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PHY 3990

A Discussion in Machine Learning – The Kemper Profiler

INTRODUCTION

In 2016, it has been over a century since Lee de Forest's insertion of a control grid into a Fleming valve, effectively creating the first triode [1]. The technological advances of the twentieth century have ushered in increasingly efficient semi-conductors, effectively dooming their once-ubiquitous glass-envelope ancestors to the history books in all but a few applications that continue to withstand the test of time, such as those in hi-fi music reproduction, professional recording and signal processing equipment, and instrument amplifiers, where vacuum tubes are prized for their rich harmonic content and unique distortion characteristics[2]. The characteristic sound of a tube amplifier is found to be the result of a combination of individual components and their interaction, including but not limited to; nonlinear behavior of output tube(s), the output impedance of the amplifier itself, the nonlinearity of output transformer inductance, and its influence on speaker excursion, the behavior of which may also be non-linear[3]. Accordingly, the nonlinear behavior inherent of a tube-based system continue to pose a unique engineering challenge to those concerned with adopting the "tube" sound in their own applications.

Though solid-state tube amplifier models and emulation have existed since the advent of digital audio in the 1980's, many users report that their performance consistently falls short when compared to a real vacuum tube-based amplifier[4]. However, the Kemper Profiler is a state-of-the-art instrument amplifier that effectively simulates the core components of a tube amplifier in order to render a user experience that goes far beyond solid-state modeling of a tube system. Rather, the Kemper Profiler employs digital signal processing techniques and the use of machine learning algorithms in a process described as "profiling" through which the unit is able to successfully fit the unique behavior of an amplifier to a finite set of parameters that work together to determine the behavior of the system. It is worth noting however that due to the highly proprietary nature of the underlying methodologies employed by the Kemper Profiler, this discussion is inherently limited in its access to the objective details of the system. Instead, provided in this paper is an overview of the operation of the unit as well as data created from the profiling process in addition to the subjective experience of the author.

ON THE PROCESS OF PROFILING…

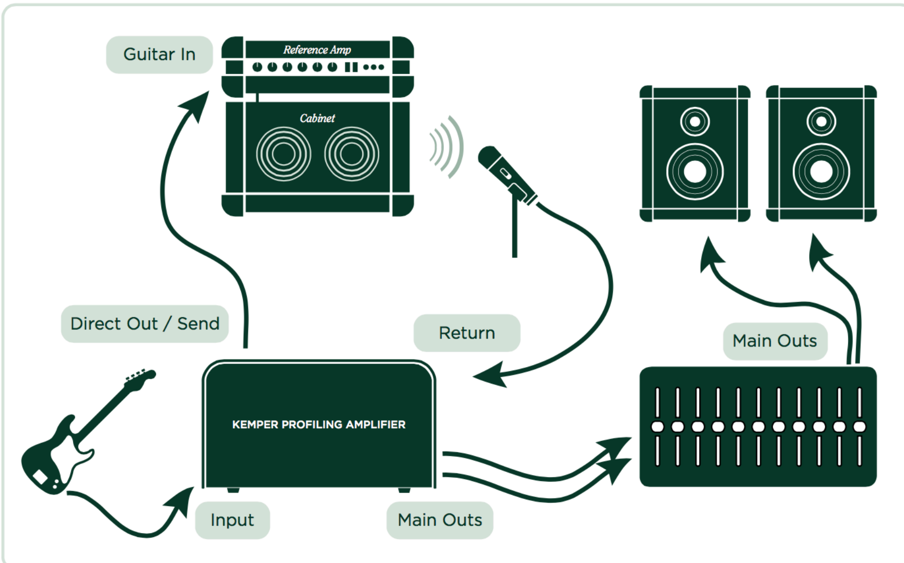
From the user manual: "the Kemper Profiler analyzes the sonic characteristics of a reference amplifier. This process allows it to faithfully recreate the characteristic sound of virtually any guitar amp, and adopt the behavior and interaction of the components of the analyzed amplifier." In *Figure 1.1* also taken from the user manual, the signal flow of the profiling process is laid out. When activated, the "Profiler" mode sends a series of test signals out the "send" of the Kemper and into the input of the reference amplifier and attached speaker cabinet. The test signal is divided into three phases, the first of which analyzes the frequency response of the reference amplifier and its circuitry. This first phase of the test signal also analyzes the frequency response of the attached cabinet, including the "the characteristic impedance curve of the speaker, including its feedback to the power amp…detected in detail".

The second phase of the profiling process includes slow pulses of white noise. The purpose of this portion of the test signal is to evaluate the unique characteristics of the reference amp when pushed to the point of saturation, overdrive, and distortion. The white noise begins near the point of distortion and continues to drive the reference amplifier at, around, and on past that point. This is key to developing a profile of the reference amp that effectively emulates the organic behavior of an overdriven tube amp.

Finally, the third step of the profiling process "sends a complex tonal texture that follows a mathematically-based set of rules to the reference amp. This texture creates unique interference patterns that allow the Kemper Profiler to take a 'fingerprint' of the DNA of the reference amp's particular sound. The distortion of the speaker, along with the partial pattern of the loudspeaker's diaphragm (also known as 'cone breakup') are excited by this tonal mixture. They complete the characteristic interference pattern that the Kemper Profiler will reproduce faithfully, once the measurements have been taken". Designer Christoph Kemper explains this "pulsing white noise modulates the saturation and thus the current of the distorting tube…By checking the residual distribution of the noise and the slight changes in the frequency response, a number of circuit parameters can be solved" [5].

A well-rounded test signal in conjunction with machine learning essentially fits the selected amplifier profile given the signal that is picked up at the unit's return. Perhaps the most interesting part of the profiling process is the ability for the user to make refinements to the profile by suspending the test signal process and instead using one's own playing as a sort of test signal in itself. Accordingly, at any point in this process, the user is also able to tweak any of the individual rotary encoders that correspond to the parameters of each unique profile: tube shape, power sagging, preamp definition, in addition to equalization parameters.

Figure 1.1 – Signal Flow of Profiling Process



TEST RESULTS

In the process of gathering data for this discussion, several profiles were taken in the process: a Fender Bassman clone, Fender Blackface Deluxe Reverb, and a Mesa/Boogie Lonestar Special. The Mesa/Boogie Lonestar Special includes a feature that allows the amplifier to run at 5, 15, or a full 30 watts. The amplifier was profiled in all three available power settings. Upon completion of the profiling process, each profile was saved and testing could begin.

