The new DZC 5.0 - not only for Double-zepps

The Doppel-Zepp (Doublet) is still one of the most popular multiband antennas, but the optimization can also be a headache for the experienced OM.
This is mainly due to the tricky task of choosing the length of the radiator and feeder so that all desired bands are equally well "operated".

From the first version (see /1/) I have made numerous improvements. which result from the wishes of many users.

The main-differences are:

- Two Baluns 1:1 or 4:1 now can be placed in the antenna system, one at the tuner output and the other directly at the feedpoint of dipole. Therefore the Doublet Calculator is not limited to double zepps but is also applicable to many other wire antennas, such as Windoms.
  With a transformation ratio of 1:1 this balun can also be used as a common-mode choke.

- For the selection of baluns and feeders, separate selection boxes are no longer used, but only a joint cable selection box.

- The transfer of own tuner and cable types into other projects has been simplified (no extra library-file). Similar to EZNEC, you can derive and overwrite new projects from existing projects (*File/ Save as...*).

- The tab for direct input of the measured values for the input- impedances of the dipole is omitted, since this task can also be taken over by the "Balun1-Input impedances" tab if you switch off booth baluns and set the feeder length 0.

- It eliminates the possibility to place a balun at the tuner input, but this is not a disadvantage, because the influence of such a balun on losses and efficiency is negligible due to the two-sided 50Ohm adjustment.

- Last but not least: To avoid problems with the decimal separator dot or comma, the following generally applies to all English versions of the JWD tools:
  Only the dot is accepted as the decimal separator.
  Which country-setting your Windows PC has is irrelevant!

However, the many improvements come at a price: **older projects cannot be taken over**.

Example 1: ZS6BKW - Antenna

The well-known ZS6BKW "miracle antenna" serves as the default antenna of the DZC, in any case, when you select the menu *File/New*, this antenna occurs.
In addition here you can learn easily the basic handling of the program.

- After having choosed the *File/New* menu click the button "START" at the bottom left.

- By the length of the green bars, you can see the efficiency on each of the 11 amateur radio bands, i.e. what percentage of the maximum available PA power is radiated. On 5 bands, the PA "sees" a SWR < 2, so that operation without antenna tuner is possible.

- With the navigator buttons you can change the feeder length while watching the green bars. You will notice that the length of 12.5m is actually optimal.

- As you can see on the "Schema" tab at the bottom right the 2x13.75m long dipole is fed via 12.4m semi-open 450Ohm tape line CQ553 from Wireman and is connected (without ATU) via a so-called "balun for undefined impedances" directly to the PA output.

F(MHz)	SWR	C1(pF)	L(µH)	C2(pF)	Re(Ω)	Xe(Ω)	Ra(Ω)	Xa(Ω)	Efficiency	%	dB
1.8	276.44				10.52	-377.95	5.04	-1845.44		0.05	32.93
3.65	6.46				12.81	39.66	25.71	-585.38		30.37	5.18
5.36	36.88				406.85	-763.41	69.43	12.05		8.6	10.66
7.1	1.02				51.25	0.05	182.24	641.35		90.7	0.42
10.1	89.4				155.51	-817.67	3966.89	5000		2.03	16.93
14.15	1.34				38.38	-5.78	144.65	-668.69		83.91	0.76
18.1	2.28				80.41	44.47	237.18	655.8		75.68	1.21
21.1	68.39				24.79	-285.76	5000	5000		2.17	16.64
24.9	1.19				45.31	-6.63	215.73	-699.05		85.14	0.7
28.5	1.99				51.44	-35.48	197.4	439.84		79.13	1.02
50	1.99				34.47	-24.72	188.93	319.97		76.16	1.18

- If you set a high-quality two-wire transmission line (Ladderline 600) in the Feeder-drop-down box instead of the CQ553, you will be surprised: SWRs and efficiencies sometimes deteriorate significantly!

- After clicking the above Tuner-CheckBox you can select a specific antenna coupler (ATU) in the top left drop-down box and observe which "bad" bands can be brought to life with it. With the exception of the 160m band, all bands can be adjusted to good to very good SWRs with the MFJ993 automatic tuner.

