THE WEST RAND AMATEUR RADIO CLUB


September 2006
Volume 7, Issue 2

# ANODE

**Inside this issue:**



## Editor's Comments

**Volume 7 Issue 3 September 2006**

**So Monday nights are a go?**

Apparently the committee decided to open the club on Monday evenings to all interested parties. So you can now meet and greet from 19:30 on every Monday.

**U571 and other bloopers**

In reality, the submarine U-571 was never actually captured. The submarines U-559 and U-110 were the ones captured with the codebooks but by the British Navy in August 1941, four months before the United States entered the war. U-570 however was in fact a u-boat captured in late 1941 (by Britain) near Iceland, and subsequently deployed as HMS Graph until early 1944. Its appearance was used by the Royal Navy to fool German ships and submarines, and destroy them by surprise.

Quotes:
Marine Maj. Coonan: How far down does this ship go?
Lt. Commander Mike Dahlgren: Oh, she'll go all the way to the bottom if we don't stop her.
[Oh my gawd! How did we win the war? Ed]

*(continued on page 2)*

## The Match Maker

[Everyone knows that antennas and transmitters should "match." But what exactly is that? And how is it achieved? Here are the answers.]

**Special points of interest:**

- Contact details on back page (updated)
- New email address for Anode and ZS6WR. See back page

The need to find the "perfect match"' is all-pervasive in life. The mechanic must fit a bolt to its matching nut. The worried mother strives to match her wonderful daughter with the perfect husband and the radio amateur tries to create the perfect match between his exciter and amplifier, between his amplifier and his transmission line, and between his transmission line and antenna.

What is all this concern about the perfect match? The mechanic's concern is obvious. None of us would suggest trying to f it a coarse threaded bolt to a fine threaded nut. Comments about the mother's concerns are best left to advice to the lovelorn. So we will discuss the concern of the amateur and leave mother to her fears.

**Why Matching?**

First we will discuss the reason for considering the matching problem. Efficiency of operation is always a concern. Why use more power than necessary to get the job done? There is a rule in electrical theory, which says that you get the most energy into the job to be done (maximum power

*(continued on page 4)*

# The Match Maker

*(continued from page 1)*


It's not often that the advertisers get it wrong. The picture above however says it all. They can't tell the difference between a lot of coax and a kitten!

**How many forum members to change a light-bulb?**
From: "Fred Hambrecht"
<w4jle@w4jle.com>
Date: 13 August 2006 10:42

How many forum members does it take to change a lightbulb?

1 to change the light bulb and 1 to post that the light bulb has been
changed

14 to share similar experiences of changing light bulbs and how the light bulb could have been changed differently

7 to caution about the dangers of changing light bulbs

*(continued on page 3)*

# The Match Maker

*(Continued from page 2)*

27 to point out spelling/grammar errors in posts about changing light bulbs

53 to flame the spell checkers

41 to correct spelling/grammar flames

6 to argue over whether it's "lightbulb" or "light bulb"

... another 6 to condemn those 6 as anal-retentive

2 industry professionals to inform the group that the proper term is "lamp"

15 know-it-alls who claim they were in the industry, and that "light bulb" is perfectly correct

156 to email the participant's ISPs complaining that they are in violation of their "acceptable use policy"

109 to post that this forum is not about light bulbs and to please take this discussion to a lightbulb forum

203 to demand that cross posting to hardware forum, off-topic forum, and lightbulb forum about changing light bulbs be stopped

111 to defend the posting to this forum saying that we all use light bulbs and therefore the posts are relevant to this forum

306 to debate which method of changing light bulbs is superior, where to buy the best light bulbs, what brand of light bulbs work best for this technique and what brands are faulty

27 to post URL's where one can see examples of different light bulbs

14 to post that the URL's were posted incorrectly and then post the corrected URL's

3 to post about links they found from the URL's that are relevant to this group which makes light bulbs relevant to this group

33 to link all posts to date, quote them in their entirety including all headers and signatures, and add "Me too"

12 to post to the group that they will no longer post because they cannot handle the light bulb controversy

19 to quote the "Me too's" to say "Me three"

4 to suggest that posters request the light bulb FAQ

44 to ask what is a "FAQ"

4 to say "didn't we go through this already a short time ago?"

