CHAPTER 5. MUSIC SAMPLES

We have investigated dozens of examples of music during this project. In this section we present detailed analyses of several of these music samples, with observations and conclusions based on the detailed examples as well as the broader set of samples which are not reported in detail. The original versions of the samples all have swing feel. In some of the detailed studies we also look at “straightened” versions which have been constructed from the originals, but with note events shifted slightly to remove or reduce the swing feel. In many cases, the swing is clearly related to a triplet rhythm, where some of the notes are played on beats that are subdivided by three rather than two or four. In other cases, particularly the Brasilian music, the simple triplet subdivision may be present, but there are also other subdivisions such as 5/12 and 7/24. Additionally, the Brasilian music often has slight differences in timing between the first and second half of a musical phrase, enhancing the swing feel. This style can be found in some American swing, such as ***Graceland*** by Paul Simon. Jazz or classic Swing tends to be rhythmically much tighter than songs like ***Graceland***, and the triplets are often very exact[1].

We want to be explicit about our opinion that there exist many types of swing. The research literature which looks at swing has mostly addressed music like American Jazz, and the concept of the *swing ratio* was developed to describe the characteristic shortening of some of the note events (mostly drums). As noted in the Appendix, professional musicians often classify different swing styles by which culture the music comes from: Cuba, USA, Brasil, etc. The swing in Reggae seems to be more enigmatic, and we show some results later in this chapter from our analysis of Bob Marley’s music.

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[1] Stu Fessant, professional musician, producer and recording engineer, Indigo Groove Studio. Portland, OR USA.

We have studied Brasilian rhythms more extensively than any other style, and now describe some of the details which we have discovered in this music style. This information is included to provide the reader some context about how one style of swing differs from another. Discussions with professional musicians makes it clear to us that each swing style is likely to have a collection of details such as we describe for Brasilian *swingee.* Not being experts in all music styles, we omit such details for other styles.

Generally Brasilian music does not emphasize a simple backbeat like American music does. Rather, an analogous construct is indicated by which ***side*** of the samba is referenced. In our experience there are two sides, and, as a drummer, one only hears about it if one is playing on the *wrong side.* This illustrates the principle of interlocking batidas, or *ensemble swing*. Each instrument plays its rhythm with its own flavor of swingee, collectively anchored at a few specific MB time locations. These combine in the performance to create a quick and complex sequence of tension/resolution effects. When played correctly, it gives Brasilian music a very smooth feeling despite its complexity. When one or more player is on the wrong side, the effect is to produce a chronic tension or ***pull*** in the music. The sidedness is not limited to a *one-two* metaphor. Most batidas have two sides, but the length of each rhythmic repetition may not match the lengths of rhythms of other instruments. This produces hierarchical complexity. For example, the pandeiro plays a constant *one-two-three-four* pattern whose timing (duration, rhythmic variation) varies slightly from phrase to phrase. The surdo also has a *one-two-three-four* structure, but each beat of the surdo corresponds to one entire phrase of the pandeiro. If the push and pull between surdo and pandeiro has a consistent feel, then the two batidas mesh like gears in a well-oiled but somewhat worn out machine. If one rhythm pushes when the other pulls, the resultant rhythm will not sound as smooth.

The rhythms of other instruments (e.g., tamborim) can be started at their canonical downbeat, or the two sides of the batida can be swapped which gives an even more syncopated feel but which is still smooth. The tamborim player may start the batida a sixteenth note ahead of the surdo/pandeiro downbeat or, more commonly, a sixteenth note after the downbeat. This type of playing around the beat is sometimes called *teleco-teco* which is an onomatopoeia for the sound of the batida.[2] Again, this produces a more syncopated feel than playing the standard tamborim rhythm, but one which still flows smoothly with the surdo/pandeiro. If the tamborim starts its pattern on the two, three or four of the pandeiro, it is still “in time” in the sense that all the 1/8 or 1/4 notes between the two instruments are played at common MB time anchors, but the accents and rhythm of the tamborim may cause a pull, with the overall feeling that something is not quite right. This is a subtle thing that I am only beginning to understand. I have not analyzed the music to this level with our algorithm but, after years of listening, understanding this notion has definitely found a sensible location in the information space in my head.

Several music software applications are available that address production of swing rhythm. We have used two of these, and processed our straight versions of some music samples using the swing algorithms in the software. We present results analysing the original swing and straight versions. We have made artificial swing versions of some samples, but the analysis of these is not presented in the current paper. Some of these “roboswing” samples are virtually identical to real samples (if carefully crafted). Creating these by hand was labor intensive and relatively tedious. For real production of artificial swing music, good algorithms are needed. We explore this in the chapter on future work.

5.1 Analyzed Music Samples

We chose our musical samples entirely by subjective considerations. Basically we picked songs we like, and that we believe have a substantial swing based on our perception. We processed short sections of the songs that represent the rhythms, making seamless loops of the audio. The loop may not represent the full range of complexity of all the rhythmic patterns contained in the songs, but they clearly show the technical details that

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[2] Jake Raar, musician from Samba-Jah performing group. Eugene, OR USA.

give rise to swing feel. We distinguish between a high level metric, the feel of swing, and lower level patterns -- the particular rhythmic patterns that generate the swing feel.

In processing the audio samples for making loops, we shaved or added very short time sections of music to try to match the rhythm exactly as the loop jumped from the end of one repetition to the beginning of the next repetition. We discovered that very short discrepancies in timing are clearly audible, and disrupt the feeling of the rhythm. These errors may be as short as 5 or 10 milliseconds, but can be heard as a timing artifact, primarily in the pulse, each time the loop starts its repetition. The difference between swing and straight feel in a sample can be caused by time differences of less than 50 to 70 milliseconds in a few note events. These timing artifacts are a very different feature from merely having a sound "glitch" such as a pop or click due to clumsy editing. Generally it is mandatory for both the beginning and end points of the loop to be at zero signal power level to avoid audio glitches. Avoiding a rhythmic anomaly is a question of getting the time length of the loop sample exactly lined up with the patterns of elapsed time in the music so the note events occur at consistent temporal locations. As we already pointed out, the human perceptual apparatus is very astute at detecting such unnatural features as are caused by the loop length not matching the time cycle of the rhythmic repetition.

The samples we investigate in detail are ***Fever*** performed by Ray Charles and Natalie Cole (2004), ***It Don't Mean a Thing (if it Ain't Got That Swing)*** played by Louis Armstrong and Duke Ellington (1962), ***Graceland*** by Paul Simon (1986), a typical pandeiro rhythm from Brasilian Samba, two additional Brasilian rhythms which are more complex than the pandeiro sample, and ***Stir it up*** by Bob Marley (1973).

5.2 MIDI for Straight Time

MIDI (Musical Instrument Digital Interface) is a widely used protocol in computer music production and research. MIDI includes specifications for communications between musical devices (synthesizers, drum machines, sequencers), as well as a file format for note and timing information. MIDI lets a composer specify the pitch, tempo and meter of note events, and can connect these computer events to output devices such as a synthesizer that produces note sounds.

We used the MIDI capabilities in GarageBand music production software from Apple Computer to produce straight versions of the pandeiro rhythm. We also used GarageBand to produce artificial swing versions of the pandeiro samples.

5.3 Detailed Analysis of Swing Samples

In this section we present analysis results from our algorithm for several musical samples that show pertinent details of swing timing variations. We compare original samples with straightened versions of the same samples, and describe the types of details that are apparent in the graphs when inspected closely. Some timing information may not be obvious except by close-up inspection of the plots.

5.3.1 Fever

Fever is a classic R&B song with backbeat and a 2/4 or 4/4 feeling. The 2004 Ray Charles version preserves the original rhythmic meter, but the conga plays with an exact triplet subdivision style, giving a strong and very hip swing feel, despite having no explicit feeling of swing in the sense of classic American Swing. We listened to this song many times before it consciously occurred to us that the extreme hipness of Ray's version is more than just a well played backbeat -- a richer version of rock and roll as it were. Well it weren't. When we ran this sample through `chkdot` and looked closely, we discovered that many of the conga notes are played *exactly* on the triplet pickups to the downbeat and backbeat. By exact we mean within a 3 millisecond time granularity. Other identified notes events are mostly on exact 1/4 subdivisions. The pulse is Ray Charles snapping his fingers. The timing variation of these events is less than 5 milliseconds.

To create the straight version, we edited the digital audio signal by hand to move as many of the conga notes as was practical, given the subtlety of the audio mix. The time difference between the triplet location and the straight 1/4 note location is slightly shorter than 70 milliseconds. The straight version sounds good but has a distinctly clunky feel compared to the original. Straightening the first half was fairly easy because the music is sparse and there is little overlap of note events from different instruments. The second half was not entirely straightened because its more complex mix meant that some instruments' notes overlapped others in a way that could not be separated without creating objectionable artifacts in the sample. In addition, the drummer skids his brushes around the snare drum with a strong but subtle rhythm that pervades the mix, and also causes artifacts if edited. The editing task involved moving appropriate (*swung*) note events forward or backward in time. Some of the swing notes could not be moved because either they were inextricably blended with another note event, or else the temporal location which would have been their landing place was already occupied by a note event and putting the conga note at that time location would obliterate or severely distort the other note event.