- However, the SWR belief that is deeply rooted in many OMs can be deceptive, because ultimately the decisive factor is the efficiency, i.e. the question "What part of power arrives in the antenna?".
  The efficiency of the ZS6BKW is below 50% on the 15m and 30m bands and the 64% on

80m is no reason for euphoria. The power lost (e.g. 36% on 80m) is converted into heat somewhere in the tuner, balun or feeder - who hasn't burned their fingers on a hot balun?

Notes

- This introductory example also offers an opportunity to convince yourself of the advantages of a balanced antenna coupler (e.g. the BX-1200), because then you can do without the "balun for undefined impedances" and the efficiencies partially improve considerably.
- The circuit diagram in the lower part provides a quick overview of the antenna system.
- The transmitter SWR, the settings of the switching elements of the antenna coupler (C1, L, C2) and the input impedance (Re+jXe) of the feeder can also be read for each frequency.
- In the menus "Tuner" and "Cable" you can find out about the exact parameters of the tuner, balun and feeder and, if necessary, make changes or add new types. Don't forget to save the changes (*File/Save as...*).

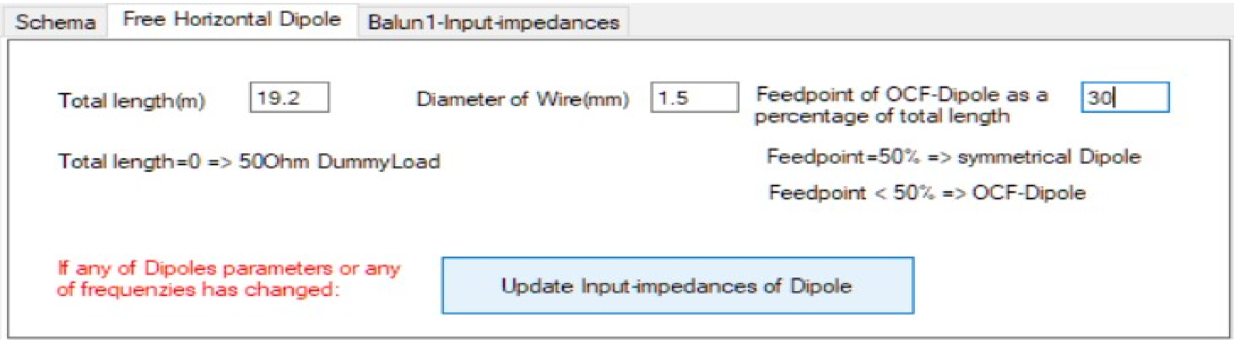
- The baluns are modeled as normal pieces of cable, since its number of turns or inductance only affects the common-mode currents or sheath waves and is irrelevant for the matching ratios.

Example 2: JWD - City zepp

This unbalanced feeded multiband antenna for the bands 40/20/10m was first described in /7/.
In this example you can see how you can create an antenna project yourself step by step.

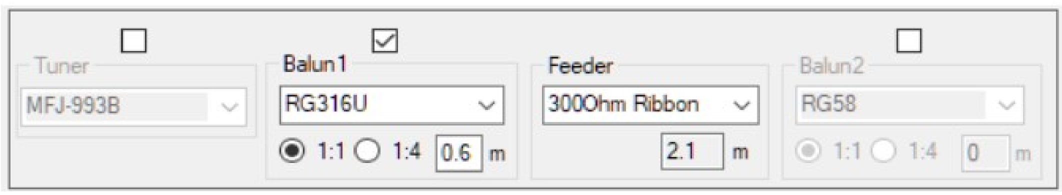
- Open with *File/New* a new DZC-project. Because the start configuration still corresponds to the ZS6BKW you have to overwrite all input-values with the parameters of the new antenna. Also clear the comment and save the project under its final name (e.g. JWD-CityZepp).

- Select below the tab "Free Horizontal Dipole", enter the new dimensions of the dipole (Total length, Diameter of Wire, OCF-Feedpoint) and click the button "Update Input-impedances of Dipole":



- The grey fields Ra and jXa of the columns "Input impedance of Balun1" of the result matrix will now be filled with the according input-impedances of the dipole.
  This data remains unchanged in the current project and will saved with it, unless you change a frequency or the dipole data.

- Now activate Balun1 (checkBox at the top of the window) and select type and length of the cable for its winding.
  Because there is no need for an ATU and a dipole-side Balun2 deactivate these checkboxes.



- Changing the feeder length by clicking on the START-button (bottom left), you will find that the optimum is close to 2.1m.
  Here, the 40/20/10m bands not only show a good SWR, but also an excellent efficiency.

