A SCIENTIFIC APPROACH TO MICROPHONE PLACEMENT FOR CYMBALS IN LIVE SOUND

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1 INTRODUCTION

Our understanding of how cymbals produce sound and how their attack, sustain, tone and volume can be controlled has developed through the study and comparison of the vibratory behaviour of flat metal disks and cymbals. In spite of this, there has been little research dedicated to the application of this knowledge in regards to optimal microphone placement at live events and in recording studios. Existing publications on this subject generally contain few scientifically backed claims.

This research focuses on how microphone placement impacts the received sound in regards to human perception of cymbals and drum kits in general. Numerous recordings were taken at different angles around crash, ride, hi-hat and china type cymbals and processed using MATLAB to produce polar plots. These plots were analysed and following this, an explanation of the results and a set of guidelines for ideal microphone placement was developed.

The paper begins with an overview of the key research in the area of the physics of cymbals and overhead microphone placement. This is followed by a description of the experimental methods used in this research and then the presentation and analysis of results. Examples of best placement diagrams are given and the paper is concluded with an emphasis of relevant future work in this area.

2 BACKGROUND

2.1 Basic physics of cymbals

Cymbals are thin, axially symmetric, isotropic (uniform in all directions) metal plates usually defined as being Turkish or Chinese. Figure 2.1 shows the primary areas of a Turkish cymbal, all of which influence the sound. China cymbals have a similar anatomy, except they have an upturned flange instead of a continuous curved bow.

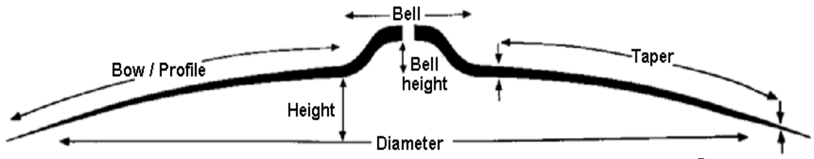

Figure 2.1 - Anatomy of traditional Turkish cymbal[5]

When struck with a drumstick, waves radiate away from the excitation area at a velocity “inversely proportional to the dimensions of the initial flexural indentation of the surface made by the drumstick”[1]. Both the initial pulse, and the reflections off the edges of the cymbal travel up the transitional section to the bell. They are then dispersed across the entire body of the cymbal, causing it to vibrate[1].

2.2 Cymbal modes

When struck, cymbals are excited and vibrate at one of several modes depending on the thickness and shape of the cymbal and the velocity and position of the strike[2]. Electronic TV holography has helped researchers compare modal vibrations of cymbals to those of flat plates. Rossing states that when initially struck, cymbals or plates produce low frequency modes which then develop into higher frequency modes[3]. Additional observation showed that the transition between low and high frequency modes involves the generation of harmonics, then sub-harmonics, followed by chaotic behaviour. Additional detail about cymbal vibratory modes can be found in Thomas D Rossing's Science of Percussion Instruments book[2].

2.3 Existing drum kit microphone technique diagrams and explanations

Many individuals have published their opinions on optimum drum kit overhead microphone positions. Amalgamating the key ideas together has highlighted some important considerations as well as areas of general agreement and disagreement for microphone placement for cymbals. Overhead microphones should be placed between 0.4 m and 1.0 m above the cymbals and equally spaced from the centre of the snare drum to prevent phasing issues[4]. The decision of the distance from the microphones to the cymbals is ultimately that of the sound engineer, however, the likelihood of other instruments on stage causing stage bleed should be considered. Finally, if a particular cymbal or area of a cymbal, such as the bell of a ride, needs to be more prominent in the mix but space is restricted, microphones can be placed underneath cymbals, positioned facing away from the snare or tom-toms. This is commonly referred to as "underhead" placement.

3 RESEARCH METHODS

3.1 Primary investigation

Five different B20 alloy cymbals were used, three from the Sabian AAX series and two from the Zildjian Z Custom range. The cymbals were mounted on a cymbal stand at a height of 1.25 m and struck in several different ways with Vic Firth 5A wooden drumsticks. A Haun MBNM 550 EL acoustic measurement microphone positioned at fixed points above, below and to the edge of the cymbals was connected to a Zoom H4N portable recorder to record several measurements for each cymbal and striking method. The striking methods used were tailored towards the cymbal and stick being used taking into account normal playing technique, for example, bell strikes on the ride and open and closed for the hi-hats.

