Demonstration of FM and AM Modulation and different Detection Methods

PC Robinson

First set up some common parrameters of carrier frequency, baseband frequency, amplitudes etc

1) Common Parameters

Carrier frequency

$\omega c := 1000\pi$

Modulation Frequency

$\omega m := 100\cdot\pi$

FM Deviation Frequency

$\omega dev := 800\cdot\pi$

Modulation Amplitude

$Am := 0.8$

Carrier Amplitude

$Ac := 1$

DC Offset

$dc := 1.2$

Random Phase Shift

$\phi := \left(2\cdot\frac{\pi}{\omega c}\right)\cdot\frac{1}{4}$

2) FM modulation

Carrier Signal ...

$xc(t) := Ac\cdot\cos(\omega c\cdot t)$

Base band Modulation signal ...

$xm(t) := Am\cdot\sin(\omega m\cdot t) + \frac{Am}{2}\cdot\sin(2\omega m\cdot t) + \frac{Am}{5}\cdot\sin(5\omega m\cdot t)$

This is a fundamental plus some 2nd and 5th harmonic

FM Deviation ...

$$\Delta(t) := \omega dev \cdot \int_0^t xm(\tau)\, d\tau$$

FM Signal ...

$$yfm(t) := Ac \cdot \cos(\omega c \cdot t + \Delta(t))$$

Modulation factor ...

$$h := \frac{\omega dev}{\omega m}$$

$$h = 8$$

3) AM modulation

AM Signal (same base band signal as FM) ...

$$yam(t) := xc(t) \cdot (dc + xm(t))$$

Plot the signals ...

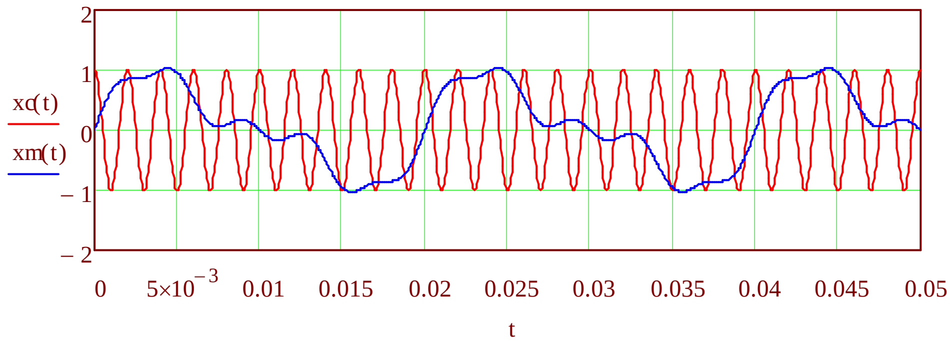

Fig 1 : Carrier (red) signal plus Modulation signal (blue)

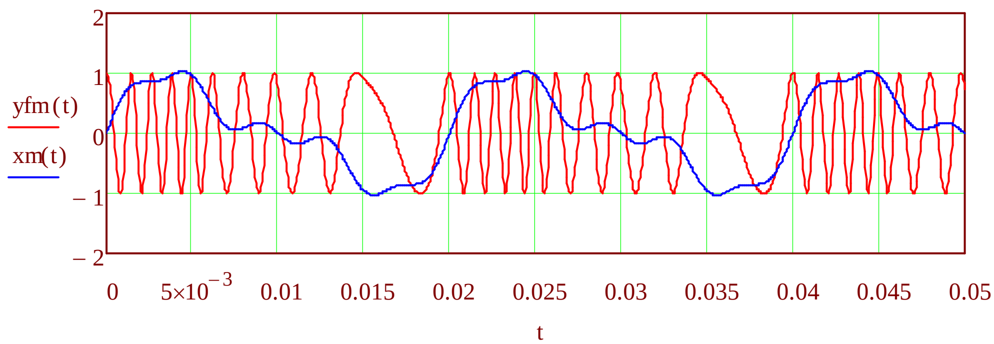

Fig 2 : FM signal (red) plus Modulation signal (blue)

