The Kennedy Half Century

Acoustical Analysis of November 22, 1963 Dallas Police Recordings

Commissioned by Professor Larry J. Sabato
Director, UVA Center for Politics
University Professor of Politics

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Analysis of the Dallas Police Department Dictabelt Recordings Related to the Assassination of President John F. Kennedy

Comparative Analysis of Recordings Derived from the Dallas Police Department

Observations on Properties of Impulses Attributed to Gunfire

Analysis of the Dallas Police Department Dictabelt Recording related to the Assassination of President John F. Kennedy

Charles Olsen, Sonalysts, Inc., Scott Martin, Sonalysts, Inc.
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Abstract — The open microphone transmissions of a Dallas Police Department motorcycle officer's radio are of continuing interest among assassination researchers. If the motorcycle was in the motorcade then it may have detected and transmitted the sounds of gunfire. This study examines features of the recording that have not been rigorously measured until now. Novel methods were applied in order to measure motorcycle engine speed versus time so that it might be compared with the known movements of the motorcade. Detailed analyses of other sound artifacts were also performed. The evidence obtained suggests that the motorcycle was not part of the motorcade and therefore was not in a position to record the sounds of gunfire.

I. Introduction

On November 22 1963, a Dallas police officer's motorcycle radio malfunctioned, and began to transmit more-or-less continuously. Several such transmissions occurred over a time period of about 11 minutes; the first encompassed the time period surrounding the assassination of the president. The sounds recorded during the transmissions consist chiefly of the motorcycle engine noise, various other ambient sounds picked up by the microphone, and radio communications originating from other sources. We use the term "open microphone" to refer to the transmissions made by the motorcycle radio.

If the microphone was in or near Dealey Plaza at the time of the assassination, then it may have detected the sounds of gunfire and these would presumably have been recorded.

II. Technical Background

The Dallas Police Department operated two radio channels on November 22, 1963: channel 1 was used for routine radio traffic, while channel 2 was used by the motorcade. The open microphone was associated with channel 1.

Channel 1 was recorded on a machine made by the Dictaphone company onto a medium called a Dictabelt. The Dictabelt machine used a stylus to emboss a groove into flexible plastic belt, the groove being much like the groove in a phonograph record. Channel 2 was recorded using a machine called a Gray Audograph; this device recorded on a disk resembling a phonograph record, but unlike the phonograph it played from inside to outside and did not rotate at a constant speed.

Both machines were designed to record intermittently. In normal operation, they would begin recording when an audio signal was detected. They would stop recording upon the cessation of the audio signal and after a short time delay. In this manner, recording medium was conserved, and subsequent playback would be free of long periods of silence during times of sparse radio traffic.

Recordings made by both machines were then copied to other media (primarily open-reel tape) by a variety of agencies.

III. Historical Background

The Warren Commission obtained and used a variety of transcripts of the Dictabelt recording, but we have not found any evidence that further research was conducted on the Dictabelt at that time.[1]

In 1979 the House Select Committee on Assassinations (HSCA) issued a report in which they concluded that there was a high probability that two gunmen were involved in the assassination and that President Kennedy was "probably assassinated as a result of a conspiracy"[2] These findings were based on an acoustic analysis study of the Dictabelt performed by Dr. James E. Barger, *et al*. of Bolt, Beranek and Newman[3] (BBN, BRSW). BRSW's research identified three shots from the Texas School Book Depository and established a high probability of a shot originating from the grassy knoll. The committee asked Weiss and Aschkenasy of Queens College of the City University of New York to review BRSW's work.[4] Weiss and Aschkenasy confirmed BRSW's research and concluded that there was an even higher probability of a shot from the grassy knoll.

In 1980 the National Academy of Sciences (NAS) was asked by the Justice Department to review the findings of the House select committee. Steve Barber, an independent researcher

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who had identified an instance of crosstalk of a channel 2 transmission in the channel 1 Dictabelt recording, submitted his findings to the NAS.[5][6] This instance of crosstalk was identified as Sheriff Bill Decker speaking the words "Hold everything secure", which was known to have occurred approximately 1 minute after the assassination.[7] This crosstalk was thought to have arisen when the open microphone picked up and retransmitted sounds from a nearby receiver tuned to channel 2.[8] BRSW identified the time of the final shot as occurring around the time of this crosstalk, which is in conflict with the known time of the sheriff's transmission. The NAS Panel concluded that there was no support for the second shooter hypothesis in the Dictabelt recording.[9]

D.B. Thomas wrote a rebuttal of the National Academy of Sciences findings, suggesting that the timing relationship of the crosstalk was in error, probably due to the crosstalk being rerecorded over existing content on the Dictabelt.[10] The NAS Panel then addressed Thomas' assertions in a separate paper.[11]

James Bowles, a former supervisor in the Dallas Police Department radio dispatcher's office, wrote a paper condemning the findings of the HSCA in which he suggested the motorcycle with the open microphone was not associated with the motorcade, but was probably stationed at a location between Dealey Plaza and the hospital.[12]

IV. Provenance of Recordings, Comparative Data, and Development of Timelines

The University of Virginia Center for politics obtained digital copies of several Dallas Police Department radio recordings from the National Archives and Records Administration. The recordings were supplied by Silver Spring Studios; a contractor that acts as a "vendor" for the National Archives. The recordings are all 16 bit uncompressed AIFF files. They are all stereo format and the content of both stereo channels is identical. A complete list of files including technical information is shown in Appendix A.

The recordings were examined and the one named *60 JFK 5 reel_1* was found to contain the relevant channel 1 Dictabelt audio. Other recordings containing relevant channel 2 audio include *60 JFK 2 reel_2* and *60 JFK 6 reel_1*.

No attempt was made to correct the playback speed of the recordings as such processing could introduce artifacts when performed in the digital domain.

Annotated timelines were developed for both channel 1 and channel 2 for the time period surrounding the assassination. The timelines are shown as Appendices B and C. These include a description of specific sounds and when they occur. Historic transcripts were surveyed where they provided relevant information. These were cross-referenced where possible. The following historic transcripts were surveyed:

1. The channel 1 and channel 2 transcripts provided by Inspector J. Herbert Sawyer of the Dallas Police Department as found in Warren Commission exhibit 705.[13]

2. The transcripts made by Sergeant Lester H. Robinson of the Texas Rangers (via Capt. Crowder, Texas Rangers and FBI), as contained in exhibit 705.[13]

3. The transcript of channel 1 provided by Sheriff Decker, found in exhibit 705.[13]

4. The transcript (author unknown) found in the City of Dallas Archives (Box 14, Folder 4, Item 11).[14]

5. Appendices to Bowles' "The Kennedy Assassination Tapes -- A Rebuttal to the Acoustical Evidence Theory" (annotated transcripts for both channels).[12]

60 JFK 5 reel_1 was selected as the basis of the channel 1 timeline, as was *60 JFK 2 reel_2* for the channel 2 timeline. *60 JFK 6 reel_1* was also examined. This decision was prompted by the abundance of skips in the latter. The other recordings we obtained either encompass different time periods or were found to contain inferior copies of the relevant audio.

V. Measurement Protocol

In this section the various methods of measurement are described. Results obtained by these methods are discussed in subsequent sections.

A. Analysis of artifacts of the recording process

The channel 1 recording was examined for evidence of multiple copies having been made in the past. We first looked at the beginning and the end of the recording in order to see the sequence of events that would be expected to arise in the case of the recording being a multi-generation copy. Evidence of this nature includes multiple hum signatures, discrete changes in broadband spectral noise density with time, and impulses caused by electrical or mechanical switching that might be expected at the onset of such events. These measurements provide an insight into how many preceding copies may have been made. Spectrographic examination provided details of the relevant features with the exception of the hum measurement. Hum measurement was performed using purpose-designed software.

Editing of the recording may have resulted in discontinuities or artifacts at the edit points. A variation in the spectral composition or hum signature might be expected on such occasions, and thus be revealed by our measurements.

We measured the AC power hum present in the recording in order to determine the correct playback speed for the recording, and as a means of identifying any discontinuities or stepwise changes in the hum frequency. This measurement also would indicate if gradual speed changes existed in the recording.

Portions of the spectrum around the hum frequencies were selected for analysis. We employed narrow high-order bandpass filters to do this. Filter bandwidths were typically 5 to 10% of the center frequency, and a Butterworth response was used to obtain a reasonable transition to the stop band while maintaining a maximally-flat passband response. The filters were characterized to ensure minimal ringing and acceptable transient behavior by measuring their response to specially-designed test signals.

Initially, AC power hum measurements were attempted by applying a zero crossing detector to the filter output. This method demonstrated poor noise immunity due to the frequent transients that occur within the recording. Longer transients tended to introduce baseline shifts that skewed the locations of the zero crossings. In other instances the transients would add to the hum signal in a way that would produce multiple peaks or nullify hum waveform peaks if they combine out-of-phase. The magnitude of these transients is many times that of the hum signal and the transients contain significant energy within the filter passband. We experimentally verified the effect of transients by creating sinusoidal test signals and adding transients to them. Measurement of these test signals revealed a correlation between measurement errors and transients. A similar detection method that measured the span between waveform peaks proved to be only slightly better as it too was amplitude-sensitive. Both methods were abandoned because of their poor noise immunity.

Subsequent experiments using a peak limiter to reduce the amplitude of the transients resulted in much better measurement performance. The peak limiter time constants were chosen to be much shorter than the period of the AC power hum. These peak limiter experiments confirm the observations obtained with experimental data suggesting that it is the transients that upset the measurement.

Finally, we devised an alternative method in which peaks were detected based on changes in slope. This method treated peaks as relative minima and maxima in the signal, rather than relying on the signal exceeding an arbitrary amplitude threshold. Whenever the signal's slope changed sign, a peak was registered at that location.

Positive and negative peaks were counted independently, and the times at which they occurred were recorded. Once sufficient samples were acquired, the number of peaks and the total time span from peak to peak were used to compute a frequency, as shown in Figure 1.

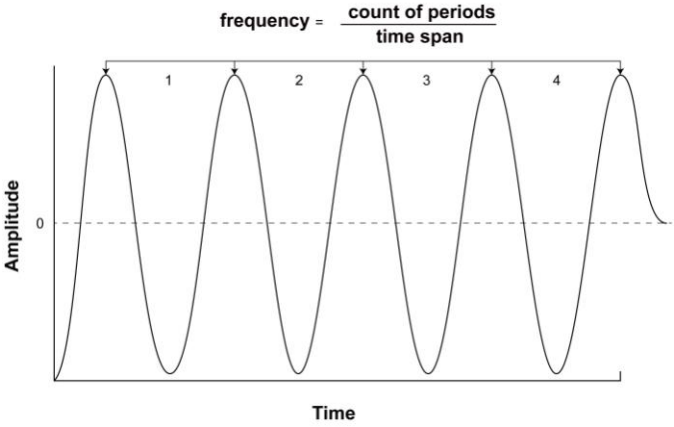

Figure 1: Hum Frequency Measurement Method

This method also had its drawbacks, including sensitivity to low-amplitude, high-frequency signals in the original recording. A convolution filter was built into the algorithm to further combat high-frequency noise artifacts. The filter smoothed the signal and reduced the high-frequency components of the signal by averaging nearby samples. (The filter time constant was considerably shorter than the period of the hum signal we wished to detect.)

B. Analysis of heterodynes, detection of underlying speech

Heterodyne tones appear during the open microphone portion of the recording. These tones arise as a result of multiple transmitters operating at slightly different frequencies. The frequency of the tone represents a difference in transmitter carrier frequencies. The number of tones can rapidly increase for more than two transmitters operating simultaneously due to intermodulation.

The heterodyne tones are important for several reasons. They can be used to identify the onset and duration of individual transmissions, even where the voice modulation is weak or absent. By examining their spectral characteristics, they may be catalogued, and in some cases this allows the identification of individual transmitters even when other identifying information is absent. Finally, instances of crosstalk (where the open microphone reproduced the sound of a nearby radio tuned to channel 2) do not have heterodynes associated with them. This is because the crosstalk sounds were acoustically coupled to the open microphone and are not representative of an additional transmitter operating on channel 1.

The frequency of the heterodyne tones was observed using Fast Fourier Transform (FFT) spectrum analysis. The tones typically contain a substantial energy and are easily distinguished. Their frequency may be measured with a varying degree of precision depending on their duration. This constraint is a property of the FFT and is discussed in further detail in the motorcycle noise analysis section.

The heterodyne tones typically occupy a very narrow range of frequencies, and a notch filter may be used to remove the

majority of these tones with minimal disturbance to neighboring frequencies. This, in turn, is helpful to better hear what is being said during the transmission, and this was done where content was ambiguous or not understandable beforehand.

C. Analysis of other sounds

Various incidental sounds appear throughout the recording. These include artifacts of the radio system operation and incidental sounds transmitted by the open microphone. Artifacts of the radio system include transients associated the operation of the radios, a transient at the end of dispatcher transmissions, and "squelch tails" – short bursts of noise associated with the cessation of a transmission and the subsequent operation of a receiver's squelch circuit.[i] Examples of incidental sounds transmitted by the open microphone include instances of a person whistling, the sound of car horns, sirens, and so forth.

In each case we attempted to quantitatively measure the sounds. We did this by examining their spectral and temporal characteristics. We took note of the harmonic composition of loud sounds as an indicator where we suspected nonlinearity due to overload.

D. Analysis of motorcycle engine sounds

The sounds of the motorcycle engine can be heard in many parts of this recording during the open microphone transmissions. The majority of these sounds have a timing relationship with the firing of the cylinders.

The Dallas Police Department operated two types of motorcycles in 1963. The first type, the 74 cubic inch Harley-Davidson Duo-glide, was employed as an escort vehicle in the motorcade. The second type of motorcycle was the Harley-Davidson Servi-car, which had three wheels and was powered by a 45 cubic inch engine. There was only one Servi-car in the motorcade, and it was the rearmost motorcycle.[15] Both types of vehicles were also used elsewhere throughout the city of Dallas.

Both types of motorcycles were equipped with Harley-Davidson V-twin engines. In these engines, the two cylinders fire alternately, with each cylinder firing once for every two rotations of the crankshaft. This alternating firing sequence results in exhaust impulse being emitted on each revolution of the crankshaft. In this way, the pulsations of the exhaust provided direct measure of the speed of the engine crankshaft. The frequency of these impulses in hertz is simply multiplied by 60 in order to obtain the engine speed in RPM.

The fundamental frequency associated with the firing of the cylinders and the motorcycle engine is below the frequency range reproducible by the radio and recording equipment. For example, an engine operating at 1200 RPM has a cylinder firing rate of 20 Hz, which is well below the range of frequencies passed by the radio system. The sound associated with the firing of the cylinders contains a broad range of frequencies and it is the pulsation of the higher frequency components that is audible. So, although the fundamental frequency of the engine cannot be detected, the higher frequency components reveal motorcycle engine speed.

The amplitude envelope of the signal provides a good method for extracting the pulsations due to the cylinders firing. The amplitude envelope can be imagined as a smooth curve connecting all of the peaks of the waveform. Sounds that exhibit a pulsating amplitude characteristic at the rate of engine firing can be expected to have an envelope that describes this characteristic. The rate at which these peaks in the amplitude envelope occur is directly related to the engine speed. This information is visible in a spectrogram of the amplitude envelope provided that it is of sufficient intensity.

A simple way of detecting the envelope is to rectify the signal (i.e. take its absolute value) and then low-pass filter the results. This is analogous to the operation of a simple AM detector, such as that found in a crystal radio. We found this method to be effective, though the operation of the low-pass filter tends to reduce this method's sensitivity to short duration features we wished to examine.

A second method of detecting the envelope is to calculate the magnitude of the analytic signal. The analytic signal allows the original signal to be represented as two components: the amplitude envelope and the instantaneous phase. This is often referred to as the *analytic representation* of the signal. In this case we are concerned only with the amplitude envelope.

Our method of computing the envelope using the analytic signal is as follows. First we performed a Hilbert transform of the original signal.[16] We then time-shifted the original signal to compensate for delay introduced by computing the Hilbert transform. In this way the timing relationship between the two signals was corrected. The magnitude of the analytic signal (i.e. the amplitude envelope) was obtained by computing the geometric mean of these two signals; in other words, by computing the square root of the sum of their squares. Figure 2 shows the sequence of operations for both methods of envelope detection.

In most cases we filtered the data prior to envelope detection in order to select frequency ranges where the energy of the motorcycle engine noise appeared to be concentrated. We also looked at portions of the spectrum where the signal was weak but otherwise free from interference. We generally used high order Bessel and Butterworth filters in order to obtain a rapid transition to the stop band while minimally affecting amplitude and phase within the passband.

Both envelope extraction processes are illustrated in Figure 2.

[i] "Squelch tail" is a term commonly used to describe this sound. It arises because of a time delay between the cessation of a transmitted carrier wave and the operation of the squelch circuit, whose purpose is to mute the audio output of the receiver. During this time interval, an abundance of noise is heard in the absence of a signal.

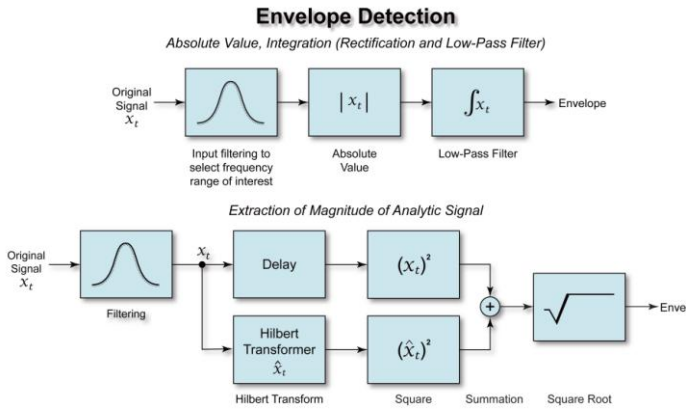

Figure 2: Envelope Detection

The amplitude envelope obtained by both methods was examined spectrographically. Any periodicity in the amplitude envelope was then revealed as a peak in energy. The motorcycle engine noise and several harmonics were clearly visible using this method. Both of the envelope extraction methods performed similarly, and the preceding filtering process (where used) had a greater influence on the quality of the results. In some instances the resultant files were converted to a 11025 Hz sample rate in order to reduce the computational workload in computing the spectra of these low-frequency data. This sample rate conversion afforded the benefit of improved low-frequency resolution for a given FFT window size. Note also that the 11025 Hz sample rate data were obtained by decimating the original data by a whole number ratio; this prevented the emergence of artifacts from the sample rate conversion process.

The *Sonic Visualiser*[ii] program provides a means of extracting time/value pairs from a spectrogram by clicking with a mouse on the features of interest.[17] We used this method to record the motorcycle engine noise frequency versus time. We did this for the amplitude envelope obtained by both methods for the broadband signal as well as specific frequency ranges where we thought the motorcycle energy might be concentrated or disambiguated from interfering sounds. The results of these measurements were plotted on the same set of axes using the *gnuplot* program in order to graph engine speed versus time.

VI. Development of Timelines

The *60 JFK 5 reel_1* recording was examined in detail. Listening evaluations (with and without the benefit of noise filtering and notch filter removal of heterodynes) were conducted. The times of transmissions and their content as well as incidental noises were documented. Heterodyne tones were examined for their spectral peaks and these are also noted in the timeline where relevant. A cursory examination of the *60 JFK 2 reel_2* and *60 JFK 6 reel_1* recordings was used to develop a timeline for the channel 2 data. This channel 2 timeline was used to identify potential instances of crosstalk or broadcast transmissions appearing in channel 1.

No attempt was made to correct for playback speed errors as the timing information was of limited importance in this study. All times we documented are relative to the start of the recordings, and all frequencies are uncorrected for the apparent playback speed error. A correction factor of 1.05 may be used to correct the ***60** JFK 5 reel_1* timing and frequency information according to the 60/57.2 ratio observed in the AC power hum signal.

VII. Analysis of Recording Process Artifacts

A. Analysis of features at beginning and end of recording

A spectrographic analysis of the initial minute of the recording shows the onset of several distinct "regions". This is shown in Figure 3.

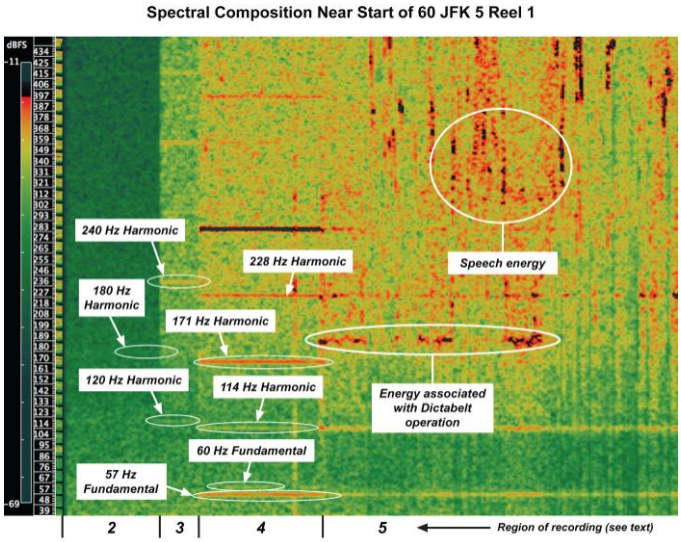

Figure 3: Spectral Composition near Start of *60 JFK 5 reel_1*

Observations at the start of the recording were divided into "regions", each showing distinct spectral composition. These regions are described as follows:

Region 1: (not shown in illustration) From 0.000s through 0.415s, the recording is characterized by extremely low noise and an absence of hum. This is consistent with modern digital recording equipment and probably arose in the duplication process that resulted in our copy of the recording.

Region 2: From 0.415s through 9.519s, 60 Hz hum and several harmonics are evident along with an increase in noise. It is not clear whether this hum originated in the tape recorder used for playback when the digital copy was made, or if it is intrinsic to the recording being played back. It is important to note that the 60 Hz hum that is visible in this region contrasts

[ii] *Sonic Visualiser* is an audio analysis application that we used to generate most of our spectrograms. It is distributed under the GNU General Public License (v2 or later). It was developed at the Centre for Digital Music, Queen Mary, University of London.

with the majority of the recording which contains a strong fundamental hum frequency around 57 Hz.

Region 3: 9.519s through 13.319s. Increase in background noise level just prior to voice announcement in Region 4. 60 Hz AC power hum and several harmonics are evident along with substantial broadband noise that is likely to be "tape hiss". This region is suggestive of a copying process.

Region 4: 13.319s through ca. 25s. The amplitude of the background hum and noise increases relative to the prior regions. This region of the recording contains a barely audible voice announcement that with the aid of noise reduction appears to say: "Police radio channel one dated November twenty second, 1963". A loud transient is evident after the voice announcement and this may be due to the announcer switching-off a microphone. This region of the recording has the following characteristics:

1. Low-frequency noise concentrated in the region below about 50 Hz (not visible in illustration).
2. A broad noise peak between about 200 and 2400 Hz.
3. A hum spectrum containing peaks at:

    - 57 Hz (-65.3 dB relative to Full Scale)
    - 114 Hz (-77.1 dBFS)
    - 171 Hz (-61.7 dBFS)
    - 228 Hz (-62.2 dBFS)
    - 286 Hz (-51.6 dBFS)

    These represent the AC power hum frequency and its first four harmonics.

This region represents the first appearance of a ca. 57 Hz hum frequency. This hum is generally found throughout the remainder of the recording in which the Dictabelts are heard.

Region 5: From ca. 29.53s the playback of a Dictabelt begins here. The Dictabelt recordings contain noise that is measurable during quiet periods. We believe that the noise arises from the motor and mechanical components of the Dictabelt machine, as the spectral composition is not related to the AC power frequency. The noise shows evidence of the Dictabelt machine starting, as its frequency rapidly changes before settling into a steady state. The first voice content recorded on the Dictabelt appears a short time later: "-five three oh nine call five five one..." [iii]

The noise characteristics of a "quiet" segment of the Dictabelt recording are shown in Figure 4.

[iii] Interestingly, an example of crosstalk is heard shortly after this message. Unit 139 (on channel 2) is heard in the background of a transmission made by unit 72. This is an example of crosstalk, where a unit re-transmits audio from a nearby radio tuned to the other channel. This demonstrates that this sort of crosstalk was not only possible, but that it happened. [Relevant channel 2 transmission just after 12:16 time announcement, concerning cars lined up on both sides of Stemmons., ca. 5m 22s on *60 JFK 2 reel_2*]

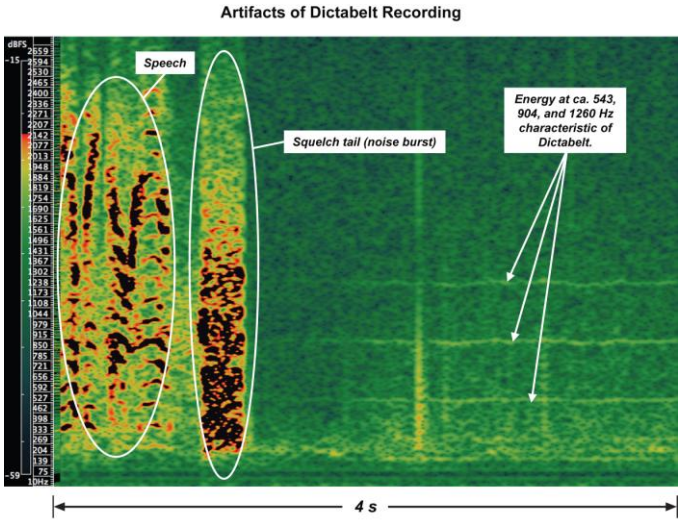

Figure 4: Artifacts of Dictabelt Recording

An analysis of the spectral composition at the end of the *60 JFK 5 reel_1* recording shows features that are consistent with the features at the start of the recording. This is illustrated in Figure 5.

