An Advanced Design System (ADS) Harmonic Balance Mixer Simulation Example

The Harmonic Balance (HB) Simulator within the Advanced Design System is a powerful non-linear/steady-state simulator; however, at times, it can be quite cumbersome to use and also yield strange simulator results.

A basic up-converting mixer simulation should show some pitfalls and solutions.

A basic Up-Converting Mixer problem is shown in the schematic in Plot 1 below.

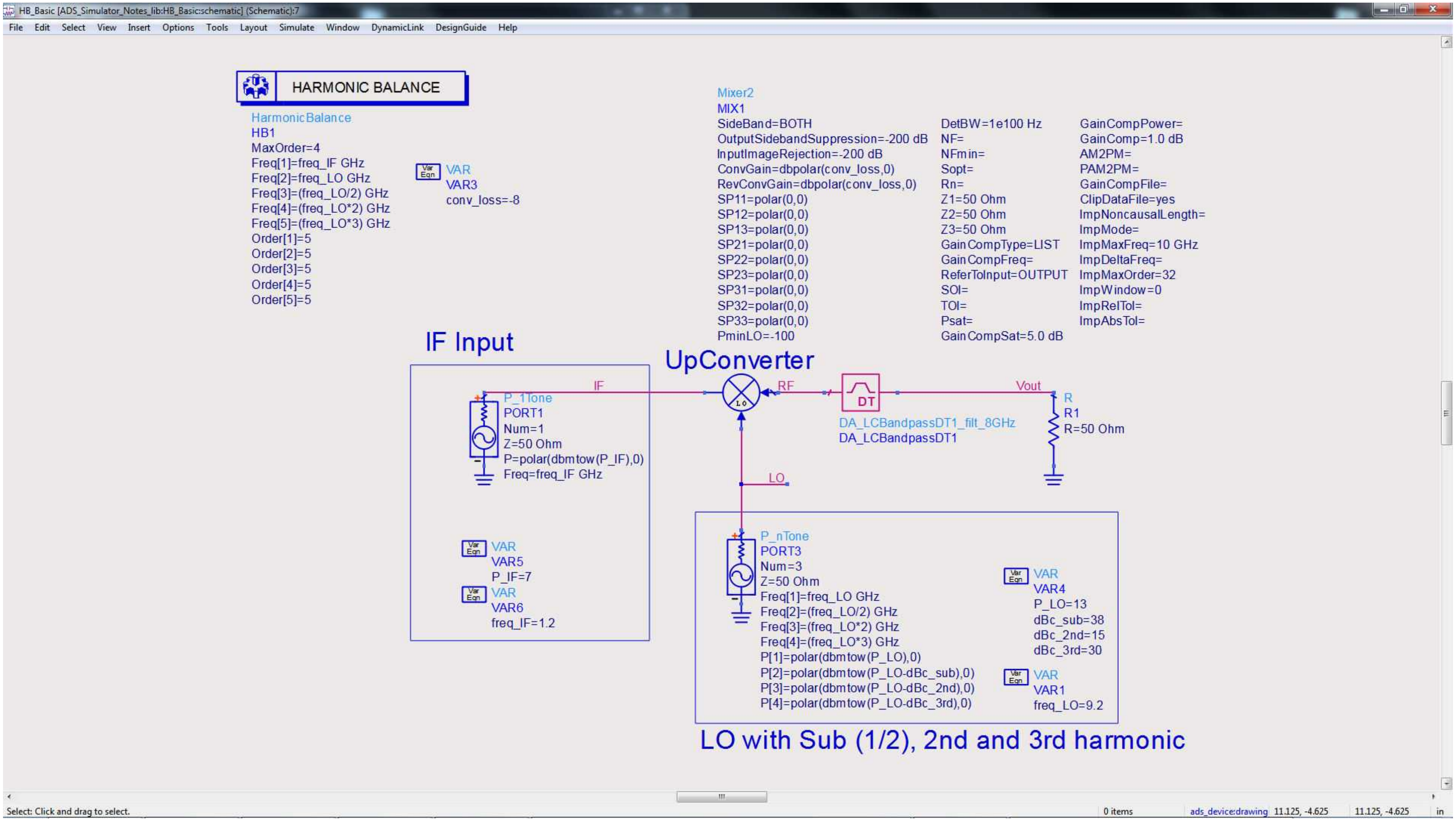
Using a 1.2 GHz IF signal, the desire is to Up-Convert this 1.2 GHz signal to 8 GHz using an LO frequency 9.2 GHz.

The LO has a sub-harmonic of 4.6 GHz and 2nd and 3rd harmonics of 18.4 and 27.6 GHz, respectively.

The IF is a single tone at 1.2 GHz.

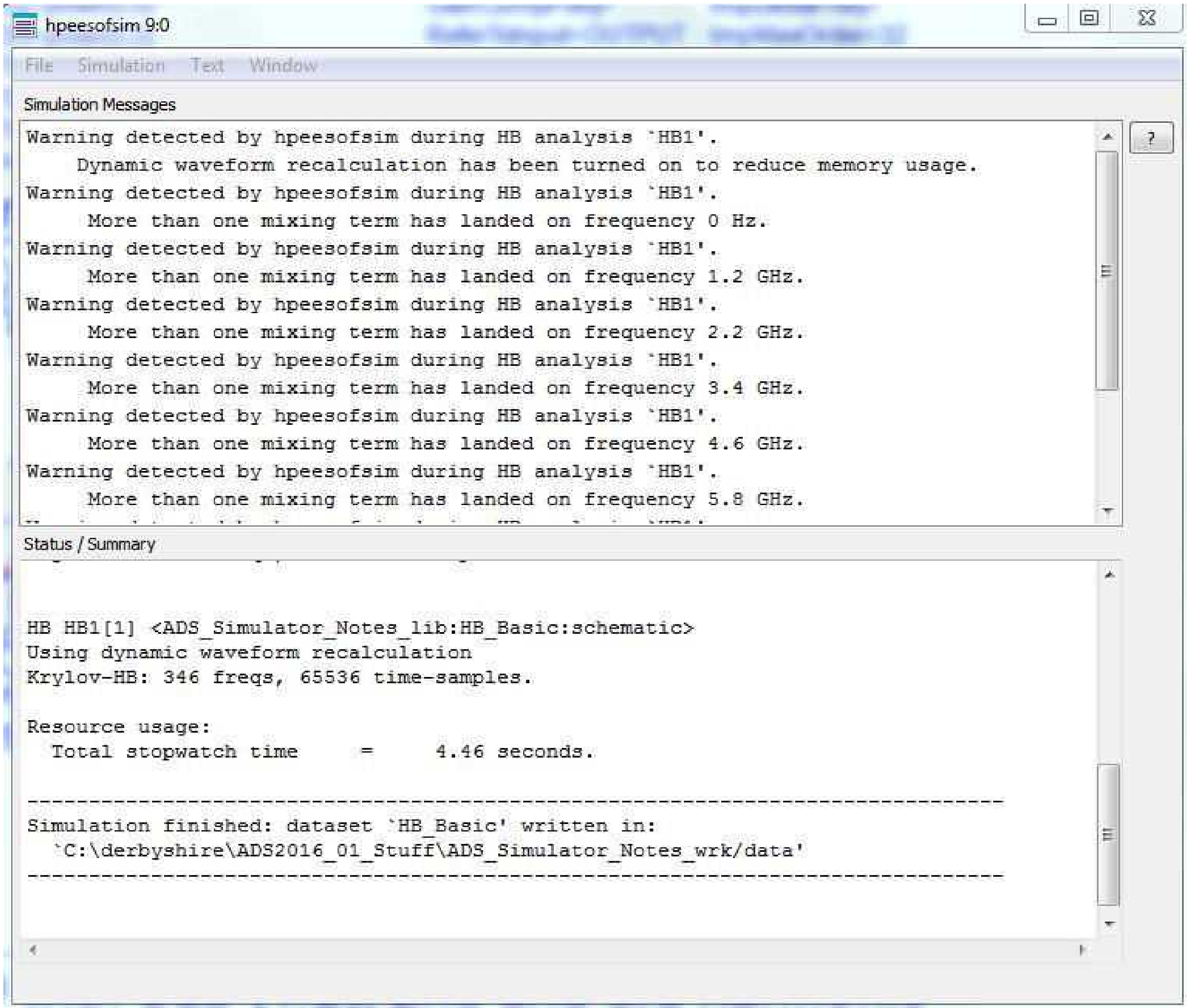
Notice that the mixer is placed with the RF port on the right side (in ADS, Ctrl y flips the mixer from the default orientation.