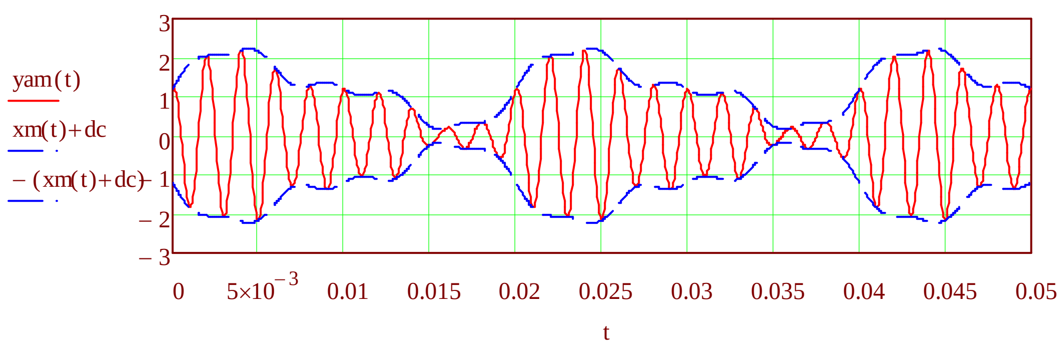

Fig 3 : AM signal (red) plus Modulation signal envelop (blue)

4) AM Detection

a) Synchronous Detection, Multiply AM signal by an inphase local carrier ...

$$ydet\_am(t) := yam(t) \cdot xc(t)$$

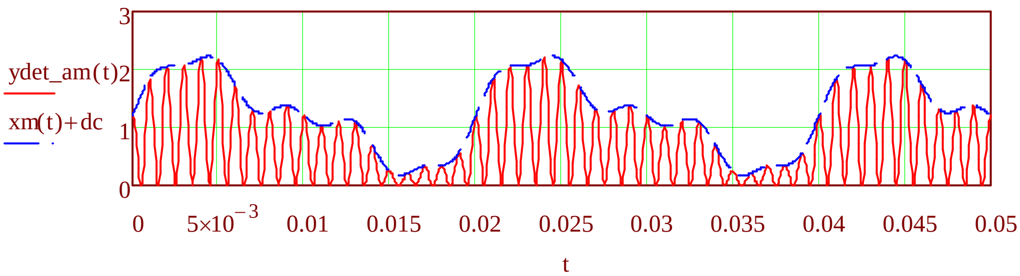

Fig 4 : Detected AM signal (red) plus Modulation signal envelop (blue), Sync Detection

Note almost perfect detection using synchronous detection with zero phase offset, now add some random phase shift ...

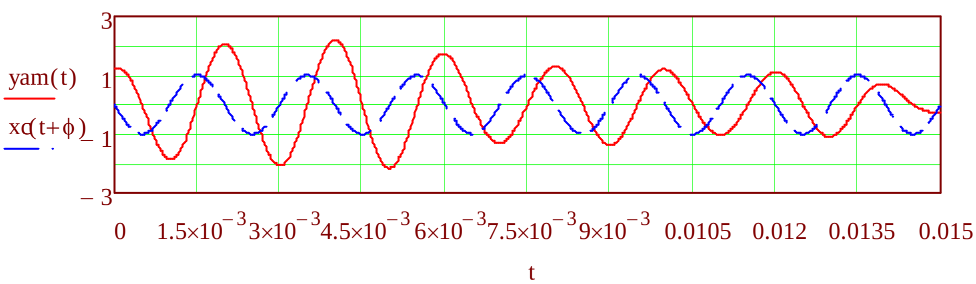

Fig 5 : Illustrating phase shift between the carrier (blue) and AM signal (red)

b) Now synchronously detect with phase shift ...