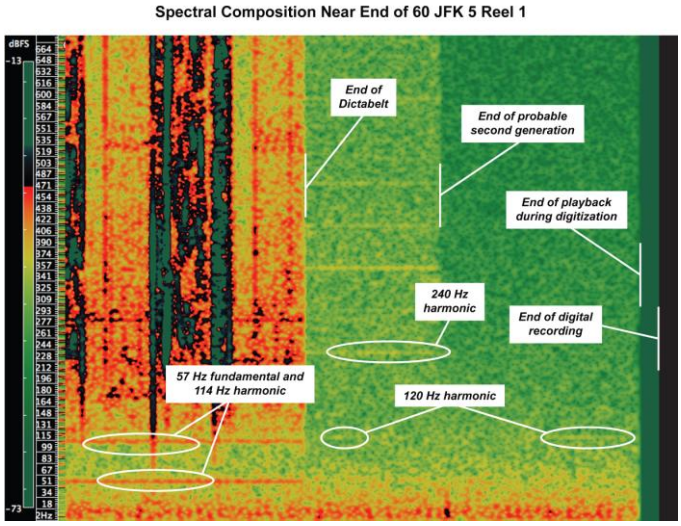

Figure 5: Spectral Composition near End of *60 JFK 5 reel_1*

From these observations we can conclude the following:

1. The digital recording that we obtained has very few artifacts and the digitization process does not contribute significantly to the background noise.
2. The period around the voice announcement in region 4 does not share the noise components associated specifically with the Dictabelt, so it was probably added when a copy was made.
3. The 57 Hz fundamental hum frequency that is found throughout the remainder of the recording is also present at the time of the voice announcement. We can therefore conclude that the speed error (relative to a nominal AC power frequency of 60 Hz) appeared

after both the original recording and the recording of the voice announcement took place.

4. A further duplication step may have caused the onset of hum and noise in region 3. This is also visible at the end of the recording.

In summary, it appears that a copy was made when the voice announcement was added, and a subsequent copy that introduced the speed error was then made. The data suggests that there may be an additional copying step, though this is uncertain. We were unable to detect any artifacts that would suggest more copying processes or editing of the recording from this data.

B. Analysis of Discontinuities

Several discontinuities were noted in the recording. We regard these as having benign origins.

A gap in the recording appears around 53:30. This occurs after the playback skips repeatedly. It may be that the Dictabelt stylus was removed and reinserted into the groove to overcome the skipping. It may also represent a splice in the recording. We do not regard this as serious as it occurs much later than the relevant portion of the recording. The spectral composition of this gap is shown in Figure 6.

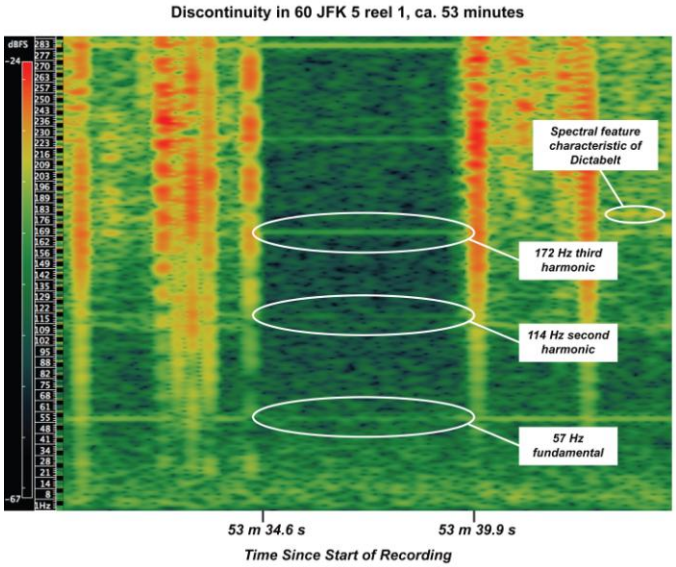

Figure 6: Discontinuity in *60 JFK 5 reel_1*, ca. 53 Minutes

Two apparent speed variations of short duration occur around the time the sirens are present. These are evidenced by a perturbation in frequency of the sounds in the recording. The AC power hum also appears to reveal this, although the events are of such short duration that they are hard to resolve at the hum frequencies. These speed variations may have arisen from a mechanical fault caused by debris, media damage, or someone accidentally contacting a moving part of the equipment at some stage of copying. It is possible that they may have arisen as a result of power line voltage variation present during a copying process. (The speed briefly decreases during these events; a speed increase would have been noted if the original Dictabelt had slowed during the original recording). The recording nonetheless appears to be continuous throughout these short events. A spectrogram of these events is shown in Figure 7 and Figure 8.

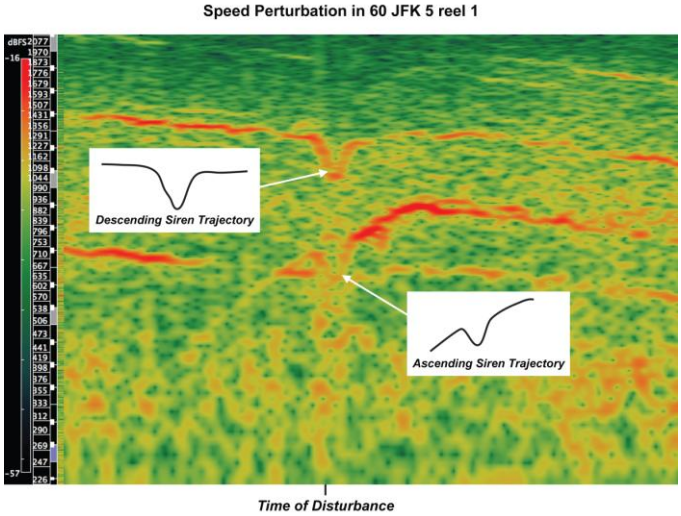

Figure 7: Speed Perturbation in *60 JFK 5 reel_1*

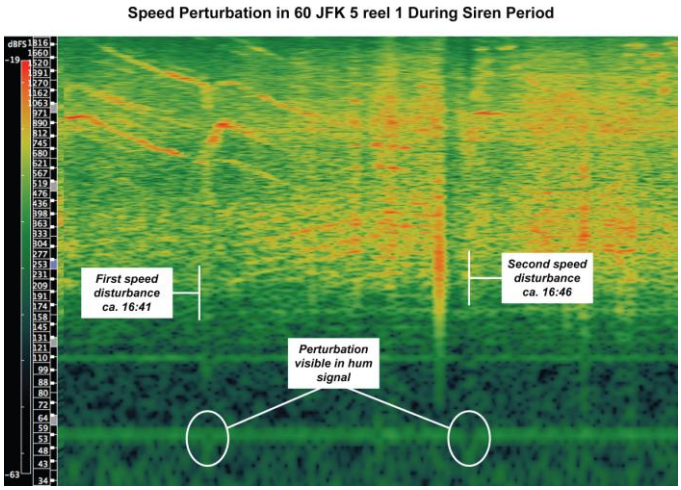

Figure 8: Speed Perturbation in *60 JFK 5 reel_1* during Siren Period

Evidence of a transition between Dictabelts is observed starting at about 23 minutes and 17.8 seconds. The speech in the first Dictabelt abruptly cuts-off at this point. A series of transients around 23 minutes and 20 seconds suggest the start of the second Dictabelt playback. Unit 269's transmission from the previous Dictabelt is then repeated. (This might be expected if the Dictabelt machine was designed to overlap the recording periods of successive Dictabelts in order to create a complete record.)

A change in spectral composition is also observed that this transition. The Dictabelt playback that begins around 23 minutes and 20 seconds contains less high-frequency

information than in the preceding Dictabelt. This latter characteristic is observable in spectrographic analysis.

VIII. Analysis of AC Power Hum

The analysis indicates that the power hum remained relatively constant throughout the recording, at approximately 57.2 Hz. This may be seen in Figure 9. The figure shows outliers in the data; as noted, these outliers are caused by transients in the signal. Also note that the discrete frequency evident for the 10 second sampling window (running parallel to the one minute sampling window frequency line) is an artifact of the sampling window size. Both of these artifacts may be discounted.

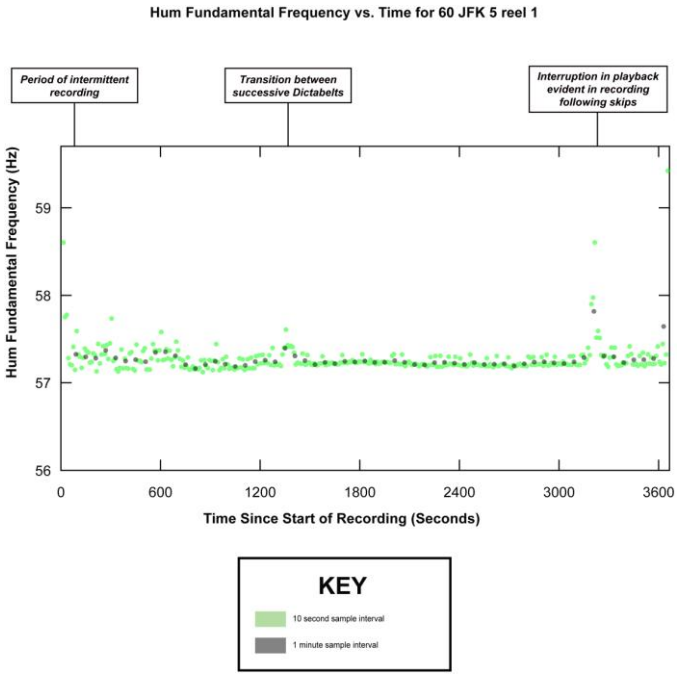

Figure 9: Hum Fundamental Frequency vs. Time for *60 JFK 5 reel_1*

The analysis was performed with sampling windows of varying sizes. Smaller sampling windows provide more frequent reports of frequency at the expense of precision and noise immunity. Conversely, large sampling windows improve measurement precision and noise immunity but provide fewer overall measurements.

The apparent bias towards high frequencies evidenced in the outlying data is due to two factors. The fundamental frequency of the signal is near the lower edge of the filter's passband, and lower frequency artifacts are thus attenuated. Also, the detection of additional changes in slope as illustrated in Figure 10 tends to increase the count frequency in a given time period.

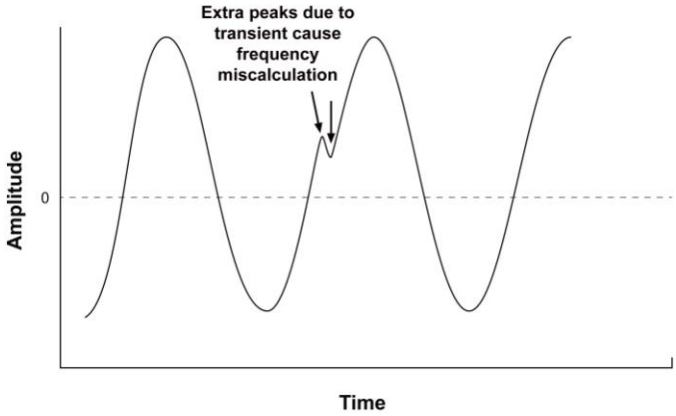

Figure 10: Effect of Transients in Frequency Computation

IX. Analysis of Heterodynes and Underlying Speech

Several instances of heterodynes and their associated speech were examined. These are:

- The alleged crosstalk instance: "I'll check it".
- Several transmissions that all appear to come from unit 75 in an effort to be heard by the dispatcher.
- Unit 4's transmissions that are subject to severe distortion and interfering signals.

The alleged "I'll check it" crosstalk was examined spectrographically, and this is shown in Figure 11. A heterodyne is clearly present, and this suggests that the alleged crosstalk is, in fact, a channel 1 transmission. Energy can be seen symmetrically distributed above and below the heterodyne, and this is consistent with the heterodyne tone mixing with the speech energy. Such mixing is expected if an overloaded circuit was exhibiting nonlinear behavior in the presence of a transmitted signal. It is also improbable that this is an instance of crosstalk appearing during the simultaneous transmission of an unmodulated channel 1 carrier. In our survey of the recording we did not see any unmodulated transmissions of this duration, and the way in which the time of the carrier encompasses the time of the speech is typical of a channel 1 transmission. We subsequently discovered that Barber had written on this same subject.[18] We agree entirely with Barber that this is not an instance of crosstalk because of the heterodyne.

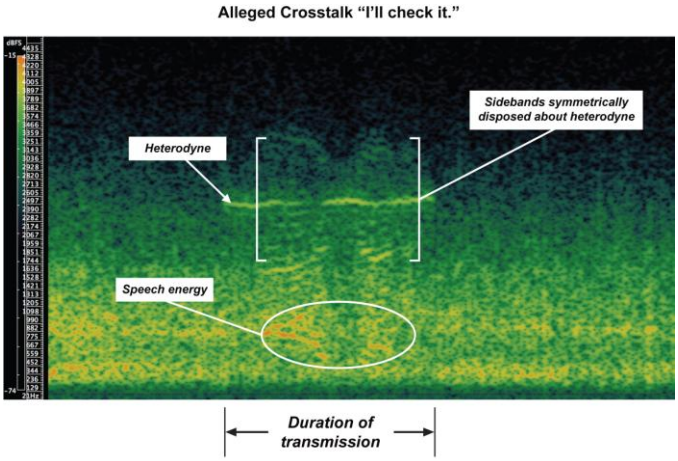

Figure 11: Alleged Crosstalk "I'll Check It"

We used three methods in an effort to more clearly hear the underlying speech. First, we applied a notch filter to the heterodyne in order to remove it. We also applied adaptive noise reduction trained on a period of nearby motorcycle noise in order to reduce the motorcycle noise present during the transmission. Finally, we realized that the sidebands around the heterodyne tone might carry intelligible audio, so we demodulated them.

This latter method performed surprisingly well in extracting audio from the upper sideband of the heterodyne. In all cases, the recovered audio strongly suggests that the officer is saying "five seven". We found instances where unit 57 identifies himself elsewhere in the recordings: In the recording *60 JFK 4 reel_2*, unit 57 can be heard to identify as "five seven" at around 58 minutes and 44 seconds. Importantly, this is not spoken as "fifty seven". (This is around 12:02 PM as evidenced by surrounding transmissions.)

The statement "five seven clear" appears around 34 minutes 9 seconds in the *60 JFK 5 reel_1* recording. Again, it is not spoken as "fifty seven".

In other areas of the recording, multiple transmissions exist that appear to contain similar content, and these were compared on the basis of their heterodyne frequencies. Notably, several transmissions appear to have arisen as unit 75 repeatedly attempted to contact the dispatcher. These have been noted in the timeline.

Unit 4 makes three transmissions that are subject to considerable distortion. Adaptive noise filtering followed by notch filtering of the heterodyne allowed some of the content to be revealed. This same process was performed in other cases of obscured voice content, and the results are appropriately noted in the timeline.

X. Analysis of Motorcycle Engine Noise

A. Times of occurrence

The motorcycle engine noise is present on several occasions. The onset is often distinctly heard, and results in a heterodyne if there is already a transmitter operating. (Similarly, other transmissions that appear while the open microphone is present will produce heterodynes.) The cessation of the open microphone transmission is generally marked by a squelch tail as there is no longer a signal present at the input of the receiver. The time of open microphone transmission occurrences are shown in Table I.

Time (MM:SS.s)	Comments
11:08	First instance of motorcycle noise. Heterodyne present during "seventy five clear" transmission.
11:27.5	Open microphone transmission ceases.
11:45.2	Open microphone resumes, coincident with word "south" from thirty eight's transmission.
17:02	Open microphone ceases.
17:03	Open microphone resumes.
17:36.4	Open microphone ceases.
18:08.4	Open microphone resumes.
18:10.5	Open microphone ceases.
18:29.1	Open microphone resumes, around time of "six five clear".
19:34.4	Open microphone ceases.
21:16.4	Open microphone resumes.
22:11.3	Open microphone ceases.
23:17.9	Approximate end of first Dictabelt in recording.

Table I: Transmission Occurrences

B. Motorcycle Engine Speed versus Time

The motorcycle engine speed was measurable for most of the time it was present. Graphs were generated for the time period between 11 minutes and 23 minutes when the motorcycle engine sound was present. Measurements made using both methods of envelope detection and different filters were plotted on the same set of axes using different colors. The individual graphs show strong agreement, with some variation appearing according to the spectral distribution of the noise energy. Confounding factors, such as strong heterodynes and speech energy, tended to confuse or impair measurements when they were present in the different frequency ranges. In some portions of the recording, multiple engines appear to be detected, and the graphs show multiple trajectories for the motorcycle engine. A listening test suggested that this is the case, and the different algorithms and filters showed varying sensitivity to this effect.

An overview of the entire measurement time period is shown in Figure 12. The associated key applies to all of the subsequent graphs in which two-minute segments of the recording are examined in detail.

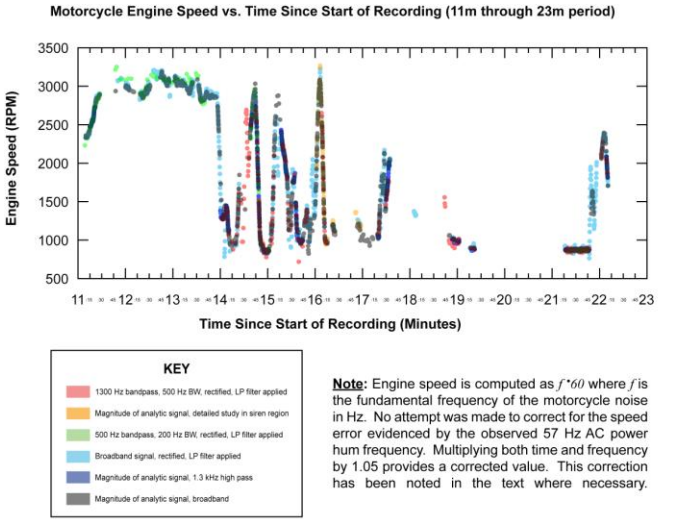

Figure 12: Motorcycle Engine Speed vs. Time (11-23 Minutes)

11 to 13 minute time frame:

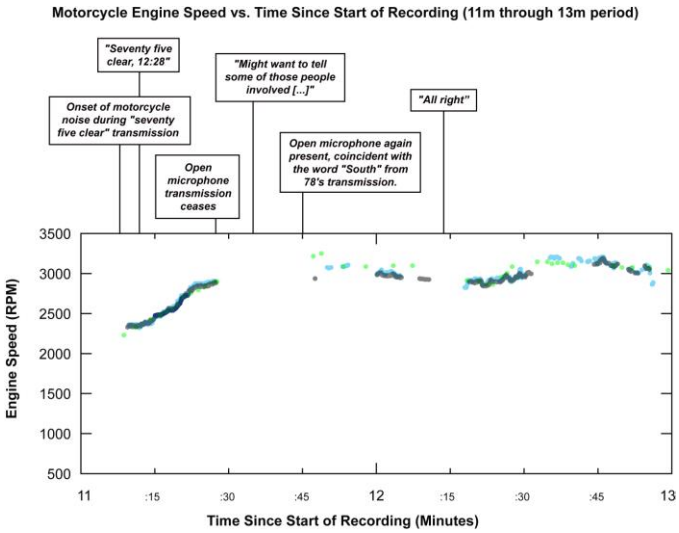

Figure 13: Motorcycle Engine Speed vs. Time (11-13 Minutes)

This time period contains the first two minutes of the open microphone portion of the recording.

The long period of high speed engine operation in this time period suggests the motorcycle is moving. A general increase in broadband noise is observed, and much of this appears to be uncorrelated with the motorcycle engine noise. The intensity of this uncorrelated noise increases with engine speed, and it is our conclusion that it likely "wind noise" caused by turbulent airflow around a rapidly moving motorcycle. The presence of this noise also degrades the signal-to-noise ratio for the engine noise signature in this time frame.

We calculated the approximate speeds at which both a Servi-Car and a Duo-Glide would be moving at this RPM range. These calculations were performed for the highest gear (lowest ratio) available in the different models: third gear for the Servi-Car and fourth gear for the Duo-Glide. This choice of gear was made as sustained high speed operation in a lower gear would not be expected under normal circumstances. There is no evidence of the vehicle starting or stopping during this time frame, and the measurements show a nearly constant engine speed associated with travel over a roadway that is free of junctions, traffic lights and other speed impediments.

The conversion of engine speed in RPM to vehicle speed in MPH is given by:

$$S = \frac{(K \cdot \pi \cdot d \cdot f)}{R}$$

where:

f is the engine (crankshaft) speed in RPM.
d is the diameter of the rear wheel in inches.
R is the overall gear ratio (published specification, includes chain and sprocket ratios).
K is 9.47×10^{-4} (the conversion factor from inches per minute to MPH).
S is the resultant speed in MPH.

Table II lists the various configurations of both the Duo-Glide and Servi-Car and the ground speeds that they attain at different engine speeds. The overall gear ratios and different tire diameters shown represent the options listed in the relevant Harley-Davidson service literature [19][20]. The version of the Duo-Glide that used a three speed transmission was not considered as these do not appear to be present in the motorcade, as evidenced by the lack of a fuel-tank-mounted shift lever in photos.

Model	Overall Ratio	Tire Size	Nominal Tire Diameter (inches)	MPH @ 2500 RPM[iv]	MPH @ 3000 RPM	MPH @ 3500 RPM
Servi-Car	5.84	500x16	26	33	40	46
Duo-Glide FL Solo	3.73	400x18	26	52	62	73
Duo-Glide FL Solo	3.73	450x18	27	54	65	76
Duo-Glide FL Solo	3.73	500x16	26	52	62	73
Duo-Glide FLH Solo	3.57	400x18	26	54	65	76
Duo-Glide FLH Solo	3.57	450x18	27	56	68	79
Duo-Glide FLH Solo	3.57	500x16	26	54	65	76
Duo-Glide FL & FLH Sidecar	4.08	400x18	26	47	57	66
Duo-Glide FL & FLH Sidecar	4.08	450x18	27	49	59	69
Duo-Glide FL & FLH Sidecar	4.08	500x16	26	47	57	66

Table II: Motorcycle Engine Speeds

13 to 15 minute time frame:

[iv] The various speed results are rounded to the nearest whole number.

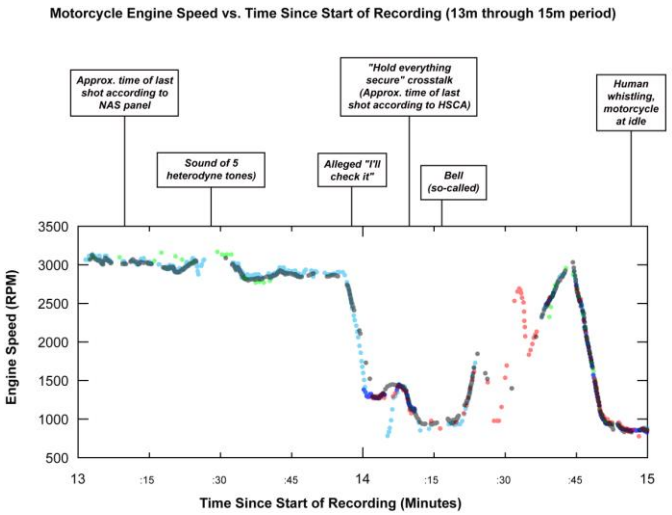

Figure 14: Motorcycle Engine Speed vs. Time (13-15 Minutes)

The motorcycle is observed to be operating at high speed for nearly a minute before it slows. This slowing coincides with the alleged "I'll check it" crosstalk. The motorcycle is then observed to vary its speed on several brief occasions over the next 30 seconds. Measurements in this region are made difficult by the abundance of other sounds present at this time. Divergent data around 14 minutes, 30 seconds suggests that there may be multiple motorcycles heard in this time frame. The motorcycle is observed to increase speed before slowing to idle RPM at the end of this time frame.

Sheriff Decker's "hold everything secure" crosstalk occurs around the 14 minute 15 second point. This is the portion of the Dictabelt in which the HSCA said the last shot was fired.[21] The National Academy of Sciences Panel indicated the last shot occurred about a minute before this in their review of the HSCA findings.[22]

15 to 17 minute time frame:

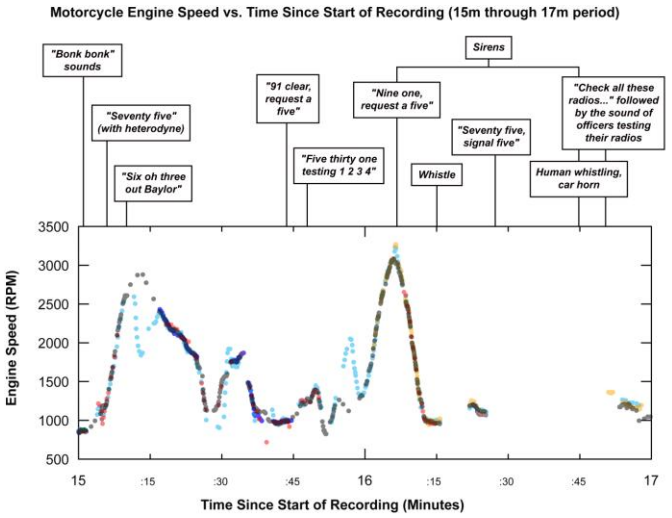

Figure 15: Motorcycle Engine Speed vs. Time (15-17 Minutes)

The first minute of this time frame is characterized by many variations in the motorcycle engine speed. Multiple trajectories in the motorcycle engine noise graph suggest that more than one motorcycle may have been detected by the microphone. Numerous heterodyne tones serve to confound the high-frequency measurements and may lessen detection accuracy in high frequency filtered spectra as well.

The motorcycle engine speed is unambiguously observed to increase at the 16 minute point, briefly exceeding 3000 RPM, and then descending to idle. This speed excursion is coincident with the onset of siren sounds. The siren sounds tend to overwhelm the sound of the motorcycle engine and make detection difficult. The presence of the loud siren sounds causes the extinction of the motorcycle engine noise graph around 16 minutes, 17 seconds. Observations in the subsequent time period show the motorcycle remaining at low RPM on the brief occasions it is measurable in the presence of sirens. The amplitude of the individual sirens is observed to gradually increase, reach a broad maximum and then diminish. This is observable in the spectrogram in Figure 16.