143 to say "do a Google search on light bulbs before posting questions about light bulbs"

1 new forum member to respond to the original post 6 months from now and start it all over again

# The Match Maker

*(continued from page 1)*

transfer) when the resistance of the source of the energy (signal generator) is equal to the resistance of the job to be done (load).

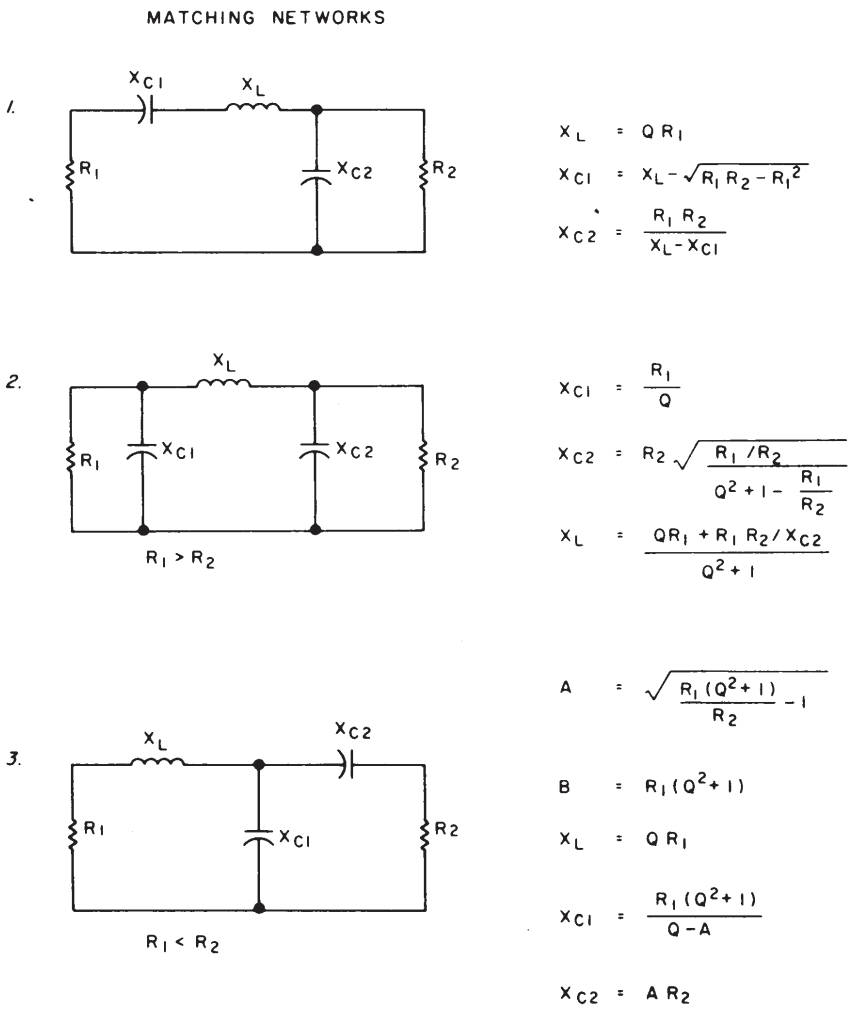


*Fig. 1. These matching networks can be used to provide a match with maximum power transfer between unequal resistances.*

You can easily verify this with a few calculations. In Fig. 2 you see calculations done for a 10-volt generator with a resistance of 10 Ohms. As you look at the power-output figures, you will observe that the output power peaks at 2.5 Watts. Also observe that this occurs when the load resistance is equal to the generator resistance. If you are quick, something else will have crossed your mind. With maximum power transferred to the load, there is the same amount of power dissipated in the generator resistance. Only 50 percent of the power from the generator has reached the load. The other 50 percent has been lost as heat in the generator.

