# SMITH CHART
in the amateur radio practise

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Basic utility focused for RF matching between source and the load

In the amateur radio practice is always needed to design some matching, because everybody knows, that optimal transfer of the energy (RF power) will be only, when the source impedance is equal to load impedance. So, let's check some fundamental schematics:
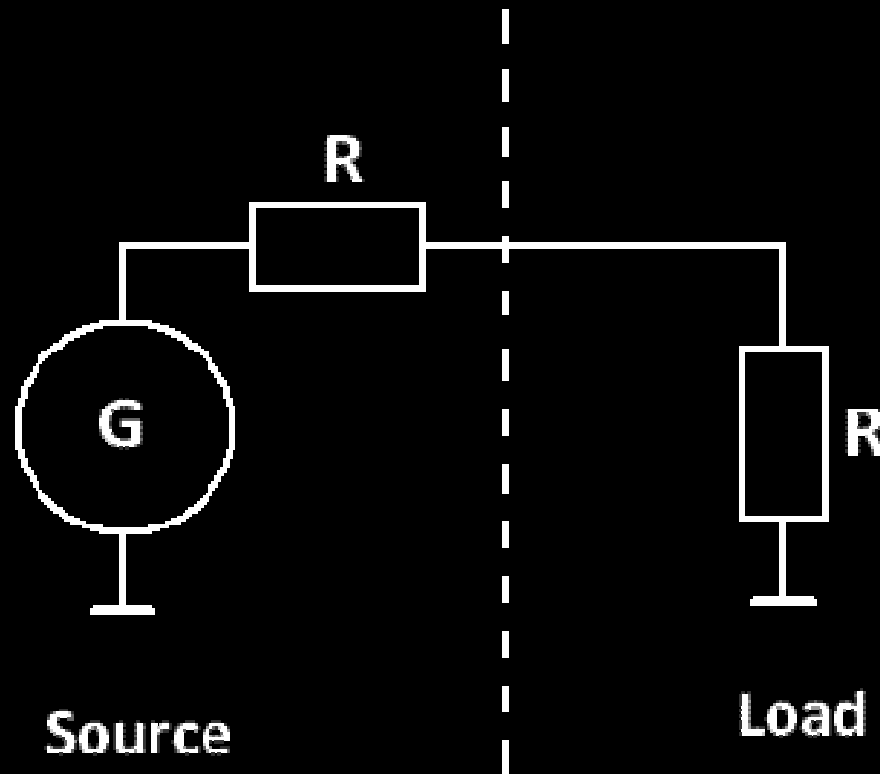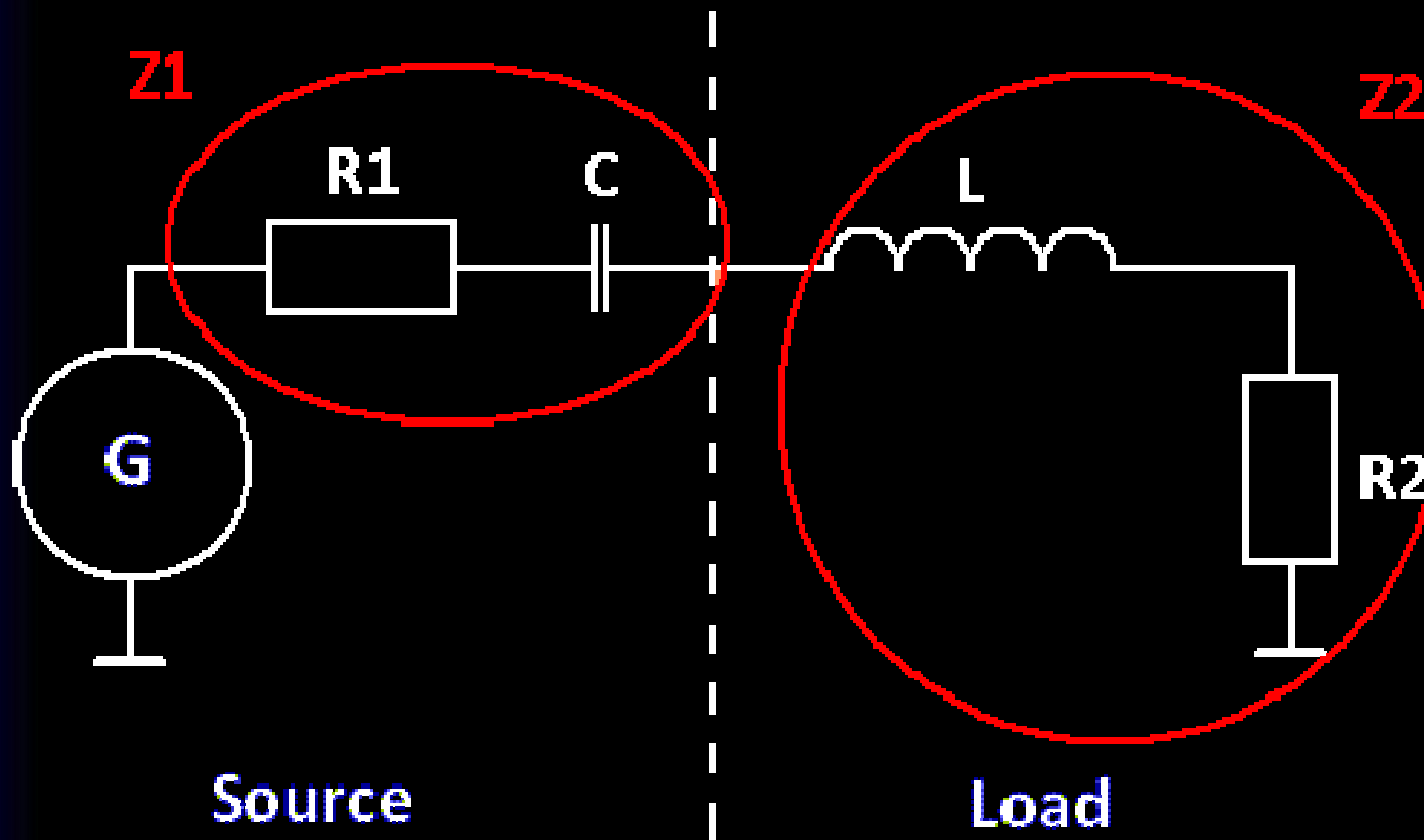
Basic utility focused for RF matching between source and the load