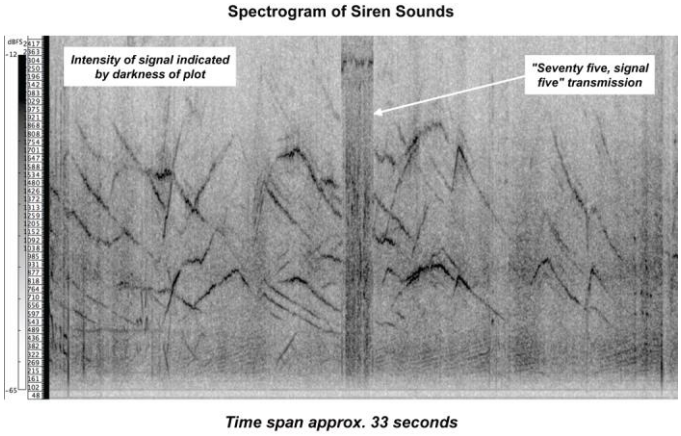

Figure 16: Spectrogram of Siren Sounds

An instance of crosstalk is heard near the end of this time frame. "I'll check all these motorcycle radios" is transmitted on channel 2 and is heard as crosstalk here. The sound of officers rapidly pressing their microphone buttons in an effort to test their radios can be heard shortly after this crosstalk. In addition, the open microphone briefly ceases transmission at the end of these tests.

The sounds of officers testing their radios in rapid succession are not found in other parts of the recording. The appearance of this unique event immediately following a transmission describing such an activity suggests a cause-and-effect relationship linked by the communication of information.

We believe the sound of a whistle being blown is evident around the 16 minute, 15 second mark. Two short bursts are audible, and the sound appears to exhibit the modulation characteristics of a "pea whistle", in which a ball rattles inside the whistle cavity. The sound of the whistle also appears to intermodulate with a neighboring siren tone, producing a low-frequency artifact. The apparent whistle sound does not show

evidence of Doppler shift, suggesting little or no relative motion between the whistle and the open microphone. Another apparent whistle sound is observable near the end of this time frame amid the heterodyne tones of officers testing their microphones. Neither whistle sound can be confused with a heterodyne as they both exhibit broad dispersion around their center frequencies and lack the transients that are present at the onset and conclusion of heterodyne-producing signals.

Figure 17 shows the sound of the second whistle amid the heterodynes originating from the officers testing their radios.

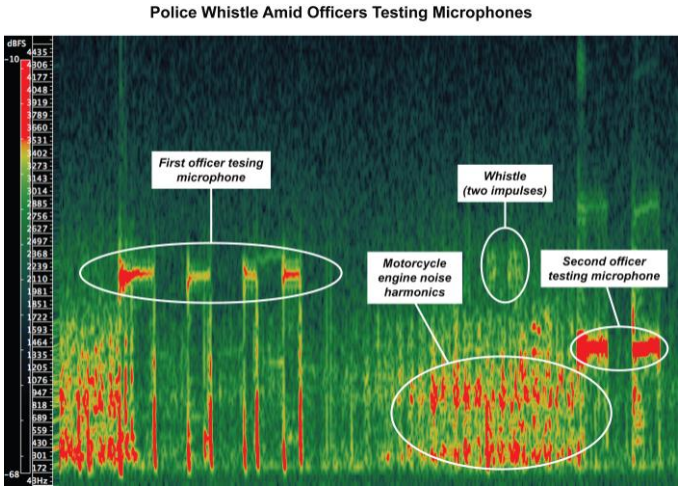

Figure 17: Police Whistle amid Officers Testing Microphones

An automobile horn is heard to sound four times around 16 minutes and 45 seconds. Doppler shift is evident in descending frequency between successive tones as shown in Figure 18 and Figure 19. (This Doppler shift is also audible to a human listener.) The vehicle sounding the horn is thus exhibiting motion relative to the open microphone.[v]

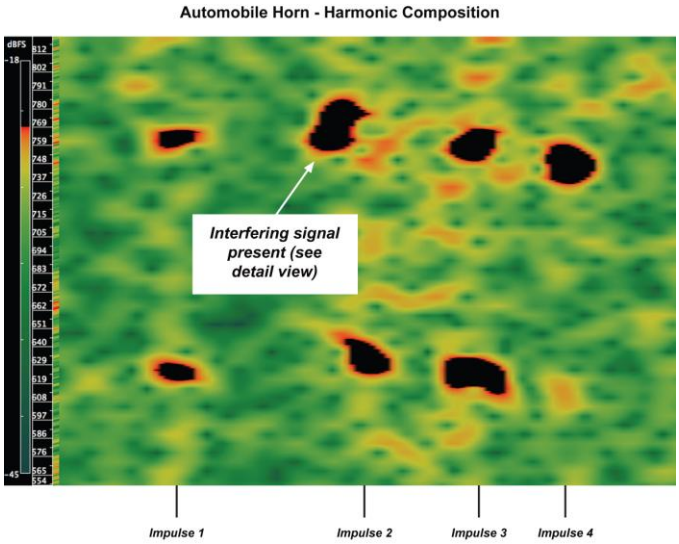

Figure 18: Automobile Horn – Harmonic Composition

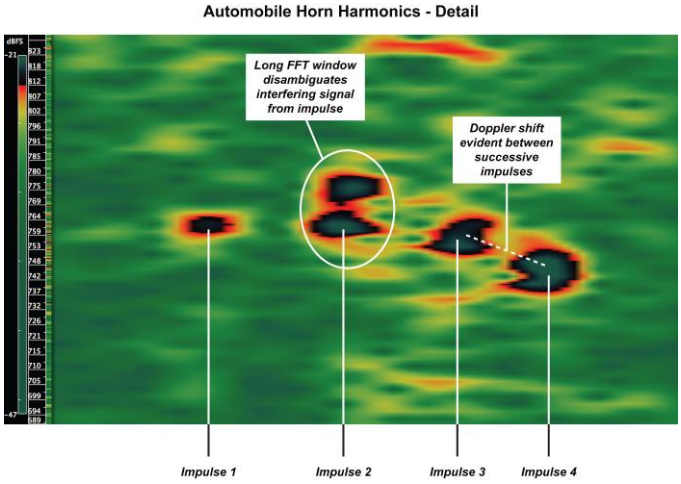

Figure 19: Automobile Horn Harmonics – Detail

17 to 19 minute time frame:

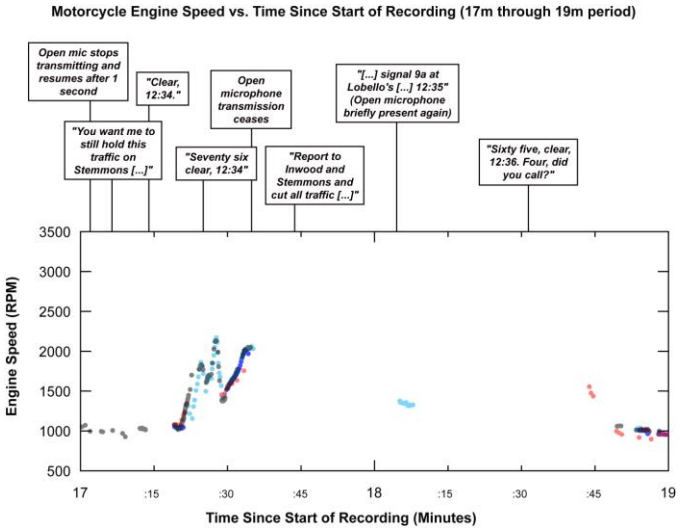

Figure 20: Motorcycle Engine Speed vs. Time (17-19 Minutes)

[v] While it is tempting to determine the relative speed, there are many solutions to the Doppler equation that will give the same result depending on other variables involving distances and angles – quantities that we don't know.

The open microphone is present during the first 40 or so seconds of this time frame. It is also briefly present after the 18 minute mark. During the remainder of the time, the open microphone is not engaged and the radio system operates normally. What little data exists in this time frame suggests that the motorcycle is operating near idle speed and then undergoes several brief accelerations before the transmission ceases. The short observation after the 18 minute mark suggests that it is not operating at high speed at that time. This time frame probably encompasses the time that the motorcade arrived at Parkland Memorial Hospital, given the various references suggesting a 12:35 arrival time at Parkland Hospital.[23][24]

19 to 21 minute time frame:

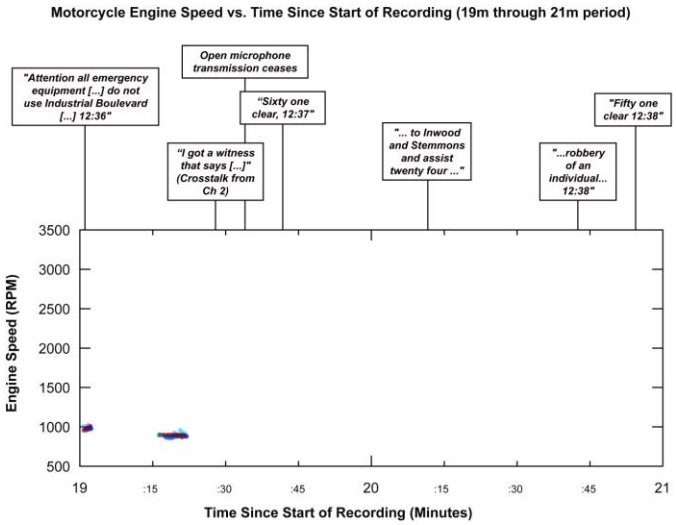

Figure 21: Motorcycle Engine Speed vs. Time (19-21 Minutes)

The open microphone is only evident on two short occasions during this time frame; otherwise it is not engaged and the radio system is operating normally. This time frame probably represents the upper limit for the motorcade's arrival at Parkland Hospital.

21 to 23 minute time frame:

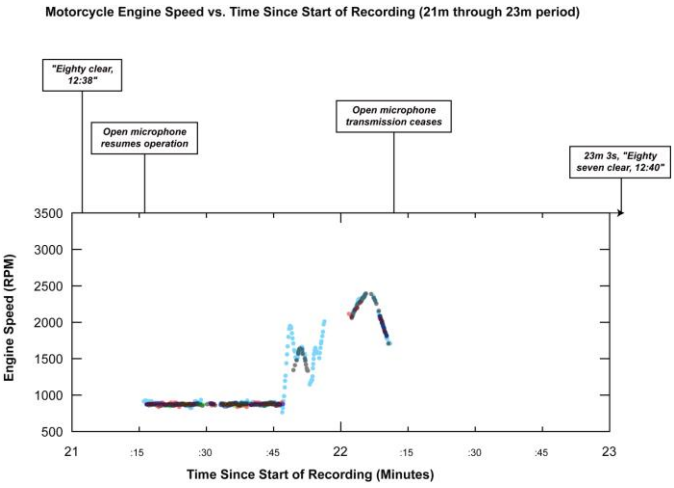

Figure 22: Motorcycle Engine Speed vs. Time (21-23 Minutes)

This time frame contains the last of the open microphone transmissions. It operates for a little under a minute during this time. A long idle period is followed by the sounds of the motorcycle engine speeding up and then reducing speed at the end of the transmission. This idle period was of technical use in determining the correctness of the engine noise frequency measurement method as we were able to observe the amplitude envelope in the waveform data and make direct measurements that agreed with the frequency measurement method.

Around 21 minutes and 50 seconds the sound of the engine revving is interspersed with mechanical-sounding transients. These may be evidential of the motorcycle shifting gears as it accelerates. These may also be the sounds of the motorcycle driving over drainage grates, speed bumps, or some similar obstruction, slowing for each one in turn.

XI. Conclusion

1. The measurements performed on the spectral composition at the beginning and end of the *60 JFK 5 reel_1* recording suggest a modest number of copies had been made leading up to the digitized version we obtained. The hum frequency measurement reveals only a few discontinuities that are easily explained as having benign origins. These observations, along with the general agreement of the timeline with published data, allow us to conclude that the recording we studied originates from the same source as those studied by previous researchers. Differences, where they are noted, appear to arise solely from mechanical defects in the recording medium, e.g. skips.

2. The alleged instance of crosstalk containing the words "I'll check it" is not an instance of crosstalk due to the presence of a heterodyne tone. Furthermore, the heterodyne tone is accompanied by sidebands that, when demodulated, contain the same audio that is otherwise evident. Audio processing reveals that the words are likely to have been "five seven", spoken in a manner consistent with other transmissions made by unit 57.

3. The measurement of motorcycle engine speed versus time is not in agreement with the known movements of the motorcade. Incidental sounds present at various times serve to reinforce this conclusion. This is shown throughout the recording as demonstrated in the following detailed examples.

The engine is operating at continuous high speed throughout most of the 11 to 13 minute time frame. Published accounts suggest that the motorcade proceeded slowly before the assassination, and this cannot be reconciled with our measurements. The extracted data suggest the movement of the motorcycle in this time period is along an unimpeded route at constant high speed with no evidence of slowing for turns, as would be expected if the motorcycle was part of the motorcade.

In the 13 to 15 minute time frame, the motorcycle is observed to slow down after a period of high speed operation. The motorcycle engine speed is then observed to vary in a manner suggestive of maneuvering. As both the HSCA and NAS Panel studies place the assassination shots within this two minute time frame, one would expect evidence of the motorcycle subsequently racing off to Parkland Hospital. This is not seen in the data.

In the 15 to 17 minute time frame, the following data can be observed:

- Measurements show that the motorcycle engine slows around the onset of the sirens and remains at low speed in the few instances where it is measurable throughout this period, suggesting that is stationary or nearly so. The engine speed data does not support the notion that the motorcycle may have lingered at Dealey Plaza and then raced to catch up with the motorcade as has been suggested by others.[25]

- The sounds of individual sirens show amplitude variation consistent with approach and departure from the motorcycle's general location. Also, none of them are heard continuously throughout the period in which they are present. In other words, the individual siren sounds are only heard briefly, and each one appears to grow in intensity before fading away. These data are visible in the spectrogram and are consistent with the sirens transiting the area where the open microphone is situated.

- The sounds of what appear to be whistles being blown are heard twice while the sirens are present. These do not show evidence of Doppler shift, suggesting little or no relative motion. A stationary officer may be reasonably expected to blow a whistle, whereas this is unlikely in the case of an officer speeding to the hospital. This observation is compatible with the conclusion regarding engine speed.

- A car horn is heard to sound four times and shows considerable Doppler shift, suggesting that it is moving rapidly relative to the motorcycle.

These data are all consistent with the motorcycle with the open microphone being more or less stationary while motorcade vehicles sped by on their way to Parkland Hospital. The car horn may well be part of the motorcade as it shows considerable Doppler shift. The apparent sound of whistles originating from stationary sources is also an agreement with the other data.

In the 17 to 19 minute time frame, the motorcycle is observed to remain at or near idle RPM for at least 15 seconds after the sirens have faded to inaudibility. This clearly shows that the motorcycle is not moving with the sirens, nor has it joined the sirens.

In summary, we can draw the following conclusions:

1. These data uniformly indicate that the motorcycle with the open microphone was not part of the motorcade.
2. Therefore, it is unlikely that the motorcycle was in a position to record the sounds of gunfire.
3. Based on these observations, we conclude that the Dictabelt recording *is not applicable* to the identification of assassination gunfire.

XII. APPENDICES

APPENDIX A. LIST OF MEDIA PROVIDED FOR RESEARCH

Name	Duration	Sample Rate (kHz)	Frames	Radio Channel	Description
60 JFK 1 reel_11	00:30:46.587	44.1	81434472	1	Appears to be dictabelt after "relevant" one. Badly damaged, many surface defects.
60 JFK 1 reel_12	00:30:35.680	44.1	80953488	1	Remarkably clear audio but many surface defects evident. Contains dialogue regarding shooting of Officer Tippet @ 4 minutes from start.
60 JFK 1 reel_13	00:31:34.387	44.1	83542452	1	Many surface defects.
60 JFK 2 reel_1	00:28:50.880	44.1	76331808	2	
60 JFK 2 reel_2	00:24:55.160	44.1	65936556	2	Contains time period spanning assassination.
60 JFK 2 reel_3	00:28:11.427	44.1	74591916	2	
60 JFK 2 reel_4	00:28:52.067	44.1	76384140	2	
60 JFK 2 reel_5	00:30:30.387	44.1	80720052	2	
60 JFK 2 reel_6	00:11:34.893	44.1	30644796	2	
60 JFK 2 reel_7	00:30:39.307	44.1	81113424	2	
60 JFK 4 reel_1	01:00:27.744	96	348263424	1	
60 JFK 4 reel_2	01:00:32.693	96	348738560	1	
60 JFK 4 reel_3	00:08:18.808	96	47885568	1	Contains dictabelt just prior to that spanning the assassination.
60 JFK 5 reel_1	01:01:04.667	44.1	161611800	1	Contains time period spanning assassination.
60 JFK 5 reel_2	00:51:22.147	44.1	135922668	1	
60 JFK 6 reel_1	01:00:17.804	96	347309221	2	Apparently afternoon/evening of 22nd. Some discussion of incidents of the day. Shutting down radio channel at end of recording.
60 JFK 6 reel_2	01:00:45.099	96	349929519	2	
60 JFK 6 reel_3	00:41:57.509	96	241680817	2	
233 JFK Exhibit A Dallas reel_1	00:38:49.840	44.1	102745944	2	Appears to be afternoon of 22nd.
233 JFK Exhibit A Dallas reel_2	01:05:49.653	44.1	174179712	Unk.	Starts around 1:28PM on 22nd. Apparent sound of tape slowing to near stop after 1:45 time announcement is a major defect. High frequency noise descending in frequency at that time. (The latter might be the sound of the bias oscillator recorded on the tape, made audible by the low tape speed.)
233JFK-F-351-353	00:03:01:147	Not listed	Not listed	n/a	Appears to be related to BBN work. Starts with short excerpt of dictabelt around time of assassination. This fades out and some impulse sounds are then heard. Later, impulse sounds, perhaps high-pass filtered are heard. Finally, the sounds of gunfire (presumably the BBN test shots) are heard.

APPENDIX B. DALLAS POLICE DEPARTMENT RADIO CHANNEL 1 TIMELINE

This timeline contains the following columns:

- "Start Time" and "End Time" refer to the start and end of events relative to the start of the recording.
- "Clock Time" is used to record time announcements from the dispatcher where they are notes in the transcripts.
- "Sonalysts Comments on Audio" refers to data collected by Sonalysts. Parenthetical references generally contain commentary.
- "Bowles" refers to the transcript found in the appendix of James C. Bowles: "The Kennedy Assassination Tapes: A Rebuttal to the Acoustical Evidence Theory".
- "Sawyer" refers to the transcript provided by Sawyer as contained in Warren Commission Exhibit 705.

n.b. All times and frequencies are uncorrected for speed errors as evidenced by AC power hum frequencies. Times and frequencies should be multiplied by 1.05 to correct for the apparent 57.2 Hz hum evident in the recording. Also, time values are necessarily approximate in the case of sounds that have poorly defined extents. Heterodyne frequencies, where noted, usually refer only to the highest frequency component. In some instances many heterodyne frequencies are evident. Also, the precision with which heterodyne frequencies are measured is dependent on their duration, and some heterodynes are broad in frequency.

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
00:10:54.71	00:10:56.29	12:28pm	83 out, 12:28.	83 out, 12:28.	Not in Transcript
00:10:57.68	00:10:58.9	-	Five six …	56 …	Not in Transcript
00:10:59.81	00:11:00.99	-	Fix six.	56.	Not in Transcript
00:11:02.42	00:11:07.25	-	Traffic, uh, on a . . . '56 Chevrolet, I can't see the last number . . .	Traffic, uh, on a . . . '56 Chevrolet, I can't see the license number . . . (followed immediately by:)	Not in Transcript
00:11:07.34	00:11:09.01	-	Seventy five, clear.	75 clear.	Not in Transcript
11:10:26	11:12:08	12:28pm	Seventy five clear, 12:28.	75 clear, 12:28. (Accompanied by microphone stuck open for 17.5 seconds transmitting sound of running motorcycle)	Not in Transcript
00:11:31.30	00:11:32.04	-	Thirty eight …	38 …	38 …
00:11:32.51	00:11:33.07	-	Thirty eight.	38.	38.
00:11:35.86	00:11:45.61	-	Might tell some of those people involved in handling this deal out here at Market Hall that there's people walking across southbound Stemmons here in front of the Marriott Hotel and all the way down south. (Motorcycle noise again present, accompanied by heterodyne at about 2308 Hz where it overlaps 38's transmission near ".. this deal". Motorcycle noise continues for about	Might tell some of those people involved in handling this deal out here at Market Hall that there's people walking across southbound Stemmons here in front of the Marriott Hotel and all the way down south. (Time fixed at this point and projected for remainder of transcript. Announced time, when given, is in parenthesis.) (Microphone remained open while the	… out here at <u>THE</u> Market Hall <u>THESE PEOPLE ARE</u> walking … Stemmons

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
			5 minutes and 25 seconds until ending just after the sounds of microphones being tested following the "check all these radios" crosstalk. The cessation of the open microphone transmission is followed by a squelch tail, as noted later.)	dispatcher asked:)	(omitted "here") in front of the …
00:11:45.98	00:11:54.24	-	10-4, thirty eight. Are you still en route to court?	10-4, 38. Are you still en route to court?	Omits "Are you still en route to court?
00:11:54.99	00:11:55.73	-	10-4.	12:29:10pm: 10-4. (Mic sticks open for next 5 minutes.)	Not in Transcript
00:12:05.3	00:12:06.97	-	… Market Hall … (Possibly "Market Office". Sounds like five syllables precede the words "Market Hall". Accompanied by a heterodyne around 2607 Hz)	12:29:20pm: … Market office …	Not in Transcript
00:12:13.66	00:12:14.21	-	… All right … (Accompanied by wavering tone)	12:29:27pm: … All right …	Not in Transcript
00:12:15.12	00:12:16.38	-	(Possible weak signal with evidence of voice modulation. Heterodyne at about 2397 Hz.)	Not in Transcript	Not in Transcript
00:12:16.85	00:12:17.60	-	(Radio that transmitted "alright" again transmitting, possibly testing microphone. Same wavering tone present.)	Not in transcript	Not in transcript
00:12:21:56	00:12:24:04	-	(Three whistle noises: first two in rapid succession followed by a pause, then the last. Spectral analysis shows first two each ascending in pitch, all are between 920 and 1050 Hz. Possibly an officer whistling to test transmitter operation.)	Not in transcript	Not in transcript
00:12:31.49	00:12:32.68	-	(Alternating tones in noise.)	Not in Transcript	Not in Transcript
00:12:41.61	00:12:44.83	-	(Intensification of noise with transient at end. Noise reduction processing suggests possible voice modulation with three syllables.)	Not in transcript	Not in transcript
00:12:46.80	00:12:47.31	-	(1853 Hz heterodyne. Succession of short tones.)	Not in Transcript	Not in Transcript
00:12:55.14	00:12:56.72	-	(Heterodyne at 2688 Hz with underlying voice modulation. Attempts to apply noise reduction were not productive.)	Not in Transcript	Not in Transcript
00:12:57.87	00:13:01.61	-	(Heterodyne at 381 and 1851 Hz. Amplitude and/or frequency of heterodyne appears to have speech modulation characteristics as it varies at syllabic frequency).	Not in Transcript	Not in Transcript
00:13:13.26	00:13:15:87	-	(Heterodyne 874 and 2289 Hz. Weak speech evident and amplitude and/or frequency of heterodyne appears to vary at speech syllabic frequency.)	Not in Transcript	Not in Transcript

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
00:13:21.49	00:13:23.10	-	(Unidentified speech accompanied by heterodyne at 2324 Hz. Heterodyne begins at about 00:13:20.28)	Not in transcript	Not in transcript
00:13:25.41	00:13:27.60	-	(A succession of 5 tones: first has low rising tone around 720 Hz, heterodynes at 1462 and 2461 Hz, second and third contain peaks at 1744 and 2436 Hz, fourth and fifth have peaks around 2430 Hz.)	Not in transcript	Not in transcript
---	---	-	---	12:30:55pm (This is the approximate time the first shot was fired. While NOT recorded on the tape nor heard on radio, it is noted here for reference.)	Not in Transcript
00:13:40.87	00:13:43.75	-	(Heterodyne(s) around 2260 Hz. Possible speech in background.)	Not in Transcript	Not in Transcript
00:13:55:16	00:13:55.85	-	(Transmitter keyed twice producing 2429Hz heterodyne among others.)	Not in Transcript	Not in Transcript
00:13:57	-	-	(Observation agrees with Bowles)	12:31:00pm: (Motorcycle engine slowed down.)	Not in transcript
---	---	-	---	12:31:03pm: (Approximate time the third and final shot was fired.)	Not in Transcript
00:13:58.15	00:13:59.54	-	(Alleged “I’ll check it” crosstalk. Sounds like “five seven” after adaptive noise reduction. See relevant text. Accompanied by a heterodyne of about 2539Hz.)	12:31:02pm: I’ll check it.	Not in Transcript
00:14:01	-	-	(Mechanical sounding clicks. Energy peak around 800-900 Hz.)	Not in Transcript	Not in Transcript
00:14:04.61	-	-	(Single noise reminiscent of "bonk bonk" sounds at 00:15:00)	Not in Transcript	Not in Transcript
00:14:04:87	00:14:06.00	-	Decker crosstalk weakly heard, sounds like "there in an effort".	Not in Transcript	Not in Transcript
00:14:06.02	00:14:06.19	-	Heterodyne. Peak around 2343 Hz.	Not in Transcript	Not in Transcript
00:14:06.41	00:14:09.10	-	(Observation agrees with Bowles)	12:31:10pm: (Motorcycle engine slowed to idle speed.)	Not in Transcript
00:14:08.10	---	-	Short voice-like tone amid noise.	Not in Transcript	Not in Transcript
??	??	-	Not Audible	12:31:11pm: 100 …	Not in Transcript
??	??	-	Not Audible	12:31:12pm: …Check wanted on P-Pecos …	Not in Transcript
00:14:09:42	00:14:13.41	-	(Decker crosstalk: "Hold everything secure until the...". Short heterodyne appears over crosstalk from about 00:14:11.93 to 00:14:12.08 at 2243 Hz. There is a transient that is	Not in transcript	Not in transcript

