AN INTRODUCTION TO THE RING MODULATION APPLICATION

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ABSTRACT

This final written review introduces the brief history of ring modulation application and the basic modulation principle with a mathematical formula in introduction part. Then two potential problems are proposed, including the problem of the integration of different types of ring modulators and the limitation of selectivity of inputs based on different durations of signals, which is solved by DSP and specified in specification part. By using the demonstrated parameters and audio signals (saxophone and harp[1]), the whole script is implemented and the relevant exported files have uploaded. Finally, two evaluation methods (physical and performance evaluations) are proposed with diagrams.

1. INTRODUCTION

Ring modulation (RM) regarded as a specific condition of amplitude modulation (AM) has been applied in radio receivers extensively and was tried to be utilized in musical instruments from the late 1940s. The Melochord created by Harald Bode in 1947 should be one of the earliest musical instruments using the principle of ring modulation (Palov, 2011). Then Werner Meyer-Eppler used the Melochord broadly especially for electronic music (The "Melochord", 1949). With the popularization of the ring modulator, that effect was applied by many audio projects. For example, the unique voice of the Daleks in the series *Doctor Who* (releasing from 1963 and produced by BBC Radiophonic Workshop) could be regarded as one of the best-known ring modulation applications (Bentham, 1986).

The electronic effect unit to implement the process of ring modulation is named ring modulator, which can multiply two signals (typically an input signal and a carrier signal) to generate a ring-modulated signal as the equation below (Orton, 2001).

$$S_{\text{ring-modulated}}(t) = S_{\text{input}}(t) \times S_{\text{carrier}}(t)$$

As for unique characteristics of the ring-modulated signal, there are only the sum and subtraction of the inputs frequencies and both input and carrier signals are indistinctive in modulated signal (Burchardi, 2008).

[1] The demonstrative audio files (saxophone and harp sounds) in this review are cited from the material lab of YiYing culture company.

2. PROBLEM DESCRIPTION

2.1. The Integration of Different Types of Ring Modulators

The effect of the ring modulation is still popular by the players seeking for the sound with unique and metallic qualities nowadays, so there are various types of ring modulator kits in the market, such as the type with internal oscillator for generating sinusoidal or rectangular carrier signal, the type only allowing self-modulation (which the both carrier signal and input signal are identical signals, or the input signal and delayed input signal) and so on. Therefore, it is worthwhile to design a well-designed all-in-one ring modulator kit to involve different types of ring modulator kits by shifting the modes.

2.2. The Limitation of Selectivity of Inputs Based On Different Durations of Signals

Another problem is the limitation of selecting carrier signal, and the two inputs signals (original and carrier signals) cannot be ring-modulated arbitrarily because the multiplication between two signals is based on the same signal duration (Orton, 2001). From a different perspective, it will be significantly experimental and endlessly possible to explore the effect of output ring-modulated signal providing that any two types of signals (such as musical, noise, speech signal) can be set as the input signals.

3. SPECIFICATION

The specification describes how the problems mentioned previously can be solved by digital signal processing.

3.1. The Specification for the Problem of the Integration of Different Types of Ring Modulators

There are four modes provided for users to select to meet the requirements of different users, namely pure tone inputs, a pure-tone carrier signal, self-modulation and unlimited inputs modes. The switch among the various modes is achieved by the MATLAB if-elseif conditional statement. Moreover, users can select and implement their preferred mode by typing the corresponding mode name, which is fulfilled by MATLAB built-in functions input and strcmp.

In pure tone inputs mode, there are two sinusoidal waves as input and carrier signals to be ring modulated by the ringmodulation_ sinusoidal_wave.m. The specified procedures are illustrated by diagram 1. Besides, at the end of each mode, the original, carrier and ring-modulated signal can be auditioned and exported by built-in functions sound and audiowrite.

