Power Amplifier In Compression With Intermodulation Products - A Basic Harmonic Balance Example

A Basic Harmonic Balance (HB) InterModulation (IMD) Example Will Provide Insight To This Powerful Yet Sometimes Cumbersome To Use Non-linear Simulator Within The Keysight Advanced Design System (ADS).

Using the Harmonic Balance Simulator, one must be careful to set the simulator up correctly in order to accurately capture higher order Intermodulation products produced by non-linear simulations.

Take a basic example... a power amplifier with 10 dB gain and Output 1-dB compression (single-tone) set to +30 dBm shown in **Figure 1**:

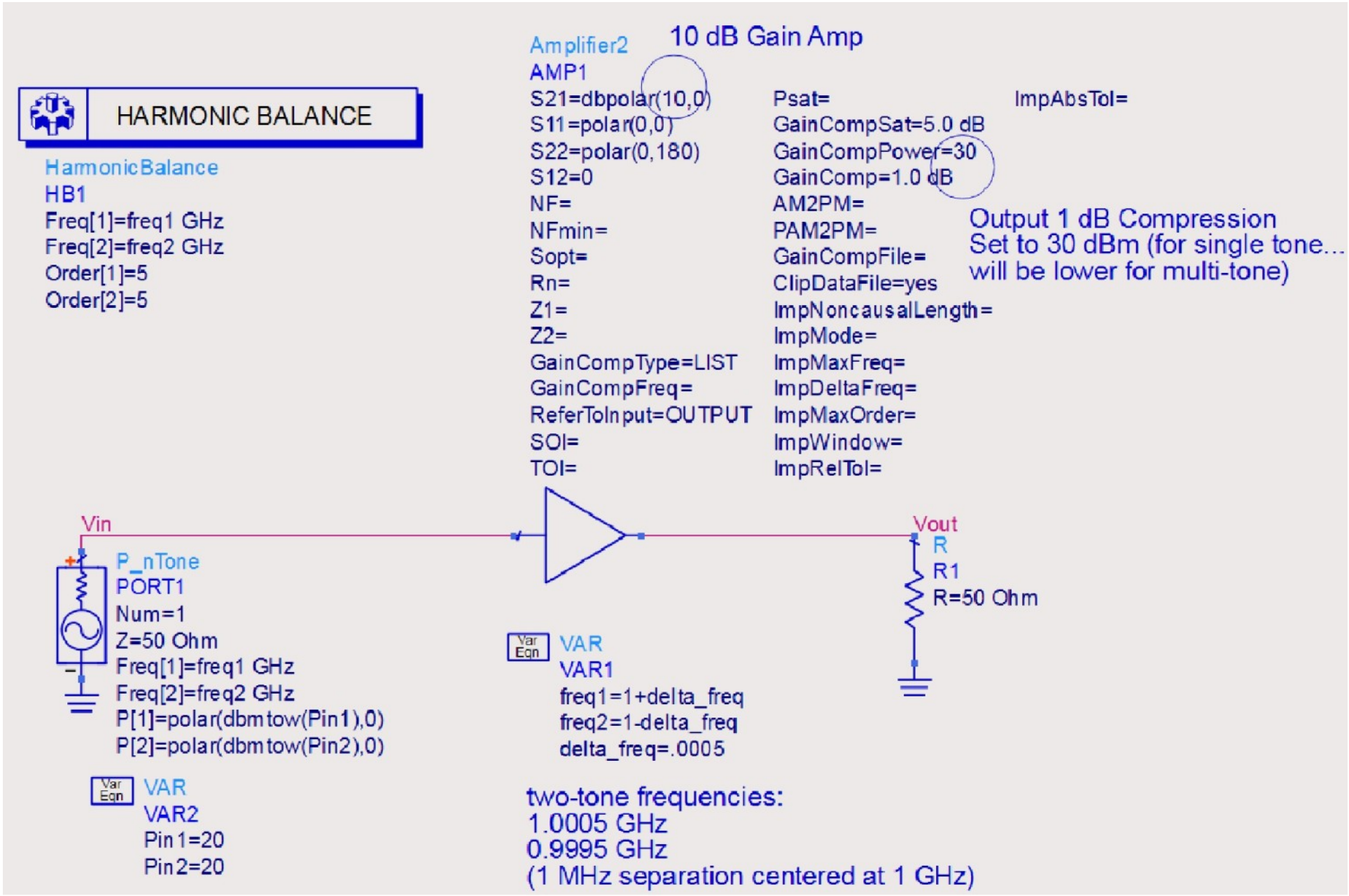


Figure 1. 10 dB Gain Amplifier with 30 dBm 1-dB Compression Point Modeled In Harmonic Balance

The simulation result below in **Figure 2** shows the main signal tones and the third order Internodulation (IMD) products.