How is this important to us? If we are creating a signal in a generator, a v.f.o., a transmitting exciter, a kilowatt amplifier, or in a transmission line and we want the maximum power supplied to the load, we must make sure that the equipment which is supplying the energy has the same output resistance as the load resistance. For example, if your transceiver has an output resistance which looks like 50 Ohms then to get maximum power transferred into the input of your kilowatt the input resistance of the kilowatt must look like 50 Ohms as well.

Fig. 3 illustrates the idea. Vgen is the signal created by the final amplifier of the transceiver and Rout is the equivalent resistance of the same

*(continued on page 5)*

# The Match Maker

*(Continued from page 4)*

circuit. If you went into your final amplifier you would not find this as an actual resistor, but the circuitry which is there can look as though it were exactly a single resistance. Looking at the kilowatt input, the Rin is not an actual resistor either, but all the circuitry attached to the input looks like this single resistor if all you can do is measure it at the input terminal.

GENERATOR RESISTANCE 10Ω
INPUT VOLTAGE 10V

POWER IN LOAD $= (I_{LOAD})^2 R_{LOAD} = \left(\frac{V_{IN}}{R_{GEN} + R_{LOAD}}\right)^2 R_L$

| $R_L$ Ω | $P_{OUT}$ (WATTS) | |
|---|---|---|
| 1 | .82 | |
| 2 | 1.39 | |
| 3 | 1.77 | |
| 4 | 2.04 | |
| 5 | 2.22 | |
| 6 | 2.34 | |
| 7 | 2.42 | |
| 8 | 2.47 | |
| 9 | 2.49 | |
| 10 | 2.5 | ← MAXIMUM POWER INTO THE LOAD |
| 11 | 2.49 | |
| 12 | 2.48 | |
| 13 | 2.46 | |
| 14 | 2.43 | |
| 15 | 2.4 | |
| 16 | 2.37 | |
| 20 | 2.2 | |
| 30 | 1.87 | |
| 40 | 1.6 | |
| 50 | 1.39 | |
| 60 | 1.22 | |
| 80 | .99 | |

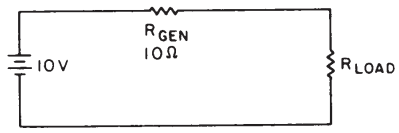


*Fig. 2.*

Another place where this is important is at your antenna. If your antenna terminals (the load) look like 75 Ohms to the signal generator (the output of your coaxial transmission line), then to get maximum power into the antenna the transmission line must look like 75 Ohms where it attaches to the antenna.

The perfect match we are thus looking for is a condition where the signal generator appears to have the same resistance as the load. This gives the desired maximum power transfer.

**Loads With Inductors and Capacitors**

If all circuits were resistive, then the matching problem would be reasonably simple. In radio-frequency circuits, however, we find capacitors and inductors as well. How do they affect our perfect match? An inductor or capacitor does not dissipate energy. All either of these does is absorb energy, then release it again later at a time when it is inconvenient.

Consider the loads of Fig. 4. They contain a resistor, which will dissipate energy (do work) and a capacitor, which accepts current from the generator and then puts it back into the system at a later time. This current Ic, which flows through C must flow through Rgen as well, where Rgen dissipates energy (Ic 2Rgen). This is energy lost without any work being seen for its loss. Remember how with just a resistive load energy was lost in the generator resistor as well, but at least some work was gained. This loss was acceptable but the losses created by the current through the capacitor are not acceptable.

The unacceptable loss of energy through the capacitor current (and the same thing would result if the capacitor were changed to an inductor) suggests that this reactive component should be removed from the circuit. This component may, however, be fixed in the circuit and not removable. Is a match possible with this situation? Yes, we can use our knowledge of resonant LC circuits to neutralize the effect of the reactive component.

