ABSTRAK

Selama lebih satu dekad, sejumlah besar produk muzik komersil telah diadun dan dicampur menggunakan platfom digital. Ini adalah disebabkan oleh perkembangan deras dalam teknologi digital audio yang membuatkan teknologi analog audio kelihatan terlalu mahal dan tidak praktikal. Walau bagaimanapun, terdapat sejumlah besar daripada golongan jurutera audio termashyur yang masih yakin bahawa kualiti audio digital masih tidak dapat menandingi kualiti audio analog.

Terdapat banyak dakwaan bahawasanya penggunaan peralatan audio analog dapat meningkatkan imej stereo, kedalaman, menambah"glue" dan karakter ke dalam hasil adunan. Namun begitu, masih ramai jurutera-jurutera audio terkenal yang percaya bahawa kualiti audio digital adalah setaraf dengan kualiti audio analog. Golongan ini mengatakan bahawa dengan penggunaan prosedur yang betul dan perisian yang khusus, semua kelebihan audio analog boleh dicapai dalam platfom digital.

Walaupun terdapat banyak ujian bunyi yang telah dilakukan untuk mencari perbezaan khusus diantara dua kaedah *summing,* namun kebanyakan ujikaji terdahulu yang dilakukan dengan tidak mengikut prosedur yang betul. Selain itu, ujikaji-ujikaji terdahulu tidak pernah mengambil kira penggunaan *analogue summing emulation plugin* dalam mencapai perbandingan yang lebih adil diantara platfom audio analog dan digital.

Perdebatan tentang dua kaedah *summing* ini *adalah* sangat relevan dalam bidang audio. Oleh itu, kajian ini telah direka khusus untuk mencari perbezaan objektif diantara

analogue summing dan *digital summing* dengan menggunakan kaedah analisis akustik. Tiga variasi *digital summing* iaitu *DAW summing, DAW* dengan *Waves NLS* dan *DAW* dengan *Slate Digital VCC* diuji dengan kaedah perbandingan terhadap *analogue summing.* Tujuan ujikaji ini adalah untuk membantu pengkaji, jurutera bunyi dan semua yang terlibat untuk memahami implikasi penggunaan kaedah-kaedah *summing* ini.

Dua lagu pop kontemporari diadun dan diexpot sebagai *stems*. *Stems* ini kemudiannya dicampur menggunakan empat kaedah *summing.* Pertama menggunakan *summing mixer* analogue (SSL Xdesk), kedua menggunakan perisian audio digital ataupun DAW (Protools 11), ketiga menggunakan DAW dengan *Waves NLS* dan keempat menggunakan DAW dengan *Slate Digital VCC.*

Analisis akustik kemudian dijalankan keatas semua hasil kaedah *summing*. Hasil ujian menunjukkan terdapat pebezaan visual yang jelas diantara kaedah *analogue summing* dan *digital summing* walaupun dengan sampel yang menggunakan *analogue summing emulation plugin.*

ABSTRACT

For over a decade, the vast majority of commercial music has been mixed and summed on digital platforms. This is partly due to rapid advances in digital audio technology that made the analogue format appear expensive and impractical. However a large proportion of famous audio engineers and music producers still believe that analogue summing cannot be matched for sonic quality.

There have been many claims over the years that analogue summing improves stereo image, enhances depth, add "glue" and "character" to the final mix. Numerous well-known audio engineers and music producers believe that digital summing can be as good as analogue summing. They have claimed that by following proper procedures and using analogue summing emulation plugins, they can achieve all the advantages that analogue summing can offer.

Although many tests had been conducted in the past to find out specific differences between the two summing methods, few were done following proper research procedures. Besides that, none of these tests considered analogue summing emulation plugin to create a more fair comparison between analogue and digital summing.

This argument is highly relevant in the audio field and so this research was set to focus specifically on audio summing. The goal of this research was to find quantifiable objective differences between analogue summing and digital summing by conducting acoustical analysis. Three variations of digital summing were tested against analogue summing with the first variation being DAW summing, second variation being DAW with Waves NLS and third variation, DAW with Slate Digital VCC. The aim was to help researchers, engineers and all who are related to understand the implications of picking either technique to work with.

Two contemporary songs were mixed and exported as stems. The stems were then summed using four different summing procedures. First using analogue summing mixer (SSL Xdesk), second using DAW (Protools 11) internal summing, third using DAW with Waves NLS and fourth using DAW with Slate Digital VCC. Panning, fader level, sample rate and bit rate were left unchanged and identical in all summing procedures.

Acoustical analyses were then performed on all summing procedures to find differences between analogue summing samples and the three variations of digital summing samples. Results showed that visual differences were clearly visible between analogue summing samples and digital summing samples even with the use of analogue summing emulation plugin.

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CHAPTER 1 BACKGROUND OF STUDY

1. Background of Study

The war between digital and analogue equipment in the audio field has been ongoing since the introduction of the first digital audio recorder by Dr. Thomas Stockham, Jr in the 70's. (Kirk, 2004). Since then, there have been plenty of opposing opinions from professionals and non-professionals of the audio industry on the two different formats. However, most generally agree that both of these formats come with their own advantages and disadvantages.

"Summing is the process of adding individual signals together just before the main output; after any processing and level changes are made, the signals are routed to a mix or summing bus to be added together."(McFarlane, n.d.)

Summing is one of the oldest and most basic process in audio history. This process goes back during the early radio broadcast era where the signal coming from the radio announcer's microphone had to be combined with the music from the record player before being transmitted to the listeners. (Rudolf, 2004)

Currently there are two main methods of summing which are analogue summing and digital summing. Analogue summing is basically combining all the audio tracks together at the group or main stereo bus of a mixing console. (Cooper, 2004). *"This operation is simply performed by adding the instantaneous signal voltages together."* (Cooper, 2004) Digital summing similarly achieves this *"by adding corresponding sample values together."*(Cooper, 2004)

The common questions between the two methods are obvious. Are there any differences between the two summing methods? And if there are differences, which one produces the better or more preferred results? The generally favored answer for the latter question had always been analogue. Some professionals however did argue that the poor results of digital summing are due to user error rather than the flaw of the system itself. (Cooper, 2004) The answer to the latter question remains unanswered.

With the advancement of modern digital technology, the superiority of the analogue equipment has been challenged by the introduction of more advanced digital audio equipment that can produce arguably similar or not the same results at a fraction of the price. The creation of advanced DAW software, analogue emulation plugins, DSP chips and large format control surfaces such as Digidesign ICON and Euphonix System 5-MC converted pure analogue disciples into digital followers. When once the digital control surface was small and limited, it now has equal, if not greater functions than its analogue neighbors. The summing capability of analogue equipment have also been challenged with the introduction of software plugins such as the Slate Digital VCC which claims to be able to deliver all the advantages commonly achieved in the analogue form. (Inglis, 2011)

The sections below will thoroughly explain issues related to the topic. It will start with an introduction of analogue and digital summing, an explanation of the analogue emulation software (Waves NLS and Slate Digital VCC) as the main contender to the advantages of analogue summing.

1.1 Analogue Summing

Traditionally, mixing was done on an analogue mixing console. After this process, all the audio signals that have been balanced by the mixing engineer will then be combined using the analogue summing bus that is built inside the mixing console itself. (Rudolf, 2004) These procedures has dominated the audio practice until digital technology came and challenged the analogue mixing console as the sole dominance in audio production.

Analogue summing has been claimed to introduce a lot of advantages into audio signal. These claimed advantages include, "more open, clear and punchier sound". (Rudolf, 2004) Another claim explains that the analogue process enhances the feeling of depth and soundstage as a result of clearer and more evident reverb and delays. (Farmelo, n.d.)

Many audio experts have come out with theories on how these advantages can be achieved. Audiophile Bob Katz (2002) explains that the enhancement that people perceive from analogue summing is due to the "friendly distortion" that is being introduced by the analogue components. The enhance feeling of depth and separation cause by this distortion according to him is a psycoacoustical effect rather than a technical one. (p. 221)

1.1.1 Dedicated Analogue Summing Mixer

Due to the superiority claimed by users, the practice of analogue summing has evolved in catching up with digital's rapid development. The use of an analogue mixer as the central instrument of mixing and summing has declined with the ever-increasing capability of digital audio workstations (DAW)[1]. This new way of working in DAW has created a new hybrid demand of working in both digital and analogue in order to offer audio engineers the best of both worlds.

Dedicated analogue summing mixer started to appear as an alternative to offer engineers who mainly work in digital audio workstations some of the analogue advantages. These small-dedicated line mixers are designed to accept audio outputs from digital audio workstations analogue I/Os and sum or combine them into stereo mixes without the need of a full fledge analogue mixer. (Rudolf, 2004)

1.2 Digital Summing

Theoretically, digital equipment that can be found today generally has better technical specifications compared to its analogue counterpart. Analogue fanatics however, still argue that digital equipment has not managed to match the sonic quality that analogue equipment can produce. Countless material has been produced ever since to compare and contrast the results from these two summing formats. Although the results have mainly favored the analogue, many pro-digital equipment users blame the lack of promotion of proper procedures for working in the digital format as the cause of poor results.

> *"there is nothing wrong with digital summing, it is essentially perfect, especially since adding numbers is the easiest thing you can ask a DSP to do – equivalent to adding voltages in the analog domain."*(Katz, 2002, p. 221)

---

[1] DAW (Digital Audio Workstation) is defined as a computer that contains the required software and hardware to digitize and edit audio. (Owsinski, 2006)

The commonly found mistakes in digital audio procedures include, *"poor gain structuring (user error, in other words), poor implementation of plug-in processing (third-party software problems) or, less commonly, to the core DSP of the system itself."* (Cooper, 2004)

Many improvements have been achieved since these problems were found. New and more advanced digital audio workstations such as Reaper, Sonar X1 and Protools 10 and Protools 11 now offer 64 bit floating point mixing/summing resolution which in theory will let the complex calculation during mixing and summing to be more accurate than previously possible. (Maningo, 2012)

> *"Aside from many advantages in digital music production; summing in digital (as compared to rendering a mix in analog) has always been considered inferior to professional mixing engineers because of this limitation. Summing digital audio in 64-bit float increases the accuracy of the mix that would stand out which would now be comparable to the mix done using analog."* (Maningo, 2012)

1.3 Analogue Summing Emulation

1.3.1 Slate Digital VCC

Designed by Fabrice Gabriel, Slate VCC (Virtual Console Collections) was introduced in 2011 to overcome the need for analogue gear in a digital audio workstation environment. It is an audio plug-in software designed to emulate the advantages of using analogue equipment during the mixing and summing process. These advantages include adding "glue" and "vibe" thus removing the sterile character typically found in digital mixes. (Inglis, 2011)

"It's also worth pointing out that VCC does not emulate any of the actual processing features of a console channel strip. There's no EQ and no dynamics processing: its sole aim is to mimic the subtle, non-linear distortion and noise that you get when passing a fluctuating voltage through a complex arrangement of analogue components." (Inglis, 2011)

Slate VCC designer, Fabrice Gabriel, explains that the software does not imitate an actual summing process but instead adds the missing ingredients into each audio signal that would then communicate (during digital summing) within itself into producing the desired results. The plugin offers four different analogue mixing console emulations. The four consoles are the SSL E series with G upgrades, Neve 8048, API and Trident 80B. (Inglis, 2011)

1.3.2 Waves NLS (Non Linear Summer)

Similar to Slate Digital VCC, Waves NLS was designed to emulate the advantages of analogue summing. The idea was to replicate the non-linear interactions between analogue components that give analogue summing an edge over digital summing. The plugin provide users with three different analogue mixing console emulations. The three consoles are the SSL 4000G, EMI TG12345 Mk IV and Neve 5116. (Noren, 2012)

The primary objective of this research is to investigate whether there are any objective differences between analogue summing and digital summing. In achieving the primary objective, two main processes will be use to achieve more identical results between analogue summing and digital summing. The processes are:

- To use analogue summing emulation plugins in imitating analogue summing.
- To use a DAW with 64bit summing engine in producing more identical results to analogue summing.

CHAPTER 2 LITERATURE REVIEW

2. Literature Review

This literature review is set to present and explore the findings of the related issues surrounding this thesis. This literature review is broken down into sub sections due to the nature of the study that covers a wide range of inter-related issues. The first section will focus on the findings of previous tests and write-ups done related to analogue and digital summing. This will include all the claimed arguments done by user of both summing methods in order to find similarities and differences between all results.

The second section will explore the benefits of modern computers on digital audio. This section will cover all the advantages of current technology that are being used to achieve better audio quality in digital format. This will help in identifying the weaknesses (if any) or possible false claim by the user of analogue summing on digital summing.

2.1 Previous Studies on Summing

In 2012, a study was conducted by Brett Leonard, Scott Levine and Padraig Buttner-Schnirer (2012) to find objective and subjective differences between different DAW summing. The study was focused on three different aspects in DAW that are gain, panning and summing. Multi-track stems were summed into stereo mix using five different DAWs and the outcomes were studied. In an email interview with Leonard (personal communication, December 2, 2014), he explained that the first procedure of analysis was to perform a cross correlation procedure using Matlab[2] to the summing samples. This was done to find precise temporal matching point. The DAW summing samples outputs were then subtracted to get the differences. Results from the study showed that there were only minimal objective and subjective differences between the five DAW summing results from the study. However, more audible differences can be heard when panning was included during summing. This was discovered when the team found significant variations in output levels and sound quality when testing DAW with different panning laws.

In another study done by Jessica Kent (2014), it was revealed that panning algorithms used for summing in DAW differs from one to another. Three open source DAW (Ardour, Audacity and Rosegarden) were studied both objectively and subjectively to draw differences on each summing outcomes. Kent (2014) has reported that all the participants could detect audible differences between the analogue summing and digital summing samples. She has also reported visual differences between both analogue and digital summing samples that were summed at higher sample rate as opposed to the ones that were summed at lower sample rate. Another interesting finding was that the differences between analogue and digital summing became less clear with the decrease of track numbers.

Both of the studies have applied objective and subjective testing methods to compare and contrast between summing techniques though specific methods differs in testing procedures and data collection. General spectrums have been looked at but no detail descriptions were given on differences of spectrum between the summing outcomes.

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[2] Matlab is a customizable software that allows its users to compute, visualize and program problems using mathematical calculations.

Study done by Kent did not considered the use of analogue summing emulation plugins that could possibly lessen the differences between analogue and digital summing.

2.2 Other Tests on Summing

In 2007, music producer, Alex Oana (11 time Minnesotta Music Award winner) had conducted a simple test to see the difference between analogue and digital summing. He had printed three versions of the same mix using three different summing variations. The first version involves only the DAW (Protools HD) using the "bounce to disk"[3] digital summing function. The second print involves using an analogue summing box (Folcrom passive summing mixer) via Digidesign 192 D/A converter[4]. The third print involves the same Folcrom mixer via Apogee DA16x D/A converter. The results from his listening test revealed that the digitally summed version appeared to be harsher in the higher frequencies and contain more low frequencies. The two analogue summed versions seemed to be smoother in the higher frequencies (above 2kHz) with the Apogee DA16x version being slightly more smooth, more body and with increase tonal clarity. A blind test conducted on his engineer friend also yielded identical results. (Oana, 2007)

Another test done by Allen Farmelo (record producer, audio engineer) who had sent his Protools mix out to analogue equipment had also reported positive results. He wrote that the analogue summed tracks created a wider stereo image, deeper (depth of field), sounded more musical and spacious compared to the digitally summed. He followed a slightly different signal flow as compared to Oana by including an analogue compressor

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[3] "Bounce to disk" is an alternative name for export function that is used by Protools.
[4] D/A refers to a digital to analogue converter which is a device that converts binary code into analogue waveform.

into the signal chain. He, unlike Oana, had chosen analogue equipment (summing box, line amp) that are known to introduce more evident analogue character into sounds that are past through it. (Farmelo, n.d.)

Oana and Farmelo did not manage to come out with solid explainations on how the advantages of analogue summing were achieved. They both however speculated on possible reasons behind it. Oana mentioned that reason that the analogue summed produced such characteristics is because of the advantage of having extra headroom[5]. He explains that the quality of digital audio tracks tend to fall when gain reduction is applied by the D.A.E (Protools). By summing audio tracks (from DAW) out to analogue summing box, the faders can stay closer to unity gain[6] that reduces loss of signal quality. He also wrote that harmonic distortion gained from transformers, tape, descrete cirsuit and tubes increases tonal density resulting sound to appear more thick, warm and vibrant. (Oana, 2007)

Farmelo did not suggest any explanations regarding analogue advantage but stressed about his disagreement with Bob Katz theory that the analogue summing advantages can be achieved by just applying harmonic distortions into the final stereo mix. He added that based on his experience in working with harmonic distortion, the analogue advantages could not be achieved by just doing this. (Farmelo, n.d.)

Both Farmelo and Oana expressed that the advantages of analogue summing is a worthwhile investment as the difference proved to be significant. Oana however

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[5] Headroom is defined as the amount of dynamic range between the normal operating level and the maximum output level. (Owsinski, 2006)
[6] Unity gain occurs when the output level of a process or processor matches the input level. (Owsinski, 2006)

mentioned that listeners of modern mp3 format would probably not be able to perceive the difference between the two summing methods. (Oana, 2007)

An explanation regarding analogue versus digital summing was published in Sound on Sound magazine in June 2004. In this article written by Paul Cooper quoted a previuos statement by Hugh Robjohns (Technical Editor of SOS magazine) that says that the digital summing essentially is not flawed. Robjohns continued to elaborate that the main issue of getting less than ideal results in digital summing is a matter of user wrong doings rather than the flaw of the system. He also added that the reason why most engineers prefer the analogue is due to the inherent imperfections (harmonic distortion etc.) that the analogue components introduce into sounds. (Cooper, 2004)

In an article published by Emusician in 2006, Orren Merton (2006) listed down similar arguments by digital users who reported that the lack of clarity and separation is actually done by the user and not the system. He pointed out that even in a hybrid system where DAW is used for mixing and analogue summing box is used for summing, digital summing have to still be performed to submix tracks into the few number of inputs that are commonly found on an analogue summing box. (Merton, 2006) Paul Cooper had also raised an identical argument in his article.

In an article published in 2011, Unne Liljeblad (2011) had argued about the validity of negative statements on digital mixing. He explained that although the low bit rates[7] (wordlength) used by early DAW did affect audio quality, modern DAW however uses 64bit floating point/48bit fixed calculation which provide more than enough headroom. He also stated that digital processing (mixing, summing etc.) is theoretically "perfect"

[7] Bit rate is the transmission rate of a digital system. (Owsinski, 2006)

(when done properly) as compared to analogue, which can never sum signals perfectly. The issue of delay and latency during digital mixing which creates phase coherency is also a past issue as most modern DAW are equipped with “automatic delay compensation” to fix this problem. (Liljeblad, 2011)

Cooper (2004), in his article, stated that the flaws in digital summing that existed during the early time of DAW was due to poor programming by the software engineers. The flaws get more and more significant as the track number increases due to the larger and more complex binary numbers involved. He also mentioned that poor plug-in design by third party software developers and poor DSP as common problems of the past. Apart from the programming error, user error such as lack of understanding in ideal gain structure is mentioned as another contributor to getting poor results.

All testing results regarding the two different camps of summing methods present very conflicting results. It could be argued that the tests done by Farmello and Oana does not represent accurate results as the listening tests only involves extremely limited number of participant. Although signal flow of both analogue-summing processes was explained, none of them described how the mix in the DAW was done. This is crucial to show that the digital summing is performing at its best. Articles posted regarding the false claim of flaws related to digital summing also did not include any objective or subjective results to prove the claims. Arguments on these articles were not even backed by a single product to support the theories.

2.3 Benefits of Modern CPU

2.3.1 Multiprocessing

Computer technology has played a vital part in opening new grounds for digital audio. The evolution of DAW from originally having 16bit wordlength to 64bit, increase of sample rate, invention of multicores processor and other inventions has contributed to very significant improvements in digital audio quality.

In 2005, the Chief Technology Officer of Cakewalk, Ron Kuper (2005) had published a paper explaining the benefits of modern computer technology on digital audio. The paper entitled “Benefits of Modern CPU Architectures for Digital Audio Applications” explores the advantages of technology back then which includes multicore computing, CPU registers and the 64bit architecture.

Kuper (2005) had explained that the multicore processor found on today’s computer does not benefit all software but only those that are programmed to work in parallel. DAW, which does work in parallelism would greatly benefit from a multi-core technology. He explained that a main task in a typical DAW could be broken down into smaller subtasks that can then be processed in parallel. He reported that a performance increase of between 30-50% (depending on the efficiency of how the DAW is programmed to take advantage of the multicore CPU) could be achieved by using a dual core CPU instead of a single core. (Kuper, 2005)

A similar report by Michal Jurewicz (Mytek, Inc.) and Timothy Self (Be, Inc.) had also explained about the advantages of using multiprocessing CPU for digital audio software. In this article, which was published in 1999, the authors reported that *pervasive multitasking* breaks down a large task into smaller ones and perform them in parallel manner. User of the system has reported significant improvements of performance. However, the authors explained that it is crucial to use an operating system (such as Be OS) that utilizes the multiprocessing on audio tasks instead of other background applications which is the normal case in a general operating system (MacOS, Windows etc.). (Jurewicz and Self 1999 [online])

Both of these papers were presented by representatives of technology (audio) developer. It could be argued that the authors were pushing towards convincing the audience of new technology that was being developed by their respective companies. Although the authors reported improvements of performance in using multiprocessing in audio but no hard data (involving real world test) were presented and improvements were mainly based on theories of the system.

2.3.2 64bit Architecture

Published in 2012, "Advantages of 64-bit DAW over 32-bit float Digital audio workstation" described how the current 64bit CPU architecture could benefit digital audio workstations. Emerson Maningo explains that although modern DAWs have implemented 64bit architecture, the resolution of audio saved actually stays as 24bit. The 64bit (floating-point) architecture instead is used in complex processes during audio mixing and summing where 24bit is seen as inadequate. (Maningo, 2012)

> *"The reason why they are processing it as a floating point is for convenience in the computation and representation of very large /very small numbers and efficiency. This makes it possible to retain resolution while doing complex computation thus benefiting audio quality during the mix."* (Maningo, 2012)

Maningo explain that the complex processes include usage of audio plug-in, setting levels and audio summing during the mixdown process. Ron Kuper (2005) from Cakewalk also reported similar findings that describe the 64bit processing as having an *"increase dynamic range and sonic clarity"*. Another mentioned advantages of having 64bit mentioned by Kuper, Jurewicz and Self is that the 64bit architecture lets the CPU address up to 1 terabyte of RAM which lets the process of working with sample libraries (sound libraries) much faster. This is due to the ability for the whole library to be loaded onto the RAM instead of running it from the hard disk drive. (Kuper, 2005)

The explanation behind the increase of and sonic clarity is that the 32bit (floating point) system DAW that it is not able to represent all the calculations of the audio processes. This will lead into the DAW simplifying the processes by rounding off the calculations. Maningo (2012) explains that the 64bit will still have to round off calculations but the ability of the system to represent more numbers will result in fewer simplifications thus yielding more accurate representations. These more accurate representations are described to be closer to the analogue sound. Kuper (2005) explains that the use of 64bit with double precision will reduce inaccuracies in summation and will result of less significant bit being lost. This according to him is especially crucial in mix tasks that have dramatic gain adjustments.

In another article written by Stan Cotey (2003), it is described that the 24bit system that were used in the past in DAWs are not enough. He explains that the 24bit system can deliver a dynamic range of up to 140 dB. This according to him is enough if one were to handle a single channel of audio that contains a dynamic range of less than 140 dB. In a typical mixing environment a lot of tracks are used in a single session. These tracks might not contain 140 dB individually but as a group they can accumulate to a very large number. (Cotey, 2003)

Maningo (2012) however pointed out that although the 64bit processing offers a lot of advantages, it also presents a big disadvantage. He explains that due to the longer representations of numbers in 64bit, the CPU will require a lot more processing power.