		Tuner-Settings			Input-impedance of Balun1		Input-impedance of Dipole		Transmission		Damping
F(MHz)	SWR	C1(pF)	L(µH)	C2(pF)	Re(Ω)	Xe(Ω)	Ra(Ω)	Xa(Ω)	Efficiency	%	dB
1.8	370.85				30.47	-749.35	2.17	-3096.52		0.0	43.35
3.65	231.32				10.6	-346.42	13.85	-1315.12		0.18	27.44
5.36	88.46				9.35	-196.93	36.73	-639.02		2.52	15.99
7.1	1.57				71.98	-16.21	90.93	-120.11		93.22	0.31
10.1	56.07				12.54	-180.32	1246.6	2269.89		4.39	13.57
14.15	1.59				48.76	-23.2	137.92	-306.86		91.89	0.37
18.1	26.19				10.1	-103.15	216.87	644.97		10.91	9.62
21.1	24.36				4.92	-59.0	1513.13	2866.81		10.99	9.59
24.9	12.09				5.19	-25.2	5000	5000		21.92	6.59
28.5	2.08				103.35	7.25	1052.87	-766.69		83.35	0.79
50	35.05				2.62	-45.65	2261.74	2838.86		3.91	14.08

Important

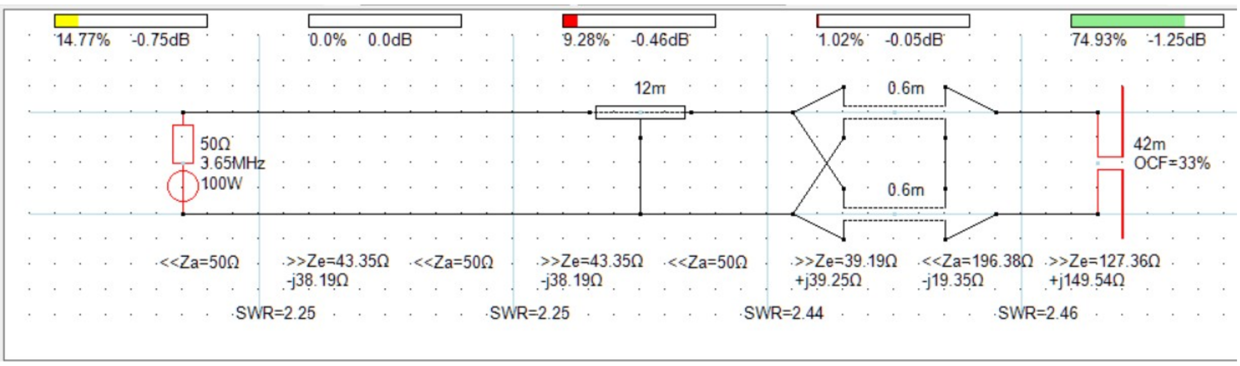
- In the left margin column of the result matrix, the 11 most used frequencies are already entered (you can overwrite unnecessary frequencies with a 0, this saves computing time).
- New frequencies should be defined as soon as possible at the beginning (after *File/New*) and not changed later.
- If you still have to change or add a new frequency later, the corresponding input field will initially appear in red.
  This is the urgent note that you need to go back to the "Free Horizontal Dipole" tab to click "Update Input-impedances of dipole", so that Ra and jXa of the dipole are also adjusted to the new frequencies.

Example 3: 42m-Windom-Antenna

This wellknown antenna uses balun1 and balun2. The 4:1 balun2 is attached at lofty heights, directly at the input of the dipole and transforms the input impedance of the 42m long OCF-dipol down to a tolerable level. The supply line is via light RG58 coaxial cable.

Notes

- Changing the parameters you will notice that for this antenna the length of the feed cable is relatively uncritical.
- Switching on an tuner, you will see, that all KW bands (except 160m) can be adjusted to a very good SWR. Nevertheless, the antenna is unusable on the bands 60m, 30m and 15m.
- The **4:1 balun** is modeled by two pieces of cable, but only the length of one piece must be entered. In other words it is created by the interconnection of two 1:1 baluns, as seen here in the model of the Windom antenna in *16_Special NetworkAnalyser*:



Example 4: Measurements of Input-impedances with an antenna analyser

Real dipoles often do not hang freely enough, are angled and/or one or two branches go down obliquely.
Therefore, the "free horizontal dipole" used in the previous examples can usually only provide rough orientation values.
You only notice how far apart theory and practice ultimately are based on your own measurements with a vectorial antenna analyzer (e.g. with a NanoVNA).

