LAPUR5.2 Upgrade for Mixed-Fuel BWR Stability Calculations

José March-Leuba (MarchLeubaJA@ornl.gov)
Oak Ridge National Laboratory, P.O. Box 2008; Oak Ridge, TN 37831-6010, USA

Alberto Escrivá (aescriva@iqn.upv.es)
Polytechnic University of Valencia; 46022 Valencia, Spain

This paper documents a series of programming upgrades to increase the available number of thermal-hydraulic regions (i.e., channels) and other parameters in the LAPUR code.[1] LAPUR is a frequency-domain code used primarily for BWR stability calculation. The original version of LAPUR was limited to seven channels; the current version, LAPUR 5.2, has been verified with up to 200 channels, each of which can have its own axial power shape. Other significant parameter upgrade is the calculation of the transfer functions for up to 100 frequencies. The motivation behind this upgrade is to facilitate the input preparation by eliminating the need for region collapsing. In addition, this upgrade makes possible detailed modeling of mixed-fuel cores with more than two fuel types.

The present LAPUR 5.2 upgrade has not affected the functionality of LAPUR. The same correlations and modeling assumptions are maintained, so this upgrade does not invalidate previous LAPUR benchmarks. The only verification effort has been to guarantee that the solutions with the new parameter limits reproduce the old results, so that the new LAPUR version is computationally equivalent to the old version. The upgrade simply makes LAPUR easier to use. To guarantee this functional equivalence, a large number of calculations have been performed to verify that the software modifications have not introduced new errors. Some of these calculations are summarized in Figures 1 through 3.

Figures 1 and 2 illustrate the effect of increasing the number of channels. In the case of Figure 1, we compare the closed-loop transfer function using one average channel versus a calculation that uses 200 channels with a flat power profile. As expected, the one-average-channel calculation (circles in Figure 1) results in the same transfer function than the 200-channel calculation (solid line). Figure 2 shows the effect of a non-uniform radial power distribution. In this figure, we used a symmetric power distribution, so a two-channel calculation implies two channels with the same average power; a four-channel calculation has two power levels, and so on. This is done to compare the results of the two symmetric channels, which should be and were identical. As seen in Figure 2, once we reach the 8-channel calculation (i.,e. 4 different power levels) the results are essentially converged. This example further reinforces the point that the LAPUR5.2 modification does not improve significantly the accuracy of the old LAPUR, which was limited to seven channels. The LAPUR5.2 modification simplifies the generation of the input deck, since essentially we can now model the actual bundles one-to-one (when symmetry is considered.) without need for channel collapsing.

Figure 3 shows the steady-state channel power and flow calculated by LAPUR5.2 for three 200-channel cases at different core flows. As seen in this figure, the calculated channel powers and flows align as expected following a constant pressure drop line (similar to the natural circulation line). From these and other calculations, we conclude that LAPUR5.2 calculates radial power/flow distributions as accurately as the old LAPUR5 version, and the increase of number of channels does not result in numerical convergence problems.

We conclude from these calculations that LAPUR5.2 code is functionally equivalent to the old version. This new implementation allows us to model quarter-symmetry cores without the need for channel collapsing and, thus, model any reasonable mixed-fuel core configuration.