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
			coincident with the beginning of the word "hold", in the channel 1 crosstalk.)		
00:14:11.34	00:14:12.26	-	(portion of Decker hold everything crosstalk)	"Tell my men (?)…" Sheriff Decker (Ch2)	Not in Transcript
---	---	-	---	12:31:13pm: Last shot, according to Select Committee.	Not in Transcript
00:14:13.30	00:14:13.46	-	(Heterodyne with peaks at 728 and 823 Hz, narrow peak at 1564 Hz, broad peak at 2279 Hz.)	Not in Transcript	Not in Transcript
00:14:14.04	00:14:14.83	-	(Heterodyne with peak at 2388 Hz., other lower freq. peaks evident)	Not in Transcript	Not in Transcript
00:14:16.49	00:14:16.85		(Transmitter keyed twice, heterodyne at 2341 Hz.)	Not in Transcript	Not in Transcript
00:14:17.08	00:14:17.52	-	(Sound, popularly referred to as "the bell" or the "carillon bell")	12:31:20pm: (Single tone of bell.)	Not in Transcript
00:14:17.86	00:14:19.71	-	---	12:31:24pm: (Motorcycle at very low idle.)	Not in Transcript
00:14:19.71	00:14:19.98	-	(Observation agrees with Bowles)	12:31:32pm: (A "bonk" sound is recorded and the motorcycle engine revved-up.)	Not in Transcript
00:14:19.79	00:14:19.96	-	(Loud heterodyne, broad peak around 2.4 kHz)	Not in Transcript	Not in Transcript
00:14:19.98	00:14:25.17	-		12:31:40pm: (Motorcycle sounds like it started moving.)	Not in Transcript
00:14:25.09	00:14:25.72	-	Heterodyne. Detailed analysis indicates start around 11:14:25.106 and continuation through 00:14:25.697. Strong component at 2464 Hz. Frequency may show slight rise with time.	Not in Transcript	Not in Transcript
00:14:25.69	00:14:29.80	-		12:31:48pm: (Motor slowed down. Perhaps, another approached.)	Not in Transcript
00:14:34.78	00:14:36.98	-	3 short "beeps" followed by unidentifiable radio speech	Not in Transcript	Not in Transcript
00:14:50.90	00:14:53.48	-	(Two short transmissions with strong heterodyne having broad peak around 2460 Hz. Followed by voice transmission having same heterodyne. The voice is strongly distorted.	12:31:52pm: … on the phone. (Motor slowed to an idle.)	Not in transcript
00:14:57.36	00:15:00.56	-	(Person whistling)	12:31:56pm: (Someone whistling a tune in the background of open microphone.)	Not in Transcript
00:15:00.75	00:15:02.05	-	("bonk bonk" sounds like car doors slamming, second has reverberant tail. Spectrum shows peaks at 211, 274 339 and 397 Hz. Notches at 235 and 315 Hz.)	12:31:58pm: (A "bonk, bonk" sound again.)	Not in Transcript
00:15:03.15	00:15:03.87	-	(Mic keyed three times producing heterodyne. Two frequency peaks, first at about 879 to 884 Hz, second	Not in Transcript	Not in

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
			around 1961 Hz. Very loud.)		Transcript
00:15:05.82	00:15:06.55	-	(This voice is accompanied by a heterodyne that last from about 00:15:05.066 to 00:15:06.727. The frequency of the heterodyne is about 2355 Hz. The voice appears to pronounce three syllables, with the first two in rapid succession. This may be the "91" that asks for a "5" later at 00:15:45.702. (May be same as heard around 14:52)	12:32:04pm: (Unreadable, sounds like "… 87 …")	Not in Transcript
00:15:07.06	00:15:09.29	12:32:05 pm	The first three "dits" of the Morse 'V' Bowles notes are almost certainly produced by the transmitter that produced the preceding transmission. (Based on observation of heterodyne frequency.)	12:32:05pm: (Heterodyne sound of Morse Code "V" and the motor seems to speed up.)	Not in Transcript
00:15:10.62	00:15:11.70		Six-oh-three out, Baylor.	12:32:08pm: 603 out, Baylor.	Not in Transcript
00:15:13.27	00:15:16.86	-	Inaudible radio speech	Not in Transcript	Not in Transcript
00:15:20.22	00:15:21.17	-	2 heterodyne tones. Around 2133 Hz	Not in Transcript	Not in Transcript
00:15:26.6	00:15:27.98	-	"Seven three" (Heterodyne at 2115 - 2119 Hz. Voice pronouncing 2-3 syllables with intermod. Seems to be same carrier as 15:20.219 (above)	Not in Transcript	Not in Transcript
00:15:26.57	00:15:28.05	-	(Not heard. Might be "seven three" transmission we reference above.)	12:32:22pm: (Motor slowed, then:) 36 …	Not in Transcript
00:15:34.35	00:15:35.55	-	(heterodyne tones, around 2355 Hz)	Not in Transcript	Not in Transcript
00:15:39.31	00:15:40.22	-	(strong heterodyne around 1110 Hz with voice. Sounds like "seven three")	Not in Transcript	Not in Transcript
		-	(Again: appears to reference the transmission we hear as "seven three" at 15:39.31)	12:32:35pm: 36 … (Motor slow and irregular.)	Not in Transcript
00:15:43.75	00:15:45.70	-	Nine one clear, request a five. (Heterodyne at 2394 Hz, broad peak at 1455 Hz.)	12:32:38pm: 91 clear, request a "5."	Not in Transcript
00:15:45.70	00:15:48.21	-	Five thirty one testing, 1-2-3-4.	12:32:39pm: 531 testing, 1-2-3-4.	Not in Transcript
00:15:48.21	00:15:51.20	-	(Observation agrees with Bowles)	12:32:42pm: (Someone whistling again; the tune is unidentifiable.)	Not in Transcript
00:15:51.20	00:15:51.99	-	Loud and clear. 2295 Hz heterodyne	12:32:46pm: Loud and clear.	Not in Transcript
00:15:54.40	00:15:55.64	-	Forty eight, loud and clear. (2357 Hz	12:32:48pm: 48, loud and clear.	Not in

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
			heterodyne)		Transcript
00:15:54.42	00:16:03.87	-	Fifty six …	12:32:56pm: 56 … (motor revved-up)	Not in Transcript
00:16:04.03	00:16:08.40	-	Nine one … request a five. (2433 - 2466 Hz heterodyne)	12:32:56pm: 91 … request a "5."	Not in Transcript
00:16:08.16	00:16:09.87	-	(Observation agrees with Bowles on appearance of sirens.)	12:33:01pm: (Blending with the end of 91's message, the sound of sirens can be heard, faintly, but increasing in loudness.)	Not in transcript
00:16:09.73	00:16:15.79	-	10-4. Anybody know where fifty six is?	12:33:03pm: 10-4. Anybody know where 56 is? (The siren sounds continue.)	Not in Transcript
00:16:15.34	00:16:15.96	-	Apparent sound of someone blowing a whistle.	Not in Transcript	Not in Transcript
00:16:15.79	00:16:16.76	-	(Possibly) He checked out on traffic. (May also be "He checked out on break", it is unclear)	12:33:08pm: He checked out on traffic.	Not in Transcript
00:16:28.01	00:16:36.26	-	Seventy five, signal five? (accompanied by 2151 Hz heterodyne.)	12:33:18pm: 75, Signal 5? (Sirens continue; motor sounds slow and irregular.)	Not in Transcript
00:16:36.26	00:16:44.63	-	Seventy six, clear.	12:33:26pm: 76 clear. (Sirens continue; motor sound revved-up.)	Not in Transcript
----	00:16:44.59	-	(Agree with Bowles)	12:33:34pm: (Sirens fade to inaudible.)	Not in Transcript
00:16:44.59	00:16:46.19	-	(Car horn, four impulses)	Not in Transcript	Not in Transcript
00:16:47.11	00:16:51.74	-	(Observation agrees with Bowles)	12:33:35pm: (Someone whistling again.)	Not in Transcript
00:16:49.74	00:16:51.63	-	Attention all units, all units …	12:33:38pm: Attention all units, all units …	Not in Transcript
00:16:50.41	00:16:52.44	-	crosstalk from CH2 … "check all these motorcycle radios"	Not in Transcript	Not in Transcript
00:16:52.44	00:16:53.41	-	Sounds like "Eight-Eighteen" or "Eighty-Ten"	Not in Transcript	Not in Transcript
00:16.55.35	00:17:01.25	-	Officers start checking their radios by pressing their microphone buttons	Not in Transcript	Not in Transcript
00:16.57.1	00:17:01.26	-	Radio testing heterodynes after "check radios" crosstalk: 1st 2187 Hz 4 impulses from about 16:55.43 to 16:56.488 Sound of whistle among heterodynes, two short blasts, Center freqs are approx 2189 and 2359 Hz, this occurs about 16:57.1 2nd 16:57.539 to 16:58.485, 5 impulses of mic keying, peak at 1449 Hz, harmonic visible around 2890 Hz 3rd 2225 Hz, three instances from 16:58;702 to 16:59.222	Not in Transcript	Not in Transcript

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
			4th 2363 Hz, 1453 Hz, 1470 Hz, 917 Hz & others. Three impulses from about 16:59.550 through 17:00.450 5th peak at 1704 Hz. Four rapid events, from 17:00.460 to 17:01.262		
00:17:01.35	00:17:02.74	-	Weak voice heard with increasing engine sound, the latter apparently due to AGC action.	12:33:50pm: (Unreadable.)	Not in Transcript
00:17:03.18	00:17:03.73	-	Open microphone briefly ceases operation. Preceded by squelch tail.	Not in Transcript	Not in Transcript
00:17:04.2	00:17:05.3	-	"Seventy Five (Heterodyne at about 2392 Hz, other tones present)	Not in Transcript	Not in Transcript
00:17:05.76	00:17:10.08	-	(Human whistling accompanied by crosstalk of) "You want me to still hold this traffic on Stemmons 'til we find out something or let it go?" (Sound of what appears to be acoustic feedback at varying frequencies accompanies this transmission.)	12:33:52pm: You want me to still hold this traffic on Stemmons until we find out something, or . . .	Not in Transcript
00:17:10.43	00:17:11.44	-	One-oh-three, clear. (Accompanied by heterodyne at 2268 Hz.)	12:33:57pm: 103 clear. (Motor is idling.)	Not in Transcript
00:17:12.93	00:17:14.11	12:34pm	Clear, 12:34. (Transient at end.)	12:33:59pm: Clear, 12:34. (Motorcycle engine revved up.)	Not in Transcript
00:17:14.58	00:17:15.67	-	Seventy six, clear. (3226 Hz heterodyne.)	12:34:00pm: 76 clear. (Motor revved up.)	Not in Transcript
00:17:16.96	00:17:17.62	-	"Twenty three clear" (?) (Analyzed with notch filters and noise reduction. Sound of what appears to be a car door slammed in this region.)	Not in Transcript	Not in Transcript
00:17:17.87	00:17:18.82	-	Sounds like a repetition of "Seventy Five", compare with 17:04.2 and 17:3.9 (analyzed with notch filters applied, 2390 Hz heterodyne present.)	Not in transcript	Not in transcript
00:17:22.81	00:17:23.93	-	Seventy six, clear (3244 Hz heterodyne)	76 clear.	Not in Transcript
00:17:24.95	00:17:26.74	12:34pm	Seventy six, 12:34. (Weak, with engine sound present.)	12:34:09pm: 76 clear, 12:34 (Motorcycle sounds like it's moving.)	Not in Transcript
00:17:28.52	00:17:30.47	-	voices audible amid noise	Not in Transcript	Not in Transcript
00:17:33.89	00:17:35.46	-	Seventy five, a five. (with 2293 Hz heterodyne)	12:34:18pm: 75, a "5." (Motorcycle seems to gain speed.)	Not in Transcript
00:17:36.43	00:17:39.11	-	(Open microphone ceases operation. Squelch tail present.)	12:34:19pm: (Microphone closed.)	---
00:17:39.11	00:17:39.57	-	Two four …	12:34:22pm: 24…	24.

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
00:17:41.90	00:17:42.83	-	"Twenty four" (followed by a different voice speaking) "three".	24… (Unknown ____ 3…)	24.
00:17:43.37	00:17:50.04	-	Report to Inwood and Stemmons and cut all traffic for the ambulance going to Parkland, Code Three.	12:34:25pm: Report to Inwood and Stemmons and cut all traffic for the ambulance going to Parkland, Code 3.	Report to Inwood and Stemmons, cut all traffic for the ambulance going to Parkland, Code 3.
00:17:54.641	00:17:55.3	-	---	12:34:30pm: (Unknown _____ seventy, probably 75.)	Not in Transcript
00:17:55.32	00:17:56.05	-	Inwood and Stemmons?	12:34:32pm: Inwood and Stemmons?	Inwood and Stemmons?
00:17:56.78	00:17:59.62	-	Inwood and Stemmons, where they come Stemmons, going to Parkland.	12:34:35pm: Inwood and Stemmons, where they come Stemmons, going to Parkland.	… off OF Stemmons …
00:18:00.32	00:18:00.85	-	10-4.	12:34:40pm: 10-4.	10-4.
00:18:01.45	00:18:03.39	-	Make your assignment Code Three, 24.	12:34:43pm: Make your assignment Code 3, 24.	Make your assignment Code 3, 24.
00:18:04.46	00:18:05.00	-	10-4.	12:34:45pm: 10-4.	10-4. (adds time stamp of 12:35)
00:18:05.23	00:18:10.48	12:35pm	Thirty five, a signal 9A at Lobello's, Ames and Northwest, 12:35. (Motorcycle transmitter stuck open again.)	12:34:45pm: 35, a Signal 9A at Lobello's, Ames and Northwest, 12:35. (Motorcycle transmitter stuck open again.)	Not in Transcript
---	---	(12:35pm)	----------	----------	---
00:18:10.96	00:18:17.79	-	Location, ninety three? … Disregard … twenty one … twenty one.	12:34:52pm: Location, 93? … Disregard … 21 … 21	Omits “Location, 93” and “disregard”
00:18:18.61	00:18:20.49	-	Code Three, Stemmons and Inwood, cut traffic.	12:34:58pm: Code 3, Stemmons and Inwood, cut traffic.	Code 3, Stemmons and Inwood, cut traffic.
00:18:20.94	00:18:21.52	-	10-4	Not in Transcript	---
00:18:22.5	00:18:23.5	-	Three forty eight	12:35:01pm: 348 … 75 …	Not in Transcript
00:18:24.6	00:18:25.4	-	Seventy five (n.b. Bowles combines this observation with his previous entry)	(see note in Comments on Audio)	Not in Transcript
00:18:26.33	00:18:26.93	-	Seventy five.	12:35:03pm: 75	Not in Transcript
00:18:27.04	00:18:27.72	-	Signal five. (75 responding)	12:35:04pm: Signal 5?	Not in Transcript
00:18:28.04	00:18:28.55	-	10-4.	12:35:05pm: 10-4.	Not in Transcript
00:18:29.3	00:18:30.5	-	Six five, clear. (Heterodyne at 2430 Hz)	12:35:06pm: 65 clear. (More heterodyne noise.)	Not in Transcript

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
00:18:30.45	00:18:31.05		Four	(See Bowles next entry)	Not in Transcript
00:18:31.15	00:18:33.57	12:36pm	Sixty five, clear, 12:36. Four, did you call?	12:35:07pm: 65 clear (4 interrupts), 12:36. 4, did you call?	Omits "65 clear, 12:36."
00:18:33.96	00:18:34.62	-	Confirmed sound identified by Bowles as slow idle, though not shown in our measurements.	12:36pm: (Motor at slow idle.)	Not in Transcript
00:18:34.29	00:18:43.71		Yeah, 10-4, I'm out on -- Springs and – Cedar Springs and Mockingbird and I don't know what happened to the traffic officers assigned there – (probably followed by) I can't find 'em. (2146 Hz Heterodyne. Speech detected by notch filtering, also using carrier injection to demodulate sideband energy.)	12:35:12pm: … Cedar Springs and Mockingbird … (Noisy signal, unreadable; motor slow and irregular.)	(could hear someone talking but could not make it out)
00:18:44.81	00:18:48.76	-	Four, we have a mike bus stu – but – button stuck open. We can't hear anything. (misspeaks)	12:35:22pm: 4, we have a mike butt stuck . . . bike . . . button stuck open. We can't hear anything. (Still unreadable; motor slow and irregular.)	4, have a mike button stuck open. We can't hear anything (still could not understand)
00:18:50.40	00:18:53.17	-	(Unreadable. Unit four transmission, based on 2170 Hz heterodyne frequency. Attempts to reveal content were unsuccessful.)	Not in Transcript	Not in Transcript
00:18:56.23	00:18:57.30	-	(Unreadable. Unit four transmission, based on broad peak in heterodyne frequency around 2165 Hz. Attempts to reveal content were unsuccessful.)	Not in Transcript	Not in Transcript
00:18:59.56	00:19:00.18	-	Ninety three …	12:35:36pm: 93…	Not in Transcript
00:19:01.75	00:19:11.12	12:36pm	Attention all emergency equipment, attention all emergency equipment, do not use Industrial Boulevard, do not use In – buh – dustrial (misspeaks) Boulevard, 12:36. (this is broadcast on both channels. 00:15m:37s on Ch2 – 2 reel 2. Announces 12:36 time at end of transmission.)	12:35:38pm: Attention all emergency equipment. Attention all emergency equipment. Do not use Industrial Boulevard. Do not use Industrial Boulevard, 12:36.	Attention all emergency equipment. Attention all emergency equipment. Do not use Industrial Boulevard. Do not use Industrial Boulevard, 12:36.
00:19:12.58	00:19:13.39	-	Ninety three.	12:35:47pm: 93. (Motor idled-down.)	Not in Transcript
00:19:14.11	00:19:14.78	-	Location?	12:35:48pm: Location?	Not in Transcript
00:19:15.91	00:19:17.07	-	Sylvian and Fort Worth.	12:35:49pm: Sylvian and Fort Worth. (Motor still slow.)	Not in Transcript
			(Several signals, appears to be	12:35:54pm: El … uh … eleven	Not

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Bowles	Sawyer
00:19:21.55	00:19:26.90	-	Spanish language. The word "nada" is clearly audible at end)	… (Unreadable.)	in transcript
00:19:26.90	00:19:28.56	-	"I got a witness that says … fifth floor …" This statement is crosstalk from around 00:16m:02s in Ch2. Ref. *60 JFK 2 reel_2*)	12:35:57pm: . . . came from the fifth floor . . .	Not in transcript
00:19:30.08	00:19:30.53	-	Two four … (appears in the middle of "I got a witness…" transmission)	24 … (interrupting)	Not in Transcript
00:19:29.35	00:19:32.15	-	. . . of the Texas Depository . . . Bookstore [sic].	. . . of the Texas Depository . . . Bookstore [sic].	Not in Transcript
00:19:34:06	00:19:34:40	-	(open mic ceases transmission. Squelch tail evident.)	12:36:04pm: Transmitter closed with this message.	Not in Transcript
00:19:35.43	00:19:36.49	-	Thirty five, did you receive?	12:36:05pm: 35, did you receive?	35, did you receive?
00:19:38.07	00:19:38.60	-	I got it.	12:36:07pm: I got it.	I'VE got it. (adds time stamp of 12:37)
00:19:38.87	00:19:39.33	-	10-4.	12:36:08pm: 10-4.	Not in Transcript
00:19:41.13	00:19:41.89	-	Sixty one, clear.	12:36:10pm: 61 clear.	Not in Transcript
00:19:42.63	00:19:44.02	12:37pm	Sixty one clear, 12:37.	12:36:15pm: 61 clear, 12:37.	Not in Transcript
00:19:49.40	00:19:52.29	-	Four to eleven … eleven thirty one.	12:36:21pm: 4 to 11 … 1131.	Not in Transcript
00:19:54.75	00:19:56.94	-	Two one …	12:36:26pm: 21 … (His siren slowing down in background…)	Not in Transcript
00:19:56.95	00:19:58.56	-	Twenty one … (Another transmission present saying "continue".)	12:36:28pm: 21 … continue … (interrupted.)	Not in Transcript
00:20:01.77	00:20:00.40	-	Twenty four …	12:36:31pm: 24 …	Not in Transcript
00:20:04.13	00:20:04.94	-	Ninety three …	12:36:35pm: 93 … (Dispatcher continued with:)	Not in Transcript
00:20:05.74	00:20:12.44	-	. . . to Inwood and Stemmons and assist twenty four . . . twenty one, go up there to Hines and cut that service road off there where that ambulance can go on to Parkland.	. . . to Inwood and Stemmons and assist 24 . . . 21, go up there to Hines and cut that service road off there where that ambulance can go on to Parkland.	Not in Transcript
00:20:14.27	00:20:14.85	-	Ninety one …	12:36:43pm: 91 …	Not in Transcript
00:20:14.96	00:20:15.39	-	10-4.	12:36:44pm: 10-4. (probably 21.)	Not in Transcript

APPENDIX C. DALLAS POLICE DEPARTMENT RADIO CHANNEL 2 TIMELINE

This timeline contains the following columns:

- "Start Time" and "End Time" refer to the start and end of events relative to the start of the recording.
- "Clock Time" is used to record time announcements from the dispatcher where they are noted in the transcripts.
- "Sonalysts Comments on Audio" refers to data collected by Sonalysts. Parenthetical references generally contain commentary.
- "Sawyer" refers to the transcript provided by Sawyer as contained in Warren Commission Exhibit 705.
- "Archives" refers to the transcript found in City of Dallas Archives JFK Collection, Box 14, Folder 4, Item 11: "Radio Traffic Transcript, by an unknown author. Transcript of radio traffic from President's arrival at Love Field to the arrest of Lee Harvey Oswald. Copy sent to the secret service, (Photocopy), 11/22/63. 00003298 82 pages"
- "Bowles" refers to the transcript found in the appendix of James C. Bowles: "The Kennedy Assassination Tapes: A Rebuttal to the Acoustical Evidence Theory".

n.b. All times and frequencies are uncorrected for speed errors as evidenced by AC power hum frequencies. Times and frequencies should be multiplied by 1.05 to correct for the apparent 57.2 Hz hum evident in the recording. Also, time values are necessarily approximate in the case of sounds that have poorly defined extents. Heterodyne frequencies, where noted, usually refer only to the highest frequency component. In some instances many heterodyne frequencies are evident. Also, the precision with which heterodyne frequencies are measured is dependent on their duration, and some heterodynes are broad in frequency.

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
00:09:32.13	00:09:33.16	-	Pretty good crowd there?	Pretty good crowd there?	10-4, is there a pretty good crowd there?	Pretty good crowd there?
00:09:33.67	00:09:34.60	-	Big crowd, yes.	Big crowd, yes.	Big crowd, yes.	Big crowd, yes.
00:09:35.06	00:09:36.09	12:28pm	10-4, 12:28.	*Not in Transcript*	10-4, 12:28.	10-4, 12:28.
00:09:37.72	00:09:39.02	-	Five to five thirty one.	*Not in Transcript*	*Not in Transcript*	5 to 531 . . .
00:09:39.62	00:09:40.01	-	Five.	*Not in Transcript*	*Not in Transcript*	5.
00:09:42.93	00:09:43.94	-	Five to, uh . . .	*Not in Transcript*	*Not in Transcript*	5 to, uh . . .
00:09:44.98	00:09:48.73	-	Uh notify Captain Souter that uh, the location of the convoy now.	Uh notify Captain Suiter the location of the convoy now.	Notify Captain Suiter that the location of the convoy --- ---.	uh. Notify Captain Souter that . . . The location of the convoy now.
00:09:49.28	00:09:50.33	-	Fifteen, car two.	*Not in Transcript*	Car 2, car 2.	15 car 2.
00:09:52.47	00:09:53.43	-	Fifteen, Car 2.	*Not in Transcript*	Come in, car 2.	15 car 2.