 On these pics has presented a bit ideal status: the RF generator has the internal impedance close to zero and the source impedance is presented by simulated resistor with LC elements combination. And on the right side is the similar load.
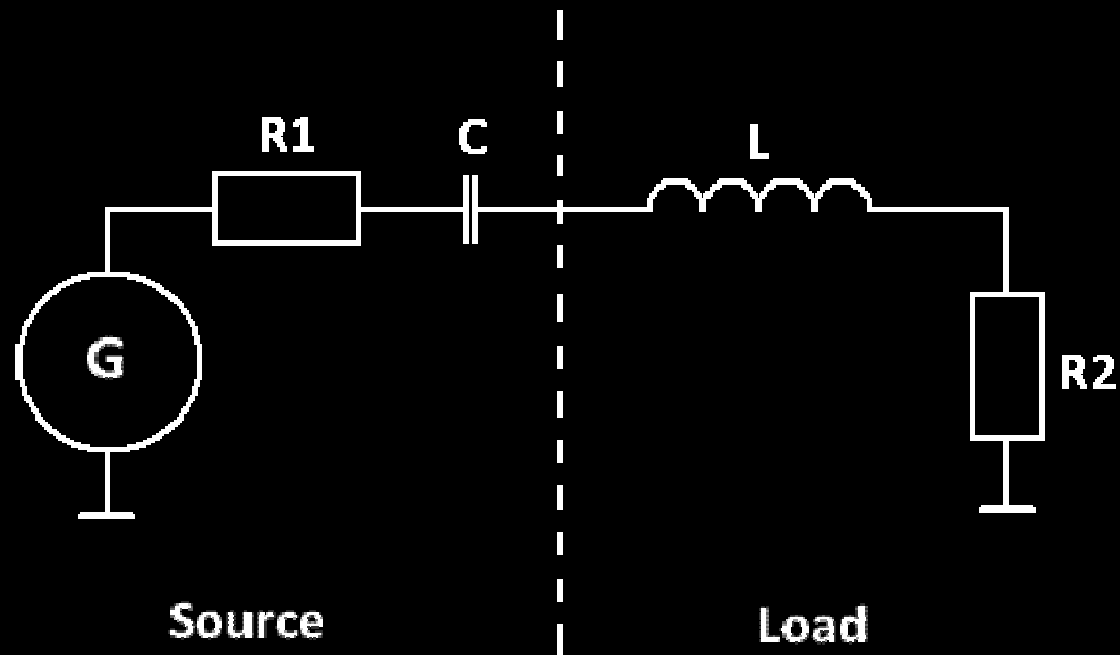
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Task for designer is to make a matching circuit, connected between the RF source (for example anode of the tube) and the load (antenna, or input of final stage PA).