The RF side of the mixer has a bandpass filter in it.



Plot 1. An Up-Converting Mixer Simulation In Harmonic Balance

When you run this simulation you notice many warnings and you are left scratching your head wondering if things have been computed correctly by the simulator:



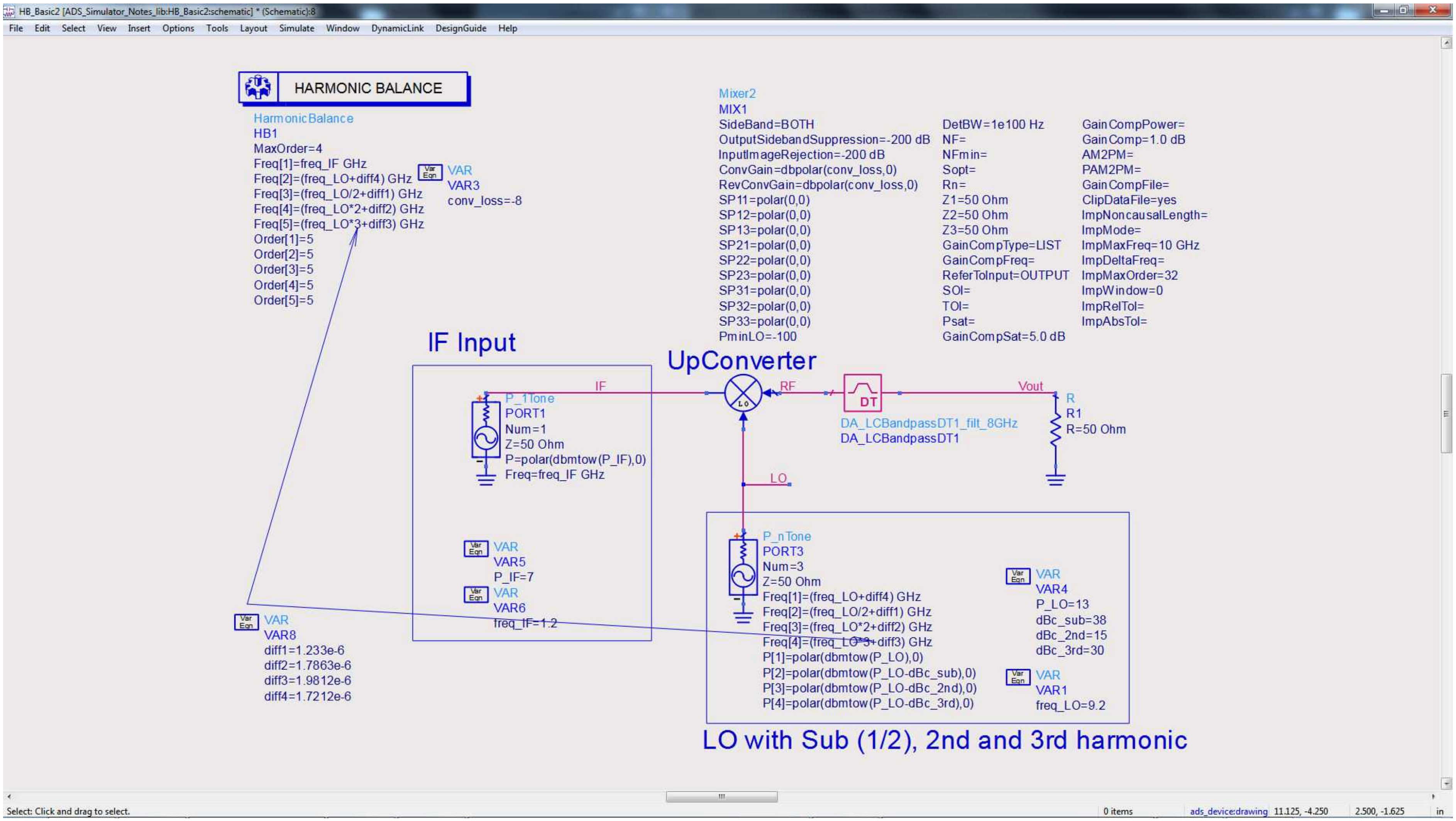
Plot 2. Confusing Simulation Results Leave You Wondering If Harmonic Balance Is Computing Correctly

These warnings arise because the source frequencies defined are numerically perfect. This causes the mixing terms to perfectly mathematically "fold" on to one another in the mixing process.

In the real-world, these source frequencies would not be so numerically perfect and would not align so precisely.