3.2 Data analysis methods

MATLAB was used for data analysis, as the visual representation of auditory results enables good comparisons to be achieved. Parameters were set to evaluate the relevant results. Gaussian windowing, Fast Fourier Transforms (FFT), normalisation and threshold detection functions were used to obtain accurate and reliable visual results. Polar plots were generated using recordings taken from the top, bottom and edge of half of each cymbal (with symmetry assumed). Figures 3.1 - 3.4 show measurement locations for all the cymbals. Fewer recordings were taken of the 14" cymbals due to minimal difference between measurements taken from the centre of the cymbal and the edge of the bell during preliminary investigations.

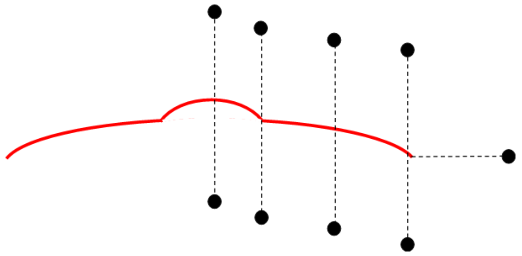

Figure 3.1 - Diagram showing recordings taken for 17” and 19” crash and 21” ride cymbals

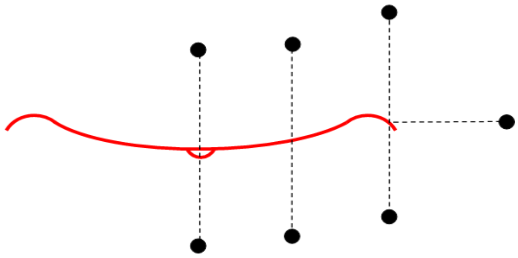

Figure 3.2 - Diagram showing recordings taken for 14” china and 14” hi-hats

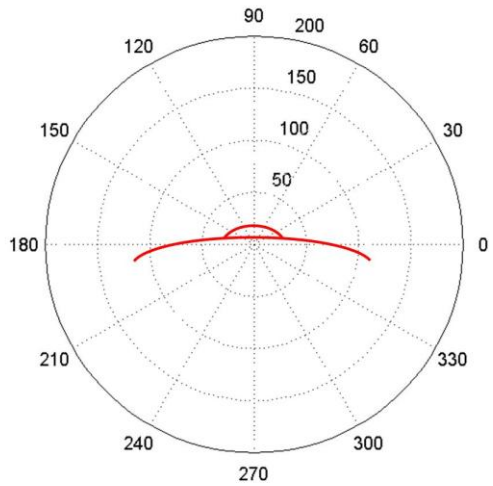

Figure 3.3 - Demonstration of how orientation of Turkish cymbals relates to polar plots

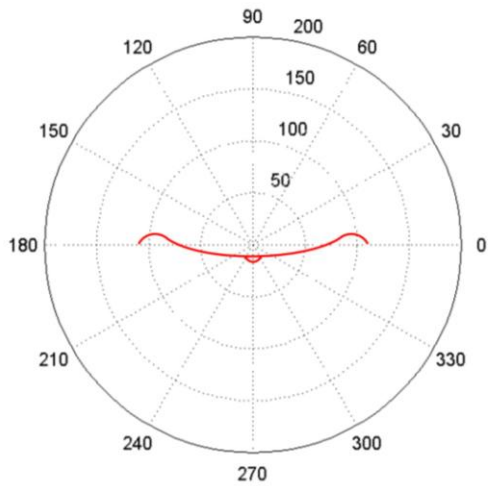

Figure 3.4 - Demonstration of how orientation of China cymbal relates to polar plots

It should be noted that the sound pressure levels (SPL) were calculated in MATLAB using a relative offset applied to the smallest recorded level. This was necessary so that negative SPLs were displayed as positive values in the correct direction rather than a positive SPL in the opposite direction. This resulted in consistently readable polar plots.

4 RESULTS AND ANALYSIS

All five cymbals being tested exhibit omnidirectional characteristics five milliseconds after being struck, shown in figures 4.1 – 4.6. There were, however, slight differences between the polar plots for each cymbal at this point. For example, the hi-hats had a much lower SPL under the centre than anywhere else when struck open and closed. Either the hi-hat stand blocked sound waves, or sound was reflected away from the centre due to the curved profile of the cymbals. Further research will be necessary to confirm this, however, if true, sound technicians should avoid placing microphones too close to the hi-hat stand.

