IM3 Measurement

Tone Offset Errors Associated With High Power GaAs MESFETs

This note describes the primary cause for measurement differences between tones when making 2 (or) more tone Intermodulation measurements. It describes what seems like a random occurrence when measuring high power GaAs FET devices. The amplitude of each tone is found to exhibit a different suppression level below the primary signals. Simple intermodulation theory does not include this phenomonom.

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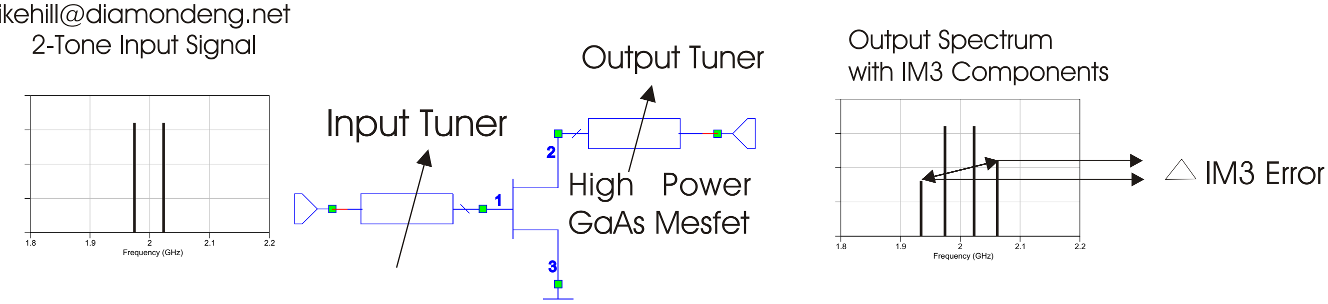
High power GaAs FET devices exhibit very low input and output impedances relative to 50 ohm measurement systems. This makes matching input and output impedances more difficult than with low power devices. In addition it is well known that GaAs MESFets exhibit an inherent mismatch for best linearity (IM3) performance. It will be shown by simulation that differences in IM3 tone levels can occur for very low impedance levels and very significant mismatch requirements. This cause also points to the intrinsic device design since S12 is primary reason for maximum power transfer mismatch.

We first point out that tuners used to make high power IM3 measurements are normally Low Pass structures. Low pass structures exhibit band pass responses when used to tune system level impedance down to very low device impedances.

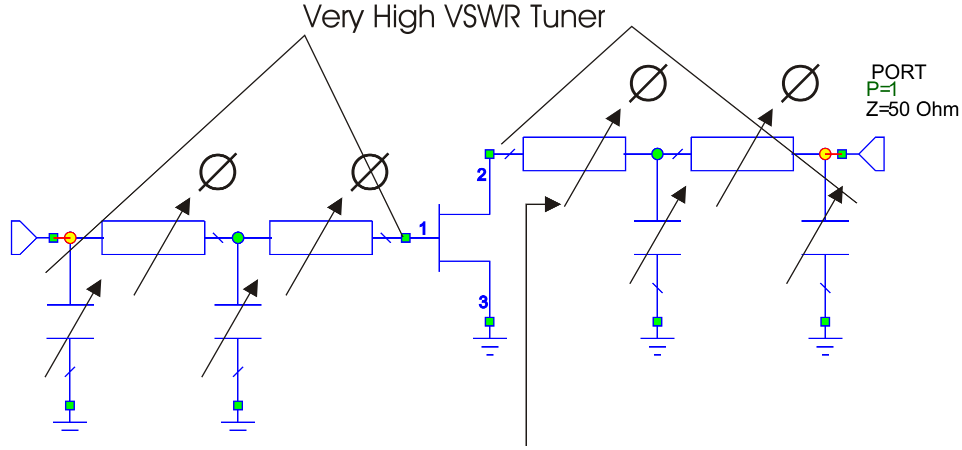


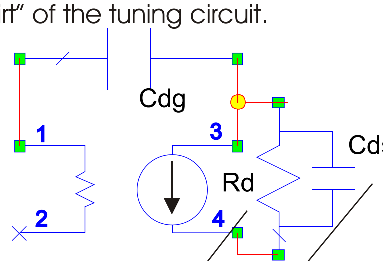
The 2-Tone measurement setup for establishing the linearity of the DUT (Device Under Test. In high power measurements the IM3 tone levels at the output may differ by several db yielding two suppression level values. This creates confusion as to which is the correct reading.

