Forensic Report

Audio and acoustic analysis |

Gunfire before, during and after the killing of Shireen Abu Akleh

Researcher in charge: Dr. Lawrence Abu Hamdan

Dr. Lawrence Abu Hamdan is qualified in the field of audio analysis with a bachelor in Sonic Arts and PhD research on the technology and techniques of forensic audio analysis. He has testified as an expert witness at the UK Asylum and Immigration Tribunal and produced evidence for Amnesty International's ***Human Slaughterhouse*** report.

Relevant previous work for this study includes audio ballistic analysis that was presented in the United States Congress regarding the killing of Nadeem Nawara and Mohammad Mahmoud Abu Daher in the West Bank on May 15th, 2014.

Abu Hamdan received his PhD in 2017 from Goldsmiths College University of London and in 2021 completed professorships at University of Chicago and at the Johannes Gutenberg University Mainz where he developed his research AirPressure.info that is due to be presented at the UN security council.

1. Introduction

1.1. This report aims to distinguish between the different sources of gunfire and to determine the sequence of gunshots that are heard in the audio recordings that capture the killing of Shireen Abu Akleh. Two sources of audio recording are analysed here, one from a mobile phone that lasts 8 minutes and 5 seconds and one from the Aljazeera cameraman lasting 3 minutes and 41 seconds. By synchronising the two recordings a continuous footage of the event lasting 10 minutes and 51 seconds is made possible. Video analysis has helped determine that Shireen Abu Akleh was killed by one of 7 gunshots fired over 2 seconds starting at minute 7 and 17 seconds of this recording. These 2 seconds will be referred to in this report as the incident.

1.2. It is important to determine the sources of gunfire before, during and after this incident to assess the feasibility of claims that “life-threatening, widespread and indiscriminate shots were fired toward IDF soldiers[1].” And that "The journalist was present in the area during an exchange of fire.”

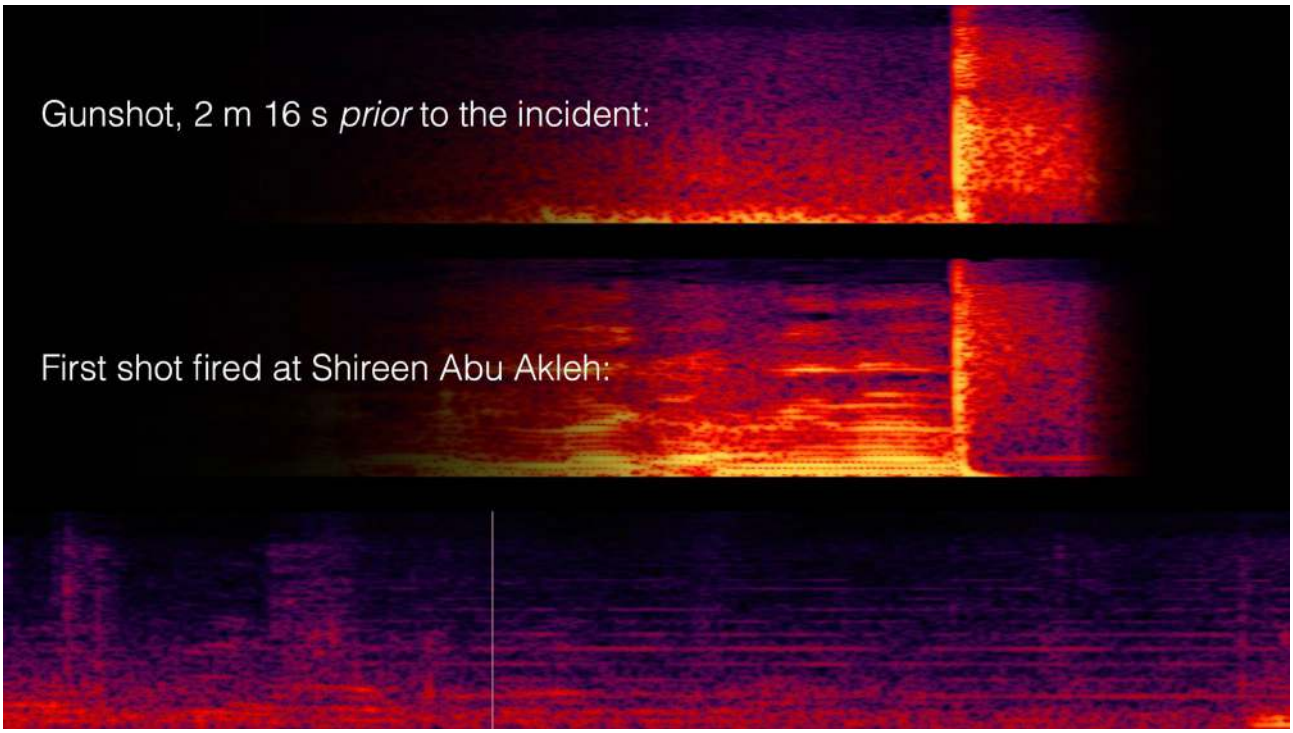
[1] https://www.idf.il/en/articles/2022/final-conclusions-of-shireen-abu-akleh-investigation/

