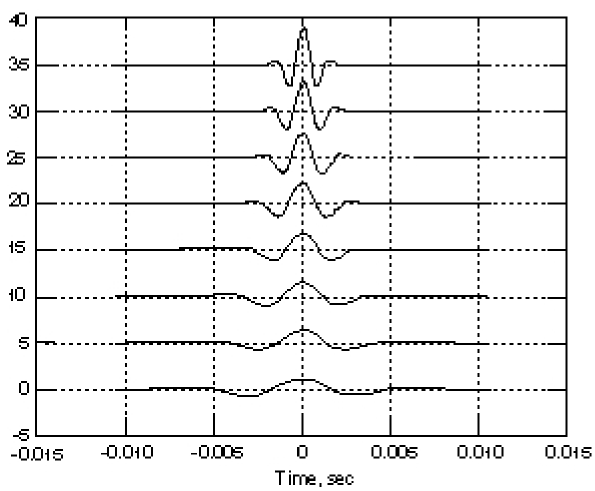
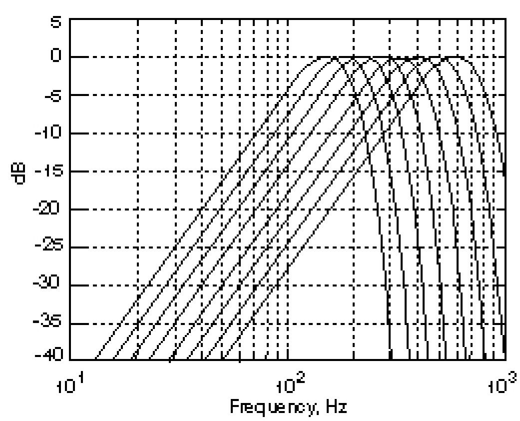
Wavelet Methods Developed to Detect and Control Compressor Stall

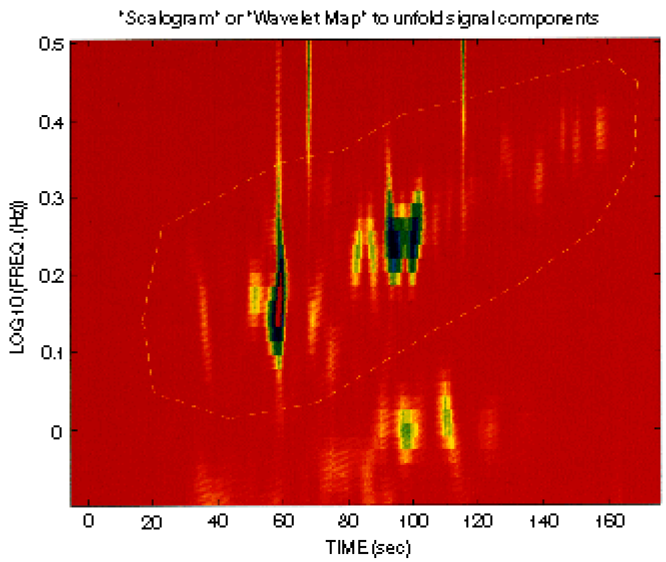
A "wavelet" is, by definition, an amplitude-varying, short waveform with a finite bandwidth (e.g., that shown in the first two graphs). Naturally, wavelets are more effective than the sinusoids of Fourier analysis for matching and reconstructing signal features. In wavelet transformation and inversion (ref. 1), all transient or periodic data features (as in compressor-inlet pressures) can be detected and reconstructed by stretching or contracting a single wavelet to generate the matching building blocks. Consequently, wavelet analysis provides many flexible and effective ways to reduce noise and extract signals which surpass classical techniques--making it very attractive for data analysis, modeling, and active control of stall and surge in high-speed turbojet compressors. Therefore, fast and practical wavelet methods are being developed in-house at the NASA Lewis Research Center to assist in these tasks. This includes establishing user-friendly links between some fundamental wavelet analysis ideas and the classical theories (or practices) of system identification, data analysis, and processing (ref. 2).





Top: Filter bank of "compact harmonic wavelets." Bottom: Power spectra of the wavelets *shown in top graph.*

NASA Lewis' Fast Wavelet Transform/Reconstruction software--which features a unique wavelet algorithm that uses compact, harmonic-like waveforms of arbitrarily sharp frequency bands--can reconstruct signal components very quickly. This double feat was not possible in earlier wavelet literature. The color plot illustrates the use of mouse-clicks in this software to reconstruct signal components of any region on the wavelet scalogram.



One region of the scalogram is isolated by a polygon (dashed lines) for signal reconstruction.

Via this ongoing wavelet research, Lewis has made substantial progress recently in the detection and control of compressor stall and surge. In particular, a wavelet-based, real-time processing scheme for inlet-pressures in high-speed compressors has been designed. This scheme can detect precursors and provide reliable feedback for active control of stall and surge (ref. 3). The stall-inducing power estimated by this algorithm using eight shroud-mounted and nearly equally spaced pressure sensors in front of the first stage showed clearly the incipient instabilities in compressor flows for more than 300 rotor revolutions before any stall or surge event. This is demonstrated in reference 3 for both the rig (AlliedSignal) and engine tests (NASA Lewis) of the axi-centrifugal turbojet T55-L-712. This scheme is being implemented on fast digital signal processing boards for the T55 Program to demonstrate in 1998 an active control technique for improving compressor performance.

The wavelet-enhanced pressure data (ref. 3) also highlight both the underdamped linear dynamics and the overdamped nonlinear dynamics of the prestall rotating waves and their interactions with low-frequency axial waves. Thus, this wavelet processing scheme is a valuable tool for empirical estimations of both linear model parameters and unmodeled, nonlinear uncertainties of compressor dynamics. These modeling data are important for robust control design.

References

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3. Le, D.K.; Owen A.K.; and Mattern D.L.: Multiscale Analysis of Stall Inception and Instabilities in an Axi-Centrifugal Turboshaft Engine. AIAA Paper 96-3174, 1996.

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