Blatt 11 - Modulationssynthese

Kreatives Programmieren 1

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1 Amplitude Modulation and Ring Modulation

Modulation occurs when some aspect of an audio signal (called a `carrier`) varies according to the behaviour of another audio signal (called a `modulator`). **Amplitude modulation therefore occurs when a modulator drives the amplitude of a carrier**. One of the pioneers of amplitude modulation in music was the composer Karlheinz Stockhausen in the 1960s (Maconie, 1976).

The `tremolo` effect may be considered to be a starting point example of amplitude modulation; it is achieved by applying a very slow sub-audio rate of amplitude variation to a sound (i.e. less than approximately 18 Hz). If the frequency of the variation is raised to the audible band (i.e. higher than approximately 18Hz) then additional partials (or sidebands) will be added to the spectrum of the signal.

Simple amplitude modulation synthesis uses only two sinewave generators (or oscillators): one for the `carrier` and the other for the `modulator`. The frequency of the carrier oscillator is usually represented as `fc` whilst the frequency of the modulator oscillator is represented as `fm`.

Complex amplitude modulation may involve more than two signals; for example, the amplitude of oscillator C is modulated by the outcome of oscillator B, which in turn is amplitude modulated by oscillator A. Signals other than sinewaves (e.g. noise) may also be employed for either carriers or modulators. The more complex the signalling system, the more difficult it is to predict the outcome of the instrument.

There are two variants of amplitude modulation: classic amplitude modulation (AM) and ring modulation (RM).

1.1 Ring Modulation

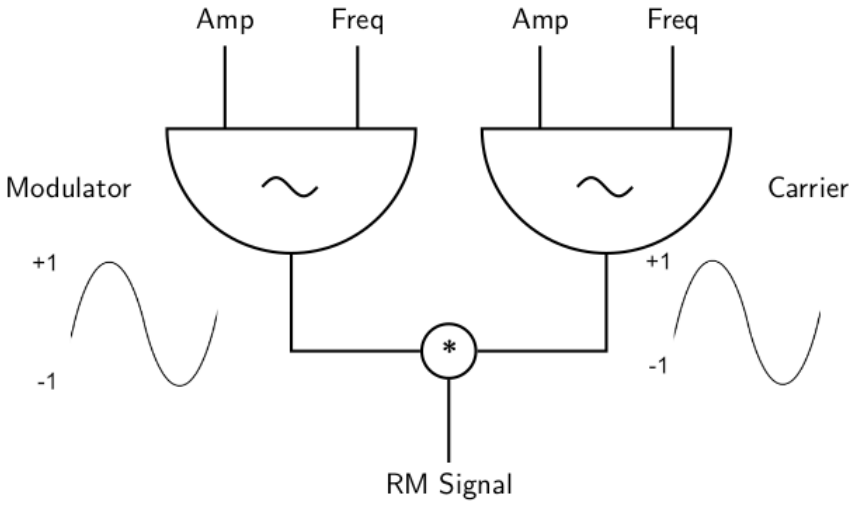
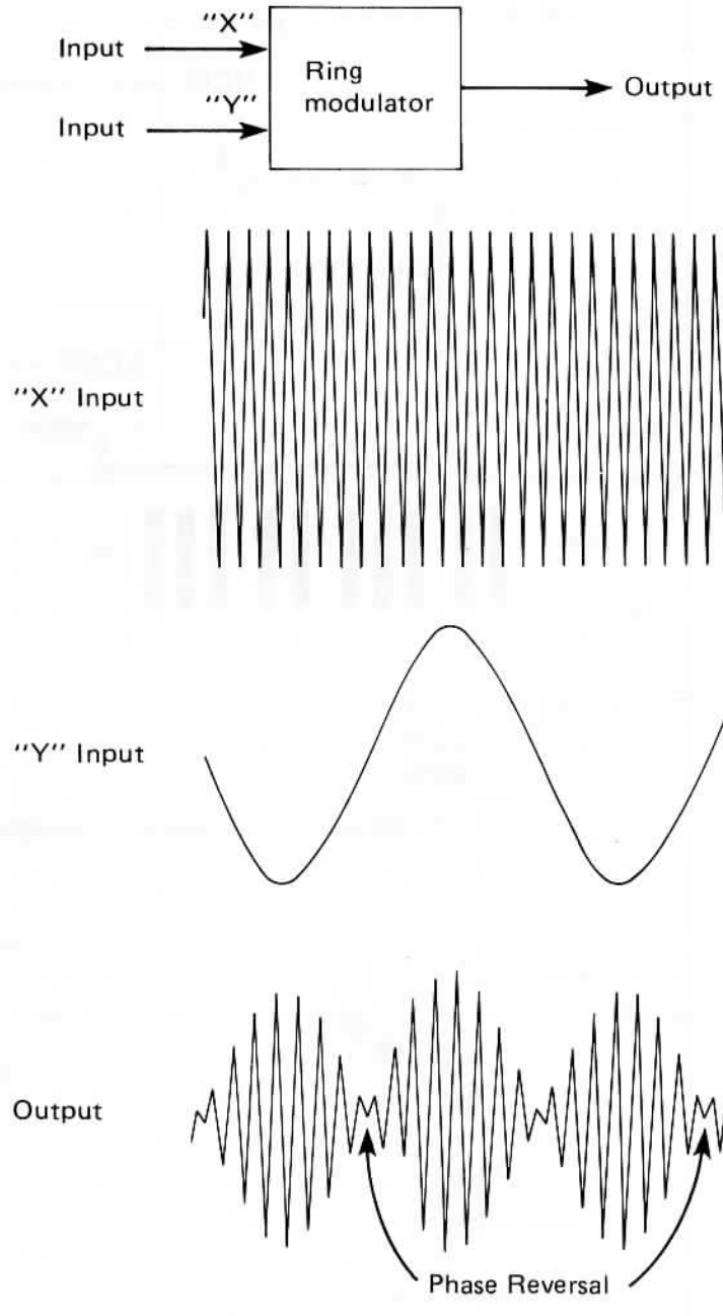