If a capacitor, inductor, and resistor are

*(continued on page 6)*

# The Match Maker

(Continued from page 5)

combined to create a resonant circuit at the frequency where the reactance of the capacitor is equal to the reactance of the inductor (resonant frequency), the circuit will look to the generator as though this were only a resistive load. The current flowing in the capacitor would be cancelled by the current in the inductor and the only current flowing through the Rgen would be resistive current.

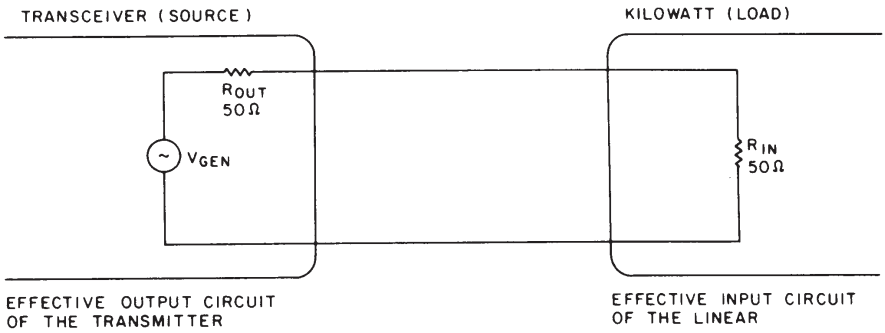


*Fig. 3.*

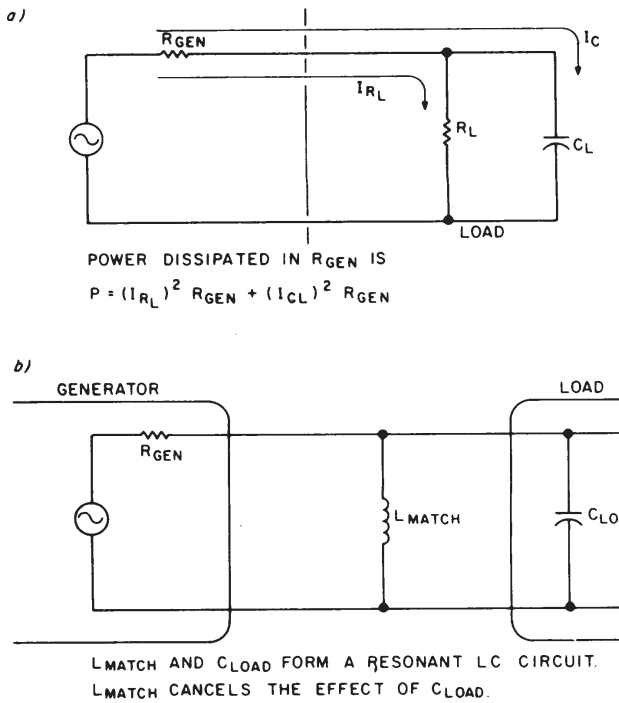


*Fig. 4.*

The circuit of (a) in Fig. 4 is not desirable for maximum power transfer, yet neither the generator box nor the load box can be modified. Consider now (b) in Fig. 4. A match has been created by attaching Lmatch in parallel with the load to cancel the effect of Cload. Now a condition where maximum power transfer is possible has been created.

This expands our condition for maximum power transfer to say that the generator resistance must be equal to the apparent load resistance and any reactive component in the generator must be matched by the opposite reactive component in the load (2 * pi * F * L = 1 / 2 * pi * F * C).

**Different Output and Input Impedances**

If this were all there is to matching, it would be an elementary problem. Life is never so simple, however. Matching involves providing a maximum power transfer from a generator of maybe 5 Ohms to a load of 50 Ohms. This is the problem of matching a power-transistor collector to a coaxial transmission line. To get the maximum power transfer out of the transistor, the transistor must be driving a load of 5 Ohms. But the load is 50 Ohms! To get maximum power transfer into the 50 Ohm load, the load should think it is being driven by a 50-Ohm generator. Our generator is

(continued on page 7)

# The Match Maker

(Continued from page 6)

only 5 Ohms! How are these two incompatible impedances reconciled?