An audio file of a test signal was used on an individual track created within the ProTools, consisting of a logarithmic 20 Hz to 20 kHz sine-wave sweep that was sent from the DAW, to the Kemper, to the reference amplifier. Two tracks could then be recorded simultaneously of each respective profile; a "direct" line from the back of the Kemper

Profiler unit, and a microphone placed on the cabinet located in an isolation booth, running directly to the DAW. Several recording passes were taken for each power setting to determine if the Profiler hardware was able to successfully emulate the amp when run at "NORMAL" (clean) gain settings, in addition to "PUSHED" and "DIMED". "NORMAL" was set by ear by the user at a point that caused a minimum amount of audible distortion, which corresponded to roughly one-third of the total value of the rotary encoder. "PUSHED" was set as two-thirds of the total value of the rotary encoder, with a light to moderate amount of audible distortion. "DIMED" was full gain. Input gain of the recording interface was set such that maximum signal could be captured at the interface without any indication of signal clipping. The two tracks could then be analyzed to determine their frequency content, and the same test signal as processed by the system could be analyzed and compared according to frequency content and power spectrum. Frequency response charts were created using MATLAB for NORMAL and PUSHED settings, available in Appendix A. Power spectrum graphs were created using SHAART audio analytics software.

DISCUSSION

From a purely subjective standpoint, the Kemper is an impressive piece of signal processing hardware. Objectively, not only do the lower-power amplifiers profiled sound exceptional to the author, but the data gathered from the testing process show a power spectrum that emulates the "power sag" that is one of the quintessential non-linear behaviors demonstrated by vacuum tube amplifiers when pushed to the point of saturation, overdrive, and distortion. *Figure 2.1* shows that variation in only the power setting of the amplifier lead to a performance that is characteristic of vacuum tube performance, along with increased amounts of distortion and signal noise. All things remaining equal, the same signal through systems that differ only in their overall power should be virtually identical, differing only in their amount of power sag, as is apparent in the figure referenced. In this case, the "direct" signals were chosen for comparison as they eliminate the added variables of the microphone and speaker cabinet. However, it is worth nothing that the characteristics of the microphone and cabinet should be included in the direct sound, in accordance with Kemper profiling process and the measurements taken therein to fit finite parameters as described in the previous section of this discussion. *Figure 2.2.* shows a comparison between the "direct" recordings and signal taken from the microphone on the cabinet in the isolation booth. As such, it is a comparison of the power spectrum of the Kemper profile version of the 30 watt Mesa/Boogie amplifier, and the real amplifier itself. While the two graphs do not show a perfect fit, they are nonetheless complimentary with remarkable similarities.