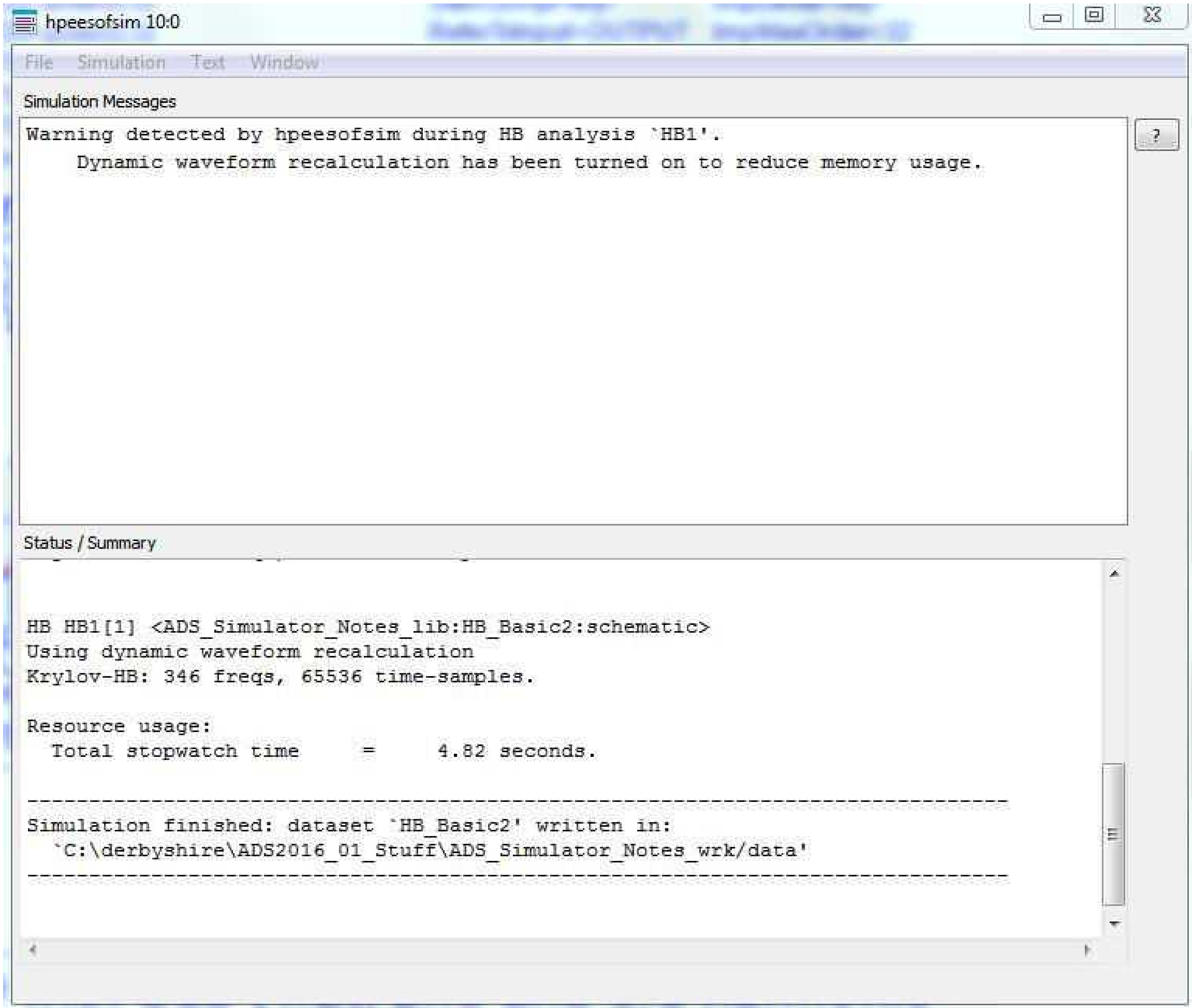
In order to mimic the real world more closely, and avoid all of these warnings, place very small/random

frequency offsets in the definitions of your source frequencies as shown in Plot 3:



Plot 3. Adding Small Offsets To The Ideal Frequency Definitions In Harmonic Balance

Now, you do not see the confusing warnings:



Plot 4. Confusing Simulator Results Are Removed After Small Frequency Offsets Are Added

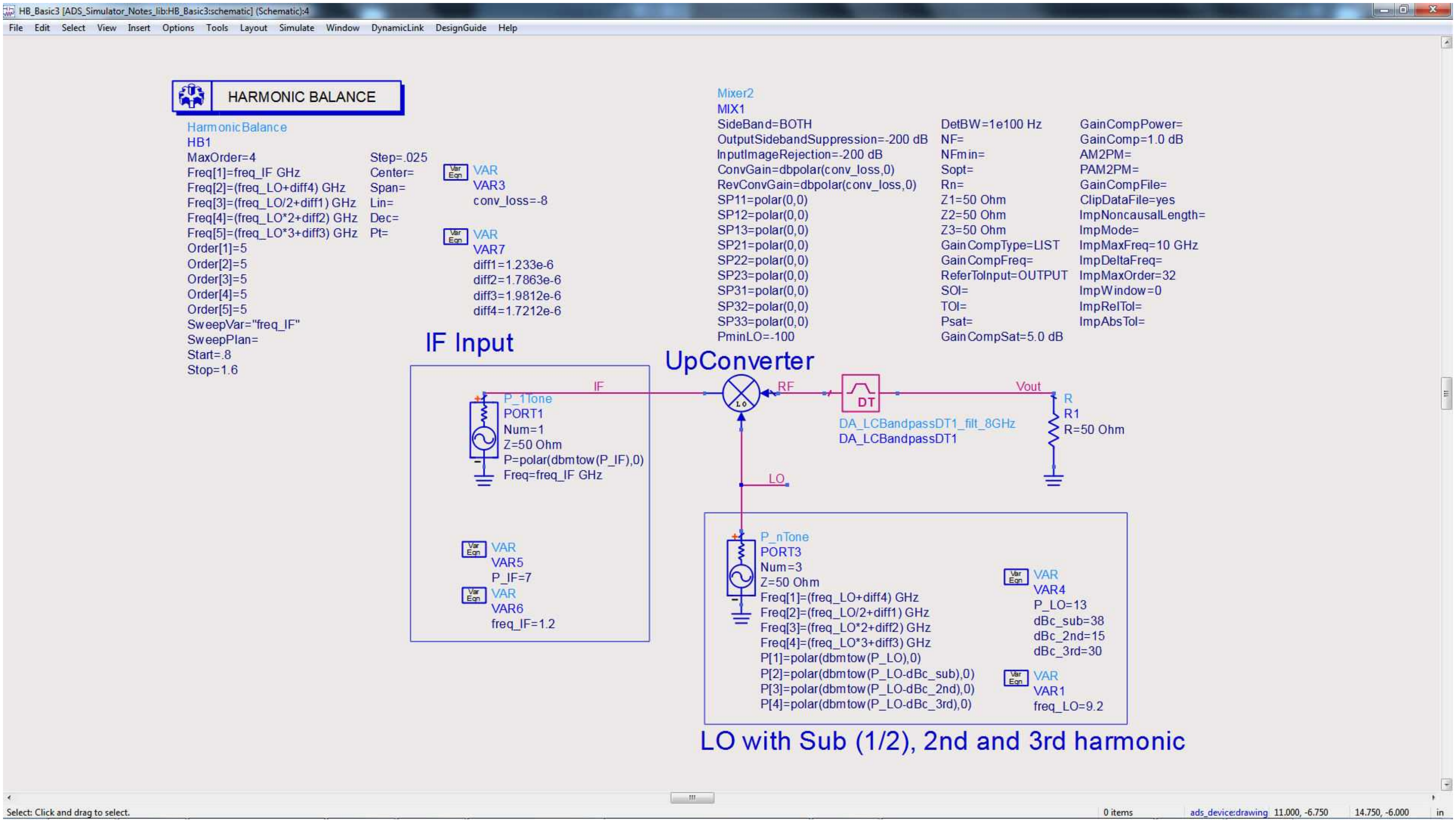
Next, what I would like to do is sweep the IF frequency (around its 1.2 GHz center frequency) and view the final sweep at node “Vout”.