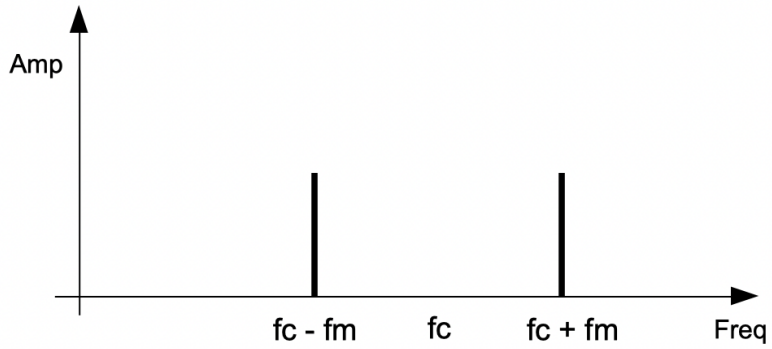
Fig. 2-15 Ring Modulator Waveforms



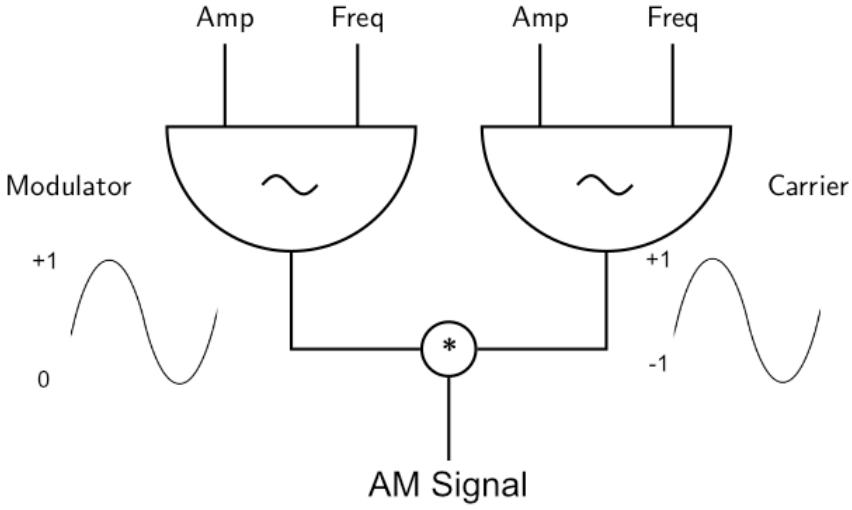
1.1.1 Multiplication von zwei Wellen

$$cos(\alpha) \cdot cos(\beta) = \frac{1}{2}cos(\alpha - \beta) + \frac{1}{2}cos(\alpha + \beta)$$

1.1.2 Spectrum of RM



