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UIUC Physics 498POM

Fourier Analysis IV:

Some Practical Examples of the Use of Fourier Analysis

In the preceding lecture notes on Fourier analysis, we have shown how the *shape* of the waveform, f(θ), where $\theta = kx$ ($= \omega t$) in the spatial (temporal) domain, determines the harmonic content of the wave, and have shown the methodology used to determine the harmonic content of the wave, from knowledge of the shape of the waveform, f(θ).

In the lecture notes on waves, we have shown that the waves on a plucked guitar string are transverse standing waves consisting of a *linear superposition* (i.e. sum) of harmonics of the fundamental (first harmonic) with the fundamental itself. A first-order mathematical description of the *shape* of the overall waveform of the transverse standing wave on a plucked guitar string is a triangle, or saw-tooth wave.

How *asymmetrical* the shape of this triangle wave is depends on *where* along the guitar string the guitar string is plucked. Playing *mid-length* along the string results in a *symmetrical* triangle wave, with relatively low harmonic content - a *mellow* sound, consisting purely of *odd*-harmonics - n = 1, 3, 5, 7, ... etc. of the fundamental (n=1). Playing closer to the bridge results in ever-increasingly *asymmetrical* triangle wave, with correspondingly ever-increasing higher harmonic content - an increasingly *brighter*, more *brilliant* sound, as we have shown in the preceding lecture notes on Fourier analysis. The asymmetrical triangle wave in general consists of a linear superposition of both *even* and *odd* harmonics, n = 1, 2, 3, 4, 5, ... etc. We have also shown *why* certain harmonics are present while others are absent - playing at certain positions along the string will *maximally* excite certain harmonics, when playing at *anti-nodes* of these harmonics (places of maximum transverse displacement of the string), whereas certain other positions along the string will *minimally* excite certain harmonics, if those string positions correspond to *nodes* associated with these harmonics (places of zero transverse displacement of the string) . Thus, the guitar player can use this knowledge of harmonic content to his or her advantage, in terms of helping to define the overall tonal quality, and overall sound output from their guitar.

Effect of the Pickup Location on Harmonic Content

An electric guitar typically has one to three pickups; some brands of guitars from the 60's even had four. The location of the pickups along the strings has a very definite impact on the tonal qualities output from the guitar. At a given point, x along a plucked string, the transverse displacement, $y(x,t) = \Sigma\, y_n(x,t)$ at that point consists of a linear combination of transverse displacements associated with the harmonics making up the transverse, triangular-shaped standing wave, with amplitudes (and phases) as determined by the Fourier coefficients, b_n. A pickup placed at this location will thus corresponding result in a signal output from the pickup which has harmonic content that is proportional to the individual transverse displacements, $y_n(x,t)$ at that location, associated with the harmonics present in the transverse standing wave.

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Thus, a pickup placed near the end of the neck on the body of the electric guitar will have an output signal which is predominantly associated with the lower-order harmonics of the triangle-shaped standing wave(s) on the guitar string(s), resulting in a more mellow sound, whereas a pickup placed near the bridge on the body of the electric guitar will have an output signal which has higher harmonic content, resulting in a more bright, or brilliant sound output from the guitar.

Obviously, it is also possible to locate a pickup at an transverse displacement *anti-node* or a *node* of a particular harmonic, at least for the open (i.e. unfretted) strings. On Fender Stratocaster and Telecaster guitars, the scale length of the Strat and Tele are both L_{scale} = 25½". The three single-coil pickups on the Strat are located at 19½" (neck PU), $21^5/_8$" (middle PU) and ~ $23^7/_8$" (bridge PU), respectively from the fretboard side of the inner edge of the nut on the neck of this guitar. On the Tele, the two single-coil pickups are located at 19½" (neck PU) and and ~ $23^7/_8$" (bridge PU), respectively. Thus, the neck PU's of the both the Strat and the Tele are located near the 2nd anti-node (from the nut) of the n = 2 harmonic, and therefore are simultaneously near the 3rd node (from the nut) of the n = 4 harmonic, i.e. both located at ¾ × 25½" = $19^1/_8$". The middle PU of the Strat is located near the 3rd anti-node (from the nut) of the n = 3 harmonic, and therefore is simultaneously near the 5th node (from the nut) of the n = 6 harmonic, i.e. both located at $^5/_6$ × 25½" = 21¼" Thus, when playing open strings on the Strat or Tele with the pickup selector switched to the neck pickup, the 2nd harmonic (4th harmonic) will be enhanced (suppressed), respectively. When playing open strings on the middle pickup of the Strat, the 3rd harmonic (6th harmonic) will be enhanced (suppressed), respectively. The bridge PU on the Strat or Tele is not located near any anti-nodes or nodes associated with the low-order harmonics of the open strings.