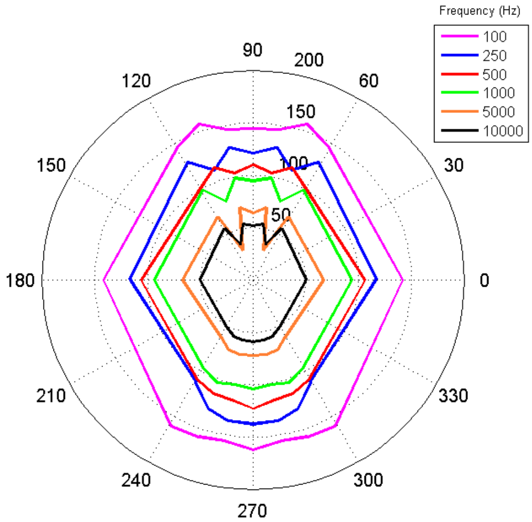

Figure 4.1 - 17" crash after 5 ms

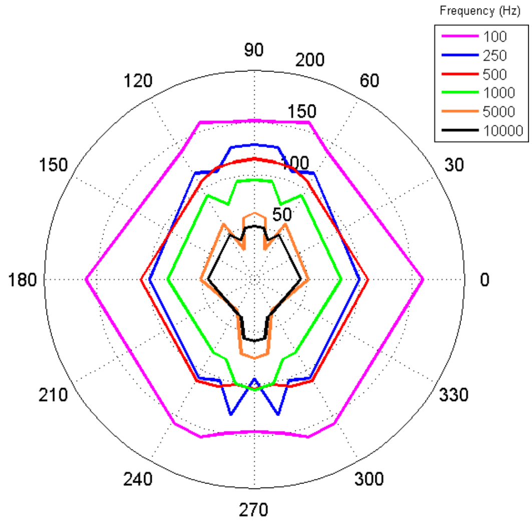

Figure 4.2 - 19" crash after 5 ms

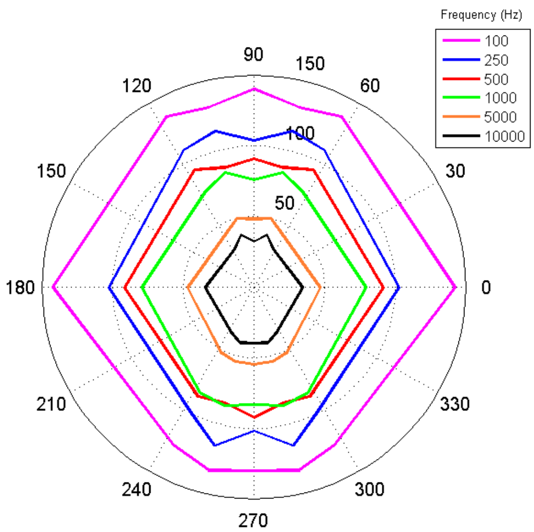

Figure 4.3 - 14" China after 5 ms

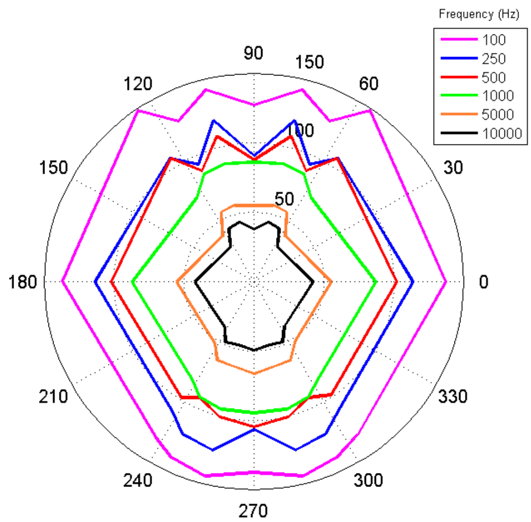

Figure 4.4 - 21" ride after 5 ms (tip of stick on centre of bow)