1.2 Amplitude Modulation (AM)



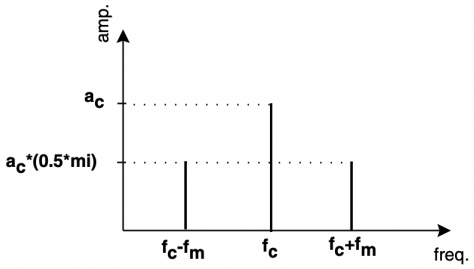
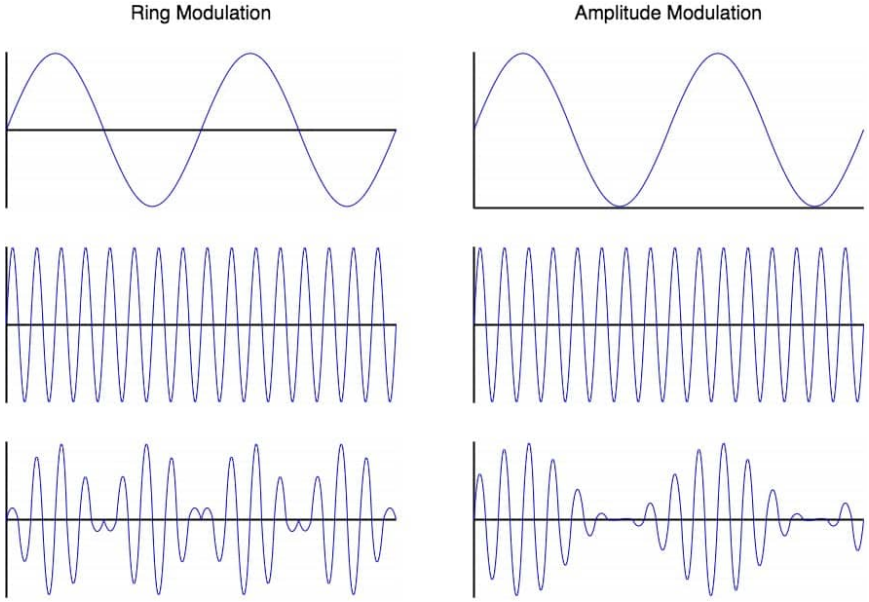


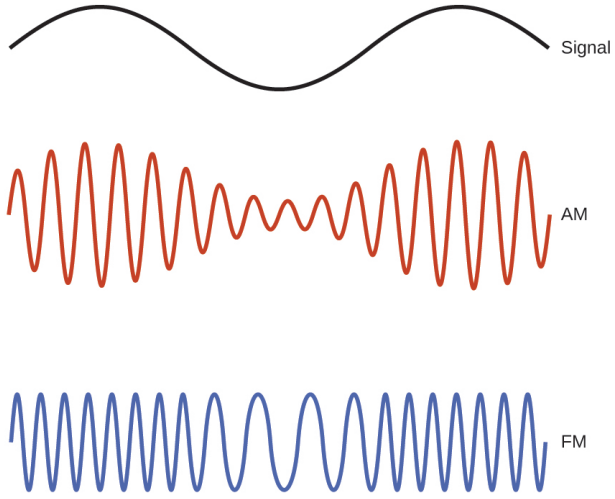
Figure 2.3 In simple AM, the spectrum of the resulting signal contains energy at the frequency of the carrier plus two sidebands