However, the simulation still does not look "natural". That is, it does not look like a spectrum one would witness when making measurements of a power amplifier well into compression in the lab.

In a real-world lab case, there would be many more terms in the spectrum...third, fifth, seventh, etc. The higher order terms would all be present and the spectrum would be significantly wider on a spectrum analyzer screen.

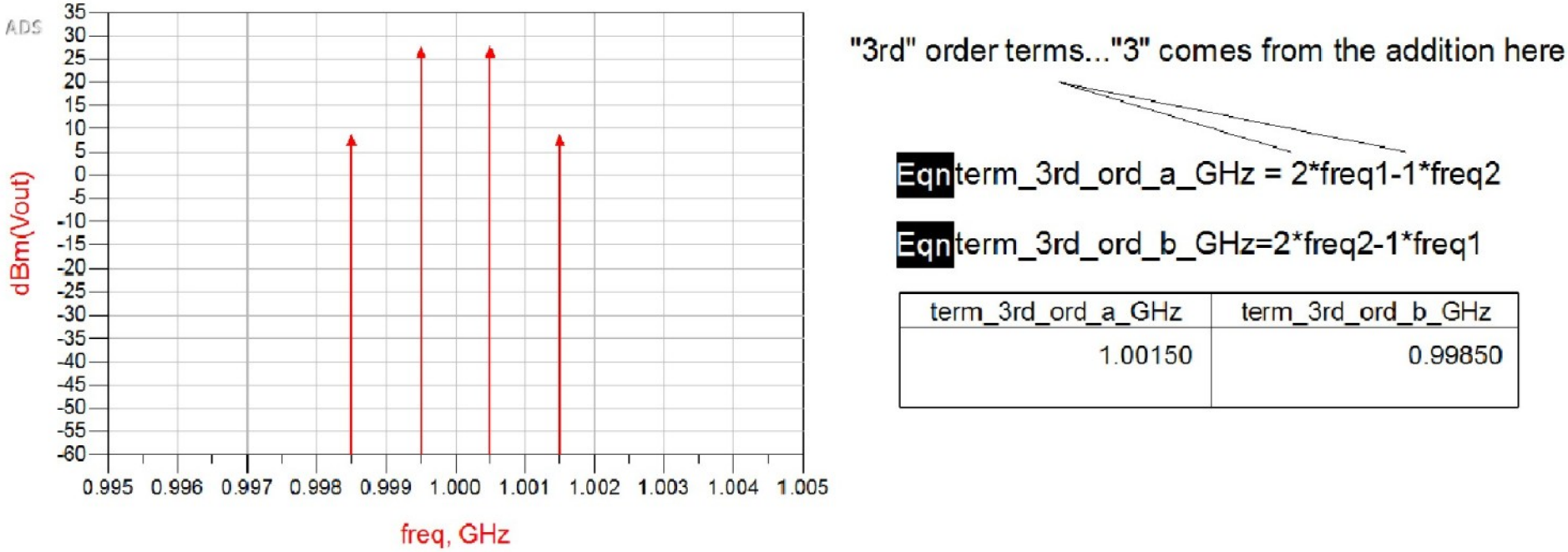


Figure 2. Simulated Spectrum From Harmonic Balance - Spectrum Still Does Not Resemble What Would Be Witnessed In The Lab

The problem is that the HB parameter "**MaxOrder**" is set to the default of 4.

This means that you are effectively shutting these higher order terms off and not including them in the simulations - essentially "shooting yourself in the foot".

Obviously, this is not something you want to do if an accurate IMD analysis is desired.

Go into the HB Simulator - Make "MaxOrder" visible and increase it to a value of 5 as shown in **Figure 3**.