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
00:09:55.44	00:09:56.40	-	SKIP of: Fifteen, Car 2.	-	-	-
00:09:57.54	00:09:58.06	-	SKIP of: Fifteen, Car 2.	-	-	-
00:09:58.79	00:10:02.44	-	Now on Main, probably just past Lamar.	On Main probably just past Lamar.	Now on Main probably just past Lamar.	Now on Main, probably just past Lamar.
00:10:02.60	00:10:03.45	-	Some sort of horn (car?) mixed with "10-4".	*Not in Transcript*	*Not in Transcript*	10-4.
00:10:03.49	00:10:04.83	-	Just crossing Market Street. (Reverberant with echoes.)	Just crossing Market Street.	Just crossing Market Street.	Just crossing Market Street.
00:10:05.08	00:10:07.35	12:28pm	Now at Market, car two, 12:28.	*Not in Transcript*	Car 2, 12:28	Now at Market, car 2, 12:28.
00:10:11.42	00:10:12.23	-	One twenty five.	*Not in Transcript*	25	125
00:10:14.20	00:10:15.02	-	One twenty five.	*Not in Transcript*	*Not in Transcript*	*125*
00:10:15.56	00:10:16.38	-	Go ahead, four.	*Not in Transcript*	Go ahead 4	Go ahead, 4.
00:10:17.42	00:10:20.70	-	One twenty five, four. What traffic personnel do you have…	*Not in Transcript*	What traffic personnel do you have on …. ?	*Not in Transcript*
00:10:20.70	00:10:25.71	-	(skip) One twenty five, four. What traffic personnel do you have on Cedar Springs in the vicinity of the field here?	*Not in Transcript*	*Not in Transcript*	125, this is 4. What traffic personnel do you have on Cedar Springs in the vicinity of the field here?
00:10:27.54	00:10:32.14	-	I had, uh, four on uh Cedar Springs … and … uh … Cedar Springs and Mockingbird?	*Not in Transcript*	--- --- Mockingbird (?)	Stand by . . . Uh, Cedar Springs and Mockingbird?
00:10:33.42	00:10:36.41	-	Yes. The traffic seems to be moving out of this lot awfully slow.	*Not in Transcript*	--- --- seems to be moving awfully slow.	Yes. The traffic seems to be moving out of this lot awfully slow.
00:10:36.48	00:10:37.60	-	What, uh . . . What's your location?	*Not in Transcript*	What's your location?	What, uh . . . What's your location?
00:10:37.87	00:10:41.23	-	I'm at the Trade Mart now headed back out that way.	*Not in Transcript*	I'm at the Trade Mart now heading back out that way.	I'm at the Trade Mart now. I'll head back out that way.
00:10:41.24	00:10:42.45	-	Nah that's alright. I'll check it.	*Not in Transcript*	*Not in Transcript*	Naw, that's all right. I'll check it.
00:10:43.28	00:10:43.58	-	10-4.	*Not in Transcript*	*Not in Transcript*	10-4.
		-	(Note: Sawyer is referring to the general conversation around	Talking about the traffic at	*Not in Transcript*	*Not in Transcript*

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
			this time.)	Love Field.		
00:10:44.61	00:10:45.62	-	… triple underpass.	… triple underpass.	*Not in Transcript*	At the Triple Underpass.
00:10:46.21	00:10:47.99	-	10-4 one, fifteen car two	*Not in Transcript*	10-4 1, 15 Car 2	10-4, 1 . . . 15 car 2.
00:10:52.16	00:10:54.49	12:30pm	12:30 KKB three sixty four.	*Not in Transcript*	12:30 KKB 364	12:30 KKB364.
00:10:57.97	00:10:59.16	-	One two five to two fifty.	*Not in Transcript*	--- --- 250	125 to 250 . . .
00:11:01.13	00:11:02.37	-	SKIP of: One two five to two fifty.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:11:03.80	00:11:04.40	-	Burst of static noise.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
----------	----------	----------	----------	Station break.	----------	----------
00:11:08.39	00:11:11.95	-	"Fifteen Car 2" interrupted by a low pitch noise and followed by "Go to the hospital officers …" (Abundant background noise. Note: The word "hospital" is somewhat obscured by a transient.)	*Not in Transcript*	Unreadable	15 car 2 . . . Go to the hospital. We're going to the hospital officers. (Someone in the background "On our way!") …
00:11:14.22	00:11:14.33	-	(Short noise burst.)	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:11:15.22 00:11:22.70 00:11:30.79 00:11:35.09	00:11:18.65 00:11:27.51 00:11:34.28 00:11:37.96	-	Go the hospital. Parkland Hospital. On our way to Parkland Hospital. And have them stand by. Get men on top of that building – underpass – see what happened up there – go up there – overpass Unidentifiable speech and static followed by what sounds like "Uh one." (Sounds like three overlapping transmissions. Each transmission obscures the previous one.) Again, unidentifiable speech and static followed by "Have Parkland stand by."	Go to the hospital, officers. Parkland Hospital, have them stand by. Get men on top of the underpass, see what happened up there. Go up to the overpass. Have Parkland stand by.	--- --- get men on top of that underpass. Unreadable Have --- --- stand by.	… Parkland Hospital. Have them stand by. Get men on top of that over . . . underpass. See what happened up there. Go up to the overpass.(At least one transmitter was open for a while, now.) (Unreadable; sounds like:) 91 Champion. _____ to 1.
00:11:42.18	00:11:43.75	-	One, Dallas One.	*Not in Transcript*	*Not in Transcript*	1 . . . Dallas 1 . . .

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
00:11:44.23	00:11:45.23	-	Go ahead, Dallas One.	*Not in Transcript*	Go ahead Dallas 1	Go ahead, Dallas 1.
00:11:45.28	00:11:49.40	-	"…my men empty the jail and up on the uh, railroad right of way there." (Note: First part of transmission appears to be obscured by previous transmission. Noise burst around "empty" obscures word.)	*Not in Transcript*	*Not in Transcript*	Tell my men to empty the jail; and up on the railroad, uh, right-of-way there . . .
00:11:49.86	00:11:53.20	-	"I'm sure it's gonna take some time for you to get your men in. Put every one of my men in there"	I'm sure it's going to take some time to get your men in there. Put every one of my men there.	I'm sure it's going to take some time to get your man in --- ---. Unreadable	I'm sure it's going to take some time for you to get your men in. Pull everyone of my men in there.
00:11:56.64	00:11:58.65	-	Repeat One, I didn't quite understand all of it.	Repeat One, I didn't quite understand all of it.	Repeat 1, I don't quite understand all of that.	Repeat, 1. I didn't quite understand all of it.
00:12:00.40	00:12:14.05	-	Have, um station five to move all men available out of my department back into the railroad yards there in an effort to try to determine if what and when happened down there and hold everything secure until the homicide and other investigators can get there.	Notify station five to move all men available out of my department back into the railroad yards and try to determine what happened and Hold everything secure until Homicide and other investigators can get in there.	--- railroad yard there in an effort to --- ---.	Have Station 5 to move all men available out of my department, back into the railroad yards there in an effort to try to determine . . . just what and where it happened down there, and hold everything secure until the homicide and other investigators can get there.
00:12:14.84	00:12:16.70	-	10-4 Dallas One. Station five will be …	10-4	10-4 Dallas 1. Unreadable	10-4, Dallas 1, Station 5 will be notified.
00:12:17.05	00:12:17.92	-	Static burst.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:12:21.53	00:12:22.10	-	Five seven.	*Not in Transcript*	*Not in Transcript*	57 . . .
00:12:23.78	00:12:24.59	-	"One" followed by squelch tail.	*Not in Transcript*	*Not in Transcript*	1 . . .
00:12:25.12	00:12:25.55	-	Cut off speech followed by short burst of static.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:12:26.97	00:12:27.90	-	SKIP of "'One' followed by static."	*Not in Transcript*	1 1 1 1	*Not in Transcript*
00:12:29.18	00:12:30.15	-	– formation whatsoever.	12:31pm: Any information whatsoever?	No information whatsoever.	Any information whatsoever?
00:12:30.95	00:12:35.37	-	(Agrees with others. The word Parkland is covered by another	It looks like the President has been hit. Have Parkland stand	Looks like the President has been hit (?) --- ---	Looks like the President's been hit. Have Parkland stand

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
			unidentifiable transmission.)	by.	stand by.	by.
00:12:35.60	00:12:38.27	12:32pm	10-4. Parkland has been notified, 12:32.	Parkland has been notified.	10-4 Parkland has been notified.	10-4. Parkland has been notified, 12:32.
00:12:40.01	00:12:40.52	-	SKIP of the word "notified" from above.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:12:43.22	00:12:44.33	-	Four, four. (This is two separate transmissions.)	*Not in Transcript*	4	4 . . . 4
00:12:44.76	00:12:47.32	-	We have those canine units in that vicinity, don't we?	12:32pm: We have K-9 units in that vicinity, don't we?	Unreadable	We have those canine units in that vicinity, don't we?
00:12:48.68	00:12:49.58	-	Uh stand by, one.	*Not in Transcript*	Stand by 1 1 1	Stand by. 1 . . .
00:12:53.41	00:12:54.62	-	(Weakly heard) Headed to Parkland. (Note: This is groove echo.)	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:12:54.64	00:12:55.72	-	Five to one.	*Not in Transcript*	*Not in Transcript*	5 to 1 . . .
00:12:56.27	00:12:58.823	-	Sirens and "Headed for Parkland" followed by, "Is something the matter with Channel 1?"	Straight to Parkland.	Is something the matter with Channel 1?	(We're) headed for Parkland ... (Sirens loud in the background.) Is something the matter with Channel 1? (Likely #57.)
00:12:59.81	00:13:00.54	-	Five to one.	*Not in Transcript*	5 to 1	5 to 1 . . .
00:13:01.01	00:13:01.92	-	"Go ahead" accompanied by sirens.	*Not in Transcript*	Go ahead	Go ahead.
00:13:02.15	00:13:05.09	-	You want … what disposition do you want me to make with these men out here with me?	What disposition do you want me to make with these men I have with me?	*Not in Transcript*	You want . . . What description do you want to make on these men I have with me?
00:13:06.36	00:13:08.19	-	Just go on to Parkland with me. (Note: Accompanied by sounds of sirens.)	Just go on to Parkland Hospital with me.	--- going toward the hospital with me (?)	Just go on to Parkland with me. (Sirens loud in the background.)
00:13:09.47	00:13:11.58	-	SKIP of: Just go on to Parkland with me.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:13:12.83	00:13:15.25	-	SKIP of: "Just go on to Parkland with me" cut off by "10-4".	*Not in Transcript*	That's all	*Not in Transcript*
00:13:19.62	00:13:20.24	-	Sounds like "Two-three."	*Not in Transcript*	*Not in Transcript*	_____ 3 . . .
00:13:21.55	00:13:25.46	-	Dispatcher on um, on one seems to have his mic stuck.	*Not in Transcript*	The dispatcher on 1 seems to be having mike --- --- (unintelligible)	Dispatcher on numb . . . uh, on "1" seems to be . . . have his mike stuck . . . (Loud

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
						sirens covered any remaining comment.)
00:13:25.47	00:13:28.95	-	Traffic noises followed by a brief unidentifiable voice transmission. (Note: Sounds of sirens in background and apparent groove echo of previous transmission.)	*Not in Transcript*	*Not in Transcript*	(Unreadable. Might be 20 or 220.)
00:13:33.86 00:13:36.88 00:13:44.45	00:13:35.75 00:13:37.76 00:13:45.03	-	… these trucks out of the way. (Note: First word(s) obscured by strong low frequency modulation.) Another voice is heard shouting in the background, sounds like "…let's go." Hold everything. Get out of the way (?) (or possibly the same as Bowles'.)	Get out of the way. (Something about trucks) Hold everything. Get on the way(?) (Recording not too clear.)	Hold everything	Get these trucks out of the way . . . Hold everything . . . Get 'em out of the way.
00:13:47.19	00:13:49.60	-	Fifteen, car two … fifteen, car two.	*Not in Transcript*	*Not in Transcript*	15 car 2 . . . 15 car 2.
00:13:50.11	00:13:55.64	-	… cycle officer up on Stemmons with his mike stuck open on Channel one. Could you send someone up there to tell him to shut it off? (Note: transmission begins on "cycle" suggesting a skip or other defect in recording. (*60 JFK 6 reel_1* contains the entire transmission.)	There is a motorcycle officer on Stemmons with his mike stuck open on channel one. Could you send somebody up there and tell him to shut it off?	Mike stuck on Channel 1. Could you send someone up there to tell him to shut it off.	There's a motorcycle officer up on Stemmons with his mike stuck open on Channel 1. Could you send someone up there to tell him to shut it off?
00:13:55.68	00:13:58.98	-	SKIP of: "… open on Channel one. Could you send someone up there to tell him to shut it off? …"	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:13:59.11	00:14:01.13	12:34pm	Note: "___ four. 10-4" and "12:34" are separate transmissions.	*Not in Transcript*	12:34	10-4. 12:34.

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
00:14:02.15	00:14:05.24	-	(Agrees with Bowles. Substantial acoustic feedback evident)	*Not in Transcript*	Unreadable	I'm up on Stemmons. I'll check all these motorcycle radios.
00:14:05.58	00:14:06.08	-	10-4.	*Not in Transcript*	10-4	10-4.
00:14:11.69	00:14:13.34	-	First transmission, strong 1772 Hz tone, also 5350 Hz. Unable to determine content. Then "One ninety".	*Not in Transcript*	19	190 . . . 190.
00:14:14.18	00:14:18.46	-	You want me to still hold this traffic on Stemmons until we find out something or let it go?	12:34pm: You want me to still hold traffic on Stemmons until we find out something?	*Not in Transcript*	You want me to hold this traffic on Stemmons until we find out something, or let it go? (Heterodyne.)
00:14:18.85	00:14:20.71	-	"got to keep everything out of this emergency entrance." Could also be "try to keep everything out of this emergency entrance." (Note: Transmission appears to be obscured by prior transmission at onset.)	Keep everything out of the Emergency entrance.	--- --- keep everything under emergency basis --- ---.	Keep everything out of this emergency entrance.
00:14:22.23	00:14:23.28	-	Burst of feedback and "10-4".	*Not in Transcript*	10-4	10-4. (Unknown to what message.)
00:14:24.31	00:14:25.38	-	"One three six" and feedback noise.	*Not in Transcript*	*Not in Transcript*	136…
00:14:27.54	00:14:28.41	-	One three six.	*Not in Transcript*	136	136.
00:14:29.65	00:14:36.33	-	"Uh, passerby found uh Texas School Book Depository that says uh shots came from that building."	A passerby states the shots came from the TX School Book Depository Building.	--- --- shots came --- ---.	A passerby says . . . the Texas Schoolbook [sic] Depository . . . Stated that the shots came from that building.[c]
00:14:36.33	00:14:37.19	-	Get everything out of the way.	Get everything out of the way.	*Not in Transcript*	Get everything out of the way. (Referring to the vehicles clustering around the emergency dock at Parkland Hospital.)
00:14:40.00	00:14:42.34	-	10-4. Get all that information, One Three Six.	Get all the information.	10-4 Get all that information 136.	10-4. Get all that information,136.
00:14:45.68	00:14:46.53	-	Burst of feedback and "10-4"	*Not in Transcript*	10-4	10-4.
00:14:49.60	00:14:50.42	12:35pm	12:35.	*Not in Transcript*	12:35	12:35.

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
00:14:57.31	00:14:59.26	-	"Four two" followed by "One-forty-two."	*Not in Transcript*	142	142 … 142.
00:15:00.73	00:15:13.64	-	"I just talk to a guy up here _____ Texas School Book Depository Building here with that Hertz Rent _____ on top."	12:35pm: I talked to a guy at the scene who says the shots were fired from the TX School Book Depository Building with the Hertz Rent-A-Sign on top.	Apparently a message about a witness who saw where shot was fired from. (Message mostly unintelligible).	142 . . . I talked to a guy up here at the scene of this, where the shots were fired at. And he said that he was sitting here close to it. And the very best he could tell, they came from the Texas Schoolbook [sic] De . . . pository Building here, with that Hertz Rental sign on top.
00:15:14.23	00:15:19.24	12:35pm	10-4. Get his name, address and phone number, and uh, all the information you can, 12:35.	Get his name, address, phone number, and all information you can.	10-4 Get name and address and phone number and all information you can. 12:35	10-4. Get his name, address and phone number, and all the information you can, 12:35.
00:15.21.76	00:15:24.35	-	Fifteen, car 2 … fifteen, car two (Note: two transmissions)	*Not in Transcript*	15 Car 2 15 Car 2	15 Car 2 … 15 Car 2
00:15.24.34	00:15:31.95	-	Audio includes "Captain" at the beginning of this transmission… Sawyer and TX DPS seem to disagree on the words used in this transmission.	Advise all emergency traffic to use some other route besides Industrial and have 283 cut traffic at Hines and Industrial.	Reroute traffic beside the Industrial and 283 cut the traffic at Hines and Industry.	(The) Captain advises, have all emergency traffic use some route besides Industrial
00:15.32.881	00:15:37.365	-	10-4. 283 cut traffic at Hines and Industrial, 283 cut traffic at Hines and Industrial.	Broadcast same.	*Not in Transcript*	. . . Have 283 cut the traffic at Hines and Industrial. (Then, using simultaneous broadcast:)
00:15.37.70	00:15:46.02	12:36pm	Attention all emergency equipment, attention all emergency equipment, do not use Industrial Boulevard, do not use In – buh – dustrial (misspeaks) Boulevard, 12:36.	*Not in Transcript*	Attention all emergency equipment. Do not used Industrial Boulevard. Do not use Industrial Boulevard. 12:36	Attention all emergency equipment . . . Attention all emergency equipment . . . Do not use Industrial Boulevard, 12:36.
00:15.52.96	00:15:53.68	-	Two sixty.	*Not in Transcript*	*Not in Transcript*	260 …
00:15.54.01	00:15:54.65	-	Two sixty.	*Not in Transcript*	*Not in Transcript*	260.
00:15.55.23	00:16:11.46	-	This transmission skips 3 times before playing through the whole thing.	12:36pm: Witness says shots came from fifth floor TX	--- --- 4th floor --- ---.	I have a witness who says they **came from** the 5th floor

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
			"I have a witness that says they came from the fifth floor of the Texas, uh, Depository bookstore at Houston ____ building. (Note: both channel 2 recordings we examined exhibit this.)	Book Depository store at Houston and Elm. I have him with me now and we are sealing off the building.		of the Texas . . . uh . . . Depository Bookstore (sic) at Houston and _____ Building.
00:16:12.49	00:16:13.01	-	Uh, 10-4.	*Not in Transcript*	10-4	10-4.
00:16:14.33	00:16:15.27	12:36pm	12:36	*Not in Transcript*	12:36	12:36.
00:16.19.94	00:16:20.66	-	Two twenty.	*Not in Transcript*	*Not in Transcript*	220 …
00:16.22.63	00:16:23.06	-	Two twenty.	*Not in Transcript*	220	220.
--	--	-	(Not in *60 JFK 2 reel_2*; *60 JFK 6 reel_1* agrees with Bowles.)	Where do you want traffic cut in the area?	*Not in Transcript*	Where do you want traffic cut going into that area?
00:16.23.75	00:16:30.88	-	Keep all traffic off of the emergency entrance to Parkland Hospital and all emergency equipment off of Industrial Boulevard.	Keep all traffic off Industrial and the emergency entrances at Parkland.	Keep all of the traffic off to the emergency entrance to Parkland Hospital and all the emergency equipment off the Industrial Boulevard.	Keep all traffic out of the emergency entrance to Parkland Hospital, and all emergency equipment off of Industrial Boulevard.
00:16.32.09	00:16:32.72	-	10-4.	*Not in Transcript*	10-4	10-4.
00:16.33.21	00:16:33.61	-	One …	*Not in Transcript*	1	1 …
00:16.35.60	00:16:36.19	-	"10-4". SKIP from two lines above this.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:16.37.27	00:16:39.00	-	We have the emergency entrance secure.	We have the emergency entrance secure.	We're at the emergency entrance of Parkland Hospital.	We have the emergency entrance secure at Parkland.
00:16.39.27	00:16:39.67	-	– Parkland.	*Not in Transcript*	*Not in Transcript*	*Not in Transcript*
00:16.40.18	00:16:42.13	12:37pm	10-4, one twenty five, 12:37.	*Not in Transcript*	10-4 125 12:37	10-4, 125, 12:37.
00:16.46.73	00:16:47.63	-	Twenty two …	*Not in Transcript*	*Not in Transcript*	22 …
00:16.48.20	00:16:48.54	-	Go ahead.	*Not in Transcript*	Go ahead.	Go ahead.
00:16.49.40	00:17:03.86	-	Get the men up there to cover this _____ Texas School Book Depository. Believe the shots come from that, facing it on a, uh, Elm Street. Looking towards the building it would be your upper, right hand corner at the second window to	12:37pm: Get men to cover the building TX School Book Depository. Believe the shots came from there, facing it on Elm Street. Looking at the building it will be the second window from the end in the upper right hand corner.	--- School Book Depository Building. The shots came from --- corner --- second window from the end.	Get some men up here to cover this building . . . this Texas Schoolbook [sic] Depository. It's believed that these shots came from that. As you're facing it on, uh, it'll be Elm Street, looking towards the building, it

Start Time	End Time	Clock Time	Sonalysts Comments on Audio	Sawyer	TX DPS	Bowles
			the end.			would be your upper . . . right-hand corner . . . at the second window from the end.
00:17.04.81	00:17:06.58	-	10-4. How many do you have there?	How many do you have there?	10-4 How many do you have there.	10-4. How many do you have there?(
00:17.08.47	00:17:17.18	-	I have one guy that was possibly hit by a ricochet, from a bullet off concrete, and another one that seen the President slump, and another one here that . . . that . . .	One guy possibly hit by a ricochet off the concrete and another one that seen the President slump.	--- hit by a ricochet ---.	I have one guy that was possibly hit by a ricochet, from a bullet off concrete, and another one that seen the President slump, and another one here that . . . that . . . (137 covered the rest of 22's message.)
00:17.19.74	00:17:20.30	-	One thirty seven.	*Not in Transcript*	*Not in Transcript*	137 …
00:17.20.55	00:17:22.21	12:38pm	10-4, 12:38. One thirty seven . . .	*Not in Transcript*	10-4 12:38 137	10-4, 12:38. 137 . . .
00:17.22.58	00:17:30.89	-	We have a man here that said he saw 'em pull a weapon back through the window off the second floor on the south . . . east corner of that Depository Building.	A witness says he saw ‘em pull the weapon from the window off the second floor on the south east corner of the Depository building.	We have a man here who says he saw a fellow with a weapon back through the window of the second floor on the southeast corner of that Depository Building.	We have a man here that said he saw 'em pull a weapon back through the window off the second floor on the south . . . east corner of that Depository Building.

XIII. Acknowledgements

The authors would like to thank Curt Ramm for his audio editing expertise, Melinda Finkle for her substantial work on the timelines and graphics, and Dr. John Jakacky for his data extraction suggestions and review of our work.

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Comparative Analysis of Recordings derived from the Dallas Police Department Channel 1 Dictabelt Recording dating to Nov. 22, 1963

Research Commissioned by Dr. Larry Sabato and The Kennedy Legacy Project of the UVA Center for Politics.

Authors: Jonathan Grant, Mark Bamforth, Charles Olsen (Sonalysts, Inc.)

6, June, 2013

Abstract

A comparison of a variety of audio files all derived from the Dallas Police Department Channel 1 recordings is made. Waveform features attributed to gunfire by BRSW are visible in the recordings and their locations have been identified in each file. The spectral compositions of the recordings differ slightly, and these differences are identified and explained. Playback speed and correction factors needed to achieve correct playback speed are identified. Waveform polarity is investigated.

Introduction

Goals

Audio impulses transmitted by an officer's open microphone and recorded by the Dallas Police Department require study. These impulses were attributed to assassination gunfire in research conducted by Bolt, Beranek and Newman (BBN). BBN identified these impulses in their report to the House Select Committee on Assassinations (HSCA). In order to evaluate these impulses, the determination must first be made as to whether they are identifiable in the various recordings that are derived from the original Dallas Police Department Dictabelt recording of radio channel 1.

Materials

Reports

"Analysis of Recorded Sounds Relating to the Assassination of President John F. Kennedy" –James E. Barger, Scott P. Robinson, Edward C. Schmidt, and Jared J. Wolf. Bolt, Baranek & Newman, Inc., 1979 (Contained in HSCA Report, Volume 8) (Hereinafter referred to as BRSW).

"An Analysis of Recorded Sounds Relating to the Assassination of President John F. Kennedy" -- Prepared for Select Committee on Assassinations, U.S. House of Representatives, by Mark R. Weiss and Ernest Aschkenasy, Department of Computer Science, Queens College, City University of New York, February 1979. (Hereinafter referred to as W&A).

Audio files

File Name	Source
60 JFK 5 reel_1.aif	Provenance: National Archives
233JFK-F-351-353.wav	233JFK_F_351_353 (HSCA/BBN Exhibits) (Provenance: National Archives)
Disc 1 of 2: 1 Audio Track.aiff	Bowles Tape (Provenance: O'Dell, Source P-01)
Disc 1 of 2: 5 Audio Track.aiff	FBI Copy (Provenance: O'Dell, Source P-03)

Process

Approach

The location of impulses attributed to gunfire are graphically identified in both the BRSW and W&A reports. A protocol using the audacity program to visually display waveforms and allow comparison to those in the cited literature is undertaken.

Some of the data shown by BRSW are not shown as traditional waveforms but instead show log amplitude versus time. A computer program developed in-house is used to obtain this representation of the data so that it may be visually compared with the cited literature.

Additional comparisons are made between the various recordings in order to determine relative running speeds and other characteristics. To this end, frequencies of heterodyne tones are measured and compared. Similarly, the measured time duration between two distinct events is compared in order to provide another view of any speed variation between recordings.

Waveform features are examined in order to determine the polarity of the recorded signal and to see if it differs between recordings.

Tools

Audacity Team, Audacity®. Version 2.0.2. Audio editor and recorder. Available from: http://audacity.sourceforge.net/

Gnuplot release 4.0.2 Copyright 1986 - 1993, 1998, 2004 Thomas Williams, Colin Kelley

In-house developed C program for generating log-scale amplitude time-value pairs from audio files.

Adobe Photoshop, Adobe Illustrator, Microsoft Word and Excel.

Results

The following results are reported:

- Timing of events (alleged gunfire impulses) for all recordings.
- Images of impulse sequences compared to graphs in BRSW report.
- Spectral Composition.
- Timespan analysis for speed determination.
- Heterodyne frequency analysis for speed determination.
- Waveform visual examination to show polarity.

Timings of Alleged Gunfire Events

The following table shows the times at which specific "gunshot" impulses as well as other easily identified features may be found in the various recordings. Note that the times correspond to the first numbered feature associated with each gunshot as shown in the BRSW paper.

