Dave's notes on including nonlinear amps

Date: 26 July 2005; added material on 11 August 2005
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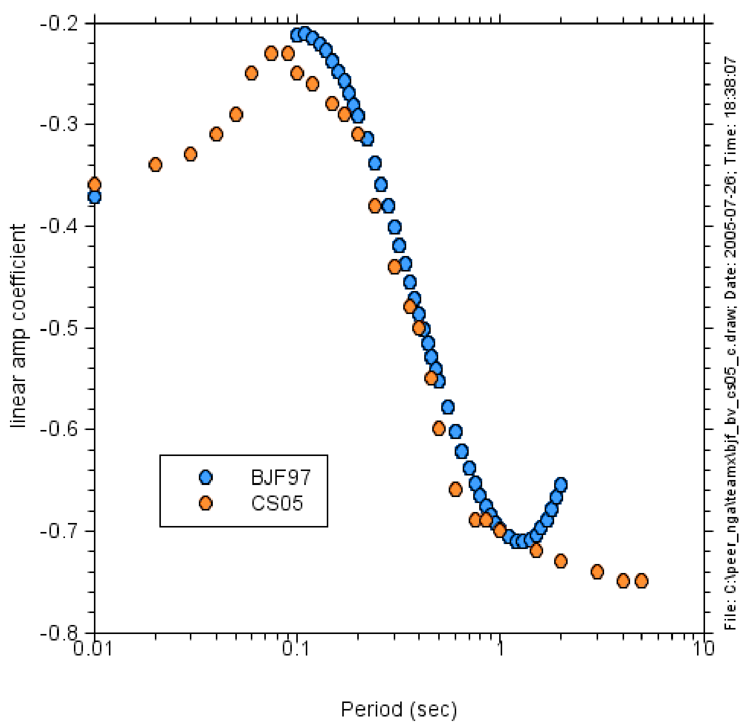
Gail suggested using Choi, Y. and J. P. Stewart (2005), Nonlinear site amplification as function of 30 m shear wave velocity, EqSpectra 21, 1—30 (CS05). Their formulation for amps is:

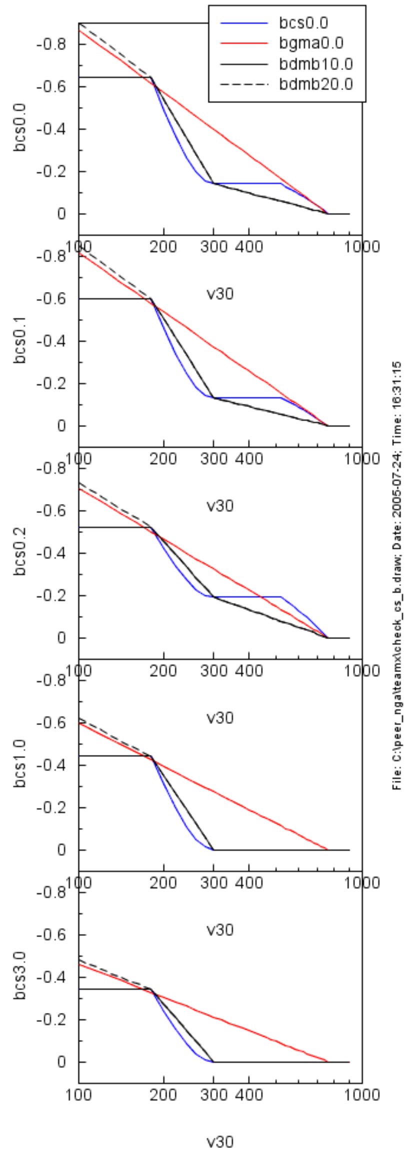
c*ln(V30/Vref) + b*ln(PHA(Vref)/0.1)

where c is a function of period and b is a function of both period and V30 (note that this is different than advocated by Joyner and Boore, and maybe NEHRP (check) where the nonlinearity is contained in the coefficient "c", which becomes a function of PGArock).