All writers have presented similarly promising data on 64bit processing. Good examples have been shown to support their claims. However, it could be again that Kuper, Jurewicz and Self are promoting the idea of 64bit being more analogue to promote their company's latest releases that offers this feature at the time the articles were written.

2.4 Conclusion

A lot has been done in finding clear differences between the two summing methods. However only few studies done contain concrete objective and subjective results. Consideration should be put on following proper methodology in getting credible results. Explanations and arguments on specific procedures should also been given to show that the entire test had been done in a fair manner.

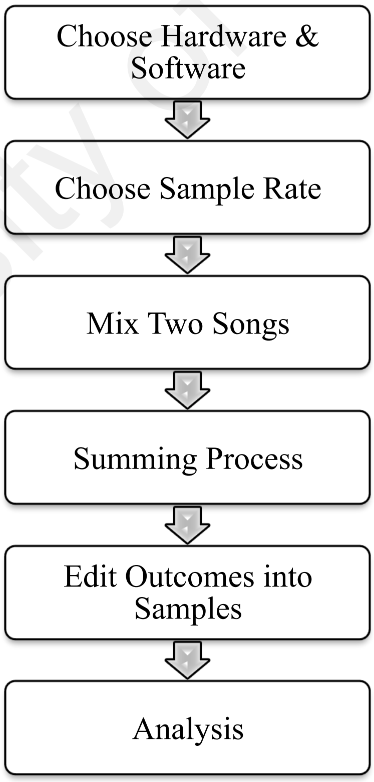
Some of the tests could have been taken in a more technical sense by using specific audio analysis equipment such as Prism Sound DSA-1 AES/EBU Digital Interface Analyzer or Prism Sound dScope Series III digital audio analyzer to gather technical data. Visualization of the summing outcomes would have probably revealed information and explanations that could not be perceived by just having a perceptual listening test.

CHAPTER 3 METHODOLOGY

3. Methodology

This particular research requires extensive amount of work ethics due to the nature of the task. Investigations on related literatures were the first step. Articles were studied to gather data to support every step of decisions made for the experiment. Online investigations were also done extensively to see what others have done in the past. This includes critically looking at videos and related forums. Knowledge acquired was then used to draw the proper guidelines to improve the working procedures.

Figure 3.1: Key Production Steps



3.1 Test Materials

When considering the reasons behind conducting this project, deep consideration was given to which DAW software should be tested against the analogue. After investigations were made, Avid Protools 10, Avid Protools 11 and Cubase 5 were chosen. The main reason for choosing Protools was because it was considered as the industry standard among DAW softwares at the time of writing. Protools 10 and Protools 11 come with the latest 64 bit summing engines that could be viewed as the closest competitor to analogue summing. Cubase 5 was chosen as another variation of DAW that still uses 32 bit floating point summing engine.

The next step was to choose the analogue summing emulation plugins to be used alongside the DAWs. After careful consideration, Waves NLS (V9, released in 2012) and Slate VCC (Version 1.5, released in 2011) were chosen based on its reputation in the audio industry. These two plugins are class leading in analogue console modeling and fit the specific requirements for this particular study. Both plugins were designed to emulate advantages of analogue circuitry during mixing and summing process.

The next step was to choose the sample rate[8] for the recording, mixing and summing process. Although the DAWs were capable of recording up until 192 kHz sample rate, the decision was made to record at 88.2 kHz. The inability of Waves NLS to operate at 192kHz sample rate was the main reason for excluding the highest sample rate. The recording and mixing process was done at 88.2 kHz 24 bit sample rate to keep the audio resolution at the highest possible level without sacrificing too much of CPU power. As stated by Bob Katz (2007),

> *"The dilemma of digital audio is that most calculations result in a longer wordlength than you started with. Getting more decimal places in our digital dollars is analogous to having more bits in our digital words. When a gain*

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[8] Sample rate refers to the resolution of an audio file that is measured in Hz. A sample rate of 88.2 kHz means that it contains 88200 samples per second.

calculation is performed, the wordlength can increase infinitely, depending on the precision we use in the calculation. A 1 dB gain boost involves multiplying by 1.122018454 (to 9 place accuracy). Multiply $1.51 by 1.122018454, and you get $1.694247866 (try it on your calculator). Every extra decimal place may seem insignificant to you, until you realize that DSPs require repeated calculations to perform filtering, equalization, and compression. 1 dB up here, 1 dB down here, up and down a few times, and the end number may not resemble the right product at all, unless adequate precision is maintained. Remember, the more precision, the cleaner your digital audio will sound in the end (up to a reasonable limit).”(Katz, 2007)

The summing process was conducted at 88.2kHz 24bit sample rate to retain the high resolution audio quality from previous processes in order to reveal more information during analysis.

”Always start out with the highest resolution source and maintain that resolution for as long as possible into the processing.” (Katz, 2002, p. 16)

Song choice for this particular study was another difficult task. This was because the songs needed to contain enough timbre variations so that sufficient scenarios could be analyzed in revealing differences between the two summing techniques. As a solution, two songs that contain slightly different instruments were selected for the purpose of the study. The two songs, “Bicycle Song” and “Old World”, were written by Cheynne Murphy and co-produced with Shahrizal Jaapar in 2008.

Table 3.1: List of instruments in the two songs

"BICYCLE SONG"	**"OLD WORLD"**
Drums	Electric Bass
Electric Bass	Acoustic Guitar
Acoustic Guitar	Harmonica
Viola	Viola
Shaker	Shaker
Male Lead Vocal	Male Lead Vocal
Male Backing Vocals	Male Backing Vocals
Female Backing Vocals	Flute

The key of achieving success in this study was to have mixes that have a very high level of clarity. With this, a more accurate analysis can be performed between analogue summing and digital summing. High level of concern was put on following guidelines to achieve clean and clear recordings. Clipping were kept at minimum (in the preamplifiers and A/D[9] converter) to save tracks from excessive distortion and channel strips were checked to avoid unwanted noise.

In the mixing stage, a set of general guidelines of working with DAW software was followed. This guideline was retrieved from a chapter "Mixing in the Box" from the book "The Mixing Engineer's Handbook" written by Bobby Owsinski (Owsinski, 2006). The guideline includes rules for gain staging and tips on usage of plugins in order to achieve the most out of DAW mixing. This guideline was important, as it is normally the common argument on why digitally summed tracks do not sound as good.

[9] A/D converter is a device that converts analogue waveform into binary codes.

Good audio references (from Bernard Fanning's Tea & Sympathy album) were also used to achieve the best possible mixes. This was an important step as previous mixes done (without any reference) had a lot of major problems such as lack of definition and clarity. The reference was also to stop from over processing (equalization, compression) the tracks and to guide towards the right mixing style. Final mixes were also checked on different monitoring setups and listening environments to make sure that there were no major problems that could not be revealed during the mixing process.

Stems were then exported from the final mix session for the summing test. This approach of separating the mixing and summing procedures was done to:

- Separate the CPU heavy mixing process from the summing process.
- Provide the summing process with mixed (polished) tracks instead of raw and unmixed tracks.
- To exclude panning, fader level and other DAW processes that could also affect the summing outcomes.

3.2 Analogue Summing Procedures

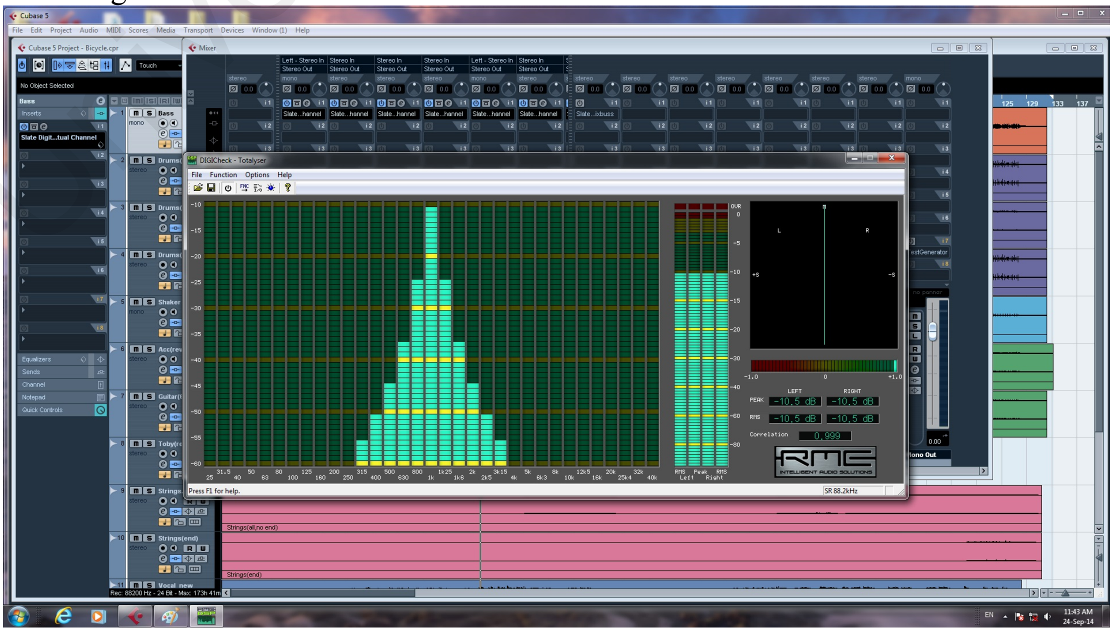
For analogue summing, mixed stems were imported into DAW (Cubase 5), group into 8 stereo bus and routed individually via Apogee DA16X (digital to analogue converter) into the analogue summing mixer (SSL Xdesk).

Figure 3.2: Diagram of the analogue summing procedures

Figure 3.3: SSL Xdesk settings during analogue summing procedures

The individual channels of the summing mixer were tested beforehand by using a 1kHz test tone. The test tone was routed into each channel and the faders were moved whilst monitoring the output level. This was done to make sure that the fader levels were set identically to ensure amplitude consistencies among each channel. RME Digicheck audio analysis software was used to perform this task.

Figure 3.4: 1kHz test tone used to calibrate each of the SSL Xdesk channels



The stereo output from the console were then routed back via Lavry 4496 (analogue to digital converter) to DAW and recorded at 88 kHz 24bit sample rate.

Figure 3.5: AD/DA converters used during analogue summing procedures

3.3 Digital Summing Procedures

3.3.1 Protools 11

For the first version of digital summing, all previously exported audio stems was imported into Protools 11 without changing their original sample rate and bit rate. All panning were left unchanged and all faders were set to nominal. The final stereo mix was then exported using Protools' "Bounce to disk" function at 88.2kHz 24bit setting.

Figure 3.6: Diagram of the digital summing procedures

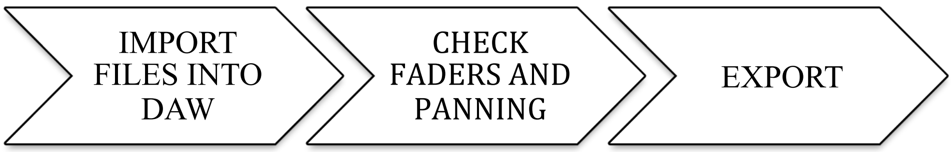


Figure 3.7: Snapshot of Protools 11 session during digital summing procedures

3.3.1 Protools 10 with Waves NLS

For the second version (Protools 10 + Waves NLS) of digital summing, audio stems were imported into a new session without changing the original sample rate and bit rate. Waves NLS Channel was then inserted into every channel. The “Spike” setting was chosen to emulate similar SSL characteristics of the analogue summed sample.

The “Drive” and “Trim” functions were left at nominal setting to avoid excessive analogue coloration. Waves NLS Buss was inserted into the master channel to complete the emulation of an analogue console interaction. The “Drive” and “Trim” function on this plugin were also set at nominal to avoid excessive analogue coloration.

Figure 3.8: Diagram of the digital summing procedures with Waves NLS

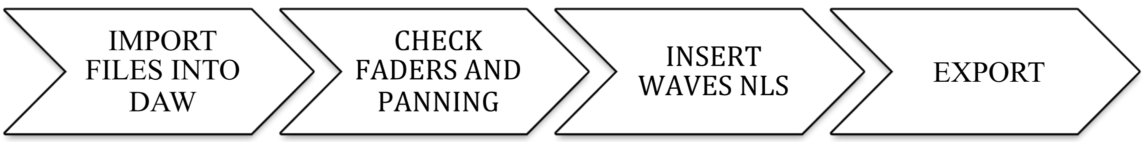


Figure 3.9: Snapshot of Waves NLS settings during digital summing procedures

Panning on all channels was left unchanged and faders were all set to nominal. The mix was then exported using Protools 10 “Bounce to disk” function at 88.2kHz 24bit.

3.3.3 Cubase 5 with Slate Digital VCC

For the third version (Cubase 5 + Slate Digital VCC) of digital summing, audio stems were imported into a new session without changing the original sample rate and bit rate. Slate Virtual Channel was then inserted into every channel. The “Brit 4k” setting was chosen to emulate similar SSL characteristics of the analogue summed sample.

The “Drive” and “Input” functions were left at nominal setting to avoid excessive analogue coloration. Slate Virtual Mixbuss was inserted into the master channel to complete the emulation of an analogue console interaction. The “Drive” function on this plugin was also set at nominal to avoid excessive analogue coloration. Panning on all channels was left unchanged and faders were all set to nominal. The mix was then exported using Cubase 5 “Export” function at 88.2kHz 24bit.

Figure 4.0: Diagram of the digital summing procedures with Slate Digital VCC

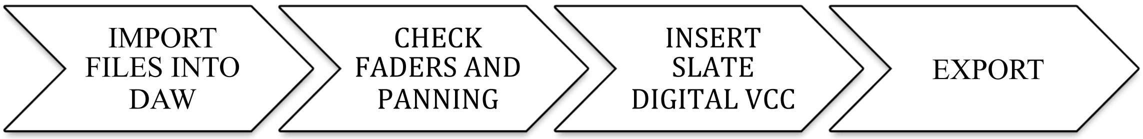


Figure 4.1: Snapshot of Slate Digital VCC settings during digital summing procedures

3.4 Method of Data Collection

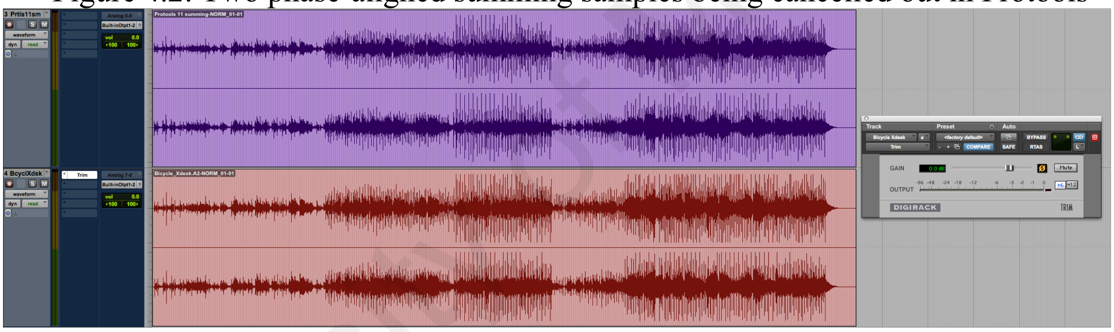
3.4.1 General Analysis

To test whether there were any visual differences, a cross correlation process was performed on the summing samples outcomes. In an email interview, Leonard explains,

> *"We extracted the difference by performing a cross-corrolation in Matlab to find the precise temporal matching point, then subtracted the two DAWs' output. For the visualization, we just plotted the actual waveform. That being said, you could easily do the same thing by phase flipping one example and summing them within a DAW; you'd just have to nudge the audio files to match each other in time (some DAWs introduced a few samples of delay in the final summed output)."*(Leonard, personal communication, December 2, 2014)

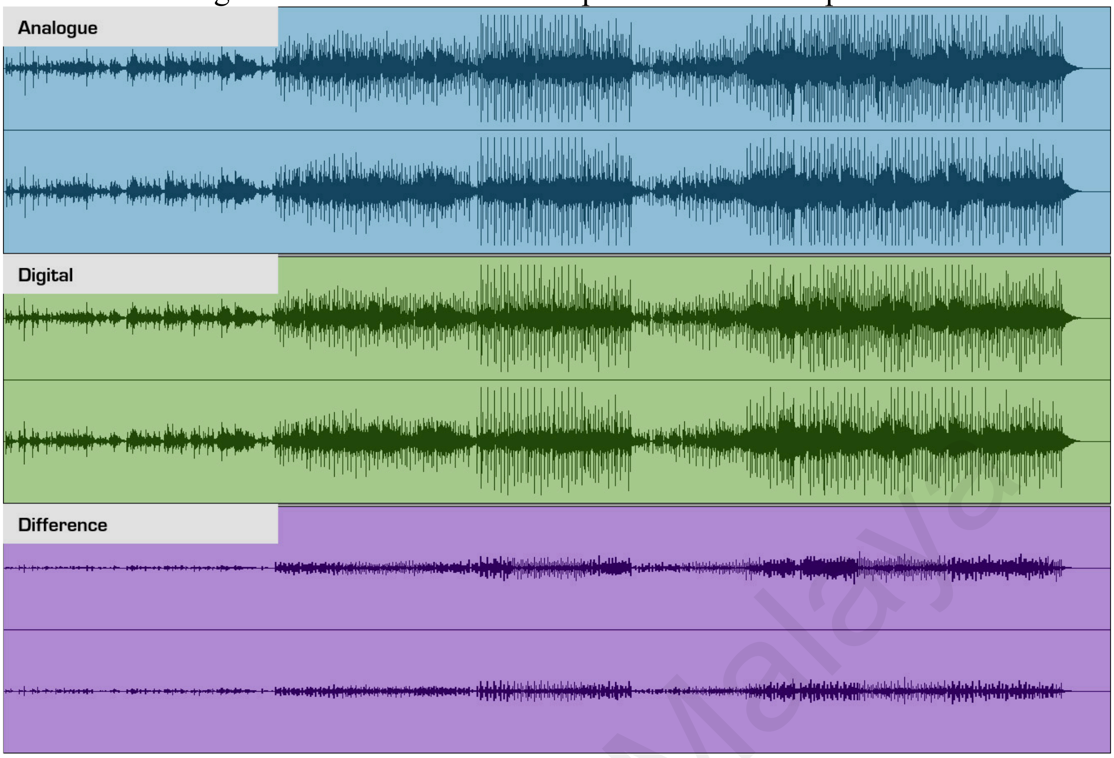
In replicating his recommendations, the summing samples were reimported back into DAW at original sample rate. These samples were then peak normalized and phase aligned against each other. The decision to phase aligned was made based on findings that “different DAWs tend to introduce between one to three samples of delay during summing.”(Leonard, Levine, Buttner-Schnirer, 2012) On top of this, the analogue summing samples was having a longer delay as the sound had to be converted out of its digital form, summed inside an analogue summing mixer and reconverted back into digital form. Phase aligning was done by visually aligning the waveforms at maximum zoom using DAW.

Figure 4.2: Two phase-aligned summing samples being cancelled out in Protools



The difference between analogue summed samples and the three digital summed samples were derived by flipping the phase for all three digital summed samples and summing them against the analogue summed sample. The identical frequencies were then cancelled out leaving only the differences between the analogue summed samples and digital summed samples.

Figure 4.3: The outcome from phase cancellation procedure



3.4.2 Detail Analysis

All 8 stereo audio tracks were imported into Protools to be edited. Sections representing different timbre variations such as harmonic sound, non-harmonic sound, noise and intense dynamic level were identified and marked. The sections were then cut and extracted for all summing variations. Prior to extracting the sections, all the summing variations were phase aligned to make sure that each of the sections was identical in timing. This was to make the process of identifying differences between summing variations easier and more accurate. Each sample was then named using a specific format to avoid confusions. The filename format was set as 'songname_section_summingtechnique'.

Summing samples were then imported into Praat to be analyzed. Praat 5.4.02 (Mac) was chosen, as it was a useful tool for producing spectrograms, spectral slices and measuring frequency peaks. A series of spectograms were drawn to see the differences of frequency intensity between summing variations. Spectograms were drawn for each summing samples according to categories below:

- 0 – 5 kHz (wide band)
- 0 – 10 kHz (wide band)
- 0 – 20 kHz (wide band)
- 0 – 5 kHz (narrow band)
- 0 – 10 kHz (narrow band)
- 0 – 20 kHz (narrow band)

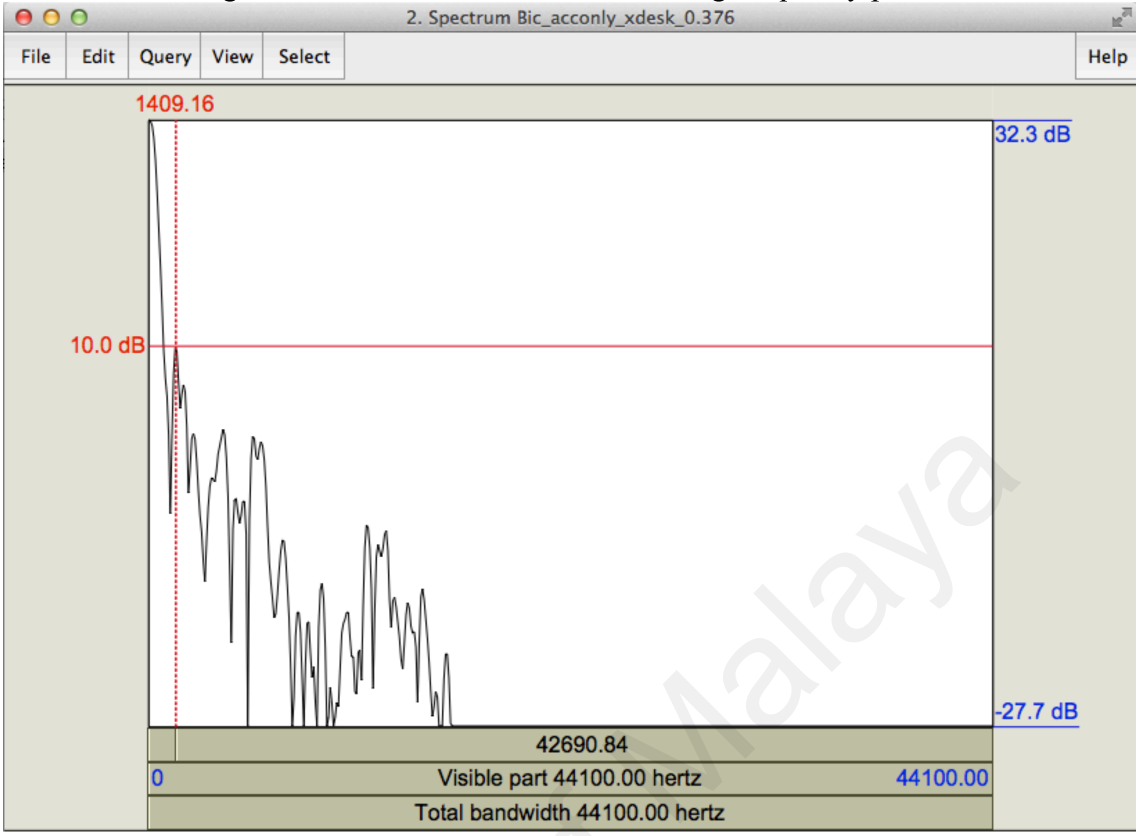
Categories were chosen to view the spectral intensity at three different perspectives using both wide band and narrow band.

A series of FFT graphs were also drawn for each summing samples according to categories below:

- 0 – 5 kHz
- 0 – 10 kHz
- 0 – 22 kHz
- 0 – 44 kHz

Spectral slices were then taken randomly from each of the FFT graphs and precise magnitude of frequency peaks were measured by using Praat's "move cursor to nearest peak" function. Results of the peaks were then compared and contrast between the analogue summing samples and digital summing sample.