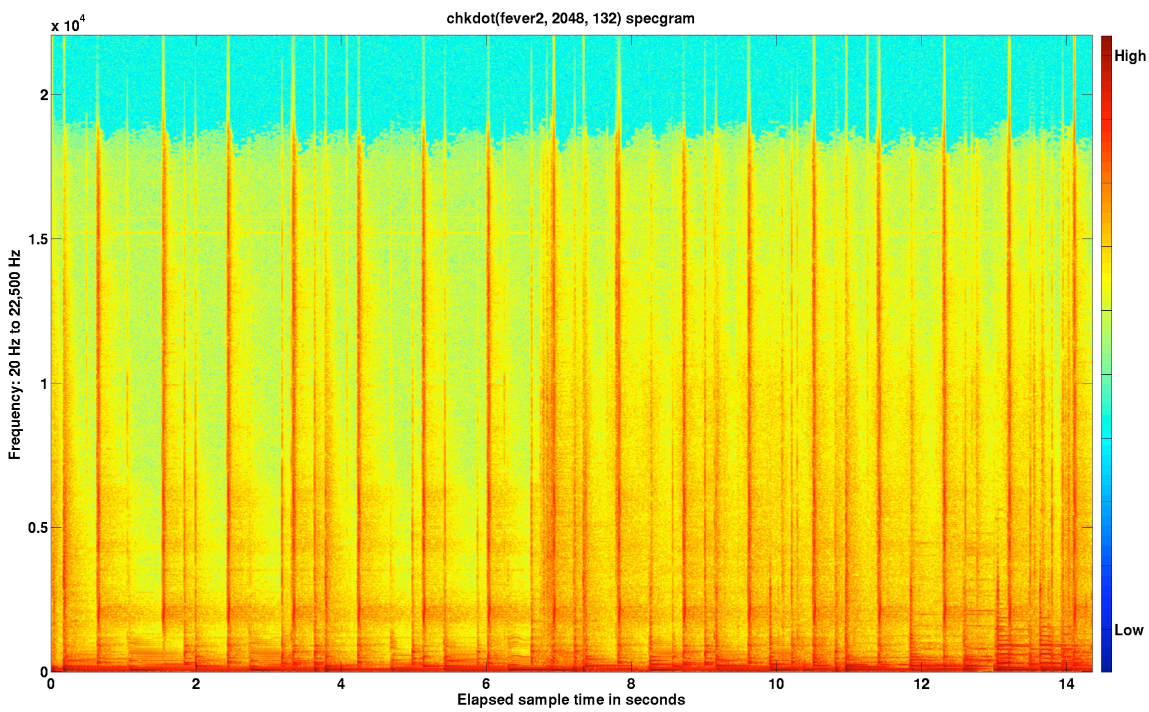

Figure 5.3.1.1 Specgram for Introduction to ***Fever***

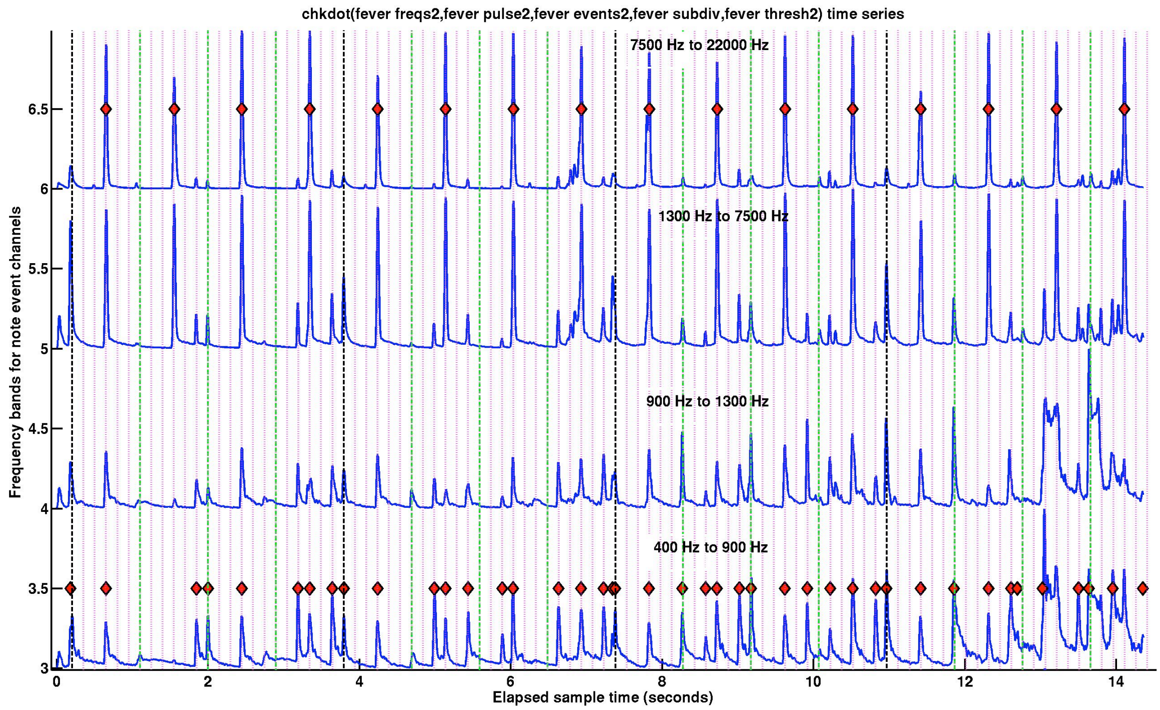

Figure 5.3.1.2 Time Series Plot for Events in Original Version of Fever

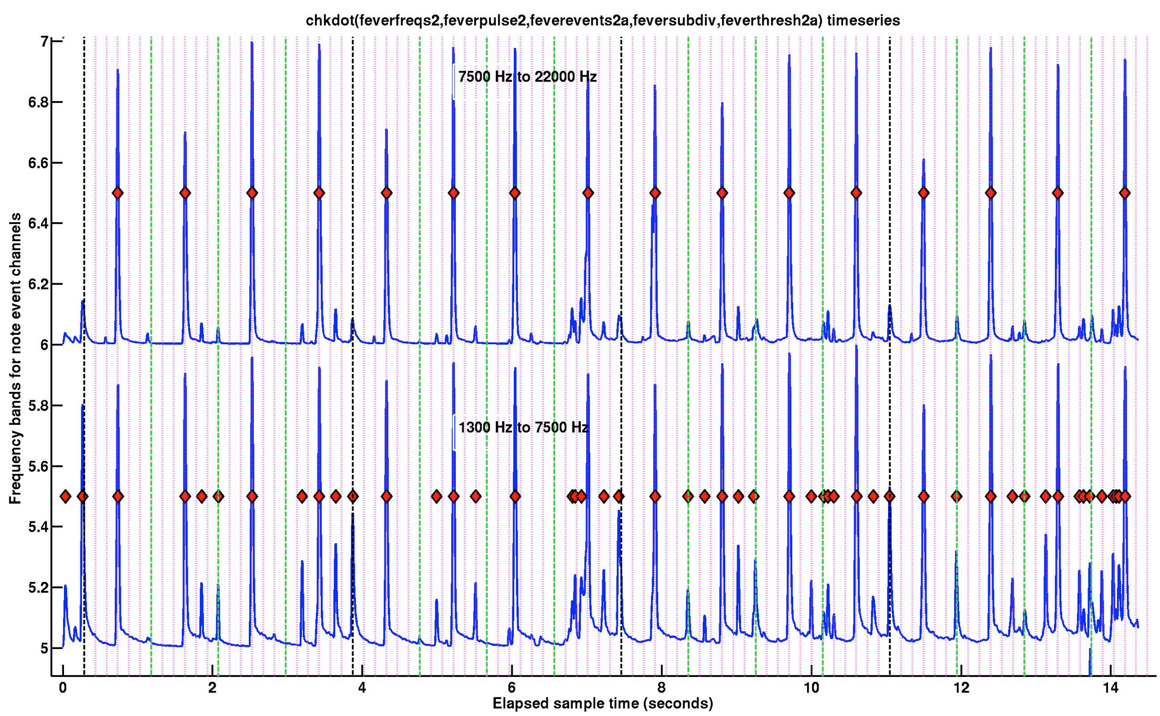

Figure 5.3.1.3 Time Series Plot for Events in Straight Version of Fever

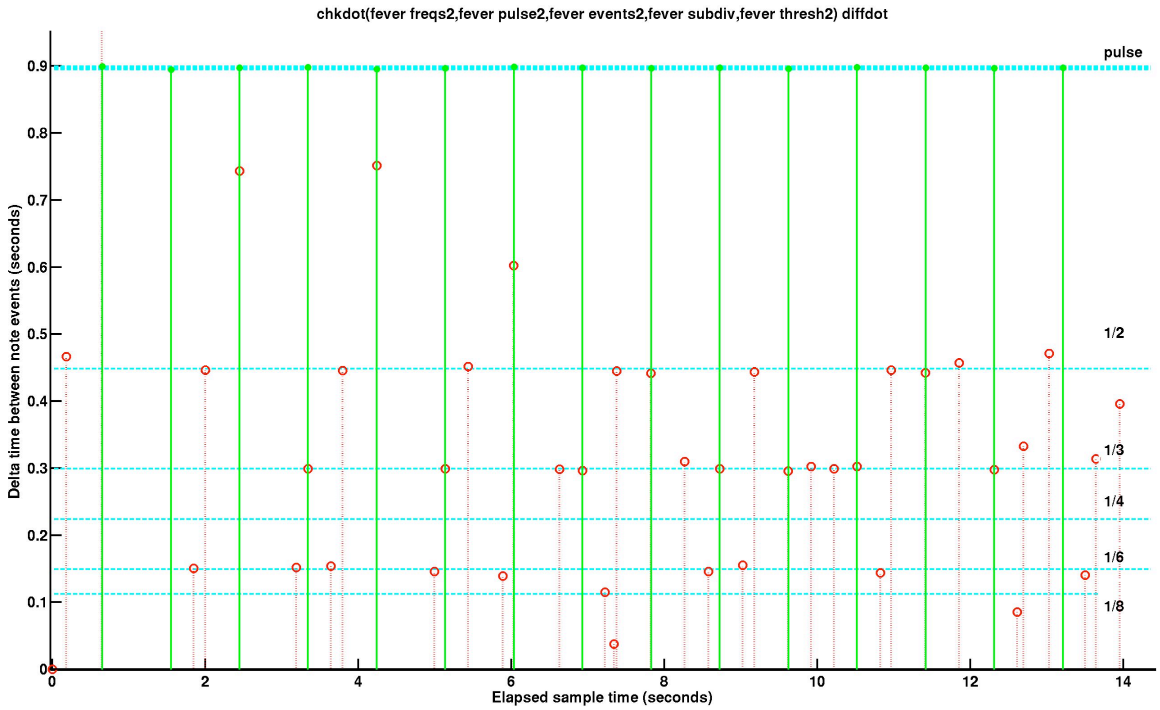

Figure 5.3.1.4 Note Timing Chart for Events in Original Version of Fever

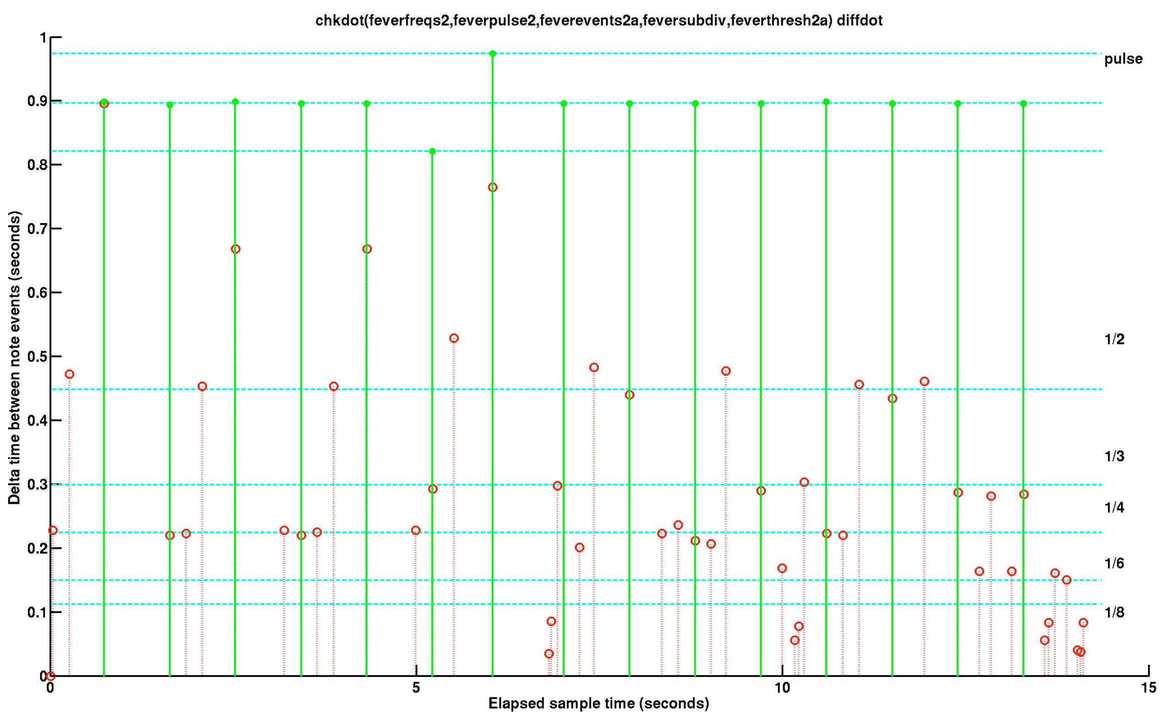

Figure 5.3.1.5 Note Timing Chart for Events in Straight Version of Fever

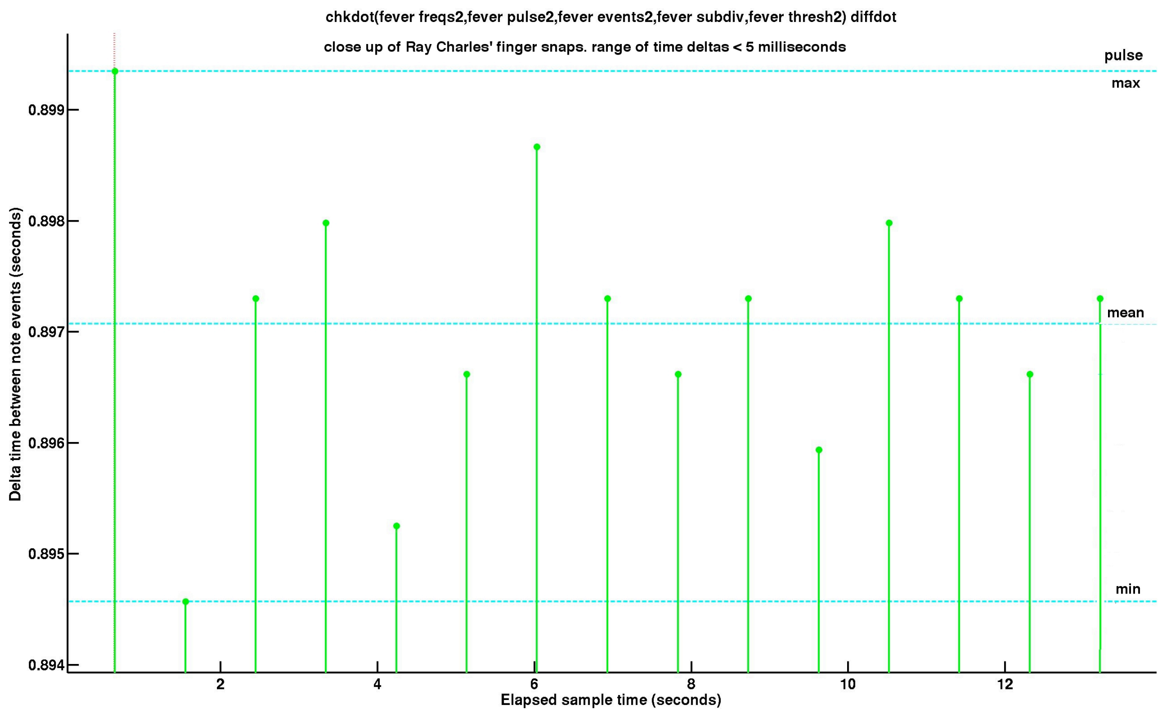

Figure 5.3.1.6 Close-up: `diffdot` Pulse Events for Original Version of ***Fever***
Variance of time deltas for Ray Charles' finger snaps is less than 5 milliseconds.

If you look closely at figure 5.3.1.2, in the pulse track at the top, straight up from the 8 second mark, you will see a small double peak. Figure 5.3.1.7 shows a close-up of this slight performance error in the second phrase.One of these events is a finger snap, and the other a conga. Everywhere else in this music sample, we found exact temporal alignment between these two instruments, but in this case, the conga plays 30 milliseconds too soon. We conclude that Ray Charles either did not hear this discrepancy during recording (unlikely), or that he was aware of it but found it acceptable. Indeed we challenge anyone to actually perceive it by direct listening (the audio sample is posted on the web). We include this anomaly because it represents an important data point in the specification of lower limits to the human audio perception system. Figure 5.3.1.8 shows an even closer view. The small bump that is visible between the first note event (conga) and the larger finger snap peak is the snare drum which has a small component of its sound in the higher frequency range where we measure the finger snap and conga.

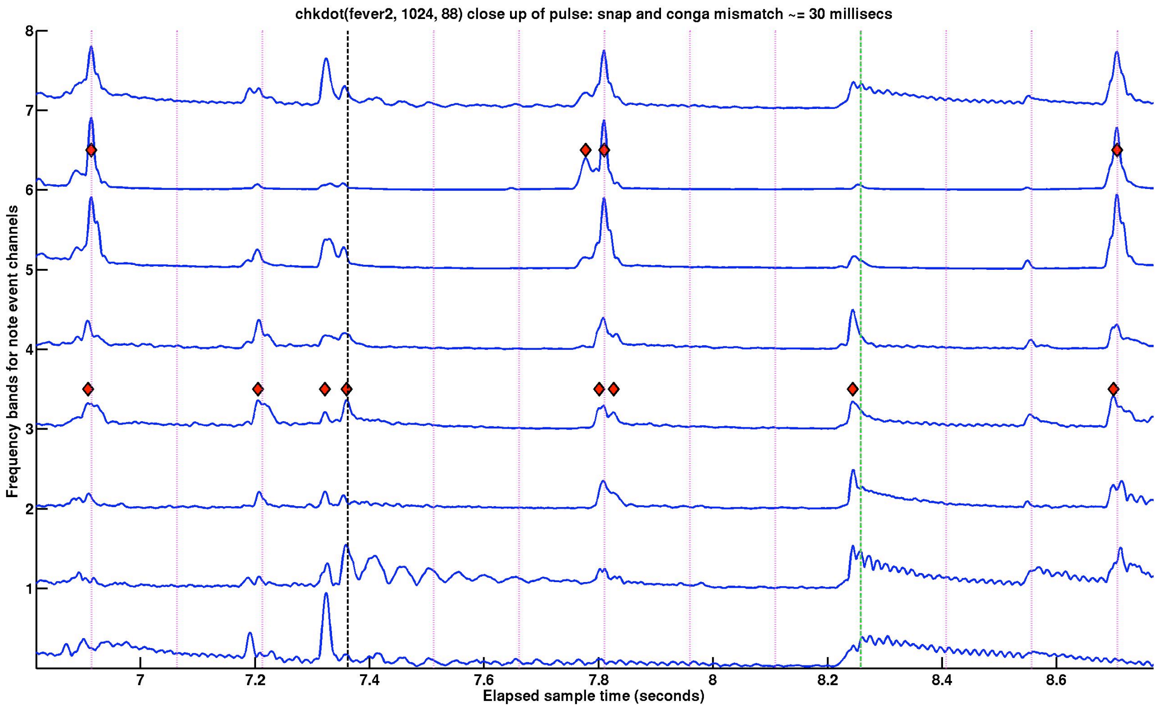

Figure 5.3.1.7 ***Fever*** missed conga note

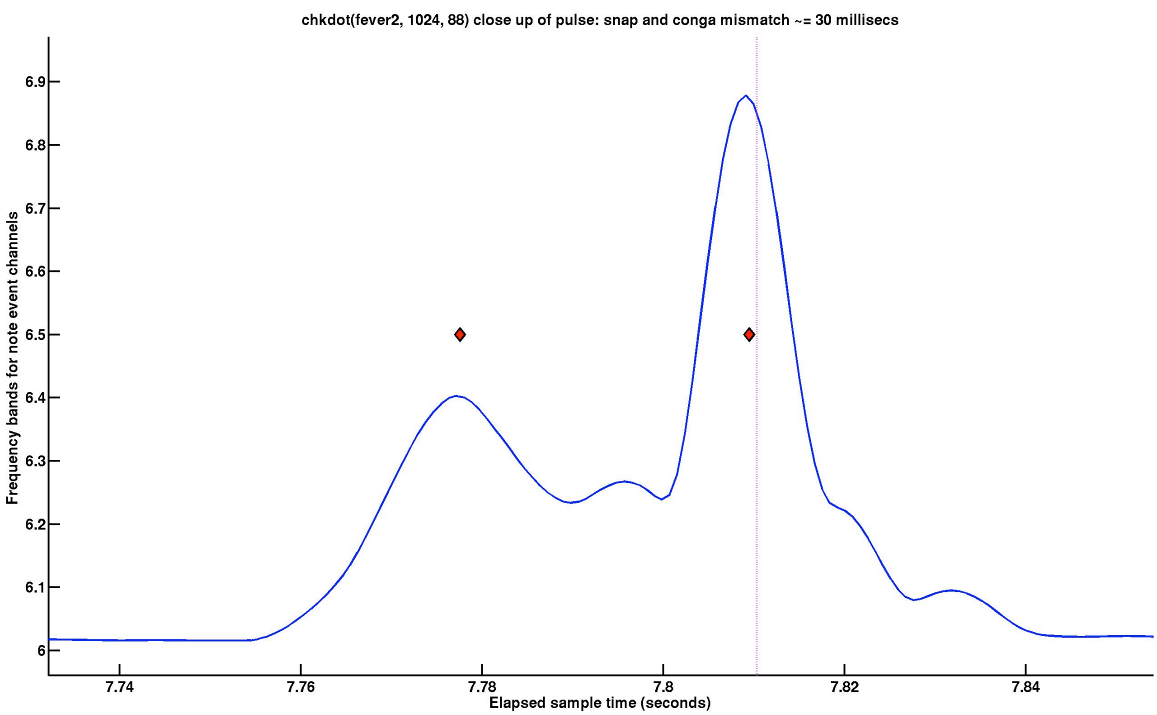

Figure 5.3.1.8 Extreme Close-up of Conga/Finger Snap Timing Anomaly

5.3.2 ***Graceland***: "Loose" Tempo

Graceland by Paul Simon is a good example of a swing feel that mimics riding on a railroad. We discovered that the several instruments in the introduction bounce around the MB beat locations in a loose swing while staying tightly synchronized with each other. Figures 5.3.2.1-3 show specgrams for the 8 bar intro to ***Graceland.*** The large scale specgram shows the subdivision of time clearly, but the spectrum appears quite broad and relatively featureless from the perspective of extracting note events. Zooming in on the low frequencies in the second and third plots show a great amount of detail visible below 1500 Hz. This shows how the resolution of the FFT is crucial for picking good frequency bands and features. The time resolution is about 10 milliseconds.

Figure 5.3.2.4 shows a ten frequency band `chkdot` time series plot for the ***Graceland*** sample. Bass drum is used as the pulse, and electric guitar is the secondary events channel. Figure 5.3.2.5-6 show `diffdot` plots of the time deltas for the pulse and guitar channels. Both event channels show significant variations in the timing. The pulse channel starts with greater variation, and settles into a somewhat tighter pattern by the second half of the sample (second 4 bar phrase). The electric guitar is much more consistent in timing variations. Close inspection shows approximately 50 millisecond range of time deltas in both event channels.

The `chkdot` subdivisions (green lines) show a triplet pattern. The pulse events in the lowest frequency band land close to the downbeat and backbeat MB lines, but drift slightly forward and backward in time. This gives a looser feel than the extremely tight swing in ***Fever*** which has every beat synchronized to less than 10 milliseconds. Looking at the ***Graceland*** `chkdot` plot, it is clear that basically every note event is played on a quarter beat subdivision. Ordinarily this would tend to sound somewhat square. The consistent variation in the electric guitar timing seems to provide a swing feel without any explicit presence of triplet subdivisions.

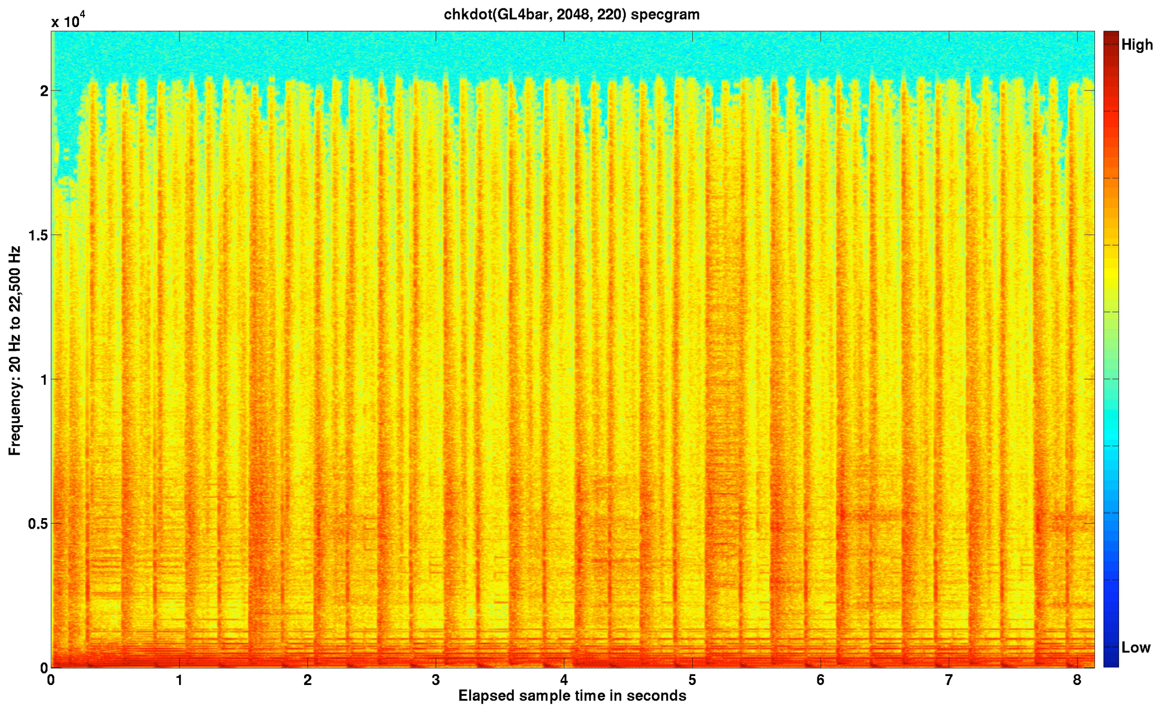

Figure 5.3.2.1 Specgram for ***Graceland***

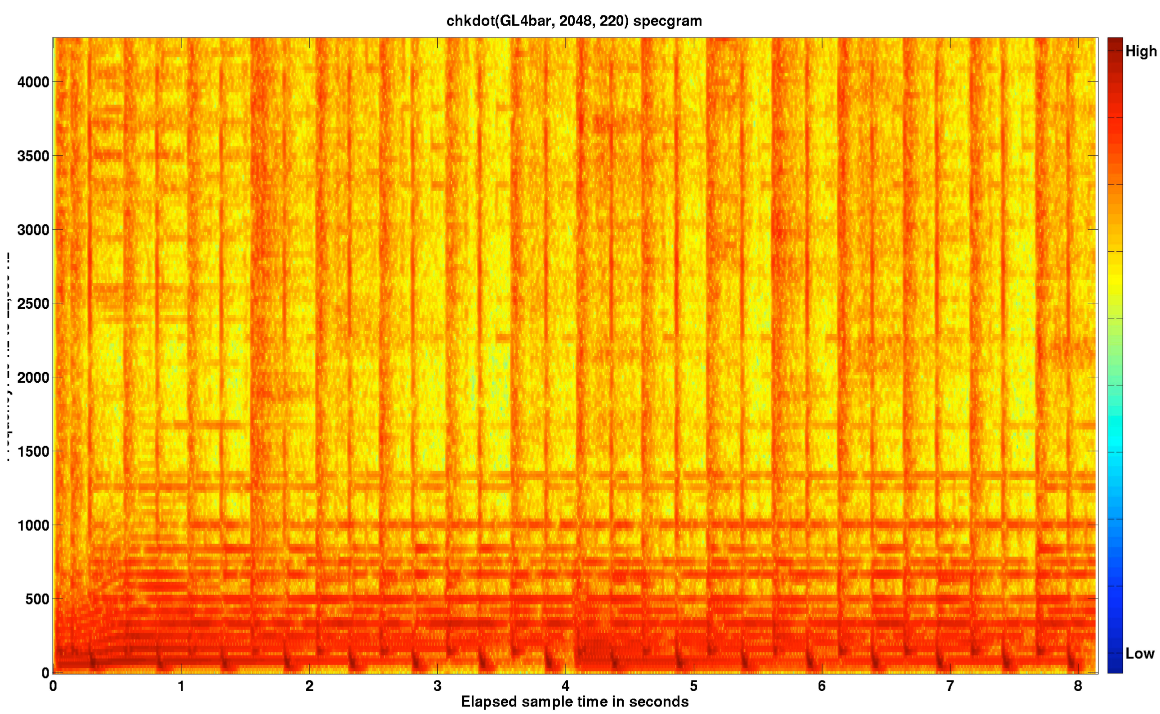

Figure 5.3.2.2 Specgram for ***Graceland*** (close-up one)