$$ydet\_am(t) := yam(t) \cdot xc(t + \phi)$$

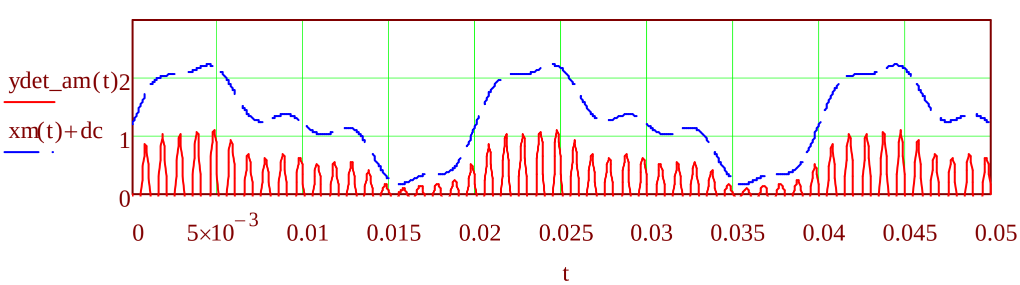

Fig 6 : Detected AM signal (red) plus Modulation signal envelop (blue), Sync Detection with phase offset

Note detected signal is much attenuated.
If the phase offset was 90 deg, there would be zero detected signal

c) Envelope detection with a square law detector

$$ydet\_am2(t) := yam(t)^2$$

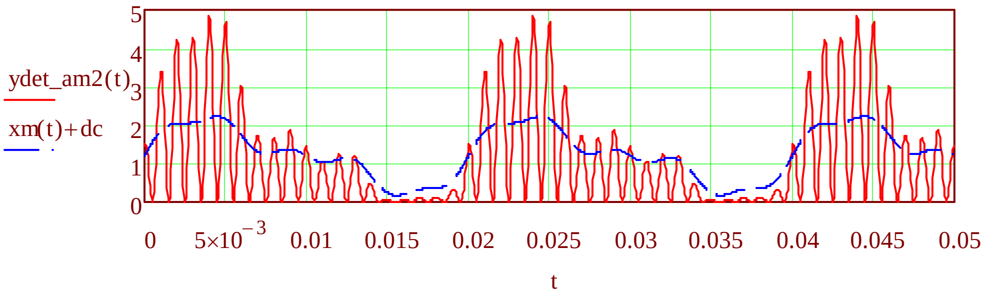

Fig 7 : Detected AM signal plus Modulation signal envelop, Square law detector

c) Envelope detection with an exponential law detector (ie Diode)

$$ydet\_am3(t) := e^{yam(t)-1}$$

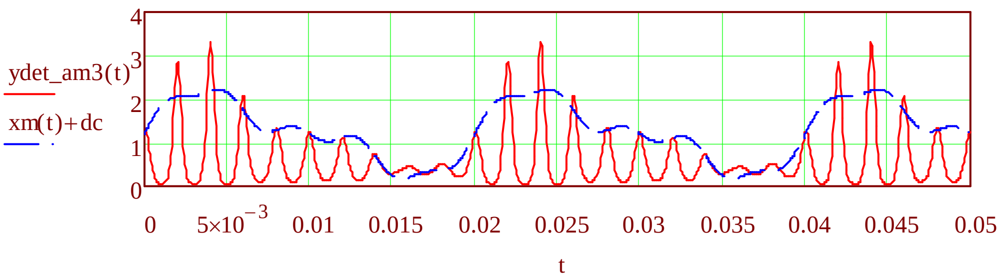

Fig 8 : Detected AM signal (red) plus Modulation signal envelop (blue)
Diode detector

5) FM Detection

a) FM detection by differentiating the FM signal and then use a square law envelope detector