Note also that the bridge PU on both the Strat and Tele are also slanted with respect to the strings - the bass side of this pickup is farther from the bridge than the treble side of this pickup. There are several reasons for this - primarily for string balance on the output of this pickup - the transverse displacement(s) of the strings go to zero at the bridge saddles, if we neglect the small vibrations of the bridge/guitar body itself; by slanting the pickup, the lower frequencies associated with the strings on the bass side of this bridge pickup are better balanced, output-wise from this pickup, with the higher-frequency signals associated with the strings on the treble side of this pickup. By slanting the pickup in this fashion, the relative phases of the signals from each string are also slightly shifted from each other, which can have interestingly complex auditory consequences when overdriving an amp with a Strat or Tele, and/or using a distortion FX box with either guitar. Another reason for slanting the pickups on an electric guitar is for aesthetic reasons - i.e. style - it looks cool!

On a Gibson Les Paul guitar, the scale length of the Les Paul is L_{scale} = 24½"-$24^3/_4$", depending on the year of manufacture. The pickup pole-adjustment screws on the two humbucking-type pickups of the Les Paul guitar are located at $18^5/_8$" (neck PU) and at $23^7/_8$" (bridge PU), respectively from the fretboard side of the inner edge of the nut on the neck of this guitar. The pole-adjustment screws of the humbucking neck PU of the Les Paul are, like the single-coil neck pickups of the Strat and Tele also located near the 2nd anti-node (from the nut) of the n = 2 harmonic, and therefore are simultaneously

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located near the 3rd node (from the nut) of the n = 4 harmonic, i.e. both located at ¾ × 24½” = $18^3/_8$”. Thus, here again, when playing open strings on a Les Paul with the pickup selector switched to the neck pickup, the 2nd harmonic (4th harmonic) will be enhanced (suppressed), respectively. The bridge PU on the Les Paul, like the Strat or Tele is not located near any anti-nodes or nodes associated with the low-order harmonics of the open strings.

From the above, one can see that the location of the pickups on electric guitars is such that the harmonic content of the signals output from the pickups tends to emphasize the higher harmonics, relative to the fundamental mode of vibration. This is one reason why electric guitars sound so much brighter in comparison to acoustic guitars.

Of course as soon as one plays notes and/or chords *anywhere* on the neck of an electric guitar, all of the above doesn’t really matter - the pickup locations may or may not be at displacement nodes of harmonics for the notes being played - the resulting complex coloration of the tonal properties output from these guitars, along with the ability to select different pickup combinations and the ability to subsequently contour their sound using the tone & volume controls on the guitar and/or at the guitar amplifier is part of what makes them such a joy to play!

As mentioned above, because the transverse displacement(s), $y_n(x,t)$ of the harmonics associated with the triangle-shaped standing waves on plucked guitar strings go to zero at the bridge, a pickup located near the bridge should be overwound (slightly), to compensate for the loss of signal, relative to that associated with the signal output from the neck pickup, where the transverse displacements of the harmonics associated with the standing waves are larger. This is especially important for guitars with two or more pickups, in order to keep the overall sound from any choice of pickup, or pickup combination balanced. If one pickup has a significantly stronger, more powerful output than the other pickups on the guitar, the sound from this pickup will dominate when combined with any of the other pickups, limiting the versatility and variability of the tonal “dynamic range” that would otherwise be possible for this guitar, if it instead had balanced-output pickups. It is for this very reason that many guitar manufacturers do overwind (slightly) the bridge pickup, in order to achieve a balanced output between e.g. neck and bridge pickups on their guitars.

One final comment is that if it is desired to *maximize* the signal output from a given pickup on an electric guitar, the guitar player should pick/play the strings of the guitar *directly* over that pickup he/she has selected to play on. This is because the overall transverse displacement, $y(x,t)$ of the string(s) is a maximum precisely at that point, *because* of playing the strings at that point. Of course, from the perspective of maximizing tonal variation, a guitar player can obviously select any pickup or pickup combination, and play anywhere on the strings - near , or even on the neck for mellow tones, or, near the bridge, for brighter, more brilliant sounds, or, anywhere in between!

