DESC9115 2012 DIGITAL AUDIO SYSTEMS ASSIGNMENT 1: INITIAL TECHNOLOGY REVIEW

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ABSTRACT

The wah-wah pedal has been used since 1960s for guitar players to increase the dynamic of their music. It is a type of guitar effect pedal that mimics human voice by changing the tone of signal to create a unique [wah] sound. The first section of this technology review will be introducing its background and how his effect was developed as a time-varying audio filter. The procedure how [wah] sound is formed by the human voice is also discussed in detail by analyzing its each sound component. Additionally, the mathematical model and equations of the bandpass filter will be focused in the later sections as well as its application M-fold wah-wah filter. This initial technology review thoroughly explains and discusses the background, the theory of the wah-wah filter and its applications.

1. INTRODUCTION

Although people may not be unfamiliar with the wah-wah sound effect from guitar performance, they probably do not know how interesting the knowledge and background behind this funny sound effect. Nowadays the wah-wah effect is mostly related to the wah-wah pedal that is for guitarist's use. Musicians also used it widely during their studio recording or in stage performance. The time-varying filter inside the wah-wah pedal is the core item that brings out the wah-wah sound effect. To be able to delve into this device deeply, it would be helpful to firstly start the review with its background, and then followed by its theory.

1.1. Background

In November 1966, the first wah-wah pedal was created accidentally by Brad Plunkett. He made it from a transistorized mid-range boost potentiometer bread-boarded circuit and the housing of a Vox Continental Organ volume pedal. After the initial invention of the wah-wah pedal, the prototype pedal was then modified by Del Casher and Brad Plunkett to improve the harmonic qualities of the electric guitar.

The wah-wah effect was originally intended to imitate the crying tone that a muted trumpet produced, but it then became an expressive tool in its own way.

Fig. 1: Wah-Wah pedal

It can be used in many occasions such as when a guitarist is soloing, or creating a "wacka-wacka" funk styled rhythm. The current method of generating the wah-wah effect is by using the signal processors that contain a bandpass filter with variable center frequency and a small bandwidth. The bandpass centre frequency can be adjusted by moving the pedal back and forth.

1.2. Theory

The wah-wah pedal is an application of time-varying audio filter. The function of a wah-wah pedals is to alter the tone of the signal to create a distinctive effect, mimicking the human voice 'wah'. Therefore, firstly we have to understand how the human vocal sound is made of in order to approach how this wah-wah pedal works.

1.2.1.1 Human vocal sound

Each sound has its unique characteristics and resonant frequencies so does human voices, which can range from 60 to 7000Hz. While speaking of the wah-wah effect, the most important voices in human vocal sound for us to focus specifically are the [u] vowel and [a] vowel, which combine together forming the [wah] sound. It is done by mouthing the [u] vowel initially and then expands the mouth for the [a] vowel by changing the mouth shape from a small O to a big O.

The wah-wah pedal works similarly in the way of its resonant frequency change**.** These resonant sound frequencies of the small "o" to the big "O" here are called "formants". The Figure below reveals the areas of human voice sound frequencies.

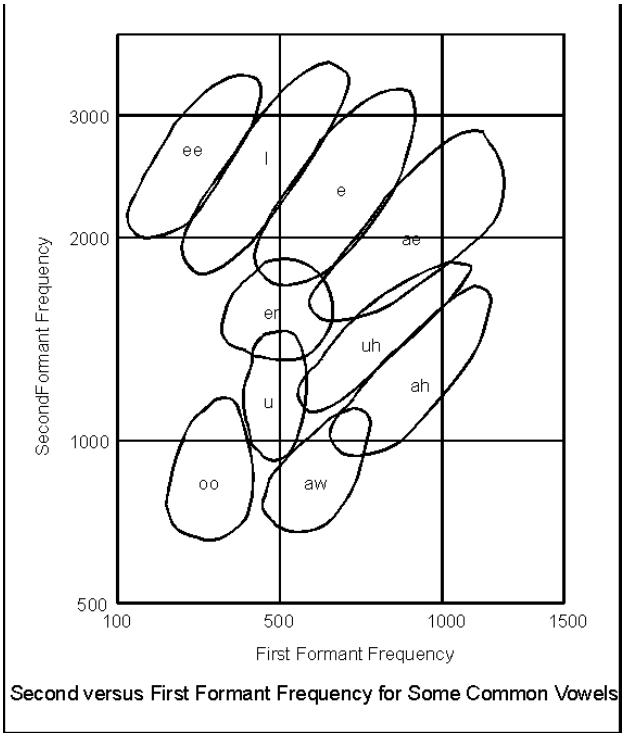

Fig. 2: Human voice sound regions.

The [ah] vowel is what we are interested in as mentioned before. As we can see from the figure above, the first formant frequency of the [ah] vowel spread between 700 Hz to 1200 Hz and its second formant frequency spread between 900Hz to 1700 Hz. Since the wah-wah pedal tries to mimic the human [wah] sound, its bandpass filter frequency range lies between 700Hz to 1200Hz as well in order to create this [ah] vowel. Currently, the bandpass filter is only able to deal with one frequency range at a time. In order to mimic this sound effect more close to the human sound voice, the larger sweep range, such as from 400Hz to 2200Hz, would be applied.

