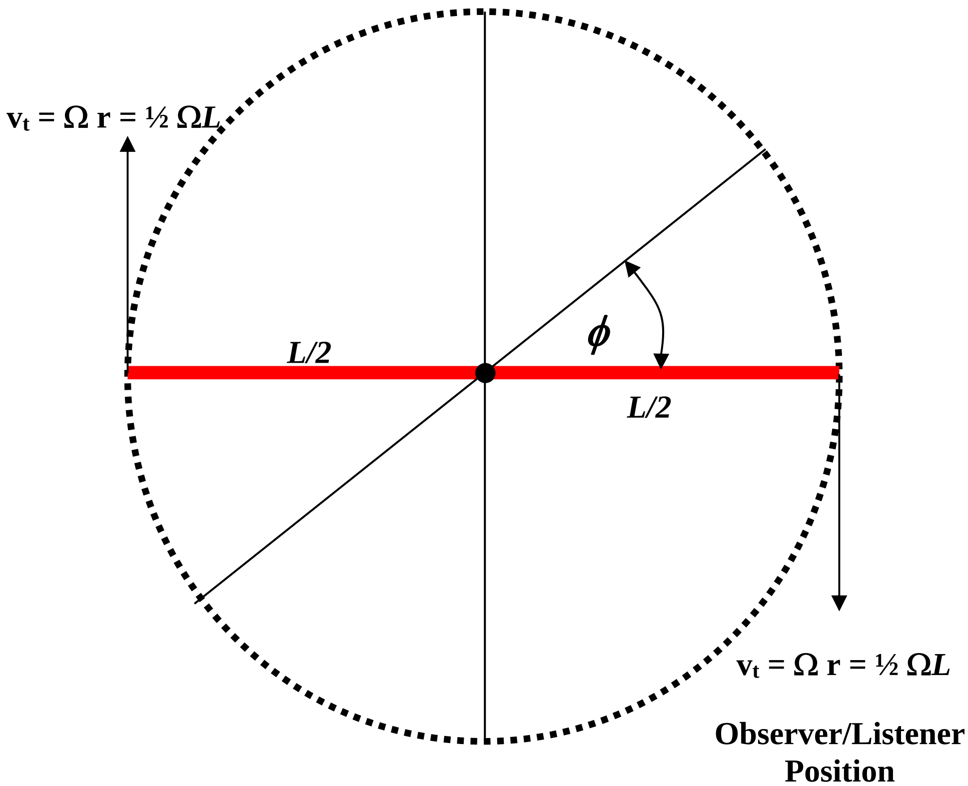
<u>Motional Effects associated with a Rotating, Vibrating Rod: Doppler Effect and Beats</u>

If the aluminum rod of length, L is excited by holding it at its mid-point and then rotated in a manner similar to that of twirling a baton, as shown in the figure below, one hears a warbling tone instead of the usual steady tone, because of the so-called Doppler effect, in honor of the German scientist who first discovered this motional effect.



The rotating ends of the vibrating rod are moving sound sources. If the (angular) frequency of rotation of the rod is $\Omega = 2\pi f_{rot}$ radians per second, this corresponds to a rotational frequency of $f_{rot} = \Omega/2\pi$ revolutions per second, or a period of $\tau_{rot} = 1/f_{rot} = 2\pi/\Omega$ seconds per revolution. The end of the rotating rod that is moving toward a listener is Doppler-shifted to a higher frequency. Conversely, the end of the rotating rod that is moving away from the listener is Doppler-shifted to a lower frequency. The ends of the rod are rotating at a tangential speed of $v_t = \Omega r = ½\Omega L$.

For a stationary observer/listener, the formula for the Doppler-shifted frequency, f' in terms of the original frequency, f, the speed of sound, v and the speed of the moving source, v_s is given by:

$$f' = \left(\frac{v}{v \pm v_s}\right) f$$

where the + sign is associated with the sound source moving directly away from the listener, and the – sign is associated with the sound source moving directly toward the listener. This configuration occurs at only at two points during the rotation cycle of the rod. At other times, the