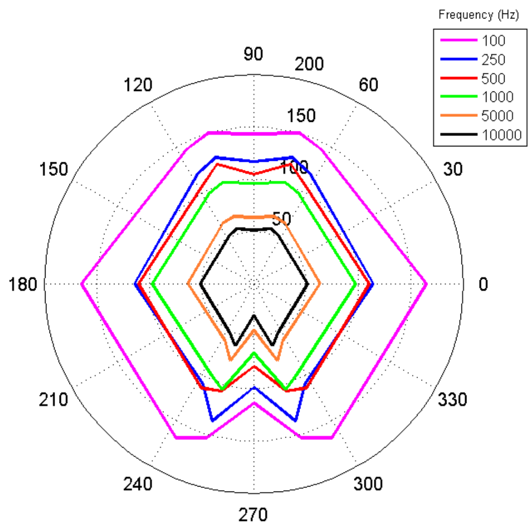

Figure 4.5 - 14" hi-hats after 5 ms (closed)

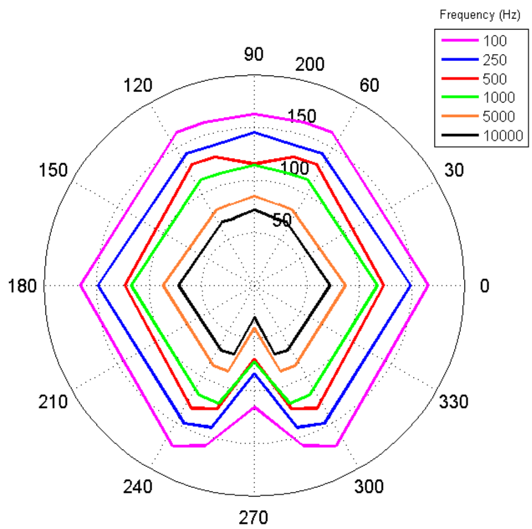

Figure 4.6 - 14" hi-hats after 5 ms (open)

The way in which the ride cymbal was struck also altered the initial frequency radiation pattern. Directionality of the low – mid frequencies (250 Hz – 500 Hz) was noticeable above the transitional area between the bell and bow of the ride cymbal when struck in the centre of the bow with the tip of the stick. When struck at the edge of the bow similar initial levels were recorded, but with less directional behaviour above the cymbal. Likewise, when the ride was struck on the edge with the edge of the stick, similar traits occurred, but with directional patterns below the bell of the cymbal, as seen in figure 4.7. The cymbal vibratory modes generated are partly dependant on the position of the strike, therefore, the drummer needs to know how their playing style will affect the sound and try to strike the most suitable spot to produce the most desirable sound.

Between 25 and 500 milliseconds, all the cymbals behave in a similar manner. Generally, the SPL increases uniformly around the cymbal. However, for the heavier cymbals, such as the Zildjian Z Custom hi-hats and ride, the increase was more noticeable, as shown when comparing figure 4.8 to 4.2 and figure 4.9 to 4.7. This is due to the their larger mass and thickness relative to the other cymbals being tested which, as stated in “The Cymbal Book” written by Hugo Pinksterboer, are factors directly related to the attack and sustain of a cymbal[5].

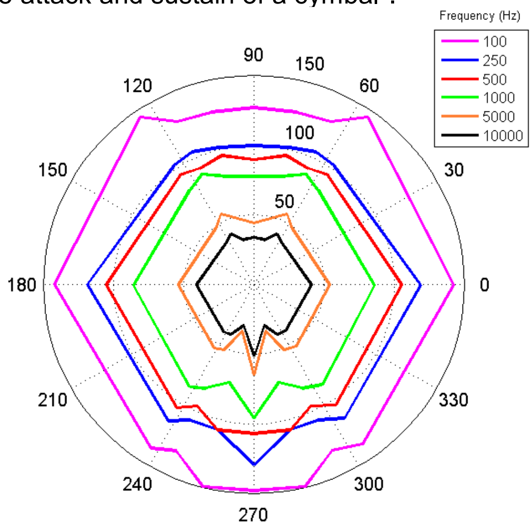

Figure 4.7 - 21" ride after 5 ms (edge of stick on edge of bow)