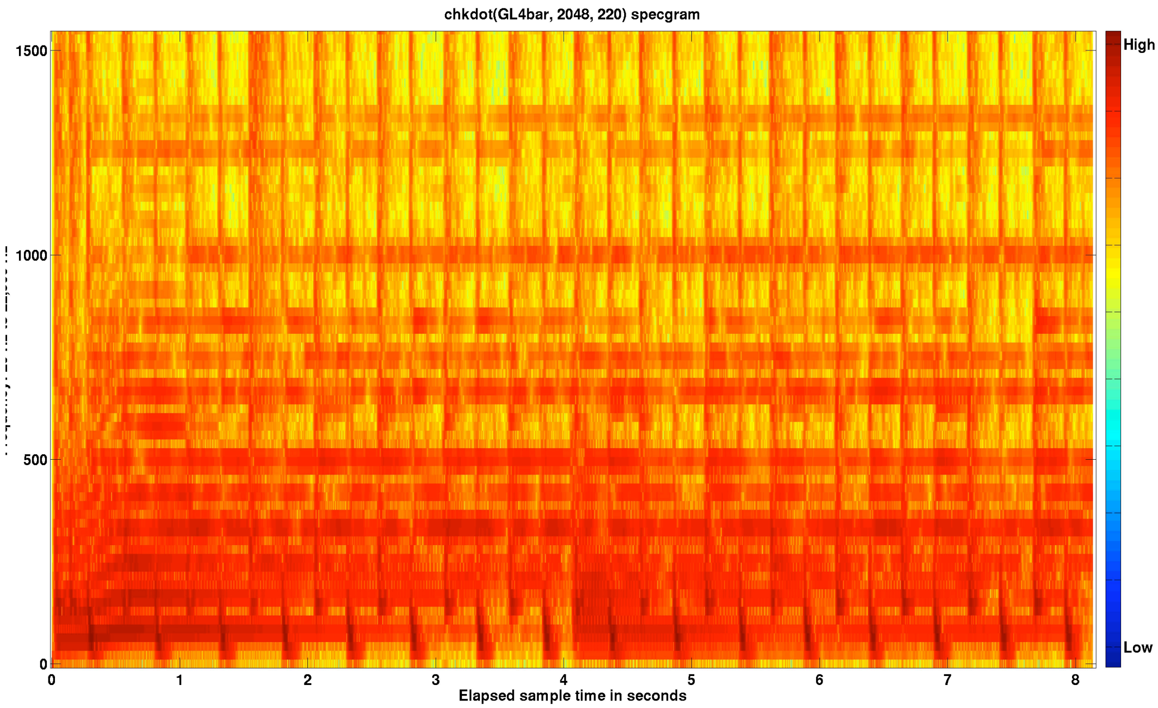

Figure 5.3.2.3 Specgram for ***Graceland*** (close-up two)

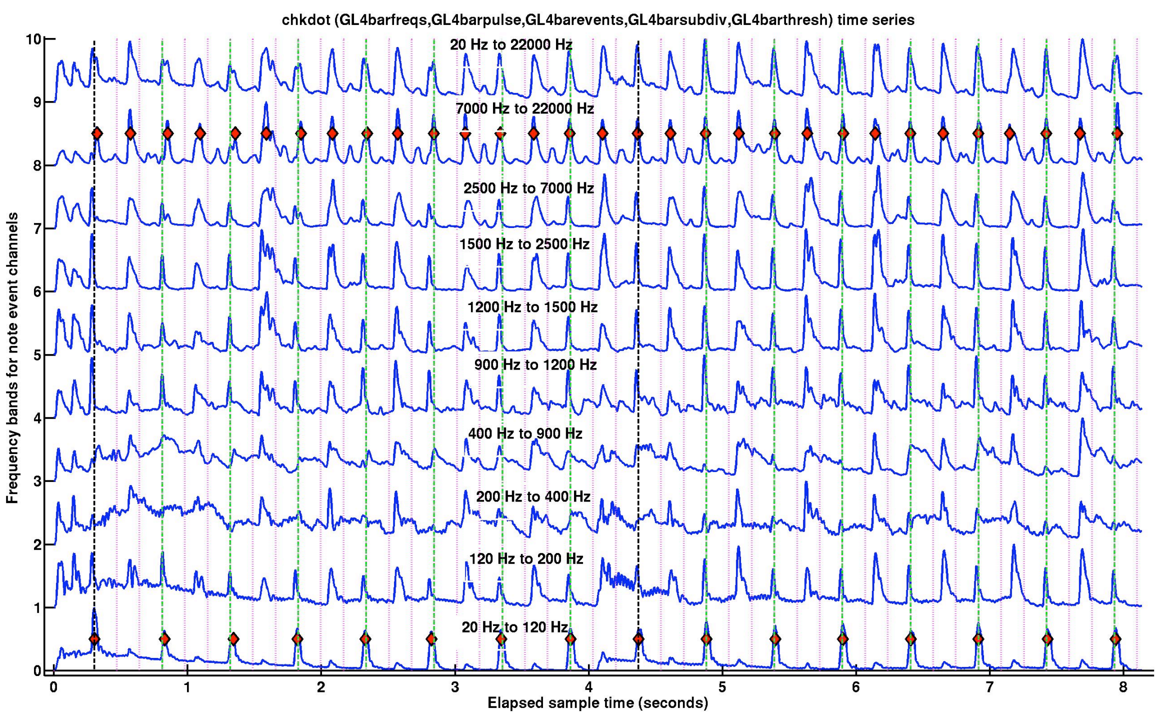

Figure 5.3.2.4 ***Graceland*** bass drum and electric guitar events

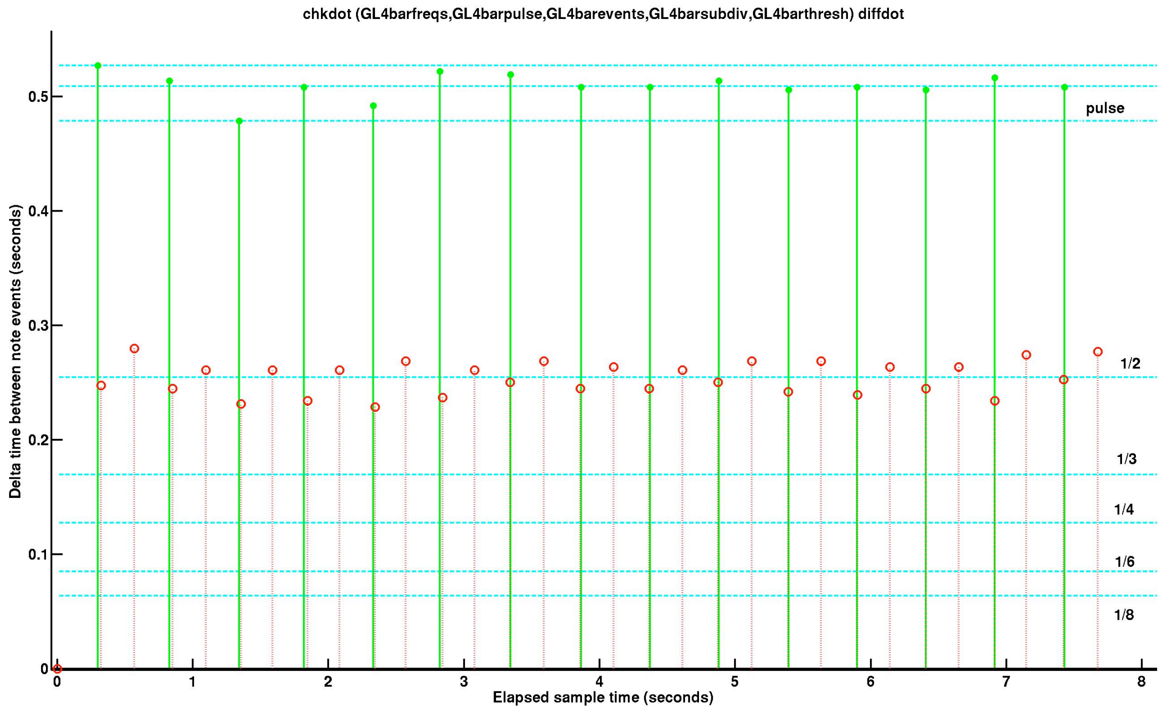

Figure 5.3.2.5 ***Graceland*** Note Event Time Deltas (`diffdot`)

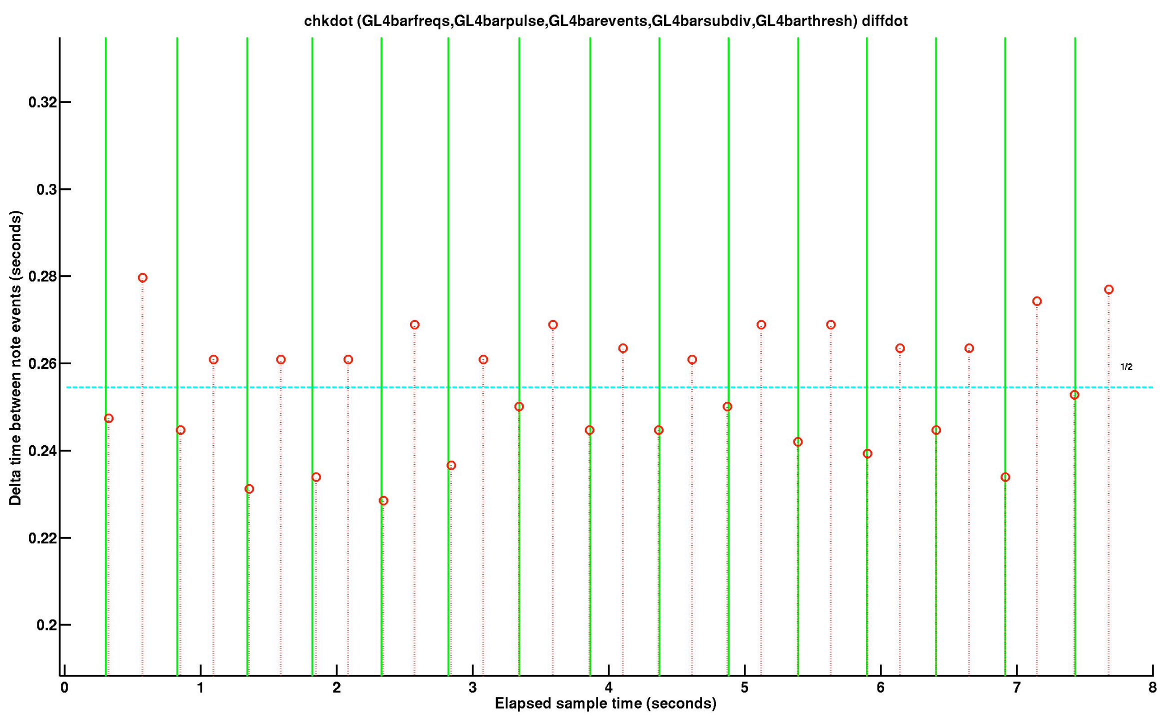

Figure 5.3.2.6 ***Graceland*** Close-up of Electric Guitar Time Deltas (`diffdot`)

5.3.3 Pandeiro

The pandeiro is a Brasilian hand drum very similar to the instrument called a tambourine in American music. Pandeiro can and does play almost every rhythmic part in Samba and Pagode: surdo, caixa, tamborim (not a tambourine, see Appendix), ganza (shaker) and cuica in addition to a variety of rhythms mostly unique to the pandeiro.[3]

The *basic* pandeiro batida is a simple 1-2-3-4 pattern played continuously with slight variations denoting which phrase of a larger pattern is being played. This pandeiro batida is invariably taught as straight time: *one-ee-and-uh* played with thumb (*one*), fingertips (*ee*), palm heel (*and*), fingertips (*uh*), over and over. American students generally have a difficult time learning to play the pandeiro. Part of this difficulty is related to posture: holding the pandeiro, Brasilian style, is as difficult as holding a violin, but with the stress on the left hand rather than chin and shoulder. The other difficulty, which became clear during the course of this research, is that most pandeiro teachers, whether Brasilian, American or other national origin, underemphasize the single most important insight: these four notes are *not* played with even time differences. As can be seen in the `chkdot` time series plots, the *uh* note is always played on the triplet pickup to the downbeat, rather than the straight quarter note. This timing variation gives the pandeiro batida a strong swing feeling. The triplet pickup to a downbeat or backbeat is a very common feature of American Swing, and also quite common in Brasilian music. In addition, the second and third notes (*ee* and *and*) are played in two very odd locations in the first half of the phrase. Neither of these is played on either a triplet, quarter or eighth note location, and there are slight time variations between repetitions of the basic batida. The pattern of these time variations is consistent by some measure, since in the `diffdot` plots the pattern is clearly a repeating waveform, rather than some kind of random pattern.

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[3] Airto Moreira, Carlinhos Pandeiro de Oura, Jovino Santos Neto, professional Brasilian musicians/composers.

In addition to the sub-phrase temporal variations, most pandeiro players also play a slight timing difference between the length of the first and second phrases of the pandeiro batida, which enhances the lopsided swing feeling. The `diffdot` pulse events plot also shows this larger scale timing pattern. A correspondence can be imagined between the two `diffdot` patterns. This correspondence relates to making the overall composite pattern feel like a smooth swing, rather than pulling on the rhythm. The difficulty of describing this adequately in language reinforces the assertion that swing is an intuitive feeling rather than an analytical construct of counting exact subdivisions. We could analyze the timing patterns exhaustively, but it wouldn't help play the batida correctly.

The typical explanation of all this hierarchical coupling of temporal patterns, after the student has become semi-competent at holding the instrument and playing the basic notes, is that the pandeiro teacher says "*Now, play with swingee!*"

In figures 5.3.3.1-8 we show plots contrasting the original swingee version of the batida with a straight version generated in a MIDI file. The first two figures are specgrams of the spectra of the samples. The spectra are relatively the same, but the spacing of the vertical bands that represent the note events are more evenly spaced in the straight version. The second set of plots (`chkdot`) show time series of the audio signal decomposed into three frequency sub-bands. The pulse (*one* notes) is shown in the bottom frequency band. We detect these downbeat and offbeat notes from the strong low frequencies generated when the thumb hits the pandeiro skin. The other notes have the high frequencies of the jingles rattling. The *one* notes are played with two tonal variations to demarcate the two sides of the two bar phrase, called the open tone and the closed tone. Since the *one* notes also cause jingles to rattle, these notes show up in the frequency band for *ee, and, uh* notes. Observe how the note events in the straight version line up with the quarter subdivision lines. In the original swingee version, the only note event that is on an MB quarter note subdivision is the pulse.

The small amount of variation visible in the straight version is due to using hand edited samples that have slight artifacts, and using more than one sample version of each note event so the note events are not all generated by identical samples for their position in the batida: *one, ee, and, uh*. The swingee samples, played by a human musician, show temporal variations at several hierarchical levels of the rhythmic structure. `diffdot` shows about 5% - 8% variation in the time delta between downbeats, with a clear repeating pattern that resembles a slightly modulated sine wave. This set of time variations could be roughly modeled by using the swing ratio concept, if it was extended to include variations which are more than a simple ratio. The subdivision notes (*ee, and, uh)* show a more complex variation which is clearly beyond the swing ratio to model adequately.

Next are the `diffdot` plots, which show the time difference between adjacent note events on the ***Y*** axis. The green vertical markers represent the series of downbeats and the red markers are the *ee, and, uh* events. Elapsed sample time is on the ***X*** axis. The straight version has all non-pulse notes clustered around the 1/4 subdivision line. The swingee version shows a repeating pattern of timing variations for both the pulse and non-pulse note events. While the *uh* note events in the `chkdot` plots are quite precisely on the triplet pickup MB markers, in the `diffdot` plots these are spread between the 1/3 and 1/4 subdivision markers. This is because the `chkdot` markers are on the absolute MB time subdivisions, while the `diffdot` markers are relative to each other, and so the `diffdot` subdivisions depends on the timing variations in the pulse events, giving a broader spread of time deltas than in the `chkdot` plots.

These complex time variations are typical features of swingee for all the samples of Brasilian music we've analyzed. Keep in mind that the basic pandeiro part is one of the simplest rhythms found in Brasilian music. The swing ratio model of timing variations is completely inadequate to describe these types of rhythms. In chapter 6, we explore an idea for generating these temporal variations using Fourier series.