**Transmission Lines and Matching**

The LC matching network is able to reconcile these two impedances without a loss of energy in the conversion. Fig. 5 shows one possible matching network and its effect on the circuit. We will argue that the generator is the final transistor of a power amplifier. The LC network is the matching network. The load is a 50-Ohm coaxial cable feeding a 50 Ohm antenna. The transistor thinks its load is the combination of the matching network and the 50-Ohm coaxial cable. This apparent load looks like a 5-Ohm resistor at the frequency of operation. To the 50-Ohm transmission line, the matching network and transistor together appear to be its generator, and this combination looks like a 50-Ohm source resistance. The-matching network has provided the impedance transformation so that the source (the transistor output) has the load it desires while the load (the 50-Ohm transmission line) has the generator it expects for maximum power transfer.

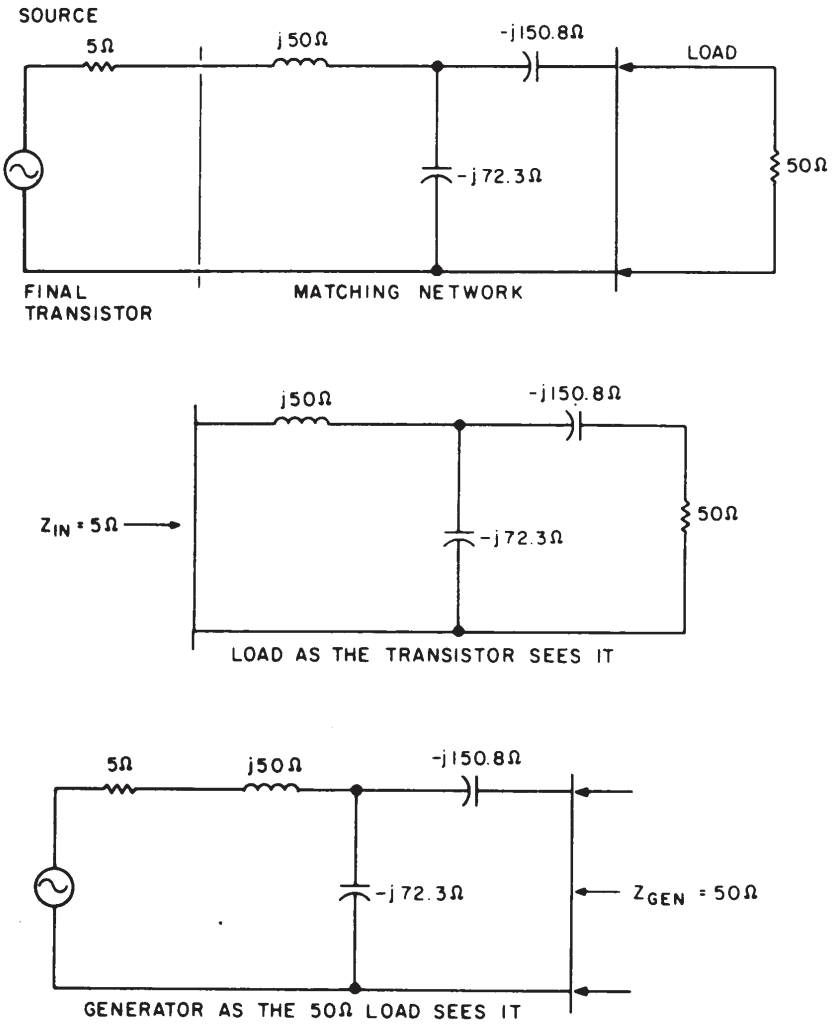


*Fig. 5.*

**Your Place in All This**

Can a radio amateur use this matching theory? You use it every time you tune your final, dipping the plate current and increasing the load coupling. Dipping the plate is effectively adding reactive impedance to the tuned circuit to cancel the opposite reactance, which is in the circuit. Increasing the load coupling is bringing the effective load impedance to equal the effective source impedance.