Figure 2.1. 30 watt Direct vs. 5 watt Direct , "DIMED" Gain

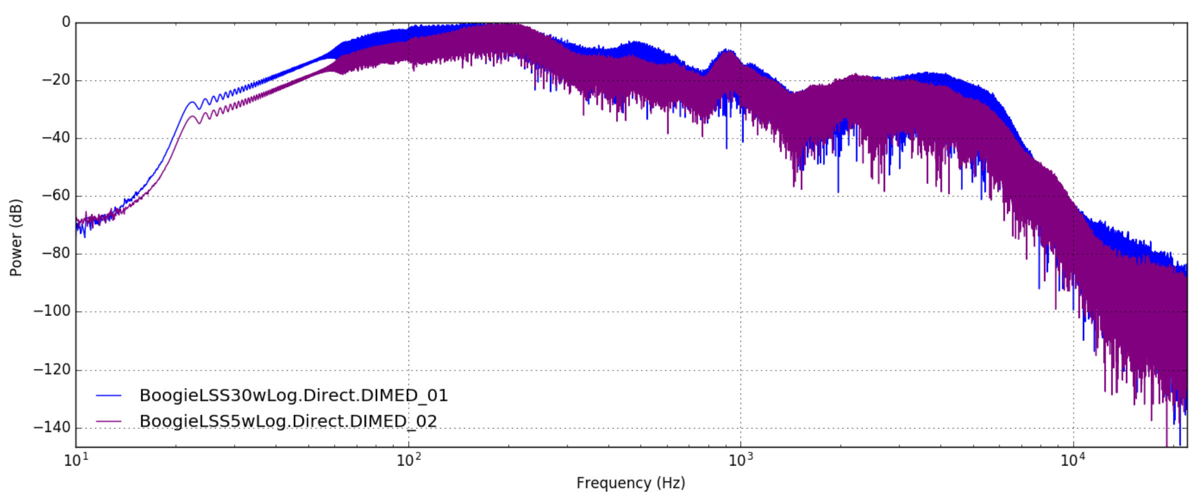


Figure 2.2 – 30 watt Cabinet vs. 30 watt Direct Power Spectrum, “NORMAL” Gain

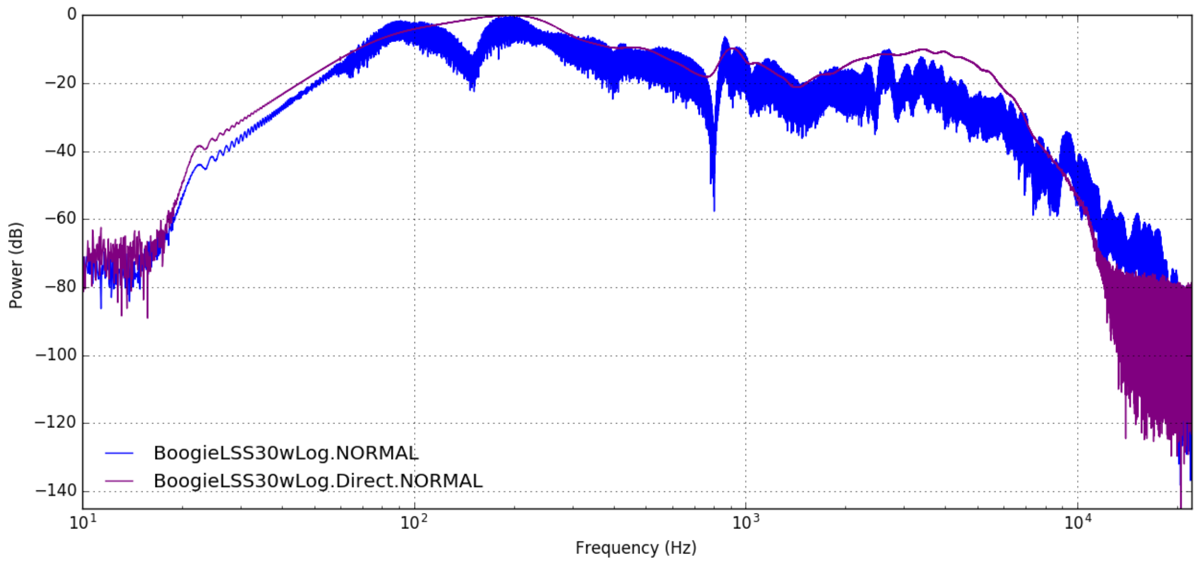


Figure 2.3 – 15 watt Cabinet vs. 15 watt Direct Power Spectrum – “NORMAL” Gain

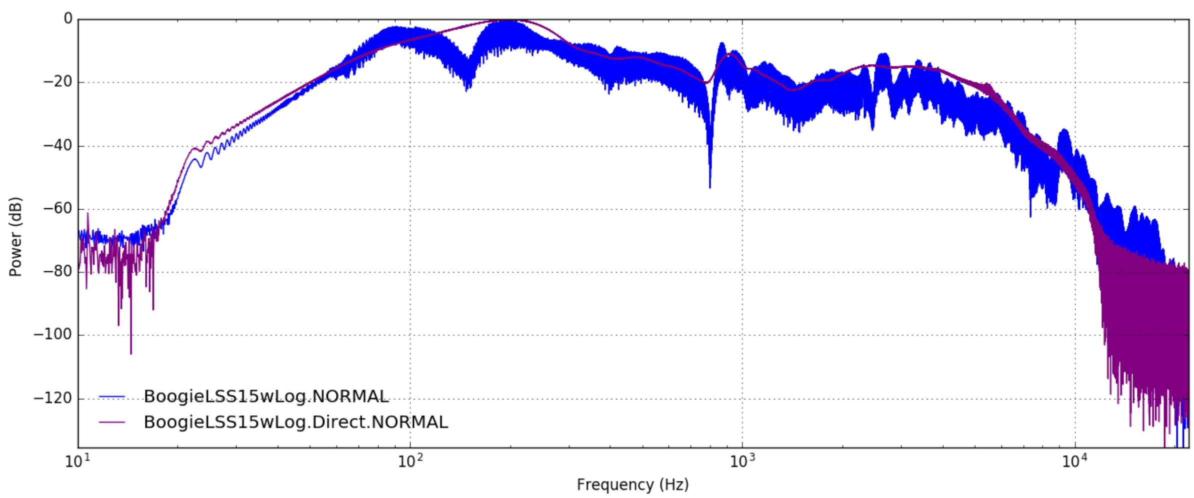


Figure 2.4 - 5 watt Cabinet vs. 5 watt Direct Power Spectrum – “NORMAL” Gain

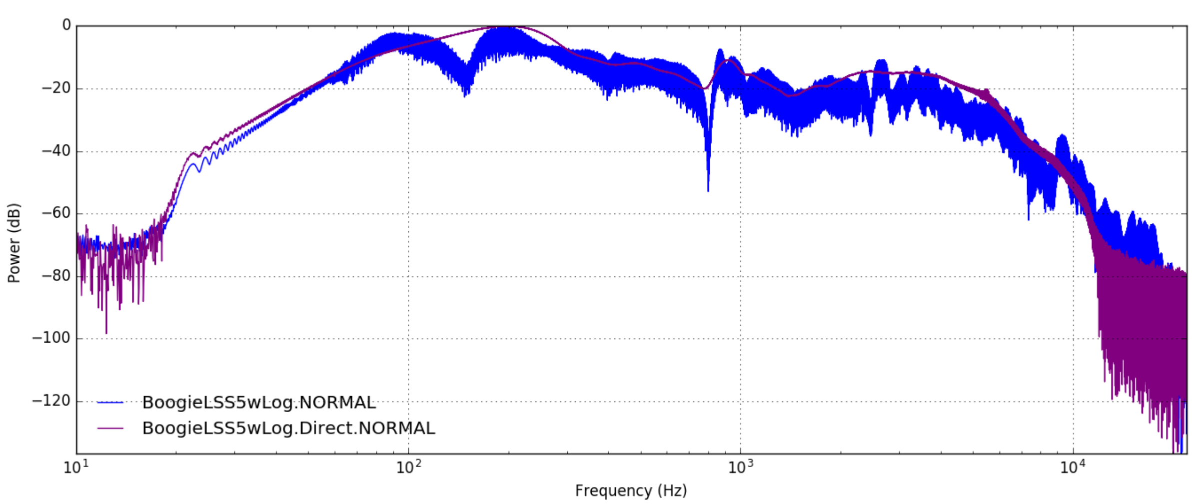
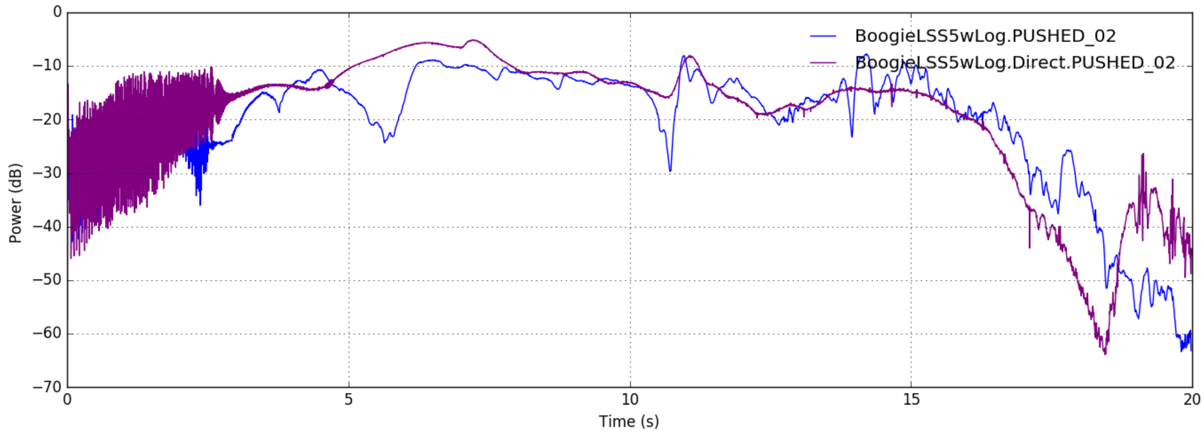


Figure 2.5 – 5 watt Cabinet vs. Direct Power Spectrum – "PUSHED" Gain



DISCUSSION (cont.)

While the data and the discussion enclosed provides objective support for the quality of the profiling process, the method of testing requires improvement to better determine the effectiveness of the machine learning aspect of the Kemper Profiler. The figures enclosed in this paper show only single snapshots of the Profiler, albeit several different ones. In the future, one might analyze the power and frequency content of the direct and cabinet sounds, before and after the process of refining the profile. To maintain consistency, it would be necessary to record a guitar signal via direct injection for use as a control. Accordingly, identical direct injection signal(s) might then be sent to the profile for the user-directed refinement process. Limitations on time have prevented the gathering of such data as of the writing of this discussion. With added time, the analytical process can be repeated with other reference amplifiers. The availability of power spectrum analysis in conjunction with a single amplifier with three variations of power settings provided a meaningful jump-off point for the machine learning-directed parameter fitting on which the Kemper Profiler operates.

