
The Conjugate-Match Debate

By Dave Gordon-Smith, [G3UUR](#)

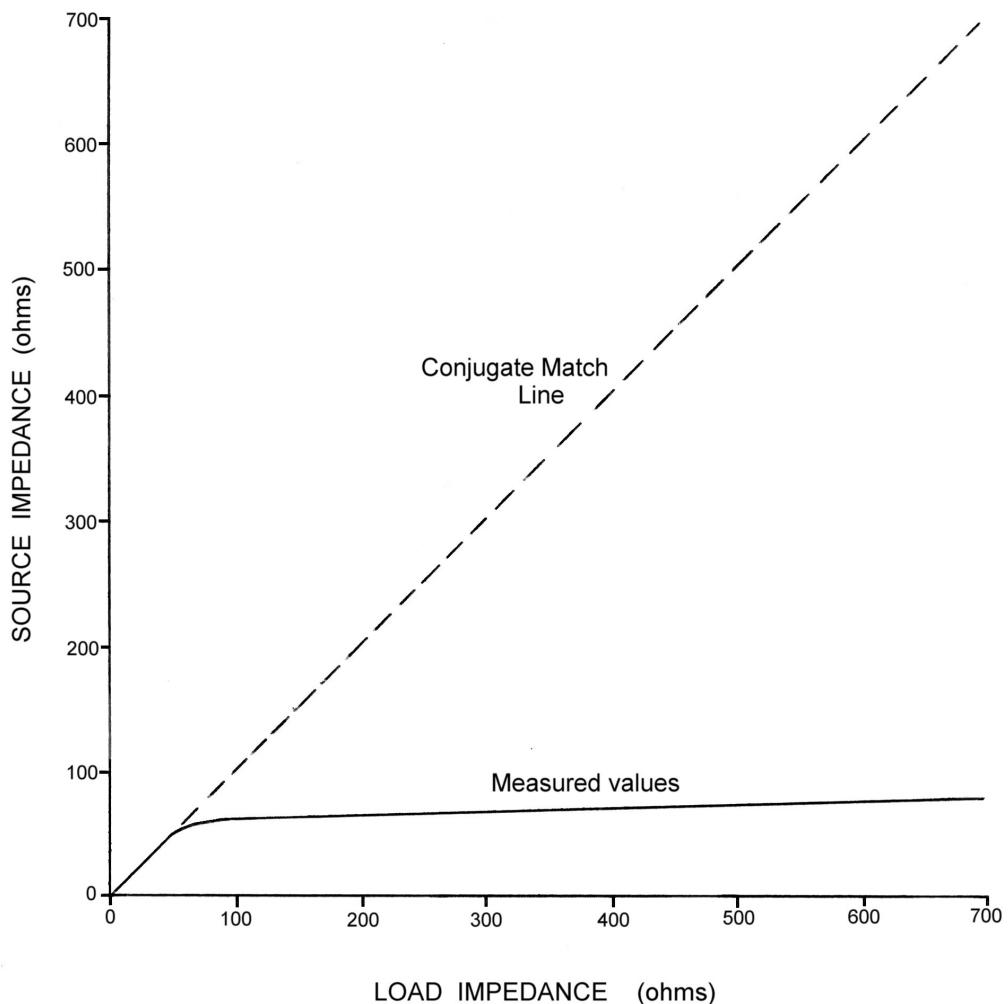
INTRODUCTION

Very few controversies have polarised the amateur radio community as decisively as the conjugate match debate, so it may surprise you to find out that I don't agree with either side. Admittedly, I can't sit on the fence as far as a final decision on the matter is concerned, but I do disagree vehemently with several of the main points put forward by both sets of "experts" to support their cases. For example, this business of the plate resistance, or some variant of it, being the source resistance of the tube really takes the biscuit. It's fine to use this for small-signal, linear, voltage amplifier applications, but it doesn't apply to situations where large amounts of power are being pumped into tuned circuits. You only have to consider the action of the coupling capacitor and plate-feed choke in a single-ended power amplifier to see that it's the plate to cathode resistance that's the main source resistance of the tube feeding the tuned circuit. Measurements of the output impedance of broadband solid-state power amplifiers confirm that it's the device resistance to ground that matters in all cases, and not the collector or plate resistance derived from the characteristic curves.