1.3 Amplitude vs Ring Modulation



2 Frequency Modulation

2.1 FM versus AM



2.2 Simple Frequency Modulation (FM)

$$FM = A \cdot sin(C + I \cdot sin(M))$$

A = Amplitude
C = Frequency Carrier / Trägerfrequenz
M = Modulationsfrequenz
I = Modulationsindex

2.3 Simple Frequency Modulation (FM)

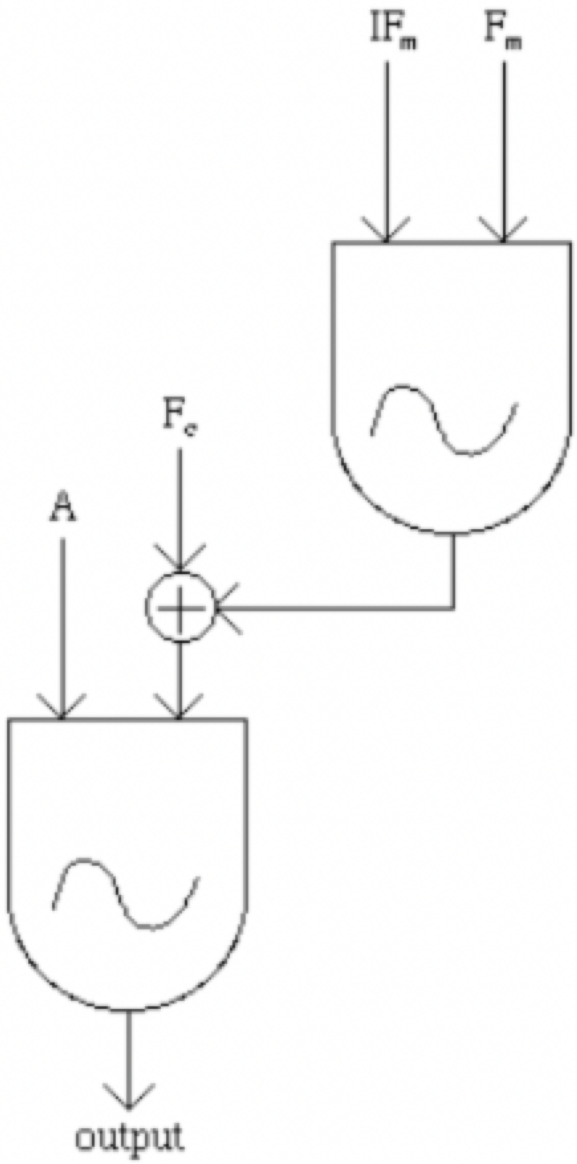
$$cos(\omega_c + I \cdot sin(\omega_m)) = \sum_{n=-\infty}^{\infty} J_n(I) \cdot cos(\omega_c + n\omega_m)$$

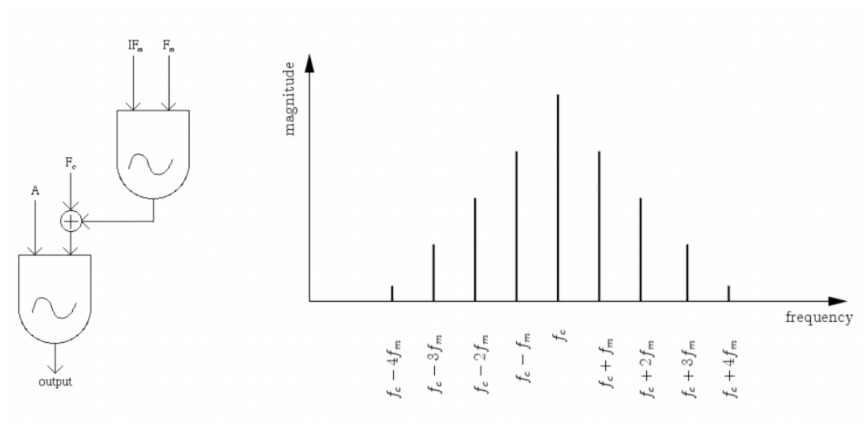
[1]