Gail showed that the linear amps for CS05 and BJF97 are similar (corrected to a common vref). This is because the "c" coefficients are similar, as shown here:

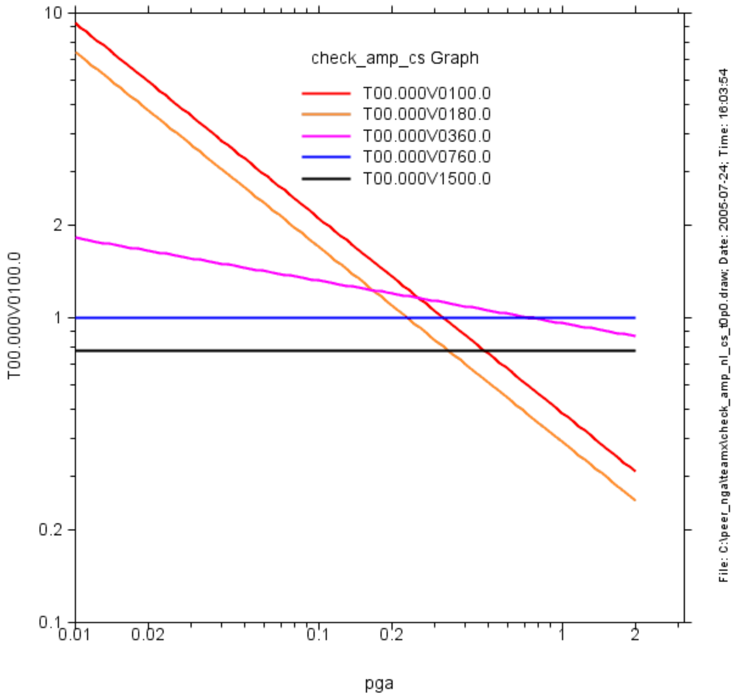


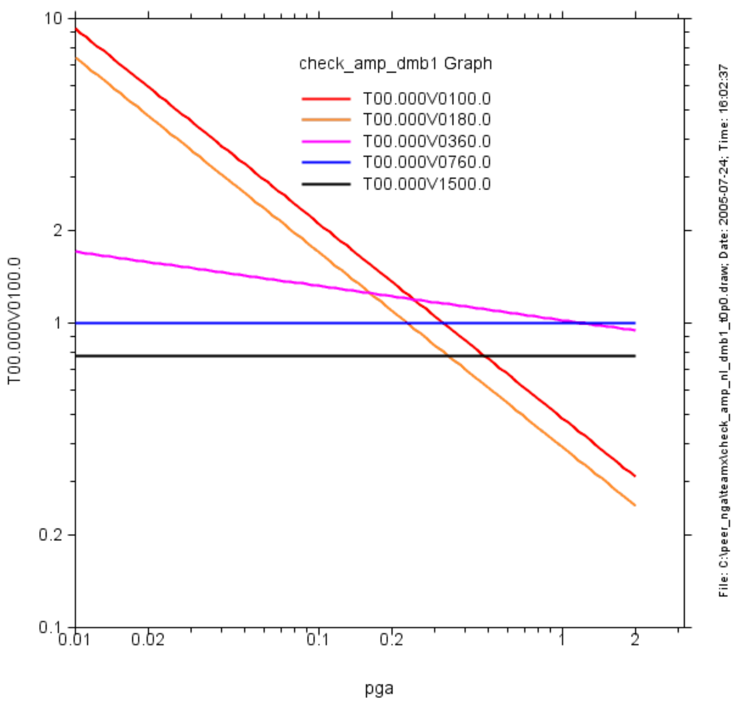
Gail advocated a simpler model than CS05 for b. I plotted b for CS05 and for Gail's simplification (see below), and found that her b would produce more nonlinearity for Vs > 300 than CS05. I have two alternatives that are closer to CS05, but similar to Gail's in using a less complicated function for the V30 dependence of c. My alternatives, along with the others, are shown below for pga, and PSA at periods of 0.1, 0.2, 1.0 and 3.0 sec:

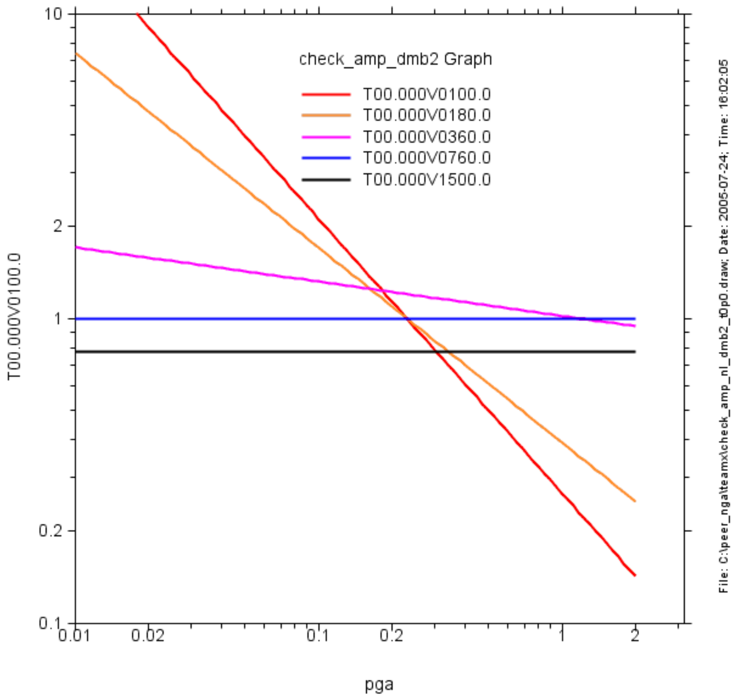


The following two sets of four figures shows the combined linear and nonlinear amplification (using the equation above, but using BJF97 values for “c”--- called “bv” in BJF97, and Vref = 760 m/s). The first set is for pga and the second set is for T=3.0sec. Within each set, the plot with the comments “check_amp_cs”, “check_amp_dmb1”, “check_amp_dmb2”, and “check_amp_gma” shows the amps for CSA05, Dave’s versions 1 and 2, and Gail’s version, respectively. (Note that in Gail’s version it can be shown analytically that for any period, there will be a value of pga_vref for which the amps no longer have any dependence on V30, for V30< Vref--- that explains the convergence seen at pga = 0.24g and 1.6 g for pga and T=3 sec, respectively. The condition is ln pga/0.1 = -(bv/b1(T))*ln(V1/Vref), where b1(T) comes from Table A1 in CS05, V1 = 180 m/s, and Vref = 760 m/s).

One point worth making: CS05 normalize the reference pga to 0.1g, but they do not limit the nonlinear response to pga > 0.1g. This is clear from their figure 3 and the comment on p. 24 that their equations are valid for pgaref from 0.02 to 0.8 g. In the figures I have extended the amps to 0.01 and 2 g.