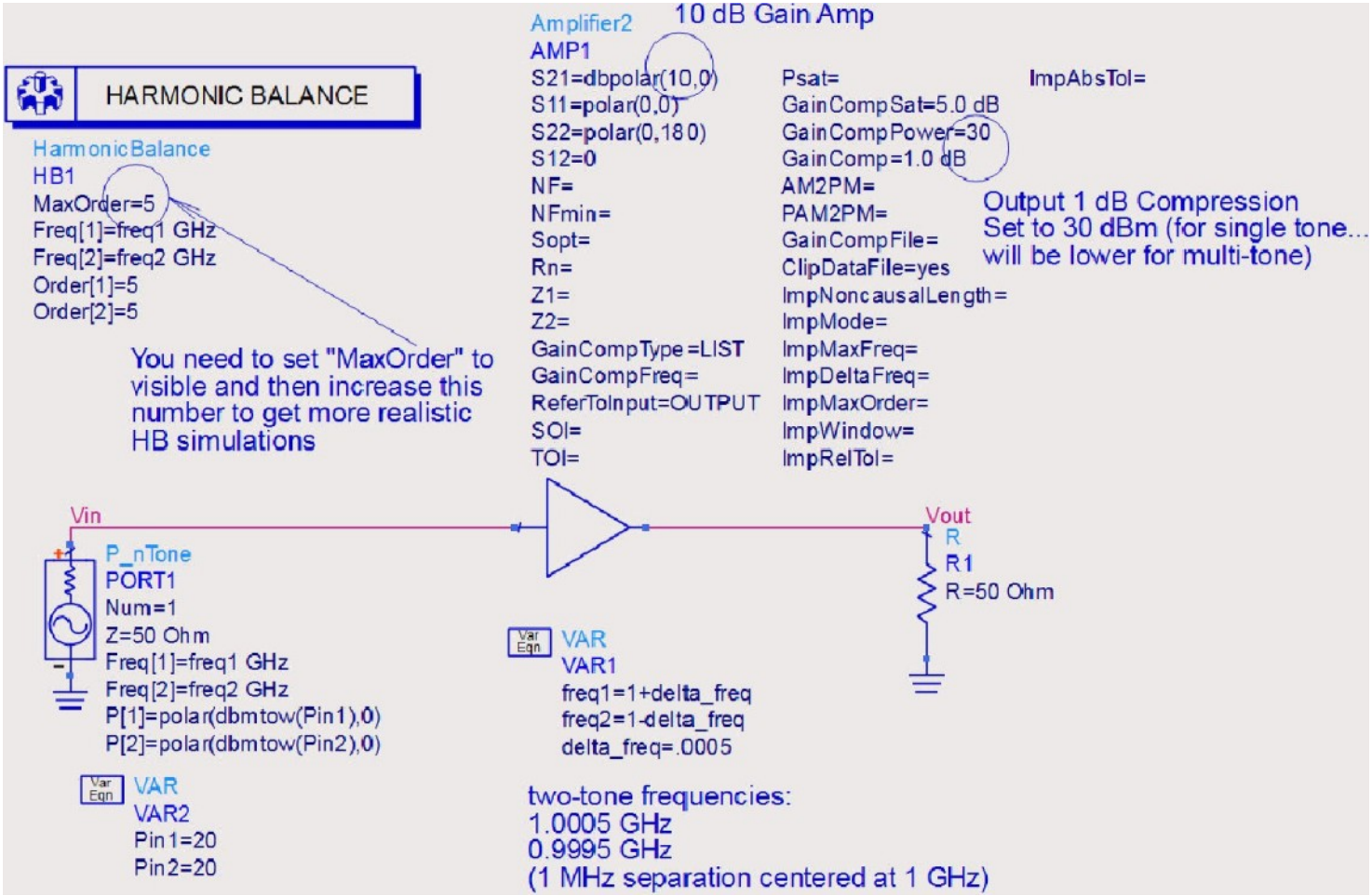
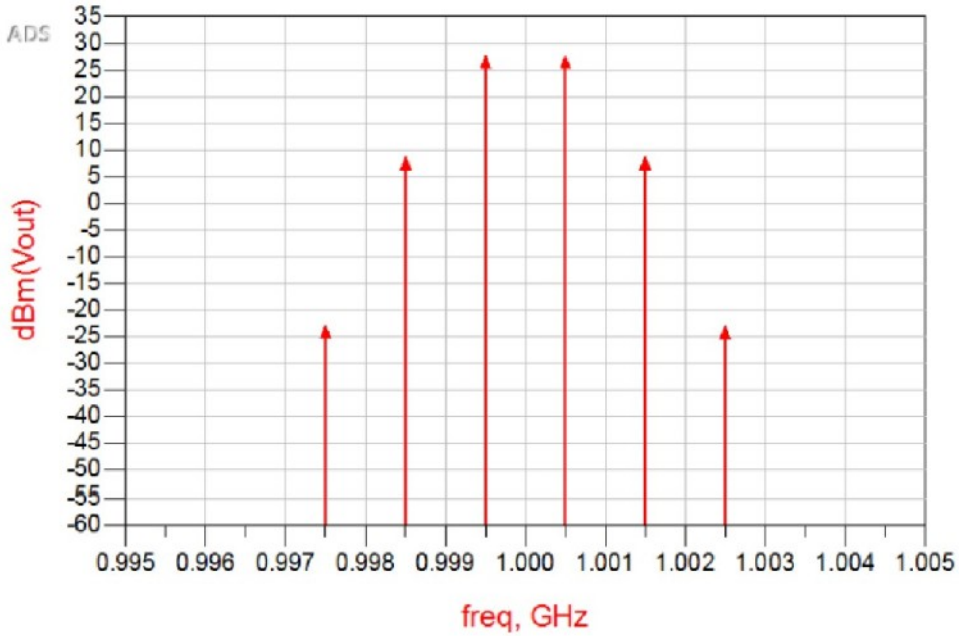