The matching circuit principle is to balance a real part of impedance of both source and load and resonate up each to other the complex part of impedance between source and load (it mean compensate capacitance and inductance parts of source and load).
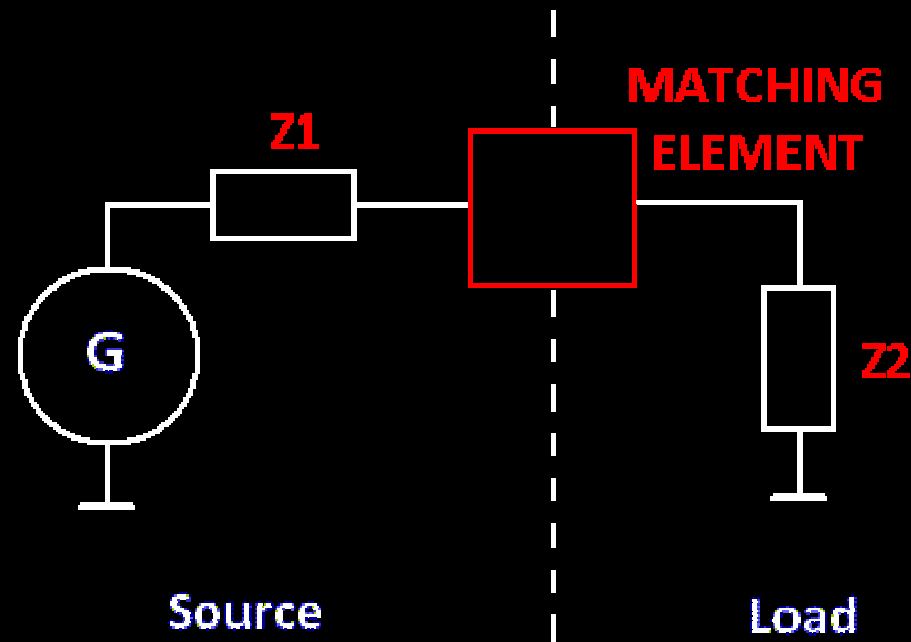
We can use some sophisticated calculations, or even graphical solution only. But always the most important knowledge is to know, which impedances on both sides we want to match!

...ance

We can look at the task of matching from the perspective of impedance (Z), or admitance (Y). Admitance is:

$$Y = 1/Z$$

For example - the resistor 100 Ω has (theoretically) 100 Ω (Ohms) impedance (resistance), however in admitance expression will have the conductance 0,01 S (Siemens). However for amateur radio practise is more common to use impedances and due to it we will use it in this presentation as well as. But take care: the impedance is not very often real, more common status is combination with some complex impedance of imaginary part. (it mean ...ance).

For example the 100 Ω resistor in serial combination of 10pF capacitor will represent on 70cm common impedance:

$$Z = 100 - (1/j\omega C) \ \Omega = 100 - j \ 37 \ \Omega$$

...ance

Similar it is in case of combination of R + L (10nH, 70cm):

$$Z = 100 + j\omega L \ \Omega = 100 + j\,27 \ \Omega$$

Complex (imaginary part) of capacitive negative impedance is a capacitamce, in case of positive complex part it is an inductance.

When we selected impedance model, we will work with terms: impedance, resistance, reactance, capacitance and inductance.

In case of conductivity model selection, we will use admitance and susceptance. All together it is seven "ances", which are mentioned in the term of title, hi.

