THE ROTARY LOUDSPEAKER EFFECT

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Abstract

Throughout this review I will be analysing detail about the rotary loudspeaker effect. Looking at its original analogue form, and the way in which we can emulate this effect with a digital audio system.

Introduction

A rotary loudspeaker effect is designed to simulate the effect from rotating speakers and a rotating bass drum. Originally this kind of effect was designed for organs, and used in amplifiers. This was known as the Leslie amplifier. Figure 1 shows an example of a rotating loudspeaker (Leslie amplifier)

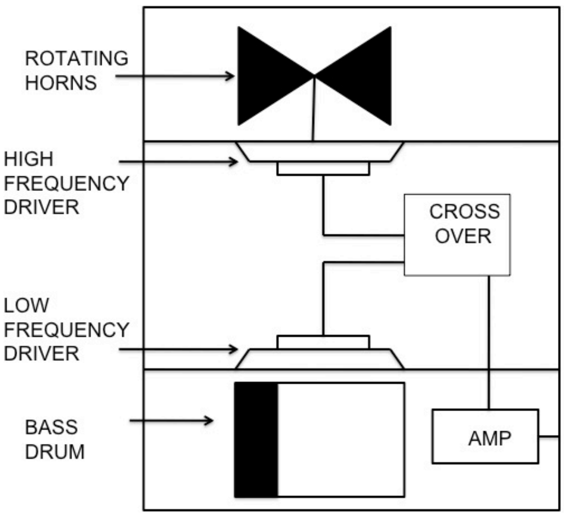

Figure 1. A Diagram of a Leslie rotating speaker amplifier

1 Rotary speaker overview

Traditional rotary loudspeaker systems were created with a pair of horns producing the high frequencies, facing 180 degrees to each other on a rotating driver. The low frequencies are then fed to a bass drum on a separate driver below (see fig. 1). The amp had two rotation speeds, choral and tremolo, they spin at speeds of 15-120 rpm and 300-498 rpm. The faster the horns spin the quicker pitch fluctuations occur, meaning that at high speeds the signal fed in to system has higher pitch, and the opposite occurs at lower speeds. It is possible to switch between these speeds during a performance [1].

2. The Doppler effect

Put simply the Doppler effect is creating pitch fluctuations around a listener. This effect can be heard in every day life. An example of the Doppler effect fig. 2 shows the effect as a car moves past a stationary subject.

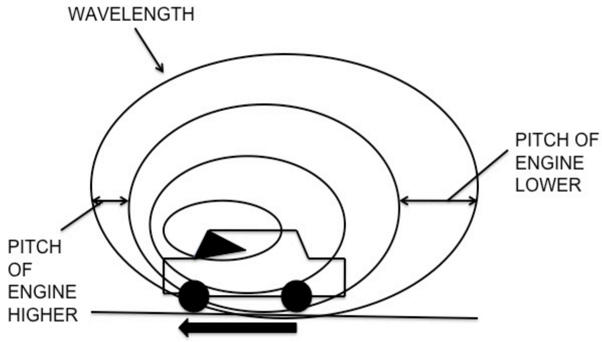

Figure 2. Doppler effect of car engine noise

With this figure we can see as the car is approaching the subject the pitch of the sound is higher in frequency and as it moves away the sound is lower in pitch. This is achieved by the fact that the sound source is moving towards the subject, therefore each sound wave that is produced by the sources takes slightly less time to reach the subject. Meaning as it gets closer and closer the time between each wave reaching the subject is reduced causing an increase in pitch. The reverse of this effect is happening as the source moves away from the subject. [2]
The Doppler shift is given by

$$\omega_l = \omega_s \frac{1+\frac{\upsilon ls}{c}}{1-\frac{\upsilon s,l}{c}}$$

[6]

"Where ω_s is the radian frequency emitted by the source at rest, ω_l is the frequency received by the listener, υls denotes the speed of the listener relative to the propagation medium in the direction of the source, $\upsilon s,l$ denotes the speed of the source relative to the propagation medium in the direction of the listener, and **c** denotes sound speed. Note that all quantities in this formula are scalars."[6]

1.3 Doppler effect of rotating horn speaker

The rotary loudspeaker creates this same Doppler effect with the horns as they spin cyclically. As the horns spin the sound waves reflect on the interior surface of the cabinet, this means these reflections experience their own Doppler effect before creating secondary reflections on to other surfaces. The sound that is emanating from the cabinet to the subject (listener or microphone) is a combination of the horns direct signal and the many reflections from within the cabinet. The spinning horns also produce amplitude and frequency response variations throughout there rotations, meaning when the horn is facing the subject it will be loudest and brightest, and as it faces away it gets softer and duller [3]. This effect is called amplitude modulation. By moving closer to the rotating speaker, the inverse square law will increase the modulation effect. [4]