CONCLUSION

While the modeling of complex tube circuitry by solid-state circuits and digital signal processing algorithms is nothing new, their pairing with machine learning methodologies remains a relatively new and novel application. The Kemper Profiler sets itself apart from comparable DSP-based modeling systems by the proprietary methods through which it is able to measure any amplifier, regardless of make or model and effectively emulate its performance by means of complex simulation. Effectively, the Kemper Profiler is not just an amplifier, but rather an entire guitar rig in a single system, complete with amplifier circuitry, effects pedals, cabinet impulse responses, speaker performance, along with the characteristics of whatever microphone(s) might be used for the profiling process. While some testing was performed with regard to the profiling process and introducing guitar effect processors in the signal chain, information about the performance of the unit under such conditions remains purely subjective. It is also worth noting that the user manual specifically warns the user that the profiling software might fall short of user expectations for certain effects processors, especially those that rely on advanced processing such as temporal processors like delay and reverberation effects. One might better ascertain the Kemper Profiler's performance with external effects pedals after further testing.

In the end, the Kemper Profile remains a valuable and practical tool for professional musicians and hobbyists alike that is more than capable of producing results whose quality performance is nothing short of intimidating. Digital amplifier modeling has come a long way since the primitive solid-sate models of the 1980's and 90's. The complex algorithms of the profiling process allow a user to access any number of amplifiers that previously might have been cost prohibitive for a user to own and maintain. Its ease of use is no doubt a boon to not only studio applications but professional touring musicians as well. However whether or not it is a viable replacement for the real tube amplifiers around which the profiles saved to its memory are built is ultimately up to the user, though there is certainly an obvious benefit from ease of use and lack of maintenance and consistent performance. Surely its user-base will only grow, and new iterations of the profiling software will only improve its performance such that it may one day replace the tube hardware on which it is based.

Anecdotally, the owner of the Kemper Profiler unit tested for the purposes of this discussion lost tens over a hundred thousand dollars in equipment in a house fire, including a collection of valuable classic tube amplifiers. If the opinions of professional working musicians tell us anything about the quality of the hardware, the fact that said individual chose to purchase a single Kemper Profiler system in lieu of replacing a number of tube amplifiers should be quite telling.

REFERENCES

[1] Santo, Brian "Volume cranked up in amp debate"

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[2] Rutt, T.E. "Vacuum Tube Triode Nonlinearity as Part of The Electric Guitar Sound", AES 76th Convention, October 8-11 1984.

[3] Schmitz, Th. Embrechts, J.J. "Nonlinear guitar loudspeaker simulation", AES 134th Convention, May 4-7 2013.

[4] Li, Shengchao "Why do tube amplifiers have fat sound while solid state amplifiers don't", AES 131st Convention, October 20-23 2011.

[5] Collins, Scott "Christoph Kemper of Kemper Amps Talks About Their New Profiling Amps" http://www.guitar-muse.com/kemper-profiling-amp-2949-2949

[6] Martin, Bryan "Gain stage management in Classic Guitar Amplifier Circuits", AES 135th Convention, October 17-20 2013.

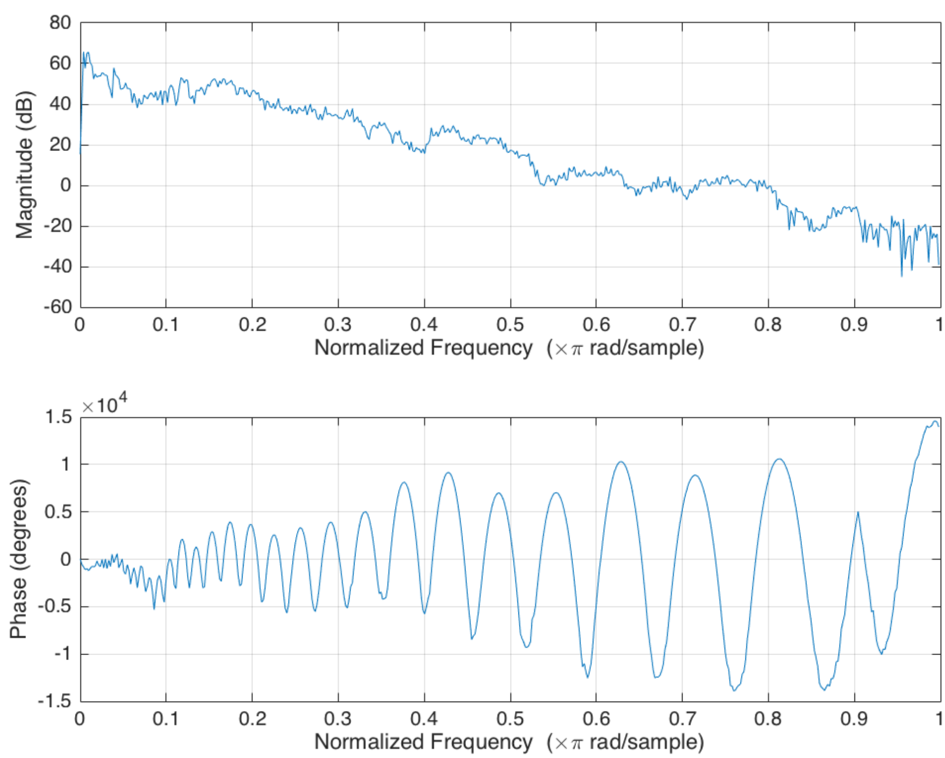
[7] Martens, William L, Marui, Atsushi. "Multidimensional Perceptual Scaling of Tone Color Variation in Three Modeled Guitar Amplifiers"

[8] Kemper Profiler "The Deeper View & Reference Manual 4.2"

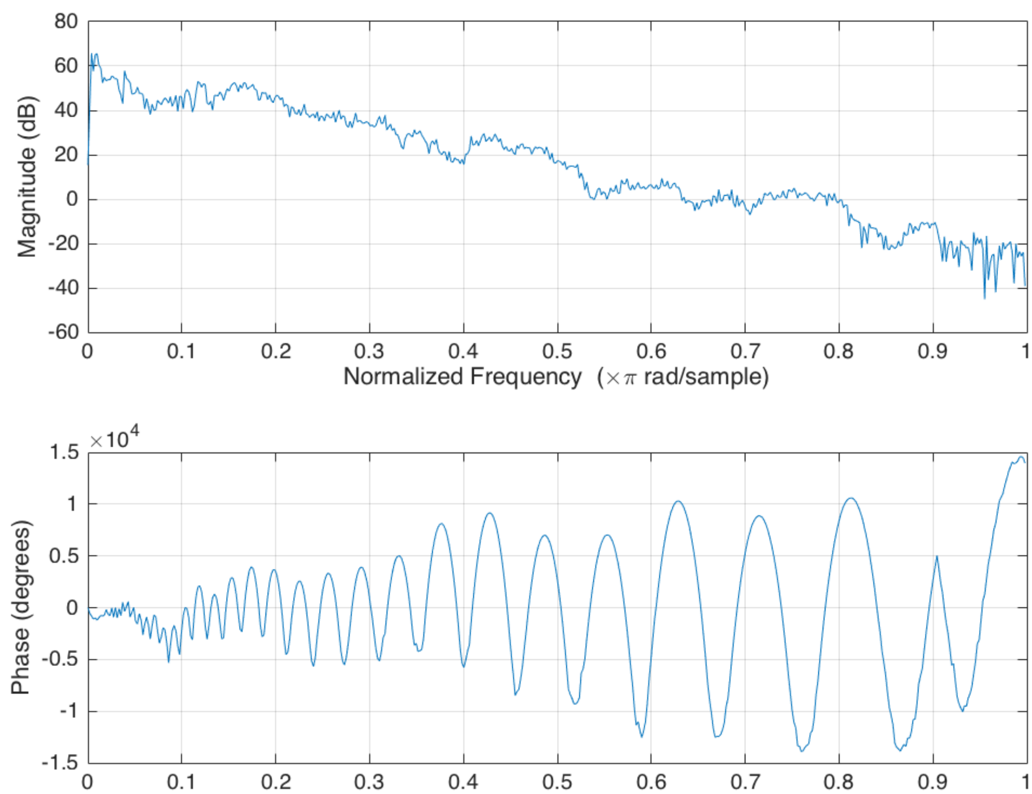
[9] Kemper Profiler "The Basics and Profiling Guide 2013"