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T00.000V0100.0
T00.000V0180.0
T00.000V0360.0
T00.000V0760.0
T00.000V1500.0
T00.000V0100.0
pga
10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
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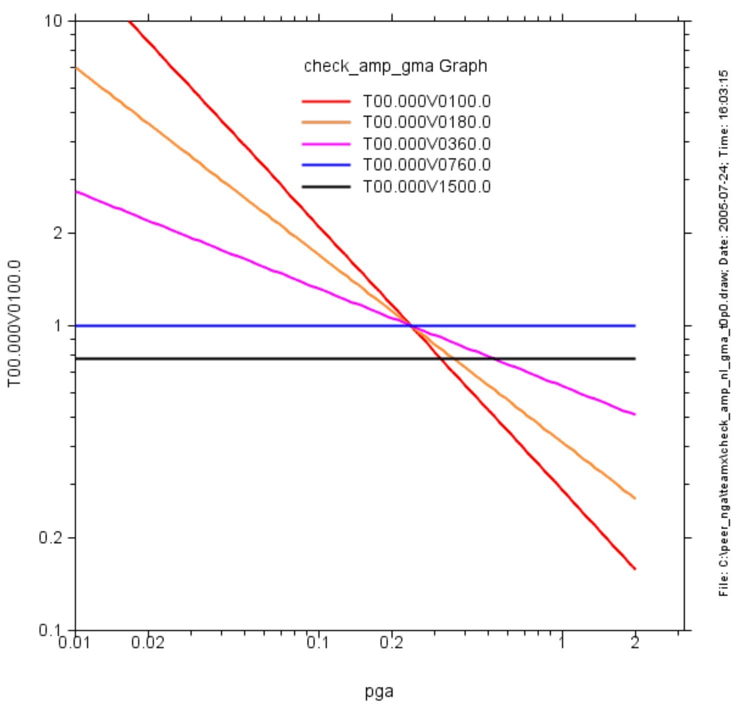
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T00.000V0100.0
T00.000V0180.0
T00.000V0360.0
T00.000V0760.0
T00.000V1500.0
T00.000V0100.0
pga
10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
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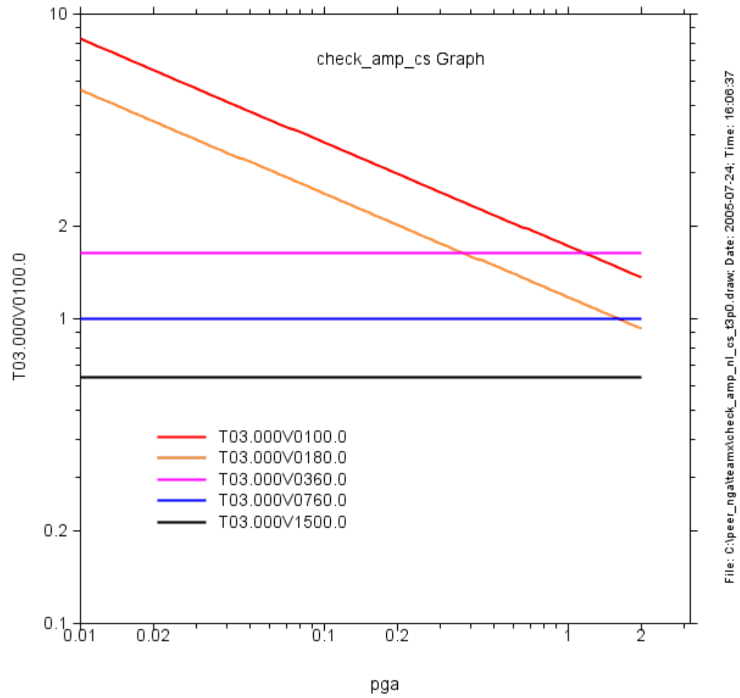