Figure 4.4: The use of Praat in measuring frequency peaks



CHAPTER 4 RESULTS

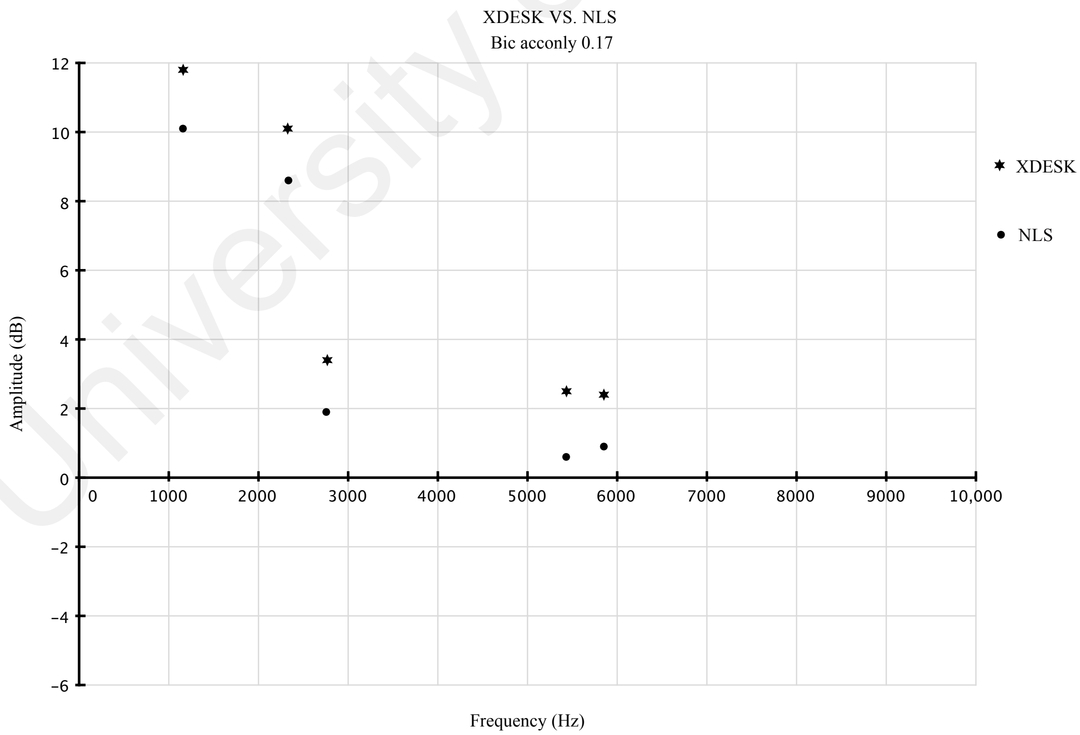
4. Results

4.1 Phase Cancelling Method

Results from phase cancelling analogue summing samples with the three variations of digital summing samples have shown that spectral differences were evidently clear. From the three digital summing samples, DAW + Waves NLS have shown the smallest difference against analogue summing while DAW + Slate VCC had the biggest difference.

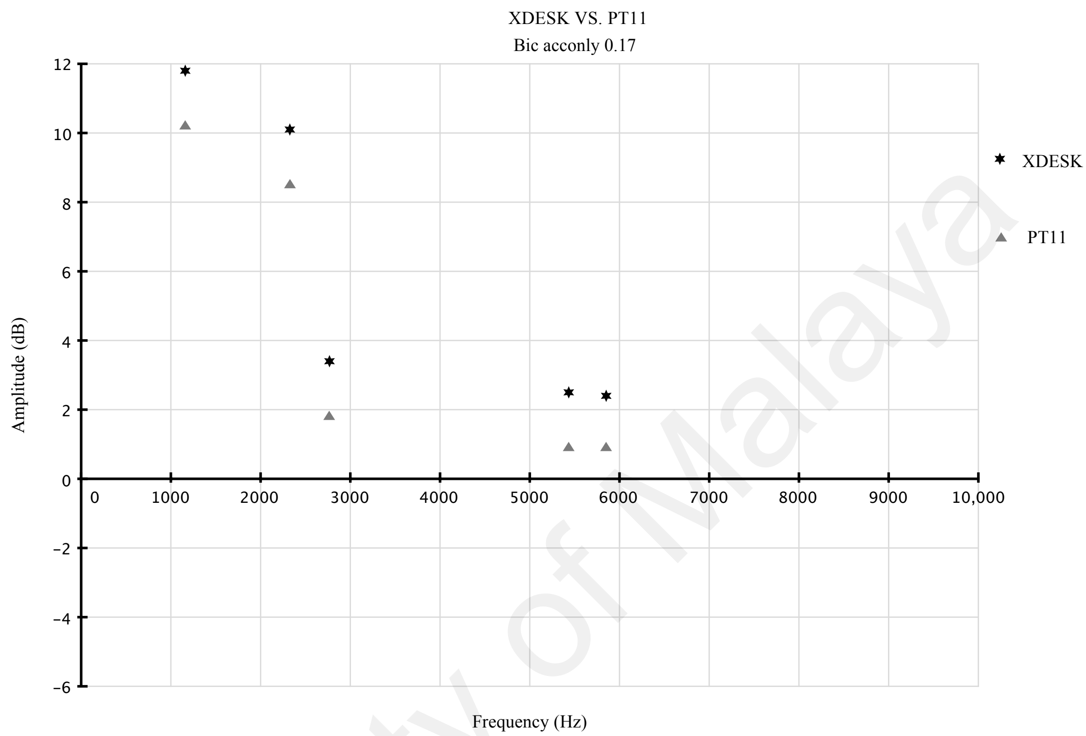
4.2 Detailed Spectral Analysis

Graph 1: Comparison of SSL Xdesk and Waves NLS (Acoustic Guitar)



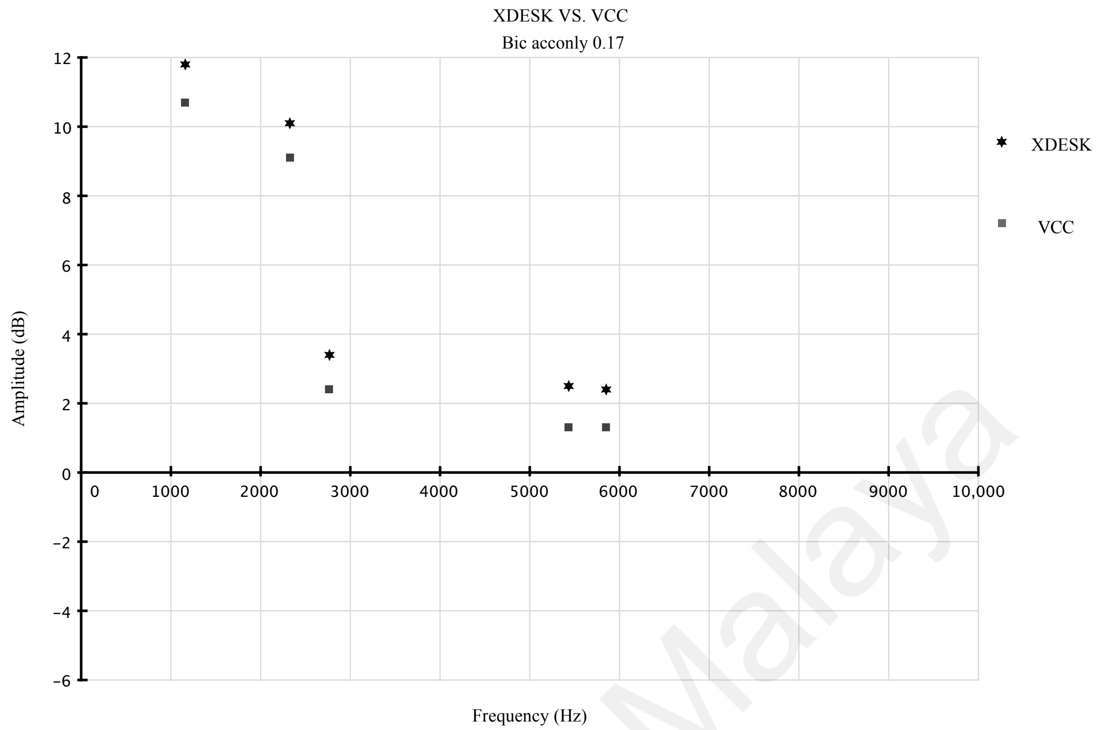
Graph 1 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for acoustic guitar. The biggest peak amplitude gap is registered at around 5400Hz with 1.9dB. The smallest peak amplitude gap is registered at three points at 2300Hz, 2800Hz and 5900Hz with 1.5dB.

Graph 2: Comparison of SSL Xdesk and Protools 11 (Acoustic Guitar)



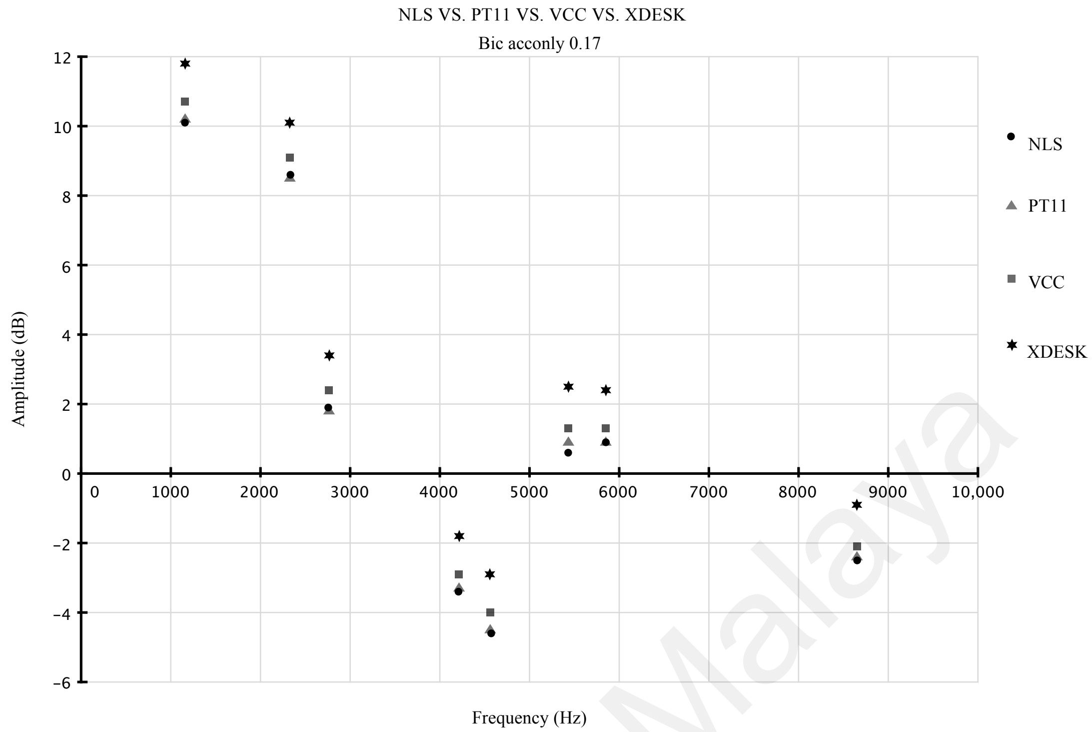
Graph 2 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for acoustic guitar. The biggest peak amplitude gap is registered at four points at around 1200Hz, 2300Hz, 2800Hz and 5400Hz with 1.6dB. The smallest peak amplitude gap is registered at 5900Hz with 1.5dB.

Graph 3: Comparison of SSL Xdesk and Slate Digital VCC (Acoustic Guitar)



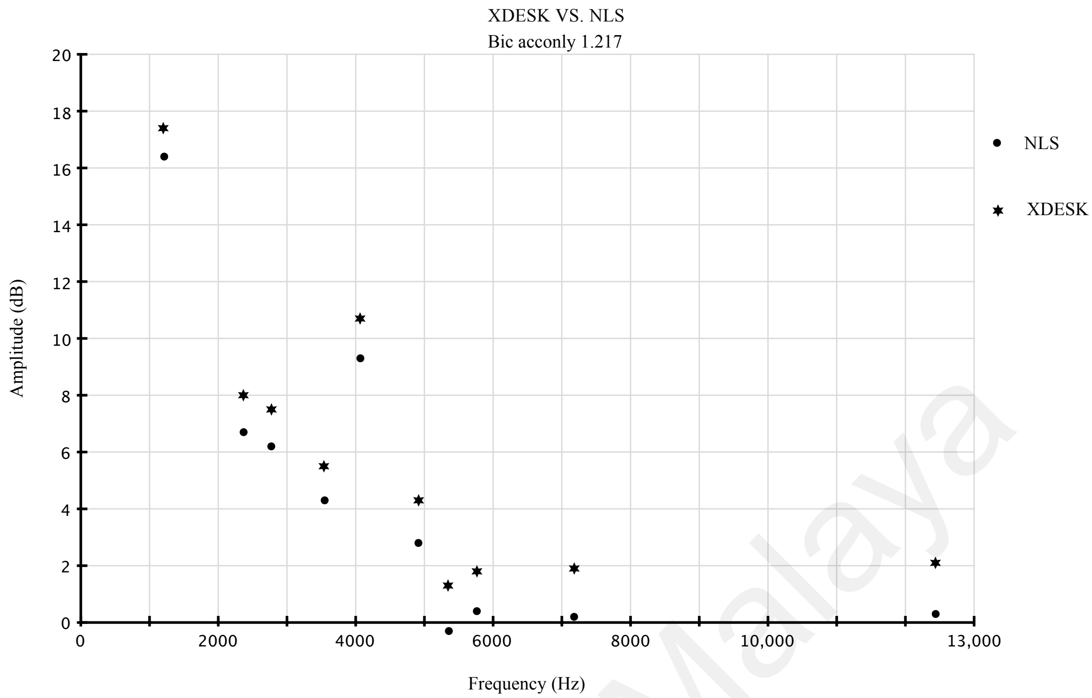
Graph 3 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for acoustic guitar. The biggest peak amplitude gaps are registered at around 5400Hz with 1.2dB. The smallest peak amplitude gap is registered at two points at 2300Hz and 2800Hz with 1dB.

Graph 4: Comparison of SSL Xdesk and All other (Acoustic Guitar)



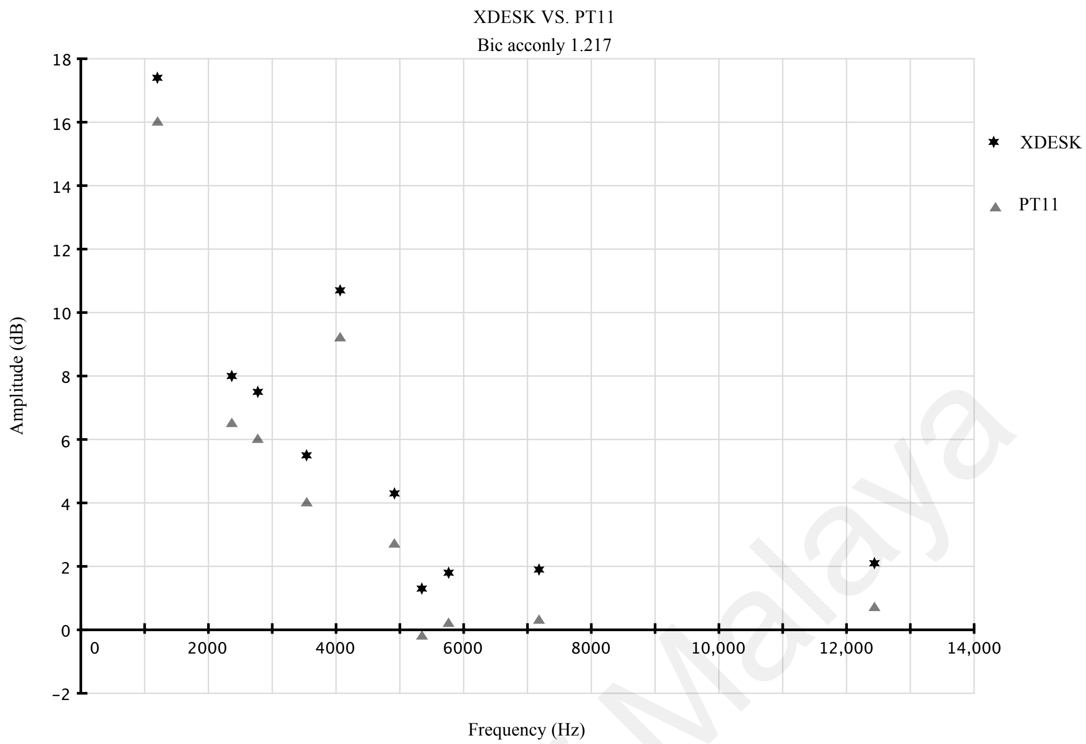
Graph 4 shows the peak amplitude comparison of the Xdesk summed sample and all of the other summed samples for acoustic guitar. The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with biggest differences in the upper midrange frequencies. The Protools 11 sample however registered its biggest differences in both the lower and upper midrange frequencies. The smallest amplitude gap differences for Waves NLS and Slate Digital VCC are registered at both lower and upper midrange whilst Protools 11 only at higher midrange. Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 5: Comparison of SSL Xdesk and Waves NLS (Acoustic Guitar 2)



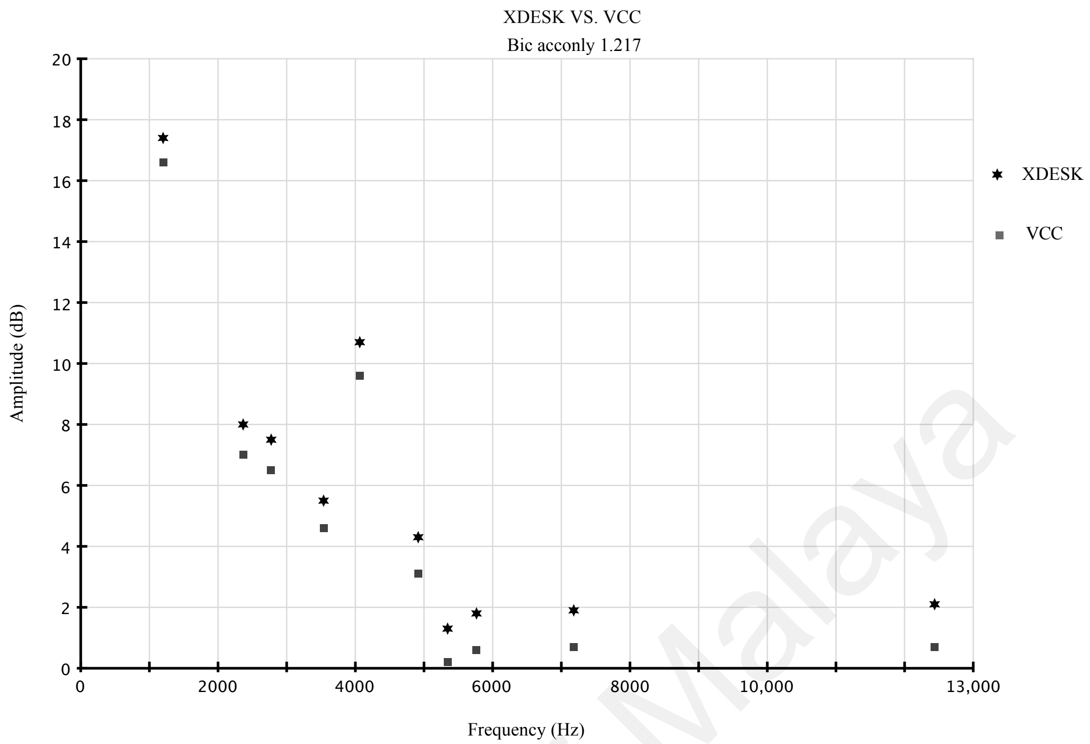
Graph 5 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for acoustic guitar 2. The biggest peak amplitude gap is registered at around 12400Hz with 1.8dB. The smallest peak amplitude gap is registered at around 1200Hz with 1dB of difference.

Graph 6: Comparison of SSL Xdesk and Protools 11 (Acoustic Guitar 2)



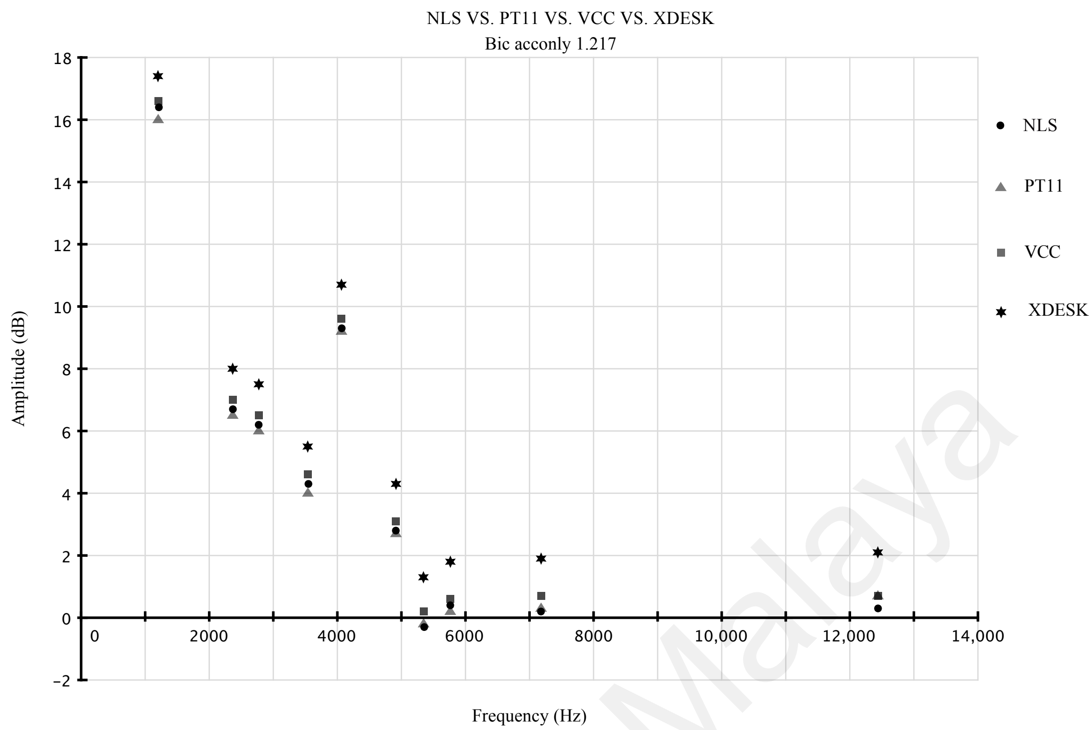
Graph 6 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for acoustic guitar 2. The biggest peak amplitude gap is registered at three points, 5000Hz, 5800Hz and 7200Hz with 1.6dB. The smallest peak amplitude gap is registered at two points, 1200Hz and 12400Hz with 1.4dB.