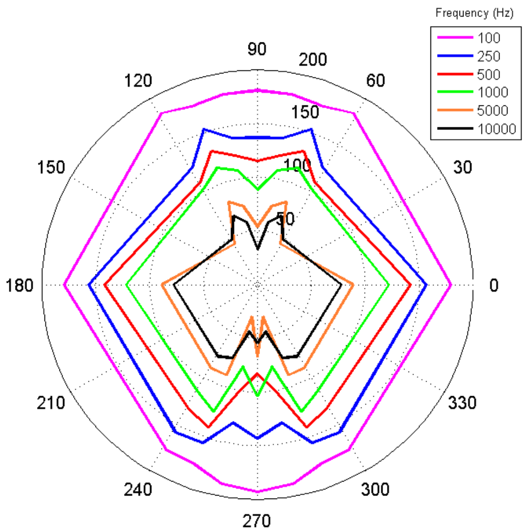

Figure 4.8 - 19 crash after 25 ms

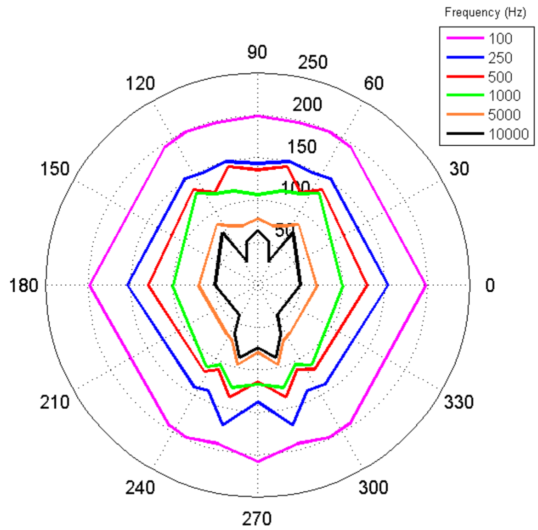

Figure 4.9 - 21" ride after 25 ms (edge of stick on edge of bow)

The omnidirectional patterns gradually diminish and clear directional behaviour is observed for all cymbals and striking methods. The speed in which this process occurred was dependent on the size and mass of the cymbal. Analysis of polar plots indicates that the low frequencies (100 Hz – 250 Hz) created during the early attack after being struck attenuate slightly, and the higher frequencies increase in SPL to become more prominent. This behaviour was expected as Thomas D Rossing explains in his book “Science of Percussion Instruments” that low frequencies decrease within this time period due to energy being converted into higher frequencies[5].

For the China cymbal, the mid to high frequencies (250 Hz – 10 kHz) became more directional, especially above and below the cymbal, seen in figure 4.10. Attenuation under the centre of the cymbal for the 500 – 10,000 Hz range and above the centre of the bow for the 250, 500, 5000 and 10,000 Hz frequencies suggests the curvature of the cymbal greatly influences where sound is directed. It was observed that each frequency increases in level until, at 500 ms, they decrease in level by approximately 15 dB.

This quick decay, in comparison with the crash cymbal, is likely due to the difference in diameter and weight, a theory that is backed up in “The Cymbal Book” written by Pinksterboer[5]. He explains how a larger amount of metal requires more energy to vibrate, but also more energy to stop vibrating. The China cymbal has a smaller mass, due to the smaller diameter and thinner profile. This in turn increases the attack and reduces the sustain creating the characteristic short, ‘trashy’ sound. If China cymbals were thicker and therefore heavier, it would take them longer to stop vibrating and, therefore, wouldn’t be suitable for short accents within songs.

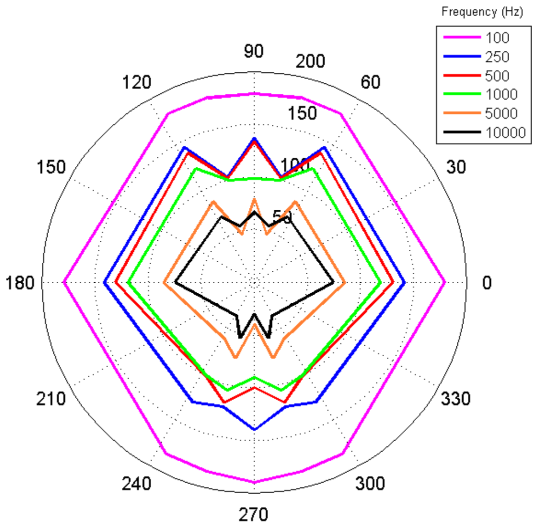

Figure 4.10 - 14" China after 50 ms

By 500 ms all cymbals reach steady state vibratory patterns which continue as their sound decays over time. Figure 4.11 demonstrates how, for a typical Turkish cymbal, the loudest and most directional areas were the points above and below the bow of the cymbal, below the centre and horizontal to the edge. In contrast, the quietest areas were under the edge of the bell, above the transitional area between the bell and bow and above the centre of the cymbal. The shape of the cymbal was the main contributing factor to these patterns. As mentioned previously, Turkish cymbals consist of a circular curved profile plate with a parabolic shaped bell in the centre. It is likely that the curvature of these two components focus sound into specific areas around the cymbal, especially underneath.

