DELAYS; VIBRATO

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ABSTRACT

For both common people and those in the audio industry, audio effects are mostly described and illustrated for their acoustical effect. For the professionals in the field, audio effects can also be categorized from a technical point of view, and described as mathematical functions. The main criteria are what type of modulation techniques are used to achieve the effects desired. After an introduction to the basic delay structures a more sophisticated delay based audio effect is presented, the Vibrato with a brief discussion of its differences compared to the Tremolo effect and its relationship with the Chorus effect.

1. INTRODUCTION

BASIC DELAY STRUCTURES

In day a day life Delays can be experienced in built spaces, the reflectance of the audio wave in close or fall walls within a room, the distance and disposition of this boundaries determine the delay imposed to the reflected sound waves. Imitations of these acoustical phenomena are implemented as signal processing units. Technically a Delay is an audio effect which records an input signal to an audio storage medium, and then plays it back after a period of time [1]. Imitations of these acoustical phenomena are implemented as signal processing units.

Delays, just like filters are the source of the majority of the useful musical effects over the audio signals. In the case of the filters, the repeated application of delays, allow us to obtain a direct effect upon the sound domain, through the manipulation of the sample's values in different ways.

1.1. ANALOG DELAY

Before digital audio Delay technology, musicians and engineers had to record in a naturally reverberant space in order to achieve a delayed echo, usually inconvenient for those involved in the process. However, the popularity of the real time echo effect, leaded the industry to the development of patents able to deliver all in one effects units that could produce echoes of any interval or amplitude.

These systems were pretty similar to conventional tape recorders, just bigger and with several heads. Their recording and playing medium was usually magnetic tape and was looped through the system by electric motors. The presence of multiple heads would give the system the possibilities to erase, record and have several replays at the same time.
The modification of the effect´s parameters would depend on the mechanism itself, in popular models such as the Echoplex EP-2 the play head was fixed and a combined head for both record and erase, was mounted on the side, therefore the delay time of the eco could be adjusted by changing the distance between the recorded and played head.

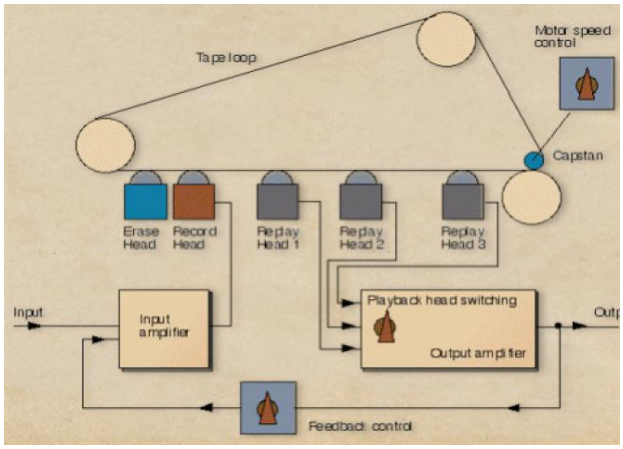

Fig 1. Analog tape delay.

The thin magnetic tape that operated in these devices was a disadvantage since was not completely suitable for continuous operation, so in order to maintain the audio fidelity of the processed sounds it was required to be replaced from time to time. Further attempts to improve the medium´s storage included the magnetic drums and analog bucket brigade delay circuits.

1.2. DIGITAL DELAY

Digital delay systems function by sampling the input signal through an analog to digital converter, afterwards the signal in passed through a series of digital signal processors that record it into a storage buffer and then play back the stored audio signal based on parameters set by the user.

Within the digital audio effects domain, the signal can be seen as a set of partials having different frequencies and amplitudes; the distance between the boundaries determines the delay that is imposed to each reflected sound wave (1), specializing these phenomena into diverse signal processing units.

$$y[n]= x[n-1]$$
$$y[n]= x[n] \qquad (1)$$

1.2.1 FIR Filters

FIR stands for Finite impulse response, this means it is a filter whose impulse response (or response to any finite length input) is of finite duration, because it settles to zero in finite time. Here, the input signal is delayed by a given time duration. The effect will become evident only when the processed signal is mixed to the input signal, which is acting as a reference. This effect has, **2** parameters for its modulation: the quantity of time delay ***T*** and the relative amplitude of the delayed signal to that of the reference signal.