2. Before the Incident

2.1. Video analysis has helped determine that Shireen Abu Akleh was killed between minute 7 and 17 seconds and minute 7 and 19 seconds of the complete and continuous recording of the entire event. At minute 7 and 6 seconds, 11 seconds before Shireen Abu Akleh was killed, a volley of 6 shots are audible. These shots are from the same source and fired from the same position as the shots that killed Shireen Abu Akleh. This can be determined due to the shared and distinct acoustic behaviour of both these volleys of gunfire (the one starting at 7:06 and the one starting at 7:17 of the recording). In particular, it is the 300-milliseconds separating ***the supersonic shockwave from the muzzle blast*** (explained in more detail on page 5 of this report) that demonstrates that the 13 audible shots between minute 7:06 and minute 7:19 originate from the same shooting position.

2.2. There are no audible gunshots in the 2 minutes and 5 seconds preceding the gunfire fired towards Shireen Abu Akleh (see Fig. 1). This disqualifies the claims that widespread and indiscriminate shots were fired toward IDF soldiers[2].” And that "The journalist was present in the area during an exchange of fire.”

2.3. There is a gunshot audible at minute 5 and 1 second of the recording, 2 minutes and 16 seconds prior to the killing of Shireen Abu Akleh. A frequency and amplitude analysis of this



sound indicates that this gunshot is consistent with the gunshots fired at Shireen Abu Akleh.

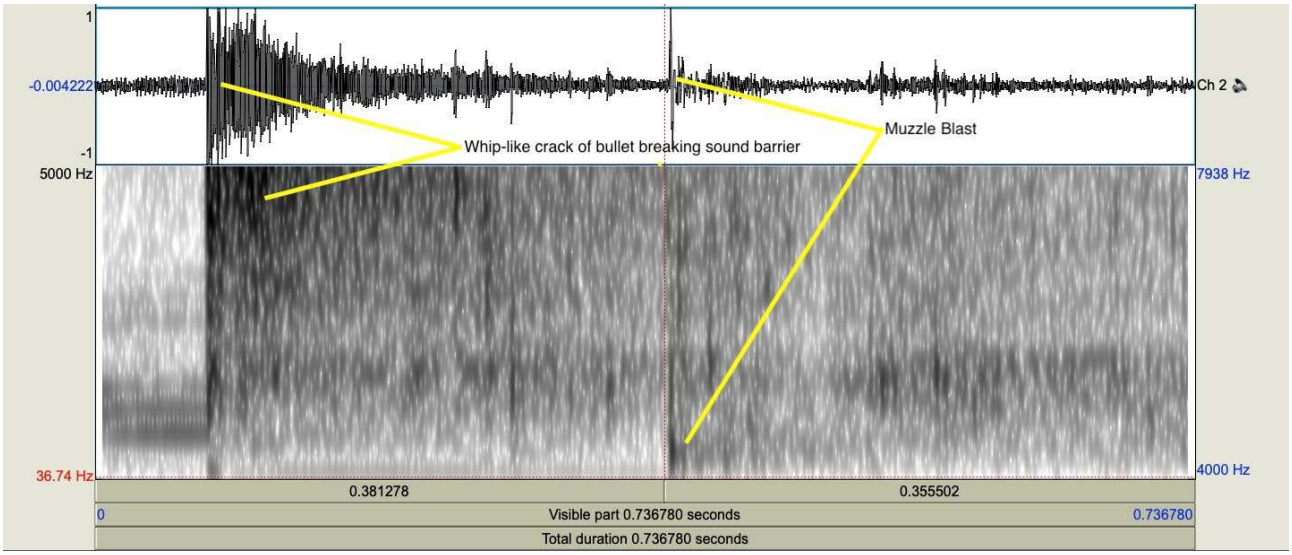
(FIG 1. HYPERLINKED IMAGE TO VIDEO ANIMATION THAT DEMONSTRATES THERE IS NO GUNFIRE AUDIBLE IN THE 2 MINUTES DIRECTLY PRIOR TO THE KILLING OF SHIREEN ABU AKLEH. LINKED HERE HTTPS://DRIVE.GOOGLE.COM/FILE/D/1Y680T3OECORJRLMQPIBG-MDRGE08-WKN/VIEW?USP=SHARING)