Basically, I would like to observe the response of the cascade through the bandpass filter.

This would be analogous to being in the lab and sweeping your IF signal generator while your spectrum analyzer is set to “Max Hold” - A poor man’s network analyzer to verify the shape of the bandpass filter.

Here’s the problem - getting this view from the Harmonic Balance simulator and the Data Display proves quite challenging.

First, Notice the Harmonic Balance simulator box has the IF sweep frequencies defined to be from .8 to 1.6 GHz in 25 MHz steps as shown in Plot 5:

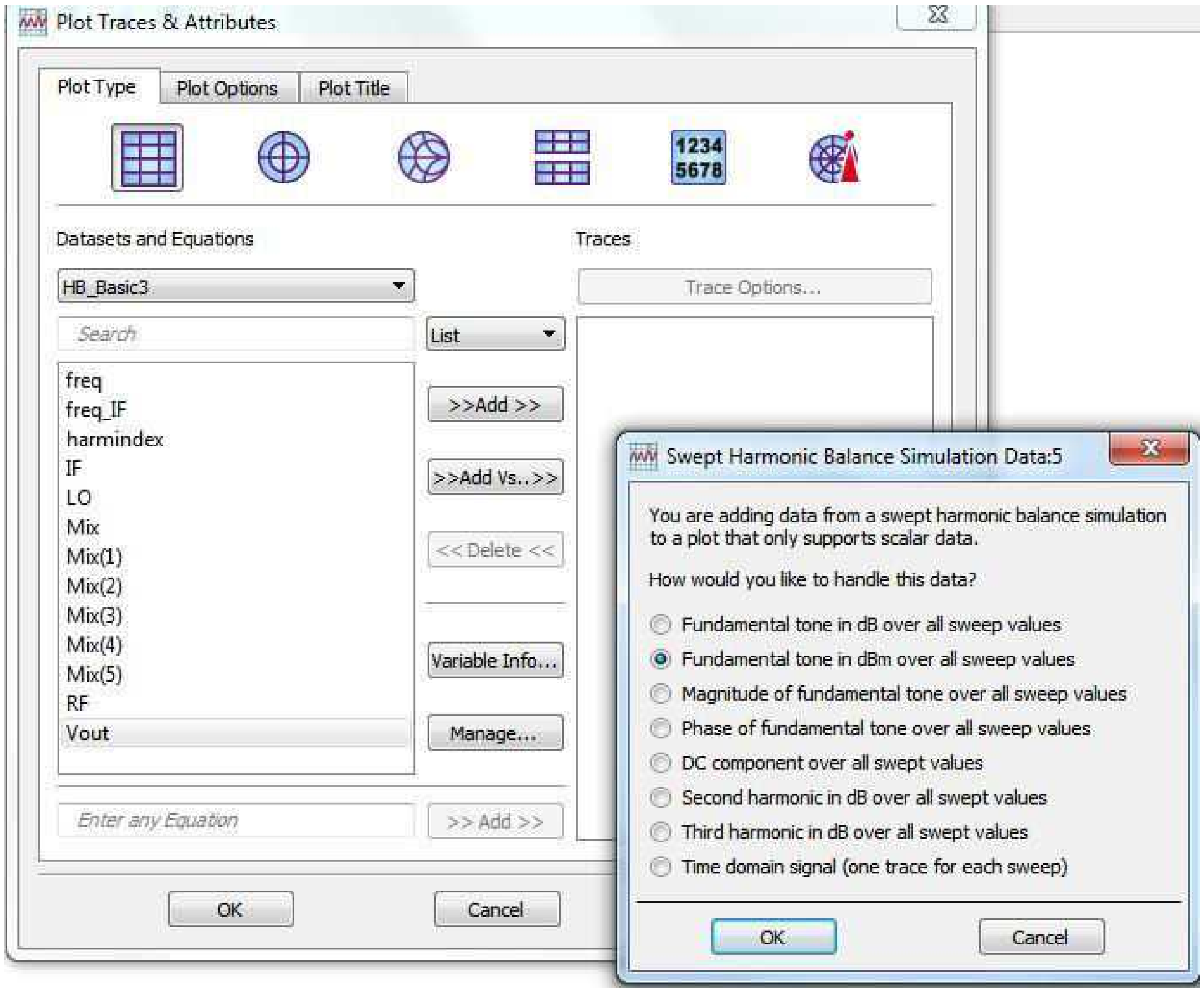


Plot 5. IF Frequency Sweep is defined from 0.8 GHz to 1.6 GHz in 25 MHz Steps

Here's the problem...after the simulation has been run and you go to Data Display to select "Vout", you will notice that none of the options given by Data Display will lead to the plot that I want!

