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Advanced Musical Acoustics
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Formal Proposal: Directivity Analysis of Electric Guitar Amplifier Radiation Characteristics

The inspiration for this project derived from the well-written text, Tonmeister Technology by Michael Dickreiter. In this book, frequency dependant radiating characteristics are illustrated for most of the common orchestral instruments (as shown on pages 28 [fig. E], 34 [fig. E], 46 [fig C.], etc.). These radiating characteristics, also simply known as directivity, show the relative strength at a particular angle of a certain frequency emanating from the instrument. Directivity, therefore, is neither dependent on the notes played by the instrument nor dependant on the overall frequency response of the instrument. By referring to such diagrams, a recording engineer can acquire a starting point in determining the microphone placement for a particular instrument. Dickreiter's illustrations allow an engineer to knowledgeably select an area in which to place the microphone that will best capture the frequencies for the desired tonality of the instrument to be recorded. One modern limitation of these fine diagrams is their omission of radiating patterns for popular instruments such as the bass and guitar amplifier. While basic radiating characteristics for speakers are presumably well known (sources yet to be uncovered), I became interested in the specific radiating patterns of guitar amplifiers. Guitar amplifiers, especially small combo units preferred in most recording situations, have unique qualities differentiating their construction from typical speaker cabinets. For example, an open-back design, the nearness of speaker housing to the amplifier, the overly heavy-duty cabinet wood for durability, etc. are all qualities found almost solely in guitar combo amps. The question arises, therefore, as to how these different factors affect speaker directivity. While this question, the "why" of directivity, must be left unanswered by this project, I wish to address the "what" of directivity for small combo guitar amplifiers, i.e. what is the basic directivity response in the audible spectrum with these unique speaker cabinets. The results from such an experiment will be a polar plot for each frequency of analysis plotting the directivity of that frequency for the amplifier under study.

In and effort to produce spectrum radiation patterns of similar quality to those in Dickreiter's text, I consulted the source from which these illustrations derived, Jurgen Meyer's Acoustics and the Performance of Music (translated from the German). Starting on page 75, Meyer's chapter is devoted to "Directional Characteristics of Musical Instruments." Since no mention of the means of experimentation is made, I was happy to find some scientific method in Meyer's publication. In describing his methodology, Meyer says, "the measurements required for this purpose have been carried out in an anechoic room, with a microphone distance of 3.5 meters." (Meyer 75). After completing the experiments, sound pressure data was organized into shaded lines-of-equal-amplitude polar plots, with denominations for within 3 decibels of loss (half the power), under 10 decibels of loss (half the perceived loudness), and greater than 10 decibels of sound attenuation. As it turns out, the diagrams in the Tonmeister Technology text were compiled from the data within 3 decibels of loss. Further information on Meyer's scientific process was unavailable and most references unattainable (as the books were German publications).

The experiments for this project obviously cannot be conducted under the same exacting tolerances used by Meyer. For one thing, I do not have access to an anechoic chamber nor a room capable of sustaining a microphone distance of 3.5 meters without capturing too much diffuse sound. Fortunately, smaller microphone distances have been used in similar studies (Nakashima 2502), although still at distance of 2 meters. I plan to position the microphone between 1 and 3 feet away from the speaker, the exact distance depending on some preliminary tests. Instead of rotating the microphone around the speaker, I will instead do the opposite: rotate the guitar cabinet with respect to the microphone while preserving the same distance of the guitar cabinet to the microphone. In other words, a microphone will be placed at point A in a room and the guitar cabinet placed at a point B 1-3 feet away from point A; the guitar cabinet will then be rotated with each test on axis with point B as the center. Through this method, I hope to cut down room tone as a changing factor with angle. Obviously, diffuse sound will color (pun intended) the results by adding a constant amount of reflected sound at certain frequencies. Closer microphone working distances will of course reveal greater variations in sound pressure with different speaker angles. The speaker cabinet will be rotated throughout 360 degrees with respect to the microphone. To more fully test complete, three-dimensional directivity, I hope to rotate the cabinet through three axes: 1) the rotation which includes front, back, and sides; 2) the rotation which includes front, back, top, and bottom; and 3) the rotation which includes top, bottom, and sides. While the diagrams in Dickreiter's text almost all examine directivity through only one axis of rotation, a more three-dimensional approach seems appropriate since the speaker is radiating in a three-dimensional space and can be mic-ed from any angle. For angles of investigation, most sources recommend increments of just 10 degrees (Nakashima 2501). Some successful directivity analyses have been conducted using much larger differences between microphone position, on the order of 22.5 degrees (Otcenasek 1330). I hope to conduct my experiments with angle gradations of 10 degrees, but may be forced to use larger gradations (as 36 angle positions for three axes of rotation equals 108 sounds to analyze for each frequency). The frequencies of analysis will also hopefully numerous, derived from the basic range of the electric guitar. As 80 Hz corresponds to the lowest E on the guitar, I will start my analysis at 100 Hz (all scientific directivity tests have been traditionally conducted at even frequencies, not those particularly related to the instrument, presumably for ease of notation and organization). The frequency bands, possibly 24 in number, will continue upward, scaled slightly to take into account the logarithmic relation of Hertz to octaves.

The only questions left to answer with the research are practical ones, specifically, what kind of tones (chords, sine waves, single notes, etc.) should be fed through the guitar amplifier and what kind of software available at NYU can be used to analyze the frequency response. I noticed that a master's thesis by Weon-Bae Kim investigating the frequency response of Korean instruments was available at the library. I hoped that similar previous work would get me started on the best path to solving such questions. Unfortunately, I cannot stand by the value of this work and thus must solve these problems myself. Kim's thesis is fraught with extremely unintelligible English (at least one grammar mistake in every other sentence), a preliminary roadblock to its utility. But moreover, the scientific method is loosely rigorous at best. Only seven microphone positions are used for each instrument, and these microphone positions are analyzed on the basis of seven different takes by a human performer (apparently no access to a multi-track or seven "Noeman" (sic) KM184 microphones). Anyway, the importance of having each take exactly the same for a different microphone position is paramount. When testing the directivity of a French Horn, previous acousticians have gone so far as to play the instrument with an electric oscillator connected to an amplifier attached to a Western Electric 555 brass conical adapter (Martin 310). Since I will determine the frequency bands of analysis prior to the experiment, I will play sine tones (at the frequency of interest) through the guitar amplifier instead of guitar notes. While the possibility exists for differences in directivity for sine tones through a speaker as compared to guitar notes, I doubt much practical deviation would be seen. At least that is the premise upon which I will base my experiments. Such a premise will streamline the experiment and make the results more defendable since no frequency analysis software needs to be used. I can simply measure the relative decibel strength of each tone as it relates to microphone position and plot these decibel readings straight to the polar pattern (with everything normalled to zero degree level).

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