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T03.000V0100.0
T03.000V0180.0
T03.000V0360.0
T03.000V0760.0
T03.000V1500.0
T03.000V0100.0
pga
10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
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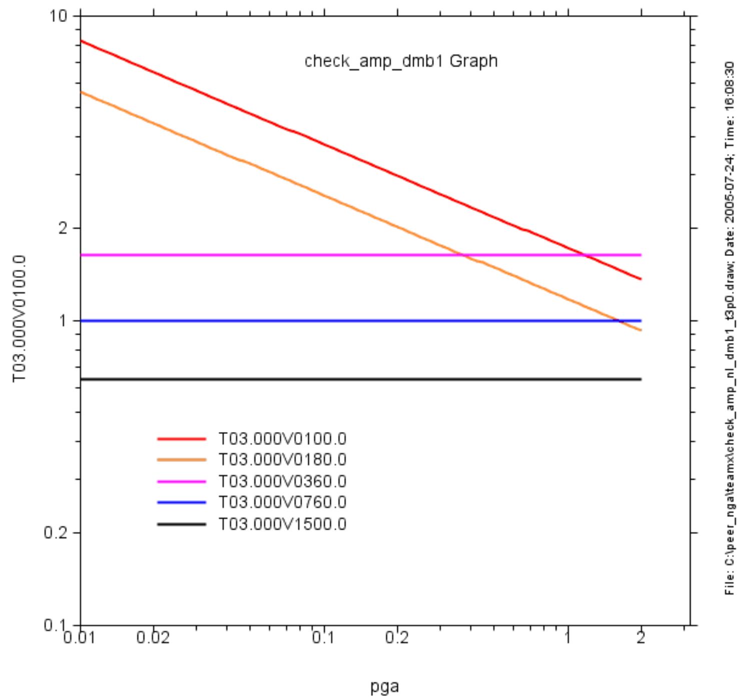
check_amp_dmb1 Graph
T03.000V0100.0
T03.000V0180.0
T03.000V0360.0
T03.000V0760.0
T03.000V1500.0
T03.000V0100.0
pga
10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
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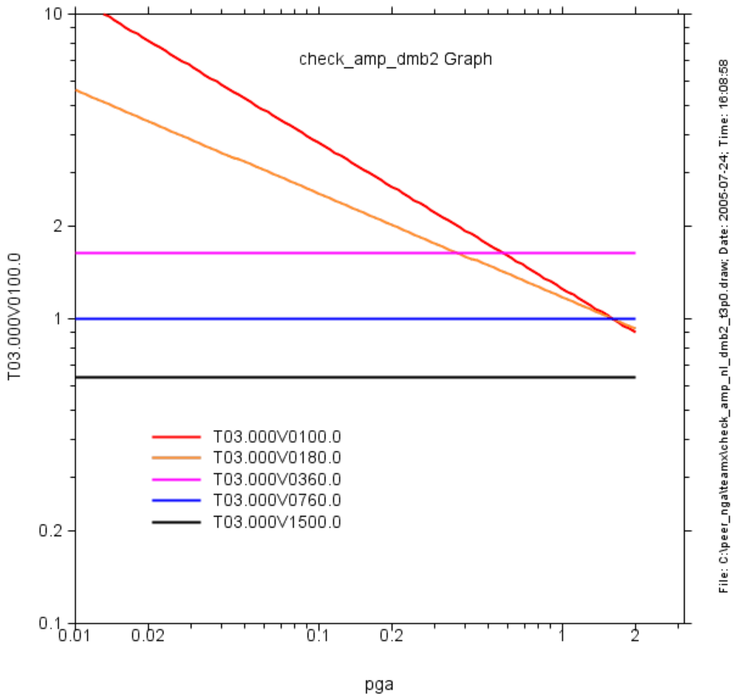
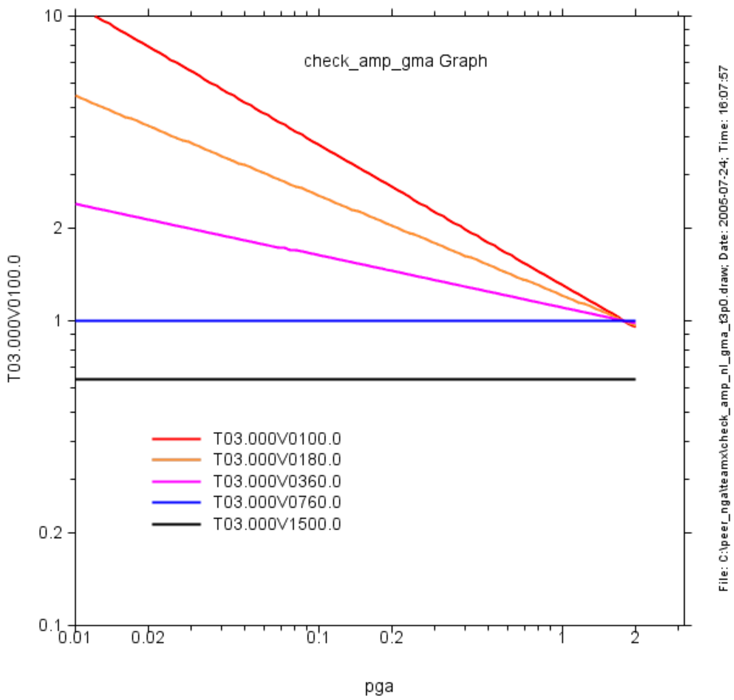