[2] https://www.idf.il/en/articles/2022/final-conclusions-of-shireen-abu-akleh-investigation/

3. During the Incident

3.1. Audio analysis is able to determine that all 13 audible gunshots fired towards Shireen Abu Akleh are fired from the same position. Between minute 7:06 and 7:19 of the recording a total of 13 shots are audible. The first is a volley of six shots, the second is a volley of seven shots divided by 8 seconds. From the analysis of the video footage, it is possible to determine that Shireen Abu Akleh was killed by one of the seven shots in the second volley, which begins at minute 7:17.

3.2. Gunfire has two main sources of sound: The first sound source is the shockwave created by the supersonic velocity of the bullet. The second and by far the most common sound source associated with gunfire is muzzle blast. Muzzle blast is caused by the rapid expansion of gases



escaping from the muzzle as a bullet exits. This manifests itself as a loud and short "bang".

(FIG. 2 INDICATING THE WAYS IN WHICH THE MUZZLE BLAST AND SUPERSONIC SHOCKWAVE ARE HEARD AS DISTINCT SOUNDS. AN ACOUSTIC EVENT THAT OCCURS WHEN THE RECORDING IS MADE MUCH CLOSER TO THE BULLET THAN THE MUZZLE OF THE GUN)

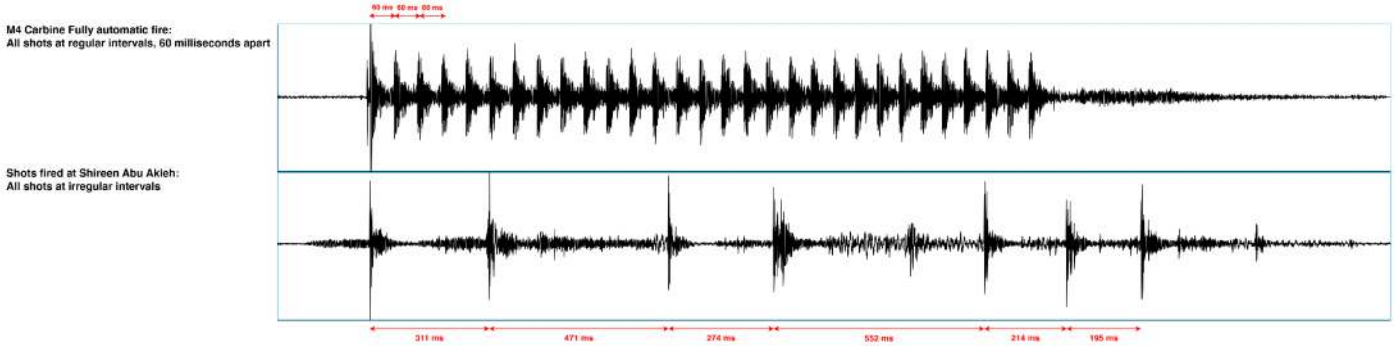
3.3. Across all the gunshots fired at Shireen Abu Akleh's position these two main sources of gunfire are heard as distinct from one another. Each time the gun is fired we hear two distinct sounds, first the whip-like crack of the bullet breaking the sound barrier and then after approximately 300 milliseconds the muzzle blast is heard (see Fig. 2). Though they emanate from the same gun, we hear these two sounds as distinct. This occurs when one is in very close proximity to the bullet and further away from the muzzle of the gun. The distant sound of the muzzle and the comparatively close sound of the bullet are consistent across the 13 shots. This indicates two things: Firstly, the proximity of the camera to the bullet, which in turn indicates that all 13 shots are fired in the direction of the cameras position and therefore also in the direction of Shireen Abu Akleh. Second, the interval of time between the supersonic crack and the muzzle blast remains consistent across the 13 shots (around 300 millisecond). If that interval in time were to significantly decrease or increase it would suggest the gunfire is coming from distinct positions in relation to the camera. Because it remains consistent, we can determine that all these shots are originating from a singular static position.