REFERENCES

1. Escriva and J. March-Leuba “LAPUR5.2 Verification and User’s Manual”. ORNL/TM-2000/340 NUREG/CR-6696, February 2001

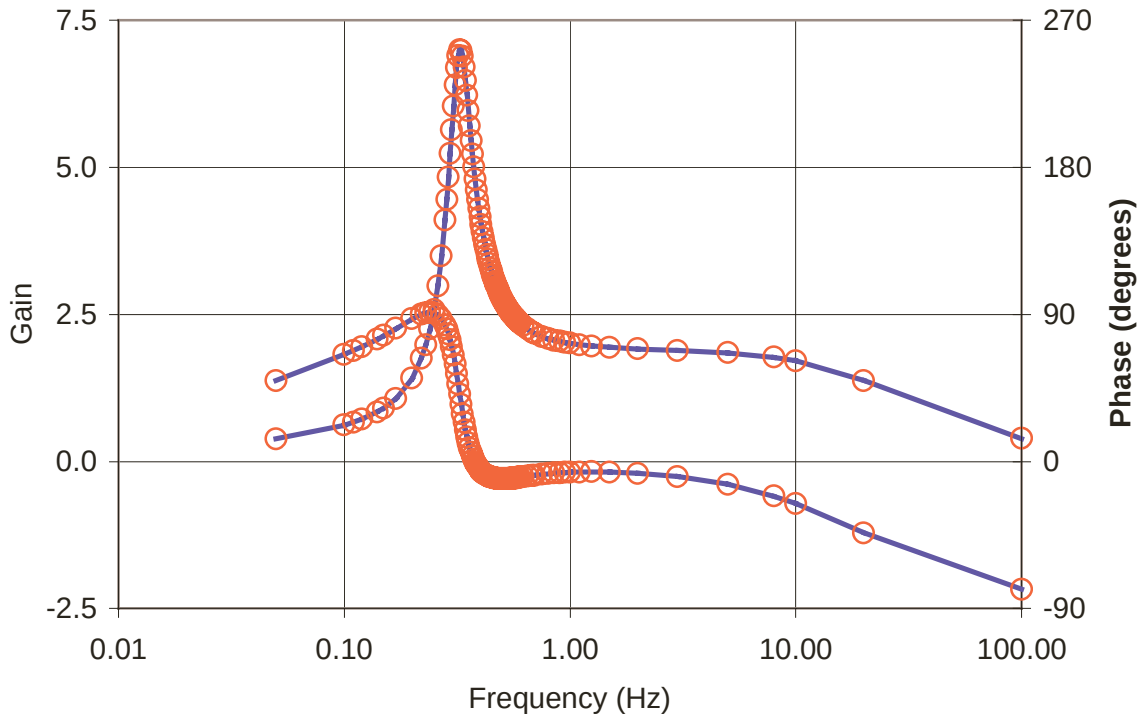

Figure 1. Closed-loop transfer function with a constant radial power profile shows consistent results for either 1 channel (circles) or 200 channels (solid line).

