From Ring Modulator to Multiplier

Originally built from two transformers and four diodes. The diodes are all connected in series: one to two, two to three, three to four and four to one again. Without getting lost in the electronics, it means that if we connect alternating voltages to the two inputs, something new arises at the output of the ring modulator: the sum and difference frequencies of the two input signals.

For example a sine wave of 440Hz at one input and another 12550Hz at the other. This yields two new frequencies at the output of: 125500 + 440 = 125944 and 125500–440 = 125110Hz. Of the two original input frequencies nothing can be detected, they have been transformed into two new sinuses, two high frequencies: one of 125944 and one of 12110Hz. The high carrier signal of 12550Hz has been converted by the modulator, the 440Hz signal, to those two high new frequencies.

This step is known as the modulation part. Now imagine that the modulator signal is formed by the signal of your voice. And also imagine that the carrier frequency would now be 1MHz. A signal would then be generated at the output of the ring modulator formed by sum and difference frequencies of the carrier and all available frequencies in the speech signal.

These sum and difference frequencies are also named upper and lower sidebands. The original signal is now, as it were gigantically ‘transposed’ and also completely 'rebuilt' when you look at the frequency ratios. The original speech signal, a harmonic spectrum, has become completely inharmonic.

Demodulate
Can you retrieve the original, the modulator, from this newly formed modulation product? Yes, that's possible. We now consider this newly formed modulation signal as a new modulator for another ring modulation process. If we do it with the same carrier frequency, the original input signal will appear as a lower sideband.

This is demonstrated in the `Mod-Demod.pch2` patch, albeit with a much lower carrier frequency of 12.55kHz, which is the highest possible frequency in the NMG2. However, you can clearly explain the principle. Just like in the transmission technique, an ultrasonic carrier frequency is modulated by an audio signal, the modulator, the sound to be transmitted. And exactly the same as in the transmission technique, you can use several broadcast (carrier) frequencies to send multiple transmitters through one medium. The receiver can now tune to the transmission frequency with its carrier oscillator, the ring modulator demodulates this signal and conjures up the original modulation signal again.

The success in electronic music
This success shows a striking parallel with what would happen much later

with another - from origin - transmission technique: FM. Essentially nothing is changed about fundamental technology. Only the ultrasonic carrier frequency is replaced by an audio frequency signal. As with FM, interesting musical possibilities arise, which are based principally on the fact that sum and difference frequencies are formed. In this way, for example, you can completely transform a sawtooth that is made up of all even and odd harmonics into a result sound with only inharmonic partial frequencies.

That was a wonderful addition to the instruments used at the time, which consisted mainly of oscillators, filters and tape recorders. With this existing equipment, all linear systems, without distortion, it was only possible to generate inharmonic sounds by means of additive synthesis, the mixing of sine waves.

Generating sum and difference frequencies is not necessarily dedicated to the ring modulator. This also can be done in many other (cheaper) ways. This budget method was also applied in the later budget synthesizers. Especially in pre-programmed instruments. The ring modulator in my Arp Odyssey was in fact just a simple electronic gate circuit.

Open the `Sideband Modulations.pch2` patch and see and hear how things can be done differently. Nowadays the ring modulator is almost always a multiplier in hardware or software. In hardware for instance the Analog Devices AD633 IC.

The multiplier

What does a multiplier do? Well exactly what his name suggests: the multiplication of the two amplitude values at the inputs. So, output = input value1 times input value2. Connect two audio signals and the output gives you very precisely all sum and difference frequencies of the signals present at both inputs.

The reason that nowadays mostly multiplication is used for ring modulation lies simply in the fact that multiplication is a very common operation in all kinds of processes. By multiplying both input values results in sum and difference frequencies. You can ask yourself How this is possible. It can be explained in different ways. The short way: $\sin a \times \sin b = 0.5 (\cos (a-b) - \cos (a + b))$ So it looks impressive and it has been adequately explained.

Even if you didn't pay attention to mathematics at school, it can be explained on the common sense method. Imagine that you connect the same sine wave signal to both inputs. Such a sine wave signal consists of a positive part and a negative part. What you certainly have remembered is that positive times positive yields a positive result. And that negative times negative returns positive.

Thus the output signal has become completely positive. The resulting output wave now has a lowest amplitude value 0 and a maximum value 1. So the amplitude has halved. But, the most striking difference: the frequency has doubled. This means sum and difference frequencies. According to addition and subtraction that gives: 1 + 1 = 2 and 1-1 = 0.

FreqDoubler

Load `FreqDoubler.pch2` patch and see and hear how it works. If you amplify the output signal in an amplifier by 6 dB, that is to multiplying the amplitude by two, subtracting an offset value from -1, you get an output signal with the same amplitude as the input that again neatly is running from -1 to +1.

`RingModulator.pch2`

In this patch you see the standard use of the ring modulator. The first four variations are pre-programmed:

1.SeqSawtooth & LFOSine Mod
2.SeqSine & Audio Sine Mod
3.Crossing Sidebands two Sine waves
4.Crossing SB Sawtooth & Sine wave

In the first example you hear what happens when one of the input signals is sub-audio, for example a LFO: amplitude modulation or tremolo.
The second variation has as input signal a sequence of tones with a sine waveform and the two input is an audio resonance with fixed frequency. What happens when you replace the sequence with a slow glissando you hear in example 3. In the fourth variation, the sine wave glissando is replaced by a sawtooth signal.

`Sala-Delay.pch2`

This patch is an example of an unorthodox use of a ring modulator. This was frequently applied by Oskar Sala, the master of the Mixture Trautonium. The ring modulator is now connected in the feedback loop of a delay. With every repetition in the delay, the signal is again and again modulated. With every repetition you can hear the timbre changing and becoming increasingly noisy. In addition to these three patches you will find even more patches that show the versatility of a multiplier. In addition to the usual internet links, there are also some specific sites where you can download PDFs related to DIY plans with the AD633 and the MC1496. Finally, four DIY building schemes in gif format.

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internet

Moogerfooger Ring
https://www.youtube.com/watch?v=cjzXb0CdSUs

Ring modulator for DIY with AD633:
http://m.bareille.free.fr/modular1/warp633/warp633.htm

Data sheet and DIY diagram of a ring modulator with MC1496:
www.onsemi.com/pub/Collateral/MC1496-D.PDF