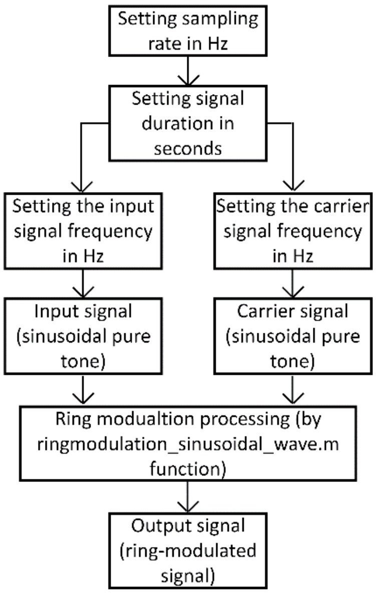

Diagram 1. *Procedures of the pure tone inputs mode (mode 1)*

As for the pure-tone carrier signal mode, a sinusoidal or rectangular wave can be selected (by built-in functions input and strcmp) as the carrier signal to modulate with an imported input signal (as the diagram 2). In case of the rectangular wave carrier signal, the function file ringmodulation_rectangular_wave.m is applied, whose principle is similar to ringmodulation_sinusoidal _wave.m but using built-in function square rather than a sin to generate a rectangular wave.

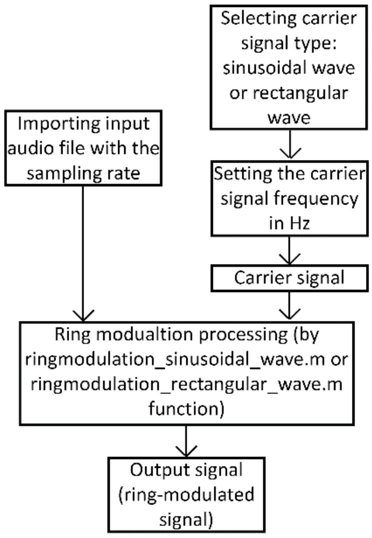

Diagram 2. *Procedures of the pure tone carriers signal mode (mode 2)*

Diagram 3 illustrates the process of self-modulation mode. The name 'self-modulation' is because the carrier signal is the delayed version of the input signal. The modulation process of self-modulation mode can be achieved in ringmodulation_mode3 .m.

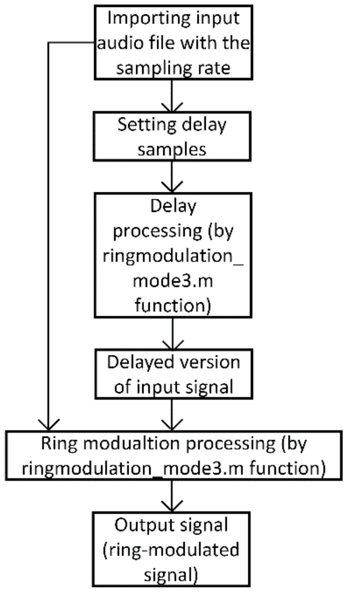

Diagram 3. *Procedures of the self-modulation mode (mode 3)*

3.2. The Specification for the Limitation of Selectivity of Inputs (Mode 4: Unlimited Inputs)

Since the core principle of ring modulation is the multiplication of input and carrier signals in time domain, the signals' durations need to be identical. The basic approach for meeting the duration requirement is concatenating a piece of extra samples to the shorter length input signal to let two signals have the same duration. Therefore, at the beginning of MATLAB function ringmodulation_mode4.m, the additional sample is calculated by the difference of two signals and created by built-in function zeros. Then the if-elseif conditional statement for comparing the lengths of two signals is applied to determine which signal should be concatenated with the extra samples. Diagram 4 illustrates the process of unlimited inputs mode.

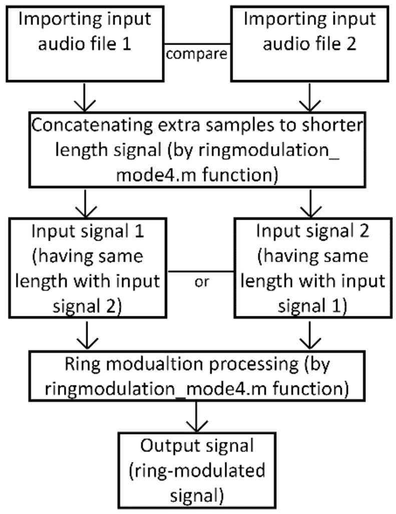

Diagram 4. *Procedures of the unlimited inputs mode (mode 2)*

4. IMPLEMENTATION

By running the script, a prompt message is displayed in the command window to ask which mode the user wants to use.

