

**Output Return Loss Of High Power Class AB Amplifiers**

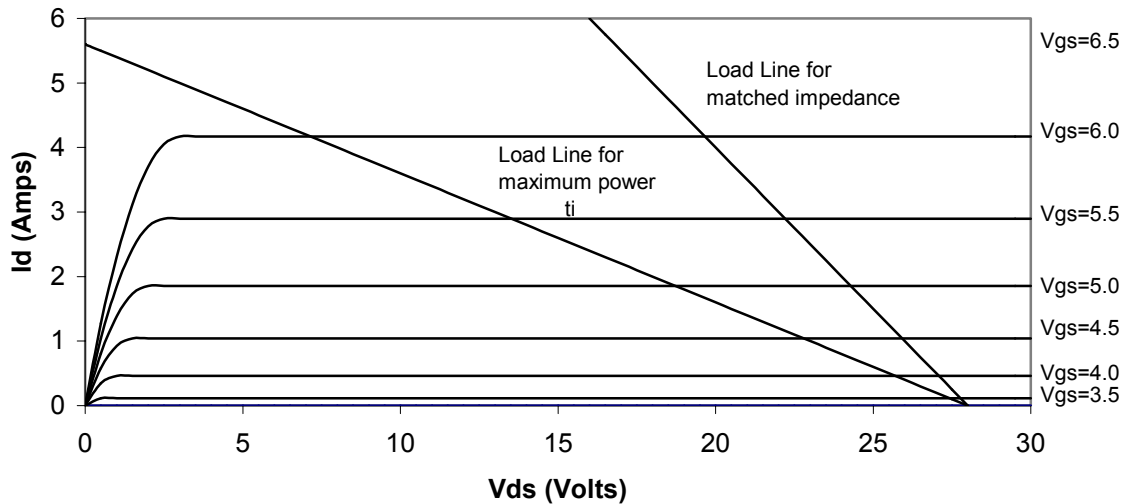
For a designer experienced at working with small signal, linear RF circuit design, moving to high frequency, high power, high efficiency power amplifier design might, initially, seem to be straight forward. Although many of the design criteria are common, high power circuits require some special considerations that may not be applicable to their small signal counterparts.

Some of the performance parameters that one might expect to use to characterize a small signal circuit have very different implications when applied to high power Class AB RF amplifiers. One of these parameters is output VSWR, also known as output return loss.

In the small signal, linear environment, output return loss, also referred to as output VSWR or S22, is an important parameter in determining how much signal will be delivered to the load, in calculating the stability of an amplifier stage, and in determining how much insertion gain ripple might be expected when cascading multiple stages. The S22 of a component is (generally) easily modeled and measured using linear simulators and vector network analyzers, respectively.

A relatively common mistake is to apply this simulation and measurement capability to higher power, Class AB devices. This fails for two primary reasons: 1) There is no single load line that allows maximum operating efficiency, maximum power, maximum gain, and highest IM3, and 2) Class AB devices have an output impedance that varies with the RF drive level.

Figure 1 shows the difference between load lines that meet just two of the common criteria. In practice there are many more that a designer might choose, depending on the particular application of that



**Figure 1. Example of graphical load line impedance illustrating the difference between a load impedance suited for maximum output power and a load impedance that is matched to the transistor output impedance.**

amplifier. And, of course, each choice results in a different dynamic output impedance

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## Output Return Loss Of High Power Class AB Amplifiers

Typical circuit design for a class AB amplifier involves the use of non-linear models, or, more often, characterization of the transistor using load pull techniques to determine the optimum load impedance for a particular application. Once the optimum load impedance is determined, a circuit implementation is developed that transforms to that desired impedance from a 50 ohm load. The optimum load impedance,  $Z_{Load}$ , is the impedance that the device would like to drive to achieve the desired transfer characteristic. This empirically determined impedance takes into account certain physical limitations, such as power supply voltage, and the effective current sourcing capability of the transistor and the DC supply.

Most often,  $Z_{Load}$  is a compromise between an impedance that allows the device to develop maximum output power, the impedance that provides best IMD performance, the impedance that provides best efficiency, and an impedance that optimally matches the device to a characteristic 50 ohm impedance. There is no one optimum impedance but several that the designer must choose between.

After accepting that the output impedance of the amplifier may not be well matched to the load, there often remains a desire to measure the output impedance in an attempt to understand what it is. Usually the test is made with DC power applied but only the normal VNA signal applied. But, a device operating in class AB mode must have an input signal applied that is large enough to drive it into a class AB region of operation before the output impedance is meaningful. One must make any measurements of the output return loss with a real input signal applied. This measurement is commonly known as “hot S22”.

Measuring “hot S22” of an amplifier is usually quite difficult. A power device operating at or near rated power levels produces enough power to overdrive and damage most network analyzers. Additionally, the “hot S22” measurement must be made with a frequency that differs slightly from the input frequency so discrimination can occur between the reflected output power and the amplified input power. Additional information on “hot S22” measurements is available from Anritsu.

<http://www.us.anritsu.com/downloads/files/11410-00295.pdf>.

If an output return loss measurement is made without the correct input signal present, the results will be significantly different from the real “hot S22” measurement results, due to the change in the device characteristics between the stimulated and un-stimulated conditions. So, simple VNA S22 measurements on a high power Class AB amplifier just don't provide useful information.

Often a maximum output VSWR is specified for an amplifier. This occurs if the amplifier will be driving impedances that may vary significantly from the 50 ohm load for which the amplifier is optimized. An example of this type of load may be a filter or an antenna. If a low output VSWR is a requirement, at least two alternatives are available: 1) “balance” the output stage of the amplifier using 90° quadrature hybrid couplers to combine two stages, which effectively provides an S22 of 50 ohms, or 2) use an isolator or circulator at the output of amplifier.

1. Cripps, S., *RF Power Amplifiers for Wireless Communications*, Artech 1999, ISBN 0-89006-989-1, Pp. 12-13