APPENDIX

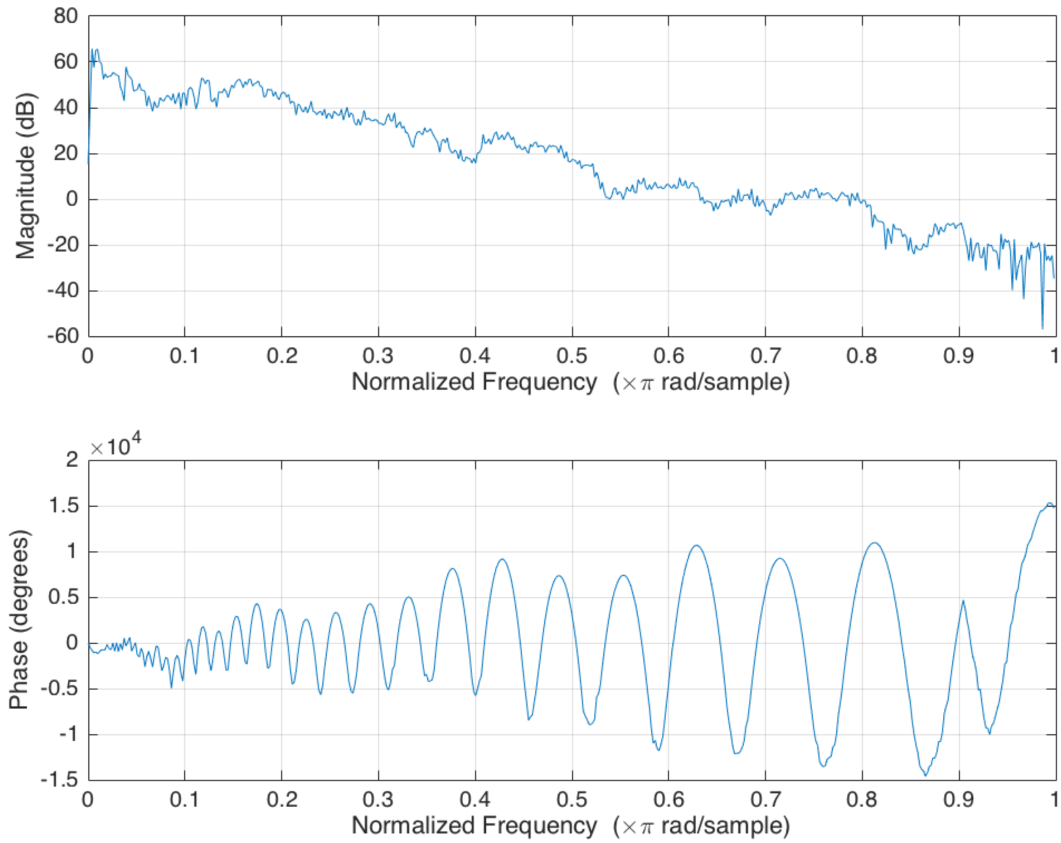
Amplifier 5w “NORMAL” – Frequency Response