Graph 7: Comparison of SSL Xdesk and Slate Digital VCC (Acoustic Guitar 2)



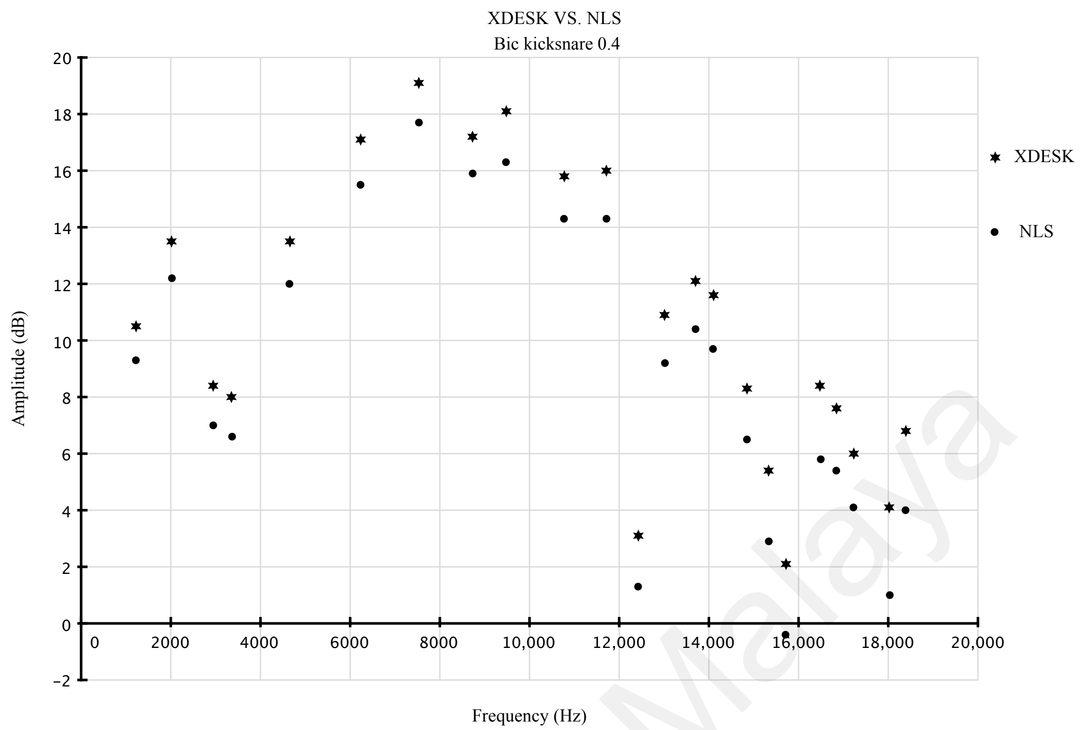
Graph 7 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for acoustic guitar 2. The biggest peak amplitude gap is registered at 12400Hz with 1.4dB. The smallest peak amplitude gap is registered at 1200Hz with 0.8dB.

Graph 8: Comparison of SSL Xdesk and All other (Acoustic Guitar 2)



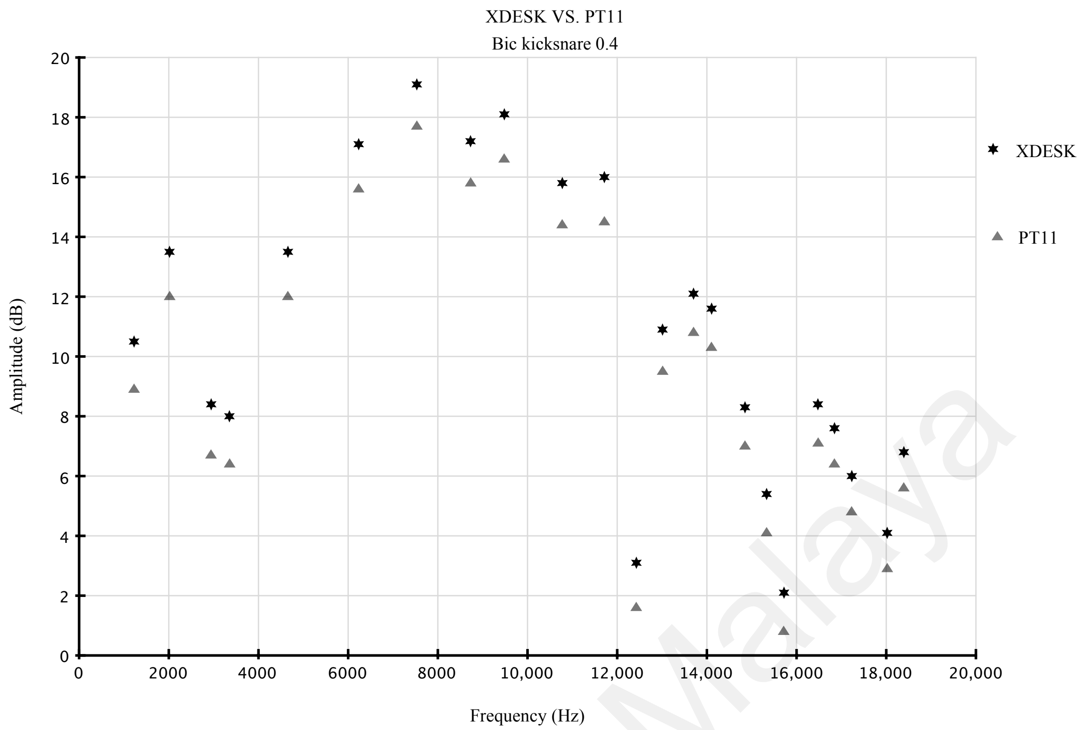
Graph 8 shows the peak amplitude comparison of the Xdesk summed sample and all of the other summed samples for acoustic guitar 2. The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with biggest differences in the high frequencies. The Protools 11 sample however registered its biggest differences in both the upper midrange and high frequencies. The smallest amplitude gap differences for Waves NLS and Slate Digital VCC are registered at lower midrange whilst Protools 11 at lower midrange and high frequencies. Generally, the amplitude differences between Xdesk and Protools 11 samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 9: Comparison of SSL Xdesk and Waves NLS (Drums)



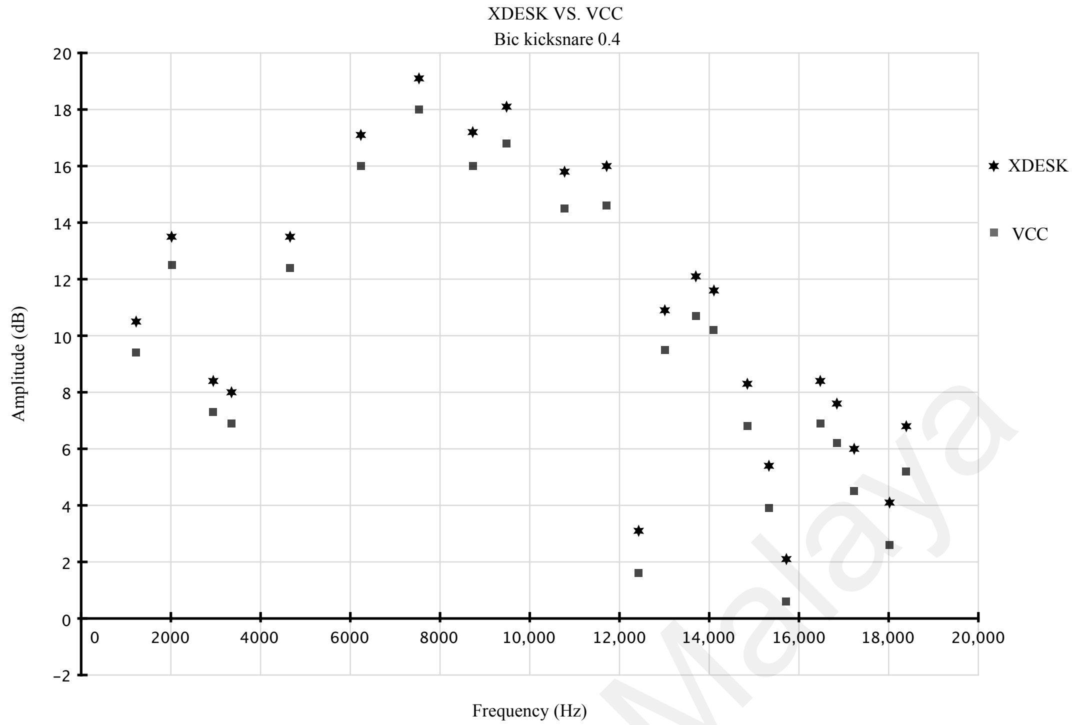
Graph 9 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for drums. The biggest peak amplitude gap is registered at around 18000Hz with 3.1dB. The smallest peak amplitude gap is registered at around 1200Hz with 1.2dB.

Graph 10: Comparison of SSL Xdesk and Protools 11 (Drums)



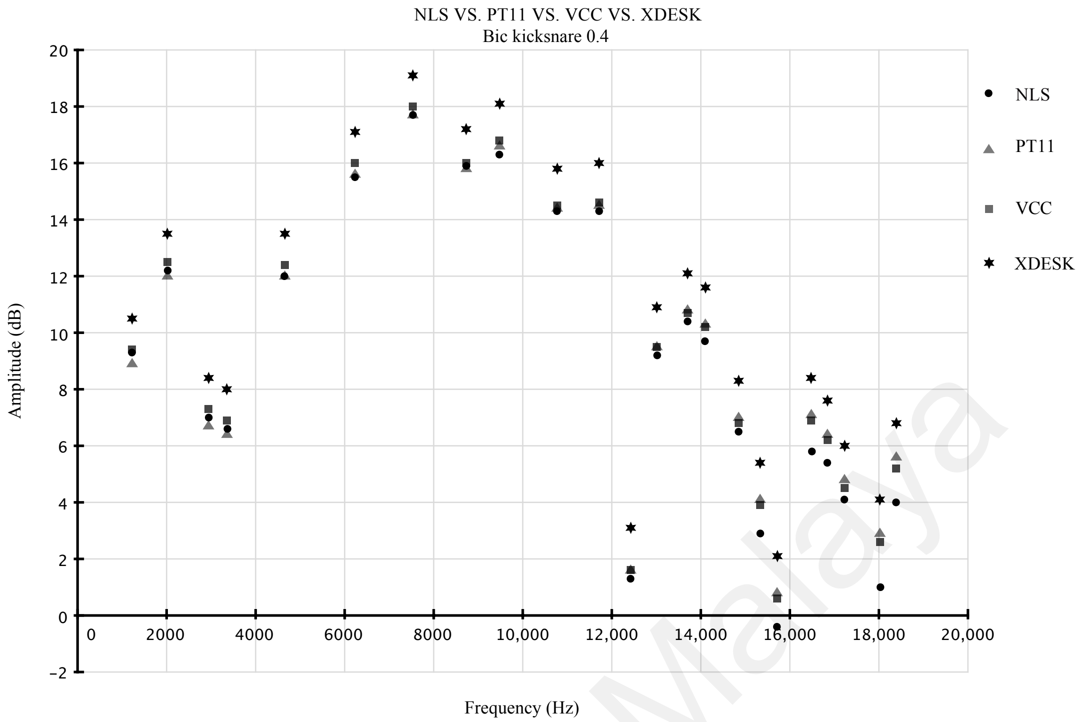
Graph 10 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for drums. The biggest peak amplitude gap is registered at around 3000Hz with 1.7dB. The smallest peak amplitude gap is registered at four points at around 16800Hz, 17200Hz, 18000Hz and 18400Hz with 1.2dB.

Graph 11: Comparison of SSL Xdesk and Slate Digital VCC (Drums)



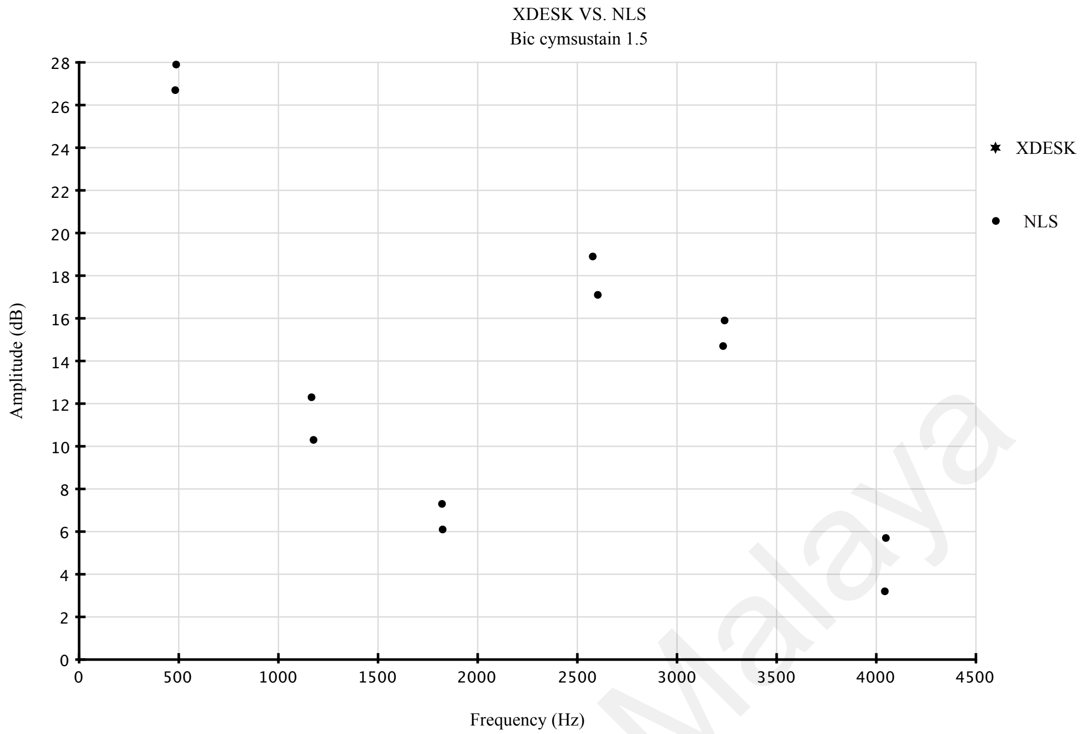
Graph 11 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for drums. The biggest peak amplitude gap is registered at around 18400Hz with 1.6dB. The smallest peak amplitude gap is registered at around 2000Hz with 1dB.

Graph 12: Comparison of SSL Xdesk and All other (Drums)



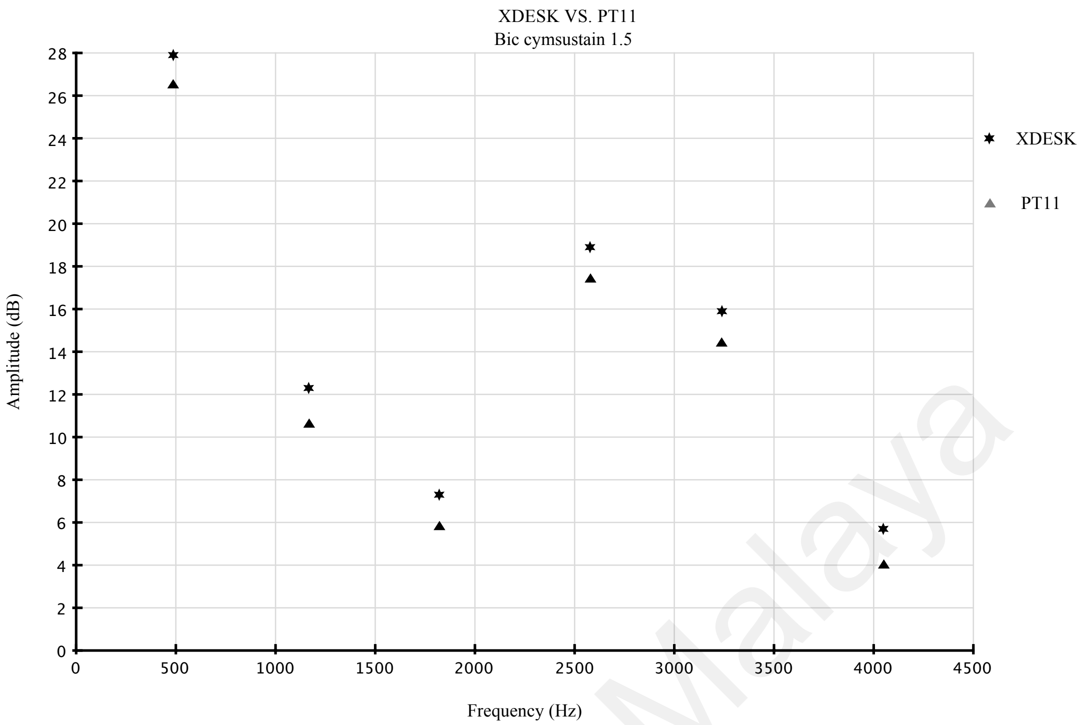
Graph 12 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for drums. The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with smaller differences in the lower midrange frequencies and bigger differences in the high frequencies. The opposite can be observed on Xdesk vs Protools 11 where the upper midrange frequencies are showing the biggest differences and high frequencies showing smallest. Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 13: Comparison of SSL Xdesk and Waves NLS (Cymbals)



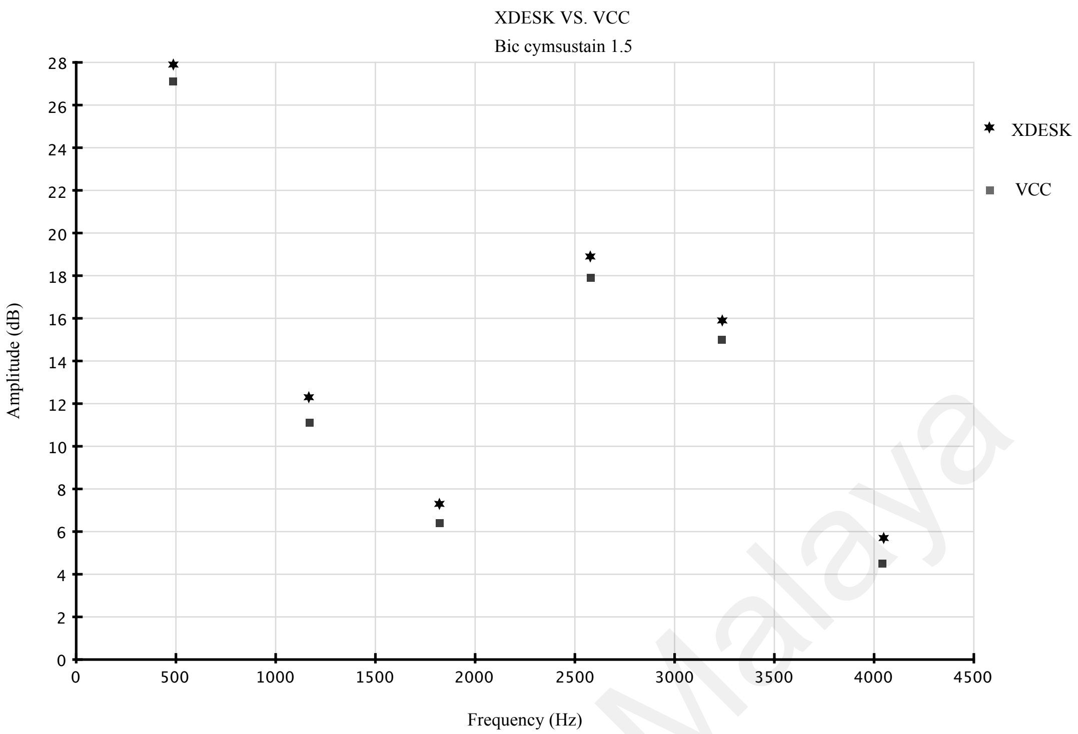
Graph 13 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for cymbals. The biggest peak amplitude gap is registered at around 4000Hz with 2.5dB. The smallest peak amplitude gap is registered at three points at around 500Hz, 1800Hz and 3200Hz with 1dB.

Graph 14: Comparison of SSL Xdesk and Protools 11 (Cymbals)



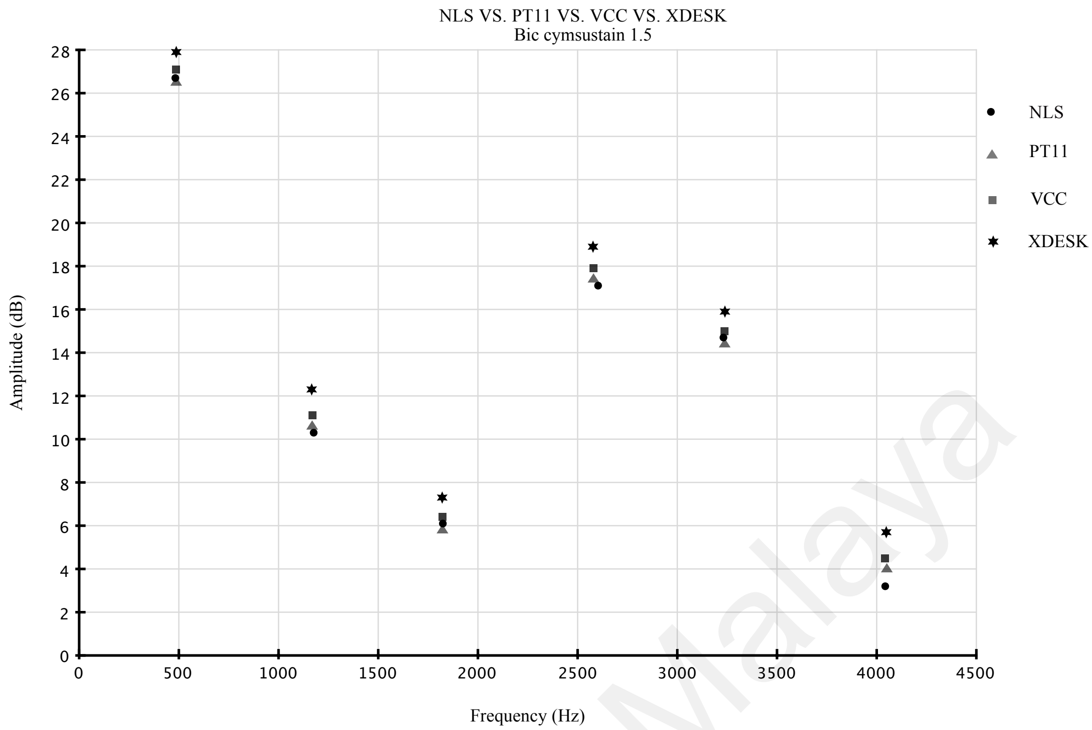
Graph 14 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for cymbals. The biggest peak amplitude gap is registered at two points at around 1200Hz and 4000Hz with 1.7dB. The smallest peak amplitude gap is registered at around 500Hz with 1.4dB.

Graph 15: Comparison of SSL Xdesk and Slate Digital VCC (Cymbals)



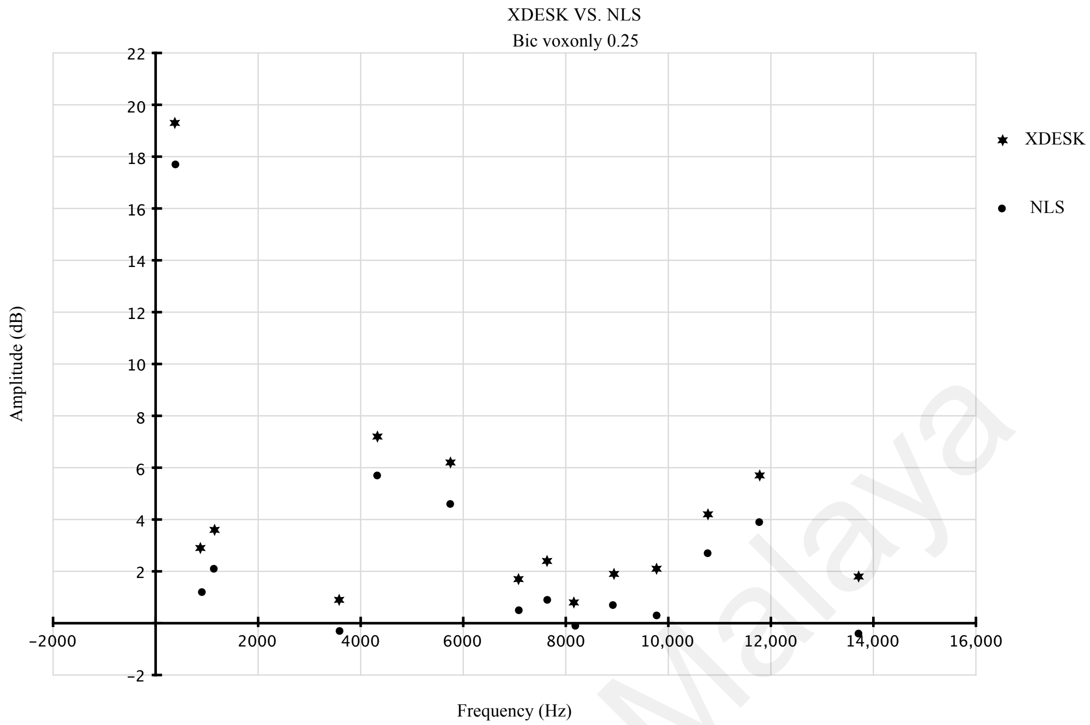
Graph 15 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for cymbals. The biggest peak amplitude gap is registered at around 1200Hz and 4000Hz with 1.2dB. The smallest peak amplitude gap is registered at around 500Hz with 0.8dB.

