The Production of Phantom Partials in the Sound of the Modern Piano

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ABSTRACT

The spectra of the sound produced by the modern piano includes frequency components that are not equal to any of the resonance frequencies of the transverse string motion. These frequency components, termed phantom partials, have been attributed to forced longitudinal vibrations in the string that occur at the sums and differences of the frequencies of the string resonances. The frequencies of the phantom partials do not coincide with the frequency components produced by the transverse motion of the string because the stiffness of the string causes the frequencies of the string overtones to differ from an exact harmonic relationship. This inharmonicity increases with the mode number, so that the frequency of the phantom partial produced by summing the frequencies of the mth and nth transverse mode of the string falls below the resonance frequency of the (m+n) mode.

Although the frequencies of the phantom partials appear to correspond to a sum or difference of the resonant frequencies of the piano string, it is not obvious that the nonlinear coupling that produces these frequency components occurs only in the string. It is possible that the motion of the soundboard, bridges, case, and frame all contribute to the production of phantom partials, although to our knowledge the origins of phantom partials have never been systematically investigated.

We have experimentally investigated the production of phantom partials that occurs in a modern grand piano and found that while the string plays an important role in the production of phantom partials, other parts of the piano also contribute. Mechanical excitation of the bridge and soundboard at two discrete frequencies can produce phantom partials even when the driving frequencies do not correspond to resonance frequencies of the string and/or all string motion is damped. A comparison of the power in a phantom partial when a string is free to vibrate versus when the string is damped provides an estimate of the importance of the piano structure to the production of phantom partials.