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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, δ, 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 noticable on the lowest strings of the guitar, resulting in a mellowing effect on the tonal quality output from these guitar strings.

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String Compensation/Intonation

Knowledge of the harmonic content of the triangle-waves on guitar strings can also be used in other ways. For example, for electric guitars, which of necessity use magnetically-permeable strings - e.g. steel or stainless steel on the higher, lighter-gauge plain strings, and on the lower, heavier-gauge wound strings, steel/stainless steel wrapped with steel/stainless steel or nickel, or nickel-alloy, because of the differences in stiffness of the lighter-gauge plain strings vs. heavier-gauge wound strings, and the action (height of the strings off of the frets on the fretboard) the effective scale length, L_{scale} associated with each string is in fact not precisely the same for each string. Thus, because of this, the bridge of electric guitars often has individually adjustable string saddles, such that the overall length of each string can be adjusted precisely to compensate for these non-linear effects, such that if the all of the open (i.e. unfretted) strings of the guitar are in tune with each other, then they will also be in tune with each other e.g. an octave above the open strings. Some guitar manufacturers, such as Gibson, will also additionally slant the bridge with a small rake-angle, such that the scale length for each string systematically increases from the high-E to the low-E strings.

Because the high-E string on a guitar is the thinnest gauge plain string - typically 0.009”-0.011” in diameter, the scale length associated with the high-E string is closest to the physical, or true scale length of the guitar - i.e. the distance measured from the inner edge of the nut (facing the fretboard) to the string contact point of the high-E string at the bridge. The physical scale length of the guitar is also that which precisely determines the location of each of the frets along the fretboard, referenced to the inner edge of the nut (the zero of the frets). The B-string on a guitar is the next thinnest gauge plain string, typically 0.011”-0.013” in diameter. Its overall length, for proper intonation over the full length of the guitar neck needs to be slightly longer than for the high-E string, requiring the bridge saddle for the B-string to be shifted back, relative to the bridge saddle of the high-E string typically by a distance of ~ 0.5-1.0 mm. The G-string, which is the thickest gauge plain string - typically 0.014”-0.017” in diameter, requires even longer overall length for proper intonation over the full length of the guitar neck, requiring the bridge saddle for the G-string to be shifted back relative to the high-E string a typical distance of ~ 1.0-2.0 mm. For the wound strings, the D-string, which is the lightest gauge wound string, typically 0.024”-0.026” in diameter, does not require as much compensation as the plain G-string; typically the D-string bridge saddle needs to be moved back relative to the bridge saddle of the high-E string typically by ~ 0.5-1.0 mm, comparable to that of the B-string compensation. The A-string, which is the next thickest gauge wound string, typically 0.032”-0.036” in diameter, requires its bridge saddle to be shifted back relative to the high-E string a distance of 1.5-3.0 mm, for proper intonation over the full length of the fretboard. Finally, the low-E string, which is the thickest gauge wound string, typically 0.042”-0.046” in diameter, requires the largest string compensation, the bridge saddle for the low-E string must be shifted back relative to the string saddle for the high-E string typically by an amount of ~ 3.0-4.0 mm.

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The exact distances that each of the individual bridge saddles need to be shifted back relative to the bridge saddle for the high-E string depends on the gauge of the string, the physical nature of the string itself - the string material, how the string was physically made (the wire-drawing process, and winding the outer string, if this is a wound string), and also the action of the guitar (height of strings from the frets on the fretboard). For a given set of strings, with a specific gauge of string diameter for each of the six strings the locations of each of the individual bridge saddles need to be adjusted for proper intonation of fretted notes over the full scale of the fretboard. If the bridge saddles are then properly adjusted, but then the guitar player decides to use a different gauge set of strings, or even a different brand of the *same* gauge strings, likely the bridge saddles will require further adjustment!