3.4. Should the shooter have been using the NATO standard SS109 5.56 mm ammunition, the velocity of the bullet would be approximately 860 metres per second. If we measure that velocity against the time between the supersonic shockwave of the bullet and the muzzle blast (300 milliseconds) we can estimate that the there is approximately 180 metres between the muzzle of

the rifle and the camera. This distance roughly corresponds to the military position defined in the video and spatial analysis as responsible for the killing of Shireen Abu Akleh.

3.5. There are no other audible gunshots than the ones fired from this position during 7:06 and 7:19 of the recording. Since all audible shots are from a single source, the claim that “The journalist was present in the area during an exchange of fire” can be disqualified.

3.6. Was the gunfire that killed Shireen the indiscriminate spray of an automatic rifle or was each bullet fired independently and intentionally? A semi-automatic weapon fires one shot with each trigger pull. An automatic weapon (or a gun set to automatic) fires at regular intervals and continuously from the moment the trigger is pulled until it is released. Video analysis has helped determine that Shireen Abu Akleh was killed by one of 7 gunshots fired over 2 seconds. As the intervals between each of the 7 shots are irregular, we can conclude that the shots fired at Shireen Abu Akleh were not fired using an automatic weapon. A fully automatic M4 carbine weapon fires 16 shots per second, with regular intervals of about 60 milliseconds between each shot (see Fig. 3). The intervals between the seven shots fired at Shireen Abu Akleh are each unique to one another and none of the shots are separated by an interval of 60 milliseconds. This demonstrates that the shooter pulled the trigger on seven separate occasions within two seconds. This analysis corroborates the claim that the shots were fired with intention by a marksmen and makes the claim that “at no point was there any intentional gunfire carried out by IDF soldiers in a manner intended to harm the journalist” highly improbable.



(FIG. 3. THE ABOVE IMAGE IS A WAVEFORM OF THE SOUND OF GUNFIRE FROM AN M4 CARBINE SET TO FULLY AUTOMATIC MODE. FOR THE ENTIRE PERIOD THE TRIGGER REMAINS DEPRESSED THE GUNFIRE IS ISSUED AT REGULAR INTERVALS OF 60 MILLISECONDS. THE IMAGE BELOW IS A WAVEFORM OF THE SOUND OF THE SHOTS FIRED AT SHIREEN ABU AKLEH. NO TWO INTERVALS BETWEEN THE SHOTS ARE THE SAME AND NONE OF THE SHOTS ARE SEPARATED BY AN INTERVAL OF 60 MILLISECONDS. THE BELOW IMAGE DEMONSTRATES THE SHOOTER PULLED AND RELEASE THE TRIGGER AT SEVEN DISTINCT OCCASIONS OVER 2 SECONDS.)