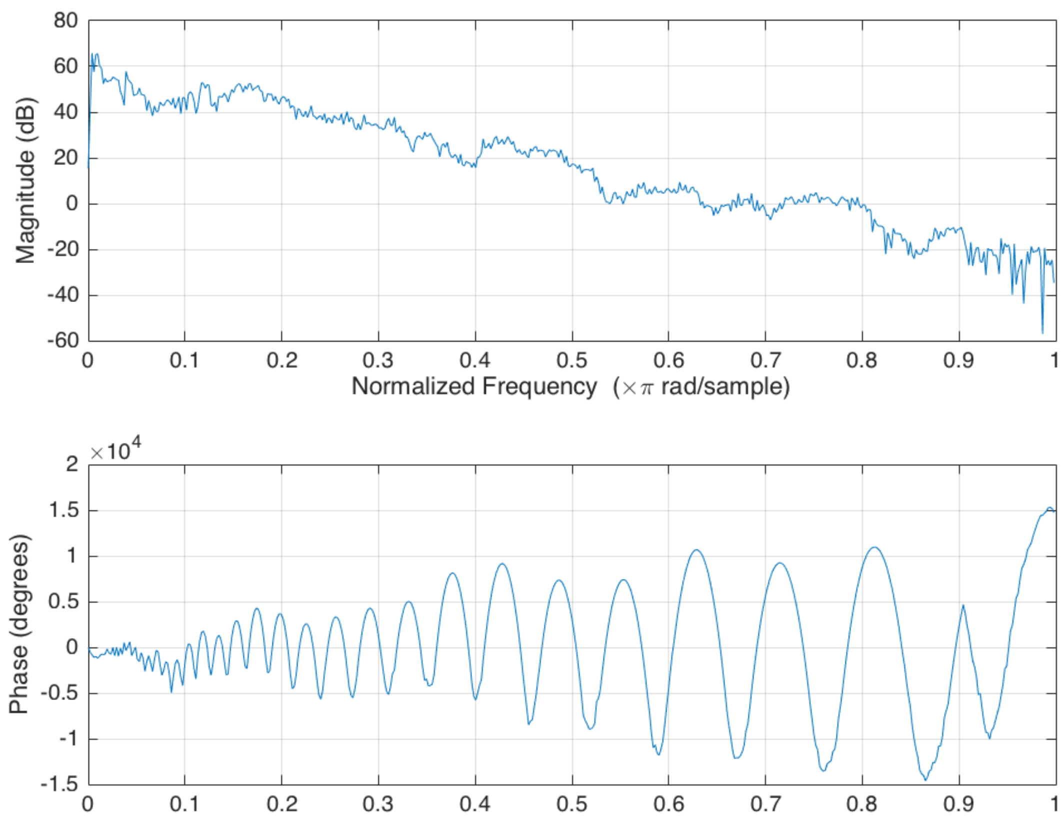
Direct 5w “NORMAL” – Frequency Response



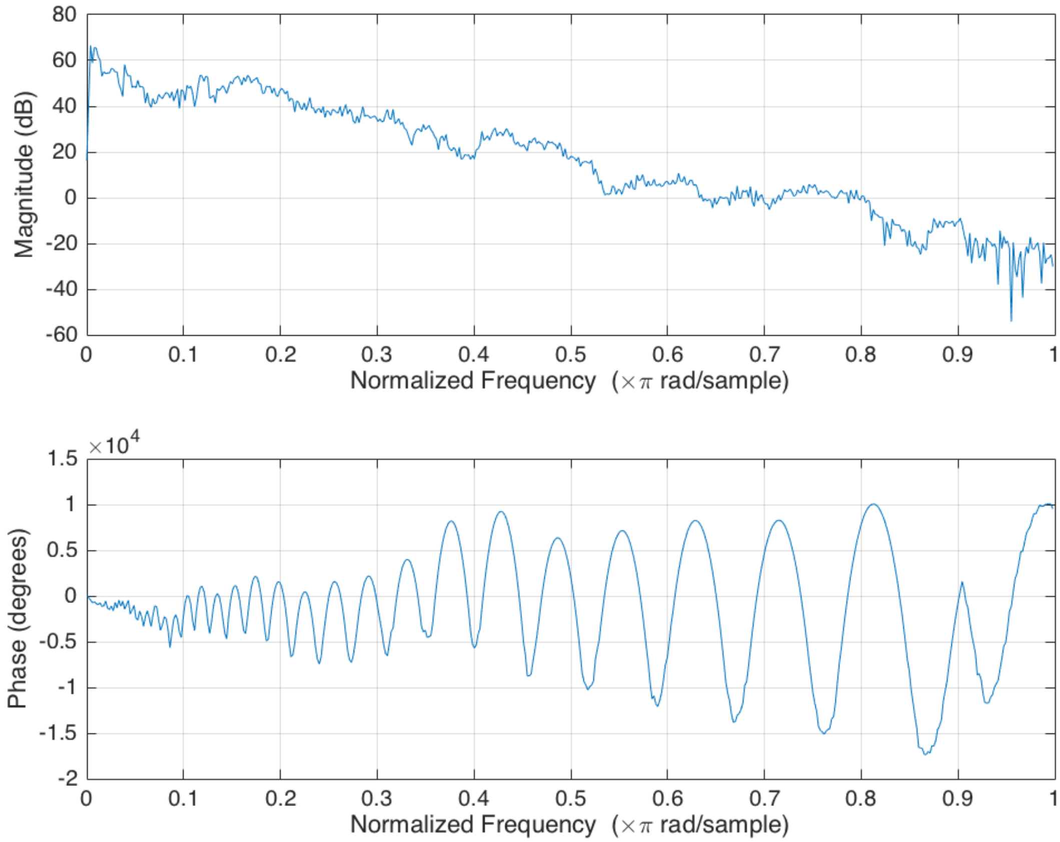
Amplifier 15w “NORMAL” – Frequency Response



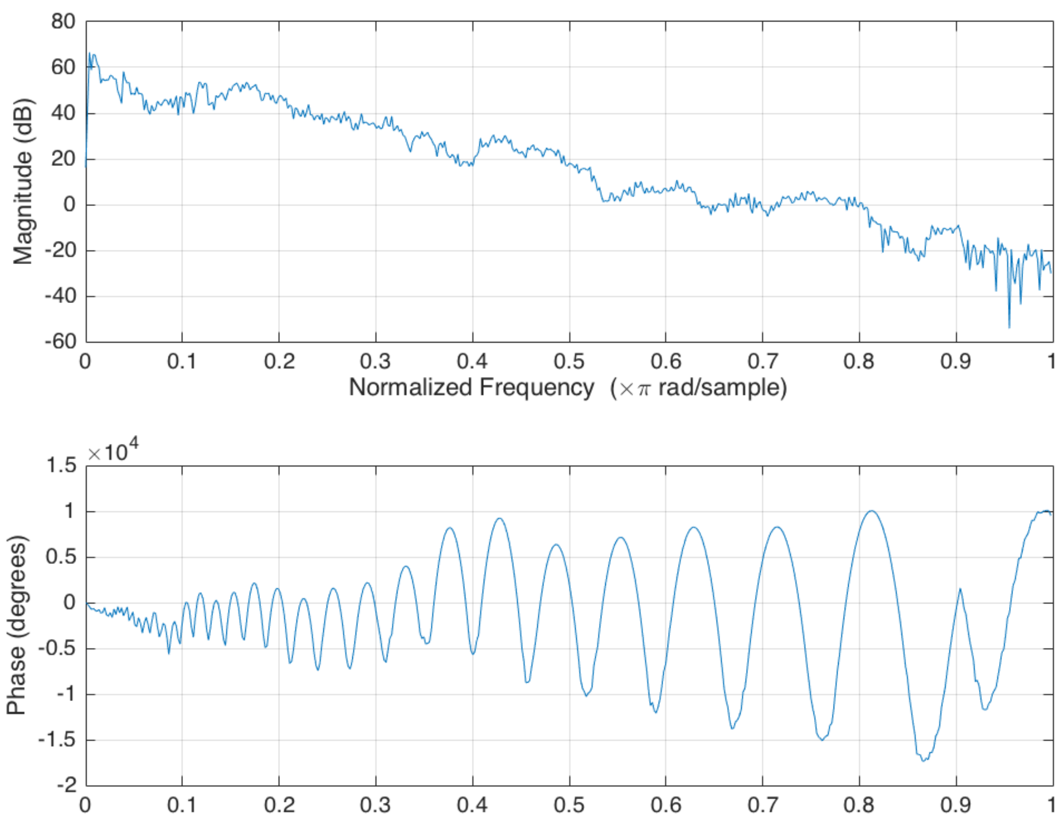
Direct 15w “NORMAL” – Frequency Response



