## ***Effect of the Pick on Harmonic Content***

Our discussion(s) of triangle waves on the plucked strings of a guitar has thusfar been idealized and simplified, in order to discuss the basic concepts associated with vibrating strings. In subsequent lecture notes, we will systematically increase the level of sophistication of this discussion. One effect we discuss now is that of the choice/type of pick used to pick the strings of the guitar, and the corresponding impact on the harmonic content.

In picking the strings of the guitar, the triangular shape we assumed tacitly implied that the ideal string was perfectly compliant/flexible, such that by using a pick of zero width to pick the strings of a guitar, a perfectly triangular-shaped transverse standing wave can be created. Mathematically, the sections of the idealized triangle wave on the string are then able to be analytically represented by perfectly straight lines. Thus, at the apex of the idealized triangle wave, the slopes of the adjoining string segments of the triangle wave are discontinuous. It therefore requires the totality of all of the higher harmonics to be superposed with each other, with their appropriate Fourier coefficients, $b_n$, representing the amplitude (and relative phase) of each harmonic in order to exactly replicate this sharp break in the slopes on at the apex of this idealized triangle wave.

However, a real string is not perfectly compliant/flexible, nor is a real pick of zero width. Because of these facts, a real triangle-type wave on a real string will not have a perfectly sharp apex, if plucked with a real pick of finite width. Depending on how soft/compliant the pick is, the apex of the triangle-type wave will be rounded over in this region. Thus, as a consequence, an effective high-frequency cut-off in harmonic content associated with this rounded-off triangle wave will exist. If the width of the pick in contact with the string during the plucking of this string has a width, $\delta$, then the high-frequency cut-off in harmonic content will occur for harmonics with harmonic # $n \sim L_{scale}/\delta$, because vibrational modes of the string with wavelengths shorter than $\lambda_{cutoff} \sim 2\delta$ will not be excited, or excited very little. For a typical guitar, with scale length, $L_{scale} \sim$ 25", and typical width of pick in contact with the string while playing, of $\delta \sim$ ¼", then this corresponds to a cut-off in harmonic # of $n_{cutoff} = \lambda_1/\lambda_{cutoff} = 2L_{scale}/2\delta \sim$ 25"/ ¼" = 100, which is quite high, given that the strings of a guitar have open-string (i.e. unfretted) fundamental frequencies in the range of $f_1 \sim$ 80-330 Hz (low-E to high-E strings). Thus, the corresponding harmonic cutoff is in the $f_n \sim$ 8.0-33.3 KHz range, which is quite high for an electric guitar, due to the limited frequency response of the guitar amplifier. However, if the width of the pick in contact with the string is doubled, e.g. to $\delta \sim$ ½", then the corresponding high-frequency cutoff in harmonics is halved, to $n_{cutoff} \sim 50$, corresponding to $f_n \sim$ 4.0-16.7 KHz, which can become noticeable on the lowest strings of the guitar, resulting in a mellowing effect on the tonal quality output from these guitar strings.