Well, when we know these terms let's look, how to use it. Beside more different ways probably the most useful is to use brilliant graphic tool by Mr. Smith, known as Smith chart.
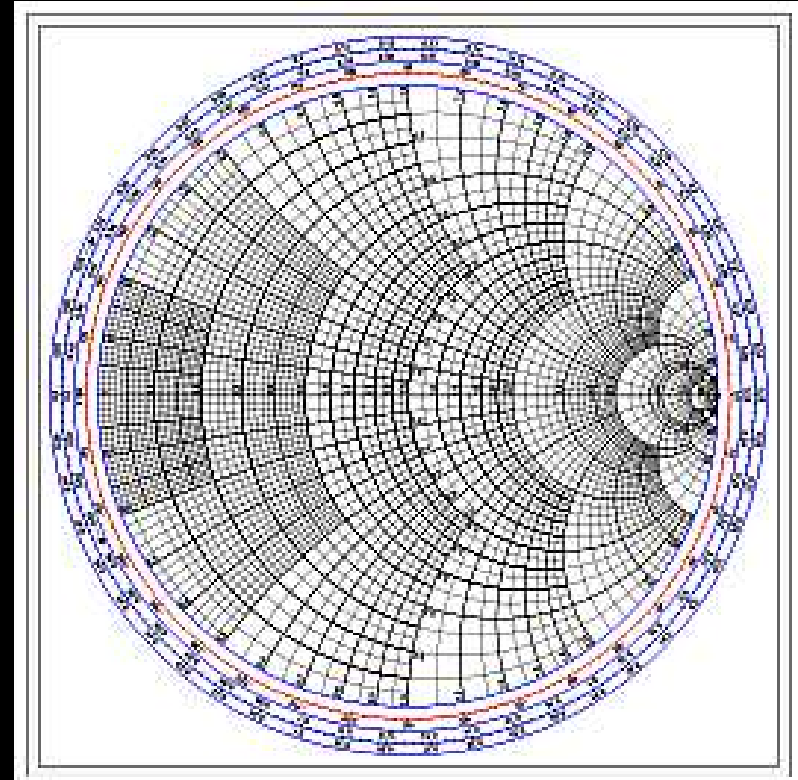
Smith chart
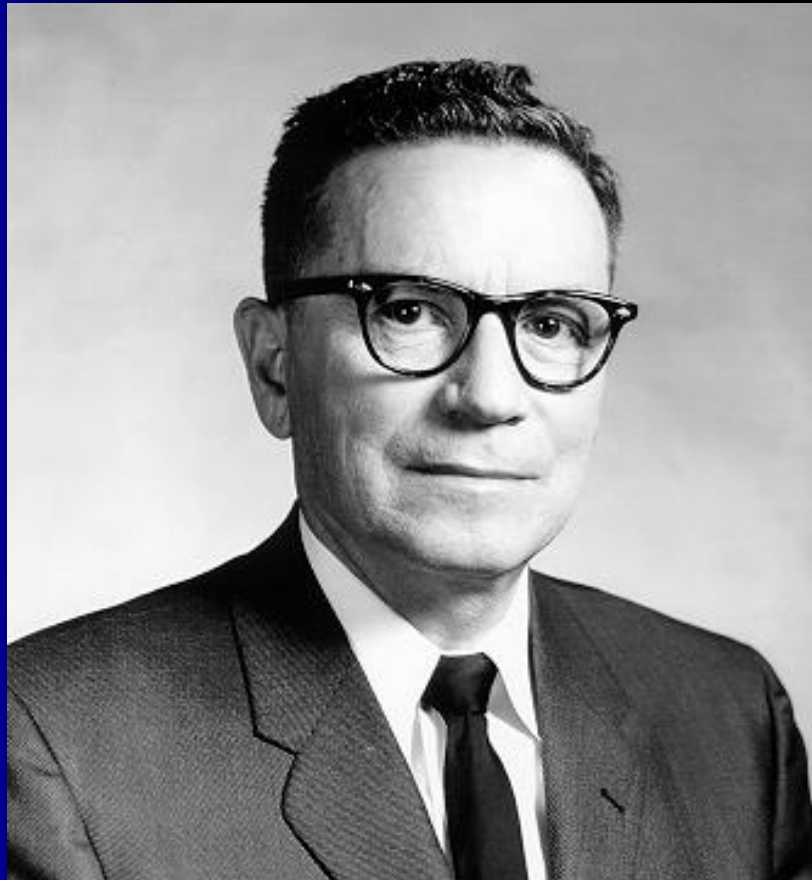
This scientist (Phillip H. Smith, W1ANB, SK 1987), when he worked for an American Bell laboratories (later RCA) made on the beginning of 1937 one ingenious magic trick:

He deformated planar and linear presentation of impedance XY chart (resistance at X axis and reactance at Y) by very interesting manner:

Smith chart

He took XY chart of real and complex impedances, used logaritmic measure for both axis (in linear measure the infinity not match the paper on the table), then cut off the negative site of real resistance, bend both complex axis ends into direction of positive resistance axis infinity to create the circle, where infinity of all three measures (inductance, resistance and capacitance) are meet in one "infinitive" point. It creates rounded chart of impedances, known as "Smith chart".

Smith chart

Result of such mathematical "deformation" of the planar chart has created new chart of unusual characteristics:

- any impedance point (both real and complex) could be directly marked and a centre of the circle is possible normalized to the unit impedance (very often as 50 Ω).

- move from such point on the circle represent transformation by use of line. Move measure is in wavelength and the full circle is $\lambda/2$. It could be easily used in VHF designs for impedance transformation.

- move by use of circle from such point in the manner, that such circle is touching zero (short connection) or infinitive (open point) represent use of (parallel, or series) capacitor or inductor (coil).

By use of such tricks is possible find many simple ways to match any different impedances. You can to do it even on paper by use of drawinng compass, or (to be it more comfortable) use some suitable software tool.

Smith chart

For suitable tool I would suggest to visit web page of Fritz Dellsperger:

http://www.fritz.dellsperger.net/

There is possible to download free of charge (a bit limited) test version of his SW for PC for simulation of Smith chart. Older, DOS version of his SW is available as well as here:

http://www.ok2kkw.com/smith.zip

And now let's look, how to use this software in amateur radio practise. It is surpisingly easy:

For test let's design input matching of 70cm kW PA with well-known tube GS35b:
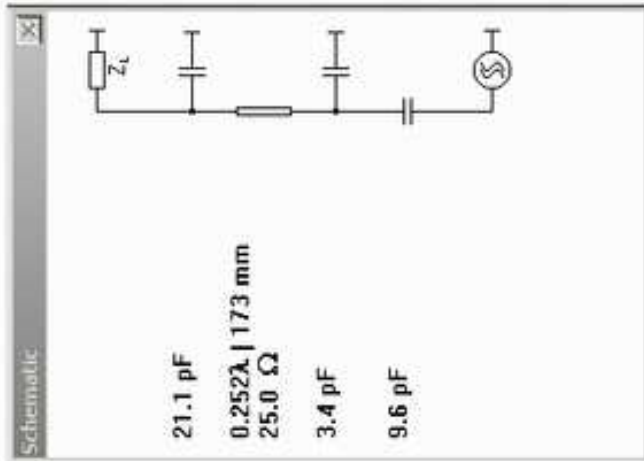
GS35b at 70cm

Input impedance of this tube is defined by transconductance - resp. it's represents real part of the input impedance. Tube datasheet say the transconductance in the common grid connection will be (for class A) abt. 30 mA/V. The transconductance is de facto admitance, it mean reciprocal value of impedance - so the real part of the input impedance of GS35b will be abt. 22 to 33 Ω. Let's say 26 Ω.

But we need to know beside it as well as the complex part of impedance, which is presented here mostly as the capacity between cathode and grid. The datasheet says cca 21pF, what we could recalculate to complex impedance (it will be negative - capacitance), or the Smith chart input calculate like parallel connection of tube input and the virtual 21pF capacity from cathode to ground.

The tube input will be matched to the 50 ohms PA input.