Graph 16: Comparison of SSL Xdesk and All other (Cymbals)



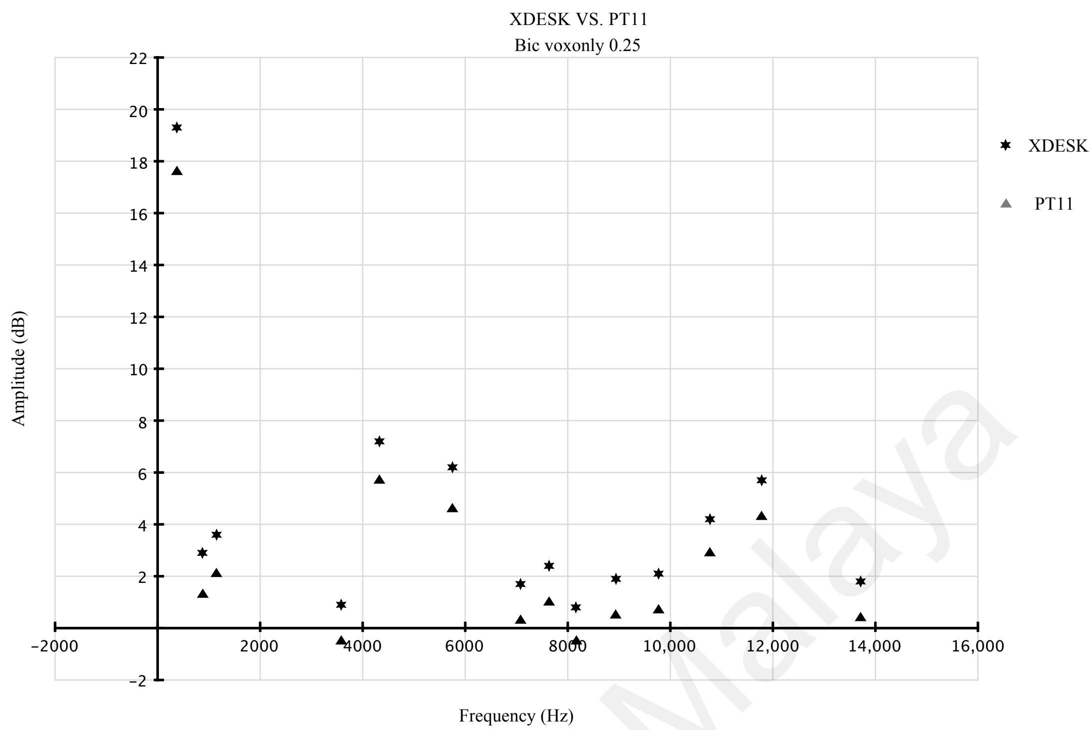
Graph 16 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for cymbals. Generally all peaks are showing a similar amplitude gap pattern except at around 4000Hz where the gap between Xdesk and Waves NLS sample is significantly wider. The amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 17: Comparison of SSL Xdesk and Waves NLS (Vocal)



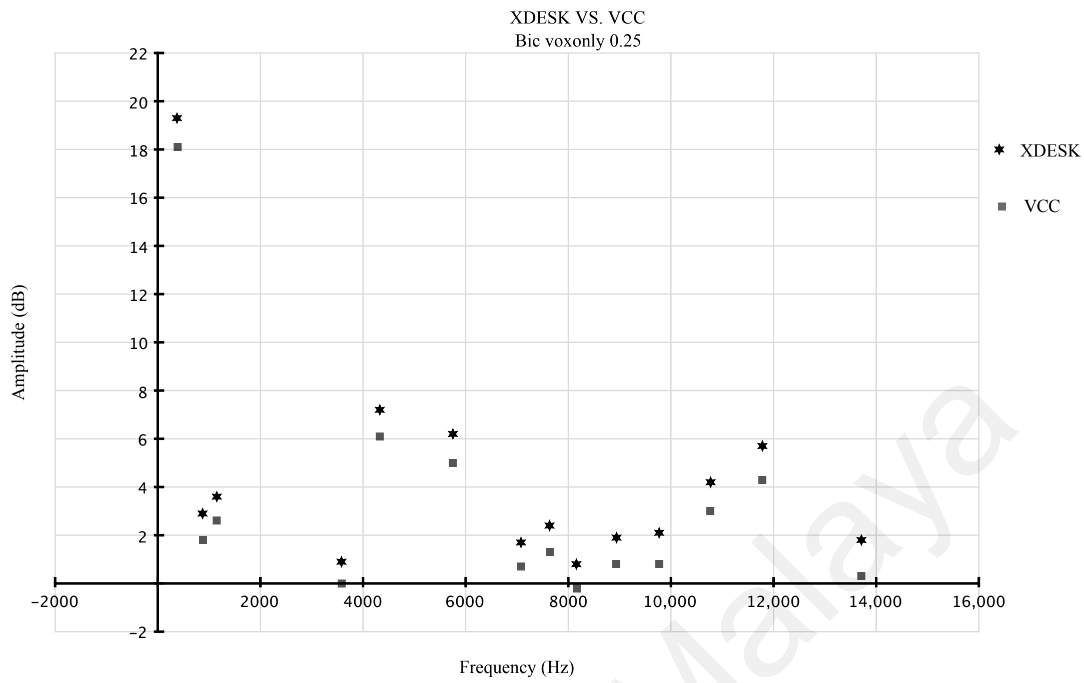
Graph 17 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for vocal. The biggest peak amplitude gap is registered at around 13700Hz with 2.2dB. The smallest peak amplitude gap is registered at around 8200Hz with 0.9dB.

Graph 18: Comparison of SSL Xdesk and Protools 11 (Vocal)



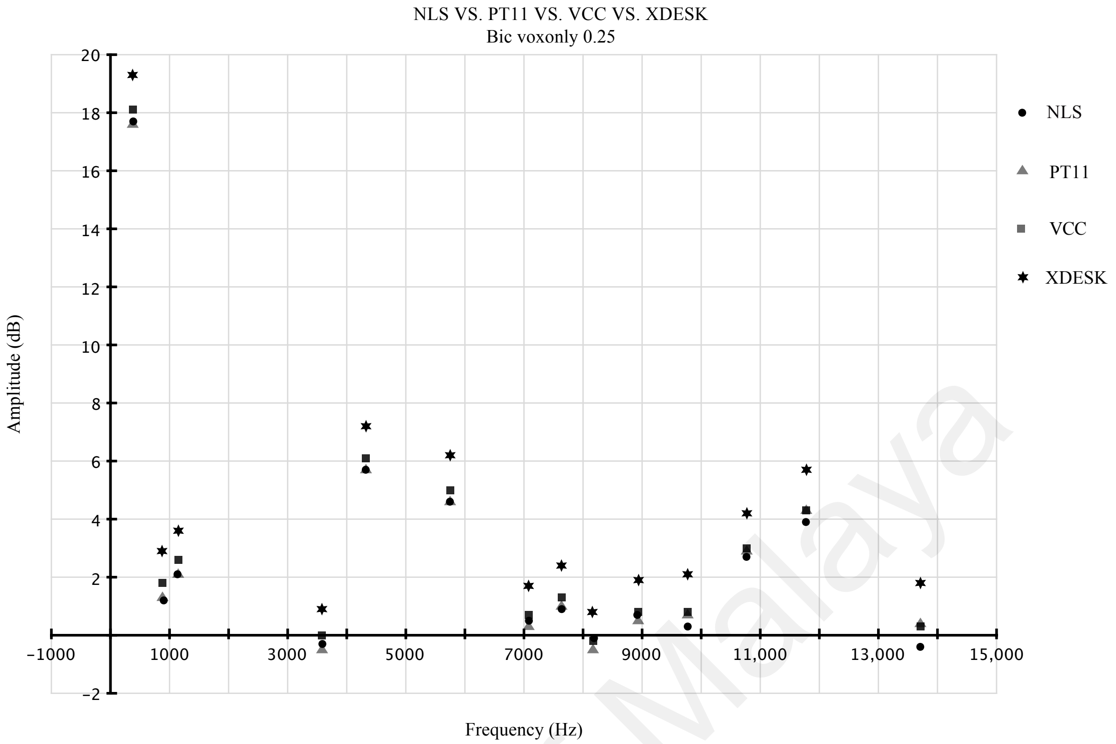
Graph 18 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for vocal. The biggest peak amplitude gap is registered at around 400Hz with 1.7dB. The smallest peak amplitude gap is registered at around 8200Hz and 10800 with 1.3dB.

Graph 19: Comparison of SSL Xdesk and Slate Digital VCC (Vocal)



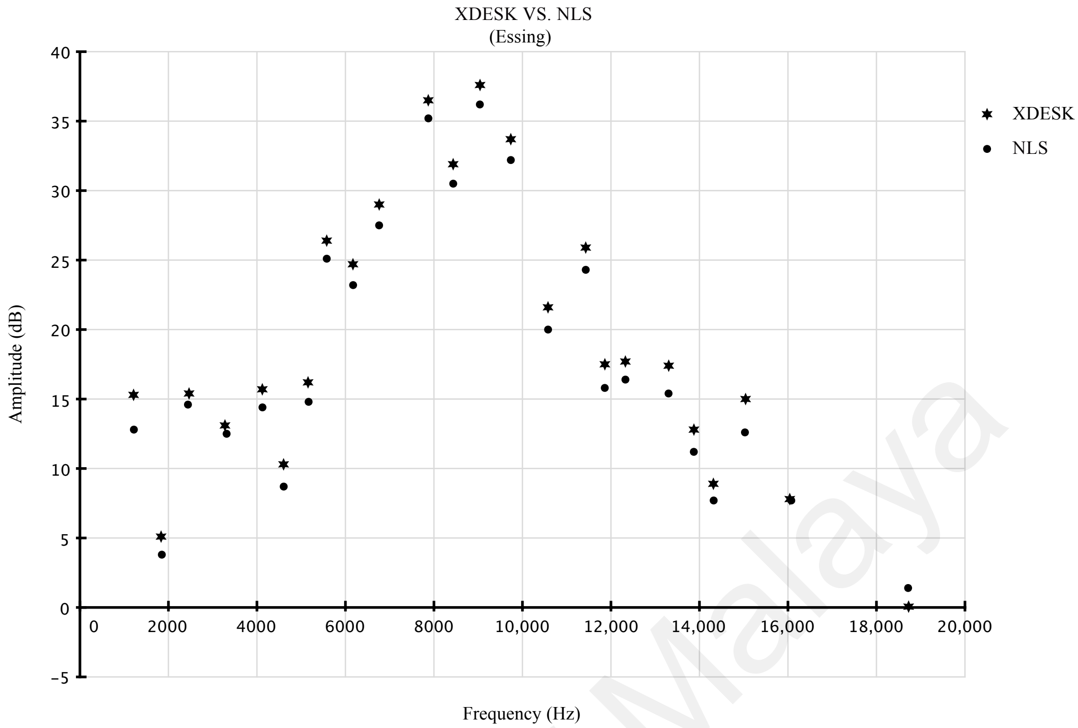
Graph 19 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for vocal. The biggest peak amplitude gap is registered at around 13700Hz with 1.5dB. The smallest peak amplitude gap is registered at around 3600Hz with 0.9dB.

Graph 20: Comparison of SSL Xdesk and All other (Vocal)



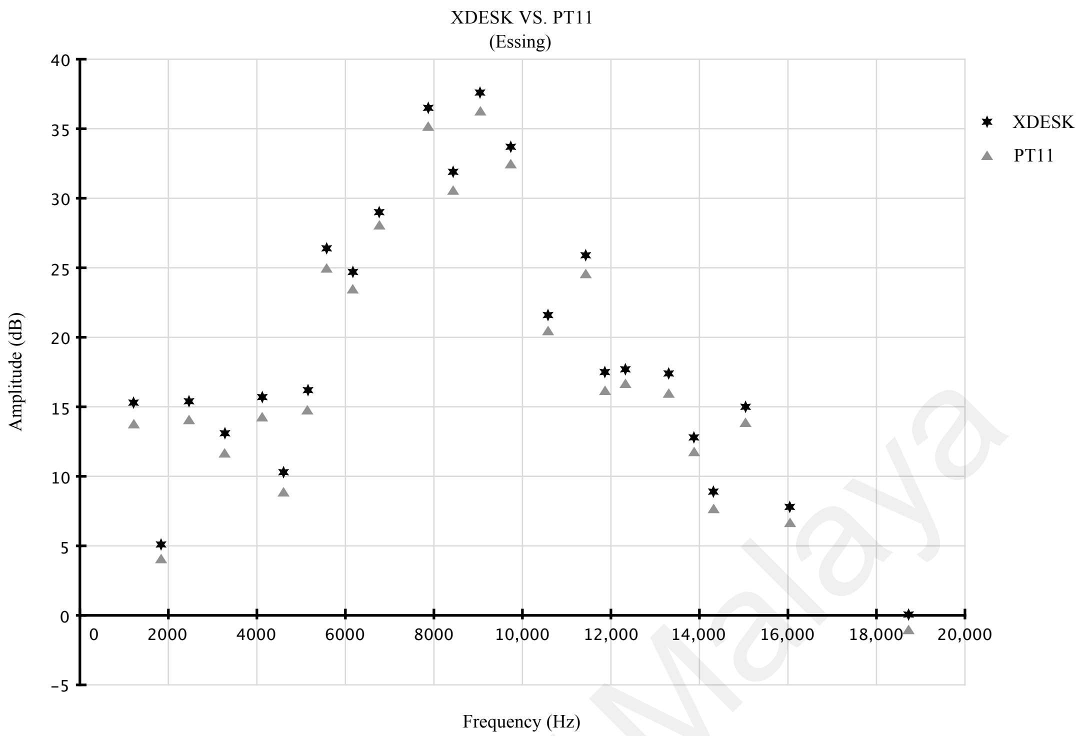
Graph 20 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for vocal. The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with biggest differences in the high frequencies. The opposite can be observed on Xdesk vs Protools 11 where the lower midrange frequencies are showing the biggest differences. Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 21: Comparison of SSL Xdesk and Waves NLS (Vocal Essing) – Song 2



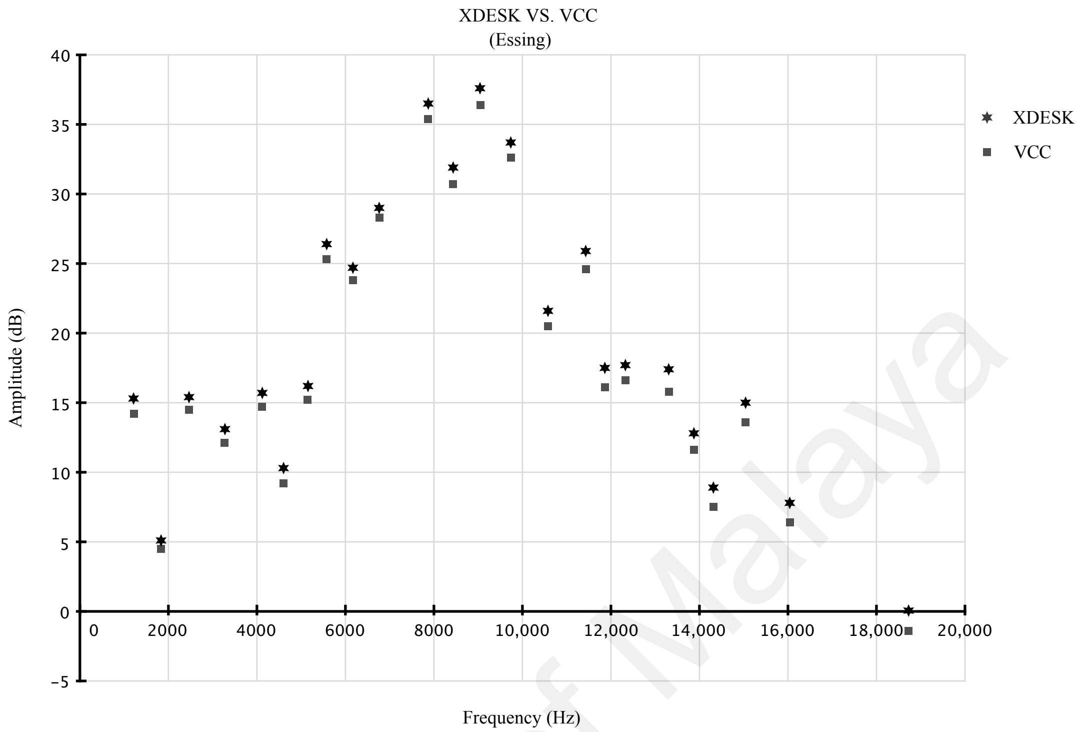
Graph 21 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for vocal essing (Song 2). The biggest peak amplitude gap is registered at around 1200Hz with 2.5dB. The smallest peak amplitude gap is registered at around 16000Hz with 0.1dB. The Waves NLS samples registered one louder peak than the Xdesk at 18700Hz.

Graph 22: Comparison of SSL Xdesk and Protools 11 (Vocal Essing) – Song 2



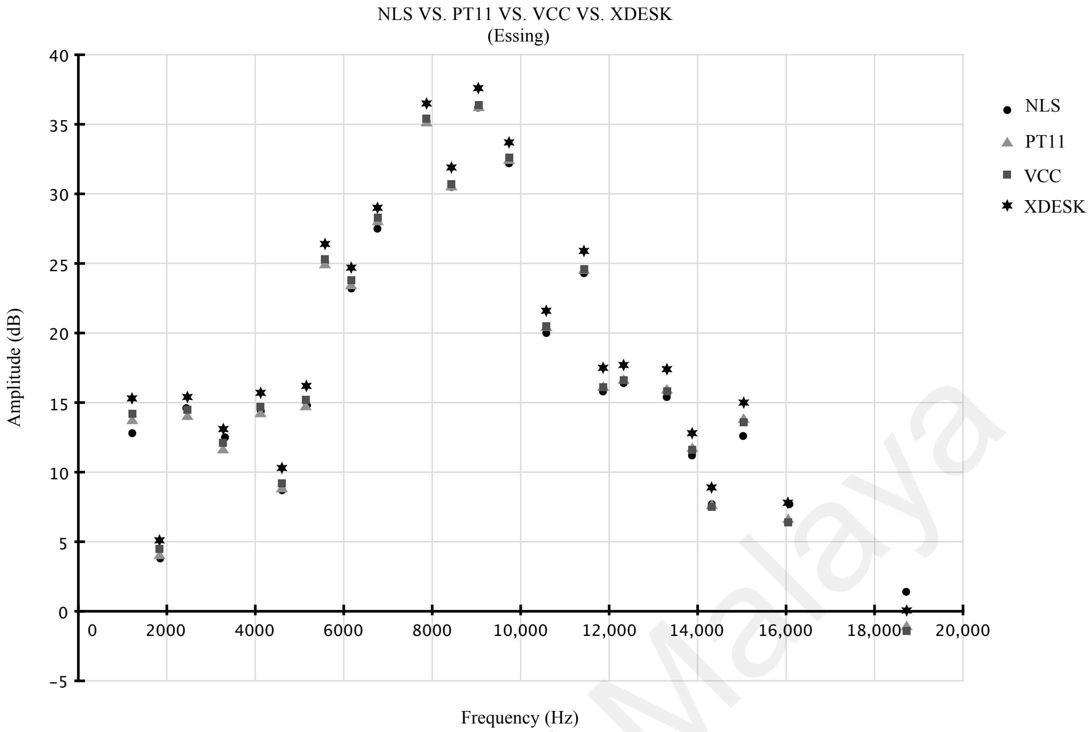
Graph 22 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for vocal essing (Song 2). The biggest peak amplitude gap is registered at around 1200Hz with 1.6dB. The smallest peak amplitude gap is registered at around 6800Hz with 1dB.

Graph 23: Comparison of SSL Xdesk and Slate Digital VCC (Vocal Essing) – Song 2



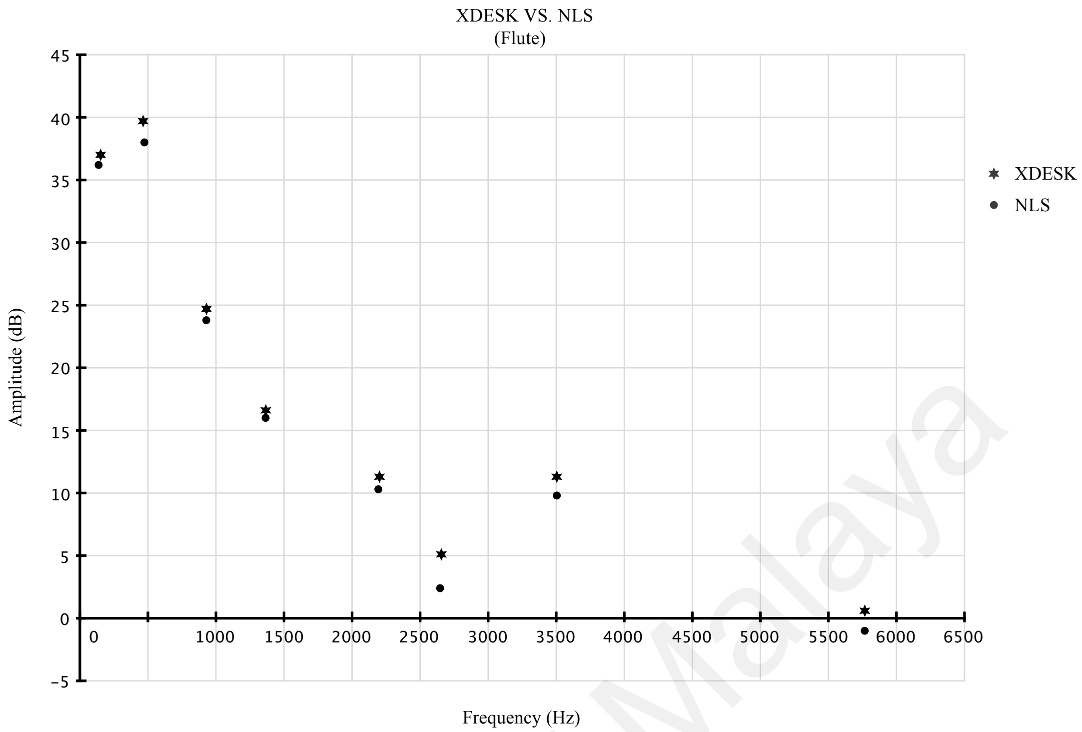
Graph 23 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for vocal essing (Song 2). The biggest peak amplitude gap is registered at around 13300Hz with 1.6dB. The smallest peak amplitude gap is registered at around 1800Hz with 0.6dB.