In mode 1 (code-lines 6-31)[1], users are asked to set the sampling rate, signals' duration, input signal frequency and carrier signal frequency. The values of 44100, 2, 200, and 600 are entered respectively for implementation and demonstration purposes. Through the designed DSP, the input, carrier and ring-modulated signals are exported and named as 'mode1_signal_input.wav', 'mode1_signal_carrier.wav' and 'mode1_signal_ringmodulated.wav'.

In mode 2 (code-lines 33-70), users need to preload the prepared input signal and are asked to select whether the user wants to use the sinusoidal or rectangular as the carrier signal. The corresponding carrier signal frequency needs to be typed in subsequently. In this review, a demonstrated saxophone sound is preloaded as an input signal and the sinusoidal wave (300 Hz) is selected as a carrier signal. The exported files are 'mode2_signal_carrier.wav' and 'mode2_signal_ringmodulated.wav' for an audition.

In mode 3 (code-lines 72-86), in addition to the prepared input signal, the delay samples need to be entered for achieving the delay processing. The saxophone audio and delay sample (1000) are used for the implementation. The delayed signal and the ring-modulated signal are saved as 'mode3_signal_carrier.wav' and 'mode3_signal_ringmodulated.wav'.

In mode 4 (code-lines 88-101), there are two audio signals to be prepared as the inputs of modulation function. The ring-modulated signal 'mode4_signal_ringmodulated.wav' is generated by the prepared saxophone and harp sounds in this demonstration.

5. EVALUATION

5.1. Physical Evaluation: The Correctness of Ring Modulation Principle in the MATLAB Function

The correctness of ring modulation process can be verified by analyzing the plot of the ring-modulated signal in frequency domain If the frequency is comprised by the add addition and subtraction of the input and carrier signals. The 200 and 600 Hz sinusoidal waves are used for verification. By adding the code-lines 39-60 in ringmodulation_sinusoidal_wave.m function and implementing the mode1, the figure 1 below is generated to verify the correctness.

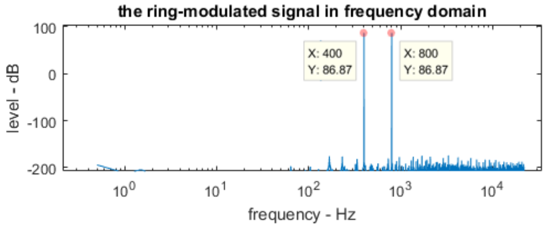

Figure 1. *The frequency of the ring-modulated signal is comprised by the add addition and subtraction of the input and carrier signals.*

5.2. Performance Evaluation: The Recommended Ranges of Related Parameters

The performance can be evaluated by the approach introduced in lecture 'Time-Variant Systems' to test the variable factors of different modes (University of Sydney, 2016). In mode 1, based on predetermined sampling rate and durations, the description of effect (such as fluctuated, harmonic, inharmonic, etc.) can be recorded in figure 2.

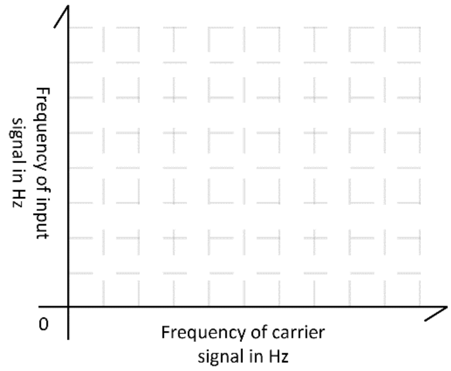

Figure 2. *The chart for evaluating the performance of mode 1*

The figure 3-5 illustrate the considered factors in x- and y-axis for evaluating the performance of mode 2-4 respectively. The evaluation rate A-E is applied in indicating the degree from good (appropriate or usable effect) to bad (too much or little effect). The evaluation could be generalized by a large amount of users' testing feedbacks.

[1] All exported files, MATLAB scripts and functions are uploaded to the University of Sydney's eScholarship Repository.