The loss of such structures must be very low if it is to reach high VSWR for best power output and IM3 match. It follows that if the entire output circuit (including the MESFET) exhibits a band pass response that it may also have a very narrow bandwidth. This is a simple expression of Fano's match tolerance theory. The form of this situation is

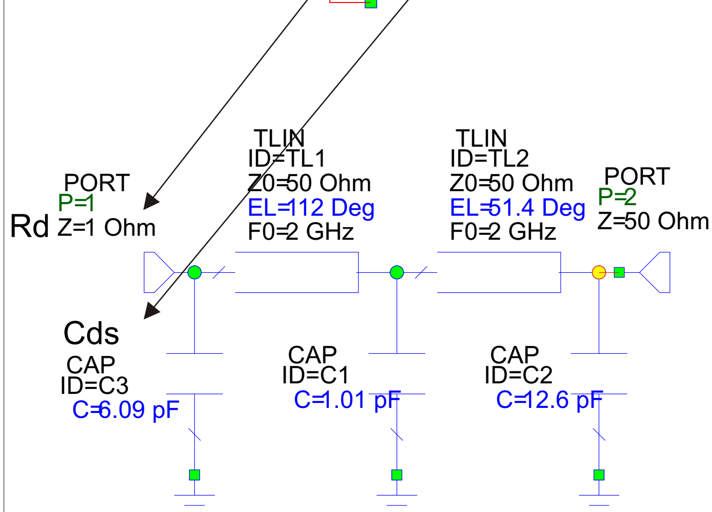
In figure 2 the low pass tuners are optimized for best power match. The output equivalent circuit can be represented by a parallel RC element with parasitic connections. To demonstrate the effect that Pmax mismatch can have on adjacent IM3 levels a simple example will be used. The output equivalent (fig 3.) is cascaded with an assumed mismatch of 1db (Γ = .891) for best linearity and power at 1.9GHz. When the tuner is adjusted for best power it must form a bandpass response. The Pmax mismatch is a reactive mismatch whic causes a shift in the tuner center frequency response. this in turn means that the entire circuit is operating on the “Skirt” of the tuning circuit.

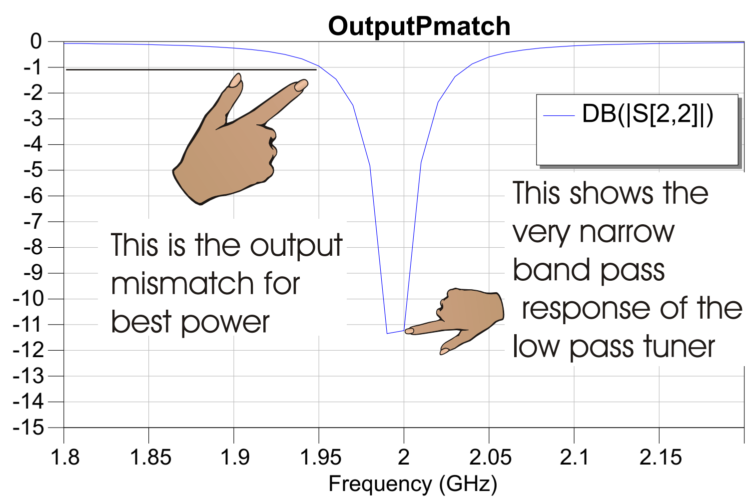
2. Equivalent Circuits For Very High VSWR Tuner



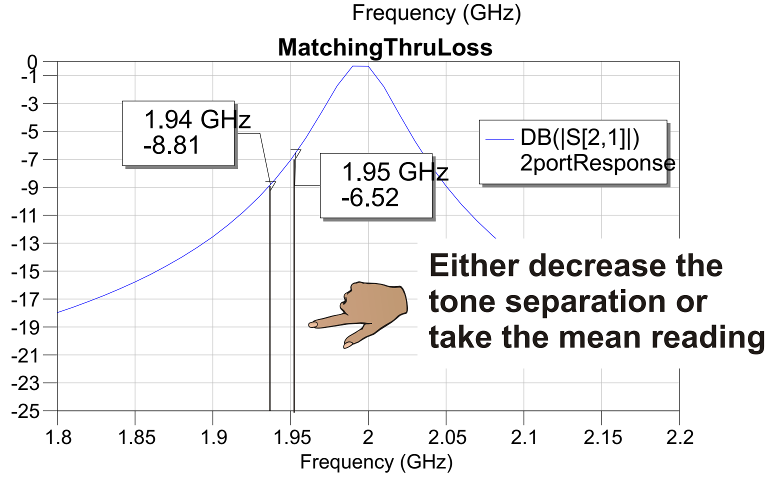


3. This very simple equivalent circuit represents the output impedance of the high power GaAs Fet. Values for Rd can be less than one ohm. Cdg feedback can create a mismatch for best power transfer to the load.