However, since you can only measure directly at the input of the dipole in rare cases, you usually have to do this at the (open) input of the supply cable (without balun!).
The feeder then transforms the measured values directly into the base impedance of the dipole (see cable calculator).

But note, that impedance measurements directly at the input of a balanced two-wire line with a unbalanced VNA (NanoVNA) are not a good idea. The interposition of a balun is urgently needed, but you have to know exactly the cable type and the length of the balunwind, otherwise nonsensical results will arise.

The following table shows the impedances of an angled 2x22m double zepp measured by a friendly OM at the open input of a balun which is connected to a 3m feeder (Wireman CQ553).

f(MHz)	1,81		3,51		7,11		14,0		21,025		28,02	
Ze(Ω)	Re	jXe	Re	jXe	Re	jXe	Re	jXe	Re	jXe	Re	jXe
	5	-256	370	-322	623	444	12,6	-103	6.5	-97	150	-131

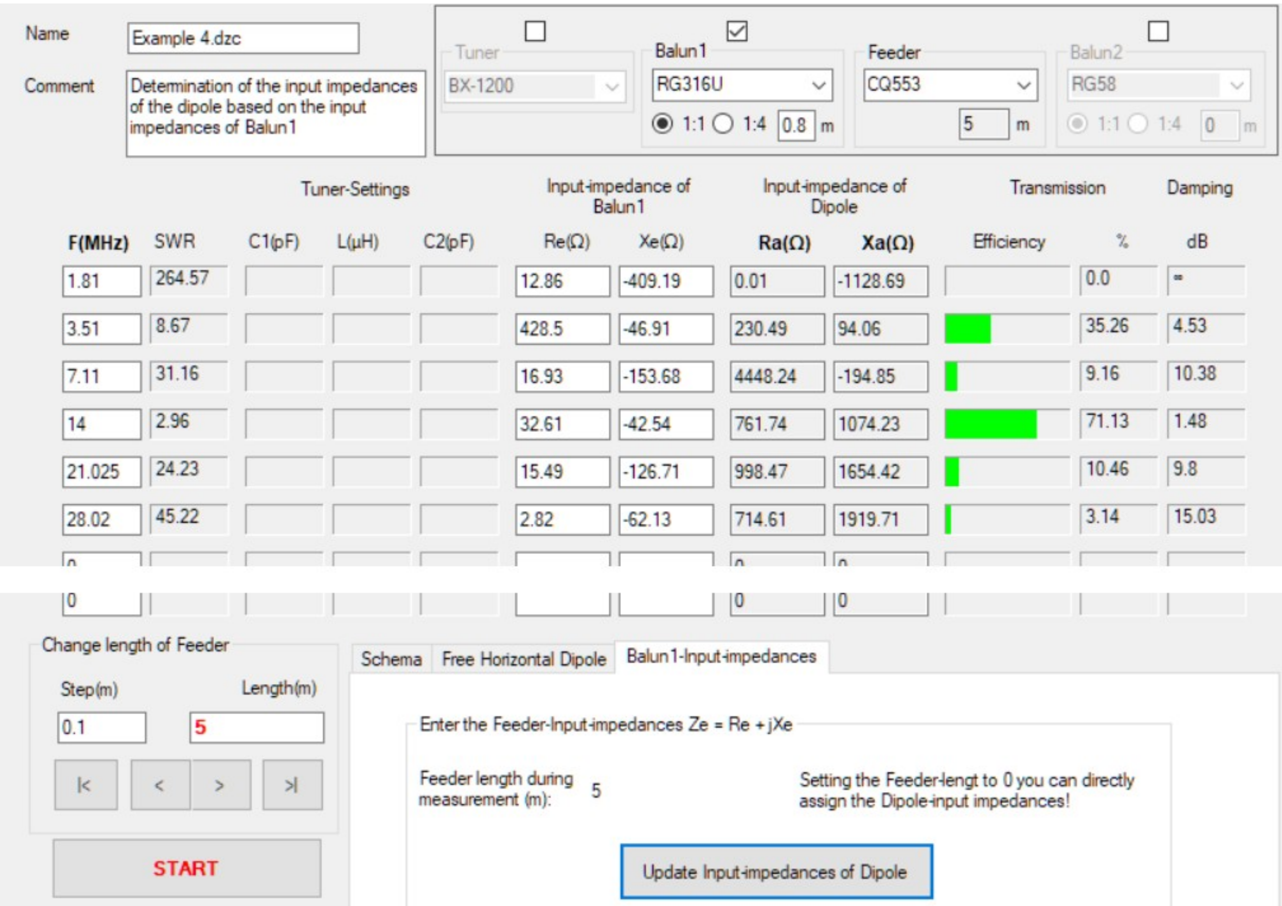
How do you enter this data into the DZC?