	60 JFK reel_1 (National Archives)	Bowles Tape (Provenance O'Dell)	FBI Copy (O'Dell)	233JFK_F_351_353 (HSCA/BBND)
MotorCycle Noise Onset	11.35.304	1.27.910	00.43.308	NA
"5-7"	13.58.201	3.46.456	3.05.016	26.277
Impulse 1	14.02.879	3.51.018	3.09.699	31.086
Impulse 2	14.04.629	3.52.749	3.11.468	32.946
"Hold Everything"	14.9.418	3.57.466	3.16.270	38.030
Impulse 3	14.10.261	3.58.285	3.17.154	38.907
Impulse 4	14.10.938	3.58.947	3.17.873	39.556

Images showing Waveform Features associated with Alleged Gunfire Events

The following images show an illustration taken from the BRSW report (upper) and a corresponding Audacity screen image (lower) with the same features identified. Note that the times reported for "60 JFK 5 reel 1" are approximate to the second and roughly correspond to the onset of the events noted in BRSW.

Impulse 1

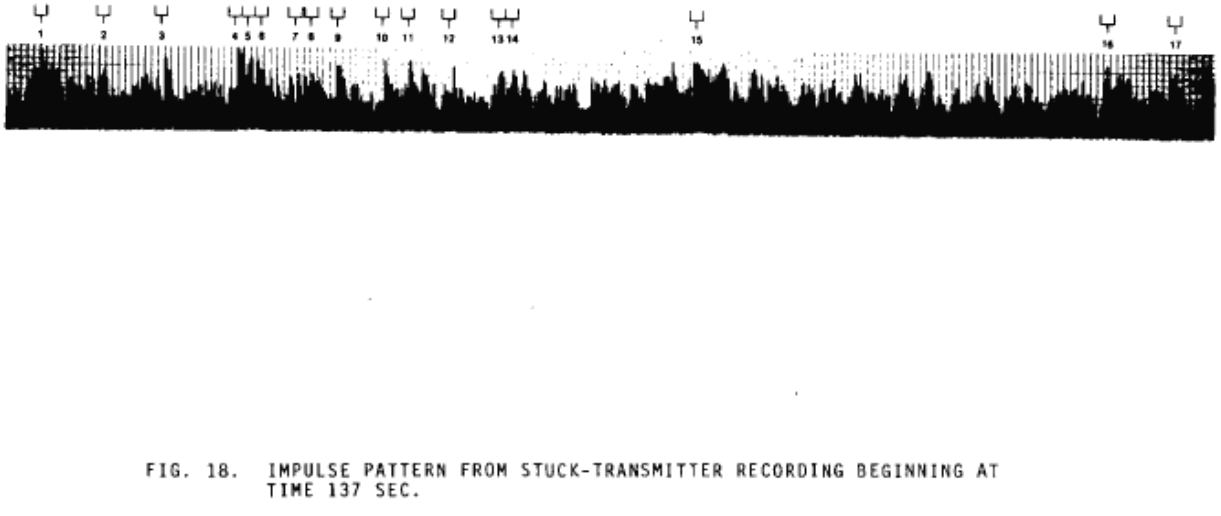
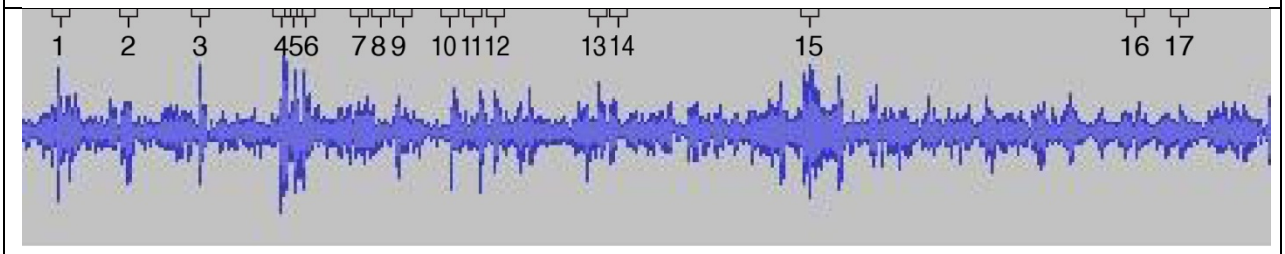


FIG. 18. IMPULSE PATTERN FROM STUCK-TRANSMITTER RECORDING BEGINNING AT TIME 137 SEC.



Location of impluse idenified by BBN as observed in 60 JFK 5 reel_1 at time 843 sec.

Impulse 2

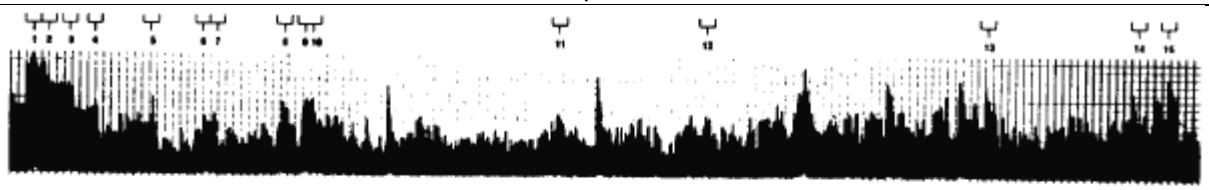
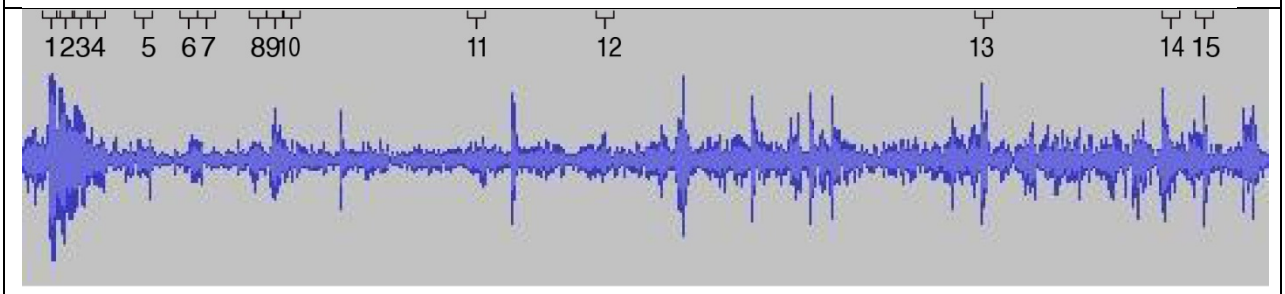


FIG. 19. IMPULSE PATTERN FROM STUCK-TRANSMITTER RECORDING BEGINNING AT TIME 139 SEC.



Location of impluse idenified by BBN as observed in 60 JFK 5 reel_1 at time 845 sec.

Impulse 3

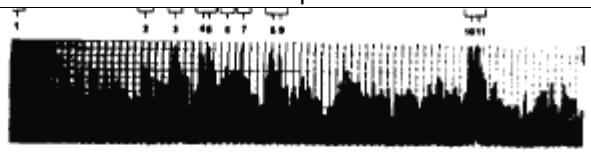
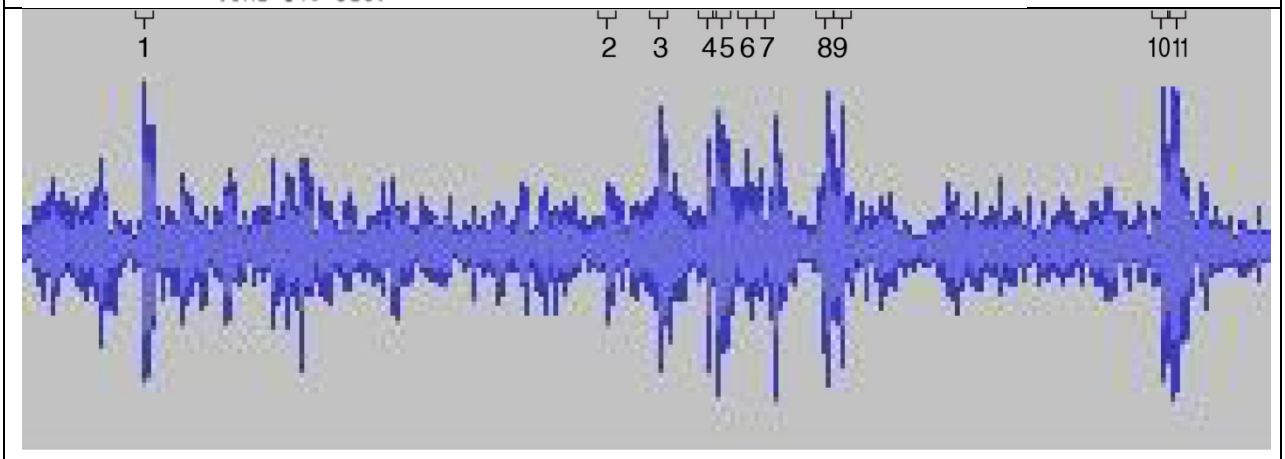


FIG. 20. IMPULSE PATTERN FROM STUCK-TRANSMITTER RECORDING BEGINNING AT TIME 145 SEC.



Location of impluse idenified by BBN as observed in 60 JFK 5 reel_1 at time 850 sec.

Impulse 4

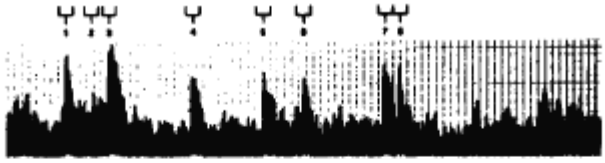
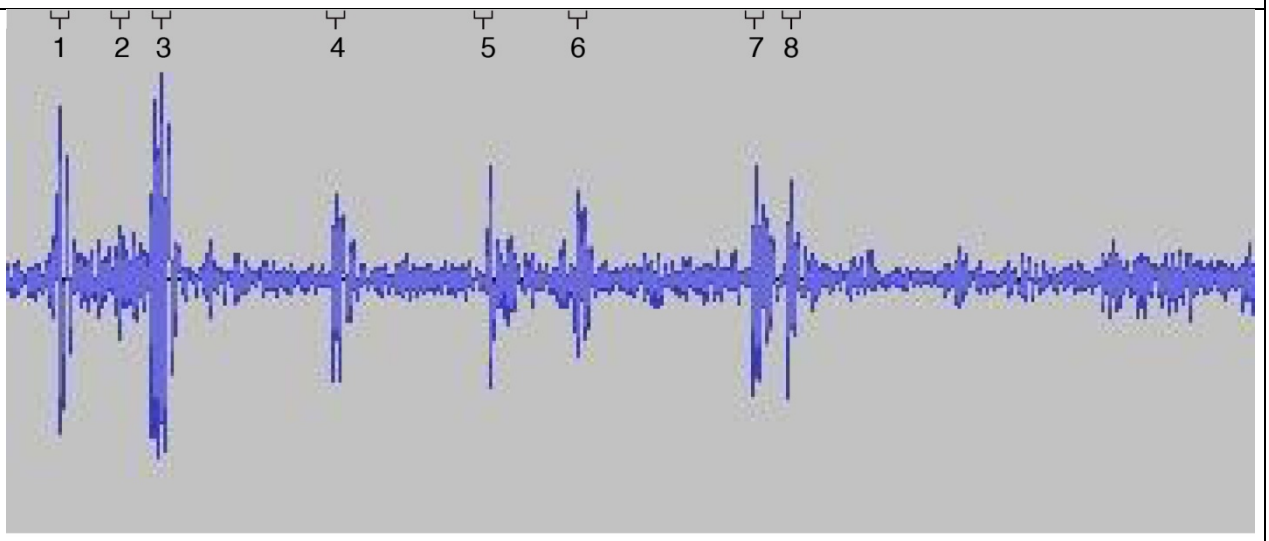


FIG. 21. IMPULSE PATTERN FROM STUCK-TRANSMITTER RECORDING BEGINNING AT TIME 145.5 SEC.

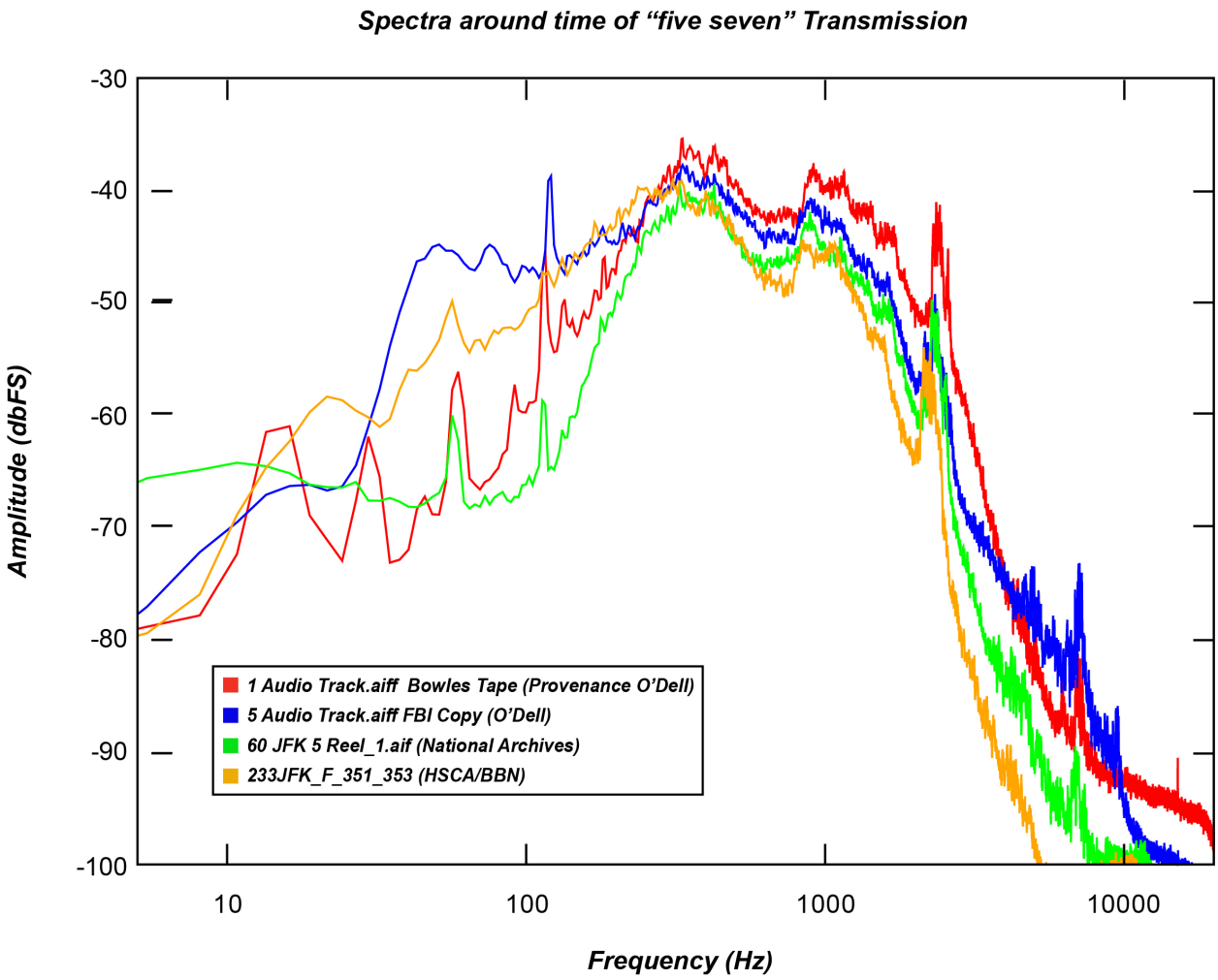


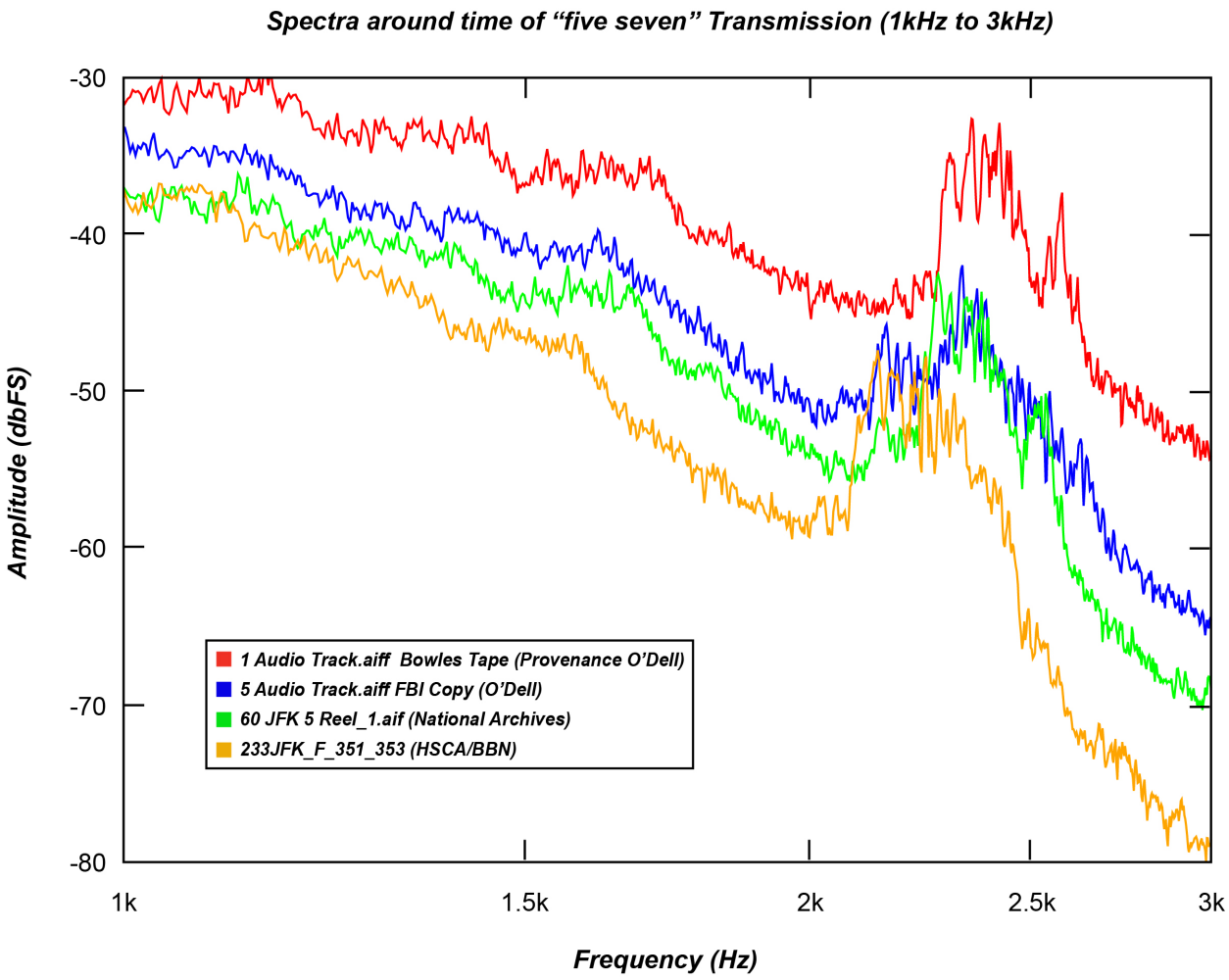
Location of impluse idenified by BBN as observed in 60 JFK 5 reel_1 at time 850.5 sec.

Spectrogram plots

The following plots show the relative spectral composition of the various recordings. In the following broadband spectral plot ("Spectra around time of "five seven" Transmission"), the FBI recording shows significant energy relative to the other recordings in the region below 100 Hz. The FBI recording contains a lot of "flutter" (cyclical speed variation induced by what is probably a mechanical fault in a tape recorder), and this probably contributes a lot of low frequency energy. In narrow spectral analysis (not shown), the narrow peaks of heterodyne tones were broadened in the FBI recording due to this same effect.

Low frequency power line hum and its harmonics are generally visible in all of the spectra. It is also interesting to note that the amount of high-frequency energy, and the steepness of the high-frequency roll-off varies substantially between the recordings, with the Bowles and FBI tapes showing the most high-frequency energy and the 60 JFK 5 reel 1 and Barger exhibit showing greater attenuation of high frequencies.

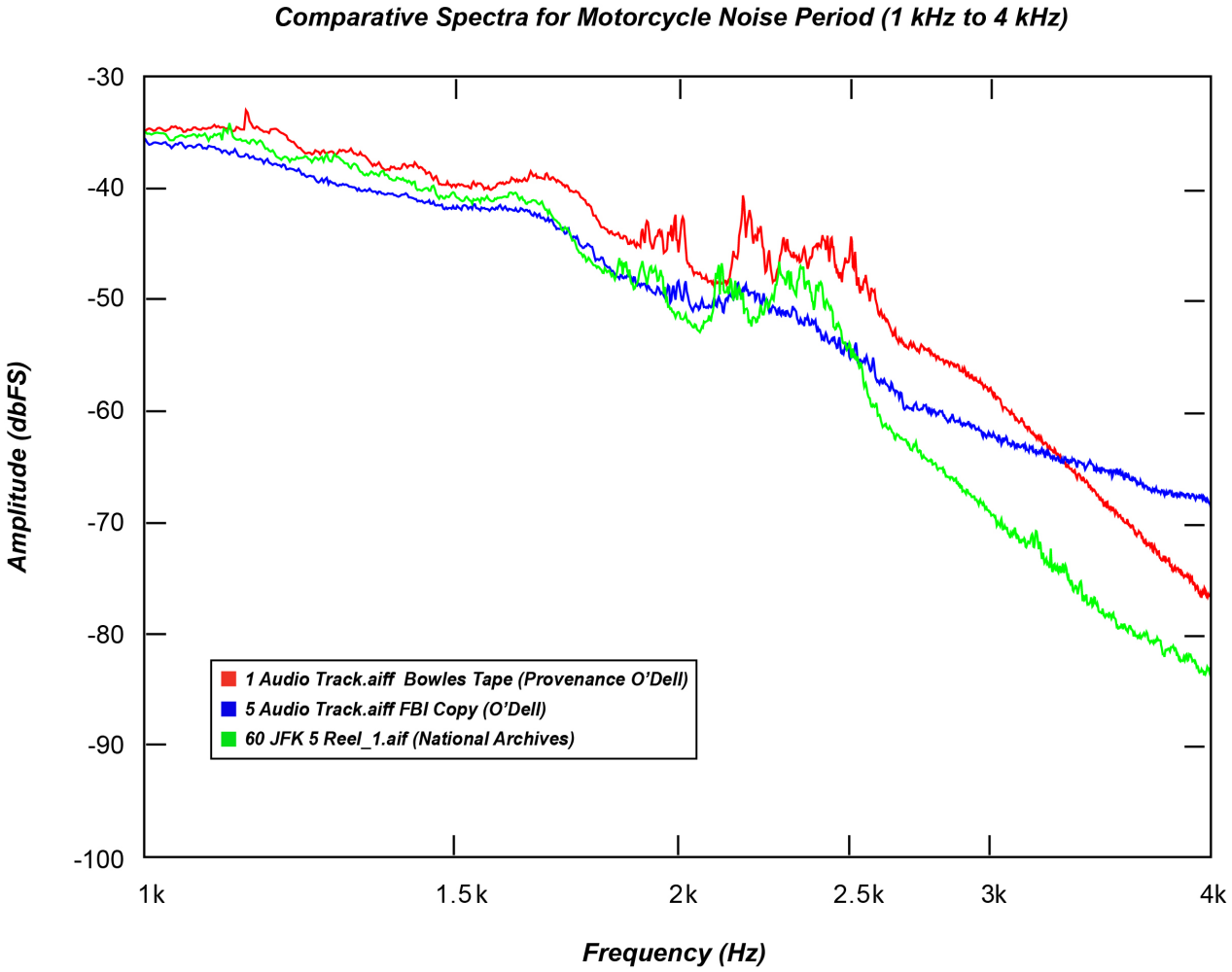

Spectra around time of “five seven” Transmission
Amplitude (dbFS)
-30
-40
-50
-60
-70
-80
-90
-100
10
100
1000
10000
Frequency (Hz)
1 Audio Track.aiff Bowles Tape (Provenance O’Dell)
5 Audio Track.aiff FBI Copy (O’Dell)
60 JFK 5 Reel_1.aif (National Archives)
233JFK_F_351_353 (HSCA/BBN)



Amplitudes are shown as measured with no adjustment or normalization in the 1kHz to 4kHz view of the spectra around the time of the “five seven” transmission (above). Identical time spans (in start and duration) of the recordings were used to generate the spectra. Note that the frequencies of the spectral peaks are offset along the x-axis according to the relative speed differences of the recordings, with the 233JFK-F-351-353 showing a significant error relative to the others. Note also that the rate of high-frequency roll-off differs between the recordings, with the Bowles Tape showing the least roll-off (and hence, greatest amount of high-frequency energy).

Spectrogram for sustained high-speed Motorcycle Operation Period

A comparison of high frequency spectral composition was made between the "60 JFK 5 reel 1", Bowles tape, and the FBI copy during the time period in which the motorcycle is observed to be operating at high speed (The 233JFK-F-351-353 recording was exempted from this comparison as it did not cover the relevant time period). The spectrum reveals that the speeds of the tapes differ by a small amount (as shown by the variation in horizontal alignment of the peaks), and it also shows a "smooth" curve for the FBI tape compared to the others. This smooth appearance of the spectrum in the FBI tape may be due to the flutter present in that recording causing the spectral peaks to dither over a small frequency range and thus appear less distinct over long time periods.



Note that the high frequency roll-offs differ between the recordings. The apparently extended high frequency response of the FBI copy is visible in this graph. Although the FBI recording contains

considerable high-frequency content, much of it is due to defects in the dictabelt. (A periodic and cyclical scratching noise is evident throughout.

Time Span Analysis

Time span measured for period directly after "5-7" transmission through "Code 3" transmission. The difference between the time spans found in the different recordings is an indicator of relative playback speed.