The network that simulates a single delay is called the FIR comb filter. Just like acoustical delays, the FIR comb filter has an effect both in the time. The time response of this filter is made up of the direct signal and the delayed version.

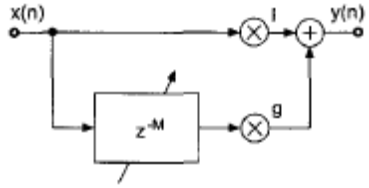

Fig 2. FIR System

1.2.2 IIR Filters

IIR stands for Infinite impulse response, If we keep on varying periodically the time delay we will produce a periodical pitch variation. Due to the feedback loop, the time response of the filter is infinite and the signal will increase in amplitude, and eventually feeding back growing endlessly. However if the gain is less than 1 then the signal eventually fades cause with each loop in the circuit the signal loses amplitude.

Each time the signal goes through the delay line it is attenuated by ***g.*** It is sometimes necessary to scale the input signal by *c* in order to compensate for the high amplification produced by the structure [3].

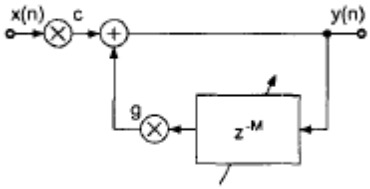

Fig 3. IIR System

1.2.2.3 FIR VS IIR Comb Filters

The only differences between FIR comb filters and IIR filters are that FIR delivers one rotation of the wavelength whereas the IIR are continuous and keep on going forever. In IIR the gain grows very high and that the frequency peaks get narrower as "g" comes closer to 1.

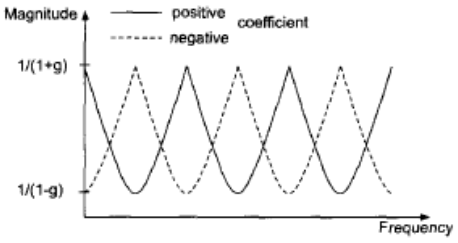

Fig 4. IIR Magnitude Response

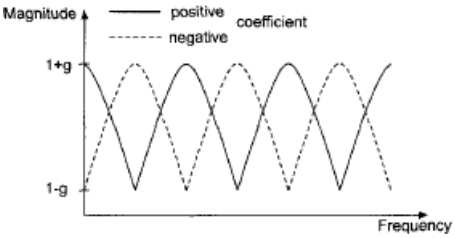

Fig 5. FIR Magnitude Response

FIR filters have several useful properties which sometimes make it more desirable than its counterpart infinite impulse response (IIR) filter. FIR filters:

They require no feedback; any rounding errors are not gathered by summed iterations, the same relative error happens each time, making implementation simpler. They actually are stable; since they don't require feedback, the poles are located within the unit circle. They can easily be designed to be linear phase by making the coefficient sequence symmetric; linear phase, or phase change proportional to frequency, corresponds to equal delay at all frequencies [2].

A disadvantage of FIR filters is the more computation power in a general purpose processor is required compared to an IIR filter with similar sharpness or selectivity, especially when low frequency (relative to the sample rate) cutoffs are needed.

2. VIBRATO

Vibrato is a delay based audio effect which consists of the regular, periodic change of the pitch (frequency). In the practice, Vibrato effect is a delay application which is produced by modulating either the phase or the frequency of an audio frequency signal. Its effect is perceived as a ringing of the audio signal and it's quite pleasant to the ear.

For instance, by varying periodically the time delay produce a periodical pitch variation. This is precisely a vibrato effect. For that, a delay line and a low-frequency oscillator are needed to drive the delay time parameter. One should only listen to the delayed signal.
Typical values of the parameters are 5 to 10ms as average delay-time and 5 to 14 **Hz** rate for the low-frequency oscillator.

