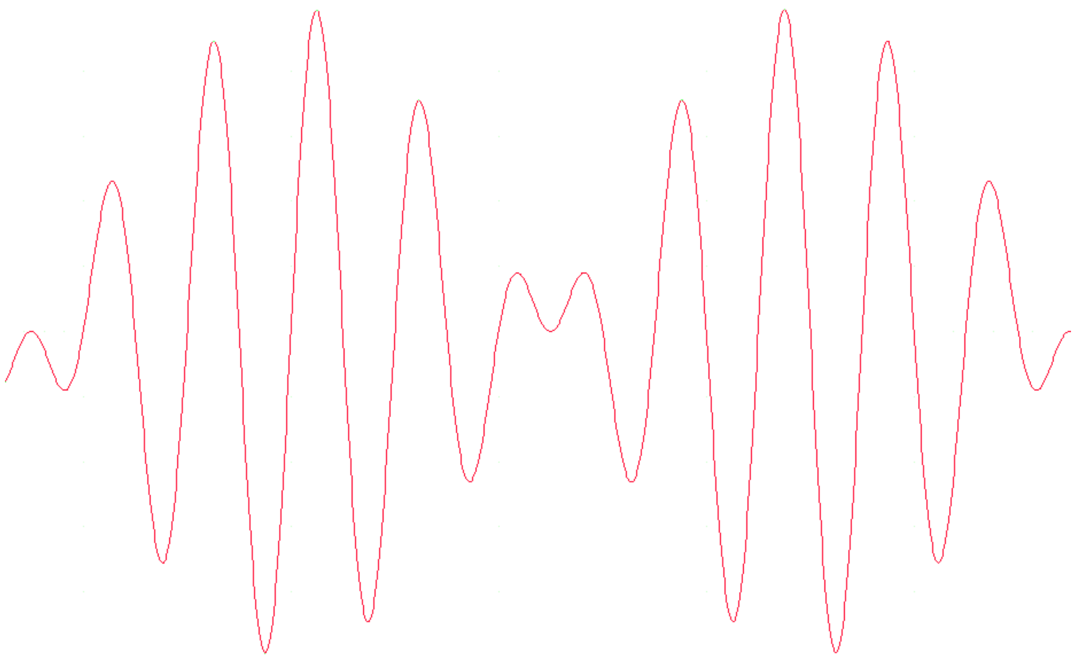
Lab-Report
Analogue Communications

Amplitude Modulation



Name:	Dirk Becker
Course:	BEng 2
Group:	A
Student No.:	9801351
Date:	10/Feb/1999

UNIVERSITY of EAST LONDON

1. Contents

2. Introduction

Amplitude modulation is used since the first days of the 20th century mainly for transmitting voice and signals through the conventional broadcast band like the long-, medium- and short-wave bands because of its easy and cheap way of realisation.
Besides the consumption of bandwidth in comparison to usual FM is relatively small and the receivers could be made up very simple.

3. Amplitude Modulation Systems

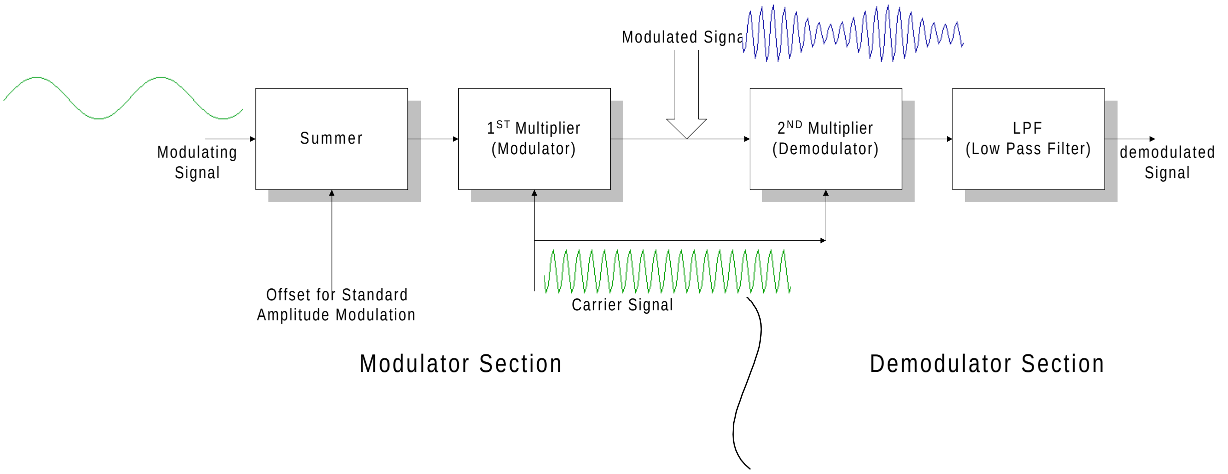


figure 1 - Standard AM - System

Figure 1 shows the block diagram of an AM modulation and demodulation system. The major blocks are the two multipliers and the low pass filter to remove the high frequency parts of the down-mixed signal.
AM modulation simply means the shifting of a signal frequency to another (usually higher) frequency. The information, or better the content of the original (modulating) signal is transferred to another frequency, the carrier.
Frequency shifting is done by multiplication of two signal in the time domain. Multiplication in the time-domain correspondents with frequency shifting in the frequency (ω) domain.