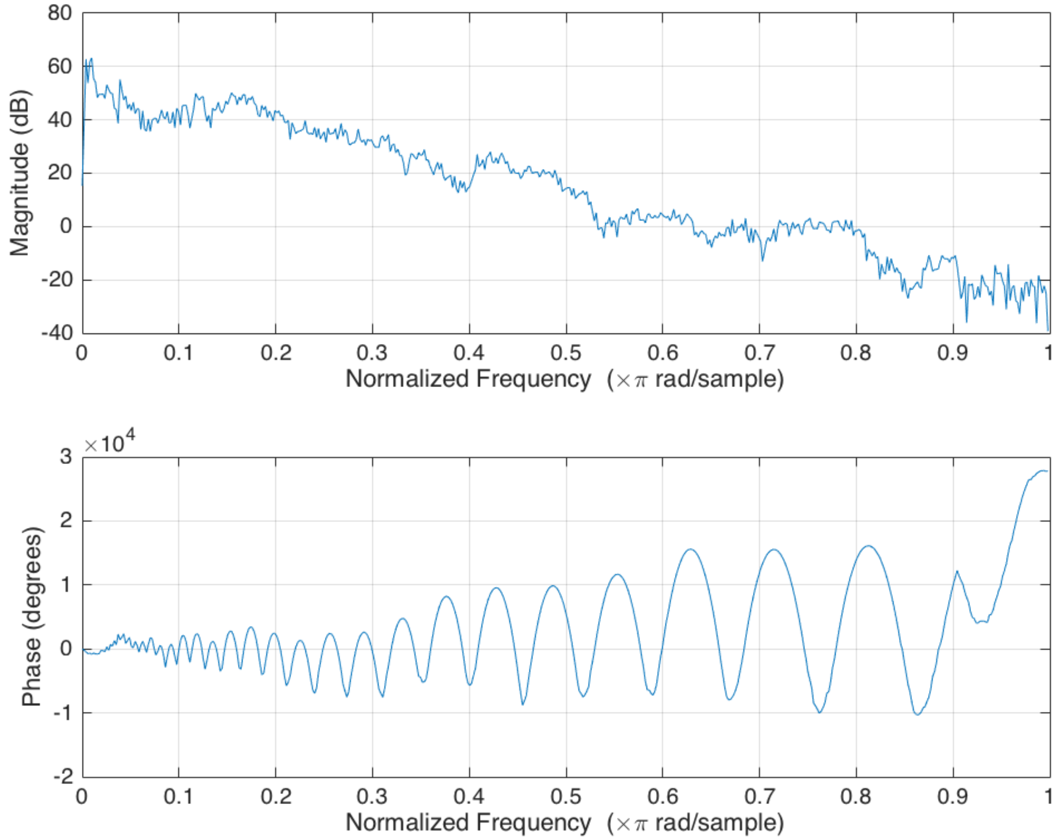
Amplifier 30w “NORMAL” – Frequency Response



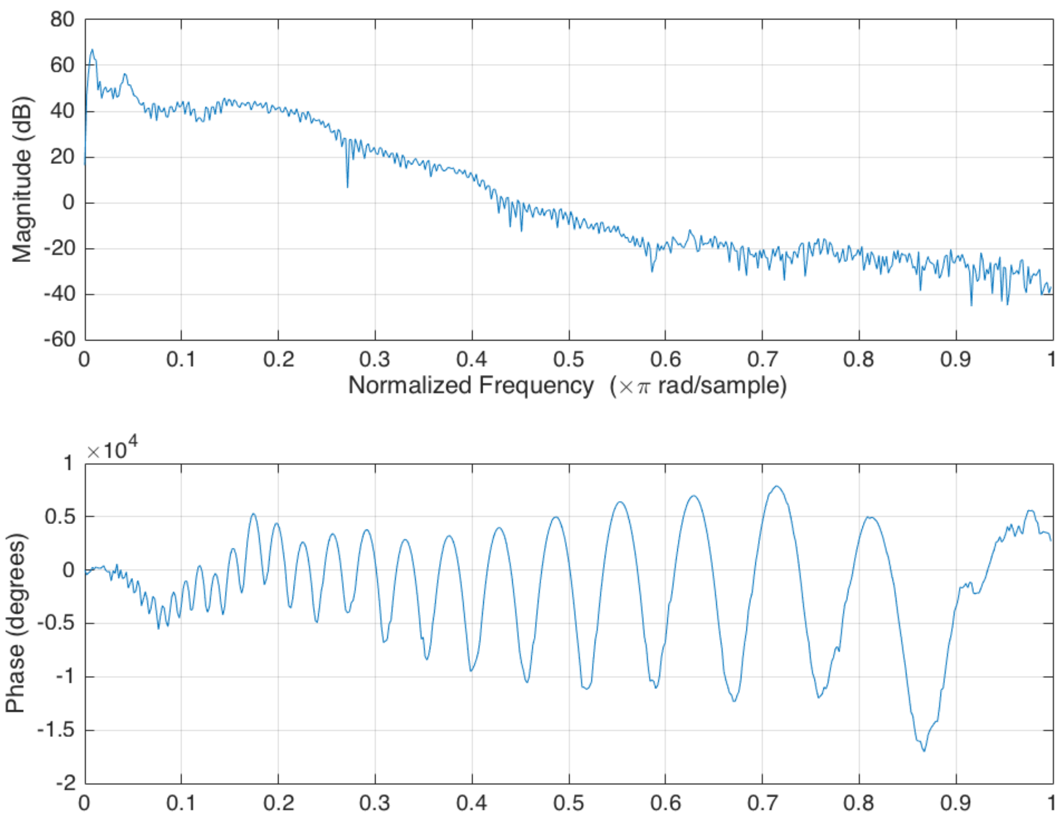
Direct 30w “NORMAL” – Frequency Response



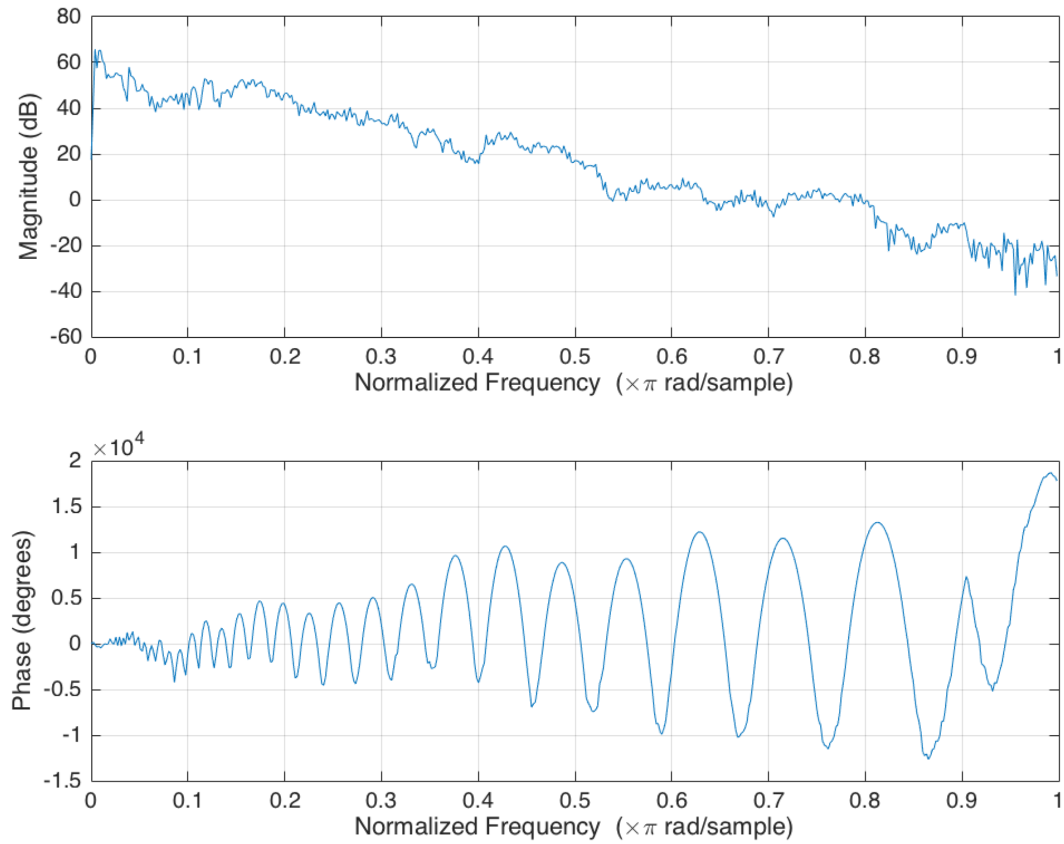
Amplifier 5w "PUSHED" – Frequency Response