Medium	Onset (time since start of recording)	End	Length (s)	Speed relative to "60 JFK 5 reel 1"
60 JFK 5 reel_1	13.59.136 (839.136s)	17.50.135 (1070.135s)	231.135	--
Bowles Tape	3.47.163 (227.163s)	7.31.580 (452.580s)	224.417	1.03
FBI Copy	3.05.935 (186.935s)	6.56.628 (417.628s)	231.693	1.00

Time span measured from motorcycle noise stutter to tone heard immediately after "bell" sound:

Medium	Start (mm:ss:nnn)	End (mm:ss:nnn)	Length(s)	Speed relative to "60 JFK 5 reel 1"
60 JFK 5 reel_1 (National Archives)	13:55.840	14:19.949	24.1	--
233JFK_F_351_353 (HSCA/BBND)	0:23.7001	0:49.055	25.3	0.953

Heterodyne Frequency Comparison

The frequencies of heterodyne times were measured in order to compare the speed of the various recordings. The frequency of the heterodyne tone varies with the speed of the playback, and since the speed error of "60 JFK 5 reel 1" is known the other speed errors may be determined.

Medium	Measured Frequency (Hz)	Frequency (and hence speed) difference from "60 JFK 5 reel 1"	Playback speed increase needed to achieve correct 60 Hz hum frequency (approx.)
60 JFK 5 reel_1 (National Archives)	2539	-	5.2%
Bowles Tape (Provenance O'Dell)	2552	+0.512 %	4.7%
FBI Copy (O'Dell)	2548	+0.354 %	4.8%
233JFK-F-351-353 (Barger exhibit)	2411	-5.31 %	10.8%

Note: The frequency accuracy of the heterodyne measurement is on the order of a few Hz, safely within the best-case error reported.

Note that the "60 JFK 5 reel 1" recording should be sped-up by a factor of about 5.2% in order to play at the correct speed. This factor was determined in a prior study by Sonalysts in which the power line hum frequency was measured. This correction factor is in general agreement with the observations made by others.

The Bowles and FBI recordings both agree very closely in speed to the 60 JFK 5 reel 1 recording. Correction factors of 4.7% and 4.8%, respectively, would be required in order for these recordings to play at the correct speed.

Curiously, the 233JFK-F-351-353 is the outlier in these frequency measurements; it is more that 5% slower than "60 JFK 5 reel 1", *which is already known to be slow by about 5.2 percent*. This may be the result of a malfunctioning piece of equipment used in making the copy that the National Archives obtained. It is also possible that compensation for speed error was attempted, but the correction was of the wrong sign, i.e. a 5% speed decrease was made when a 5% speed increase was called for. It may be possible to determine if this speed error is evident in, or has been properly corrected for in prior researchers' work.

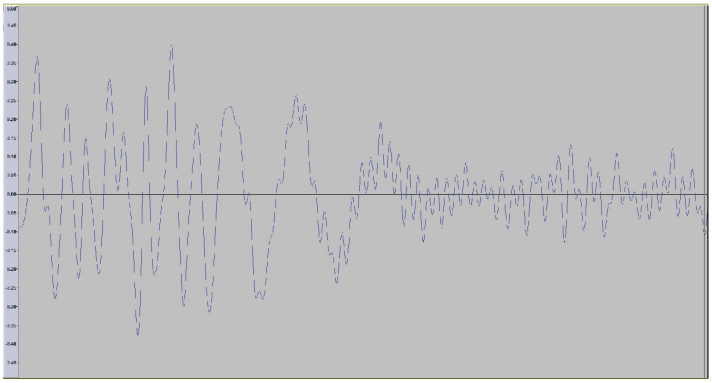
The disparity between time interval measurement and heterodyne frequency measurement results may be due to a number of factors. The heterodyne frequency measurement operated over a comparatively small time scale and this longer-term speed variations may not be revealed by it. The time interval

measurement may yield different results depending on which portion of the tape is being examined. This latter outcome may appear if a long-term speed change is evident in the recording. These measurements nonetheless provide a good initial assessment of the recording speed differences.

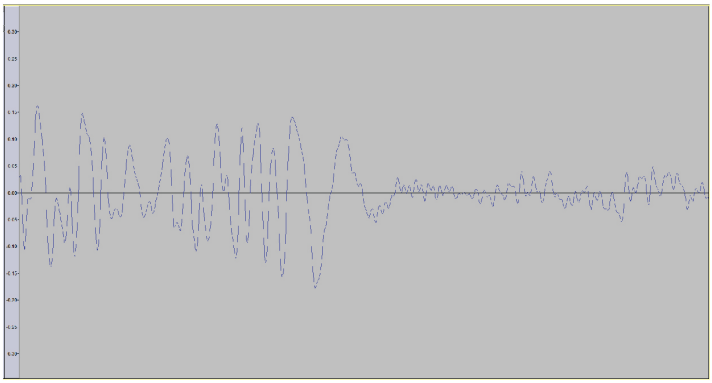
Waveforms selected to show Polarity

A visual analysis of a distinctly featured part of the waveform was made for all of the recordings. This allowed the relative polarity of the signal to be measured, and all of the recordings are shown to be of the same polarity. The period of time shown spans the onset of the first of two heterodyne tones that are heard just before the "five seven" transmission, aka the alleged "I'll check it" transmission. The following images show the waveforms obtained from the various recordings for the same time period. Note that the macroscopic features all agree in sign, suggesting that the polarity of the recorded audio is the same in all of the recordings:

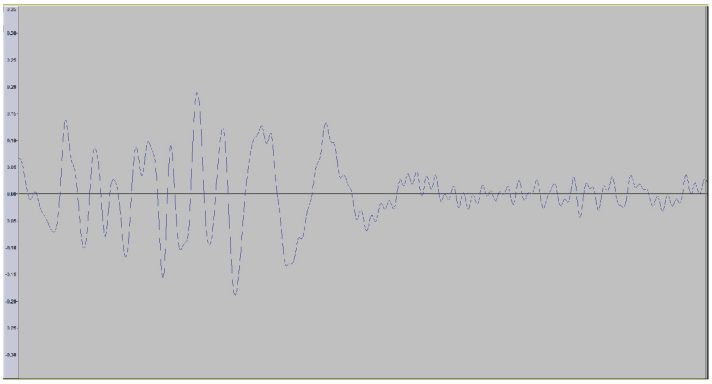
Waveform for Polarity Identification in Bowles Tape



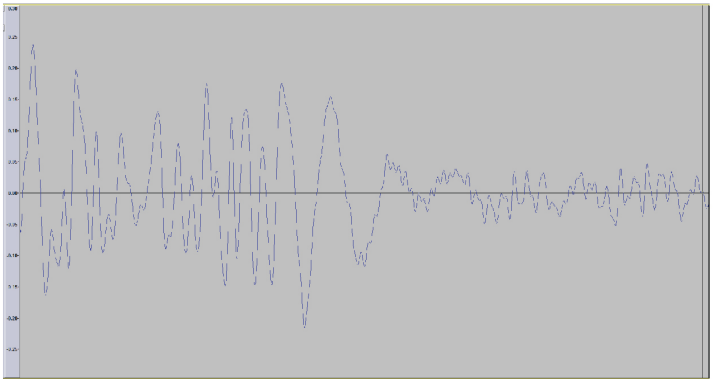
Waveform for Polarity Identification in FBI 12/9/81 copy



Waveform for Polarity Identification in 60 JFK 5 reel 1



Waveform for Polarity Identification in 233-JFK-F-351-353 (HSCA/BBN Exhibit)



Observations on Properties of Impulses Attributed to Gunfire

Authors: Charles Olsen, Mark Bamforth, Jonathan Grant (Sonalysts, Inc.)

Research Commissioned by Dr. Larry Sabato and The Kennedy Legacy Project of the UVA Center for Politics.

11, June, 2013

Abstract

Transient sounds in the Dallas Police Department dictabelt recording attributed to gunfire by the House Select Committee on Assassinations are compared to other sounds in the recording. Waveforms alleged to contain these transients are visually examined in order to determine whether they are unique or indicative of having some other origin. Waveforms are also examined in order to determine if they represent oscillatory phenomena versus features reconcilable with the arrival of individual impulses. Adaptive filtering is applied to reduce the effect of motorcycle noise and the remaining waveforms are examined to see if they are altered and thereby exhibit a dependency on the motorcycle noise. An examination of the detection method used to inform the HSCA findings is conducted.

Overview

Goals

The goal of this work is to identify and characterize the impulses in the Dallas Police Department dictabelt recording that were attributed to gunfire by the House Select Committee on Assassinations (HSCA) and determine whether they are unique or artifacts of other sounds, and hence, sources.

Provenance of Audio Recordings

Recordings used in this analysis were obtained from the University of Virginia Center for Politics. The Center for Politics obtained two of the recordings from the National Archives. These are "60 JFK 5 reel 1" and "233JFK-F-351-353". The former includes audio copied from multiple dictabelts in a more-or-less continuous sequence. The latter contains exhibit material used by Dr. Barger of Bolt, Beranek and Newman (BBN, BRSW) in his testimony before the HSCA. This latter recording contains a short sample of dictabelt audio around the time of the alleged gunshots as well as a variety of recordings of gunshots from the BBN test firings in Dealey Plaza, and what appear to be impulse test signals. The Center for Politics obtained other recordings from Michael O'Dell. These include a copy of the channel 1 dictabelt marked "From Bowles Tapes". Another file of interest O'Dell provided is noted as "Dictabelt FBI 12/9/81".

The "60 JFK 5 reel 1" recording was used for the bulk of the waveform examination as it is very similar to the dictabelt audio found in "233JFK-F-351-353" but covers a significantly longer time span. This similarity was confirmed by inspection of specific features of the recordings. We are also very familiar with the “60 JFK 5 reel 1” recording, having worked with it in the past. The other recordings were found to be in agreement with “60 JFK 5 reel 1”, differing only in duration and technical quality.

Methods

Waveform Data

The majority of this analysis consists of a meticulous visual review of the audio waveforms; in particular the “60 JFK 5 reel1” audio recording. The waveforms associated with the impulses attributed to gunfire were visually examined and their features were measured, bearing the following questions in mind:

Are the waveforms associated with the sounds of gunfire unique?

Do the waveforms associated with alleged gunfire appear to be discrete events, or are they portions of longer duration sounds?

Do any of the waveforms associated with alleged gunfire correspond to what would be expected to arise due to defects in the recording medium?

Motorcycle Engine Noise

Another area of analysis was a test to determine the effect of the motorcycle noise on the identification of impulses. This work addresses the question: Does the presence of motorcycle noise contribute to the identification of gunshot events in the waveforms?

The sound of the motorcycle is present throughout the time period in which the impulses are audible. In their research for the HSCA, Bolt, Beranek, and Newman (BRSW report) used a Widrow LMS filter in an effort to remove the sound of the motorcycle engine from the recording. In broad terms, this filter compares a sample of the noise to be filtered to the recorded audio and isolate those features that resemble the sample by minimizing the error in its output. We decided to apply a variety of adaptive filters in order to approximately reproduce this process in order to see if attenuation of the motorcycle noise had an effect on the detectability of the impulses. We used both commercial and non-commercial adaptive filter software to perform the noise reduction process.

If the impulses said to have arisen from gunshots are removed or significantly altered by the noise reduction process, this may indicate that the impulses have a dependency on the motorcycle noise being present. In other words, if the filtering of the motorcycle noise has a pronounced effect on the appearance of the impulses, then some of the impulses may in fact be due to the motorcycle noise.

Results

Waveform Data

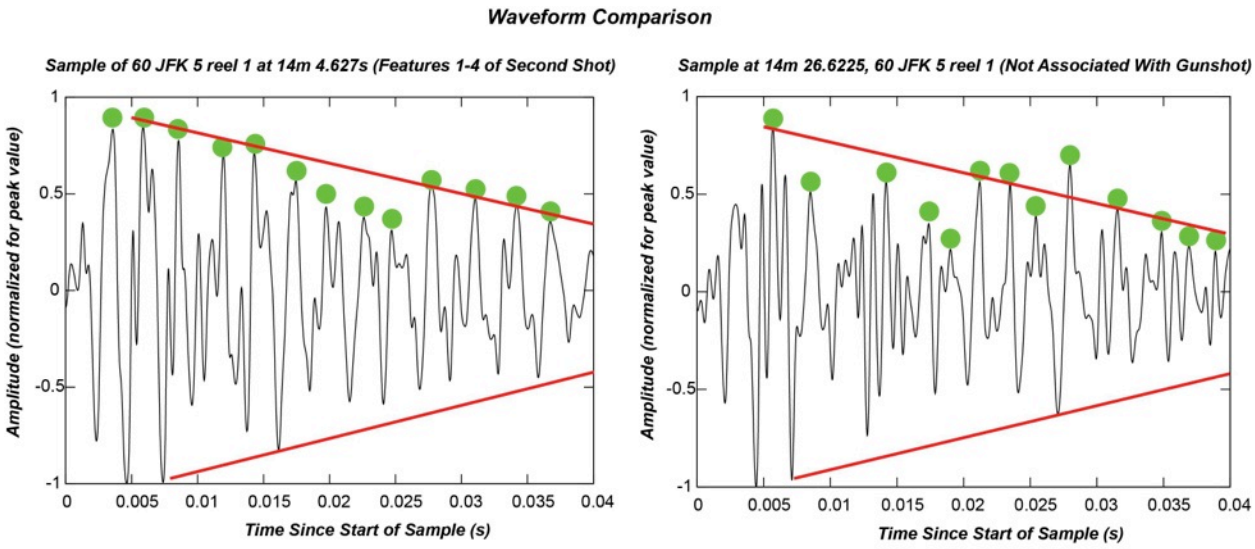
In the following sections we show detailed indications that the impulses are not unique, nor are they reliably distinguishable from other impulses. We discovered that transients identified as gunshots by BBN and Weiss and Aschkenasy may have been features of longer duration waveforms. We also found waveforms that are nearly identical to those labeled as gunshots throughout neighboring portions of the recording.

On several occasions, individual impulses ascribed to gunshots by BRSW and Weiss and Aschkenasy (W&A) are portions of larger waveforms that exhibit a damped oscillatory characteristic. These waveforms correspond to sounds that are heard as knocking or tapping noises, and which are likely to have a mechanical origin. (For example, the microphone may have been rattling in its holder, or another component of the motorcycle may have vibrated as the motorcycle traversed a rough surface. These may also have arisen as an artifact of the engine slowing.)

These waveforms are typical of those produced by an object which is struck and vibrates for a period of time with diminishing amplitude. Individual peaks in these waveforms were selected by BRSW and W&A according to their selection criteria that, in our opinion, over-relied on timing information and did not

adequately consider amplitude. While the peaks neatly fit the timing relationship these researchers sought, they are almost certainly parts of larger (longer duration) waveforms that arise by different means.

To illustrate this, figure 1 shows a waveform coincident with impulses 1-4 of shot 2 as identified by BRSW (left image). On the right is a similar waveform that occurred some 22 seconds later, long after the gunfire is thought to have occurred. Both of these waveforms have two important characteristics in common. The first is that the amplitude envelope (an imaginary line connecting the peaks of the waveform) diminishes with time; this is shown in red. The other characteristic is that an object vibrating after being struck will often show a *periodicity* in its movement; this is evidenced by the more-or-less even spacing between the peaks of the waveforms along the horizontal (time) axis, shown in green. (Alternatively, the lower peaks could have been measured, or the *zero-crossings* could have been measured.) Together these characteristics suggest that all of the peaks are related to a single event - an initial impulse that caused them to arise. It is incorrect to describe the individual peaks within such a waveform as discrete events having separate causes.



These waveforms display similar features and are likely to have the same, or similar, origin. The graph on the left shows a waveform associated with gunfire (shot 2, impulses 1-4 as identified by BRSW), while the graph in the right shows a waveform occurring some 22 seconds later when no gunfire is thought to be heard. The red lines show the amplitude envelopes. Note how the amplitude diminishes with time. The green dots highlight the peaks of the waveforms, note the uniform spacing of the peaks that is indicative of oscillation. Both of these waveforms show characteristics of damped oscillation due to these features. The sound of an object being struck, and then vibrating with diminishing amplitude over time is one way in which these waveforms might have arisen. The sounds of gunfire do not generally share these characteristics.

Figure 1 Comparison of waveform features

A survey covering a little over a three-minute period of the recording found a dozen such waveforms. Three of these waveforms were identified as matching one or more impulses attributed to gunfire by BRSW, while the other nine were not. These waveforms were found before, during and after the alleged gunfire, and the survey was by no means exhaustive: the three-minute period was chosen to encompass the time in which the alleged gunshots occurred.

These waveforms that arise at different times appear to have a common cause, due to their similarity in peak amplitude, frequency composition, duration, and structure.

It is also interesting to note that these waveforms appear shortly after the motorcycle has slowed. A later instance of the motorcycle slowing well after the time of the alleged gunshots shows waveforms having the same properties. These may arise as a consequence of the motorcycle slowing, the officer's activity after stopping, or they may be something that is otherwise present but only audible when the motorcycle is at rest.

Transients due to Surface Defects in Dictabelt Medium

We identified and cataloged transients (impulses) to do surface defects in the dictabelt itself. (The dictabelt is a mechanical recording medium that operates similarly to a phonograph and similarly exhibits sensitivity to dirt and scratches on its surface.) While we were able to readily identify the waveforms arising from these defects, we saw no examples of these that had been attributed to gunfire by the BRSW and W&A. (We include the waveform illustrations for completeness.)

Motorcycle Engine Noise

We also show that by removing the motorcycle noise via a filter many of the distinct features that were identified as possible gunshots are greatly altered if not removed all together. This test suggests that the sounds identified as gunfire may actually be due, at least in part, to motorcycle noise. This area of study presents an opportunity for further research.

Visual Analysis of Waveforms

Common impulse patterns similar to alleged gunshot patterns

Throughout the recording there are impulses that share characteristic features of the impulses that were identified as gunfire. By finding other impulses that closely resemble those allegedly due to gunfire, a similar source may be indicated for both, and the uniqueness of the impulses associated with gunfire is challenged. Clearly, all of the impulses can't be due to gunfire, yet instances of remarkably similar impulses are found elsewhere – before, during and after the alleged gunshots.

The following images represent features of the impulses that were identified by BRSW as being associated with gunshots 1, 2, and 4. Also shown are transient impulses found in the neighboring three-minute period. The fact that these features are similar across many seconds of the recording suggests that they share a common source that is not gunfire. (The waveforms previously shown in figure 1 are taken from this set of waveforms.) Data corresponding to some of the impulses attributed to the first and second alleged gunshots are colored green in figure 2. The black graphs show similar waveforms found during the three-minute time span that were not identified as possible gunshots. These impulses all exhibit periodicity at close frequencies, and many show a decreasing amplitude envelope versus time.

The presence of interfering noises can have a pronounced effect on the waveforms, and this is visible in many of these examples. In spite of this, these waveforms all show similar periodicity, and to a listener they all sound substantially the same.

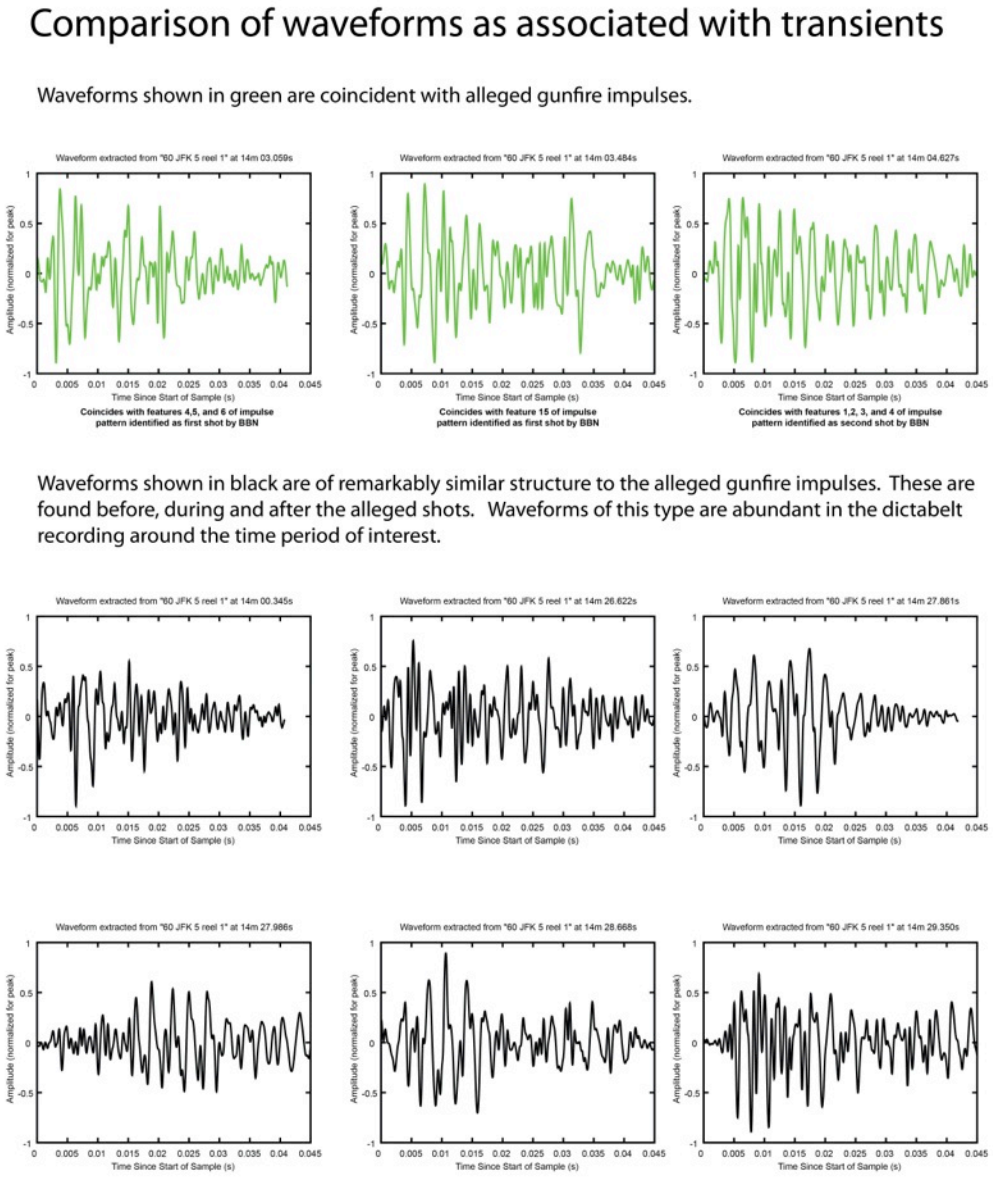


Figure 2: Alleged gunshot 1 and 2 and transient impulse examples and comparison

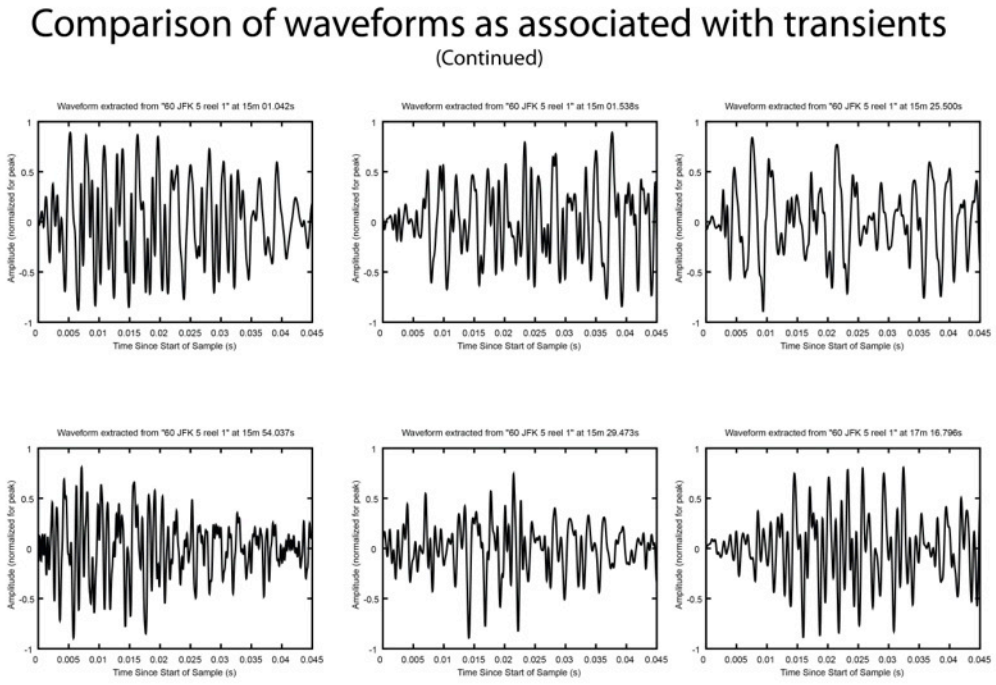


Figure 3: Alleged gunshot 1 and 2 and transient impulse examples and comparison (cont'd.)

Figure 4 shows a set of waveforms that are similar to one another, yet entirely different in appearance when compared with the preceding examples. The topmost waveform in figure 4 was identified by BRSW as a component of the fourth gunshot. The similar impulses found in neighboring regions of the file are shown below it. Again, the general shape of the waveform, the duration of individual features, and the amplitude versus time all suggest a common origin of these impulses. All of these occur around the same time, but only one of them is identified as gunshot-related by BRSW because of its time of occurrence.