Graph 24: Comparison of SSL Xdesk and All other (Vocal Essing) – Song 2



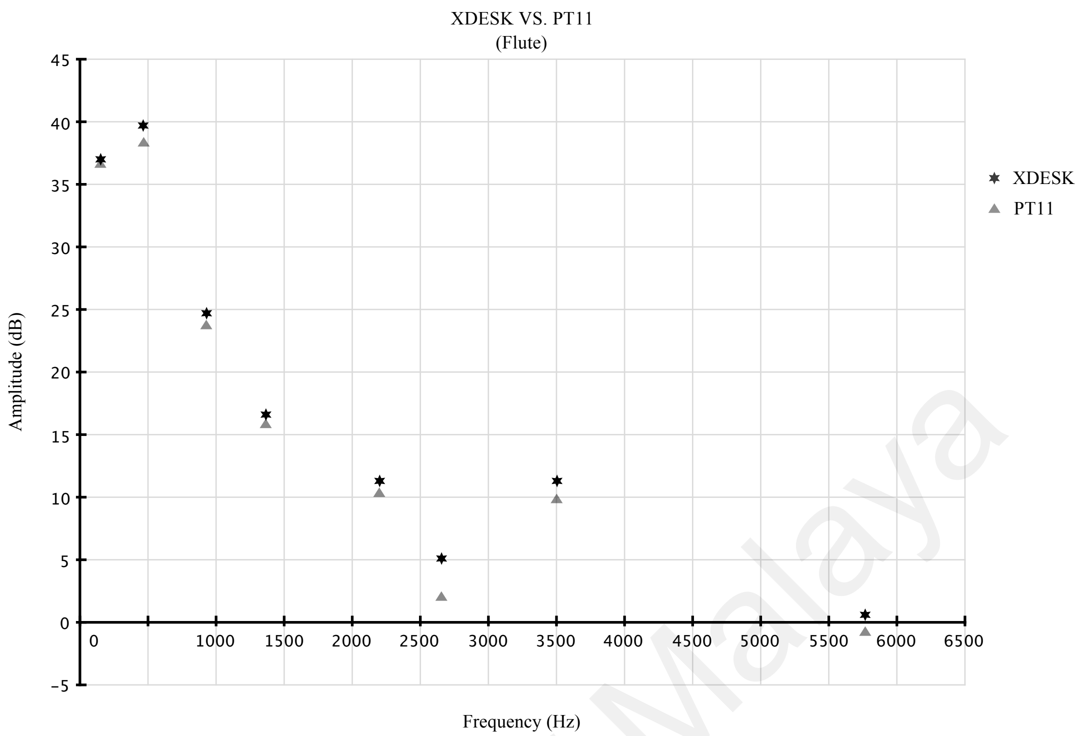
Graph 20 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for vocal essing (Song 2). The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Protools 11 with biggest differences in the lower midrange frequencies and smallest differences at high frequencies. The opposite can be observed on Xdesk vs Slate Digital VCC where the high frequencies are showing the biggest differences and lower midrange frequencies the smallest. Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 25: Comparison of SSL Xdesk and Waves NLS (Flute) – Song 2



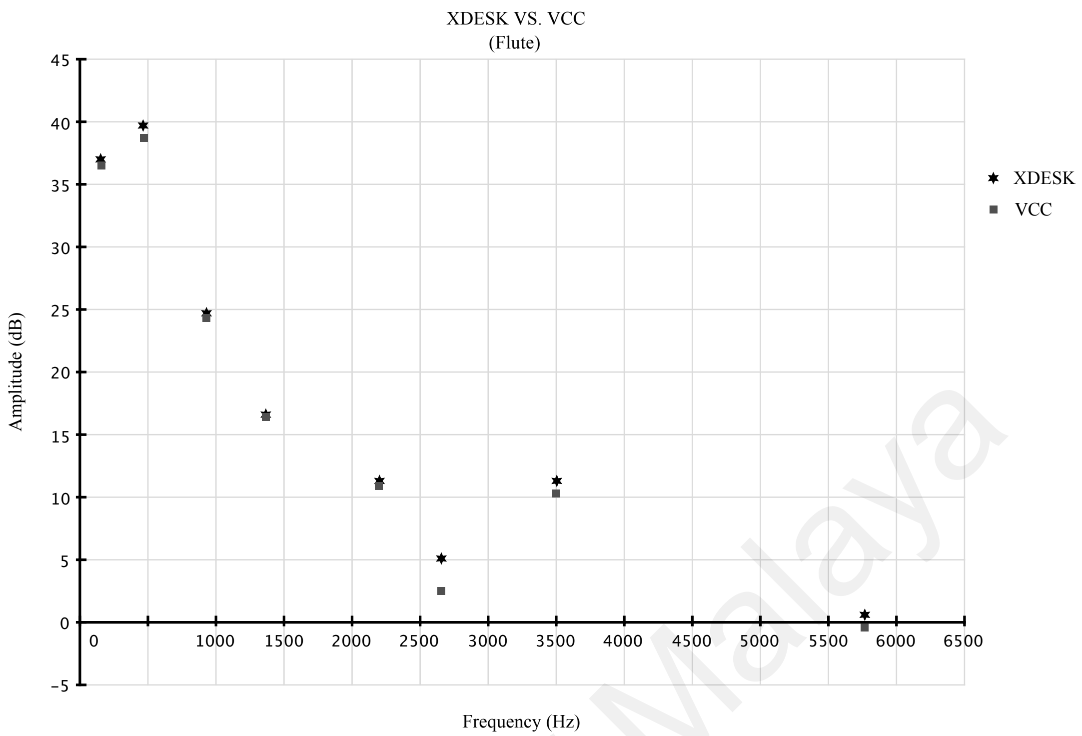
Graph 25 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for flute (Song 2). The biggest peak amplitude gap is registered at around 2700Hz with 2.7dB. The smallest peak amplitude gap is registered at around 1400Hz with 0.6dB.

Graph 26: Comparison of SSL Xdesk and Protools 11 (Flute) – Song 2



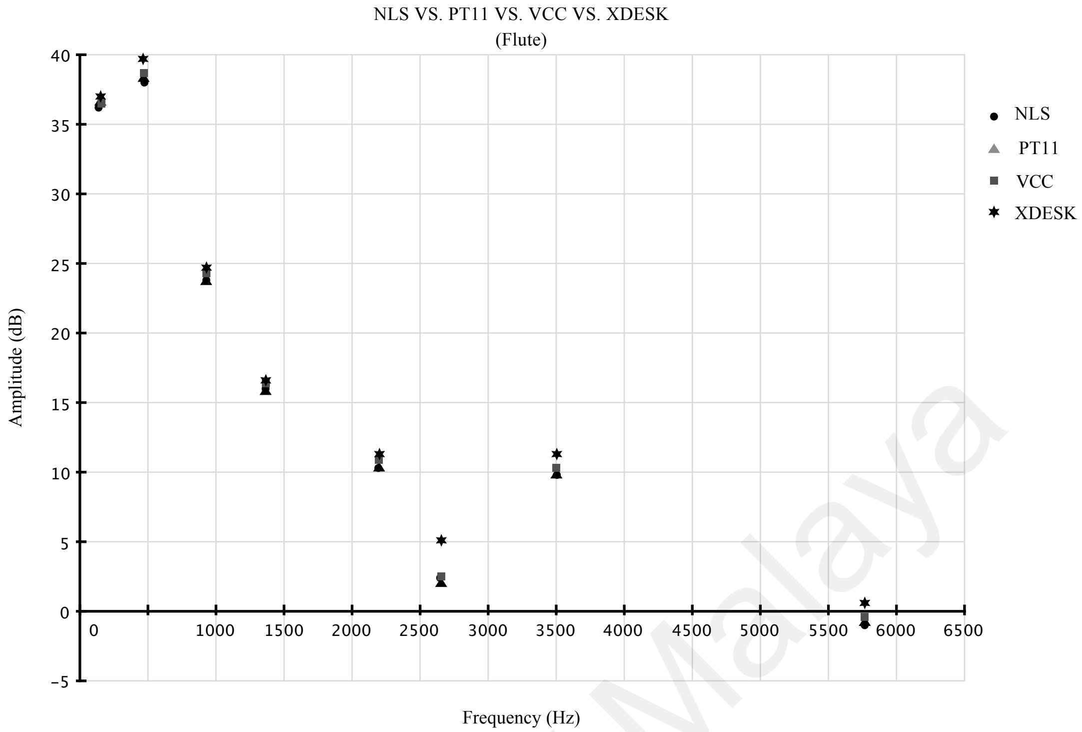
Graph 26 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for flute (Song 2). The biggest peak amplitude gap is registered at around 2700Hz with 3.1dB. The smallest peak amplitude gap is registered at around 150Hz with 0.4dB.

Graph 27: Comparison of SSL Xdesk and Slate Digital VCC (Flute) – Song 2



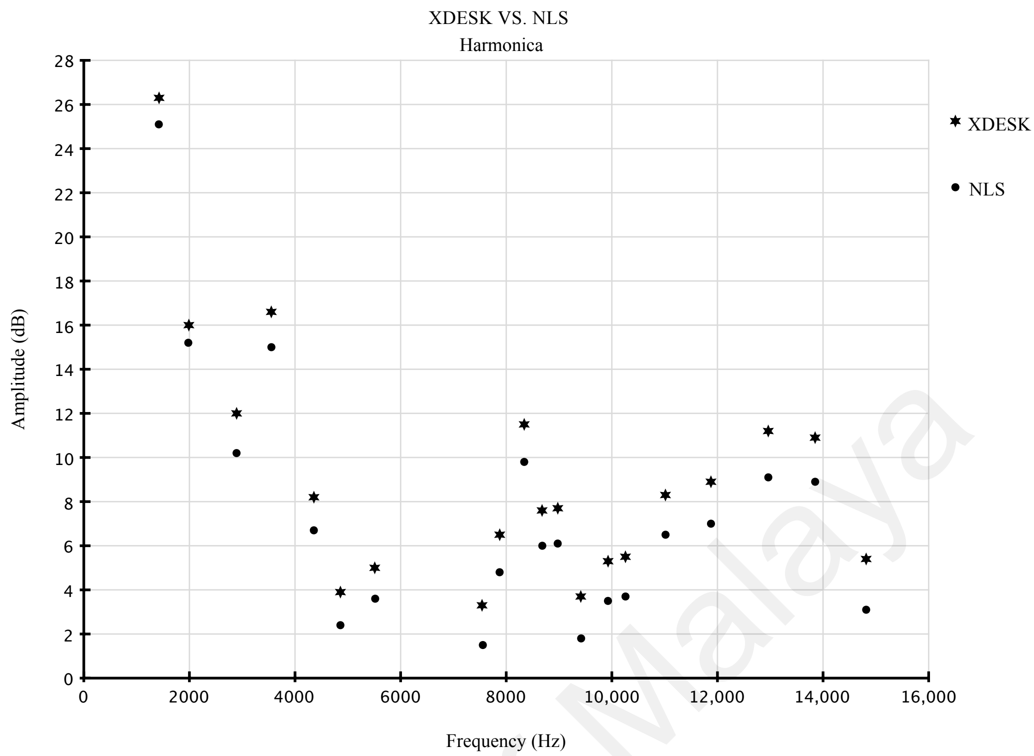
Graph 27 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for flute (Song 2). The biggest peak amplitude gap is registered at around 2700Hz with 2.6dB. The smallest peak amplitude gap is registered at around 1400Hz with 0.2dB.

Graph 28: Comparison of SSL Xdesk and All other (Flute) – Song 2



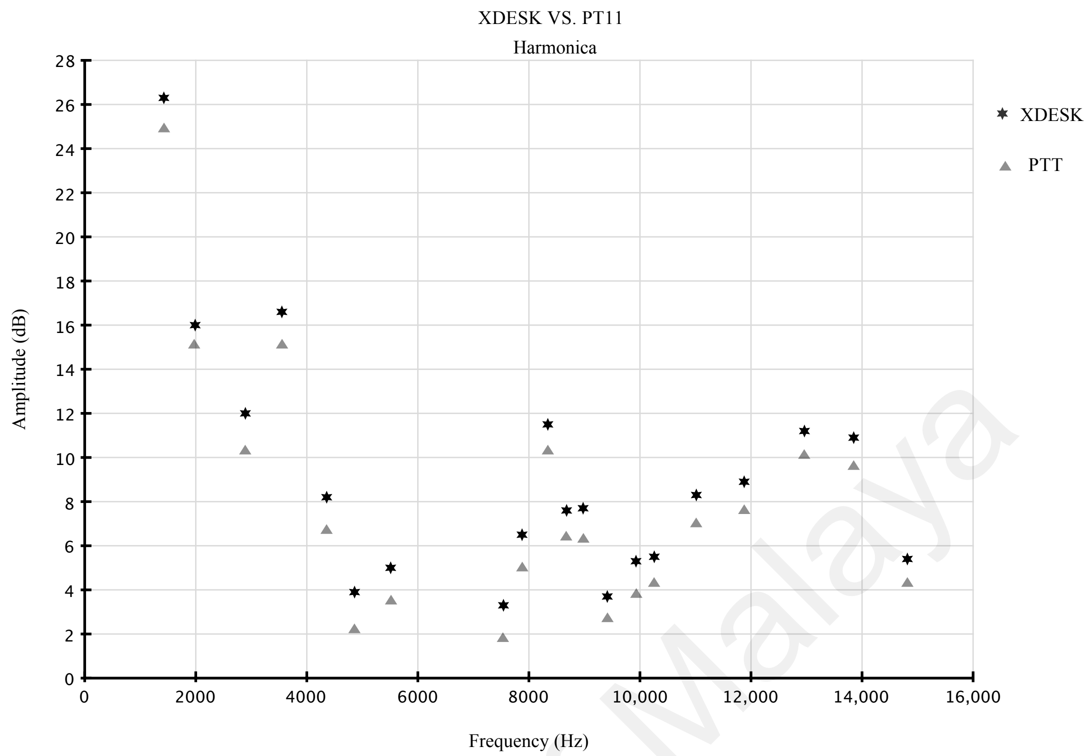
Graph 28 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for flute (Song 2). The pattern for peak amplitude differences is similar across all three with biggest differences registered at 2700Hz (upper midrange). Both Waves NLS and Slate Digital VCC registered their smallest gap at 1400Hz (lower midrange) whilst Protools 11 at 150Hz (bass). Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 29: Comparison of SSL Xdesk and Waves NLS (Harmonica) – Song 2



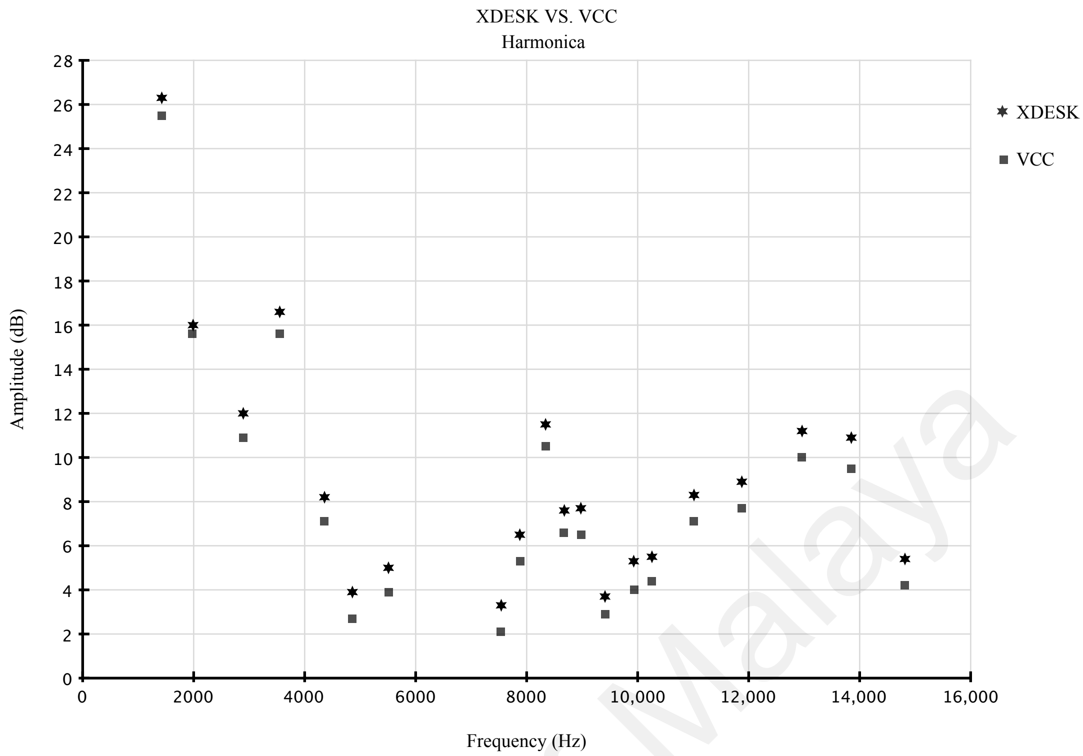
Graph 29 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for harmonica (Song 2). The biggest peak amplitude gap is registered at around 14800Hz with 3.1dB. The smallest peak amplitude gap is registered at around 2000Hz with 0.8dB.

Graph 30: Comparison of SSL Xdesk and Protools 11 (Harmonica) – Song 2



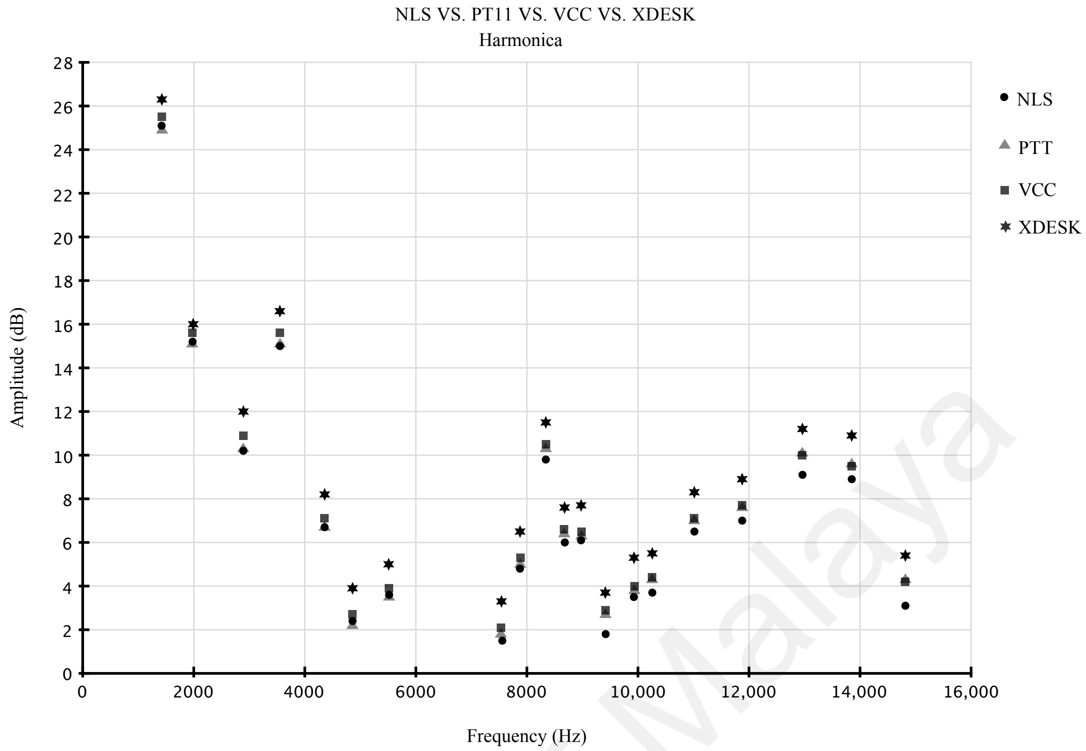
Graph 30 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for harmonica (Song 2). The biggest peak amplitude gap is registered at around 2900Hz and 4900Hz with 1.7dB. The smallest peak amplitude gap is registered at around 2000Hz with 0.9dB.

Graph 31: Comparison of SSL Xdesk and Slate Digital VCC (Harmonica) – Song 2



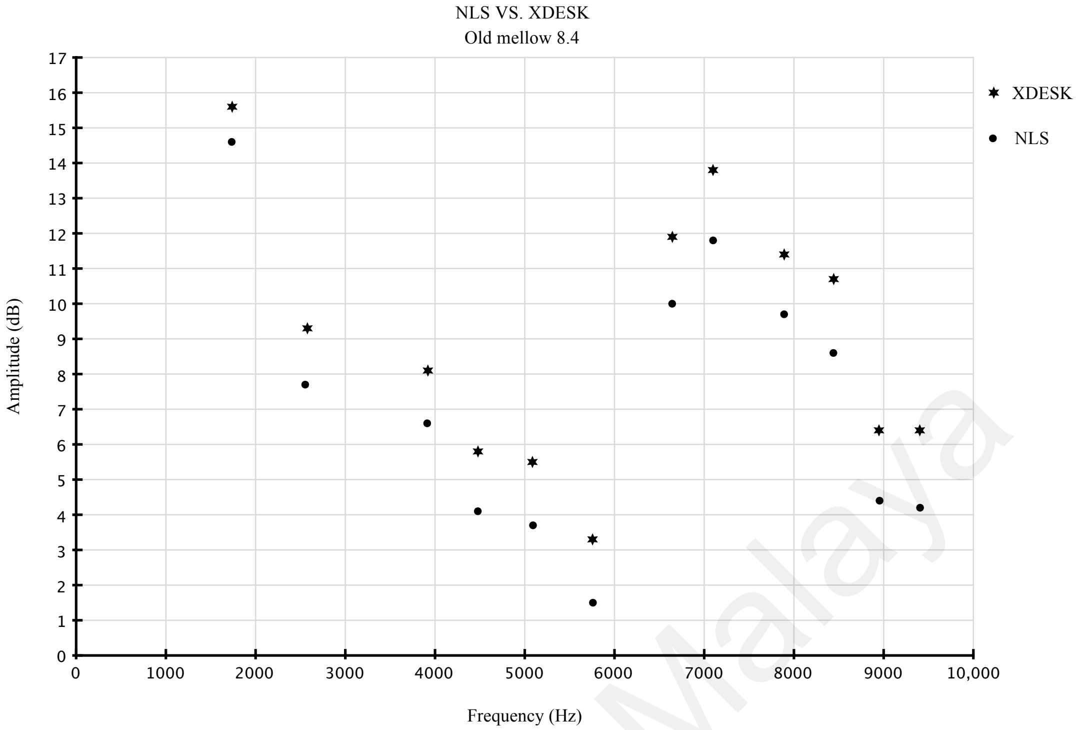
Graph 30 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for harmonica (Song 2). The biggest peak amplitude gap is registered at around 13800Hz with 1.4dB. The smallest peak amplitude gap is registered at around 2000Hz with 0.4dB.