1.3. Bandpass filter

The aim of this technology review is to explain the process of how the bandpass filter performs the wah-wah effect effectively. The bandpass filter creates a peak in the frequency response. Amounts of resonance can be controlled by adjusting the peaking centre. This effect leads to a spectrum shaping similar to speech and produces a speech-like "wah-wah" sound. This wah-wah sound is then mixed with the direct signal as below.

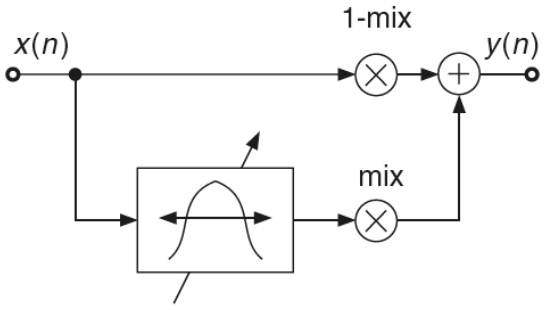

Fig. 3: Wah-wah: time-varying bandpass filter.

This foot-controlled signal processor contains a bandpass filter with variable center frequency and a small bandwidth. The bandpass filter can create a peaking variable centre. By moving the pedal back and forth, users are able to adjust the peaking center frequency freely on the frequency spectrum. The following figure shows that the wah-wah pedal has its peaking centre frequency moves between point 41 and point 42.

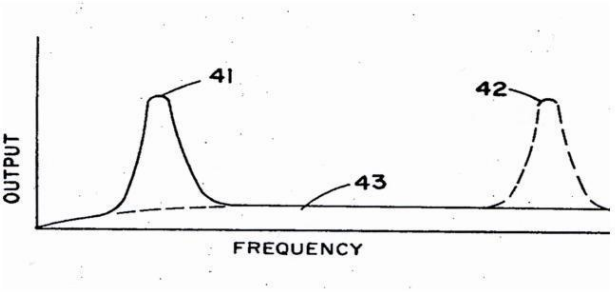

Fig. 4: Peaking centre frequency of the wah-wah filter

1.4. Bandpass filter equation

A wah-wah filter was created combining a bandpass filter with a time varying centre frequency. A second order bandpass filter was used to create the effect.

$$H(z) = \frac{1}{2}\left[1 - A(z)\right]$$

$$A(z) = \frac{-c + d(1-c)z^{-1} + z^{-2}}{1 + d(1-c)z^{-1} - cz^{-2}}$$

$$c = \frac{\tan(\pi fb / fs - 1)}{\tan(2\pi fb / fs + 1)}$$

$$d = \cos(2\pi fc / fs)$$

Fig. 5: Bandpass filter equation. Where fs is the sample frequency, fb is the filter bandwidth and fc is the filter center frequency.

1.5. M-fold wah-wah filter

- By allowing a low-frequency oscillator to control the centre frequency, an effect is created, called an auto-wah filter.
- If this effect is combined with a low-frequency amplitude variation, which produces a tremolo, the effect is denoted a tremolo-wah filter.
- Replacing the unit delay in the bandpass filter by an *M* tap delay leads to the *M*-fold wah-wah filter, which is shown in Figure 6 below.

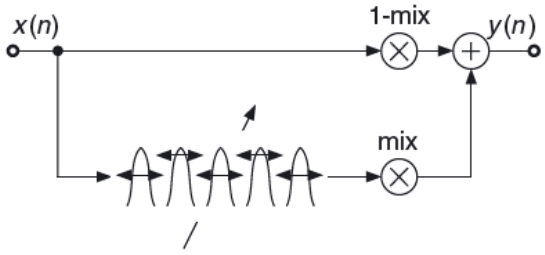

Fig. 6: *M*-fold wah-wah filter.

2. CONCLUSION

The wah-wah filter has been used for a long time since 1960's. Its usefulness has come from mimicking the human crying tone to an impressive solo too for guitarists. By combining a bandpass filter with a time varying centre frequency, the concept of wah-wah effect can be easily implemented practically. Dealing with the guitar, the wah-wah filter has greater range of peaking centre frequency than human vocal sound to emphasis the sound effect. In conclusion, this technology review has provided an opportunity of learning such an interesting topic.

3. REFERENCE

- Wikipedia http://en.wikipedia.org/wiki/Wah-wah_pedal
- DAFX 2nd edition [p67]
- Fig.1: Dunlop GCB95F Crybaby Classic Fasel Wah Pedal skysun.co.za
- Fig.2:http://www.geofex.com/article_folders/wahpedl/voicewah.htm
- Fig.3: Wah-wah signal diagram, DAFX2 [p67].
- Fig.4: Peaking frequency moving through spectrum. http://vimeo.com/20902369
- Fig.5: Bandpass filter equation. DAFX2 [p43].
- Fig.6: Wah-wah signal diagram, DAFX2 [p67].