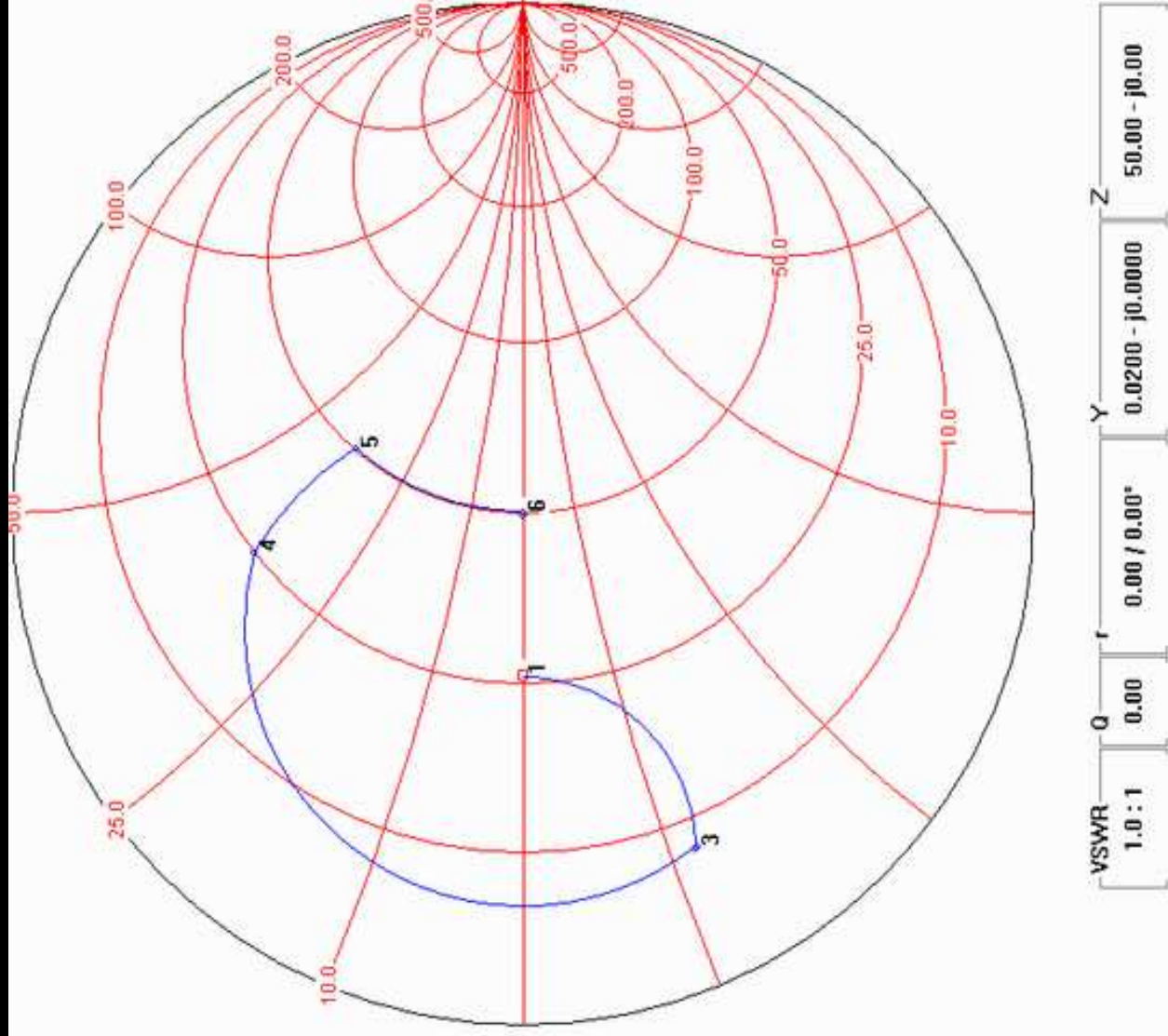How to design it by use of the Smith chart?

VSWR 1.0 : 1   Q 0.00   r 0.00 / 0.00°   Y 0.0200 - j0.0000   Z 50.00 - j0.00

Toolbox

SERIES
C | L | R
LINE

SHUNT
C | L | R
LINE

TRANSF.
DATAPOINT

Schematic

Z_L

21.1 pF

0.252λ | 173 mm
25.0 Ω

3.4 pF

9.6 pF

Data Points

DP-Nr. 1	[26.0 + j0.1
DP-Nr. 2	[8.1 - j11.8
DP-Nr. 3	[8.0 - j12.0
DP-Nr. 4	[24.8 + j36
DP-Nr. 5	[50.4 + j38