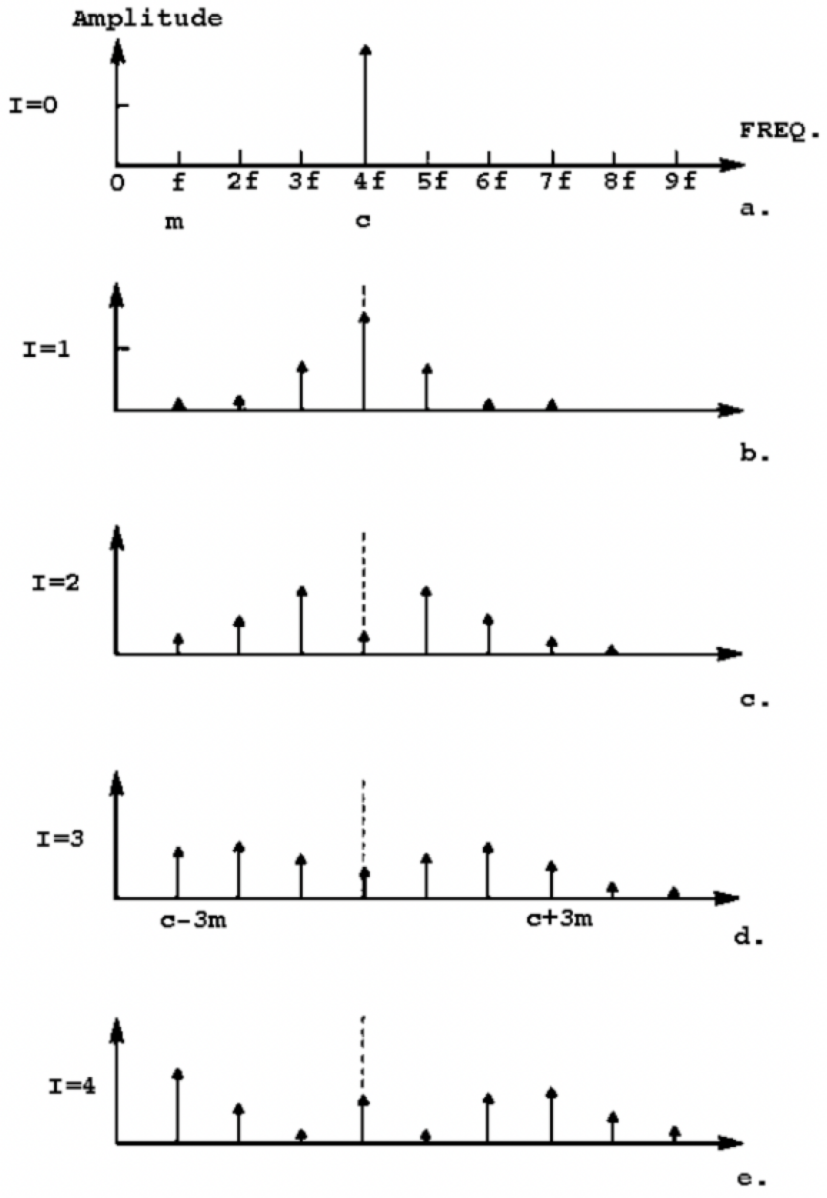
where Jn(I) are Bessel functions of the first kind (of order n), and c = 2 fct and m = 2 fmt are known as the carrier and modulator frequencies, respectively

[1]The expression for the simple form of PM, with one carrier, and one modulator, is given by the expression. In Computer Music Instruments, Victor Lazzarini

