

# Technical Brief No. 33

All Technical Briefs are based on past projects at RH Lyon Division

Transmissions  
Axles  
Gear boxes

## Amplitude Modulation Wow, wow sounds impair Sound Quality

### Sound Modulation Not Acceptable

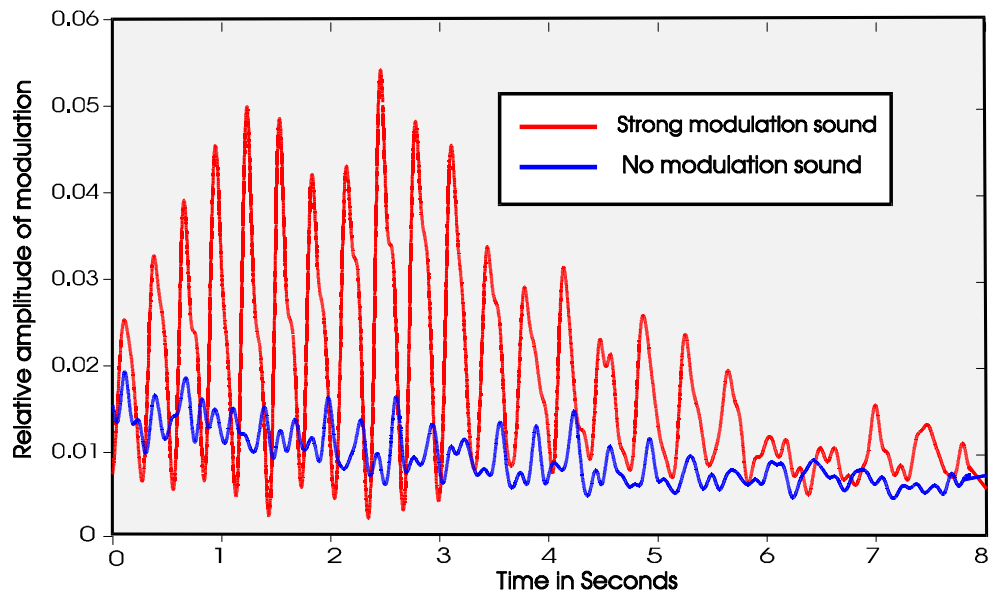
A common issue in product sound quality has to do with the degree of *modulation* of a sound - that is, even if the sound itself is not particularly loud, the presence of an unsteady component in the sound can make it more noticeable. This was the case for a manufacturer of axle-transmission assemblies, who was receiving feedback from some end-users, complaining of "gear whine" coming and going every 2 to 3 seconds during vehicle coasting. In addition to the annoyance factor, this sound also made users suspicious of the quality of the transmission in general. It was eventually determined that only some of the axles behaved this way, and that it would be desirable to "catch" these axles before they were shipped. A procedure was therefore developed to automatically determine the degree of modulation present during a coastdown run of an axle on a test stand, using vibration measured on the transmission housing.

### Extraction of Amplitude Envelope

After digitizing a segment of coastdown vibration data, the resulting sequence is then bandpass filtered in order to isolate the fundamental frequency and sidebands of a particular gear mesh as the axle slows down. Earlier studies had shown that the modulation of this particular vibration tone was well correlated to audible impressions of modulation during coastdown.

After bandpass filtering the vibration, a signal processing technique is employed to extract the amplitude envelope of the vibration as a function of time. This technique utilizes the concept of an *analytic* signal - that is, a signal having no negative frequency components in its Fourier transform. For a real signal, the corresponding analytic signal is its complex valued

envelope, and thus, the magnitude of this signal yields the amplitude envelope of the modulated "carrier" in the original signal. (The *phase* of the analytic signal can be related to the degree of *frequency* modulation.) The analytic signal itself is obtained through the use of the Hilbert transform of the bandpass filtered signal. The resulting envelope signal is then lowpass filtered in order to remove higher frequency artifacts that might be present, while still preserving the fundamental



Envelope signals extracted from vibration measured on a "good" and "bad" axle

modulation component and its first one or two harmonics. A spectrum of the lowpass filtered envelope signal is next computed, from which the strength of the fundamental modulation component can be derived. This is done by normalizing the peak value by the mean value calculated over the entire lowpass filtered envelope signal. This single number parameter is then compared to a threshold parameter value determined from previous runs of the procedure on "good" and "bad" axles. The routine fails the axle if the parameter is greater than this threshold value.