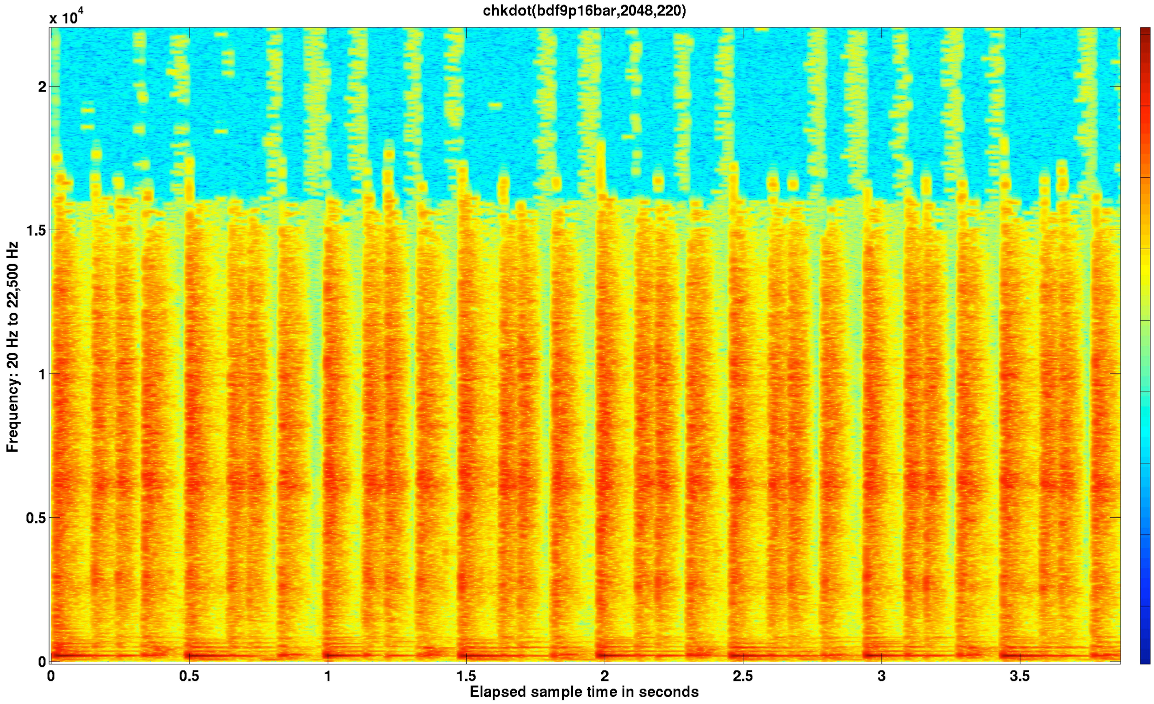

Figure 5.3.3.1 Specgram of Swingee Pandeiro Batida

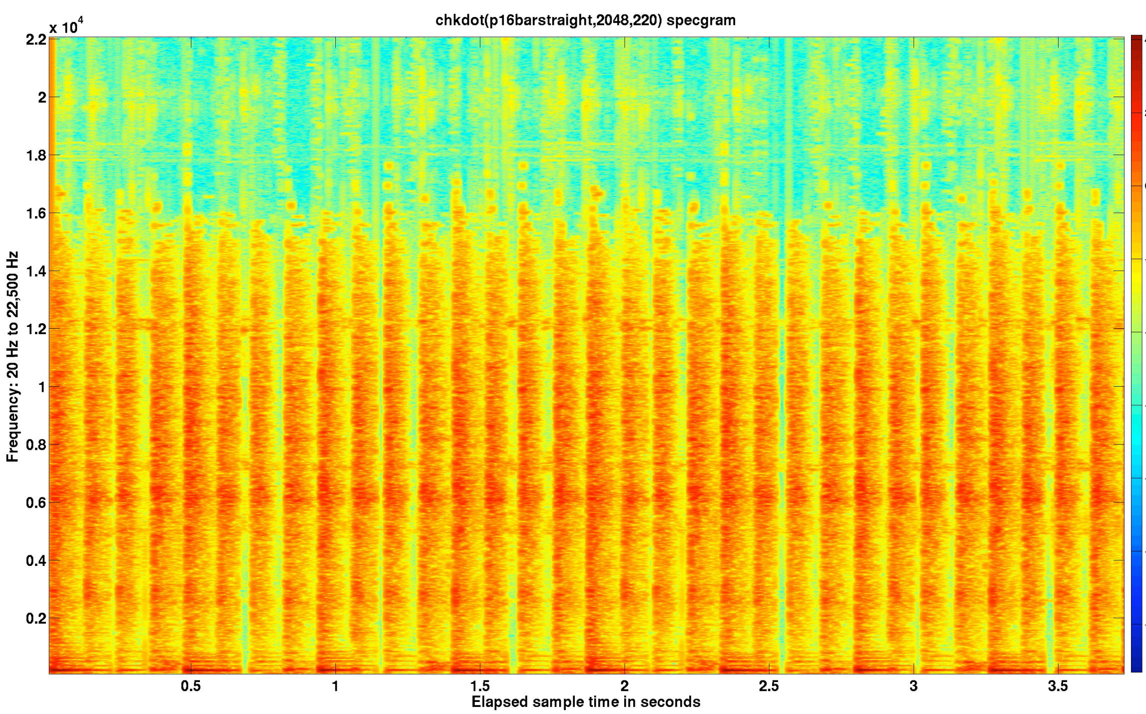

Figure 5.3.3.2 Specgram of Straight Pandeiro Batida

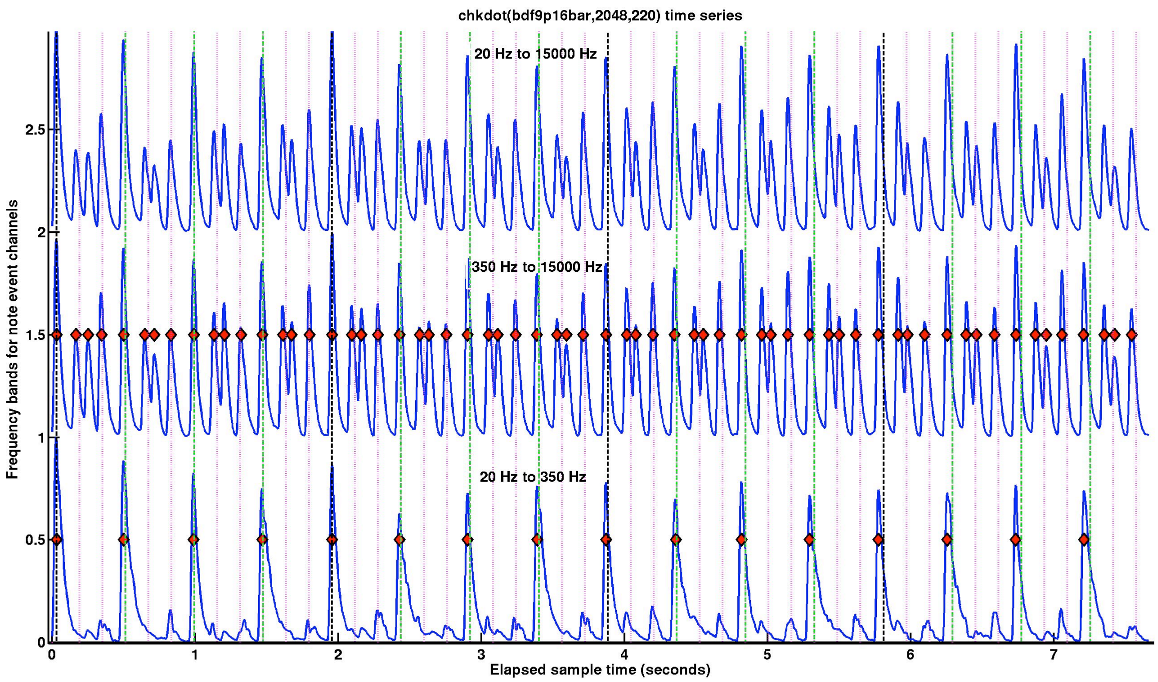

Figure 5.3.3.3 Time Series Plot for Events in Swingee Pandeiro Batida

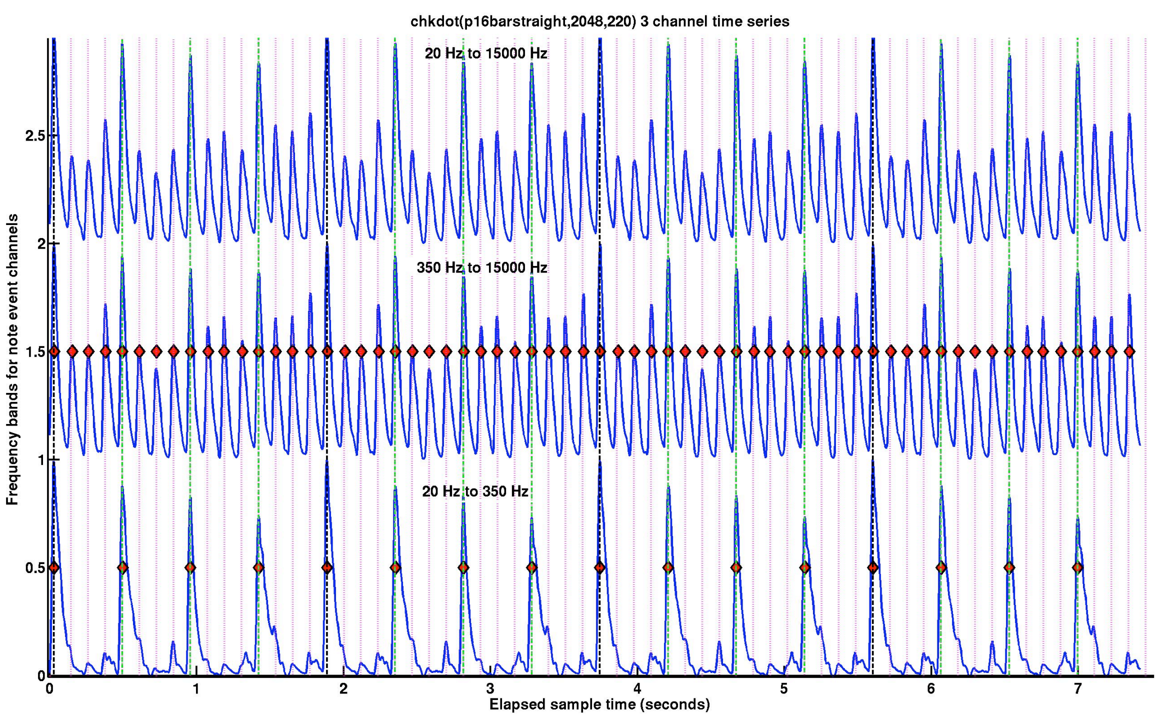

Figure 5.3.3.4 Time Series Plot for Events in Straight Pandeiro Batida

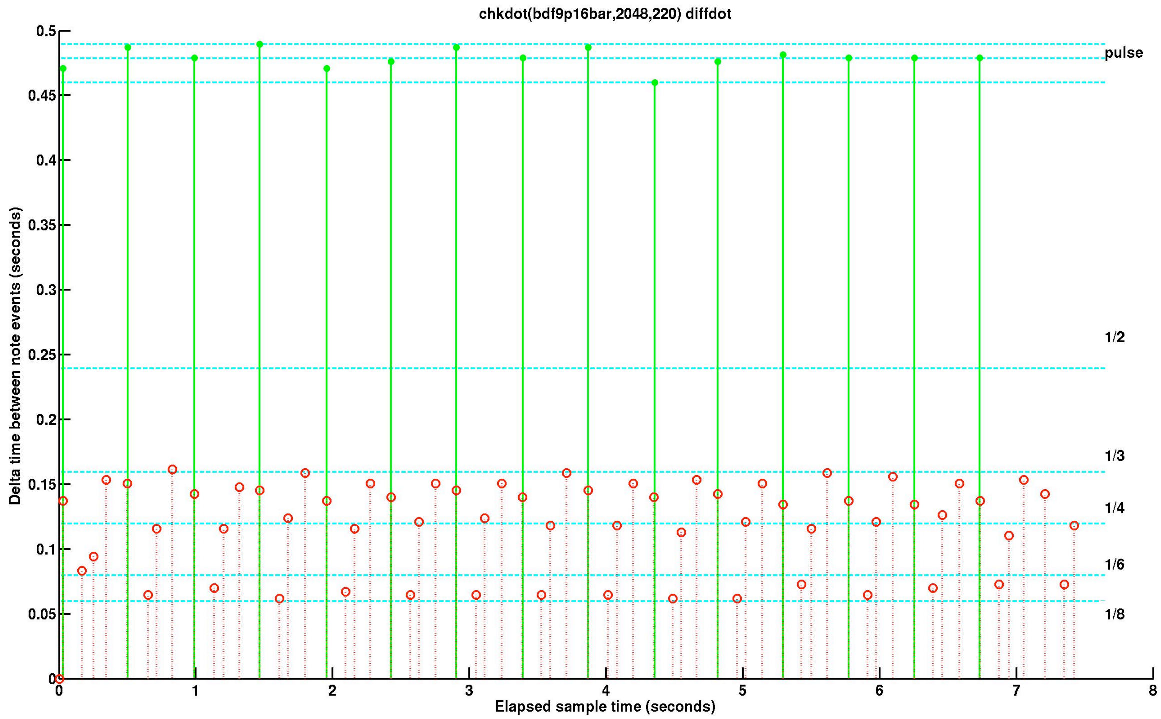

Figure 5.3.3.5 Note Timing Chart for Events in Swingee Pandeiro Batida

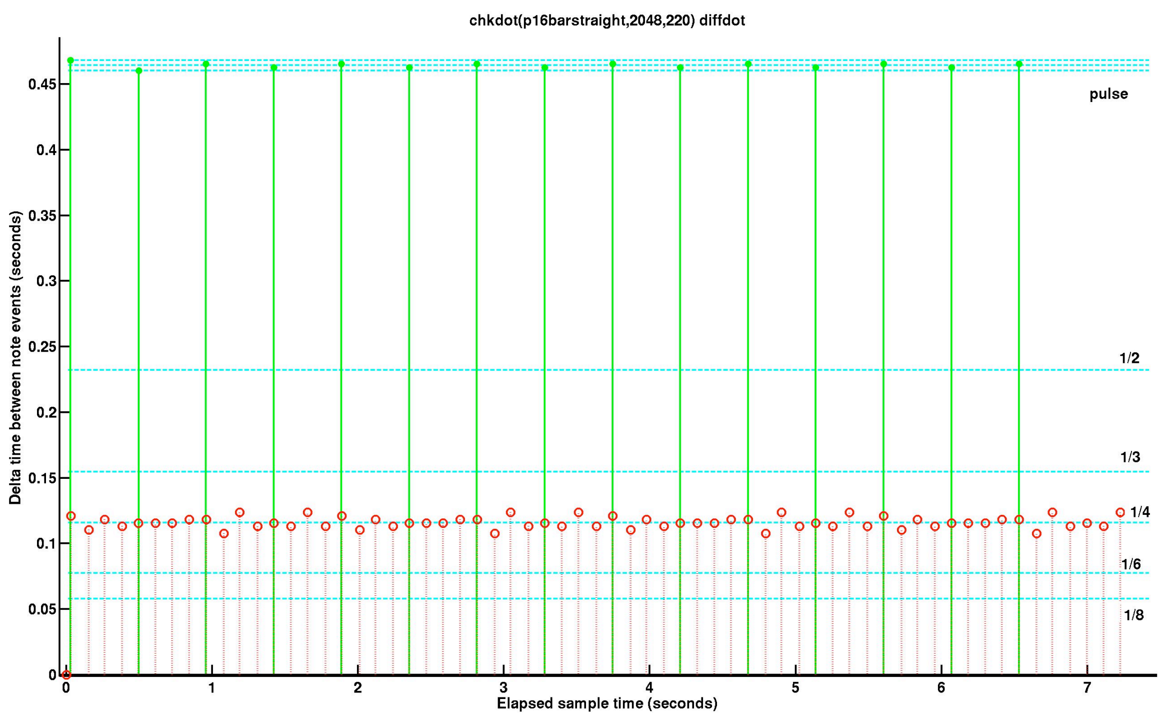

Figure 5.3.3.6 Note Timing Chart for Events in Straight Pandeiro Batida

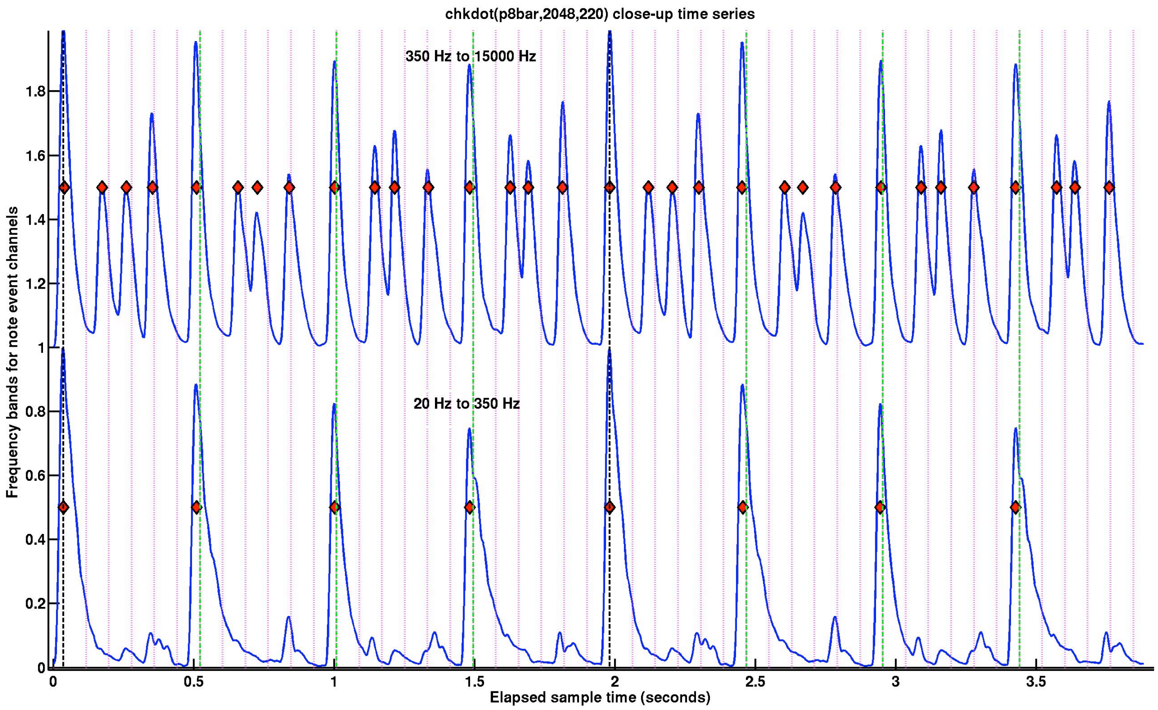

Figure 5.3.3.7 Close-up of Events in Swingee Pandeiro Batida

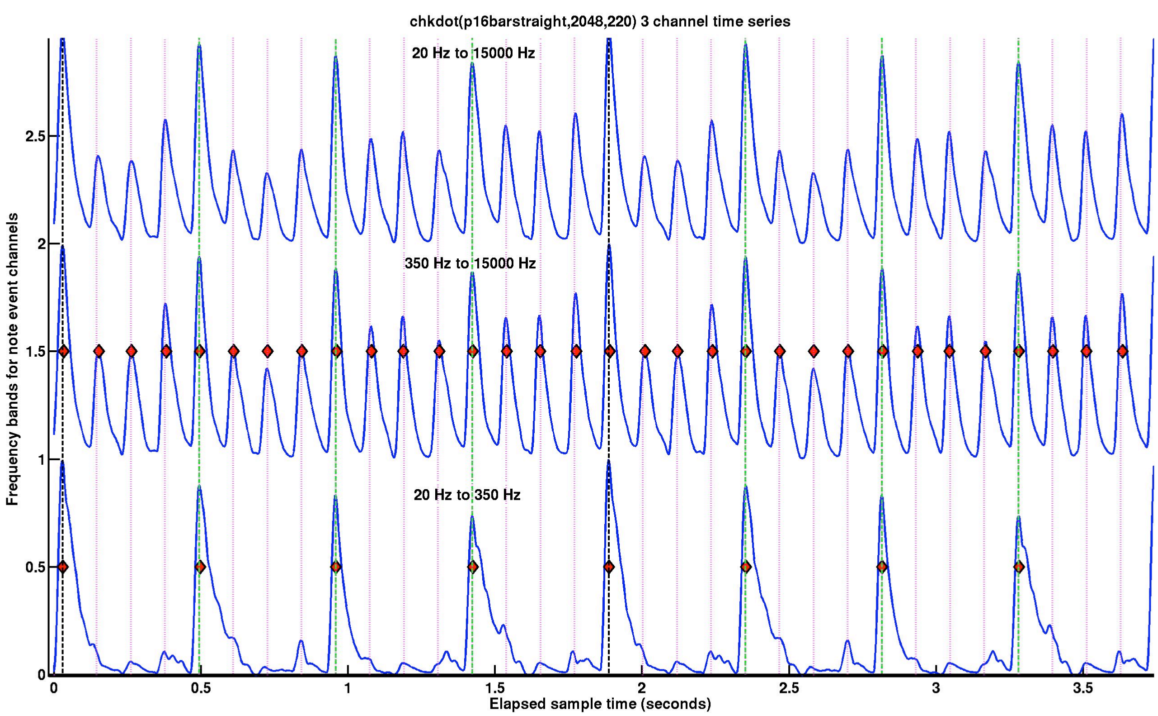

Figure 5.3.3.8 Close-up of Events in Straight Pandeiro Batida

5.3.4 ***It Don't Mean a Thing if it Ain't Got that Swing***

Figure 5.3.4.1 is a time series plot for the beginning of Duke Ellington and Louis Armstrong's 1962 performance of ***It Don't Mean a Thing if it Ain't Got that Swing***. The upper event track shows the hi-hat cymbal sound as the drummer fades himself into the mix by playing slightly louder with