Figure 3. Make "MaxOrder" Visible And Increase Its Value

Now, things are looking better as shown in **Figure 4**...but, still not quite "natural" as there would still be even more IMD terms in the real world...



"3rd" order terms..."3" comes from the addition here

Eqn term_3rd_ord_a_GHz = 2*freq1-1*freq2

Eqn term_3rd_ord_b_GHz=2*freq2-1*freq1

term_3rd_ord_a_GHz	term_3rd_ord_b_GHz
1.00150	0.99850

"5th" order terms..."5" comes from the addition here

Eqn term_5th_ord_a_GHz=3*freq1-2*freq2

Eqn term_5th_ord_b_GHz=3*freq2-2*freq1

term_5th_ord_a_GHz	term_5th_ord_b_GHz
1.00250	0.99750

Figure 4. Harmonic Balance Spectrum Showing Main Signal Tones, 3rd Order IMD Products, and 5th Order IMD Products

Increase “MaxOrder” again to 7 as shown in **Figure 5**...you get the idea ...keep going...

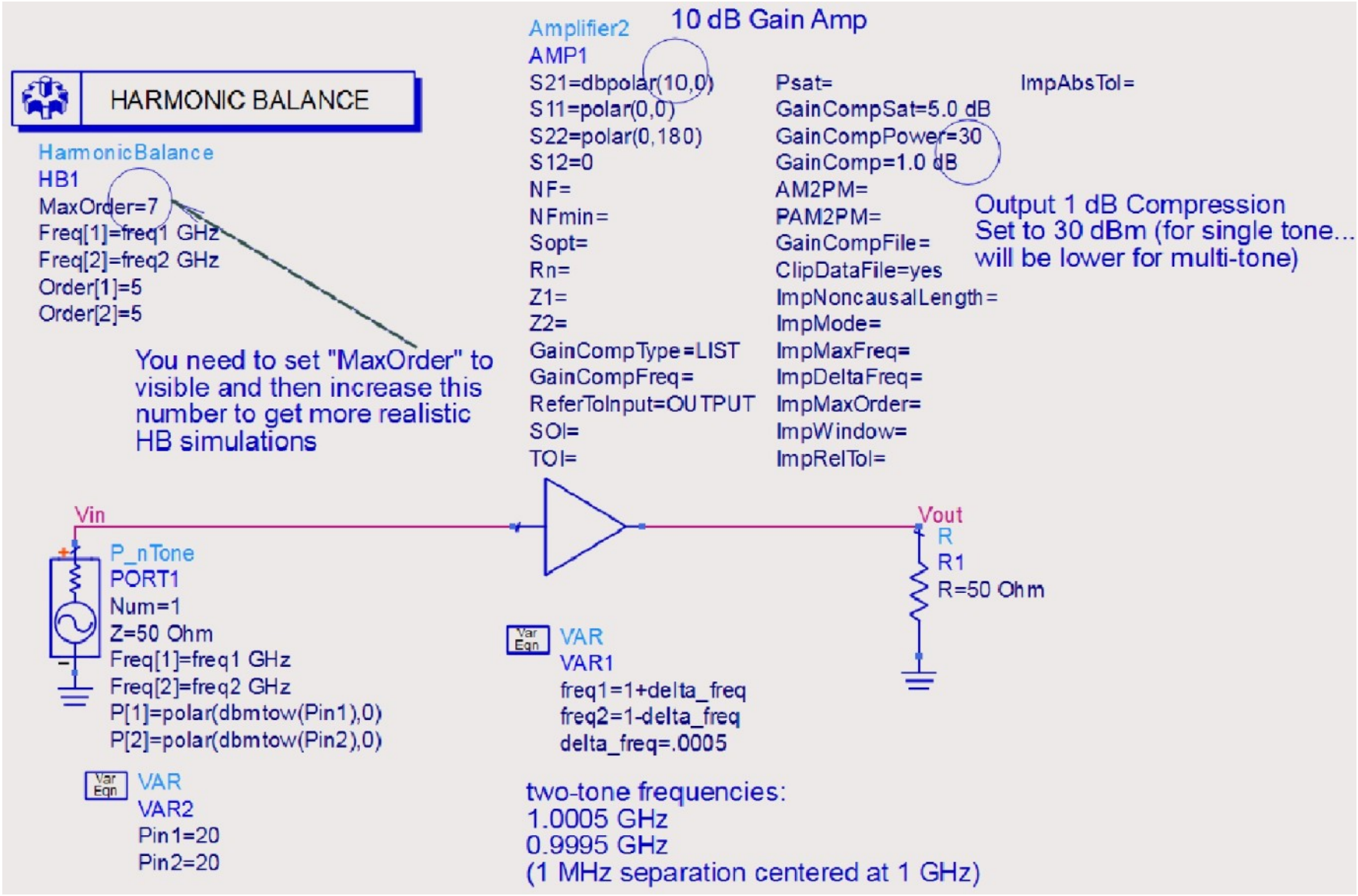
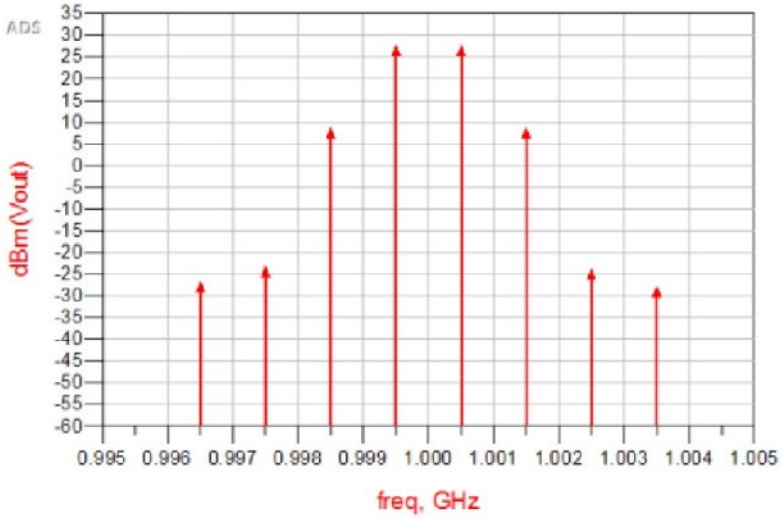