- Deactivate the "Tuner" and "Balun2"-checkboxes.
- Overwrite the left margin column of the matrix with the 6 measuring frequencies according to above table, in the 5 remaining fields you can enter 0.
- All fields are initially highlighted in red, because the input impedances of the dipole have not yet been updated.
- With the START-button set exactly the feeder length at which the measurements were taken.

- You don't need the "Free Horizontal Dipole" tab at all, instead open the "Balun1 Input-impedances" tab.
  This will release the columns for Re and jXe for editing in the matrix.
  Enter all measured values here (see table above).

- Click the "Update Input-impedances of Dipole" button in the "Balun1-Input impedance" tab to transform the measured values for Re+jXe into the corresponding input impedances Ra+jXa of the dipole.

- The measured values now are being transferred in the dipole-input impedances and the columns Ra and Xa are updated.



- Now you can continue as usual, so gradually change the feeder length to achieve good efficiency on as many bands as possible.
  A good solution in this case is a feeder length of 5m using a balanced tuner.

- You will realize that for a 2x22m dipole an acceptable solution is impossible with an unbalanced tuner, because the then necessary balun1 brings high losses with it.

Note: If you can measure the input impedance of the dipole directly or calculate it with EZNEC**,** then **deactivate both baluns and set the feeder length to zero.**

Insertion of new tuner and cable types

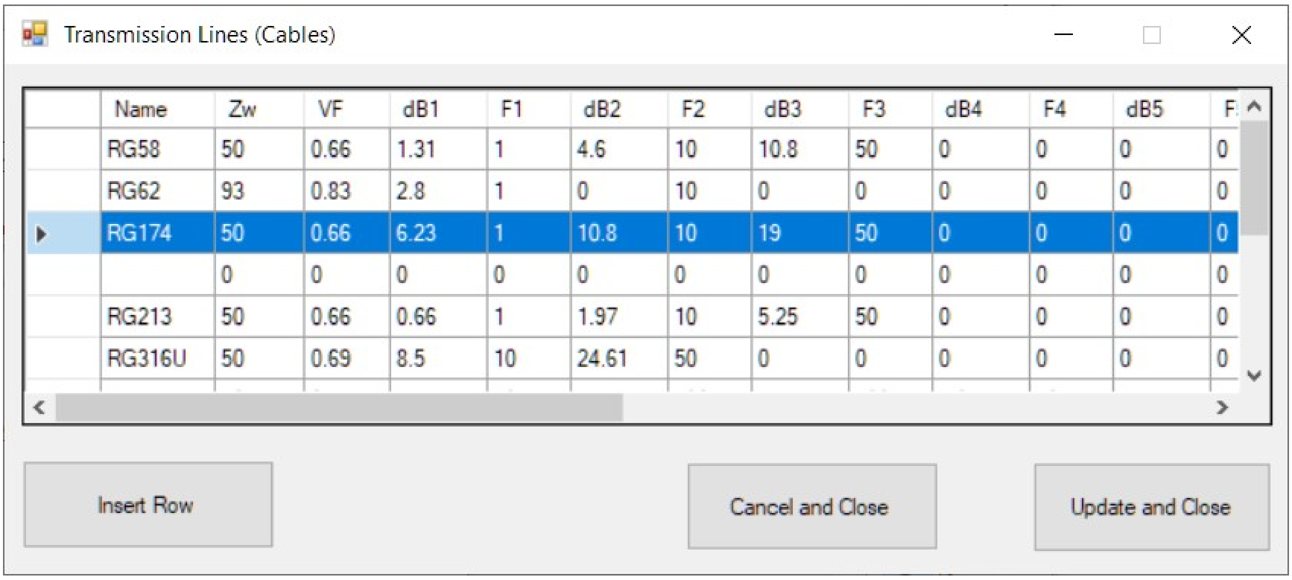
The default tuner and cable types are included each time a new project is opened (*File/New*).
This standard offer cannot be changed.
However, you can this types overwrite or delete, or you cann add new types, but this only affects the current project.
If you want to use your own tuner and cable types in other projects, you should (similar to EZNEC) do this with *File/Save as ...*

The electric units generally used in the DZC are MHz, ohms, µH, pF, dB and meter(m).