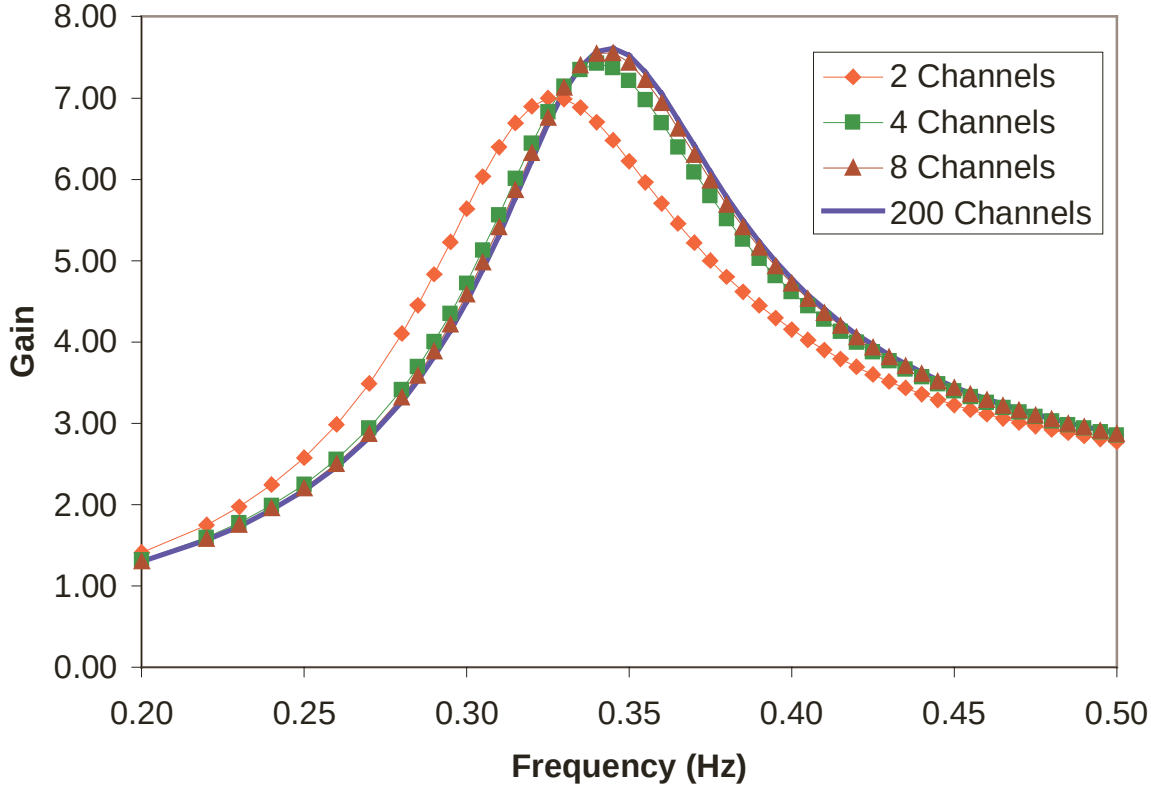

Figure 2. Closed-loop transfer function calculated with different number of channels shows good convergence, demonstrating good behavior with a radial power profile

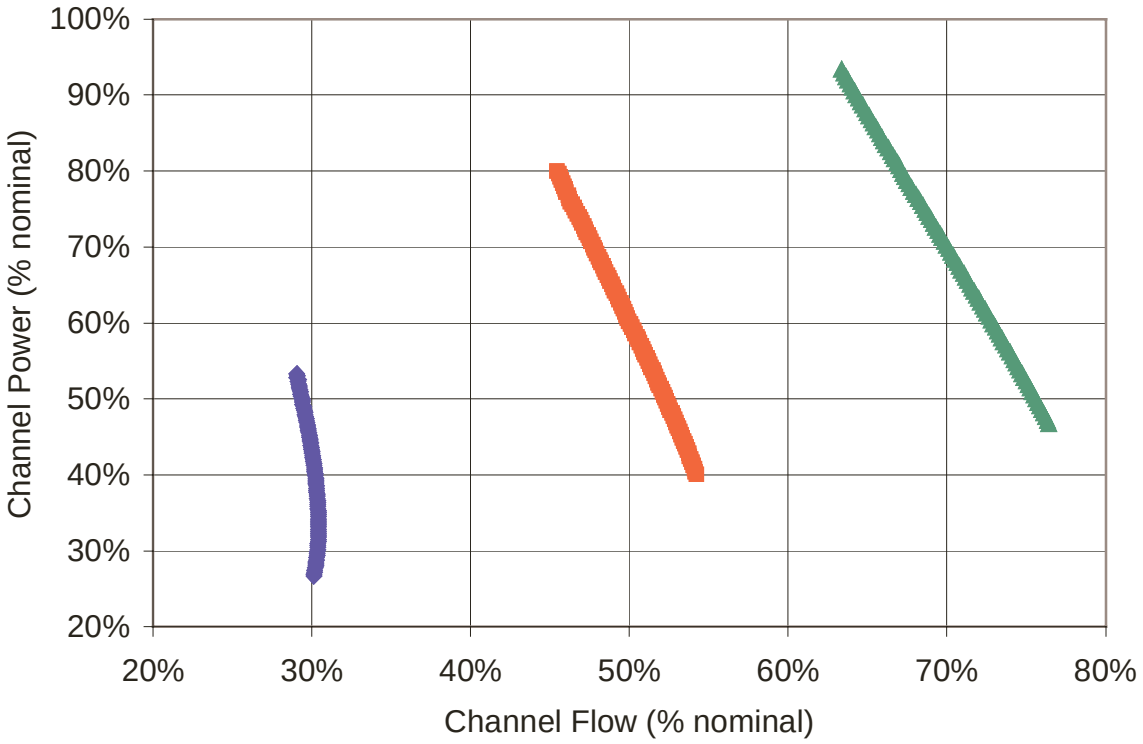

Figure 3. Channel powers and flows from 200-channel LAPUR 5.2 calculations at 30%, 50%, and 70% core flow, respectively, show consistent results