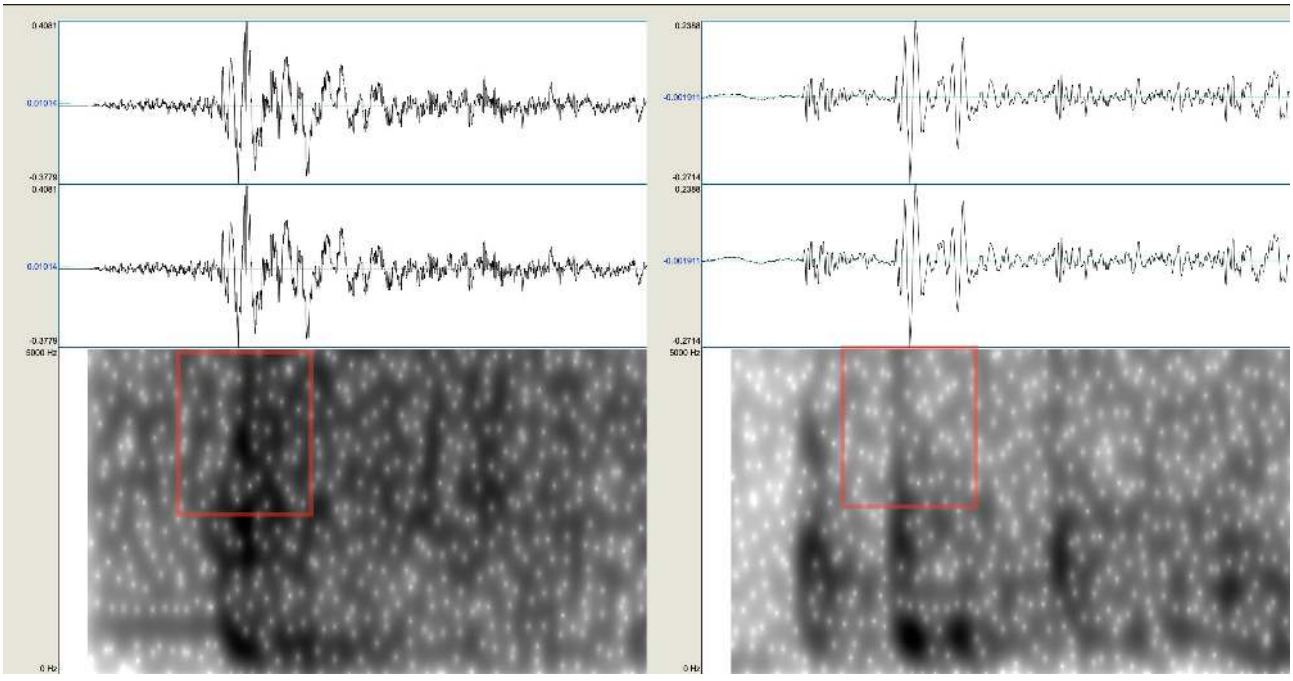
4. After the Incident

4.1. Five seconds (at 7:25 of the recording) after the shots that killed Shireen Abu Akleh we hear a volley of three shots. These gunshots have a distinct acoustic behaviour from the gunfire identified on page 5 of this report.

4.2. A comparative frequency analysis (see Fig. 4) of the shots that killed Shireen Abu Akleh and the shots fired 5 seconds after demonstrates that the shots fired at Shireen Abu Akleh are generally louder than the shots heard 5 seconds after she was killed, especially in the high and high-mid frequency range (2-5 kHz).

4.3. Low-frequency waves travel further than high-frequency waves because less energy is transferred to the medium (anelastic attenuation). The fact that the gunshots during the incident are generally louder, but also have greater intensity in the higher and higher-mid frequency ranges, indicates that the camera is considerably closer to the shooter firing at Shireen Abu Akleh than to the shooter firing the shots heard 5 seconds after she was killed.

4.4. This analysis determines that the gunfire audible 5 seconds after she was killed did not originate from the vicinity of Shireen Abu Akleh or from the road between her and the military position identified as killing her. This disqualifies any claim that the "The journalist was present in the area during an exchange of fire."



(FIG. 4. THE SHOT DURING INCIDENT IS DEPICTED ON THE LEFT AND SHOT 5 SECONDS AFTER THE INCIDENT IS ON THE RIGHT. THE AREA MARKED BY THE RED RECTANGLES SHOW THAT THE SHOT ON THE LEFT IS CONSIDERABLY LOUDER IN THE 2-5KHZ FREQUENCY RANGE. THIS INDICATES THAT THE SHOT DURING THE INCIDENT IS CLOSER TO THE RECORDING DEVICE THAN THE SHOT HEARD AFTER THE INCIDENT.)