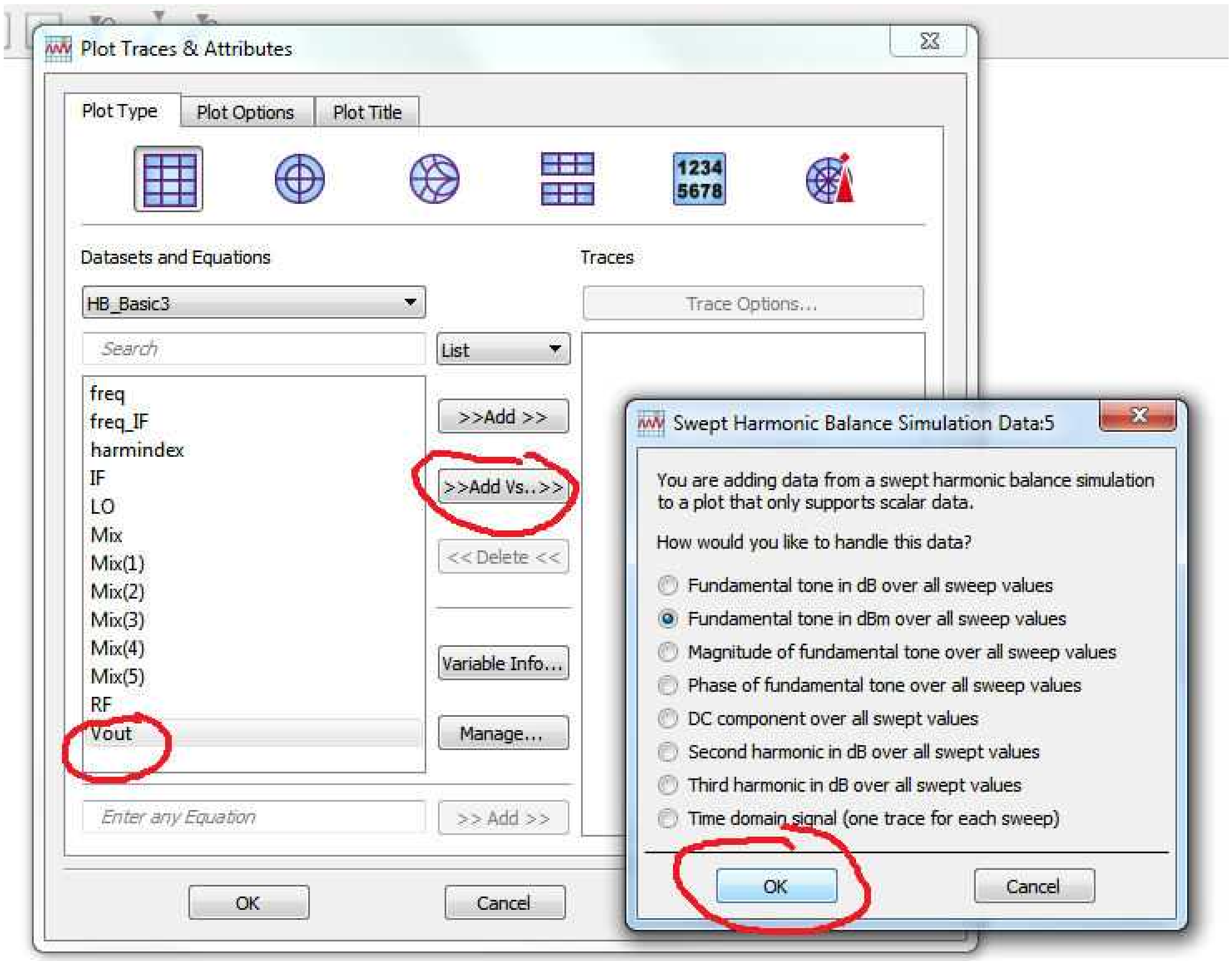
None of the options make sense for this particular sweep...this is one of the biggest frustrations with Harmonic Balance.

Getting used to how the HB data is presented in Data Display is a bit of a learning curve.



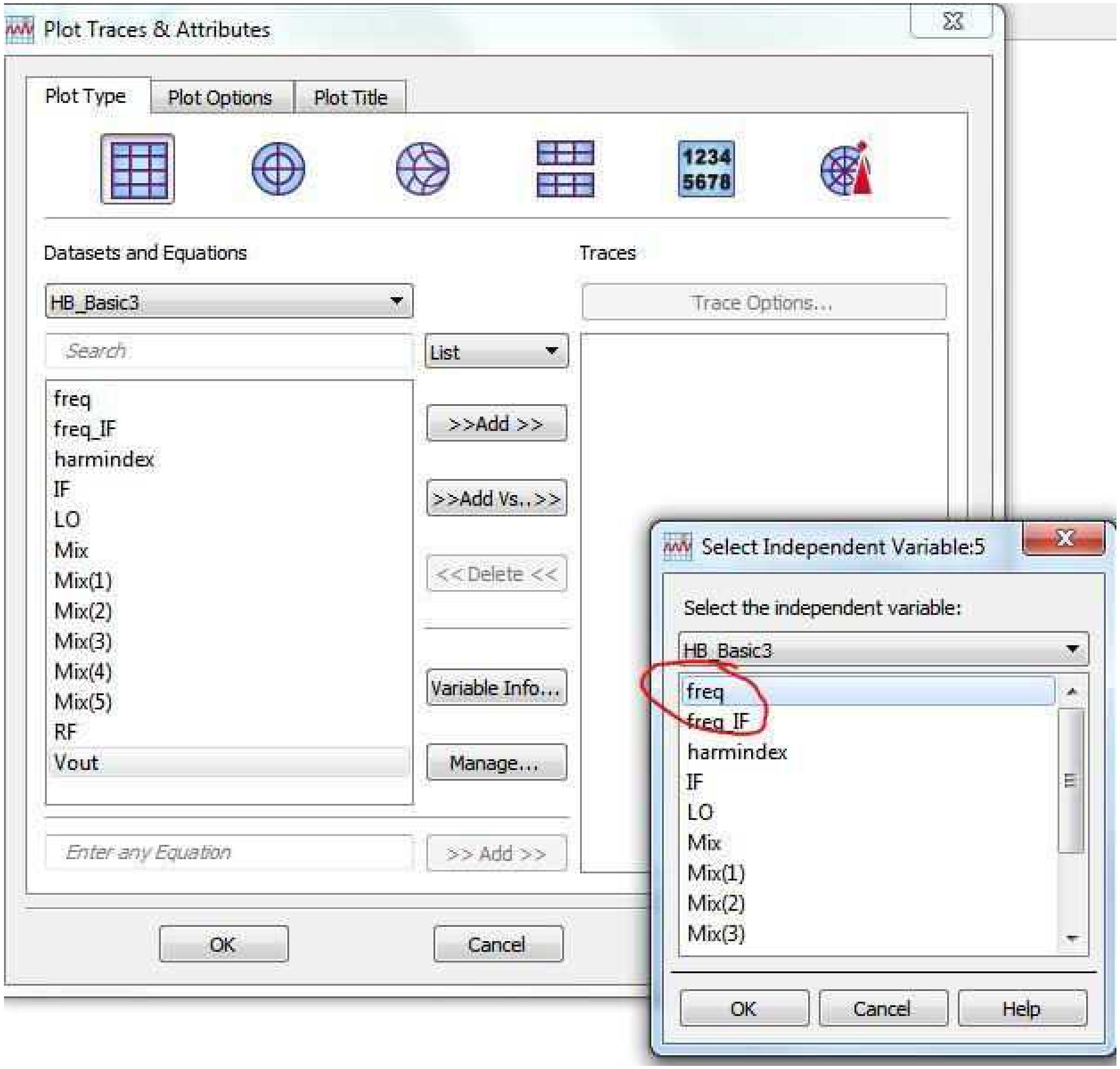
Plot 6. None of the default simulation results to choose from give the desired output

Here's how I get to the desired plot within Data Display..select "Vout", select "Add Vs.", select "OK"



Plot 7. More HB Settings To Choose

select “freq”:

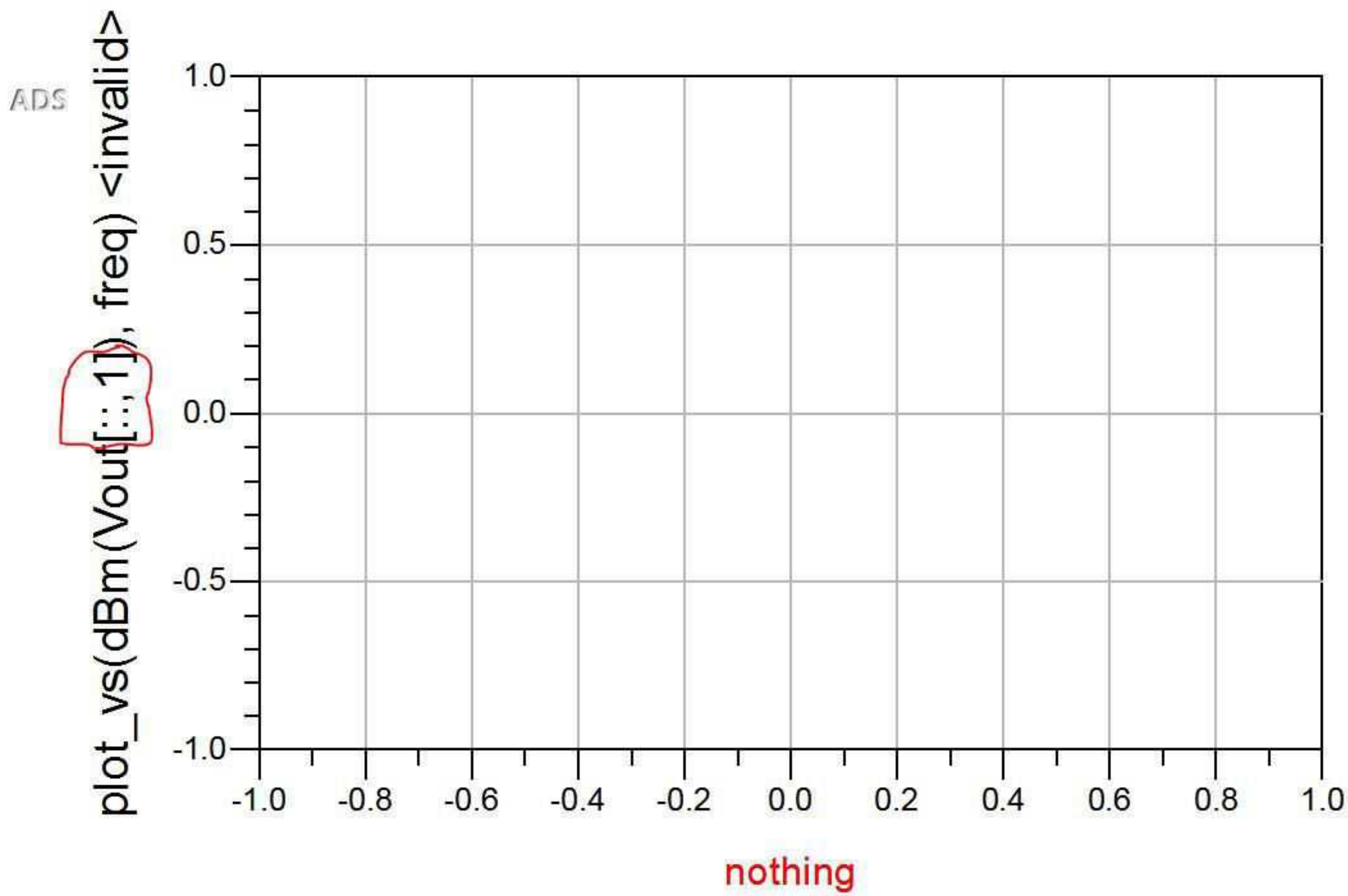


Plot 8. More HB Settings To Choose

This will come up with a plot that still gives you nothing useful.

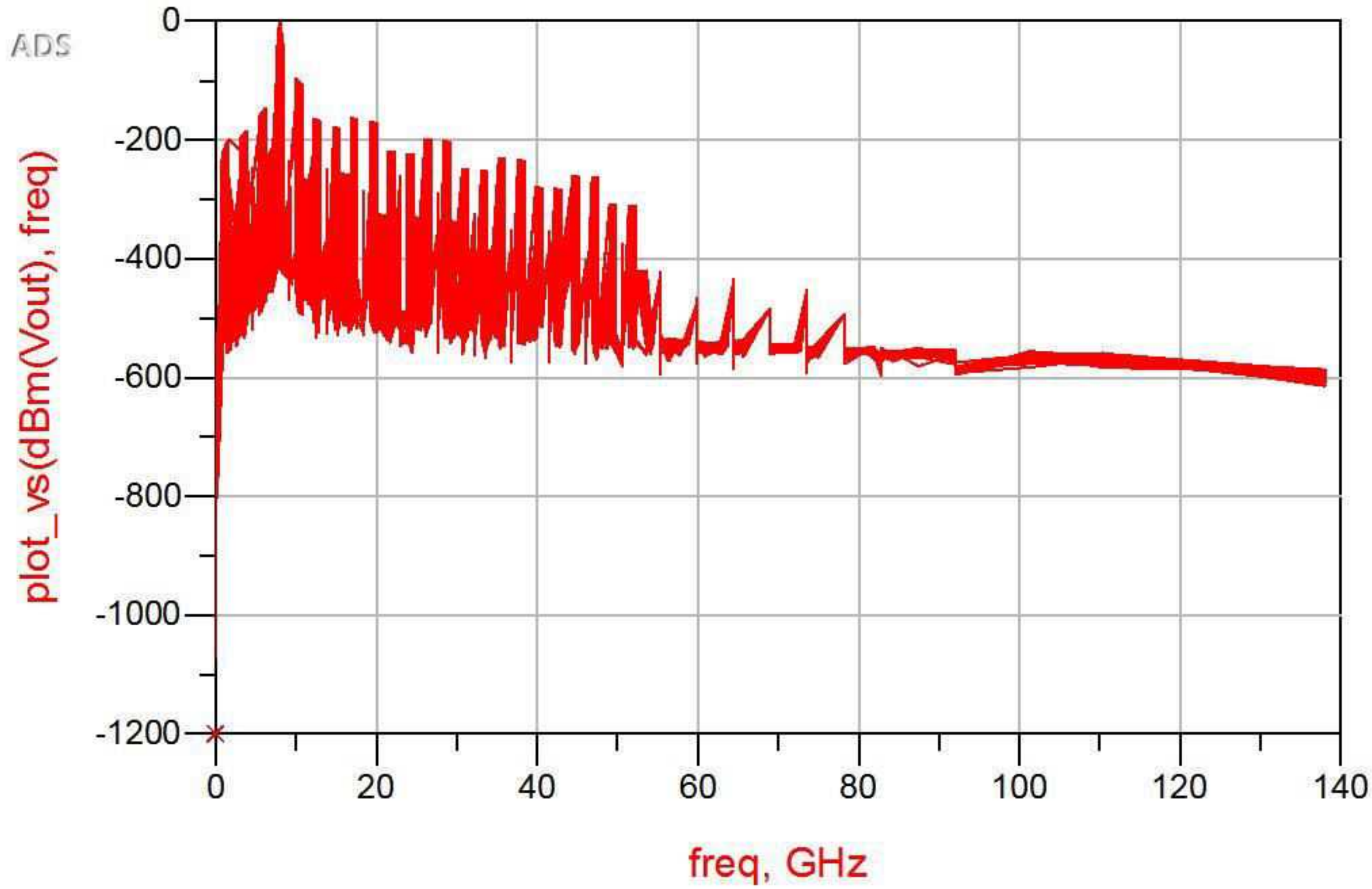
You need to click in the plot text (encircled in red) and backspace/delete the “[::,1]”...delete this.

