Amplitude Modulation and Dynamic Processing

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All information in this paper comes from the work of Reiss and McPherson [1].

Introduction

This report will focus on two related kinds of effects. Those which modulate the amplitude of the signal periodically and those which modulate the amplitude of the signal in a way which depends on the amplitude of the signal. The first category generally results in a very noticeable effect. Two examples of this which will be explored in this report are tremelo and ring modulation. The effect from the second category which will be explored is compression.

Tremelo

Tremelo is a very straight forward effect. Basically the amplitude of the signal is multiplied by a local oscillator (LFO) to add a swelling and fading sound to the output of the instrument. This effect was commonly used in the surf music of the sixties. Tremelo was even built into some guitar amplifiers from that era. This was commonly achieved by creating an LFO with a vacuum tube triode which would power a small light bulb coupled to a photo-resistor which was part of a voltage devision circuit. In a less common version of the effect involved connecting the LFO to the bias circuit of a tube, either in the preamp or the power amp, in the signal path of the amplifier and is known as a bias shifting tremelo.

Achieving a tremelo effect digitally is very simple. The difference equation is shown in Eq 1.

$$y[n] = m[n]x[n] \tag{1}$$

$$m[n] = 1 + \alpha cos(\omega_{LFO} n) \tag{2}$$

Where m[n] represents the LFO as expressed in Eq 2 with α representing the variable depth of the tremelo. The cosine function in Eq 2 is the most common

LFO function but triangle, saw-tooth, and square wave functions can also be used for different sounds.

Ring Modulation

Tremelo is perceived as a rhythmic change in amplitude because the LFO for tremelo is set below 10-20 Hz. This is because the human ear cannot perceive sounds below about 20Hz. By raising the frequency of the LFO beyond this perception cutoff the effect begins to be perceived to affect the timbre of the sound rather than the amplitude. This is called ring modulation and can be achieved using the same difference equation Eq 2 and with a slight modification to m[n] shown in Eq 3. Ring modulation is hard to use and uncommon in traditional music. It is fairly easy to imagine why. Multiplication of two frequencies results in a sum and a difference of the two frequencies. When the LFO frequency is set there are very few frequencies which, when summed and differenced with the LFO, will result in a sound that harmonizes with the rest of the piece. Ring modulation is sometimes used in experimental or psychedelic music and famously used in scoring for sci-fi movies.

$$m[n] = cos(\omega_c n) \tag{3}$$

Dynamic Range Compression

Compression is a vital effect for making guitar and music in general sound good. It's often describe as something you don't notice when it's there but you'll miss when it's gone. Basically compression applies a variable gain to a signal to control the dynamic range of the signal. If the signal's amplitude is under a given threshold then the gain is 0 dB, if the amplitude is greater the gain will be less than 0 dB. In order to implement a compressor digitally there are two basic processes which must occur. The gain must be calculated then applied. The application of the gain is a simple multiplication process. The calculation of the gain is more complicated and there are many ways to achieve a working result. A simple and common equation for the gain computer is shown in Eq 4. Where $y_G$is the gain, T is the threshold, x_G is input gain, and R is the compression ratio. This equation is applied when the peak amplitude of the input to the gain computer is above the threshold as determined by a simple peak detector. The gain computer can take either the input or the output signal to the effect to create either a feed-forward or a feedback configuration respectively.

$$y_G = T + (x_G - T)/R \tag{4}$$

Conclusion

The three effects discussed in this report span the spectrum of frequency of use. Dynamic range compression is ubiquitous in modern music, tremelo is moderately common and not too hard to find if you look for it, and ring modulation is so rare in music you'd have to find either an experimental musician or a specific film soundtrack to hear it. The common thread in these effects is that the real effect is a simple multiplication to adjust the amplitude of the signal but how that gain is calculated varies.

References

[1] Reiss, Joshua D., and Andrew McPherson. Audio effects: theory, implementation and application. CRC Press, 2014.