Graph 32: Comparison of SSL Xdesk and All other (Harmonica) – Song 2



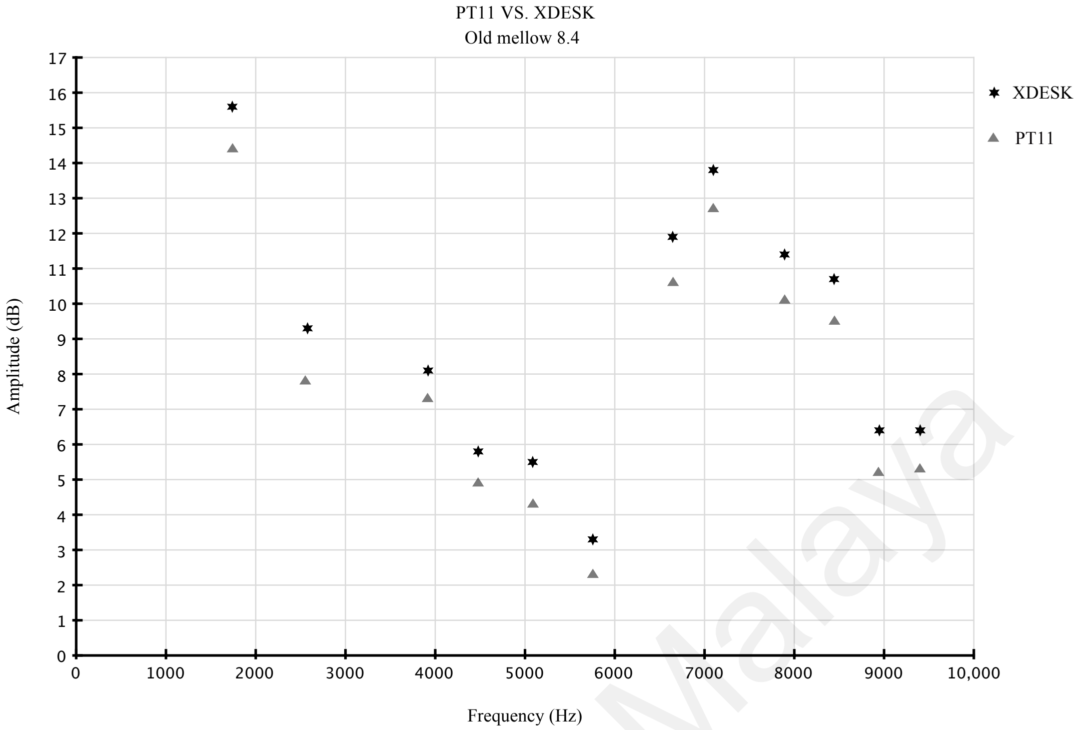
Graph 32 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for harmonica (Song 2). The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with biggest differences in the high frequencies. All three methods registered the smallest differences at the same frequency, which is at 2000Hz (lower midrange). Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 33: Comparison of SSL Xdesk and Waves NLS (Mellow) – Song 2



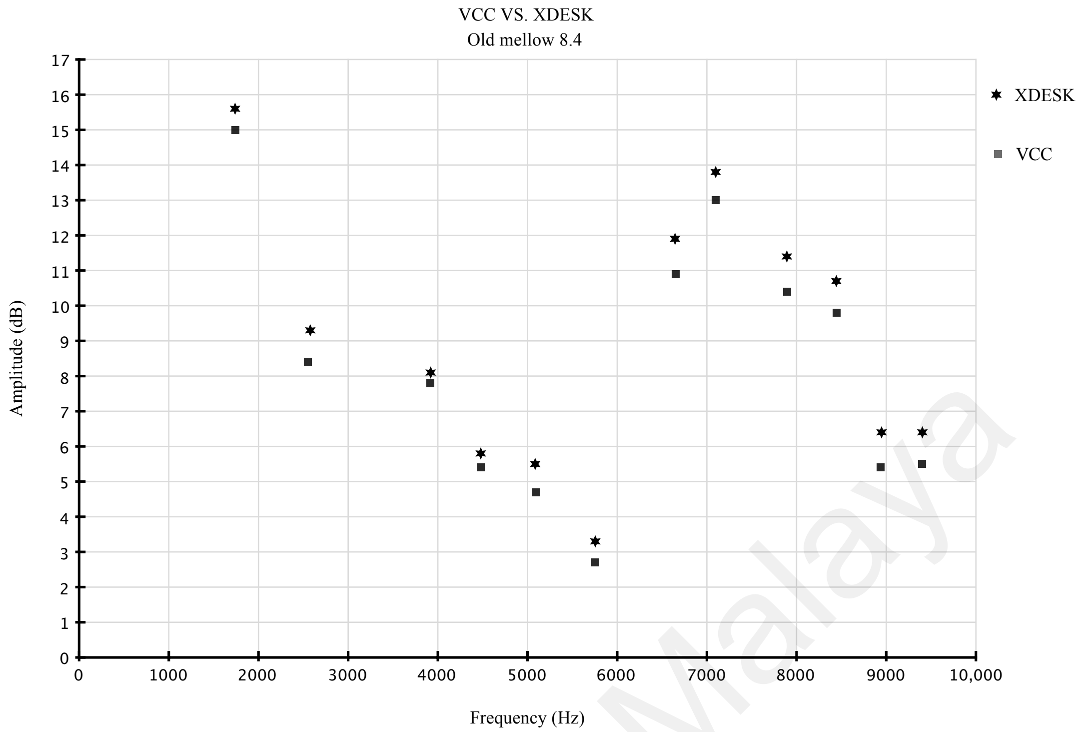
Graph 33 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for mellow music (Song 2). The biggest peak amplitude gap is registered at around 9400Hz with 2.2dB. The smallest peak amplitude gap is registered at around 1700Hz with 1dB.

Graph 34: Comparison of SSL Xdesk and Protools 11 (Mellow) – Song 2



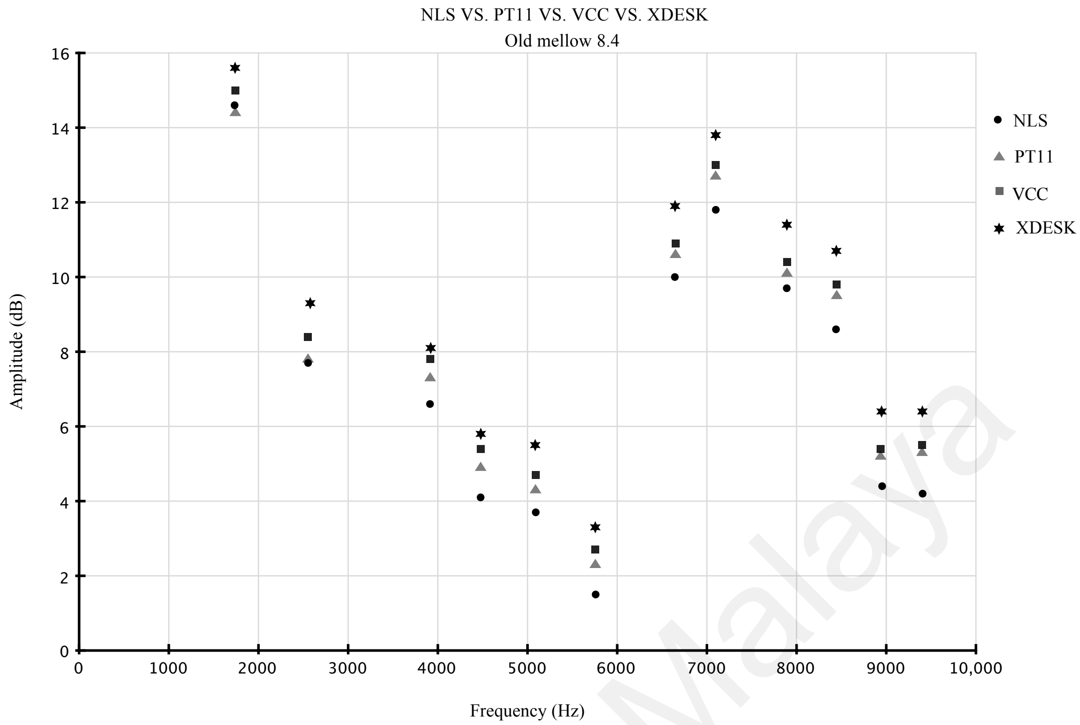
Graph 34 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for mellow music (Song 2). The biggest peak amplitude gap is registered at around 2500Hz with 1.5dB. The smallest peak amplitude gap is registered at around 3900Hz with 0.8dB.

Graph 35: Comparison of SSL Xdesk and Slate Digital VCC (Mellow) – Song 2



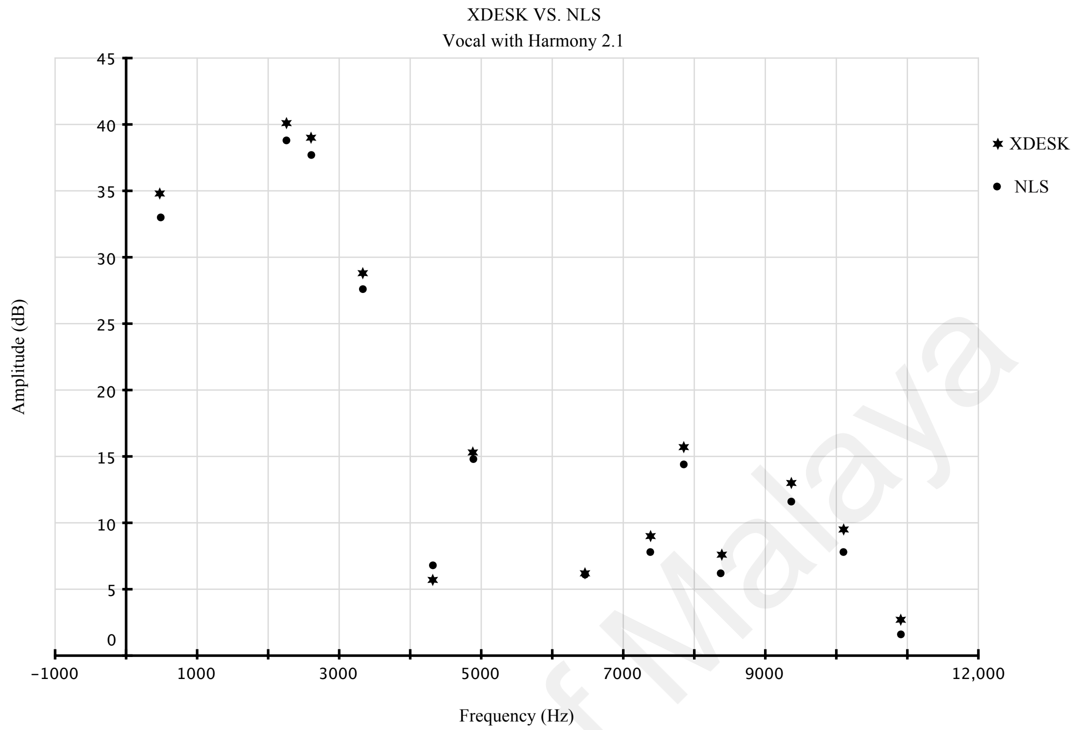
Graph 35 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for mellow music (Song 2). The biggest peak amplitude gap is registered at around 6700Hz, 7900Hz and 8900Hz with 1dB. The smallest peak amplitude gap is registered at around 3900Hz with 0.3dB.

Graph 36: Comparison of SSL Xdesk and All other (Mellow) – Song 2



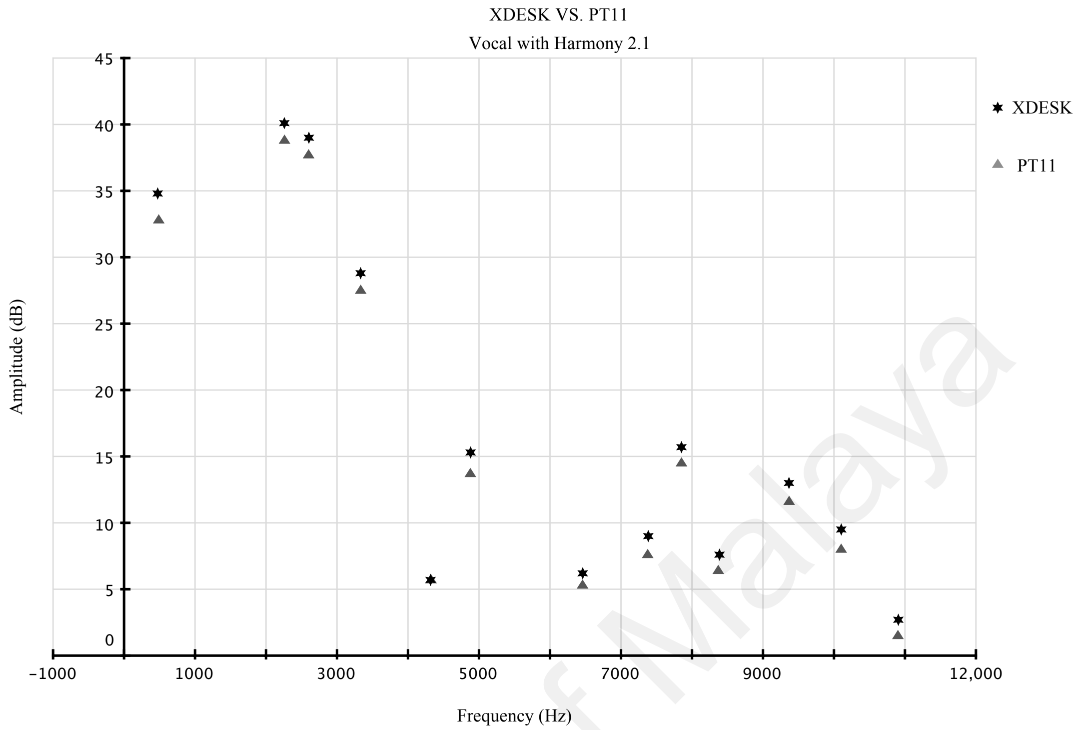
Graph 36 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for mellow music (Song 2). The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with biggest differences in the higher frequencies. The Protools 11 sample however recorded its highest gap at the upper midrange. Both Protools 11 and Slate Digital VCC registered the smallest differences in the upper midrange frequency of 3900Hz whilst Waves NLS at the lower midrange of 1700Hz. Generally, the amplitude differences between Xdesk and Waves NLS samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 37: Comparison of SSL Xdesk and Waves NLS (Vocal with Harmony) – Song 2



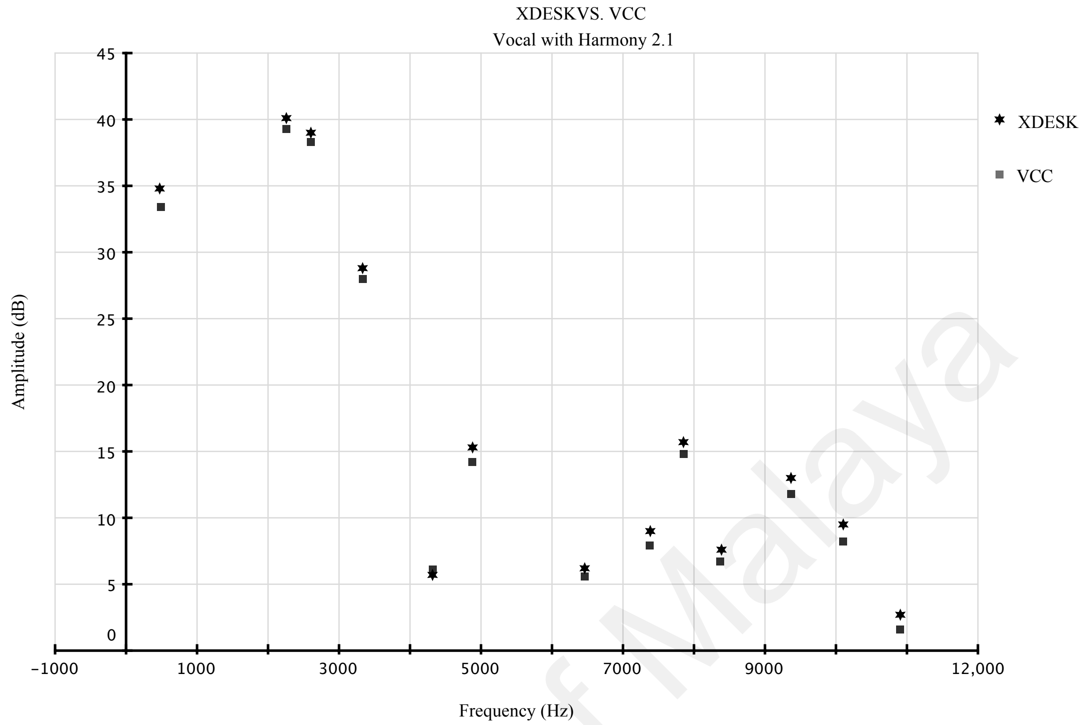
Graph 37 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for vocal with harmony (Song 2). The biggest peak amplitude gap is registered at around 500Hz with 1.8dB. The smallest peak amplitude gap is registered at around 6500Hz with 0.1dB. The Waves NLS samples registered one louder peak than the Xdesk at 4300Hz.

Graph 38: Comparison of SSL Xdesk and Protools 11 (Vocal with Harmony) – Song 2



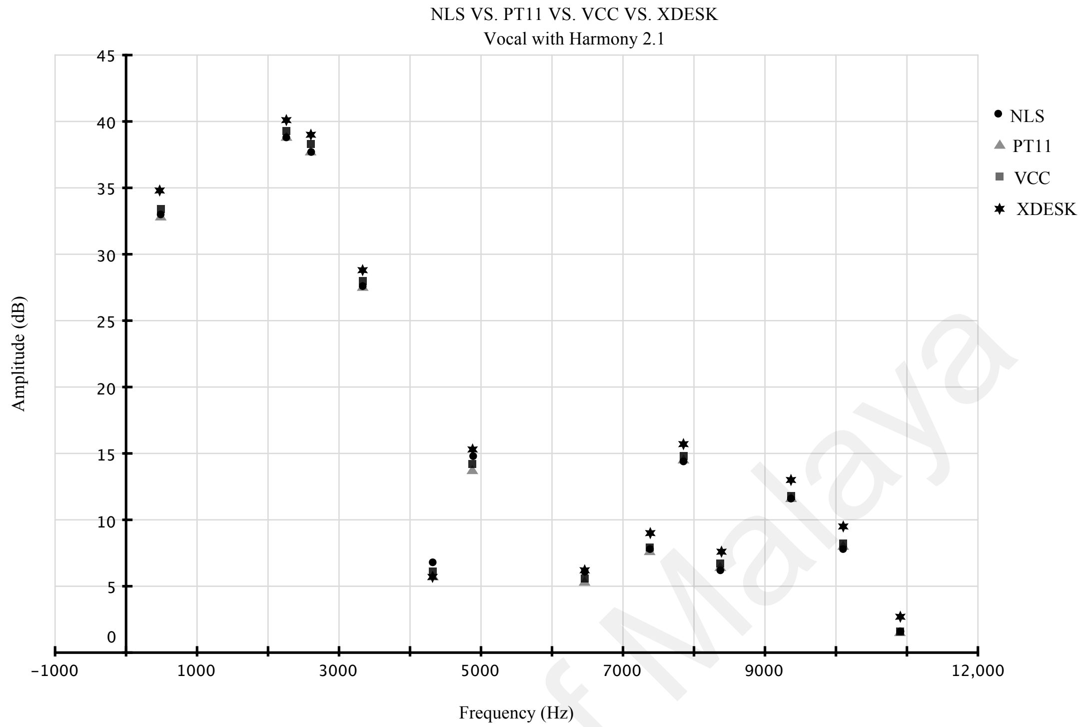
Graph 38 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for vocal with harmony (Song 2). The biggest peak amplitude gap is registered at around 4900Hz with 1.6dB. The smallest peak amplitude gap is registered at around 4300Hz with no difference of amplitude between the Xdesk and Protools 11 sample.

Graph 39: Comparison of SSL Xdesk and Slate Digital VCC (Vocal with Harmony) – Song 2



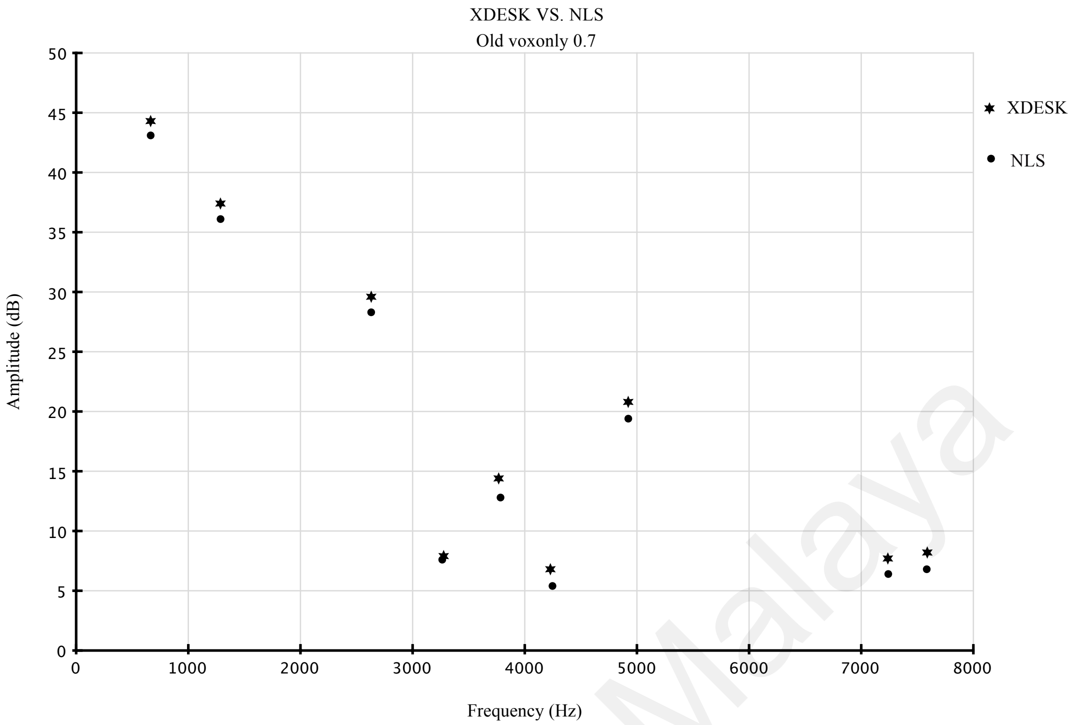
Graph 39 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for vocal with harmony (Song 2). The biggest peak amplitude gap is registered at around 490Hz with 1.4dB. The smallest peak amplitude gap is registered at around 4300Hz with the Slate Digital VCC sample being 0.4dB louder than Xdesk.

Graph 40: Comparison of SSL Xdesk and All other (Vocal with Harmony) – Song 2



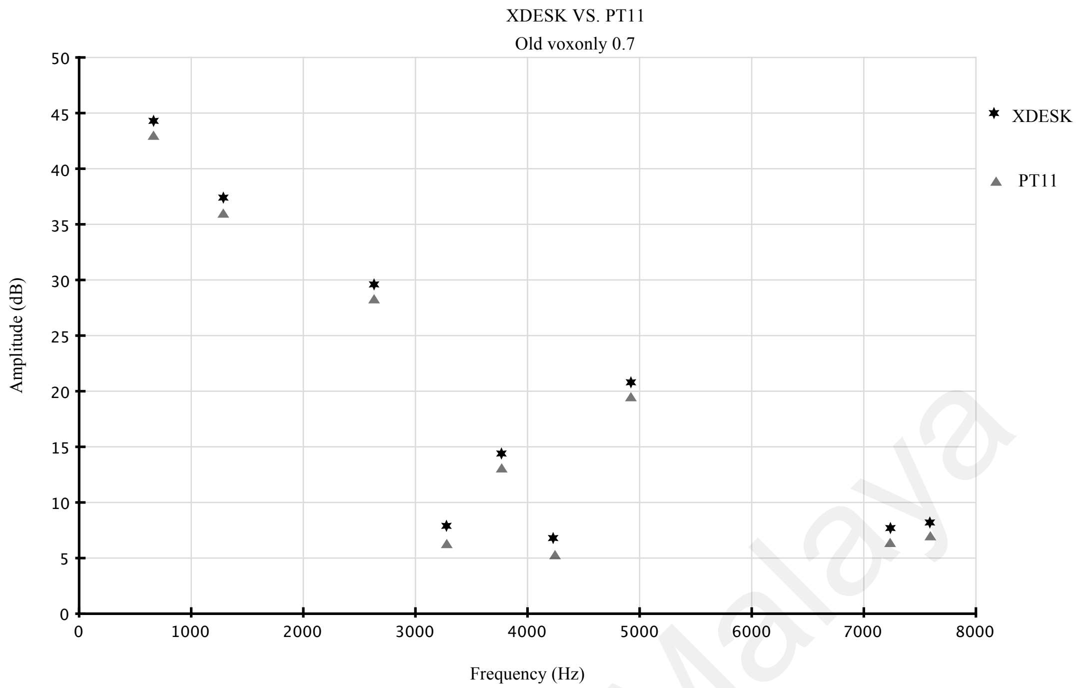
Graph 40 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for vocal with harmony (Song 2). The pattern for peak amplitude differences is similar between the Xdesk vs. Waves NLS and Xdesk vs. Slate Digital VCC with biggest differences in the lower midrange frequencies. The Protools 11 sample however recorded its highest gap at the upper midrange. All three methods registered their smallest differences in the upper midrange frequencies. Generally, the amplitude differences between Xdesk and Protools 11 samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 41: Comparison of SSL Xdesk and Waves NLS (Vocal) – Song 2



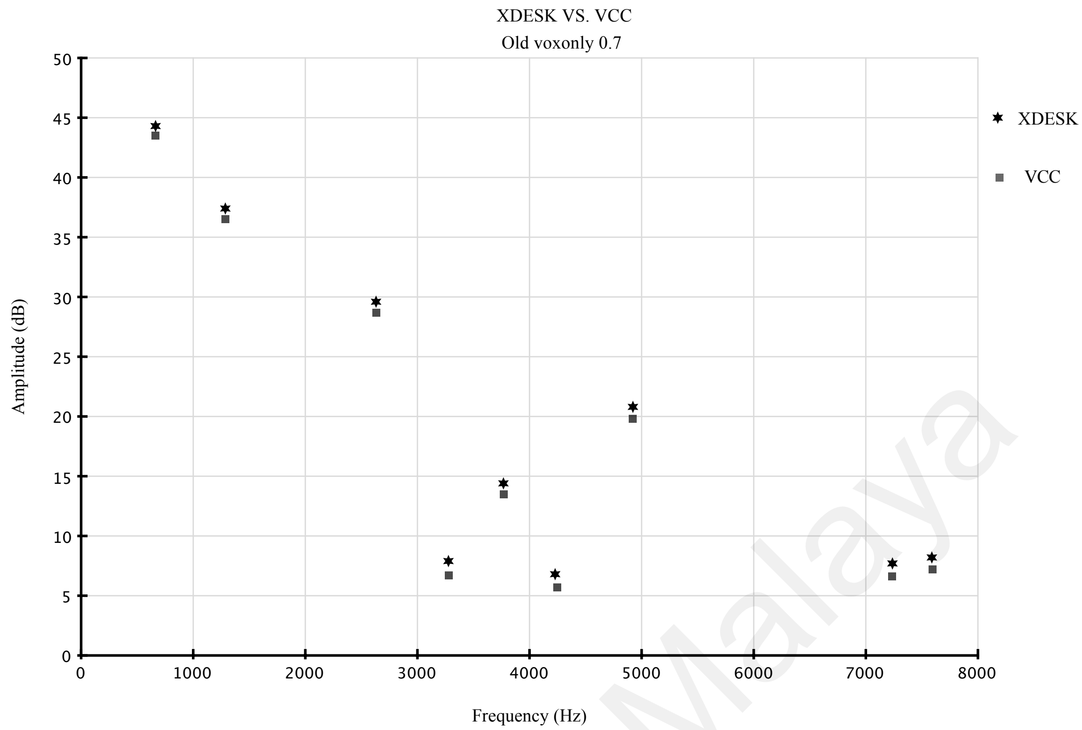
Graph 41 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for vocal (Song 2). The biggest peak amplitude gap is registered at around 3800Hz with 1.6dB. The smallest peak amplitude gap is registered at around 3300Hz with 0.3dB.