$$yfm3(t) := \frac{\left(\frac{d}{dt}yfm(t)\right)}{\omega c}$$

$$ydet\_fm1(t) := \left(yfm3(t)^2\right)$$

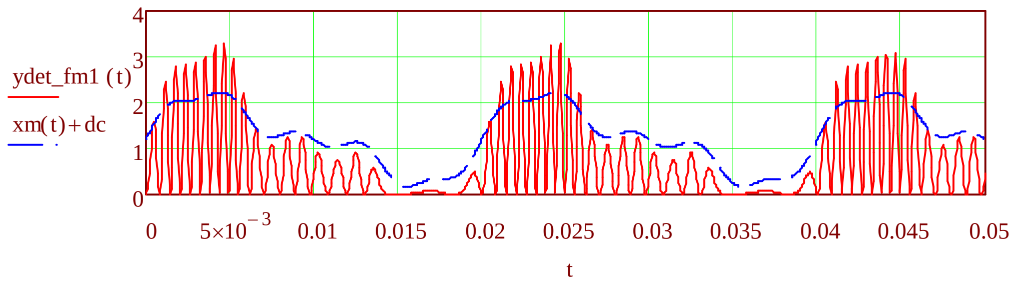

Fig 9 : Detected FM signal (red) plus Modulation signal envelop (blue), diferentiator followed by a square law detector

b) FM detection by differentiating the FM signal and then use an exponential law envelope detector

$$ydet\_fm2(t) := \left(e^{yfm3(t)-1}\right)$$

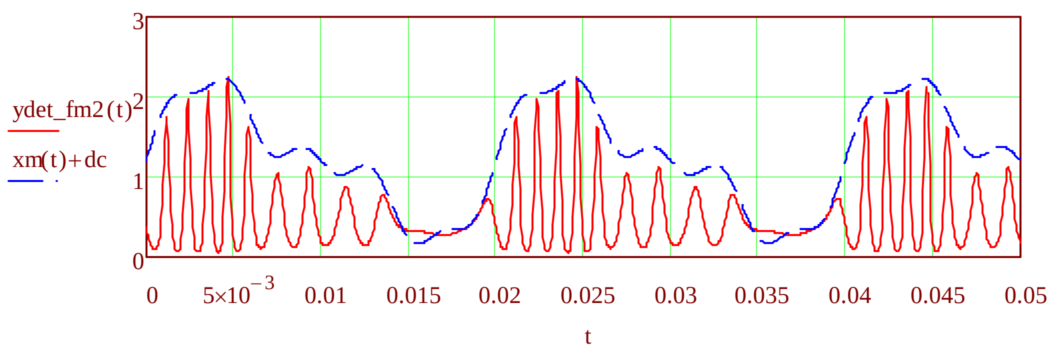

Fig 10 : Detected FM signal (red) plus Modulation signal envelop (blue), diferentiator followed by a diode detector

This gives supprisingly good results.

It works because differentiating the FM produces and AM component

- so the signal is both amplitude and frequency modulated.

The following envelope detector, then detects the AM component.

This also known as slope detection (differentiation) and can be crudely demonstrated by taking an AM reciever and slightly off tuning it from the carrier frequency so that the reciever is working on the skirt of the tuned circuit which differentiates the signal.

Otherwise a simple CR circuit (differentiator) plus diode.
Simple, however the time constant would need to track the FM carrier signal.

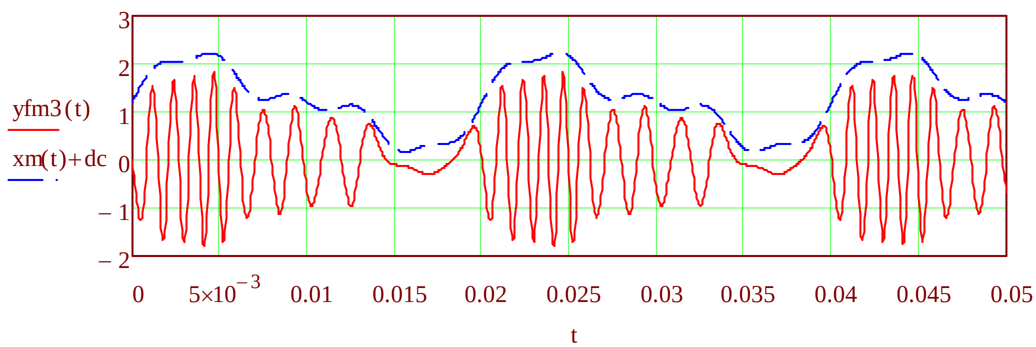

Fig 11 : Differentiating an FM signal produces a signal that is both amplitude and frequency modulated (red).