Bottom line: for two reasons I want to use DMB1 as the model for the coefficient "b": 1) it agrees with CS05 for V30 < 300 m/s, is close for 180<V30<300, and has less amplification for small pgavref than does DMB2; and 2) it has less nonlinearity than GMA for 180< V30. (SEE END FOR MORE ON THIS)

Also, I want to use CS05 values for “c” because it is better behaved for long periods (and is in fact defined to periods of 5 sec, whereas BJF’s bv is defined only to 2 sec) and is close to BJF for most periods.

For the record, the equations to determine the DMB1 “b” coefficient are below:

b = b1 for V30 < 180 m/s

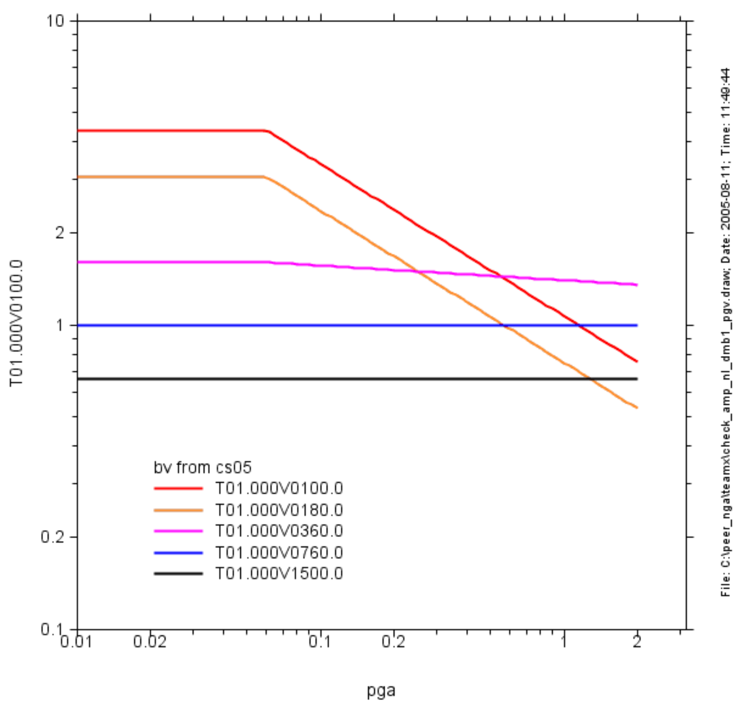
b = (b1-b2)*ln(V30/300)/ln(180/300) + b2 for 180<V30<300

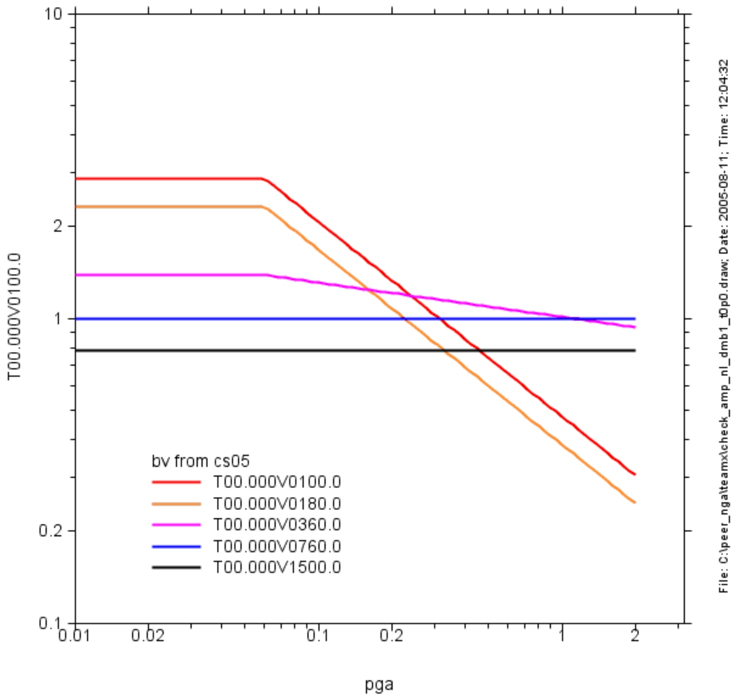
b = b2*ln(V30/760)/ln(300/760) for 300<V30<760

b = 0.0 for 760 < V30.

Where b1 and b2 are given in CS05 Table A1.