The “::” is telling Data Display to look at all frequencies of the sweep, the “1” is telling Data Display to look only at the first harmonic of the results...neither of these apply to our situation so we need to delete the restrictive clause.



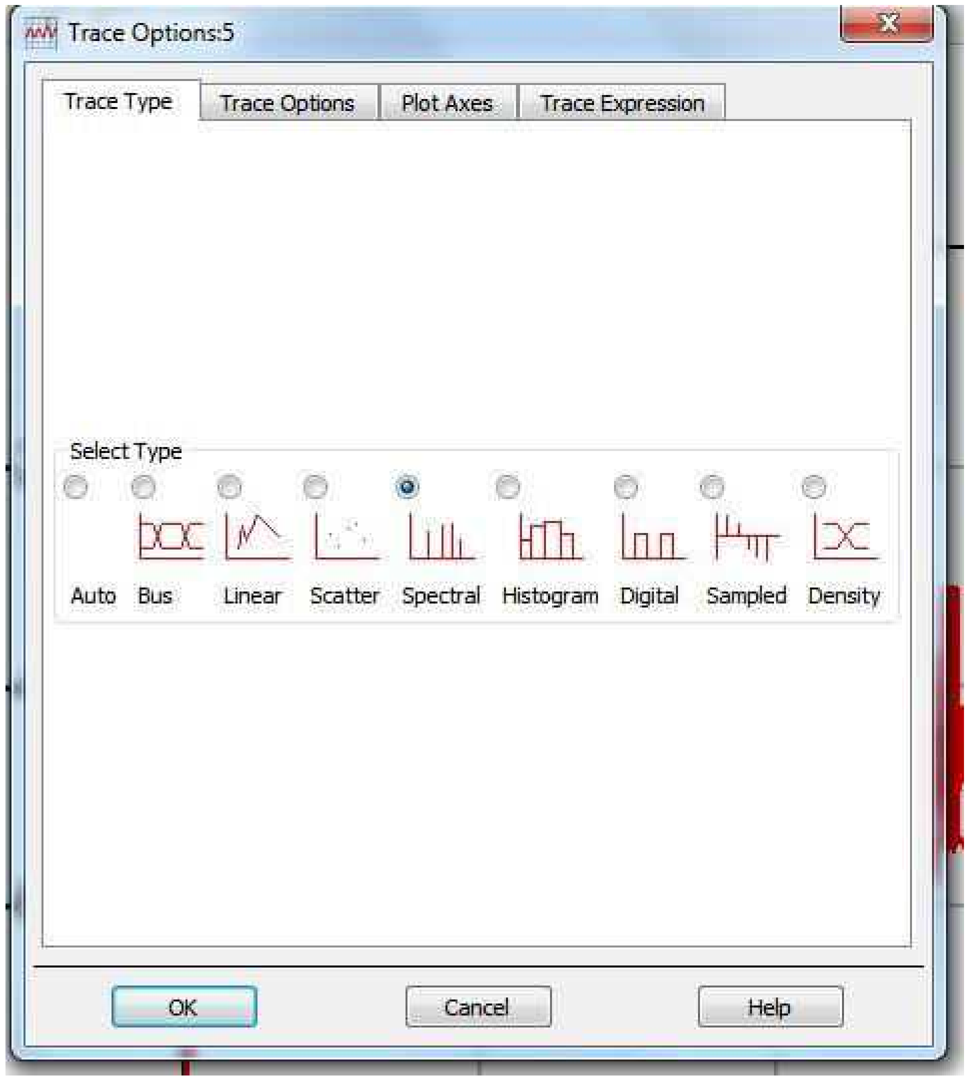
Plot 9. Yet More HB Settings To Choose

Now you arrive at a plot but it still does not look like much (bear with me here):



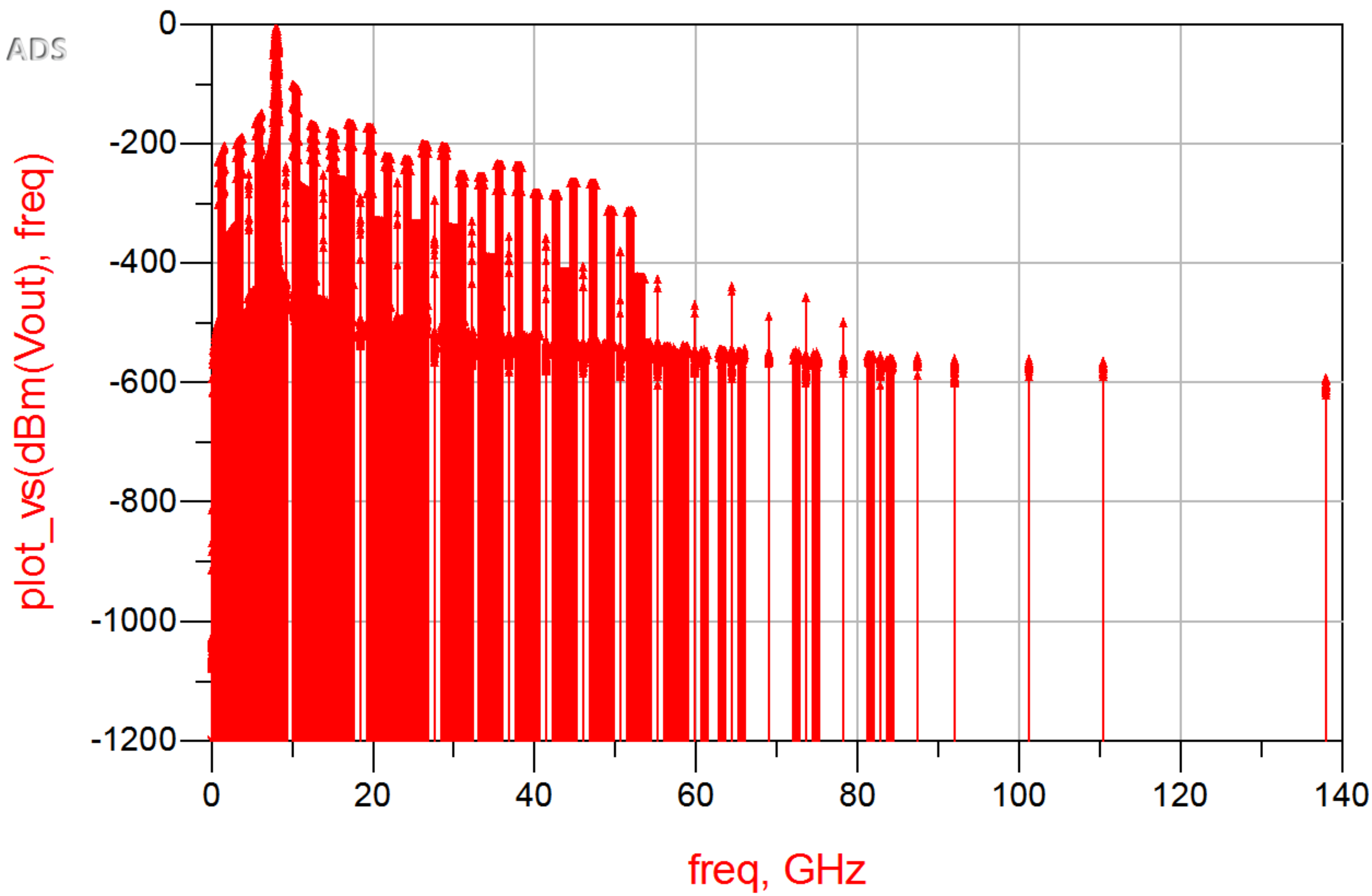
Plot 10. Even after all the setting changes a plot that doesn’t look like much