Figure 5. Increase “MaxOrder” Again To 7 In Order To Introduce Further IMD Products



"3rd" order terms..."3" comes from the addition here

Eqn term_3rd_ord_a_GHz = 2*freq1-1*freq2

Eqn term_3rd_ord_b_GHz=2*freq2-1*freq1

term_3rd_ord_a_GHz	term_3rd_ord_b_GHz
1.00150	0.99850

"5th" order terms..."5" comes from the addition here

Eqn term_5th_ord_a_GHz=3*freq1-2*freq2

Eqn term_5th_ord_b_GHz=3*freq2-2*freq1

term_5th_ord_a_GHz	term_5th_ord_b_GHz
1.00250	0.99750

"7th" order terms..."7" comes from the addition here

Eqn term_7th_ord_a_GHz=4*freq1-3*freq2

Eqn term_7th_ord_b_GHz=4*freq2-3*freq1

term_7th_ord_a_GHz	term_7th_ord_b_GHz
1.00350	0.99650

Figure 6. Spectrum Showing More Components as "MaxOrder" Is Increased Again

However, the “buck stops here”. What you notice is that, if you increase “**MaxOrder**” again, no further IMD products are introduced Into the Spectrum.

This is because the Harmonic Order terms are now the limiting factor instead of the “**MaxOrder**” term.

The Harmonic Order for each tone in the simulation above is set too low at 5 - see “Order[1]” and “Order[2]” above.

These terms set how many harmonics will be considered for each main tone in the Harmonic Balance simulation. So, by having these at 5, you have essentially “shot yourself in the foot” again.

By having the number of harmonics set too low at 5, you are again limiting the number of IMD products that can show in the Spectrum.

By increasing “Order[1]” and “Order[2]”, you will now see more and more terms added to the Spectrum.

The Spectrum will continue to fill out (get wider) and more accurately resemble what would be witnessed in the lab.

The lesson here is to correctly set both “MaxOrder” **and** “Order” high enough in the HB simulations so that you are getting an accurate picture of **all** of the non-linearities in the Harmonic Balance simulation.

Other Advanced Design System Examples can be found at https://bbt-line.com/ads-examples/