Graph 42: Comparison of SSL Xdesk and Protools 11 (Vocal) – Song 2



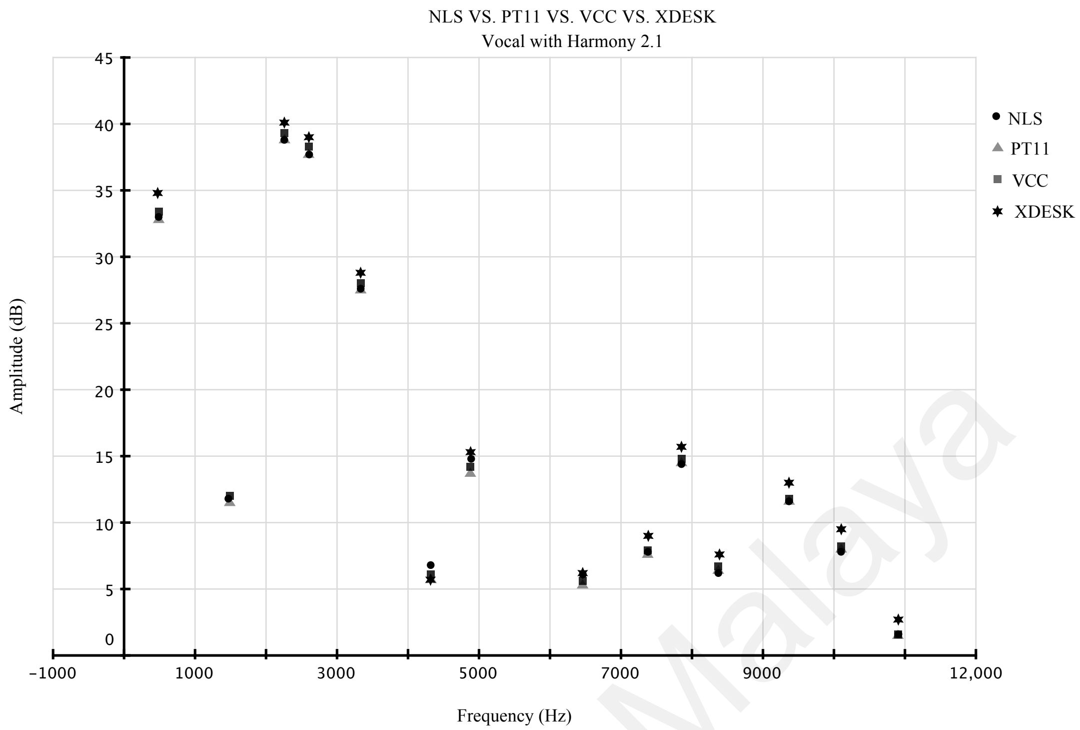
Graph 42 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for vocal (Song 2). The biggest peak amplitude gap is registered at around 3300Hz with 1.7dB. The smallest peak amplitude gap is registered at around 7600Hz with 1.3dB.

Graph 43: Comparison of SSL Xdesk and Slate Digital VCC (Vocal) – Song 2



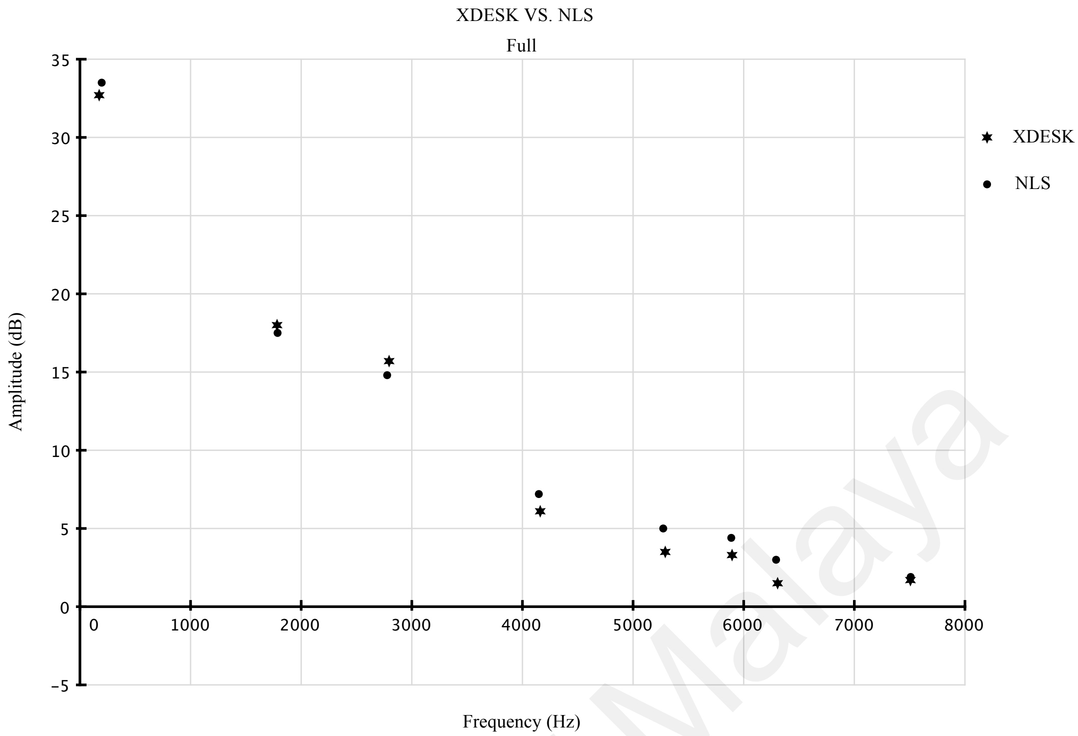
Graph 43 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for vocal (Song 2). The biggest peak amplitude gap is registered at around 3300Hz with 1.2dB. The smallest peak amplitude gap is registered at around 700Hz with 0.8dB.

Graph 44: Comparison of SSL Xdesk and All other (Vocal) – Song 2



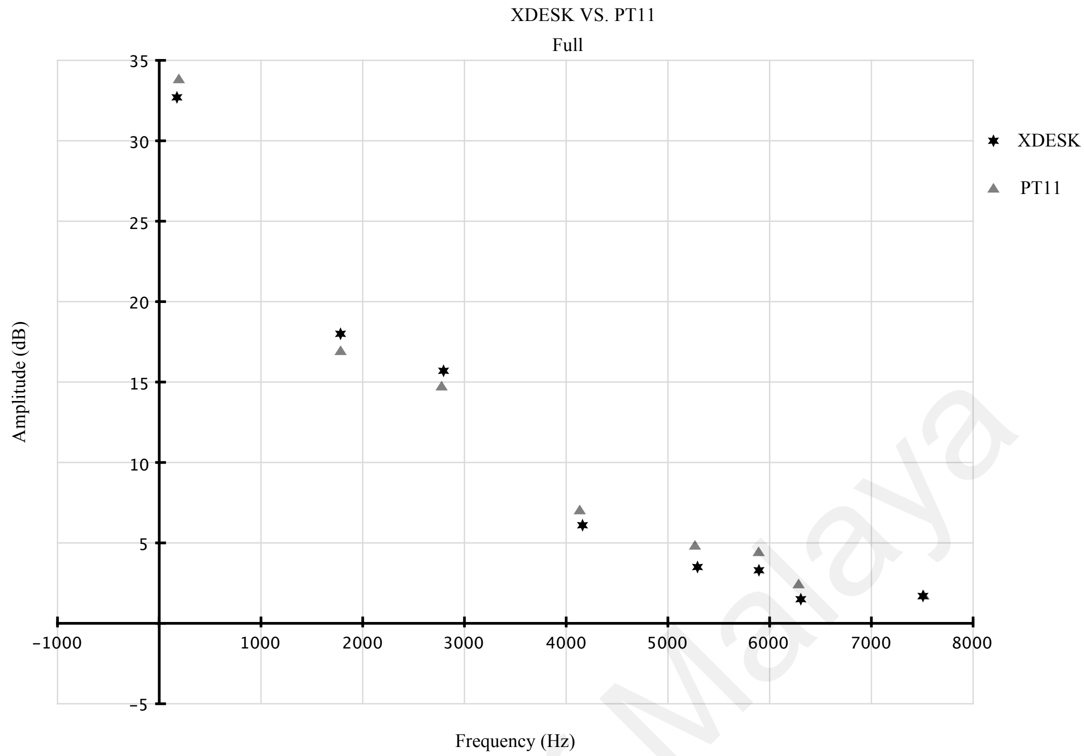
Graph 44 shows the peak amplitude comparison of the Xdesk summed samples and all of the other summed samples for vocal (Song 2). The pattern for peak amplitude differences is similar with all three methods with biggest differences in the upper midrange frequencies. The smallest differences for all three however fall in separate region with Waves NLS in the upper midrange, Protools 11 in the high and Slate Digital VCC in the lower midrange frequencies. Generally, the amplitude differences between Xdesk and Protools 11 samples are the widest whilst Xdesk and Slate Digital VCC are the narrowest.

Graph 45: Comparison of SSL Xdesk and Waves NLS (Full Band) – Song 2



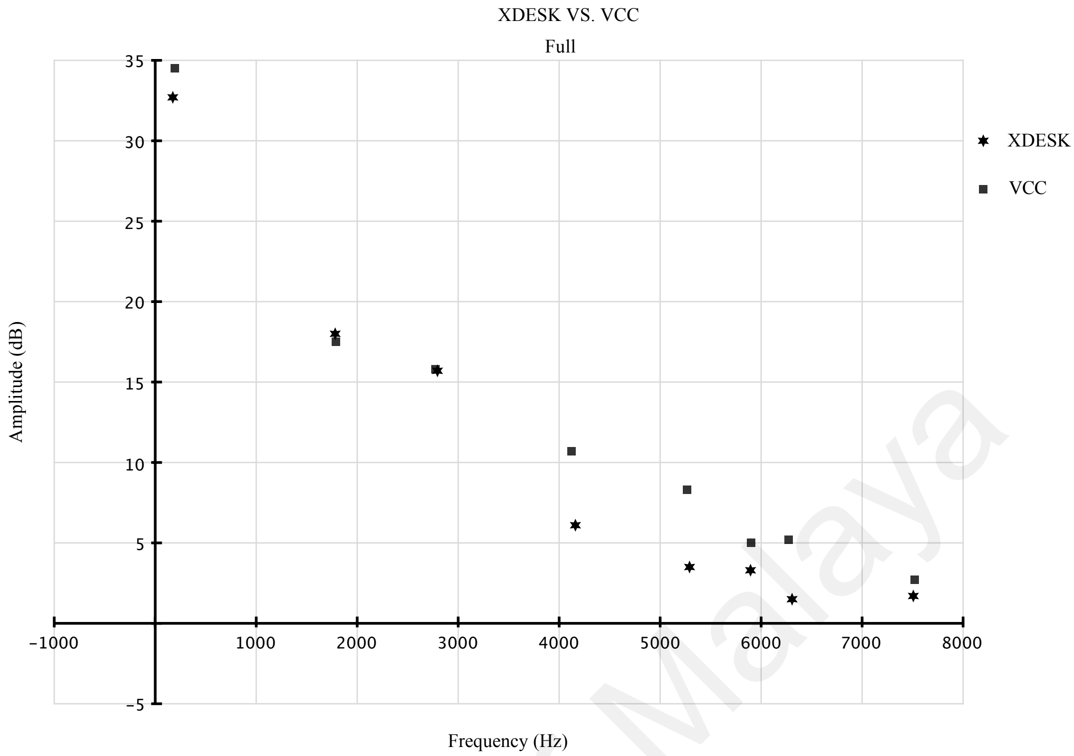
Graph 45 shows the peak amplitude comparison of the Xdesk summed sample and Waves NLS summed sample for full band (Song 2). The biggest peak amplitude gap is registered at two points around 5300Hz and 6300Hz with Waves NLS being 1.5dB louder than Xdesk. The smallest peak amplitude gap is registered at around 7500Hz with Waves NLS being 0.2dB louder than Xdesk.

Graph 46: Comparison of SSL Xdesk and Protools 11 (Full Band) – Song 2



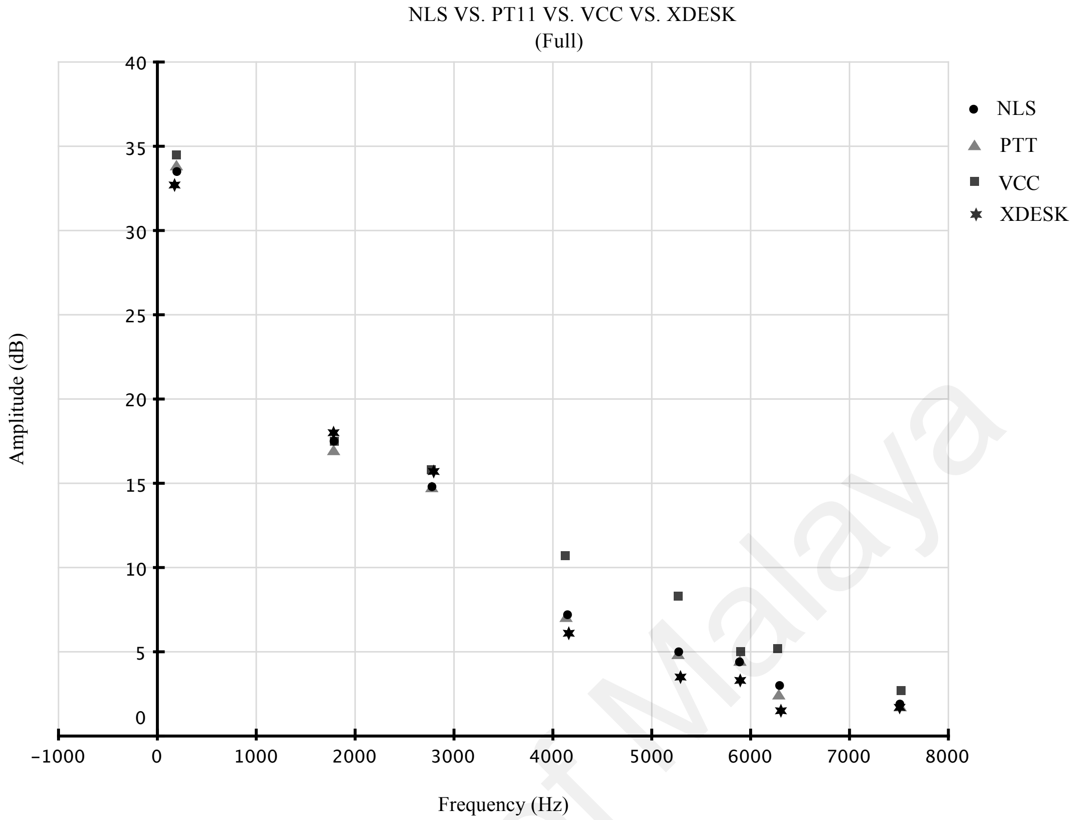
Graph 46 shows the peak amplitude comparison of the Xdesk summed sample and Protools 11 summed sample for full band (Song 2). The biggest peak amplitude gap is registered at around 5300Hz with Protools 11 being 1.3dB louder than Xdesk. The smallest peak amplitude gap is registered at around 7500Hz with no difference of amplitude between Protools 11 and Xdesk.

Graph 47: Comparison of SSL Xdesk and Slate Digital VCC (Full Band) Song 2



Graph 47 shows the peak amplitude comparison of the Xdesk summed sample and Slate Digital VCC summed sample for full band (Song 2). The biggest peak amplitude gap is registered at around 5300Hz with Waves NLS being 4.8dB louder than Xdesk. The smallest peak amplitude gap is registered at around 2800Hz with Slate Digital VCC being 0.1dB louder than Xdesk.

Graph 48: Comparison of SSL Xdesk and All other (Full Band) – Song 2



Graph 48 shows the peak amplitude comparison of the Xdesk summed sample and all of the other summed samples for vocal (Song 2). The pattern for peak amplitude differences is similar with all three methods with biggest differences in the upper midrange frequencies. The smallest differences for Waves NLS and Protools 11 are similar which falls in the high frequencies whilst Slate Digital VCC falls in the upper midrange frequencies. Generally, the amplitude differences between Xdesk and Slate Digital VCC samples are the widest whilst Xdesk and Protools 11 are the narrowest. Majority of peaks for all three digital summing methods recorded higher amplitude than the analogue summing sample.

CHAPTER 5 DISCUSSION & CONCLUSION

5.0 Discussion

The findings from this study have showed that amongst the four different summing methods, three being digital and one analogue, the latter have recorded the highest peak amplitude across all but one sample. This result is consistent amongst all of the tested samples except for the "Full Band – Song 2" where digital summing recorded higher peak amplitude across almost all frequency range.

Among the three digital summing methods, Waves NLS recorded the lowest peak amplitude average. This can be seen in nine out of twelve samples tested where Waves NLS recorded the biggest peak amplitude differences as compared to the Xdesk. Slate Digital VCC on the other hand, recorded the highest peak amplitude average among the three digital summing methods. This can be seen in eight out of twelve samples where it recorded the smallest differences as compared to the Xdesk.

Table 5.1: Biggest differences in peak to peak amplitude range (analogue vs. digital)

Frequency Range / Samples	Extreme Low Bass (20 – 60Hz)	Bass (61 – 300Hz)	Lower Midrange (301 – 2500Hz)	Upper Midrange (2501 – 7000Hz)	High (7001 – 20000Hz)
Acoustic Guitar				Waves NLS	
Acoustic Guitar 2					Waves NLS
Drums					Waves NLS
Cymbals				Waves NLS	
Vocal					Waves NLS
Vocal Essing – S2			Waves NLS		
Flute – S2				Protools 11	
Harmonica – S2					Waves NLS
Mellow					Waves NLS

Table 5.1, continued

Vocal with Harmony – S2					Waves NLS
Vocal – S2				Protools 11	
Full Band				Slate VCC	

Majority of the biggest peak amplitude differences are recorded in the high frequencies followed by the upper midrange region. This can be confirmed with six samples recorded in the high region and five samples recorded in the upper midrange. The lower midrange recorded one biggest difference. Differences in the upper midrange region are critical as some of these frequencies are the most sensitive to the human hearing system.

Table 5.2: Smallest differences in peak to peak amplitude range (analogue vs. digital)

Frequency Range / Sample	**Extreme Low Bass (20 – 60Hz)**	**Bass (61 – 300Hz)**	**Lower Midrange (301 – 2500Hz)**	**Upper Midrange (2501 – 7000Hz)**	**High (7001 – 20000Hz)**
Acoustic Guitar			Slate VCC		
Acoustic Guitar 2			Slate VCC		
Drums			Slate VCC		
Cymbals			Slate VCC		
Vocal				Slate VCC	Waves NLS
Vocal Essing – S2					Waves NLS
Flute – S2			Slate VCC		
Harmonica – S2			Slate VCC		
Mellow				Slate VCC	
Vocal with Harmony – S2				Protools 11	
Vocal – S2				Waves NLS	
Full Band					Protools 11

Majority of the smallest peak amplitude differences are recorded in the lower midrange followed by the upper midrange and high frequency region. This can be seen with six samples registering its biggest differences in the lower midrange, four samples in the upper midrange followed by three samples in the high frequency region. There are neither biggest differences nor smallest differences recorded in the bass and extreme low bass region. This result is consistent across all tested samples.

There was an odd observation on the "Full Band – S2" sample where all digitally summed samples recorded a higher peak amplitude than analogue summed sample. This is the opposite of other samples where the majority of peaks for digital summing were recorded lower than analogue summing. The widest amplitude range has also been recorded in this sample with 4.8dB of difference between the loudest and the softest peak. This could be link to the increase of track number in the sample where there were many more dominant instruments playing as compared to other samples. This finding is similar to that of Kent where she found that the differences between digital and analogue summing became less evident with the decrease of track number (Kent, 2014).

Harmonic and non-harmonic sound samples were not showing any differences in peak to peak amplitude comparison. This can be observed when non-harmonic samples such as "vocal essing" and "cymbals" was not showing any significant differences as compared to harmonic samples.

Other Observations

After visually comparing spectrograms of all the six categories that were set before, it was found that differences was hard to detect between analogue summing and digital summing samples. This was consistent even when looking at spectrogram of a range between 0 – 5kHz.

Analogue summing samples was also found to have bigger range between the peaks and valleys as compared to digital summing samples. This could be translated as a sign of an increase in dynamic range in the analogue summing samples as opposed to the digital summing samples.

Appearance of new high frequency content was also detected in the analogue summing samples and DAW + Slate VCC samples. These high frequencies were later identified as distortion that was imparted by analogue circuitry.

5.1 Conclusion

This study was set to look at objective differences between analogue summing and digital summing. The study was also aimed to find out on whether advancement in digital summing has helped in producing more similar results to the analogue counterpart. The results have showed that there are clear objective differences between analogue and digital summing. The results also showed that the use of analogue summing emulation plugin do not necessarily help in producing more similar outcomes between analogue and digital summing. This can be clearly seen when the use of Waves NLS recorded a bigger peak-to-peak amplitude differences as compared to Protools 11 summing. Slate Digital VCC however has managed to bring the gap closer between analogue and digital summing.

The majority of significant differences were observed in the upper midrange and high frequency region. The difference in both of these regions would in theory translate into the analogue summing samples having more “clarity” as compared to digital summing.

The study was set to look at the objective differences of the two summing techniques for the purpose of helping audio engineers to understand their options more deeply. This is to promote the idea of not choosing between the two formats completely but rather integrating them to take advantage of both worlds.

Although this study have provided spectral analysis comparison between analogue summing and digital summing, there are various of other factors that also have to be look at when comparing the two methods such as distortion, cross talk, phase etc. These other factors are just as important as spectral analysis and should be undertake in further studies.

The results from this study should also be tested subjectively by conducting perceptual listening tests to see whether the objective differences are audible. Different sets of listening format (e.g. studio monitor, ear phone, head phone, car stereo etc.) could also be considered, as these would provide an idea whether the differences can be detected in everyday environment.

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