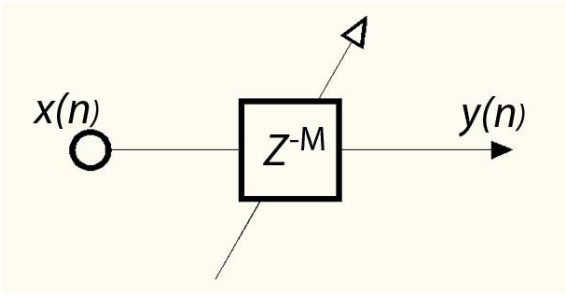

Fig 6. Basic Vibrato System

2.1. Vibrato VS Tremolo

The effects of Vibrato and tremolo are frequently confused and used indistinctly, though they are different effects. Vibrato functions as a periodic variation of the pitch (frequency), a fluctuation of the frequency applied to a sound of constant amplitude. Tremolo is a fluctuation of amplitude applied to an audio frequency signal

The difference between Tremolo and Vibrato become evident graphically on the scope with a 1Khz sine wave [4] (Figure 2). Tremolo will always look as amplitude (volume) going up or down. On the other side, vibrato always looks like a pitch shift or the phase moving back and forth.

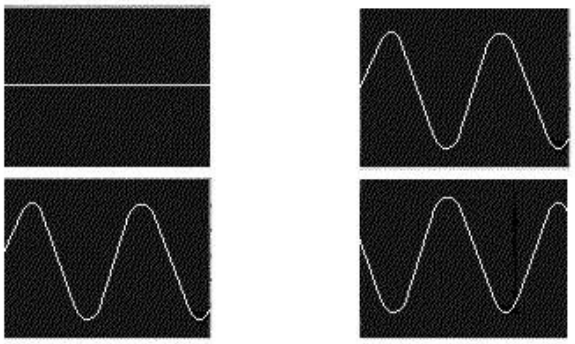

Figure 4.Left Tremolo change in the amplitude, right Vibrato change of the frequency.

2.2. Vibrato, Flanger and Chorus Effects

Several different effects can be achieved with the comb filter, just by changing the delay length, depending on the length of the delay expressed in milliseconds, as described in the table below.

Delay Range (Typ.)	Modulation (Typ.)	Effect Name
0 … 20	-	Resonator
0 … 15	Sinusoidal	Flanging
10 … 25	Random	Chorus
25 … 50	-	Slapback
>50	-	Echo

To add a bit more complexity to the vibrato effect I added the "flanger" effect to it, which is implanted by just adding the original signal to the one with by vibrato and playing them together. Original signal split into two, one vibrato added with a signal given a gain stage of less than 1 and then the original signal added to this to create a "flanger".

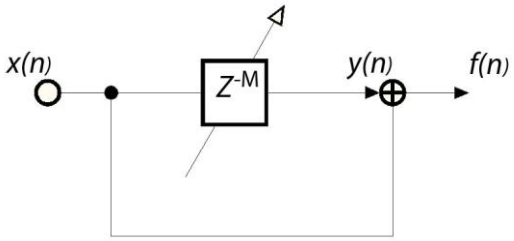

Fig 2. Diagram of the "flanger" effect.

Another example of this is the Chorus effect which is based upon the Vibrato plus the direct signal. Its structure consists of several copies of the input signal are delayed in the range 10 to 25 ms. with small and random variations in the delay times.

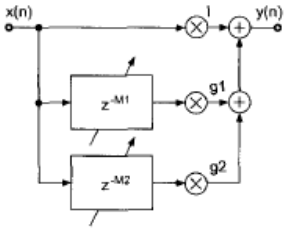

Fig 7. Chorus System

(7)Original signal, split into three vibrato added to two signals, given a gain stage of less than 1 and then added back with original signal to create chorus.

3. CONCLUSION

I've explained the principles of the Delay effect and focused on Vibrato comparing and differentiating it from other basic Delays structures.

Delays are used in audio processing to solve several practical problems, liker delay compensation for sound reinforcement systems, and as basic building blocks for delay-based audio effects, artificial reverberation and physical models for instrument simulation [1].

4. REFERENCES

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