The procedure for saddle adjustment, for proper intonation of an electric guitar is as follows. First, *never* attempt to adjust the bridge saddle locations on a guitar with old, or "dead" strings on the guitar - do this *only* after you have put on a new set of strings *and* have played them just long enough (with clean hands!) so that they have "settled down" and are stable, tuning-wise. Dead strings, which are dirty from the build-up/accumulation of skin cells, sweat, finger grease, dirt, etc. do *not* intonate properly - the mass per unit length, μ of the string is no longer constant along its length (!), and the accumulation of "grunge" on the strings also has a direct impact on the effective rigidity of the strings - especially the wound strings. Do *not* attempt to adjust the bridge saddle string compensation immediately after re-stringing your guitar - the strings need some time to settle down - break them in by playing a bit, allow the strings to stabilize, e.g. overnight.

Since the high-E string is closest to an "ideal", perfectly linear guitar string, start with this string. Holding the guitar as you would normally play, tune up all of the strings to their correct pitch using an electronic guitar/bass tuner, or some other kind of electronic tuner – e.g. a chromatic tuner. Use a good-quality tuner, one which the tuner also displays how far away from the desired note's frequency you are, in cents. Having done this, then fret & pick the twelfth fret, of the high-E string, one octave above the open high-E string, playing the guitar exactly as you would normally do. Using the cents reading from the electronic tuner, if the bridge saddle for the high-E string is adjusted correctly, the pitch (i.e. frequency) should be identical to that of the pitch associated with the open high-E string.

If the pitch of the fretted note on the 12th fret of your guitar is *low* relative to the pitch of the open-E, this means that the bridge saddle for the high-E string is *too far back*, and needs to be moved *forward* (i.e. closer towards the neck). If the pitch of the fretted note on the 12th fret of your guitar is *high* relative to the pitch of the open-E, this means that the bridge saddle for the high-E string is *too far forward*, and needs to be moved back (i.e. farther away from the neck). Make the adjustments to the position of the high-E string bridge saddle, using a good-quality, suitably-sized screwdriver. If the bridge saddle adjustment screws are at all stiff or sticky, when you *next* re-string your guitar, it is a good time to clean the bridge saddles, and e.g. lubricate them (very sparingly!) with a good-quality lubricant, such as medium-grade key oil, used for lubricating the keys & valves of brass & wind instruments.

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Note that each time you adjust the saddle location on a given string, you will have to re-tune the open-tuning of that string, since changing the saddle location changes the length of the string, hence changes the frequency of the open string vibration. Retune the string and then repeat this procedure, using the information from the electronic tuner, until the frequency of the fretted note on the 12th string, played normally is exactly in tune with that of the open note on that same string, one octave lower. Then move on to the B string, adjust the bridge saddle for this string to get correct intonation, following the same procedure. Repeat the process for the remaining 4 strings.

When this entire process is completed, the guitarist should be able to play e.g. an E-chord (A-chord) at the bottom of the neck, and an E-barre (A-barre) chord at the 12th fret, and they should now be perfectly in tune with each other. If not, the strings not in tune need to be identified as such, and iterated upon using the above-described procedure.

Playing Notes and Melodies Using Only Harmonics

With the knowledge of where the 2nd, 3rd, 4th 5th & higher harmonics associated with the strings on a guitar are located, it is possible to play melodies using only harmonics, which are interesting/pleasing, due to their bell-like tones and ringing sustain. Doing so requires some practice to perfect this playing technique - it requires one to place one of their playing-hand fingers lightly and momentarily *precisely* at the *node* of that harmonic, while simultaneously picking the string at an *anti-node* of that harmonic (in order to maximally excite that harmonic), as shown in the following table.