The problem of the perfect match also rears its

(continued on page 8)

# The Match Maker

(Continued from page 7)

head in transmission lines and antennas. It is desirable to get a maximum percentage of the generated power to the antenna.

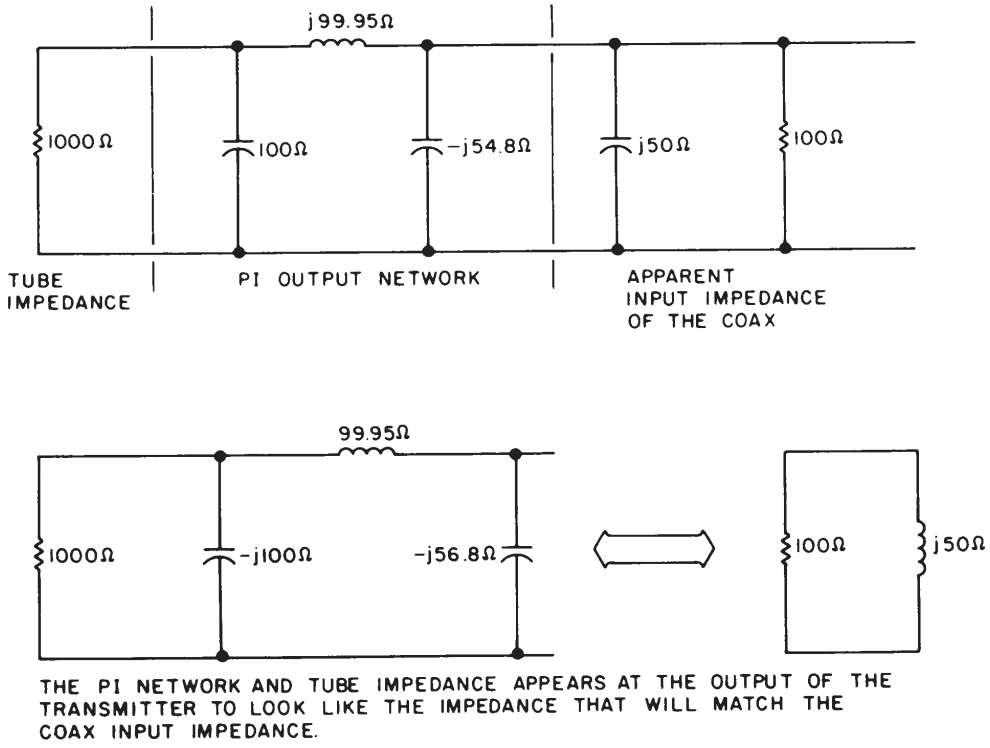


*Fig. 7.*

Transmission lines such as, a coaxial cable are very interesting components. If the cable is one thousand miles long, then its input terminals look like a resistor. A generator attached to this input appears to have a resistor for a load. Now if the cable is much shorter, more like the length we would use, but the far end of the cable is terminated in a resistor equal to the resistance which the very long cable looks like (the characteristic impedance of the line), then the input would still look like the same resistor. All energy put into the coax would travel down the coax and be used in the termination resistor 0 load).

But now the interesting phenomenon! If the load at the far end of the transmission line is not equal to the characteristic impedance of the line, all of the energy put into the input would travel down the transmission line but not all of it would be absorbed by the load at the far end. Some of the energy is reflected-sent back the way it came. Here we do not have maximum power transfer. All of the energy is not used in the load. Some of it travels back to the transmitter again, and now the transmission line becomes a signal generator with the reflected signal as the signal and the transmitter output device becoming the load. This returning energy would be used to heat the plate of the final or heat the transistor heat sink.