each beat -- no overdubs or mixer board fading here. You can see how hi-hat note events start the phrase slightly off from the MB time locations and then home in on the exact time location of the triplet pickup to the beat.

Figure 5.3.4.2 shows the `diffdot` plot. The pulse timing shows some variance, but the red events (hi-hat) are tightly clustered on the 1/2 and 1/3 subdivisions, with a third cluster midway between the 1/6 and 1/8 subdivision. Figure 5.3.4.3 shows a larger view. The trumpet note events are visible in frequency bands 3,4 and 5. Figures 5.3.4.4-6 are specgrams showing both the rhythm section and Louis Armstrong's trumpet solo.

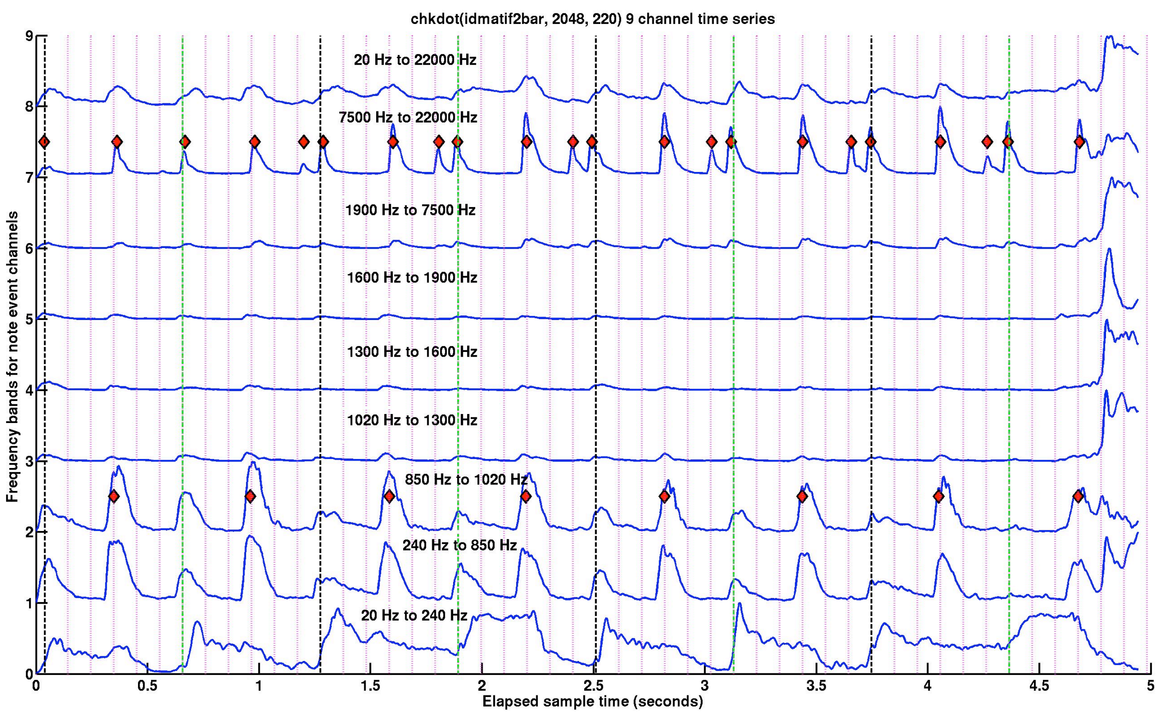

Figure 5.3.4.1 Events for ***It Don't Mean a Thing if it Ain't Got that Swing***

Hi-hat cymbal events marked in upper row, piano/bass in lower rows.

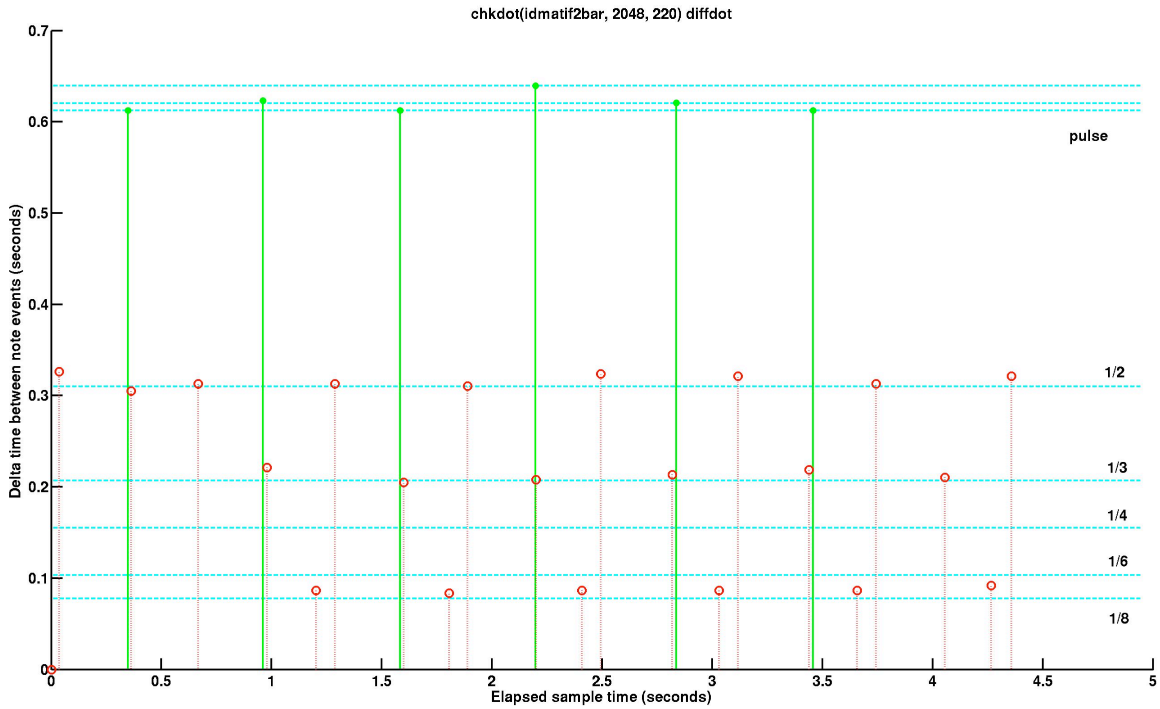

Figure 5.3.4.2 Event Times: ***It Don't Mean a Thing if it Ain't Got that Swing***

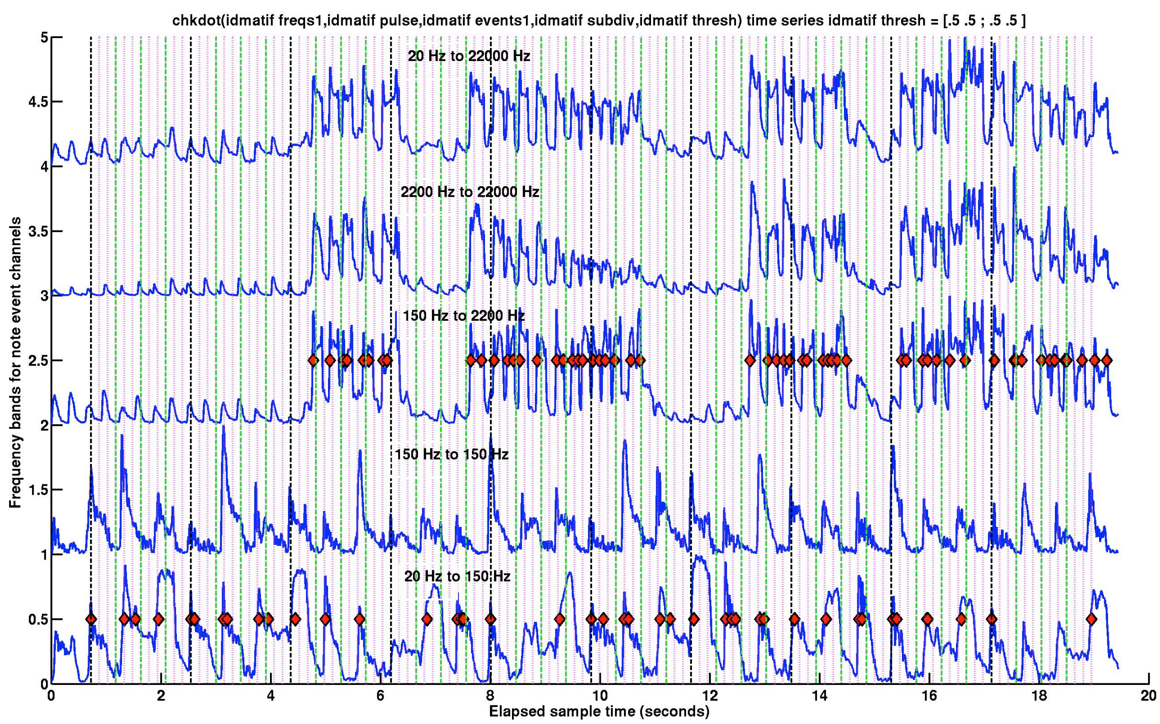

Figure 5.3.4.3 Time Series Plot Showing Rhythm and Trumpet Events

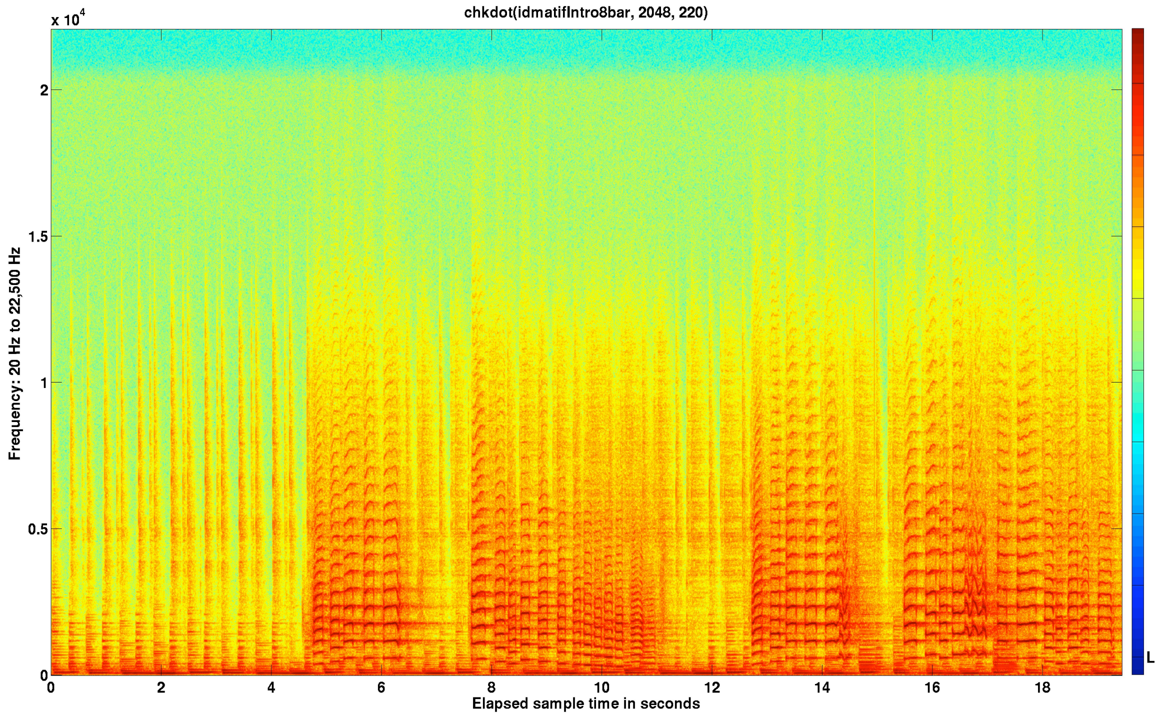

Figure 5.3.4.4 Specgram of Intro for ***It Don't Mean a Thing if it Ain't Got that Swing***