Zo 50.0 Ohm

GS35b at 70cm

The result could be for example such matching circuit:
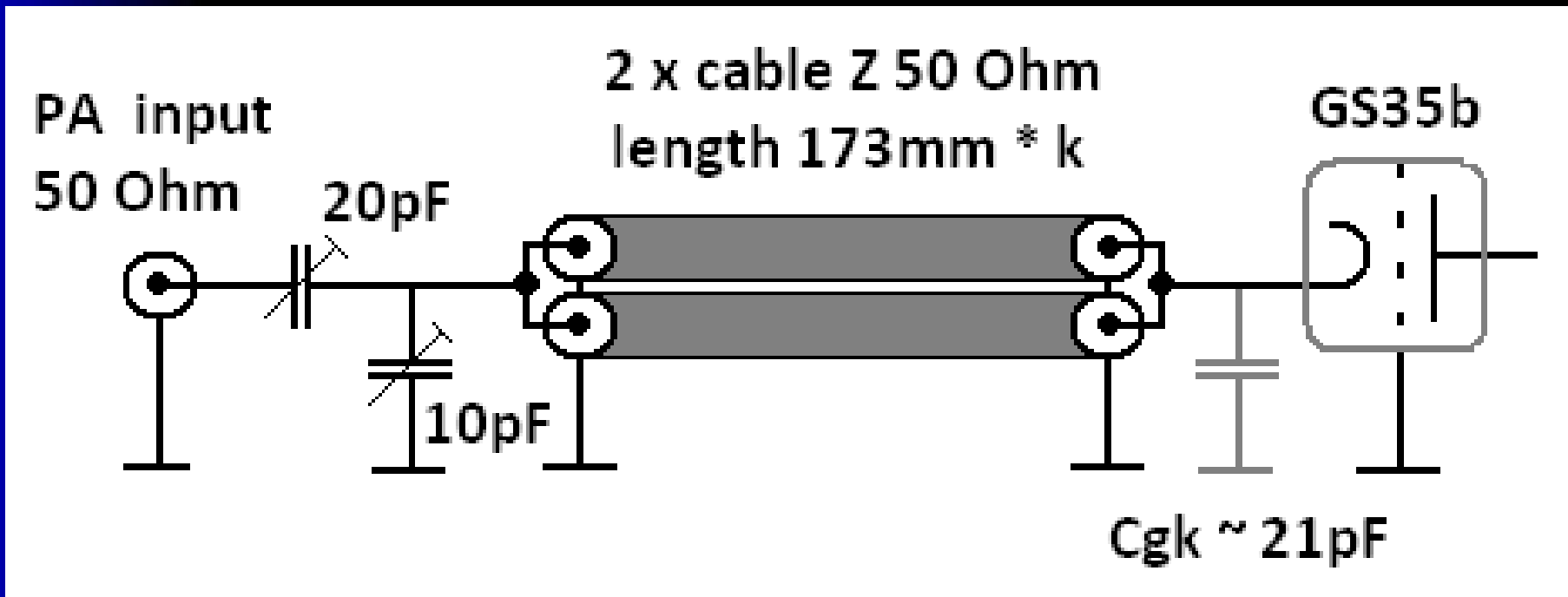
GS35b at 70cm - and not only:

Of course - result of PA design is not everything, what we can to do with the Smith chart. It can help us with design of anode circuit, LPF for transmitter, input splitters for common drive of more PAs for contesting as well as many other RF electronic circuits - for example study the area of stability of LNA...

Just 3 links between many other:

http://www.ok2kkw.com/xyz/smith/smith_splitter.htm
http://www.ok2kkw.com/00003016/dp144/coilfree_lpf/nocoils_lpf.htm
http://www.johng4bao.webspace.virginmedia.com/Files/Orebro2011.pdf

But Smith chart has use not only in electronics but it may help as well in case of mechanical designs and even for study of fatigue fractures..

But it is already very different story and I'm not mathematician, but only ordinary amateur radio designer. Anyway - try to use Smith chart yourself as well as. It is a real fun!

Thank you for attention!

The presentation will be places as usual to OK2KKW web HW corner.

http://www.ok2kkw.com/qro_cz.htm

73 de OK1VPZ

member of OK2A / OK2KKW Contest team.