The China cymbal also demonstrates clear directionality of the mid to high frequencies above the bow of the cymbal compared to underneath it, as shown in figure 4.12. As with the Turkish cymbals, the shape is likely to be the main contributing factor to this, due to the large parabola focusing sound upwards towards to the centre of the cymbal, but dispersing in all directions below it. Placing a microphone above the centre of the cymbal will pick up the most even sound with the best high frequency presence.

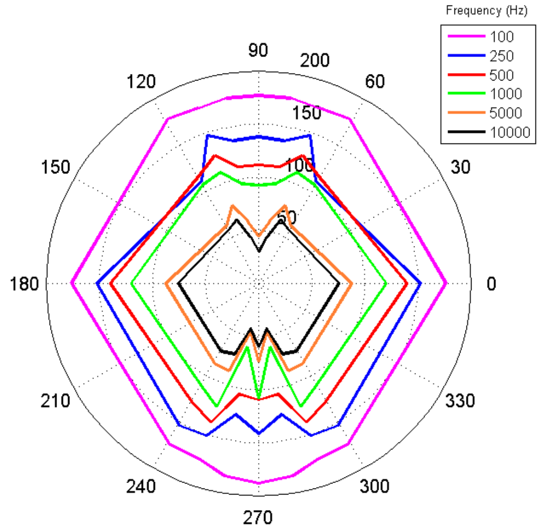

Figure 4.11 - 19" crash after 500 ms

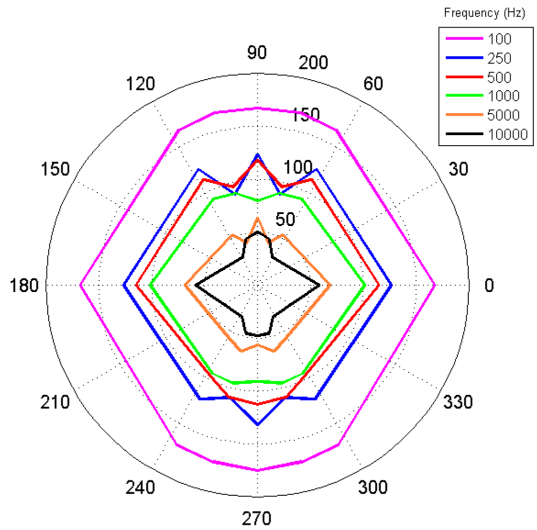

Figure 4.12 - 14" China after 500 ms

There is evidence to suggest that there are similar generic places around Turkish cymbals where microphone placement should be avoided. Figure 4.13 shows that when a microphone is positioned under the centre of the 17" crash cymbal, 100, 250, 500 and 1000 Hz frequencies dominate the sound, while the higher frequencies of 5000 and 10,000 Hz project very little energy. However, directly above the centre of the same cymbal, the higher frequencies have more presence than the low frequencies, specifically 250 Hz, which project very little energy. Conversely, figure 4.14 shows that during the same time interval, the 19" cymbal has different characteristics. Under the centre of the bell, the 1000, 5000 and 10,000 Hz frequencies have strong peaks in comparison to under the edge of the bell, while the centre of the top of the cymbal had much higher attenuation of the same frequencies.