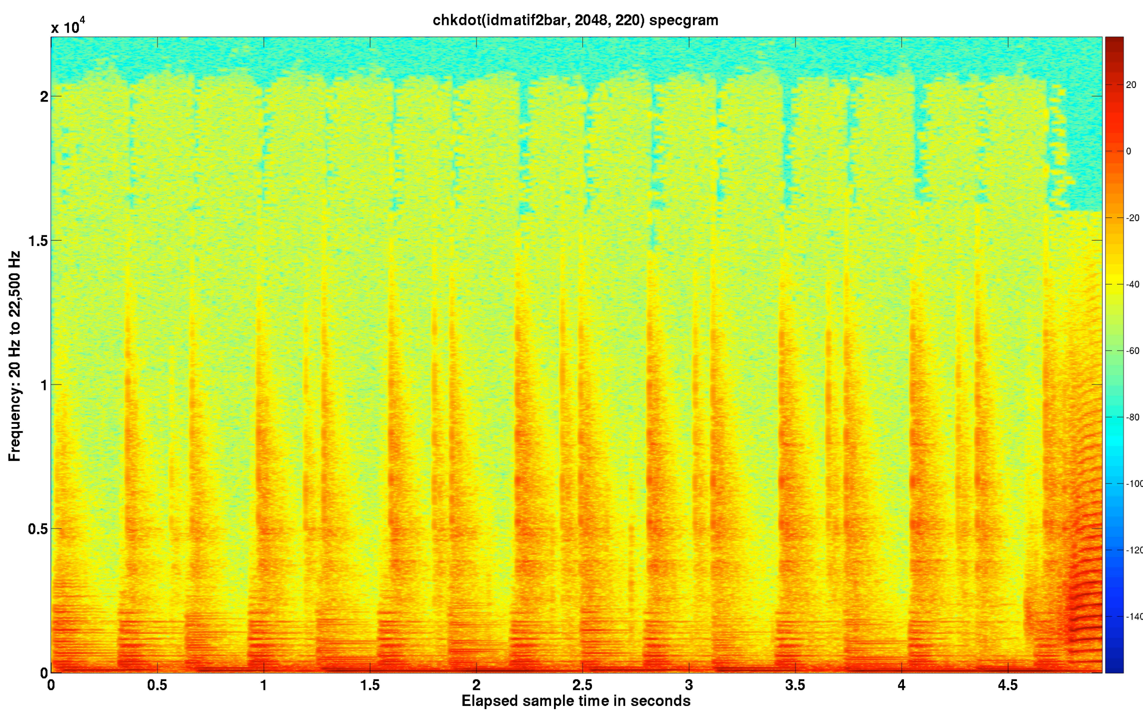

Figure 5.3.4.5 Close-up of Specgram of Intro Showing Piano and Drums

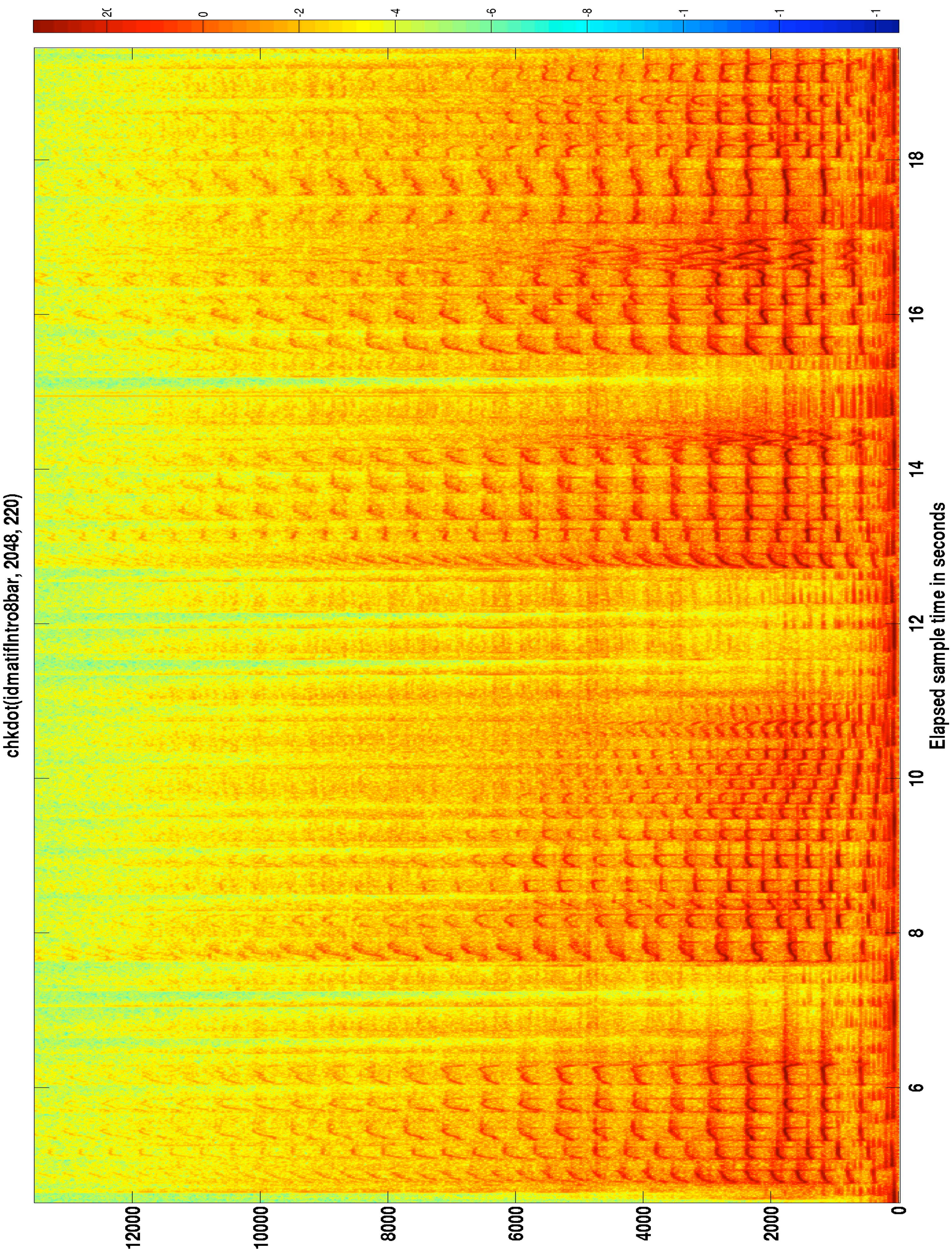

Figure 5.3.4.6 Close-up of Specgram Showing Trumpet Note Events

5.3.5 Tamborim Batida: Playing Around the Beat

Figure 5.3.5.1 shows slight timing variations in the performance by a tamborim player. We discovered these during extreme close inspection. In this sample, the pandeiro plays the principle beats (downbeats and offbeats) in the lower plot. The other notes in the pandeiro batida are not shown but are the same as in the previous analysis of the pandeiro batida. Note that the principle beats are not all exactly on MB subdivisions. This intentional and quite precise looseness is part of the swingee style. Both the tamborim and the pandeiro play some notes exactly on the MB subdivisions and some notes slightly off, generally ahead of the beat. These variations are typically between about 20 milliseconds and 50 milliseconds.

In the upper plot when the tamborim starts playing, it is not at the standard beginning of the batida. Instead the drummer plays a variation on a portion of the second half of the entire tamborim phrase, which leads into the downbeat. The downbeat is indicated by the green marker at time location 1700, except there is a further variation -- it is not the primary downbeat but the offbeat, so the tamborim is playing on the opposite side from the pandeiro. This is not however, the *wrong* side. It is very common in Brasilian music for some two phrase batidas to be played with the two phrases swapped. This is analogous to the 3-2 clave and 2-3 clave style in Cuban music. Swapping the sides gives a different feel, usually more syncopated if the unfamiliar variant is played.

The tamborim batida is very syncopated even when played straight. The "standard" place to start the basic tamborim batida is at note event #6 in figure 5.3.5.1 at temporal location 1700, very slightly ahead of the beat. Many batidas have beats that are played ahead of the MB subdivision beat, and/or also slightly ahead of or behind the note events of other instruments. In this example, at this temporal location, the pandeiro plays about 30 milliseconds ahead of the MB subdivision downbeat, and the tamborim plays about 15 milliseconds ahead of the pandeiro. This is not accidental but is used to give a push to the feeling of the rhythm by both instruments. A few beats on either side of the

1700 point, both instruments have notes that are played exactly on an MB subdivision. The feeling of this pattern is quite consistently the same throughout the entire sample which is several minutes long.

Looking at the two sets of three evenly spaced notes starting at 1700 and 2000, note that the first and third beats are slightly ahead of where they would be if played exactly according to *some* even MB subdivision, however complex the subdivision might be. To reiterate, these beats push the rhythm slightly and give a somewhat more energetic feeling to the music than if they are played “straight”. This is what we referred to previously as parallel time shift of non sequential but related note events. In this case, these two tamborim note events are also accented, further emphasizing the push to the rhythm at these two time points. The combination of time push and accent are caused by the tamborim player putting a little extra “juice” into the rhythm for these note events. (Waadelund, 2004) has studied the relation between this type of “body english” and the rhythms played by drummers on drum kits. The investigation of the relation between motion and rhythm started in the early 20th century. (Seashore, 1938) and (Gabrielsson, 1987) both include a variety of reports, insights and opinions about this phenomenon.

In our example, the tamborim plays the first beat right on top of the pandeiro on the “real” downbeat, instead of playing at the “standard” temporal location for the note. This portion of the batida starts its repetition at the ninth event location (time 2000, triplet pickup to downbeat), just before the main downbeat, marked by the black line at time 2050. You can see that the first beat ordinarily is on the triplet pickup to the downbeat, and the next two beats are *almost* exactly evenly spaced on the subsequent triplet time points. The slight variations from playing exactly on temporal locations that correspond to an MB subdivision are part of the swingee style. While there is some looseness similar to the ***Graceland*** example, generally Brasilians play these slight temporal variations quite precisely, consistently and intentionally.

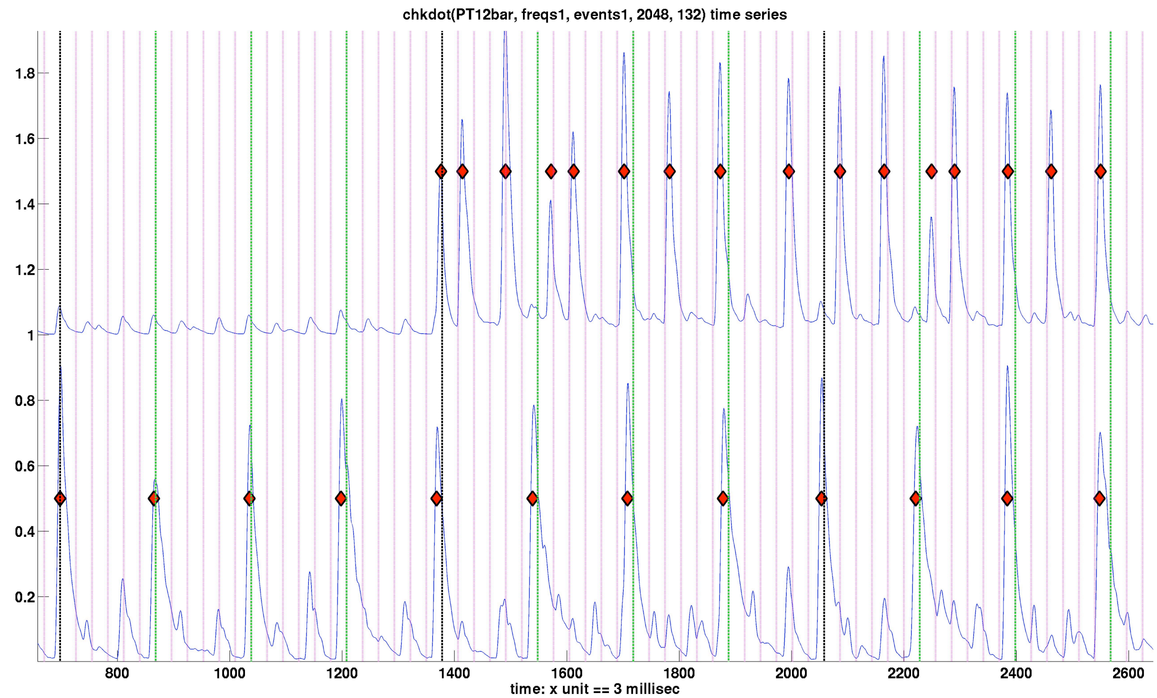

Figure 5.3.5.1 ***Tamborim Batida***: Playing Around the Beat

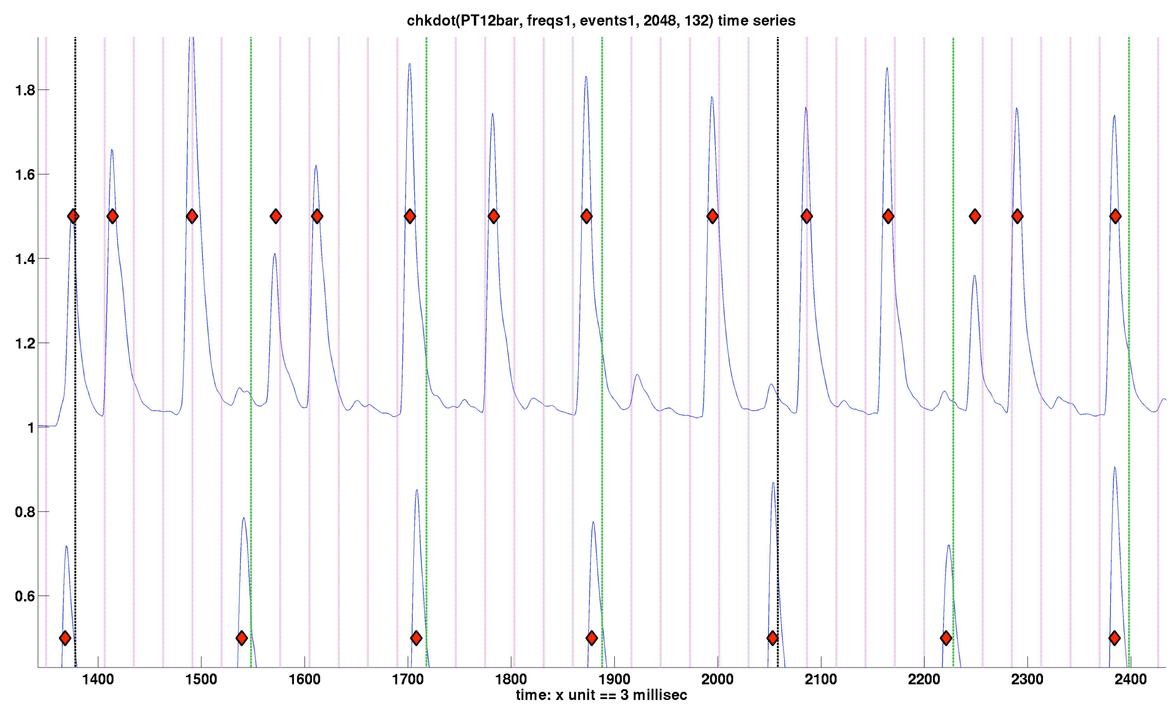

Figure 5.3.5.2 ***Tamborim Batida***: Playing Around the Beat (close up)

5.3.6 Shuffle (Surdo and Afoxe)

We use the term shuffle to describe a wide range of swing rhythms. A shuffle has a temporally less exact sound than typical percussion note events. Shakers, brushes on a snare drum or hi-hat cymbal, caixa, afoxe, guiro are all examples of shuffle instruments. Single events can be identified, but overall there is a feeling of blurring and blending of each note event into the next. The meter of the rhythm is defined by the loudness peaks or other identifiable but somewhat temporally ambiguous events. Shuffle is an odd combination of vagueness and precision, difficult to describe with language.

Note ID is more difficult for these less precise musical events, and marking the onset time locations precisely can be subject to interpretation of how the rhythm feels. The standard Brasilian ganza (shaker) rhythm usually has a noticeable snap that leads the downbeat, but the remaining notes are more blurry. The snap gives a precise anchor to the rhythm which makes the blurry parts sound well integrated to the ensemble swing, rather than being played carelessly. It is easy to see in the `diffdot` plots how the swingee and straight versions of this sample have quite different timing variations in both the pulse and secondary events tracks. Even the straight version has a substantial amount of temporal variations, similar to ***Graceland.***

