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Dimensioning and comparison of Pi and T couplers

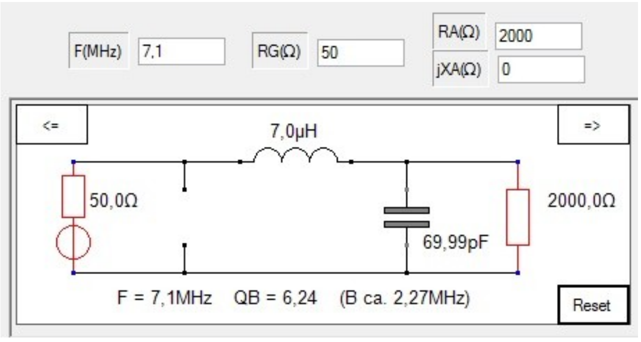
Pi and T couplers are among the best-known tuners that the radio amateur uses to adapt his power amplifier to a wide variety of antennas.
Both coupler types consist of two tunable capacitances and one tunable inductor.

The tool calculates (neglecting the losses in L and C) at a given input impedance of the antenna cable the various settings to achieve a standing wave ratio of 1.0 and allows insightful comparisons between both types of couplers.

Example 1:

An end-feeded half-wave radiator for the 40m band has a real input impedance RA = 2000Ohm at 7.1MHz.
What values would a Pi link connected directly to the antenna base point have to have, to achieve the best adaptation to the 50Ohm feeding cable?

After entering the data, click on "<=" in the upper left corner of the Pi circuit until the LC values no longer change or on "Reset".
In this case, the operating quality has reached its lowest possible value and the pi link has degenerated into an LC half-link (low pass).
This promises maximum broadband capability with the lowest possible adaptation losses.



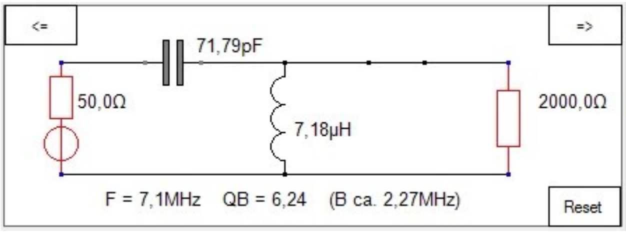
By means of the "=>" button, the operating quality is gradually increased.
Although this means better selection properties, at the same time the adaptation losses also increase.

Since modern power amplifiers already have good harmonic filters, a high operating quality of the coupler is neither necessary nor desirable, the optimization therefore usually follows criterion of the lowest adjustment losses.

Example 2:

The predecessor example is to be realized as a T-link.

With the same procedure, only this time on the right side, the following optimal solution results:



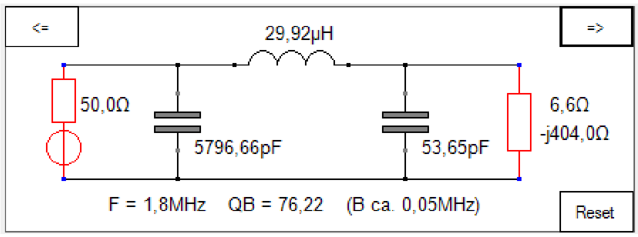
It can be seen that here too the T-circuit has degenerated into a simple high pass, whose switching elements and its operating quality correspond approximately to those of the predecessor example.

Interesting, but for other purposes, would also be an interconnection of both solutions on the 2000 ohm side to realize a low-loss bandpass with 50 ohm termination on both sides.

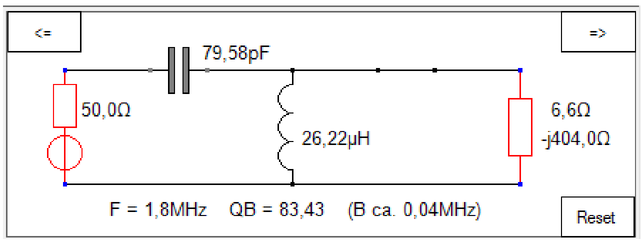
Example 3:

At the input of the feed line of a dipole that is greatly shortened for 1.8MHz operation, we measure the impedance Za(Ohm) = 6.6 - j404 with a VNA.
A 30µH coil and two 100pF rotary coats are available for our coupler.
Which type of coupler (Pi or T) would be more suitable?

With the Pi coupler, after the "reset" and repeated click on "=>" for C2, we initially only get negative values (i.e. C2 should actually be an inductor).
After a further increase in QB, we will eventually get into positive territory for C2, but the limit values for L and C1 cannot be met together with the available components.
Although L is just at the limit in the following solution, C1 is still much too large:



However, a construction as a T-coupler would be possible without any problems, which clearly made the decision in favor of this variant:



However, the relative narrowband (3dB bandwidth only 40kHz) should also be noted here, which also requires frequent retuning within the band.

Theory

The complex impedances ZA at the transmitter-side input of the supply cable, which differ per band, must be transformed to the real 50 ohm output of the PA.
This is only possible with a matching network (antenna coupler), in which the reactance resistors jXA are compensated and the real active resistances RA are transformed. One therefore also speaks of a "conjugate complex adaptation".

The power adjustment of a generator (PA) with the internal resistance RG to a consumer (antenna) with the complex resistance ZA is achieved if ZA = RG applies (see power adjustment).

In this case, the maximum available generator power is converted at ZA (with a 100W PA this is 100W) and a SWV=1.0 at the PA output is reached.

When adjusting non-tuned antennas, the condition ZA = 50Ohm is usually not met, since their base point impedance is additionally transformed by the supply cable and the PA usually "sees" a complex load impedance:

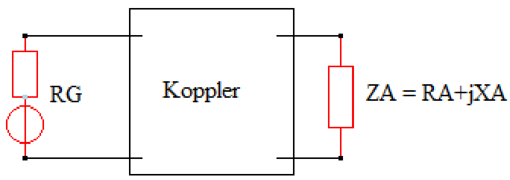
$$ZA = RA + jXA$$

with RA <> RG and XA <> 0.

The coupler therefore has two tasks to fulfill:

1. Transformation of the real component of load impedance Za to the value of Ri (50Ohm).

2. Compensation of the blank component jXa to the value 0 by inserting a conjugate complex L or C with the value -jXa.



While the calculation of CLC-Pi couplers (Collins filters) is already extensively anchored in the relevant literature, this is less true for CLC-T couplers.

The latter were long frowned upon due to their high-pass character, but have now gained in importance again, as the task of harmonic suppression is usually taken over by upstream 50Ohm filter chains, which are integrated in every modern PA.

The tool "Pi- vs T-Coupler" developed by me facilitates the comparison of both complementary coupler types, which are almost equivalent in terms of their material effort.
For the self-builder, the decision ultimately depends on the value range of the available components and the scope of the tunable impedance range.

For the final assessment (selection curve, heat losses and stresses) the program *Special NetworkAnalyser* (SNWA) does a good job.