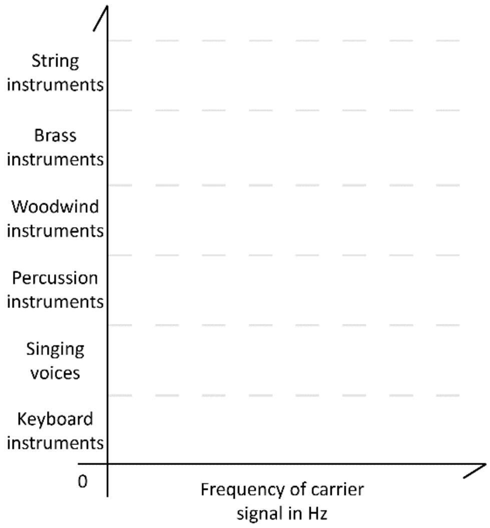

Figure 3. *The chart for evaluating the performance of mode 2*

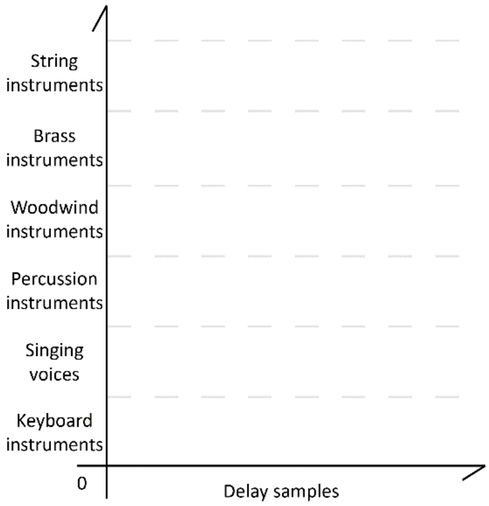

Figure 4. *The chart for evaluating the performance of mode 3*

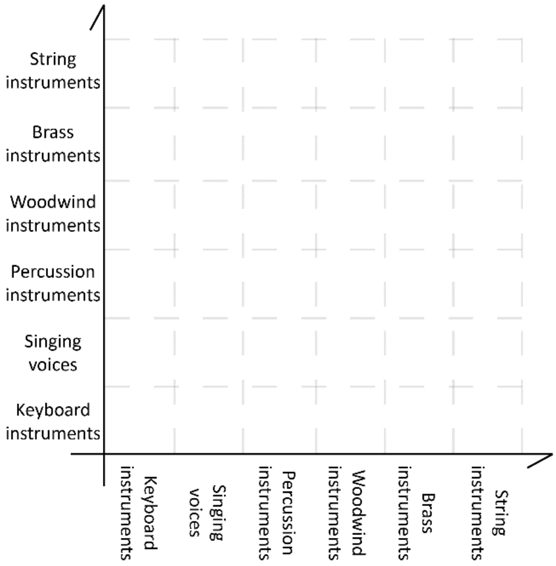

Figure 5. *The chart for evaluating the performance of mode 4*

6. SUMMARY

This final written review introduces the brief history of ring modulation application and the basic modulation principle with a mathematical formula in introduction part. Then two potential problems are proposed, including the problem of the integration of different types of ring modulators and the limitation of selectivity of inputs based on different durations of signals, which is solved by DSP and specified in specification part. By using the demonstrated parameters and audio signals (saxophone and harp), the whole script is implemented and the relevant exported files have uploaded. Finally, two evaluation methods (physical and performance evaluations) are proposed with diagrams. With the further study on DSP and collecting feedbacks of users, the all-in-one ring modulator could be improved and developed to fit more users' requirements.

7. REFERENCES

[1] Burchardi, R. H. (2008, 9). Digital Simulation of the Diode Ring Modulator for Musical. Proc. of the 11th Int. Conference on Digital Audio Effects (DAFx-08),. Finland.

[2] Jeremy Bentham (1986), Doctor Who: The Early Years, p. 127, ISBN 0-491-03612-4

[3] Orton, R. (2001). Ring Modulator. In R. Orton, The New Grove Dictionary of Music and Musicians. London: Macmillan Publishers.

[4] Rebekkah Palov (2011), "Harald Bode — A Short Biography", *eContact!* (Canadian Electroacoustic Community) 13 (4)

[5] The "Melochord" (1947–9), *The Keyboardmuseum Online*, archived from the original on 2007-11-14 (description and history)

[6] University of Sydney (2016) "Week 11 – Time variant systems" DESC9115 Digital Audio Systems [Lecture Content].

8. LIST OF ILLUSTRATIONS

Diagram 1-4 are originally created by Changlong Li (the author of this review).

Figure 1. *The frequency of the ring-modulated signal is comprised by the add addition and subtraction of the input and carrier signals.* is created from MATLAB.

Figure 2-5 are originally created by Changlong Li (the author of this review).