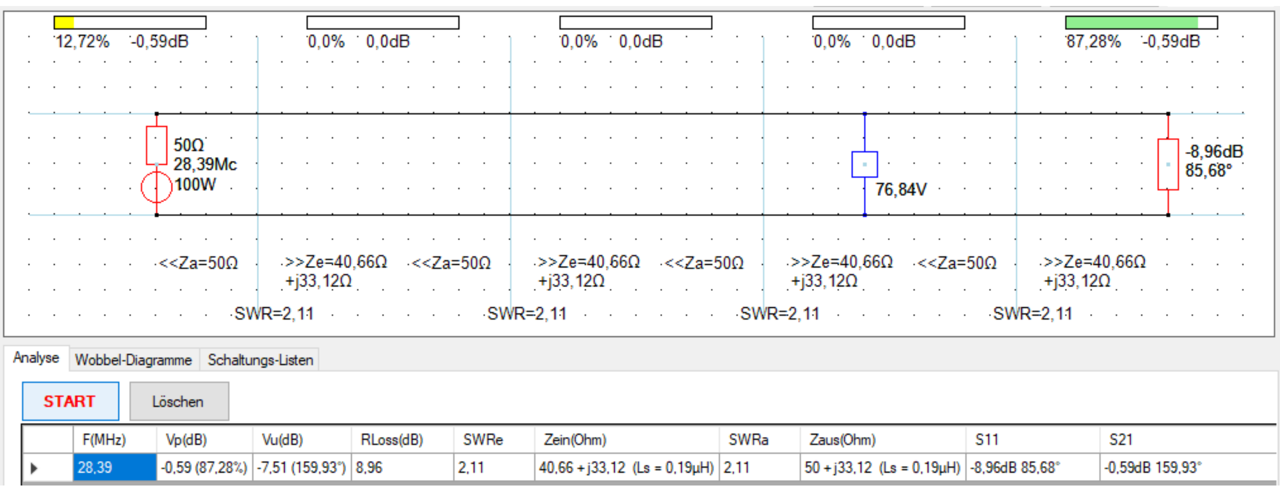
In practice, the most commonly quoted parameter in regards to antennas is S11. It represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma: or return loss. If S11=0 dB, then all the power is reflected from the antenna and nothing is radiated.

Example 12.ama shows the simplest case how you can also use the input reflection factor S11 as a "component" as an alternative to ZA.

We assume that you have measured the values -8.957dB and 85.68° with your NanoVNA at the input of the antenna power cable for S11.

Instead of "ZA", place the component "S11" in the rightmost segment of the designer and assign the two values to it.

You can see that "S11" offers two more parameters: RA and jXA. However, you do not enter anything in these two fields, they only serve as a control display of the load impedance ZA after completion of the analysis, which the KNWA has calculated from S11 (40.7Ohm + j33.1Ohm).



Quick Start Guide to Using the Designer

- Each circuit has exactly one generator resistor RG and one load impedance ZA (or dipole, groundplane or input reflection S11).

- If "Segmentation" is switched on (and only then), some special features must be taken into account, otherwise no exact loss analyses and SWR calculations are possible:

  - RG should always be placed in the first segment and ZA (or DIP, GP or S11) always in the last segment

  - the connecting wires between the segments must intersect the vertical blue lines at the same height as RG or ZA, DIP or GP

  - components must not lie on the vertical blue lines

  - the individual segments must always be connected with exactly two horizontal wires

- After clicking on the component-selection button ("RG", "ZA", "R", "C", ...), you first rotate and mirror each component into the desired position, then click on the designer and move the component to its final position while holding down the **left** mouse button.

- Once you have placed all the components, click on the "Connection" button to establish the connections between them.

- A subsequent rotation or mirroring of a component within the circuit is not possible.
  So delete it and recreate it in the desired position.
  However, it is always possible to move components and connections (see below).

- You delete components and connections by clicking (marked red) and then pressing the Delete key.
  For oblique connections, it is sometimes necessary to click several times near the beginning or end until the marker appears.

- Connections can also be entered one after the other, so the "Connection" button can only be clicked once!

- To move a component, a connection point or a circuit cutout, you have to drag a frame around while holding down the **right** mouse button, starting with the upper left corner.
  Then click with the **left** mouse button in the frame to move it.

- A complete overview of the circuit is provided by the tab "List of components and connections" .
  Here, too, you can check and edit components, parameters and connections directly.

- Rows in the data grids can be deleted after selecting the row (clicking on the left column) and pressing the Delete key.

- You can confirm the input of electrical parameters by clicking on the "OK" button or by pressing the ENTER key.

- A left mouse click on the designer reads the circuit again from memory.

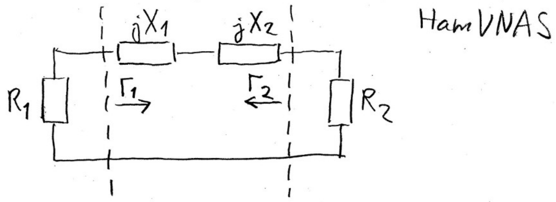
It is best to look at the attached sample files or modify them to familiarize yourself with the operation of the program.

Theory

The *SpecialNetworkAnalyser* is based on the classical four-pole theory, whereby the complex reflection factor *Γ i*s always measured against a **real** generator resistance *R1* and a generally complex load *Z2 = R2+jX21*[2]:

Γ = (R1 - **Z2**) / (R1 + **Z2**).

If the generator resistance is also complex (Z1=R1+jX1), the generator "sees" its own X1 as an additive component of X2:



$$\Gamma_1 = \frac{R_1 - (R_2 + j(X_1+X_2))}{R_1 + R_2 + j(X_1+X_2)} \qquad \Gamma_2 = \frac{R_2 - (R_1 + j(X_1+X_2))}{R_1 + R_2 + j(X_1+X_2)}$$

$$a = R_1 - R_2$$
$$b = -(X_1+X_2)$$
$$c = R_1 + R_2$$
$$d = X_1 + X_2$$

$$\Gamma_1 = \frac{ac+bd}{c^2+d^2} + j\frac{bc-ad}{c^2+d^2} \qquad \Gamma_2 = \frac{-ac+bd}{c^2+d^2} + j\frac{bc+ad}{c^2+d^2}$$

$$|\Gamma_1| = |\Gamma_2| = |\Gamma|$$

$$SWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Note: The worldwide used antenna analysis program *SimSmith* allows complex system resistances, but this can lead to serious irritations.

2 According to exactly this principle, you also measure the input reflection S11, e.g. with your NanoVNA (50Ohm system).