What if you have a high vswr on your transmission line and 20 Watts is sent back from the load, which was sent 100 Watts by the transmitter? How can you protect your finals from this vswr of 2.6? Fig. 6 shows a possible situation, which could cause this. The antenna with its impedance of 130 Ohms is connected to the 50-Ohm transmission line.

For reasons explainable by transmission-line theory, we will say for our example that the input end of the transmission line looks like a resistor of 100 Ohms in parallel with a capacitor of 50-Ohm capacitive reactance. This near-end impedance is the load presented to your transmitter.

The transmitter connected to this point cannot tell the difference between the end of the coax

(continued on page 9)

# The Match Maker

(Continued from page 8)

and a real resistor and capacitor of our example value. Again we use a matching network as our solution. The effect of the capacitance can be cancelled by using an inductor to' make a resonant circuit. Fig. 6 (b) shows this inductor added to make the input look like a resistor only. Now we have a resistive load, which will accept power without causing extra final heating.

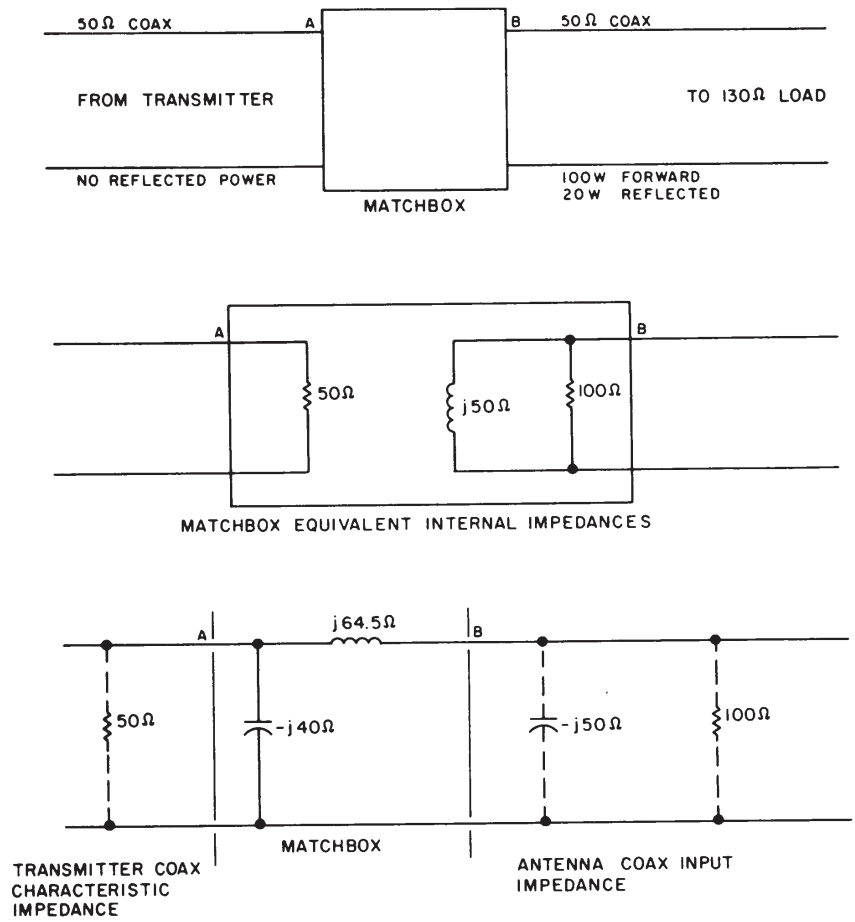


*Fig. 8.*

**Tube Final Match**

If your transmitter has a tube final, its pi network will be able to convert this 100-Ohm apparent resistance to the tube output impedance while adding the necessary inductance to cancel the capacitance. Fig. 7 shows a pi network solution (network 2 in Fig. 1), which creates this match from our transmission line to a 1000-Ohm tube output. Notice that XC2 in Fig. 1 is made of two capacitors. One is the transmission line's apparent capacitance and the other is a real capacitor found in the matching network. Looking into the network where it attaches to the coax. The network would look like 100 Ohms of resistance in parallel with a 50-Ohm inductor. We have a good match to our coax input and it cancels the capacitance of the load.