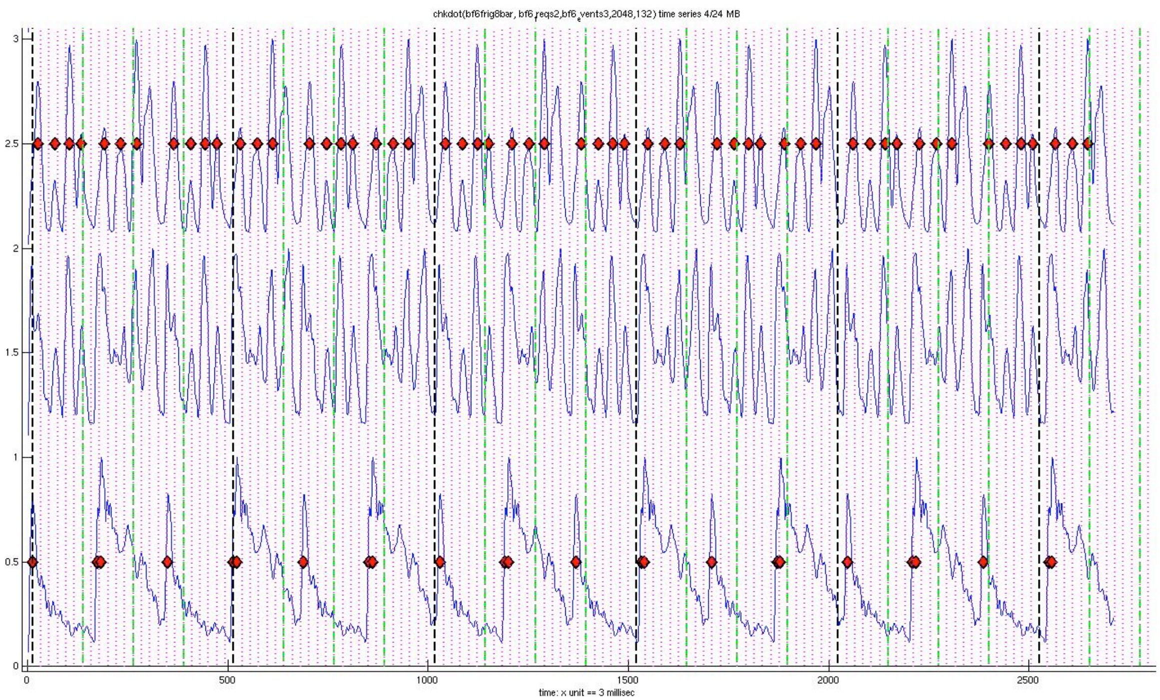

Figure 5.3.6.1 Time Series Plot for Swingee Shuffle Batida

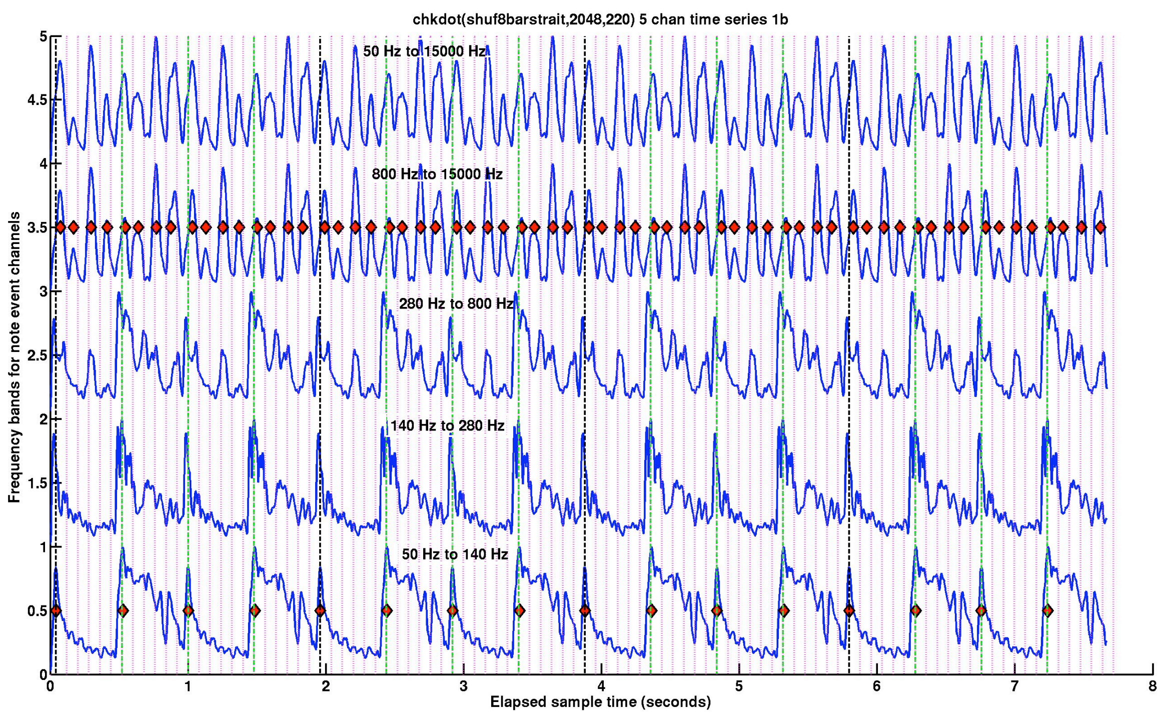

Figure 5.3.6.2 Time Series Plot for Straightened Shuffle Batida

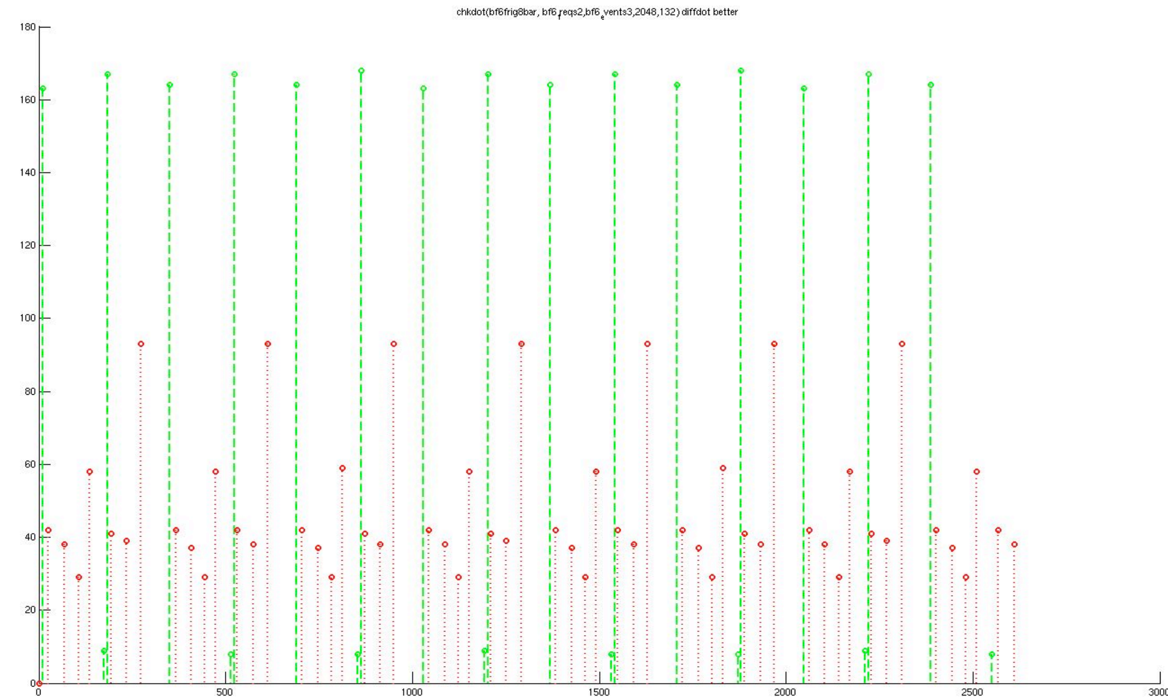

Figure 5.3.6.3 Note Timing Chart for Swingee Shuffle Batida

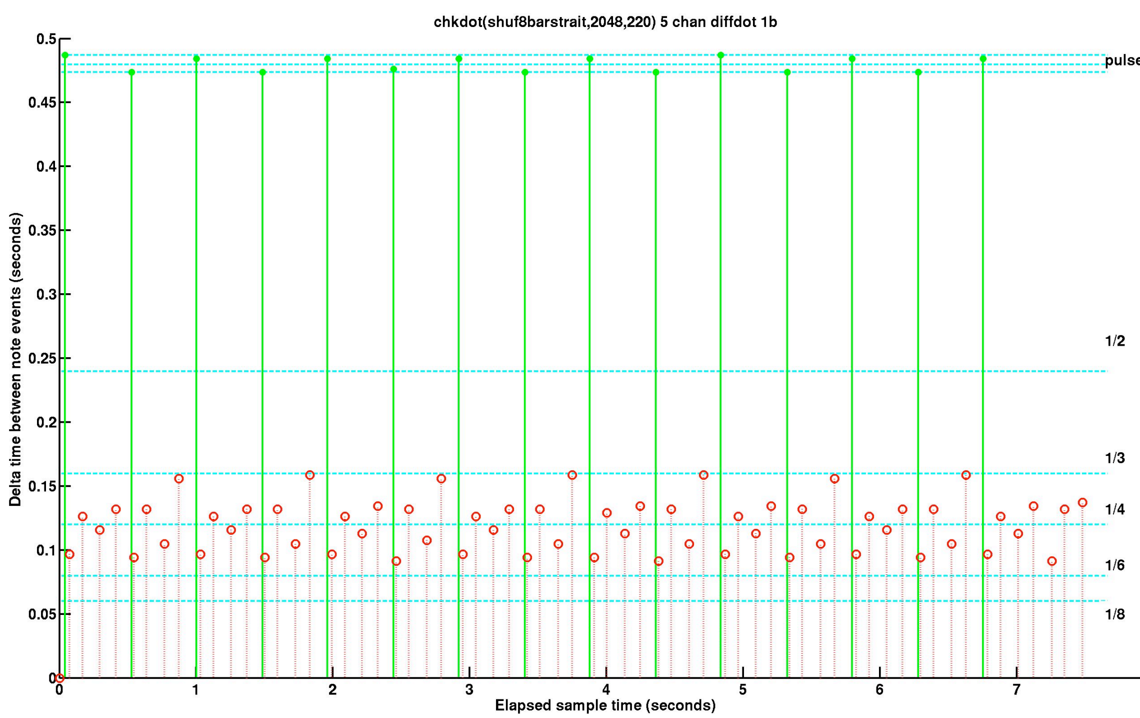

Figure 5.3.6.4 Note Timing Chart for Straightened Shuffle Batida

5.3.7 Reggae by Bob Marley

Reggae music from Jamaica is characterized by complex rhythms, many of which explicitly use the *absence* of a note event as a rhythmic anchor. In American music, note events on the downbeat or backbeat typically anchor the rhythm at the 1 or 3 beat of a 4 beat measure. In Reggae, the downbeat is often not played by any instrument, and other canonical MB beat locations may be demarcated by silence, perhaps followed by several very quick drum beats in a complex rhythm which may *end* on the next canonical MB beat. Detection of rhythms which have an empty note event as an important feature of their pattern is a challenging task, both for a musician or a computer algorithm. In addition, the counting scheme in our algorithm was developed for more conventional rhythms, and is quite inadequate for satisfactory extraction of the rhythmic structure of Reggae. Nonetheless, we had some success and show these results in this section.

Stir it up (1973) is one of the best love songs ever written (in my opinion, and my fiancee's). It begins with a very tight and clipped *kip* played on the backbeat of the rhythm by Bob Marley on the electric guitar. As the other instruments join in, a sparse and relatively simple sounding gestalt emerges, and the kip is revealed as a backbeat, whereas played by itself, it could be interpreted as the downbeat. I find it impossible not to dance to this tune (making it difficult to write this section sitting down).

Figure 5.3.7.1 shows the specgram for the intro to ***Stir it up.*** The six double short vertical red lines at the left are the kip. Later in the song this double beat is sometimes played as a triple or quadruple set of beats, maintaining the same tight rhythm. One outstanding feature of the specgram for this song is the presence of the row of pyramids in the lower part of the figure. This is caused by the sound of the keyboard as its notes roll smoothly up and down in frequency. Given the large number of Biblical references in Bob Marley's lyrics, I suspect he would like this revelation. Indeed, he might even claim that it is an intentional accident.

The pulse and bass drum events are shown in figures 5.3.7.2 and 5.3.7.3, which are subdivided in thirds, even though we have not yet found any real evidence for triplets in this song. We made plots using other subdivisions, but the figures we present seem the clearest. The pulse beats are either on the MB beat location lines, or exactly between two of the triplet lines, indicating a very straight and tight quarter note subdivision.

Figures 5.3.7.4 and 5.3.7.5 show close-ups of the pulse, and drum break. Both are very exactly subdivided in a multiple of two, 1/8th or 16th notes, depending on how one chooses to count and subdivide a measure. Figures 5.3.7.6 and 5.3.7.7 show specgrams of Bob Marley singing. These are quite beyond our current analytical approach, and would require both finer resolution in the spectral decomposition and much more sophisticated pattern recognition than we now use. We include them, like the pyramids, for their peculiar and somewhat mysterious beauty. Figures 5.3.7.8 shows a tempo change of the pulse.