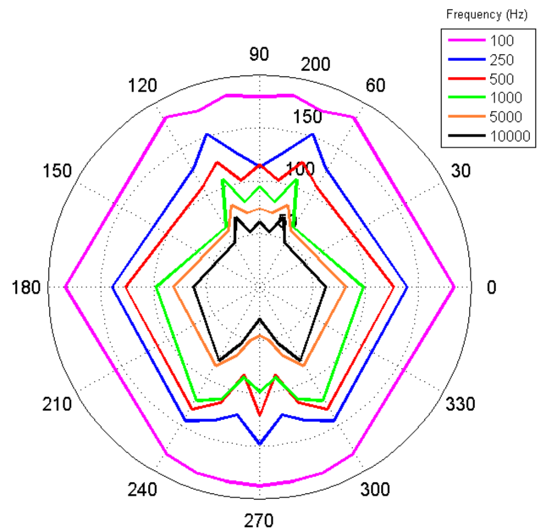

Figure 4.13 - 17" crash after 2.5 s

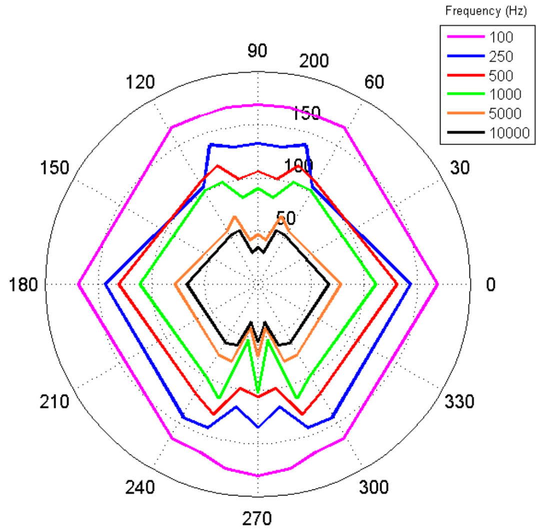

Figure 4.14 - 19" crash after 2.5 s

The 21” ride cymbal exhibits some unusual behaviour for 250 Hz when struck in the centre of the bow and 500 Hz when struck at the edge (figures 4.15 and 4.16). They show a sudden loss of around 100 dB for the 250 Hz and 50 dB for the 500 Hz along the 0°-180° horizontal axis. More testing and analysis will be required to prove this isn’t an anomaly. For a sound engineer this unpredictable behaviour would be undesirable because large attenuation of narrow frequency bands will create an uneven and highly coloured sound.

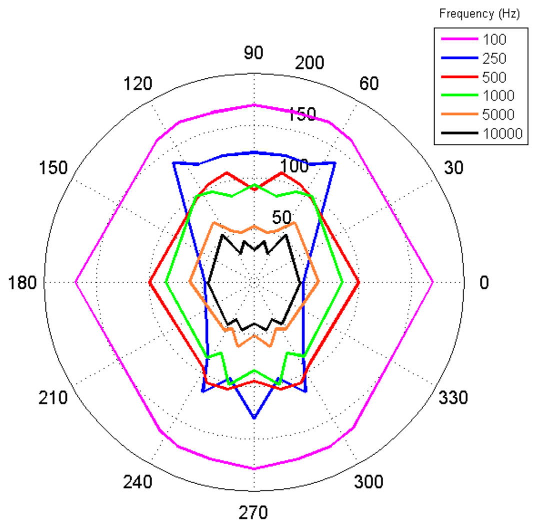

Figure 4.15 - 21" ride after 500 ms (tip of stick on centre of bow)

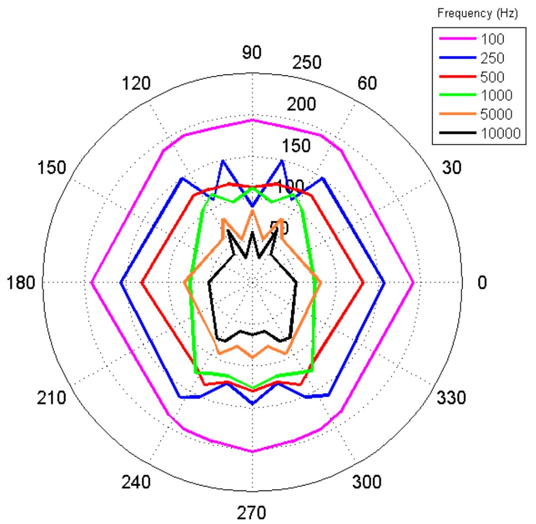

Figure 4.16 - 21" ride after 500 ms (tip of stick on edge of bow)

4.1 Best Placement for Different Drum Kit Configurations

Various drum kit configurations were created using DW’s Drum Workshop KitBuilder2.0TM[6] and then modified to show microphone best placement recommendations.