Adding new cable types

- Open the "Transmission Lines" window (menu *Cable*).

- The data grid is easy to edit:
  To add a new cable type, highlight the insertion position by clicking on the left margin of a row and then on the button "Insert Row":



- Now enter the name, Zw(ohm) and the shortening factor VF.

- For the frequency-dependent cable attenuation you need at least one measuring point (frequency in MHz and attenuation in dB/100m), which can usually be found in the manufacturer's catalog information. You enter this pair e.g. at dB1 and F1, if other values are available also at F2/dB2 etc.

- The entry of further measuring points only makes sense if they are located in the considered frequency range of the antenna. In order to calculate the attenuation for a certain frequency, the program searches for the nearest measuring point and interpolates from there according to the root method.

- To remove a row, click on the left margin (the entire line turns blue) and press the Delete key.

- Click the "Update and Close" button to return to the main window.

- So that the modified cable list is also available in further projects, you have to save the current project again under the name of the new project (*File/Save as...*) and adjust it.

- In contrast to the feeder, a balun usually uses very thin coaxial cable or insulated twin strands such as speaker cables. The length of the winding results from the height and width of the core and the number of turns and must be determined in advance by yourself.

Adding new balun types

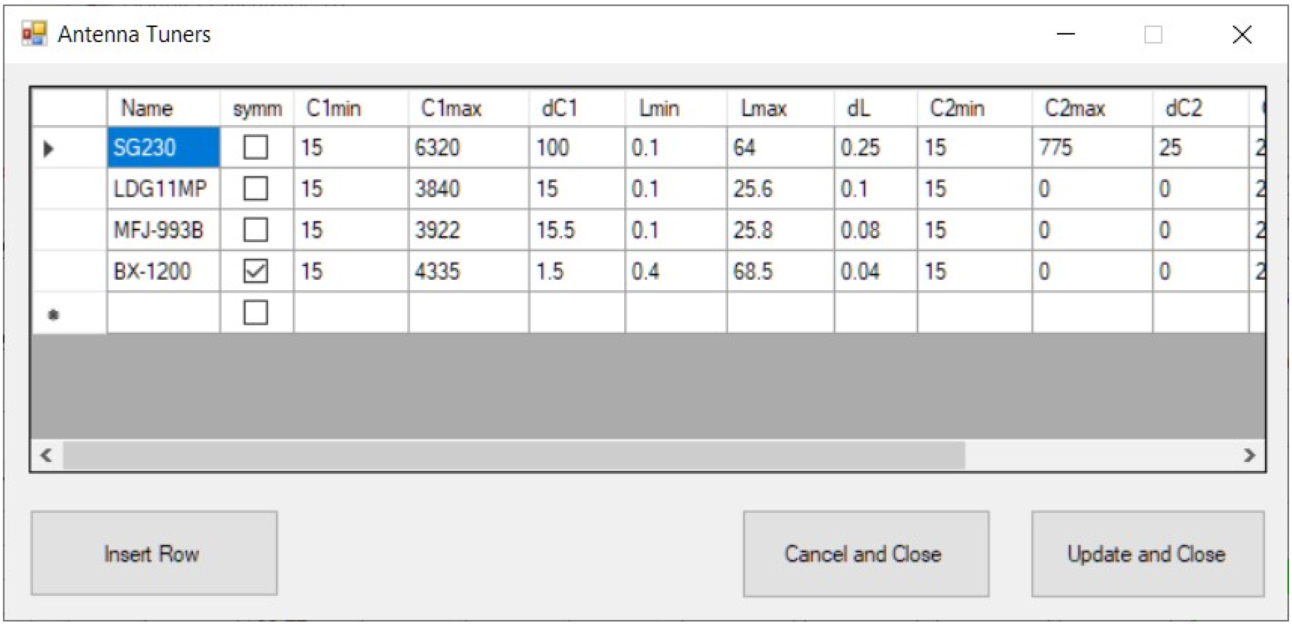
- In contrast to a transmission line, a balun usually uses very thin coaxial cable or insulated twin wires such as speaker cables. The length of the winding results from the height and width of the core and the number of turns and must be determined in advance by yourself.