Harmonic # ***n***	$\beta_{finger} \equiv L_{finger} / L_{scale}$ ***for Node***	$\beta_{pick} \equiv L_{pick} / L_{scale}$ ***for Anti-Node***
1 (Fundamental)	**–**	$^{1}/_{2}$
2	**½ (12th fret)**	$^{1}/_{4}$
3	$^{1}/_{3}$, $^{2}/_{3}$ **(7th & 19th frets)**	$^{1}/_{6}$, $^{3}/_{6}=^{1}/_{2}$
4	$^{1}/_{4}$, $^{3}/_{4}$ **(5th & 24th frets)**	$^{1}/_{8}$, $^{3}/_{8}$
5	$^{1}/_{5}$, $^{2}/_{5}$, $^{3}/_{5}$ **(4th, 9th & 16th frets)**	$^{1}/_{10}$, $^{3}/_{10}$, $^{5}/_{10}=^{1}/_{2}$
6	$^{1}/_{6}$ **($3^{1}/_{4}$ fret)**	$^{1}/_{12}$, $^{3}/_{12}=^{1}/_{4}$, $^{5}/_{12}$
7	$^{1}/_{7}$, $^{2}/_{7}$, $^{3}/_{7}$, $^{4}/_{7}$, $^{5}/_{7}$ **($2^{3}/_{4}$, $5^{3}/_{4}$, $9^{3}/_{4}$, $14^{3}/_{4}$, 22nd frets)**	$^{1}/_{14}$, $^{3}/_{14}$, $^{5}/_{14}$, $^{7}/_{14}=^{1}/_{2}$
8	$^{1}/_{8}$, $^{3}/_{8}$, $^{5}/_{8}$ **($2^{1}/_{3}$, $8^{1}/_{4}$ & 17th frets)**	$^{1}/_{16}$, $^{3}/_{16}$, $^{5}/_{16}$, $^{7}/_{16}$
9	$^{1}/_{9}$, $^{2}/_{9}$, $^{4}/_{9}$, $^{5}/_{9}$ **(2nd, $4^{1}/_{3}$, 10th & 14th frets)**	$^{1}/_{18}$, $^{3}/_{18}=^{1}/_{6}$, $^{5}/_{18}$, $^{7}/_{18}$
10	$^{1}/_{10}$, $^{3}/_{10}$ **($1^{3}/_{4}$, $6^{1}/_{3}$ frets)**	$^{1}/_{20}$, $^{3}/_{20}$, $^{5}/_{20}=^{1}/_{4}$, $^{7}/_{20}$, **...**

In the above table, the fractional distance, $\beta_{finger} = L_{finger}/L_{scale}$ is defined relative to the *nut*, and the fractional distance, $\beta_{pick} = L_{pick}/L_{scale}$ is defined relative to the *bridge*. These are *exact*. Note that the fret locations listed in the table for the node positions of the harmonics are *approximate* locations. Note also that some nodal positions for certain harmonics may be "missing". This is because they are simultaneously nodal position for lower-order harmonics, the amplitude of which overwhelms that of any higher harmonics, at least to the human ear. Thus only the lowest-order harmonic is really perceived clearly in that nodal location.

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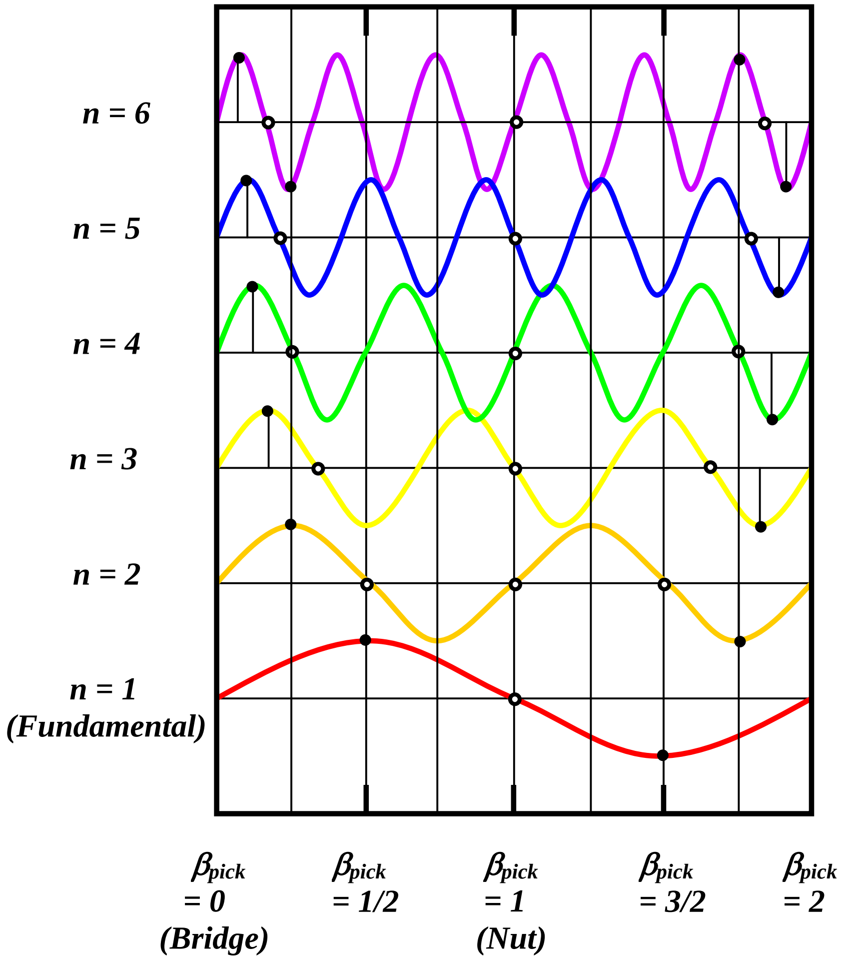
In practice, it is easier to successfully play the lower-order harmonics - locating their nodal positions with a finger tip of the playing hand is easier than for the higher-order harmonics. In general, *where* one plays along the string with the pick is not as important as accurately locating the nodal position of the harmonic with the playing hand finger tip. Successfully exciting the higher harmonics is in fact easier picking closer to the bridge, as can be seen from the following figure, for the first few harmonics. Note also that the sound level (i.e. loudness) associated with each of the harmonics excited in this manner decreases with increasing harmonic #. This fact is correlated with the last few statements in the previous paragraph.