However, this is only half the story because the opponents of the theory have consistently denied that the pi-network has anything to do with the source impedance of a power amplifier. This is not surprising, since one of them admitted to me in an e-mail that he found the pi-network confusing. If he can't work out its role in the amplifier, then, what the heck's he doing participating in the debate? There's nothing more infuriating, in my book, than "experts" putting out misinformation with great authority, when it's no more than a poor opinion based on limited knowledge. I suspect their dismissal of the tuned circuit as a source of output resistance is due to a lack of knowledge about the limitations of circuit theory. It's an extremely powerful method for certain steady-state applications, but doesn't tell us everything. We need field theory if we don't want to miss anything, and that can get pretty messy even for simple circuits. If you want to see the true possibilities of a tuned circuit without resorting to field theory, just work out the energy stored in one with a Q typical of that used in tube transmitters. At a Q of 15, the energy stored is about two and a half times what is delivered to the load every cycle, and the circuit containing this energy is sitting between the tube and the output connector. What do you think would supply the extra energy if we suddenly lowered the value of the load momentarily? Well, that's what we'd have to do to measure the output impedance, and I know what I'd go for theoretically. I'm not one to rely solely on theory, though. So I'd have to check it out experimentally, just in case I'd missed some vital point and my understanding wasn't as complete as I thought.

You may be wondering at this point, what I have against the proponents of the conjugate match theory in power amplifiers. Well, the answer is simple – it's the humble parallel-tuned circuit. This exhibits an output resistance equal to the load resistance divided by its Q, and that's patently not a conjugate match to any load. Also, it's not possible to measure this output resistance by any steady-state means, so a VSWR check done by stuffing a probe signal from a second transmitter back into an amplifier wouldn't measure the true source resistance. It wouldn't do it for a pi-network, either. All you'd be measuring is the time-averaged resistance of the tube to ground. In other

words, it's the effective dissipation resistance of the tube that's terminating the input end of the pi-network. The input and output resistance of the pi-network is non-dissipating, and is only evident in the build up to equilibrium or when there is a momentary change in the value of the load. It can't be determined from steady-state measurements because the energy stored in it acts as a secondary voltage generator and that masks its true input and output impedance. Think about what you might measure if you put a parallel-tuned circuit composed of an inductor and capacitor each of 5 ohms reactance across your 50-ohm dummy load. Your SWR Bridge would show a perfect match still, but if you could examine the build up of energy in the parallel-tuned circuit at switch-on you'd notice that initially it behaves as if it is 5 ohms. As the energy builds up to the equilibrium level it looks as if it is a greater and greater value. Finally, at the equilibrium state, it looks like it's the value of the inductor loss resistance. How do I know this? Because I've designed and built simple test equipment that I can use at home in my shack to study how these circuits work, and also checked out the various techniques used by others to see if they're valid. I wouldn't have dared to write this editorial without the certain knowledge that I have substantial evidence to back up my claims.



CONCLUSION

After a good deal of experimentation, my conclusion is the only valid way of measuring the output resistance of a tuned power amplifier is by dynamic differential loading, and the results from a range of measurements using this technique are shown in the diagram. It's interesting to note that anyone doing measurements at 50 ohms, or less, might be misled into thinking that a conjugate match is a reality in tuned power amplifiers, but the results at higher values of load resistance show that it is not. If you still need to be convinced, visit my website at <http://mysite.orange.co.uk/g3uur> and see more evidence so you can make up your own mind. -30-

BRIEF BIOGRAPHY OF AUTHOR

Dave Gordon-Smith, G3UUR, holds a PhD in materials science from the University of Bath, and was a tenured member of the academic staff at the University of Warwick for many years, specialising in the characterization and study of defects in crystalline solids. During this time he was also a Visiting Professor at SUNY (Stony Brook) and a regular Guest Scientist at Brookhaven National Laboratory (BNL) on Long Island.



Dave Gordon-Smith,
G3UUR

While at BNL in the '80s, he discovered a Ham Shack full of old tube radio gear from the '50s and '60s, and this revived his flagging interest in amateur radio. His interest in radio and electronics started at the age of 11 and obtained his amateur radio license (G3UUR) a few years later in 1965. Filter theory, antennas and propagation have always fascinated him, and much of his radio hobby time has been spent trying to understand them.

He's now semi-retired and a confirmed vintage radio enthusiast, spending much of his hobby time restoring and operating old tube equipment, as well as writing articles on vintage radio and his amateur radio experimental work.

Dave is married with two grown-up children, and lives with his wife near Norwich in Eastern England.

antenneX Online Issue No. 113 — September 2006
Send mail to webmaster@antennex.com with questions or comments.
Copyright © 1988-2006 All rights reserved - antenneX©