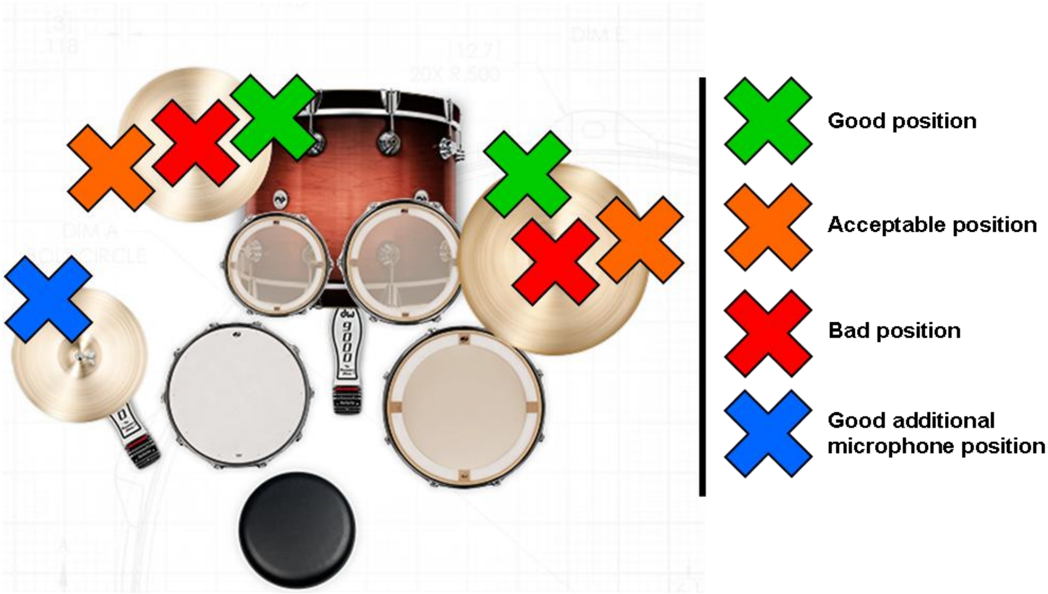

Figure 4.17 - Microphone placement recommendations for basic 5 piece drum kit

Cymbals featured (working clockwise from left) 14” hi-hats, 16” crash, 20” ride

Figure 4.18 - Microphone placement recommendations for 7 piece drum kit

Cymbals featured (working clockwise from left) 14” hi-hats, 16” crash, 20” china, 22” ride, 8” splash, 19” crash

The diagrams above shows how the positioning of two or three overhead microphones can capture the sound from a set of cymbals. Ideally, to get the best overall sound from their different areas such as the bell and profile, one or two microphones would be used for each cymbal. However, the financial burden of extra microphones, cabling and mixing desk inputs and logistical issues such as space around the drum kit mean that for a live sound setting, between two and four overhead microphones will be sufficient.

5 CONCLUSION AND FUTURE WORK

With the rise in global metal prices and importance of cymbals in such a wide variety of music genres it is important to know how best to position microphones in order to get the best sound from them. This research looked at how the positioning of a microphone alters the sound received at an overhead microphone and how the method of striking a cymbal can affect the frequency response pattern produced.

Through the analysis of the data collected it has been found that the frequency radiation pattern varies with shape, size, weight and profile of the cymbal as well as the striking position. The results of the research support previous experimentation into the modes of cymbals, especially how the amount of energy put into an area of a cymbal affects the overall frequency range produced. Whilst this study did not provide enough data to draw up definitive microphone placement rules, it did generate enough data about five different cymbals for the formulation of general guidelines. The information and data presented will hopefully enable sound engineers to adapt and improve their overhead microphone technique to ultimately get better results.

This investigation has highlighted several areas where additional studies could benefit cymbal manufacturers, drummers or sound technicians. The results presented in section four imply that the shape of the cymbal is the primary influencing factor of sound directionality; researching flat plates of equal diameter and comparing the results would confirm this. Furthermore, section 4.1 featured diagrams suggesting microphone positions for a variety of drum configurations made using DW’s Drum Workshop KitBuilder2.0TM[6]. The data could be incorporated with this or a similar program, creating a useful and powerful tool that shows users good microphone positions when they construct and customise their personal drum setup.

6 REFERENCES

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