**Transistor Final Match**

For the modern amateur, this pi-network solution is not possible. Solid-state final transistors have an output impedance of maybe 1 Ohm and broadband transformers are used to transform this to an output impedance of 50 Ohms. The solid-state power amplifier must have a 50-Ohm load presented to its output by the transmission line. We will still consider our same problem and see how we can create a desired match with an antenna tuner or matchbox.

Fig. 8 shows the desired situation. The 50-Ohm coax from the transmitter must be terminated in a load at A which looks like 50 Ohms. This will make the transmitter see no reflected power. The 50-Ohm coax going to the antenna must see an impedance at the output of the matchbox which matches the 100-Ohm resistance in parallel with the 50-Ohm capacitance ap-

(continued on page 10)

# The Match Maker

*(Continued from page 9)*

pearing at its input. This will give our desired maximum power transfer into the antenna transmission line.

An L network will provide the conditions to match both transmission lines effectively. If we could measure the impedance looking into port A (using an antenna noise bridge would work) we would be able to measure a 50-Ohm impedance and the transmitter would be able to put all its power into this resistive load. Looking into port B of the matchbox, we would be able to measure a 100-Ohm resistance in parallel with a 50-Ohm inductor, just the impedance we need for maximum power transfer into the antenna transmission-line impedance.

This example describes what you are doing when you adjust your antenna-matching unit. The transmission line on the transmitter side of the matchbox has no reflected power in it so the transmitter is happy. The transmission line on the other side of the matchbox continues to have the same vswr as it did before but the' matching network makes maximum power transfer possible from the transmitter into the antenna transmission line. Notice it has not made maximum power transfer possible into the antenna itself. To get this condition there would have to be something done to match the transmission line to the 130-Ohm antenna. Here the same principles of matching hold as we have already discussed. Get the driving impedance to look like a resistor equal to the load and cancel any reactive components in the circuit.

**Conclusion**

The "perfect match"' in rf circuits is desirable and possible. Although you will make contacts without it... you will put less stress on your equipment and put more signal into the air if you study these principles and use them. Hopefully, this article has given an understanding of what happens when you tune your equipment and what causes the change in vswr as you adjust your transmatch.

From 73 Magazine - April 1986

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**[NEW EMAIL ADDRESS]**

**Bulletins** (Sundays at …)
11h15 Start call in of stations
11h30 Main bulletin start

**Frequencies**
439.000MHz 7.6MHz split
(West Rand Repeater)
145,625 MHz (West Rand Repeater)
10,135 MHz (HF Relay)

# Radio Amateurs do it with more frequency!

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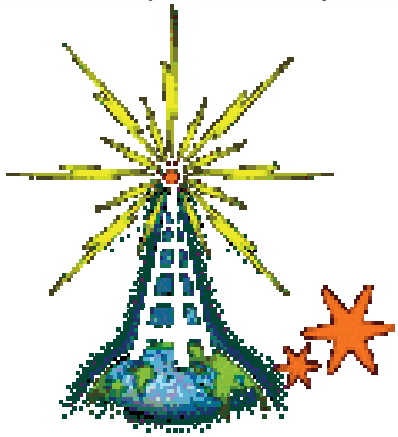
# West Rand members - we need your input!

To make this the best ham radio magazine in South Africa we need your input. Please submit articles, comments, suggestions etc.

Please send plain text with no formatting to the email address below.

In July 2003, we re-published an Anode Compendium on CD. It has the issues from July 2000 until June 2005. This included the new Adobe reader. It has been updated, check with the chairman for details.



**We need your input! Email us articles, comments and suggestions please.**
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