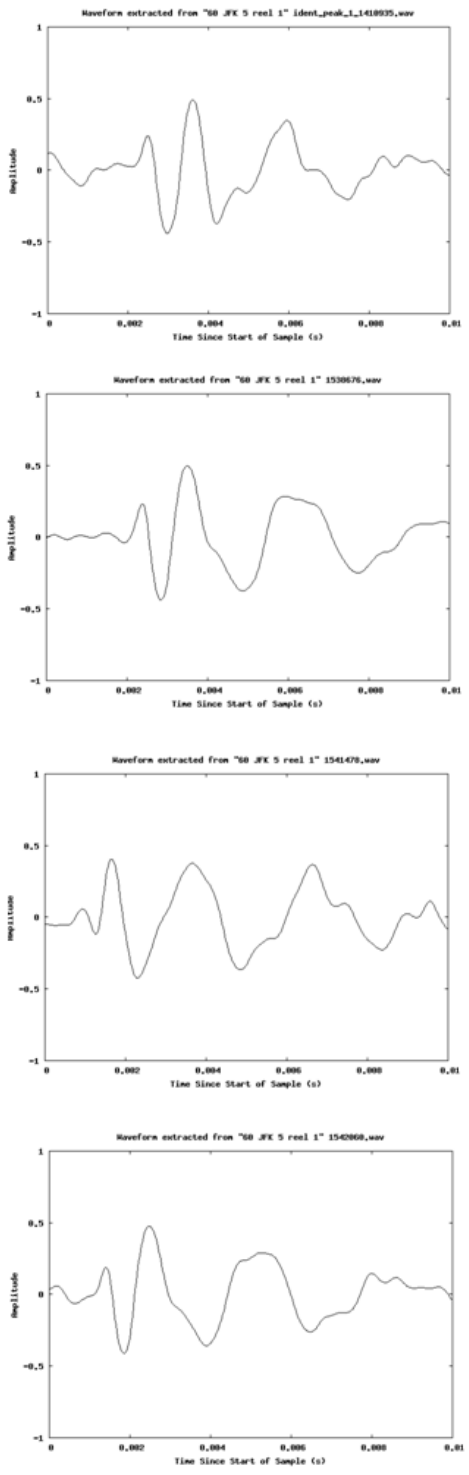


Figure 4: Gunshot 4 impulse as identified by BRSW/W&A (top) and similar nearby impulses not associated with gunfire.

Observations on the W&A Depiction of the "Grassy Knoll" shot

Figure 5 depicts the initial portion of the impulse pattern identified by BRSW and W&A as being associated with the "grassy knoll" shot. Our best estimates of the locations of the individual numbered impulses identified by W&A are shown in the illustration. (We say “best estimates” here because the waveforms shown in the W&A report are not very clear.) This audio sample was obtained from the "60 JFK 5 reel 1" recording. Its polarity was inverted for this illustration in order to agree with the polarity of the image in W&A, Figure 7.

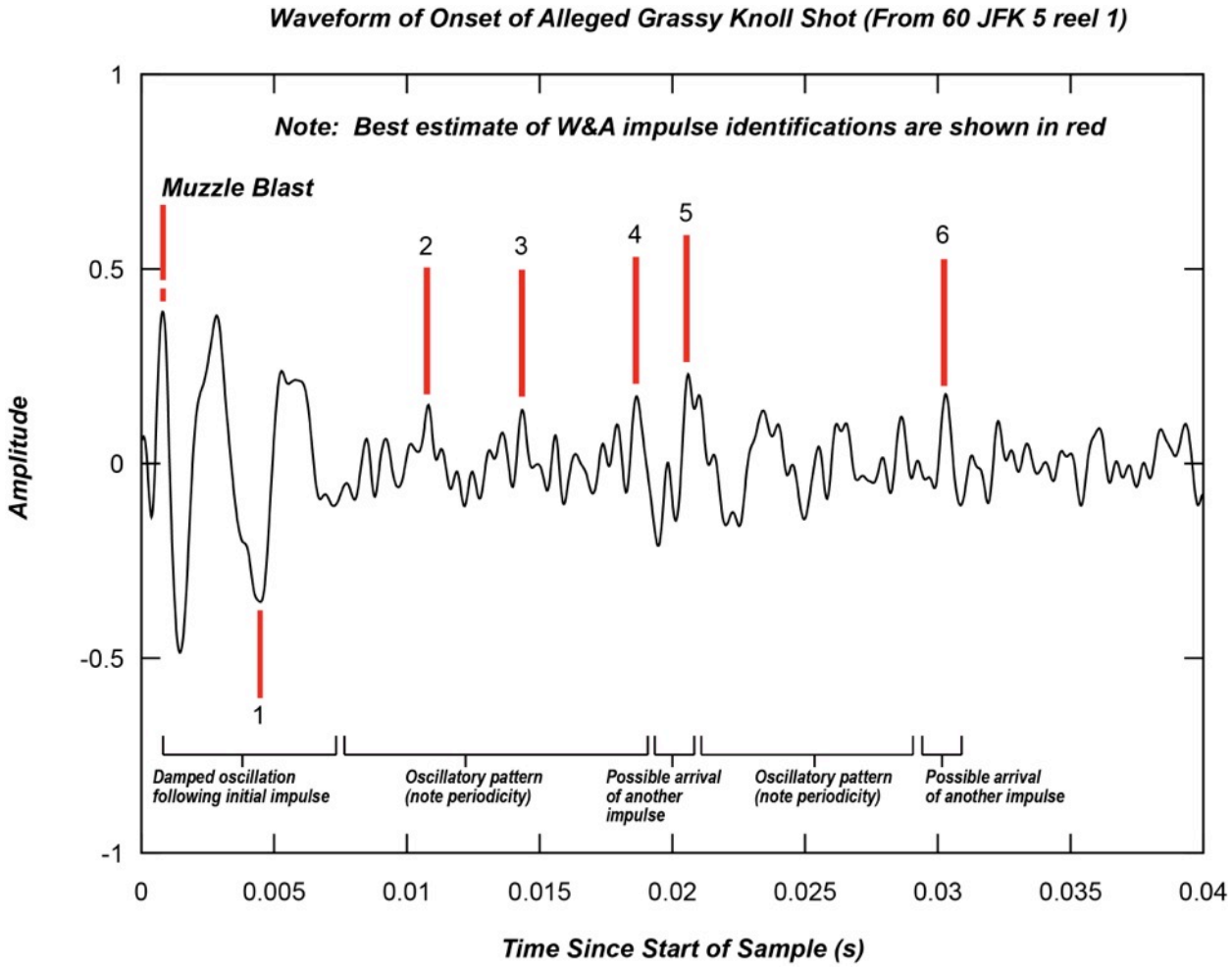


Figure 5: "Grassy Knoll shot" composition

The waveform during this time appears to show periodic characteristics. This is expected in a system where damped oscillations are observed, and there are many good examples to be found in the recording.

The impulse identified as the muzzle blast by W&A clearly exhibits a damped oscillation characteristic of resonance following initial excitation. The feature numbered 1 by W&A appears to be one of the peaks associated with this oscillation. After about three cycles this oscillation ceases. This cessation of oscillation may be due to the arrival of an impulse having a phase relationship such that the oscillation is largely cancelled out. A subsequent period of oscillatory behavior showing abundant high frequency energy then begins. This corresponds to the impulses labeled 2, 3 and 4 in W&A Figure 7. The apparent arrival of another impulse identified by W&A as number 5 begins another period of oscillatory behavior.

The appearance of the waveform over this time period is more reconcilable with the scenario just outlined than the notion of the individual peaks arising from discrete transient events. The periodicity in the waveform is apparent in spite of the complex mix of frequencies that are evident. The notion of individual impulses causing the waveform peaks to arise is dubious given the clear oscillatory characteristic of the signal. Although not shown here, impulses numbered 18 through 26 nearly all correspond to short bursts of oscillatory behavior. The relatively high amplitude of these peaks and their relative abundance in this portion of the recording would seem to provide many opportunities to match peaks based on timing alone, which is what BRSW and W&A did.

Surface Defects in the Dictabelt

The origin of many of the impulsive sounds and recording is a matter of speculation. Listening evaluations suggest that many of the sounds have a common origin based on the perceived pitch, but sounds of sufficiently short duration do not yield easily to frequency measurement. The short time Fourier transform might yield coarse descriptive data, while direct waveform observations are often hampered by abundant noise or an inadequate number of cycles to measure. In short, rigorous and conclusive measurements that support or refine subjective judgments are probably not easily obtained for very short impulses.

One exception to this is the occurrence of various clicks and pops due to surface defects on the dictabelt itself. Like a phonograph, the dictabelt uses a needle to trace an undulating path in a mechanical groove. Surface contaminants, embedded particles, and scratches have a similar effect to that observed in phonograph playback and produce clicking and popping sounds. The waveforms corresponding to these events are easily distinguishable.

We created a catalog of the waveforms arising from surface defects by examining portions of the recording in which the motorcycle noise was absent and the dictabelt machine was engaged in its normal intermittent mode of operation. We looked for regions of the recording that were bracketed by a squelch tail (indicating the cessation of a transmission) and the characteristic features associated with the recorder stopping and then restarting. Within these regions, surface defects could be clearly and unambiguously heard as there were few other sounds and audio from the radio receiver was absent.

Figures 6 and 7 show the waveforms that correspond to the appearance of surface defects. In our examination of the recording, we did not find impulses attributed to gunfire matching these waveforms.

We therefore conclude that BRSW and W&A did *not* mistakenly include impulses due to surface defects in their identification. Waveforms are shown here as an aid to other researchers who wish to carry out investigations in waveform comparison. Note that these waveforms are probably the best representation of the transient response of the playback system.

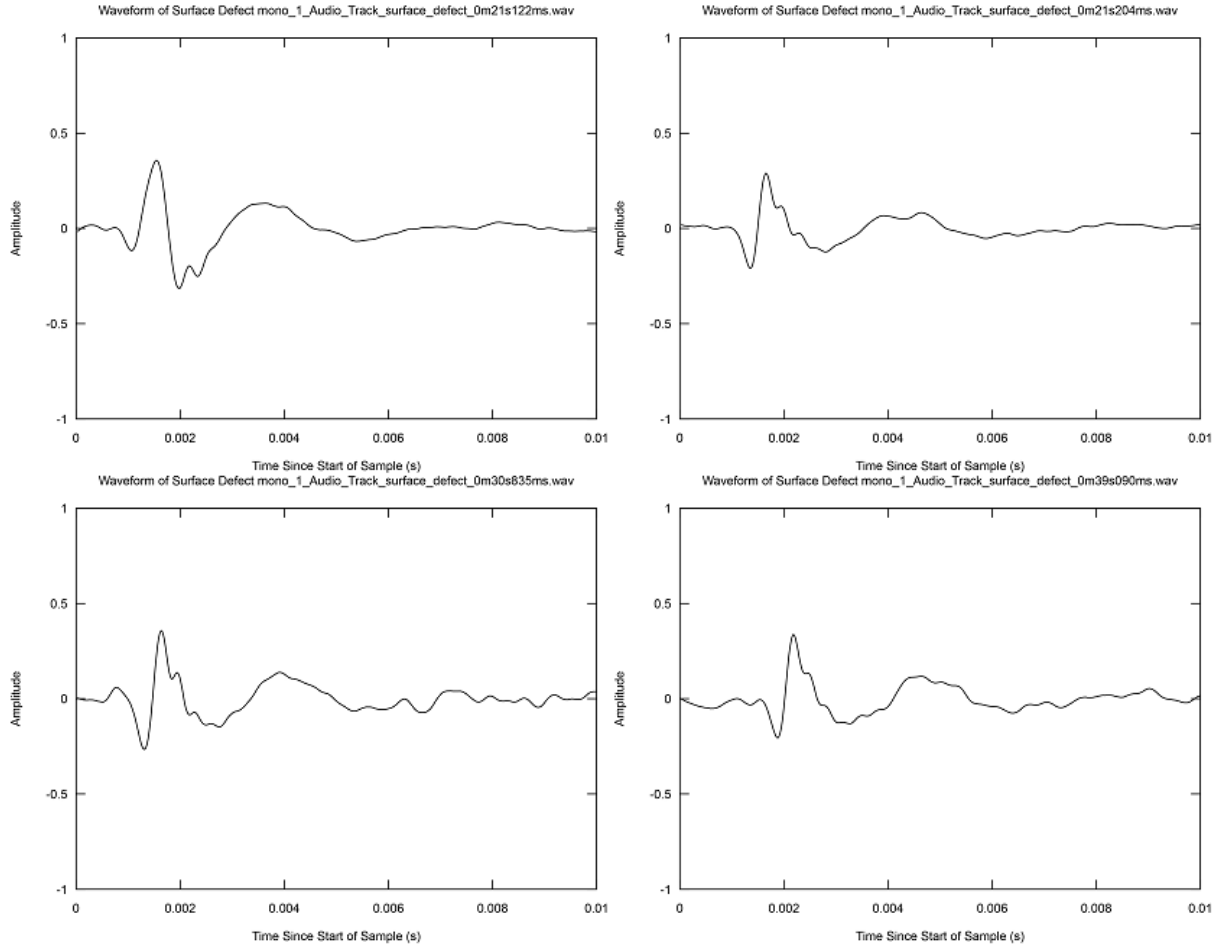


Figure 6: Waveforms arising from mechanical defects in the dictabelt medium

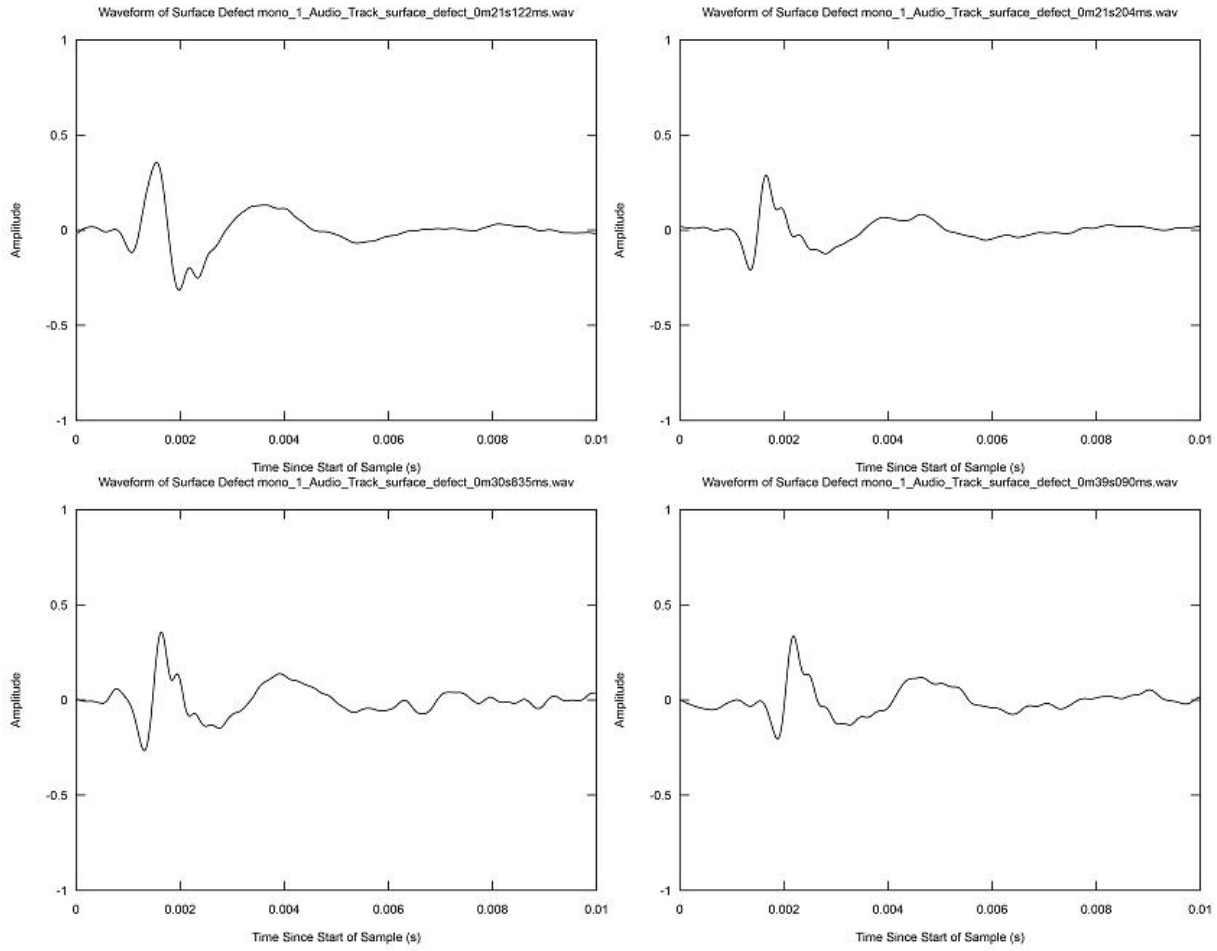


Figure 7: Waveforms arising from mechanical defects in the dictabelt medium (cont'd.)

Motorcycle Noise Effect on Impulse detection

We employed adaptive filters in an effort to remove the motorcycle noise from the recording in the time period encompassing the alleged shots. One of the alleged gunshot patterns was examined in detail as part of this effort. While all of the larger peaks ascribed to gunfire by BRSW and W&A were still present, many of the smaller peaks were greatly diminished. This suggests that some of the smaller peaks identified by BRSW and W&A may be artifacts of the motorcycle noise.

Figure 8 shows a portion of the recording said by BRSW to contain the sounds of gunfire. The numerals show the location of individual impulses within the alleged gunshot as depicted in BRSW's illustrations.

Figure 9 shows the same audio after an adaptive filter was used to reduce the motorcycle noise.

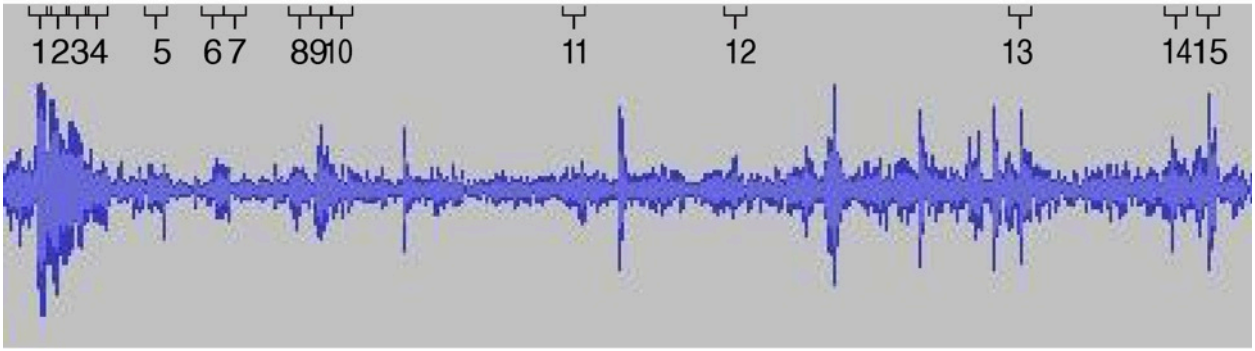


Figure 8: Impulse 2 without motorcycle noise filtered (original signal)

Figure 9: Impulse 2 with motorcycle noise filtered

It is clear from the illustration above that an adaptive filter trained on the motorcycle noise will greatly diminish many of the peaks. In the image above, impulses 5, 6, and 8-11 appear to be greatly diminished in the lower trace (post noise-reduction) when compared with upper trace (original signal). In contrast, impulses 1-4 and possibly 13 and 15 are less affected, suggesting they have an origin that is uncorrelated with the motorcycle engine sound.

Comments on the BRSW Test Methodology

BRSW's preliminary analysis included the identification of impulses that exceeded a certain amplitude threshold. This is a reasonable course of action, and was designed to lessen the influence of motorcycle noise on the initial identification of candidate impulses. They also applied an adaptive filter in an effort to reduce the magnitude of the motorcycle engine noise; again, a reasonable course of action.

BRSW then used a matched filter in order to identify potential sounds of gunfire in the DPD dictabelt recording, focusing on the areas identified in the preceding screening phase. This filter resembles a cross correlation algorithm with the exception that instead of directly comparing the waveforms, the audio in the dictabelt recording is compared to a binary pulse train that exhibits the timing characteristics corresponding to the echo patterns experimentally obtained in Dealey Plaza. The width of the binary pulses was set to accommodate the time uncertainty due to the spacing of the microphones along the motorcade route. (This uncertainty is due to the discrete spacing of the microphones along the motorcade route. A motorcycle traveling this same route might have received the sounds of gunfire at an intermediate point between these microphone positions. Setting the pulse width in this way accommodates that fact that the motorcycle might be at a microphone position, or anywhere between

two microphones at any instant in time.) BRSW correctly describe this filter as a binary correlation detector.

One constraint of this filter is that while it considers both the timing and amplitude of features in the dictabelt recording, it uses a simple threshold to measure amplitude. A positive correlation for an echo pattern within the dictabelt recording might be indicated where the actual amplitudes of the individual impulses within the echo pattern are markedly different. This is evident by comparing the peak amplitudes in figures 6 and 7 of the W&A report. (W&A provided a finely detailed waveform view of the alleged "grassy knoll" shot, this makes it a good candidate for study.) In W&A figure 6 the later echo patterns are greatly diminished in amplitude relative to the muzzle blast. The corresponding selection from the dictabelt recording reveals that the amplitudes of these later echoes are nearly as great as the muzzle blast, while other, earlier reflections are diminished in amplitude. One would expect to see broadly similar amplitudes in both the test data and the dictabelt recording in the case of a match. Also, this observation cannot be explained by AGC action in the recording process; in fact, AGC in the dictabelt recording would be expected to suppress these later transients having sensed and responded to the large amplitude muzzle blast a short while before.

The amplitudes of the impulses in W&A figures 6 and 7 suggests that the binary correlation detector is more likely to make a false positive determination than a cross correlation algorithm that considers both amplitude and timing information. (W&A figure 6 depicts the waveform of gunshot sounds received at microphone 4, array 2 in the BBN test shots, while figure 7 depicts the dictabelt waveform said to show corresponding peaks.)

In the case of these two figures, a true cross correlation measurement would be expected to show a weaker match then the method used by BRSW due to the cross correlation's sensitivity to differences in amplitude. In other words, the method used by BRSW would product an optimistic measurement relative to a true cross correlation measurement.

The BRSW paper makes no mention of testing the binary correlation detector prior to employing it on the dictabelt recording. Such measurements would have yielded performance data for the detector.

As an example, performance of the binary correlation detector could have been measured if a number of audio files had been prepared, each containing the sounds of the test gunfire combined at varying levels with portions of the dictabelt recording known to be outside the time of the assassination (but having similar noise composition to the time period in question). Using test audio prepared in this way, the tester would have an a priori knowledge of where the gunshot impulses were to be found. The binary correlation detector could then be applied to these specially prepared recordings and the results would have allowed characterization of the process. If this test had been performed, it would have provided a measure of the ultimate sensitivity of the filter as well as the likelihood of it producing false positives for various signal to noise ratios in the recording. If recordings of the BBN test shots could be obtained, this measurement could be made today.

Conclusion

The data gathered support the following conclusions:

1. Some of the impulses attributed to gunfire are very similar to other impulses found in neighboring regions of the file. This is even true of impulses not attributed to gunfire that occur within the alleged gunshot periods. These observations suggest that at least some of the impulses attributed to gunfire are by no means unique, nor are they even generally discernible from other impulses contained in the relevant portion of the recording.
2. Some of the impulses associated with gunfire are quite common. A cursory examination revealed twelve similar impulses in a period spanning a little over three minutes. Three of these impulses were said to represent gunfire by BRSW but the other nine were not. The waveforms all suggest these impulses have the same or similar origins.
3. An impulse, unlike those mentioned above, was attributed to gunfire. Three nearly identical impulses occurring around the same time were not. This provides a second example, using different data, of the attribution of ordinary and common features of the audio recording to gunfire when the timing supports it.
4. An examination of the "grassy knoll" shot suggests that cyclical phenomena, i.e. damped oscillations, may have been chosen as representing individual transients. As these types of impulses are common throughout the audio files, we suspect that additional study would find more instances of this.
5. A study of transients due to mechanical defects in the recording medium show that BRSW's detections were not due to mechanical defects. In other words, the BRSW detections were of audio that was contained in the recording.
6. The application of an adaptive filter to remove motorcycle engine noise from the recording substantially change the appearance of one of the waveforms in unexpected ways. Some peaks were greatly diminished after filtering while other peaks emerged. This suggests that the motorcycle engine noise plays a substantial role in the appearance of the resultant waveform, even during the relatively "quiet" periods when it is at or near idle. Furthermore, the comparison of the original audio to the noise-reduced audio shows that many of the peaks selected as indicating gunshot impulses disappeared almost entirely.
7. An examination of the BRSW test methodology suggests that the binary correlation detector (matched filter) used by them was likely to have been overly optimistic in scoring candidate impulses, thereby allowing false positive detections to arise. Through over-reliance on timing information and under-reliance on amplitude information, it is likely that matches were made that would not have arisen using other methods. The performance of the algorithm does not appear to have been tested, so quantitative measures of its effectiveness or immunity to false positive detections are unknown.

Suggestions for further research

1. A statistical analysis of transients found in the recording might allow for broad classification of transients according to their various properties (peak amplitude, duration, frequency composition, density, et al.) The transients alleged to have arisen from gunfire could then be evaluated to see if they differ statistically from the general population of transients.
2. If recordings of the BBN test shots could be obtained, these could be compared using correlation algorithms to the dictabelt recordings. The binary correlation detector could also be reproduced, and its performance could be compared with other detection methods. Both types of detector could be applied to longer segments of audio, in order to characterize their likelihood of detecting correlations where none should exist.
3. Digital signal processing has advanced greatly since the work of BRSW and W&A. A more thorough analysis of the contribution of motorcycle engine noise to the detection of transients is possible. This may further help to identify detections that require the motorcycle noise to be present. (We focused on one of the alleged shots for this analysis, and a broader study would help identify the extent of the motorcycle's contribution to all of the alleged gunshot impulses.)

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(Referred to as BRSW in report.)

• Mark R, Weiss and Ernest Aschkenasy, "An Analysis of Recorded Sounds Relating to the Assassination of President John F. Kennedy", Department of Computer Science, Queens College, City University of New York, New York, February 1979.

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(Referred to as W&A in report.)