- The inductance of a 1:1 current balun prevents the continuation of the common-mode currents, which are created by the transition unbalanced to balanced.
  Since the energy transport through the line does not generate any noticeable magnetic flux in the ferrite core and only the common-mode currents (sheath waves) can build up a voltage over the core winding, the size of the inductor has no effect on the calculation results, because the DZC "sees" only one line.

Adding new tuner types

Until now in the DZC only Pi filters with a low-pass structure can be processed as tuners[1].

- Via the "Tuner"-menu you open the window "Antenna Tuners".
- Each row of the table contains the data of a discrete Pi coupler that can be switched via relays.



Name	symm	C1min	C1max	dC1	Lmin	Lmax	dL	C2min	C2max	dC2	
SG230	☐	15	6320	100	0.1	64	0.25	15	775	25	2
LDG11MP	☐	15	3840	15	0.1	25.6	0.1	15	0	0	2
MFJ-993B	☐	15	3922	15.5	0.1	25.8	0.08	15	0	0	2
BX-1200	☑	15	4335	1.5	0.4	68.5	0.04	15	0	0	2
	☐										

1 However, these can be converted into high-pass types e.g. with the *09_Pi-T coupler* tool.

- The unbalanced coupler SG-230 can be equipped with its 6 Trx-sided C of 15pF ... Combine 6320pF in 100pF increments.

- The eight inductors cover the range of 0.1µH ... 64µH with a gradation of 0.25µH.
The 5 antenna-side C went from 15pF ... 775pF with 25pF increment.

- In total, more 64x256x32=524,288 different settings are possible, which are traversed by the program in three nested loops.

- The setting is found that results in the smallest Trx-side SWR at a known load impedance, taking into account the losses in coil (QL) and capacitance (QC).

- Any not-too-lame PC can handle the half-million loop passes required by this type of coupler in fractions of a second!

- Some tuners, such as the LDG11MP, belong to the **"fake" Collins filters** (LC tuners), i.e. there is only one tunable capacity (C1), which is connected in front of or behind the L as required.

- **In order for the DZC to recognize that it is a "fake" CF, the values for C2max and dC2 must be set to zero in the "tuner list".**
C2min represents the output side minimum (parasitic) capacitance.

- A **balanced couple**r you first have to "convert" into an unbalanced coupler.
Let's take the BX-1200 (available through the FA) as an example:
Each of its two L-decades reaches a maximum value of 34.25µH (all relay contacts open), the gradation of each decade is 0.02µH, the residual inductance 0.2µH.

  The largest value of the C-decade (all relay contacts closed) is 4335.5pF, the smallest switchable value is 1.5pF. Input and output capacitance are set at 15pF each.

  Therefore, the following values must be entered in the data grid of the BX-1200:
Lmin = 0.4µH; Lmax = 68.5µH; dL=0.04µH;
C1min=15pF; C1max=4335.5pF; dC1= 1.5pF; C2min = 0;
C2max=0; dC2=0; (see "fake" Collins filter).
QL=250; QC=1000; (medium grades of coils or capacitors)

- The calculation results displayed by the DZC for C1, L, C2 always refer to an unbalanced tuner and must be interpreted by you afterwards as balanced values, e.g. L=5.8µH means 2.9µH per branch.

- The check mark in the column "symm" is only relevant for the graphic representation (tab "Schema").

Further information

- If you enter the total length 0 for the dipole, the dipole will automatically be replaced by a 50ohm dummy load.

- If you have calculated the input impedances of the dipole with an antenna simulation program (**EZNEC**, MMANA-GAL), set the feeder length 0 and enter these values via the "Balun1 input impedance" tab (switch off tuner and both baluns!).

- A low efficiency (transmission) with at the same time perfect SWR must always make you suspicious, somewhere (tuner, balun, feeder) the power must have been lost.
  The *16_Special Network Analyser* is a useful addition to the DZC for loss analysis.