Note further that as the harmonic # increases, e.g. for the 6th harmonic and beyond, the locations of the nodes for this harmonic are noticably no longer precisely over a fret. The position of the *first* node location from the nut for increasing harmonic #,if marked on its own fretboard, would look like a fretboard in reverse. In fact, one could develop a totally new type of guitar with such fretboard markings, dedicated specifically for playing harmonic/overtone sequences only – an admittedly highly specialized instrument



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The easiest and quickest way to make such an instrument would be to use e.g. a lap steel guitar and make an attachable/removable fretboard cover, with the positions of the harmonics laid out on this cover. Simply attach this fretboard cover to the existing fretboard of the lap steel, referencing it to the inner, fretboard side of the nut and have at it! This way, the lap steel could be used for the dual purpose of traditional lap steel/slide guitar and for harmonic playing, without making any time-irreversible modifications to the instrument, especially if it is a very old lap steel guitar!

Learning to play e.g. a rapid sequence of such harmonics can be initally quite challenging until this playing technique is mastered (i.e. read: requires lots of practice). Because of the standard E-A-D-G-B-E tuning of a 6-string guitar, the harmonic melodies that can be concocted are somewhat limited, but they are/can be interesting, especially for the harmonic combinations & sequences available using the higher-order harmonics located near ther 2nd, 3rd, 4th and 5th frets. However, note that other melodic harmonic possibilities can also be created by using different *tunings* of the guitar – e.g. open E, open A, etc. – give it a try, experiment and see!

It is also possible to pick notes on a guitar in such a way as to initially pick the note with the *edge* of the pick, held between the index finger and the thumb, but with the the pick held such that the tip is angled back (towards the bridge), and with the tip of the pick close to the thumb, to let the string *slide* off of the edge of the pick, sliding the string from the top section edge of the pick to the tip section edge of the pick, allowing it to "bounce" momentarily off of your thumb just after leaving the tip of the pick, thus killing/damping out the fundamental, leaving only the overtone(s) present! This picking technique works best for picking notes near and above the 12th fret of the guitar, and with a thin pick (it can also work for notes played near the bottom of the neck). In order to pick a note such that the 2nd harmonic is the dominant remaining tone, e.g. play a note on the 15th fret on one of the higher strings of the guitar, picking *half-way* between this fret and the bridge. To excite predominantly the 3rd harmonic, use the same picking technique, but pick 1/3 of the way from the bridge, etc. Immediately after doing this, the fretted note can also be bent, for even more auditory thrills. This picking technique works especially well when overdriving an amp, and/or using a distortion FX box. Billy Gibbons of ZZ Top and Eddie Van Halen are two famous guitarists who are well-known (or well-heard) for using this picking technique.

It is also possible, using two hands on the fret board, to simultaneously fret a note with the left hand, as one normally does (for a right-handed guitar) but then also momentarily fret the same string with the right hand, but e.g. exactly 12 frets above the note fretted with your left hand – in sort of like a hammer on/pull-off motion. This damps the fundamental, leaving the 2nd and higher harmonics present, which, if the amp it turned up, enough can couple back to the guitar for nice sustaining sound effects.

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