1.4 Creating Rotary Algorithms

Before we can create a rotating speaker effect we first need to understand what is modulation? U. Zölzer states, "Modulation is the process by which parameters of a sinusoidal signal (amplitude, frequency and phase) are modified or varied by an audio signal"[5]. This means modulation is used to shift the frequency of an audio signal. Effects such as tremolo or a Wah-wah are examples of amplitude modulation and a chorus or vibrato are examples of phase modulation. [5]

To create a rotating speaker effect you need a combination of both amplitude modulation and delay line modulation. In figure 3 below, which is showing the simulation of a rotating dual speaker, you can see how the simulation has created pitch modifications by using a modulated delay line, and has used amplitude modulation for the intensity modifications. To simulate the Doppler effect of the two horns two delay lines using modulated 180-degree phase shifted signals in vibrato configurations have to be implemented. To create the directional characteristic of the rotating speakers an amplitude modulation of the output signal of the delay lines must take place. The amplitude and delay line modulation occur at the same time, such that as explained in the previous section, the horn facing the front appears higher in pitch, and as it moves to rear the pitch lowers and the amplitude is lowered. A stereo rotary effect seems to be created due to the unequal mixing of the two delay lines being sent to the left and right output channels. [5]

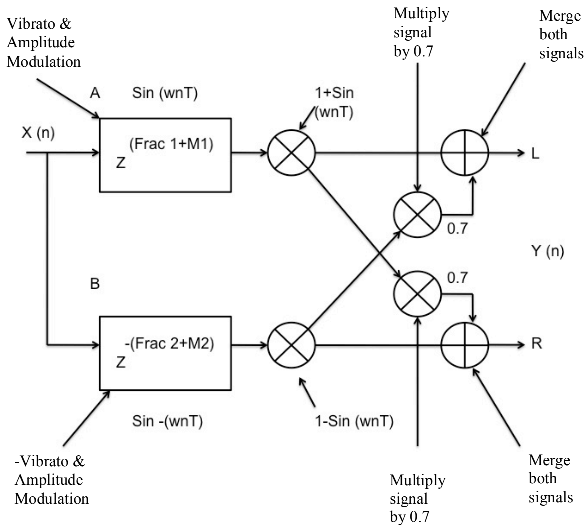

Figure 3.Simulation of rotating speakers [1]

Once this simulation of rotating speakers has been created the next step is the different speeds that a rotating speaker is capable of producing. To simulate this a ramp signal must be applied to a voltage-controlled oscillator (VCO) to change the rotational frequencies. Due to the fact there is a bass drum rotating as well as the rotating horns, the signal must be split to send low frequencies to the drum and highs to the horns. To complete this the signal must be split and a low and high pass filter must be setup and these two portions must be processed separately. Below in Fig. 4 we can see the entire application. [1]

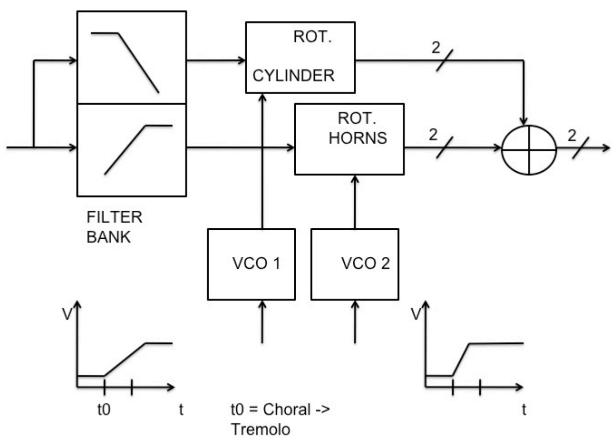

Figure 4. Rotary Speaker Simulation [1]

1.5 Musical Applications

As mentioned earlier the classic use of this rotating speaker effect is for organs such as the Hammond, Wurlitzer and Baldwin. However it has been taken from its intended use to create effects for electric guitars, bass's and even vocals on occasion. Depending on the application this effect can be thought of differently. If it is used with a voice it can be perceived as a rotating microphone in between two loudspeakers, or even as if the subject is sitting on a rotating object and passing two loudspeakers. An artist who was a major contributor to the popularity of this sound was Jimmy smith, his cover of “When I grow to old to dream” by Sigmund Romberg and Oscar Hammerstein II is a classic example of a Hammond organ and a Leslie speaker cabinet. Examples of this effect on a guitar can be found on Stevie ray Vaughan’s “cold shot”, or Jimi Hendrix’s “little wing”.

Conclusion

In this review I talked about the rotary loudspeaker. I showed examples of the traditional analogue effect and what it did, then moved on to the creation of a digitally modeled version. As is the case with many digital audio systems a number of techniques had to be implemented to create this effect such as modulation with delay and filters added. These types of effects are common in many of the audio effects in the world today, both digitally and in the real world. The rotary loudspeaker has had countless uses in modern music and I believe with the advent of digital audio systems and creating digital copies of this effect it will continue to be used for a very long time to come.

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