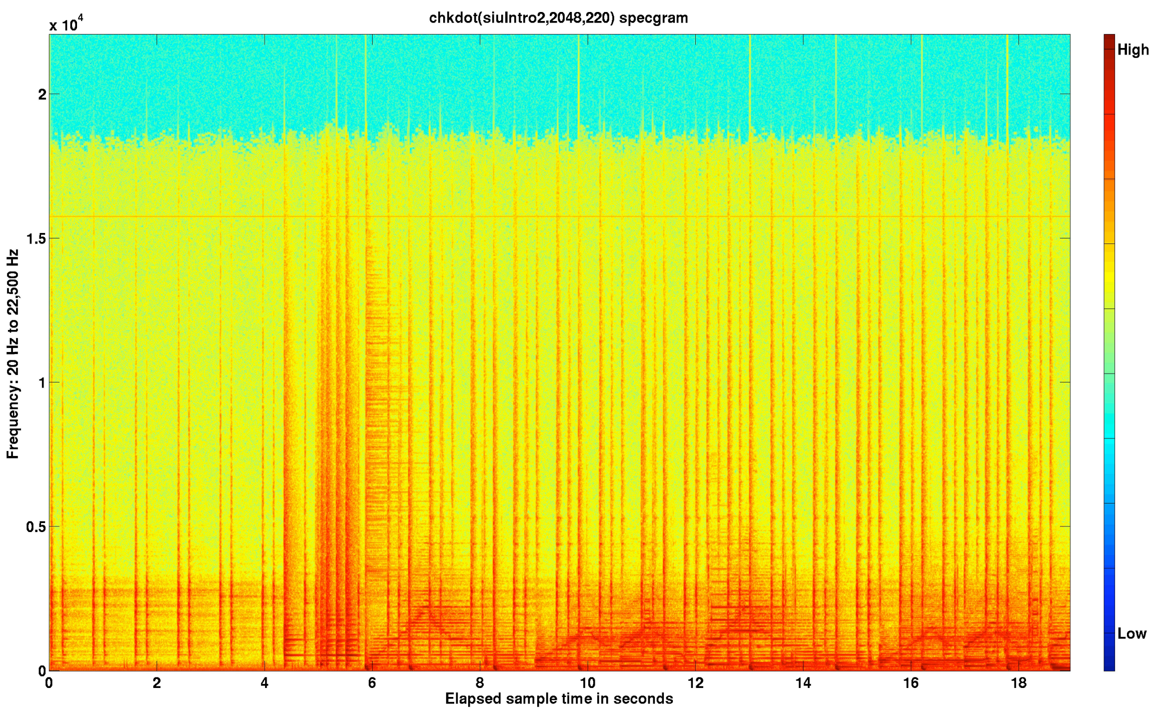

Figure 5.3.7.1 Specgram for Intro of ***Stir it up***

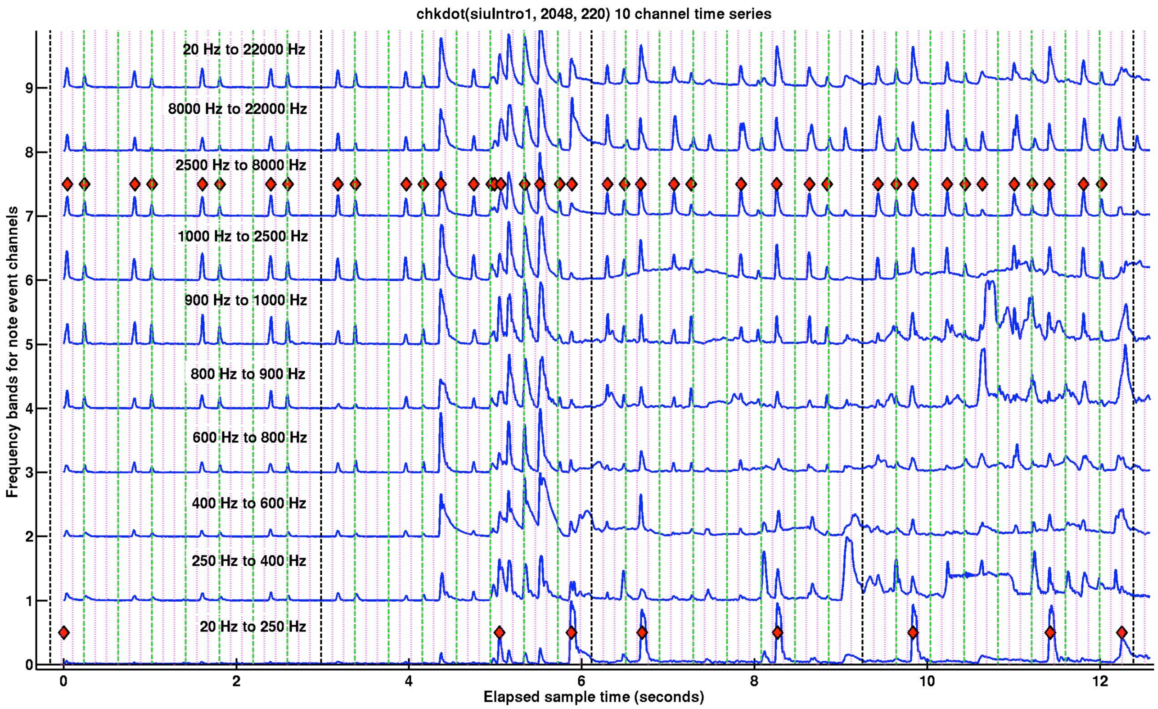

Figure 5.3.7.2 Ten Channel Events Time Series for ***Stir it up***

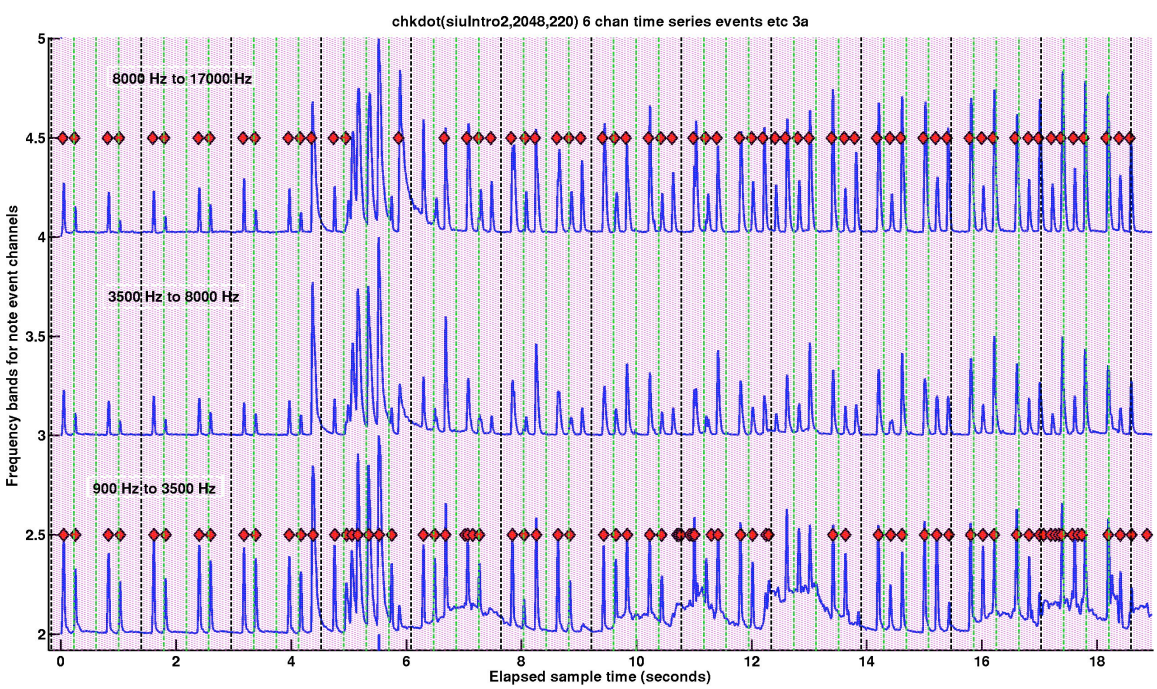

Figure 5.3.7.3 Close-up of Pulse and Drum Channels for ***Stir it up***

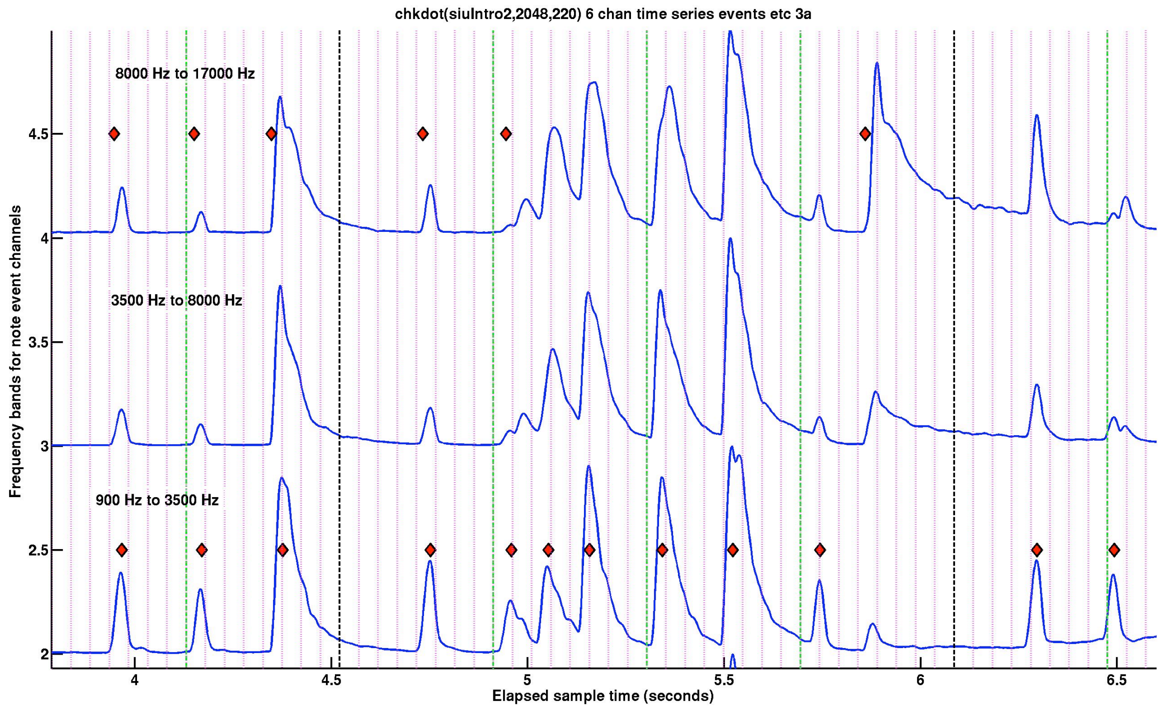

Figure 5.3.7.4 Close-up of Pulse and Drum Break for ***Stir it up***

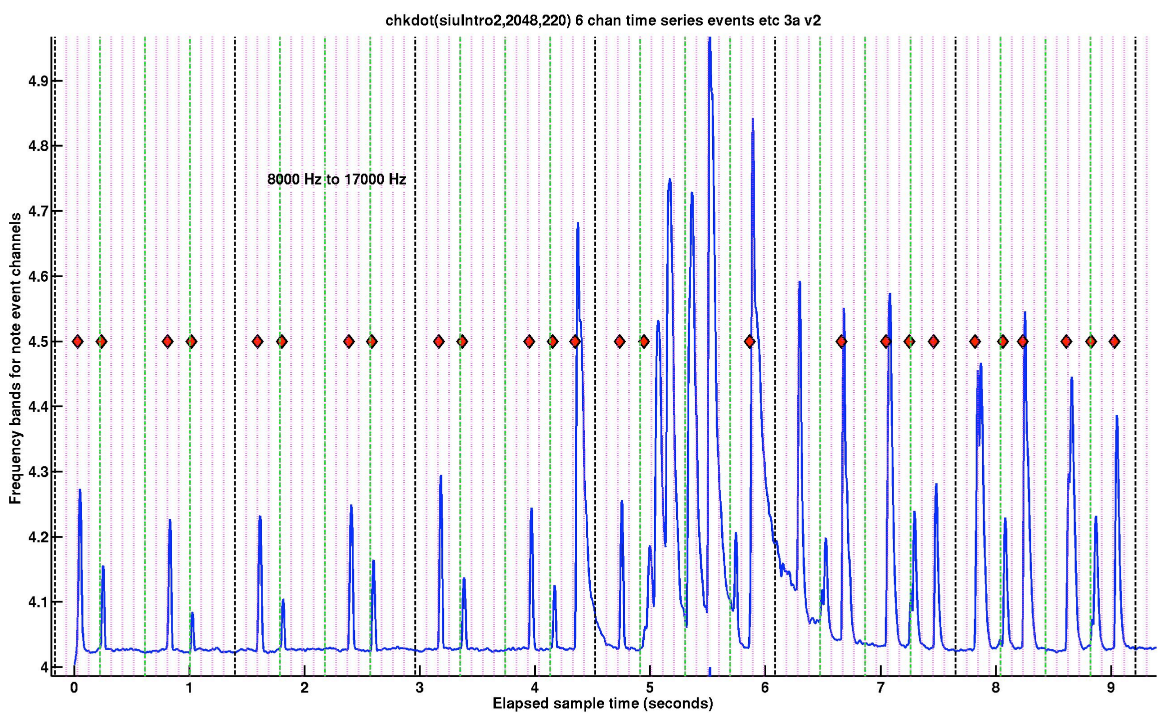

Figure 5.3.7.5 Close-up of Pulse for ***Stir it up***

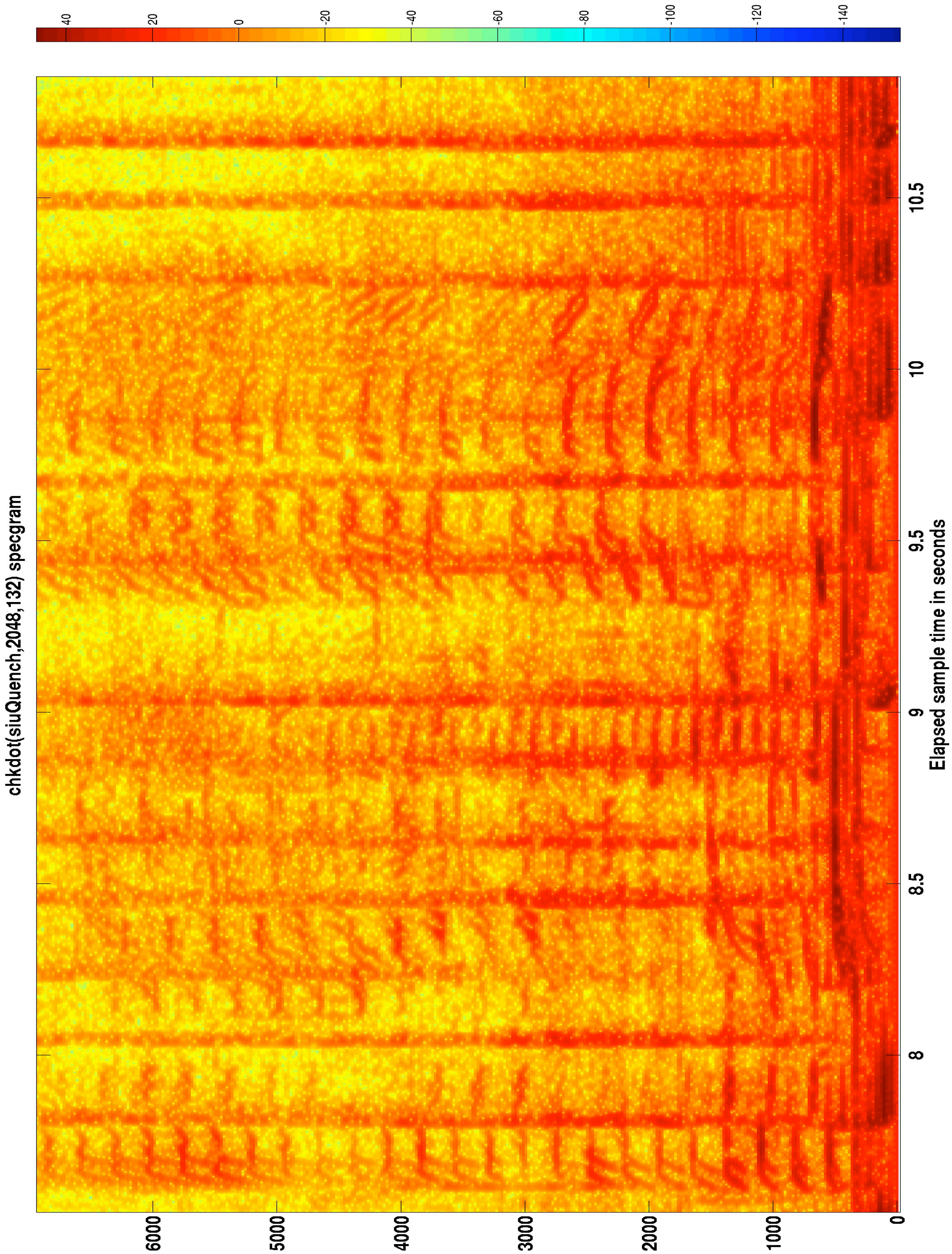

Figure 5.3.7.6 Specgram of Vocal for ***Stir it up: "C'mon cool me down baby ..."***

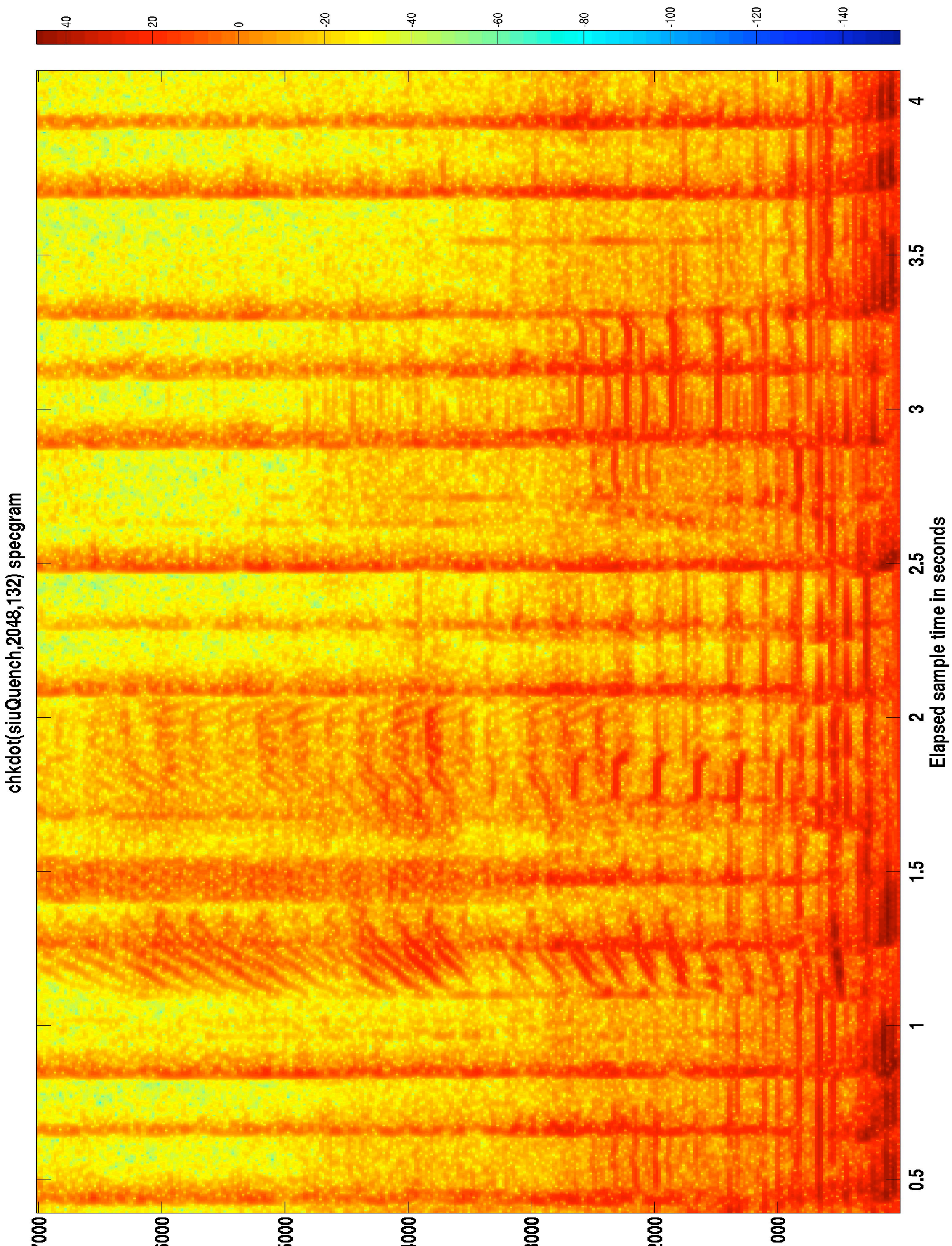

Figure 5.3.7.7 Specgram of Vocal for ***Stir it up: "When I'm thirsty"***

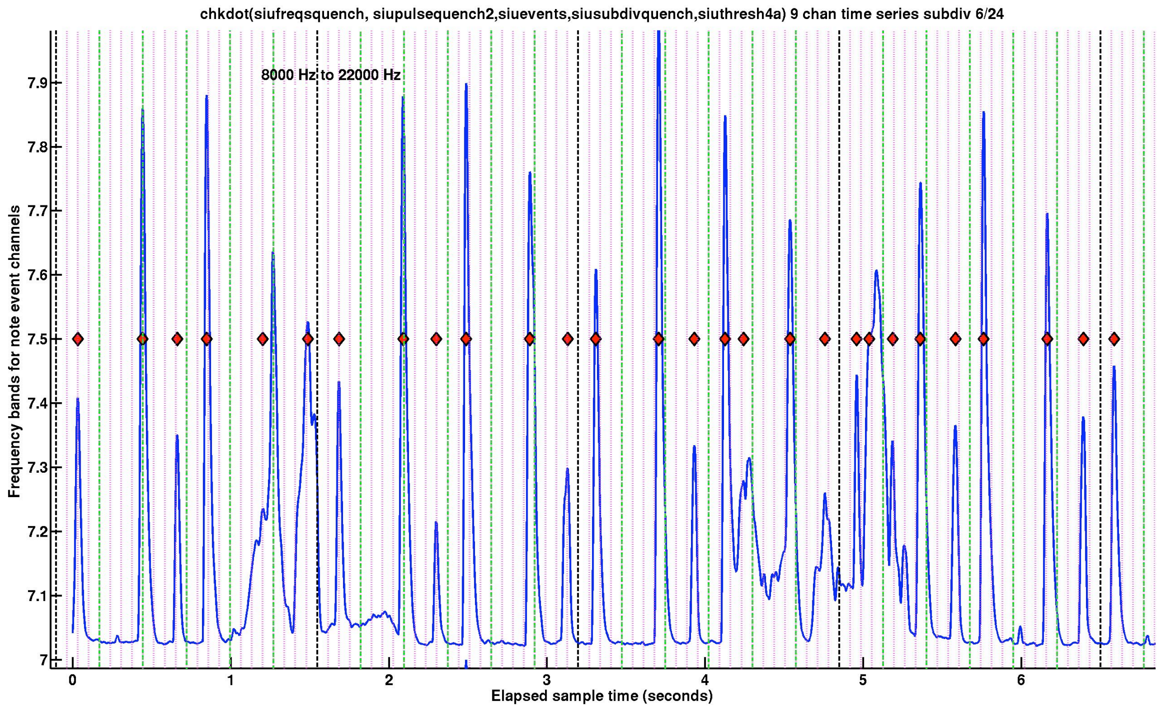

Figure 5.3.7.8 Tempo change in ***Stir it up***

Bob Marley had a very distinctive singing voice. While it might not be considered particularly "good" by some metrics, it is a very expressive and soulful voice. The specgrams showing the singing of lyrics show a great deal more complexity and subtlety than the vocals shown earlier for Natalie Cole singing ***Fever.*** My opinion is that the inter-twining waveforms visible in the specgram are the technical correlate of the emotional expressiveness that is clear when listening to Bob Marley singing. The actual data and information representations presented here are at the limits of what I could achieve with standard Fourier spectral analysis at this time. Techniques that allow finer resolution in the time and frequency domains are needed in order to produce clearer representations of the subtleties of the singing voice. We are addressing some of these technical issues in a separate project, "Optimization strategies for FFT use in musical audio analysis."

5.4 Swingee Notation Music Format

We have devised a novel form of notation that is intended to be a more informative form than standard MB notation. The idea is to make a simple visual rendering, in the context of standard notation, of the types of timing details we have investigated. Figures 5.4.1 and 5.4.2 show this idea using tablature for a pandeiro batida as an example. The pandeiro batida is rendered as straight quarter notes, which is how it is usually taught. Note events which should be played ahead of the MB beat are shown with a red leading edge. The amount of red indicates the amount of temporal variation from the MB beat. Since the triplet pickup to a downbeat, backbeat or offbeat (all canonical MB beat locations) is an important special case, we indicate a perfect triplet subdivision by including a “3” as a footnote to the note glyph in the tablature. Additionally, we color the triplet blue to indicate its special status.

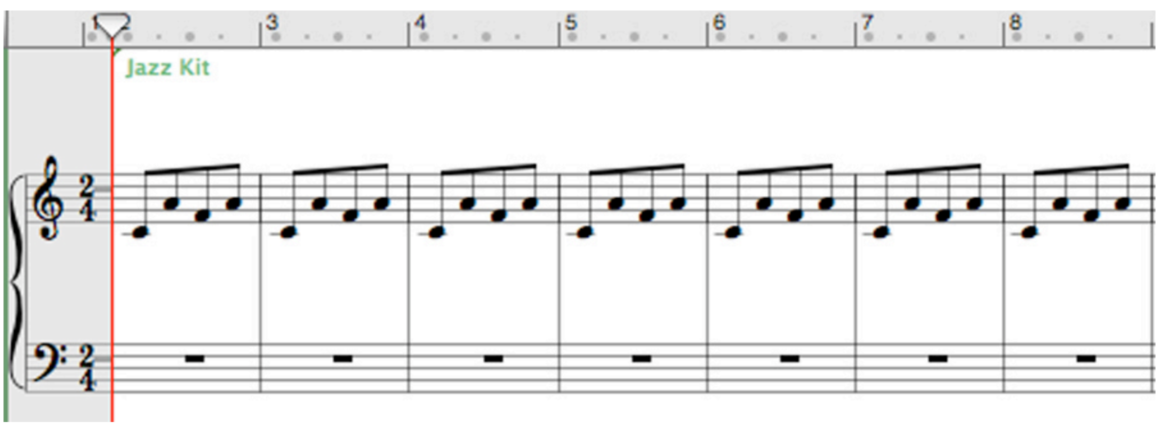

Figure 5.4.1 Standard Notation for Pandeiro Batida

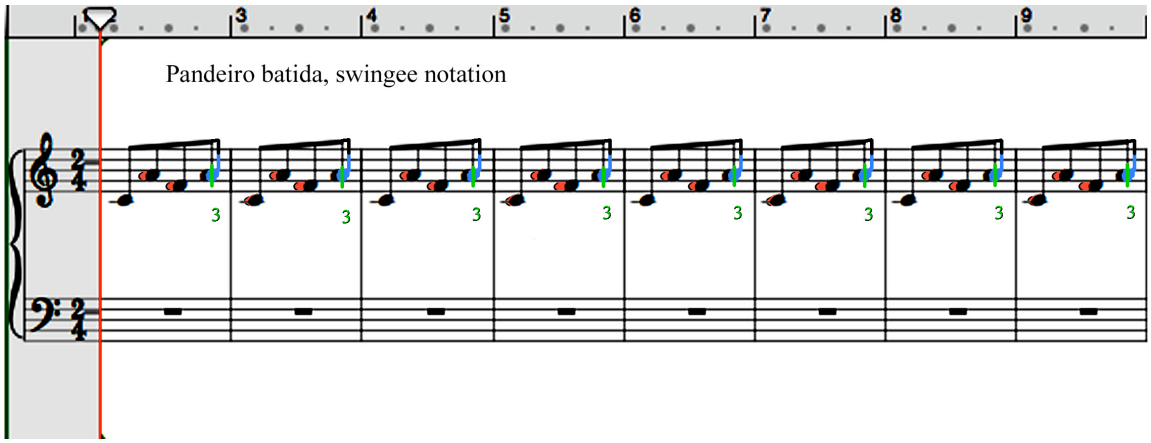

Figure 5.4.2 Swingee Notation for Pandeiro Batida