Added notes (11 August 2005): When I presented the material above at the last developer’s workshop, it was made clear to me that I should not let the amps increase for as pga decreases forever. Looking at plots that Norm made, using a model to avoid this, I (and he agreed) decided to cap the amps at what they would be for pga = 0.06g. I call this parameter pga_g_low. Here is a series of plots for the CS05 lin and DMB1 nonlin models showing the amps as they are being used in the regression analysis:




10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
T00.000V0100.0
pga
bv from cs05
T00.000V0100.0
T00.000V0180.0
T00.000V0360.0
T00.000V0760.0
T00.000V1500.0
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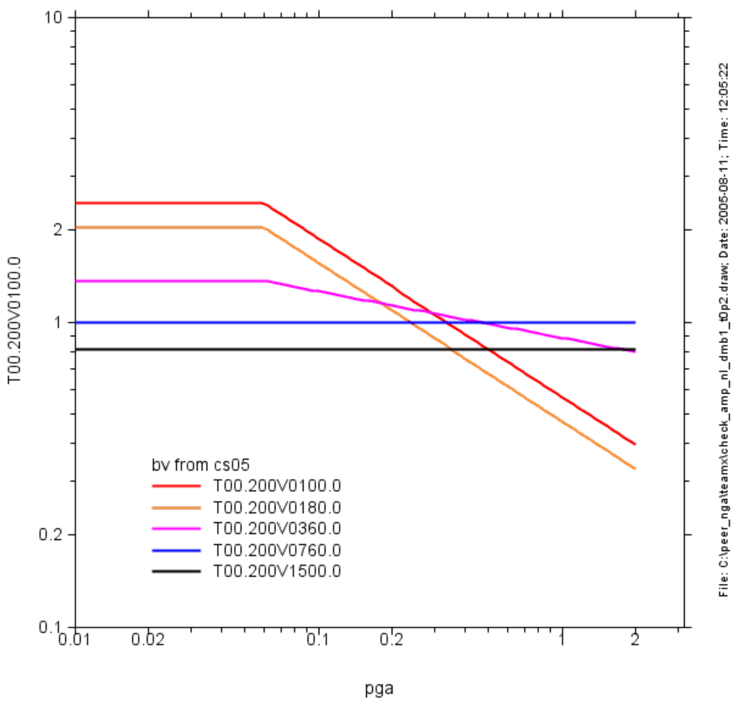
10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
T00.200V0100.0
pga
bv from cs05
T00.200V0100.0
T00.200V0180.0
T00.200V0360.0
T00.200V0760.0
T00.200V1500.0
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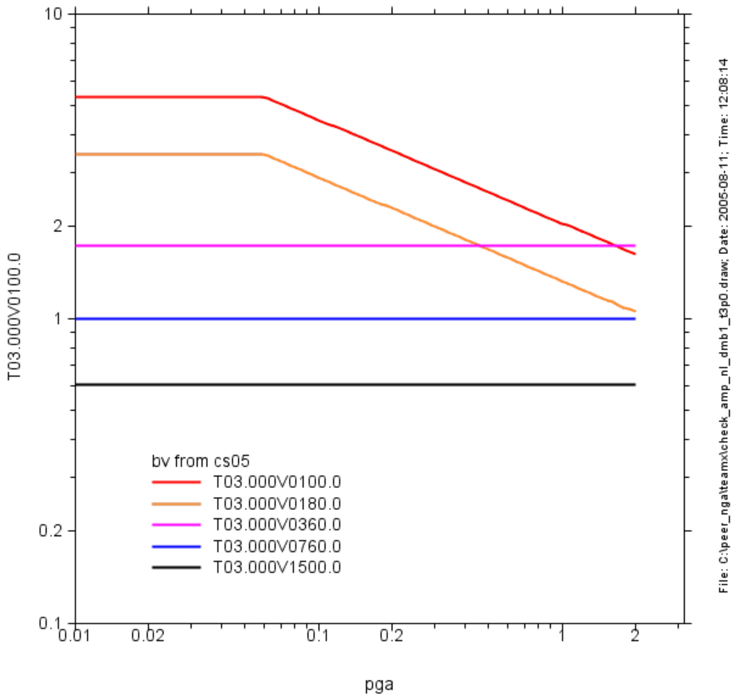

10
2
1
0.2
0.1
0.01
0.02
0.1
0.2
1
2
pga
T03.000V0100.0
bv from cs05
T03.000V0100.0
T03.000V0180.0
T03.000V0360.0
T03.000V0760.0
T03.000V1500.0
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