Lumped Element Thermoacoustics Applied to Pulse Tube Cryocoolers

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Lumped element thermoacoustics is an approach to describing regenerative coolers, where pressure amplitude and volume flow rate, instead of pressure amplitude and mass flow rate, are the flow variables. Energetics are described using enthalpy flow, entropy flow, and acoustic power, instead of simply enthalpy flow as in conventional descriptions. The two main pulse tube components- the regenerator and thermal buffer tube (pulse tube), are simply compressible volumes that support temperature gradients, with flow entrances at the warm and cold ends. The compressible volume behavior allow the complex volume flow rates to be separated into components in-phase and in-quadrature with the pressure amplitude. The component in-quadrature generates the pressure amplitude- essentially compression of a gas in a can, while the component in-phase with the pressure amplitude time-averages with the pressure amplitude to provide acoustic power. This deconstruction separates the compliant, or gas spring behavior of the pulse tube from the power conversion behavior of the pulse tube, and provides a very simple picture of many of the processes within the cooler. These basic concepts have been generally developed for thermoacoustic systems, so in this paper I summarize the specific application to an idealized pulse tube and discuss implications regarding cooler performance.