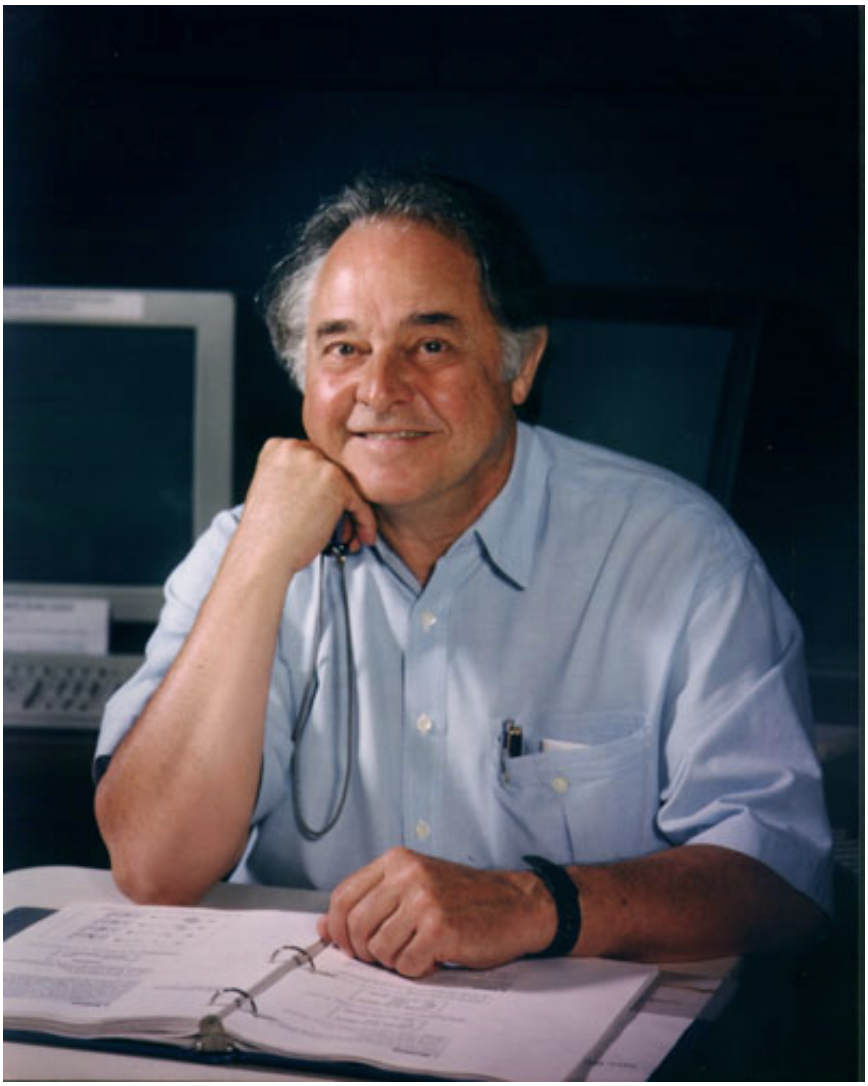
2.4 Simple Frequency Modulation (FM)




IF_m
F_m
F_c
A
output
magnitude
frequency
$f_c - 4f_m$
$f_c - 3f_m$
$f_c - 2f_m$
$f_c - f_m$
f_c
$f_c + f_m$
$f_c + 2f_m$
$f_c + 3f_m$
$f_c + 4f_m$


Amplitude
I=0
FREQ.
0
f
2f
3f
4f
5f
6f
7f
8f
9f
m
c
a.
I=1
b.
I=2
c.
I=3
c-3m
c+3m
d.
I=4
e.

2.5 John Chowning (USA 1934)



2.6 Yamaha DX7 1983

3 References

- **Charles Dodge & Thomas A. Jerse: Computer Music. Synthesis, Composition and Performance. Shirmer, 1985**
- Eduardo Miranda: Computer Sound Design Synthesis
- MillerPucket: The Theory and Technique of Electronic Music