- A balanced coupler (e.g. BX-2000) is always the first choice, there is no need for a balun1. There is a significantly higher efficiencies on all bands than an unbalanced coupler wich ultimativly needs a balun1.

  The latter variant also requires a particularly careful optimization of the feeder length, otherwise there is a risk that the balun will be destroyed by overheating. This can, despite a very good SWR at the transmitter output, destroy considerable parts of the transmission energy.

- The *08_Coil Calculator* can be used to analyze the sheath attenuation of the balun.

- If you do not have a coupler with LC low-pass structure, you can also transform the calculated values into other coupler types (see *09_Pi_T_Coupler*).

Questions and answers

Some OMs had kindly agreed to test the DZC, thank you very much, because I was able to improve some things! Here are the answers to the most important questions:

I have already worked with older DZC versions. Why do I get different results with the new version when I use Wiremann tape cable CQ553?

- In versions 1.x of the DZC, the attenuation values of the CQ553 for a certain frequency f were still interpolated according to the simplified method, starting from a single measuring point (attenuation at 10MHz):

$$a(dB)_f \;=\; a(dB)_{10\,MHz} \;*\sqrt{\frac{f}{10}}$$

- In the current version, the data published in /2/ of the CQ553 with multiple measuring points are taken into account, which allow a much more accurate interpolation for the intermediate frequencies.

How does the DZC calculate the input-impedances of the dipole?

- Let's take a 2x22m dipole as an example.
  For the 160m and 80m bands, this dipole is considered "short" and the integral known from the antenna theory and also shown in /3/ is used to calculate the real part Ra of the input impedance, which is applicable in the length range $l/\lambda < 0.38$ (l = half length of the dipole):

$$R_a = \frac{120\ \Omega}{\sin^2 2\pi\frac{\ell}{\lambda}} \int_{\varphi=0}^{\pi/2} \frac{[\cos(2\pi\frac{\ell}{\lambda}\sin\varphi) - \cos 2\pi\frac{\ell}{\lambda}]^2}{\cos\varphi}\, d\varphi, \quad \frac{\ell}{\lambda} \lessapprox 0{,}38$$

- As "terrifying" as this integral may seem, the numerical solution does not cause any problems in the PC age. For the determination of the reactance Xa I have also implemented approximation formulas from /3/.

- For longer antennas, integrals from /6/ are implemented, as they also provide the calculation basis for other JWD-tools (*13_DipoleAndGP, 14_OCF_Dipole, 18_MultiResonanceFinder*).

- The maximum values for Ra and Xa are limited to 5kOhm for practical reasons.

- Especially in the very low-impedance range (below 10 ohms), the measured values of the amateur VNAs should be treated with caution. Here it helps, for example, to place two low-inductance 10Ohm resistors symmetrically in series.
  Do not hold the analyzer in your hand, but place it on a table, e.g. with a thick non-conductive surface!

- Of course, the transmission line (feeder) must go as vertically as possible from the dipole in order to avoid radiation coupling, which can significantly distort the measured values.

Why did the feeder suddenly disappear in the schematic?

- Do not be surprised, because the feeder then probably has the length 0 (zero), so it is virtually no longer available.
  Consequently, it is only shown in the drawing as a normal wire connection.

Can I simulate other antennas with the DZC?

- For inputs directly in the column "Balun1 input impedances" it ultimately does not matter what type of antenna is attached to the rear (it could be e.g. a GP or any other complex load resistor), ultimately the input impedances Ra+jXa are decisive.

Why for measurements it is called "Balun1 Input impedances" even though Balun1 is switched off?

- In the DZC-simulation, Balun1 is still present, it is only bridged, i.e. the length of the winding is temporarily set to zero. The measuring points remain the same.

My DZC calculates and calculates and does not come to the end. What did I do wrong?

- Probably you have added a new tuner type with nonsensical values, so that the program is in an infinite loop or you have chosen too small gradations (ΔC1, ΔC2, ΔL) so that the calculations take minutes. Use the Windows Task Manager to force the termination.

I calculated my antenna with the DZC and then set it up practically.
However, the measured resonances are much too low. Did the DZC calculate incorrectly?

- No, that's ok, because the DZC always calculates the length of the dipole under the conditions of free space. In a real environment and depending on the height above the ground, the dipole must always be more or less shortened.
  The required shortening factor shall be determined by the final SWR measurements.

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