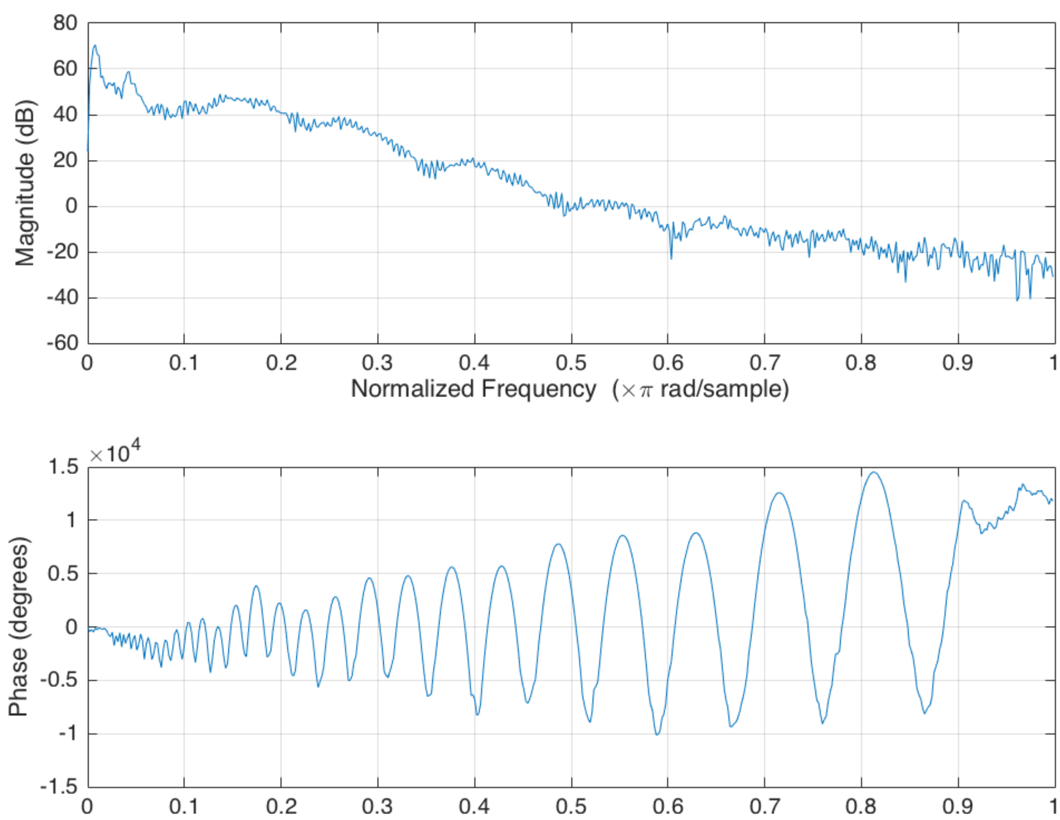
Direct 5w "PUSHED" – Frequency Response



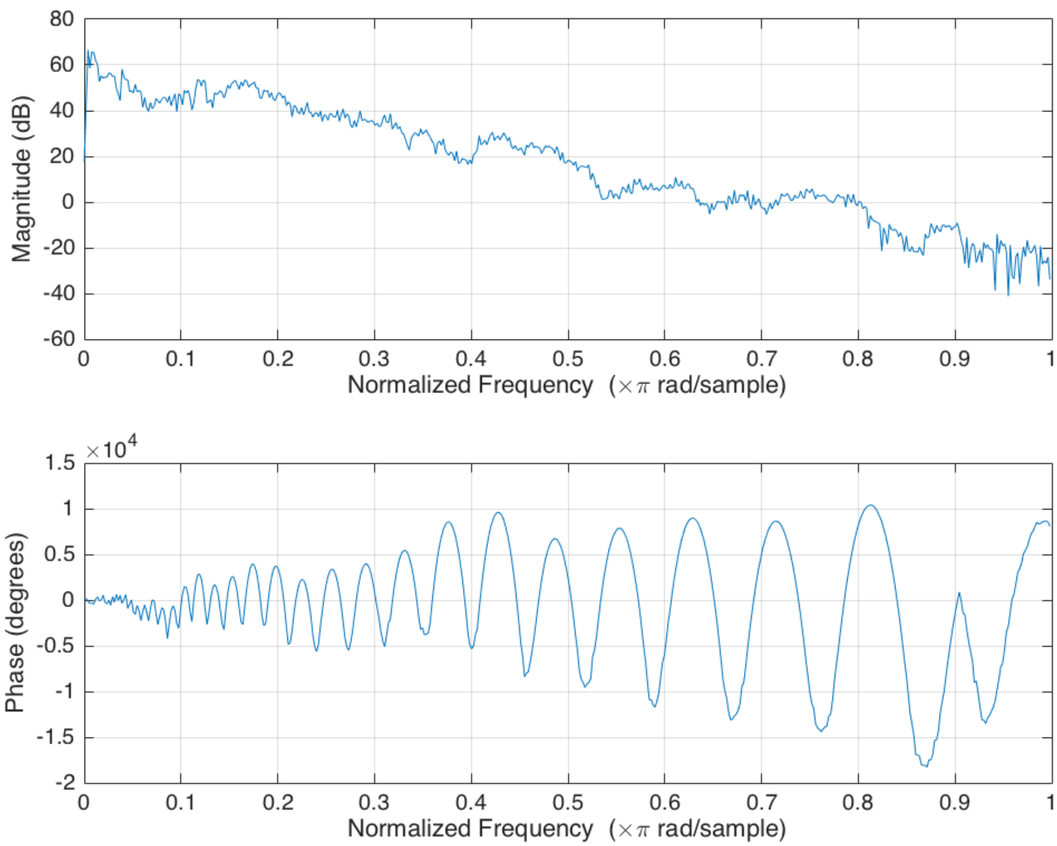
Amplifier 15w "PUSHED" – Frequency Response



Direct 15w "PUSHED" – Frequency Response



Amplifier 30w "PUSHED" – Frequency Response



Direct 30w "PUSHED" – Frequency Response