5. Method

5.1. There are 3 main methods of analysis used in this report:

5.2. The first and most commonly used method is a comparative study of the frequency and amplitude of gunshots. For this purpose, I used “Praat”, a free computer programme primarily intended for speech analysis, developed by the University of Amsterdam. As a software specifically designed for analysis it offers the possibility to analyse sounds with precision in terms of intensity, pitch, amplitude and duration. I used it here to compare all the shots audible in the recording of the event: The measurements of how the individual shots behave in the frequency spectrum are then compared. If the shots occupy the same range of frequencies with the same intensity, this may indicate whether the shots were fired from the same weapon or position. An example of this technique of forensic audio profiling with Praat can be seen on page 7 of this report. In Figure 4 you can see an annotated screenshot from the Praat software showing a spectrographic representation of the behaviour of two different shots in the frequency spectrum, with the x-axis indicating time, the y-axis indicating frequency bandwidth and the depth of black indicating intensity. The results of this comparison suggest that the gunshots that killed Shireen Abu Akleh were much more intense in the 2-5 kHz frequency range. Since the shots to which they are compared did not have the same intensity in the high and high-mid frequencies and based on anelastic attenuation (a law of physics that can be summarised as low frequency waves travel further than high frequency waves), we can conclude that they cannot have come from any point closer to the journalists than the Israeli military position.

5.3. The second method of analysis is a comparative study between semi-automatic and automatic gunfire, which was carried out with a simple analysis procedure using the digital audio workstation "Reaper". Two audio files were entered into the software and placed on a timeline, creating two waveforms - one for the sound of an M4 carbine rifle in fully automatic mode, the other for the gunshots heard during the incident in which Shireen Abu Akleh was killed. For the sound of the fully automatic rifle, I sampled audio data from this video *https://www.youtube.com/watch?v=vhSlJuCQ64I* where it can be clearly seen and heard how the rifle works in different modes. Examining these waveforms by measuring the intervals between the audible shots allowed a comparison between the two: The intervals between shots of a rifle in fully automatic mode were 60 milliseconds, while the intervals between shots fired at Shireen Abu Akleh were never the same and none of the shots were 60 milliseconds apart. From this I could conclude that the shooter pulled and released the trigger within two seconds on seven different occasions and that none of the shots were fired from an automatic weapon (or a weapon set to fire automatically).

5.4. The last method used in this report examines the acoustic behaviour of the shots. In the first phase of playback, I was able to determine that each shot fired at the journalists was heard with two different sounds, representing two different characteristics of gunshot: First, we hear the shockwave of a supersonic bullet (travelling faster than the speed of sound) moving close to the camera recording the incident, producing a high-frequency ‘crack’. Second, we hear the muzzle blast, which is caused by the rapid expansion of gases escaping from the muzzle when a bullet is fired, and is louder in the lower frequency range than the shockwave. The reason we perceive these sounds separately is that the camera is much closer to the bullet than it is to the muzzle of the gun that fired the shot. Since these two sounds occupy different parts of the frequency spectrum, I was able to use "Praat" to create spectrographic images that clearly show these two different sounds, and thus measure the temporal distance between them. The interval between the shockwave and blast was consistently around 300 milliseconds for each shot. From this I could conclude that all shots were fired from one location. If this interval shortened or lengthened

significantly, this would indicate that the shots were fired from different positions in relation to the camera. Moreover, using this 300 millisecond interval I was also able to estimate the distance between the camera and the shooter (see paragraph 3.4).

6. Conclusions

6.1. The shooter fired a semi-automatic weapon from approximately 180 metres away from Shireen Abu Akleh. This shooter pulled the trigger on seven separate occasions within two seconds making the claim that at no point was there any intentional gunfire carried out by IDF soldiers in a manner intended to harm the journalist" highly improbable. All gunshots audible in the 2 minutes prior to the killing of Shireen Abu Akleh are fired from the same position. No other shots in this recording are firing towards the military position from the the vicinity of Shireen Abu Akleh and her colleagues. This report finds no evidence to support the claims that life-threatening, widespread and indiscriminate shots were fired toward IDF soldiers[3]." The journalist was not "present in the area during an exchange of fire.[4]."

[3] https://www.idf.il/en/articles/2022/final-conclusions-of-shireen-abu-akleh-investigation/
[4] https://www.idf.il/en/articles/2022/final-conclusions-of-shireen-abu-akleh-investigation/