You need to now double-click the data in the plot above (the actual red data… make sure the data is seleted when you double click - not the black outer frame of the plot) and select “Spectral” plot type to give you the normal HB spectral arrows:



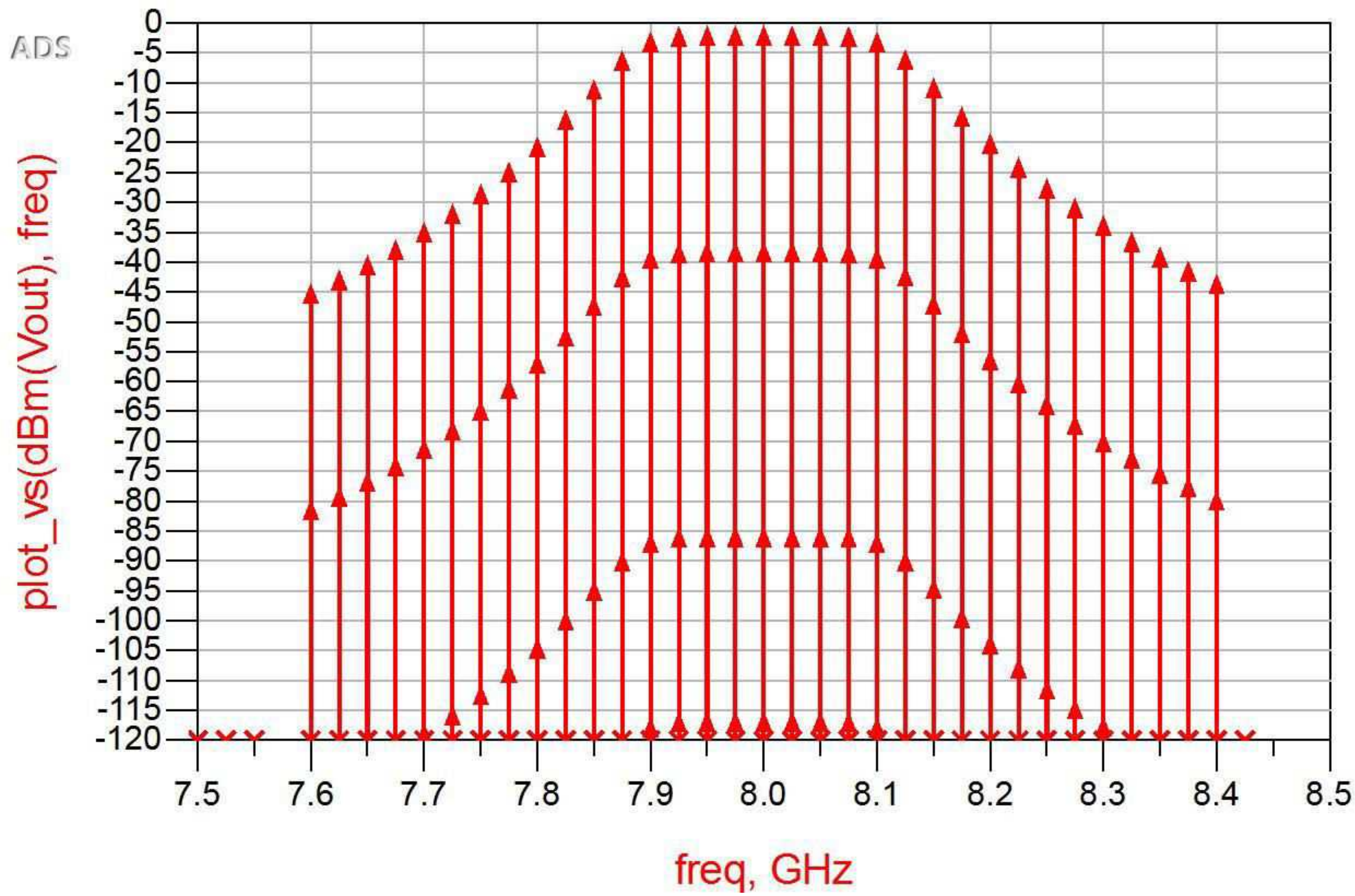
Plot 11. More Adjustments...we’re going to get there some day

You’ll still end up with another unintelligible looking plot:



Plot 12. Plot still doesn’t look great

But, once you scale the frequency and amplitude appropriately…voila! You have what you want:



Plot 13. Finally, Finally Have What I want

Notice that there are multiple signals at each frequency…this is truly what would be happening in the real world… mixing products from the sub-harmonic and harmonics of the LO are folding over on to one another during the mixing process. Notice the shape of the bandpass filer that is being swept out...just like it would in the lab if you were sweeping the IF source and observing “Vout” on the spectrum analyzer in “Max Hold” mode.

It was cumbersome to get to this plot; but, once you get the hang of how to bypass the usual Data Display settings, you will be a lot more comfortable with Harmonic Balance.