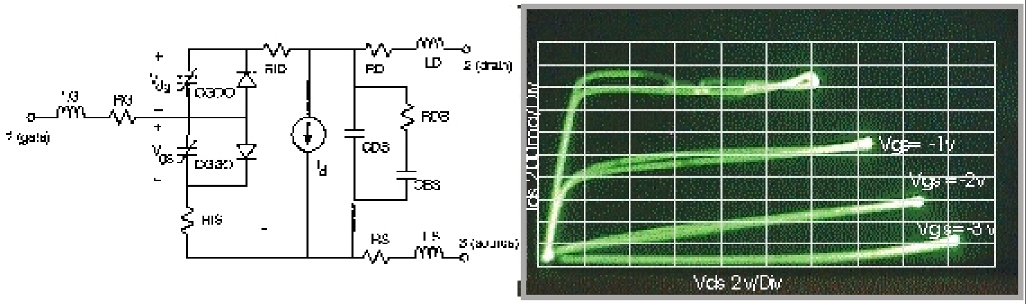
The insertion loss simulation shows that for extreme cases of (low Rd and high Cdg) a steep skirt is created that can easily change the normally equal IM3 signals. One solution to the problem would be to try to re-tune the tuners for a staggered band pass response. The required Pmax mismatch may not be attainable which is probably why the problem occurred in the first place. The second solution is to assume a linear skirt and take the mean value. A third solution is to narrow up the tone separation until both are equal.

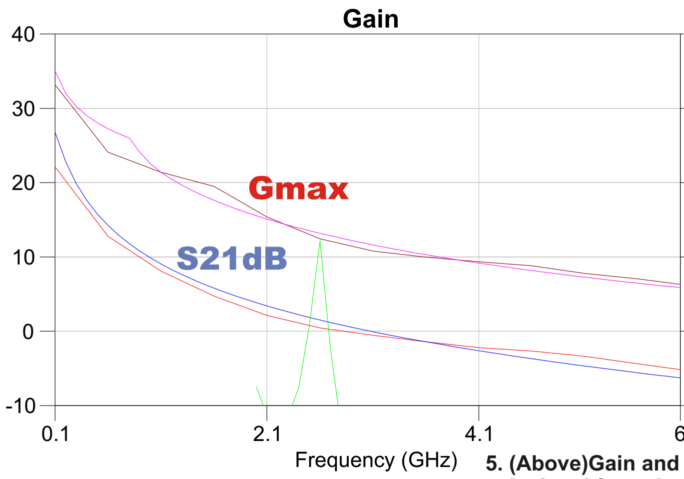


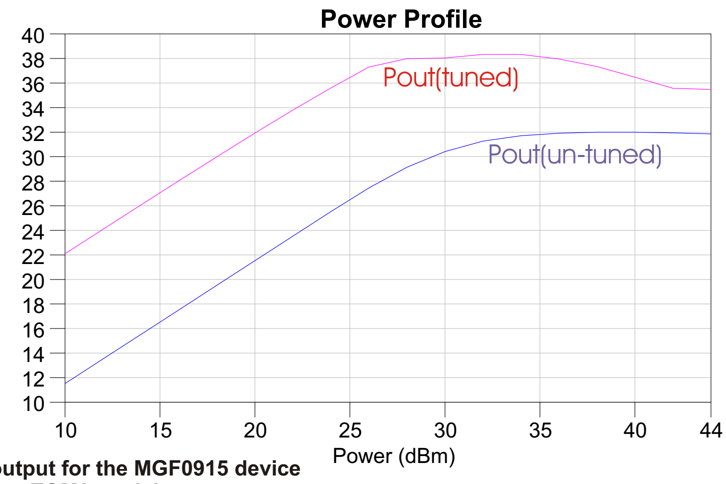
To see this effect more clearly we turn to a non-linear model. In this case we select the Mitsubishi MGF0915A Power Mesfet. This device is capable of 10Watts power output and has a typical IDSS of 2Amps. The non-linear model was created using the TOM2 model in AWR's Microwave Office Design Suite. Figure 4 shows the model topology and the component values resulting from detailed parameter optimizations.

We first demonstrate the characteristics of the device by calculating the Gain, Power output and input Q parameter.

4. The TOM2 FET model optimized to the MGF0915 small signal, DC and high power performance.







5. (Above)Gain and power output for the MGF0915 device calculated from the non-linear TOM2 model.

The input impedance displays a resonance profile. If we ignore the feedback effects of the device we may estimate the approximate Q by establishing yet another circuit model for the reactance locus. By inspection and prior device knowledge this is a series RLC circuit. Fig. 6 shows the optimized element values for the input equivalent circuit. In the classical sense the matching tolerance is dictated by the elements exhibiting the highest Q. For the gate circuit this is:

$$Qo = \omega oLs/Rg$$

For the plot shown the equivalent circuit encompasses the entire frequency band over which the device is useful and is there a valid circuit. The simple calculation for Q yields:

$$Qo = 3.01$$

This value of Q gives rise to a band-width factor of f/fc. For this example the device is used at 2.6GHz yielding a 3dB bandwidth limitation of :

2.6/3 ~ 866MHz

We now turn our attention to the narrowband response profile (green trace Fig. 5) created by tuning the DUT with low loss high Q tuners.

It is clear the low pass tuners are set to transform the high system impedance (50) level down to the gate impedance level. To accomplish this the tuners must take on a band pass response. This does not necessarily require that the band pass response be centered at the measurement frequency. In fact this is rarely the case. Device internal and external feedback and desire for maximum output power shift the center frequency of the individual input and output responses for a specific overall response. This is easily seen by observing the overall response and the response of the individual equivalent