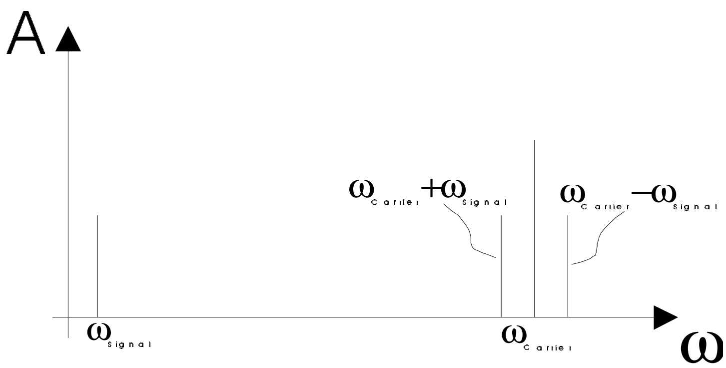


figure 2 - Standard Amplitude modulation

a) Mathematical justification for the frequency shifting

The Frequency shifting can be proofed by applying the Fourier Transform to a function f(t) multiplied with an cosine function.

$$f(t)\cos\omega_0 t = \frac{1}{2}\left(f(t)e^{j\omega_0 t} + f(t)e^{-j\omega_0 t}\right) \quad \text{where } f(t) = \text{modulating signal and } \omega_0 = \text{carrier signal}$$

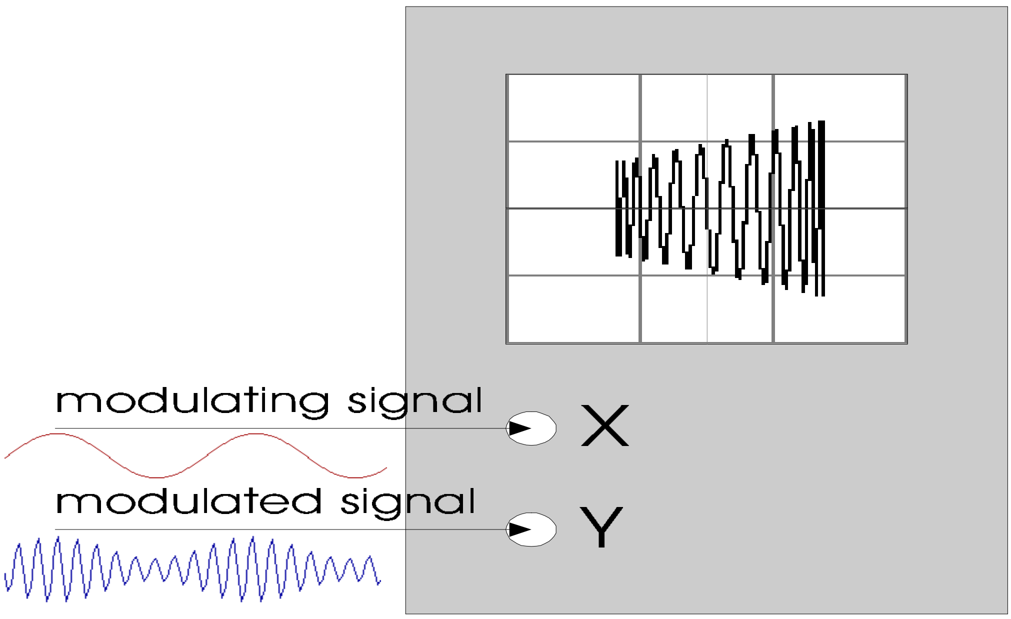
$$f(t)\cos\omega_0 t \Leftrightarrow \frac{1}{2}\left(F(\omega-\omega_0) + F(\omega-\omega_0)\right)$$

This shows that multiplication of a signal f(t) by a sinusoid frequency ω_0 shifts the spectrum F(ω) by $\pm\omega_0$. Multiplication of a sinusoid $\cos\omega_0 t$ by f(t) amounts to modulating the sinusoid amplitude. This kind of modulation is called (balanced) amplitude modulation.

b) Standard amplitude modulation

Balance amplitude modulation, like shown above results in loss of the carrier signal, which carries only redundant information. But for different reasons the carrier is transmitted at standard amplitude modulation. Therefore an offset is added to the carrier and the carrier is transmitted as well.

Mathematical justification for standard amplitude modulation:



where m is called the modulation index (ratio of peak modulating signal to peak carrier signal), and A is the amplitude of the carrier signal.

Standard amplitude modulated signals can be demodulated by means of simple. diodes.

c) Balanced Amplitude Modulation

The opportunity of balanced amplitude modulation is the suppression of the carrier signal, which contains no useful information and consumes a lot of energy, when transmitting. Hence balanced Amplitude Modulation can be described as:

V_m=Af(t)cos($\omega_{carrier}$t) where f(t) is the modulating signal and $\omega_{carrier}$ the carrier frequency.

The main difference in generating balanced amplitude modulation to standard amplitude modulation is the missing offset of the (1) offset in the modulating signal.

Mathematical justification for balanced amplitude modulation:
(see also a) Mathematical justification for the frequency shifting)

$$V_m = A\sin(\omega_c t) m\cos(\omega_{mod} t)$$

$$V_m = A\left(-\frac{1}{2j}\right)\left(e^{jw_c t} - e^{jw_{mod} t}\right)\frac{1}{2}\left(e^{jw_{mod} t} + e^{-jw_{mod} t}\right)$$

$$V_m = -\frac{Am}{4j}\left(e^{j(w_c+\omega_{mod})t} - e^{-j(w_c+\omega_{mod})t} + e^{j(w_c-\omega_{mod})t} e^{-j(w_c-\omega_{mod})t}\right)$$

$$V_m = -\frac{Am}{4j}\left(-\frac{1}{2j}\sin(\omega_c + \omega_{mod}) - \frac{1}{2j}\sin(\omega_c - \omega_{mod})\right)$$

$$V_m = -\frac{Am}{2j}\left(-j\sin(\omega_c + \omega_{mod}) - j\sin(\omega_c - \omega_{mod})\right)$$

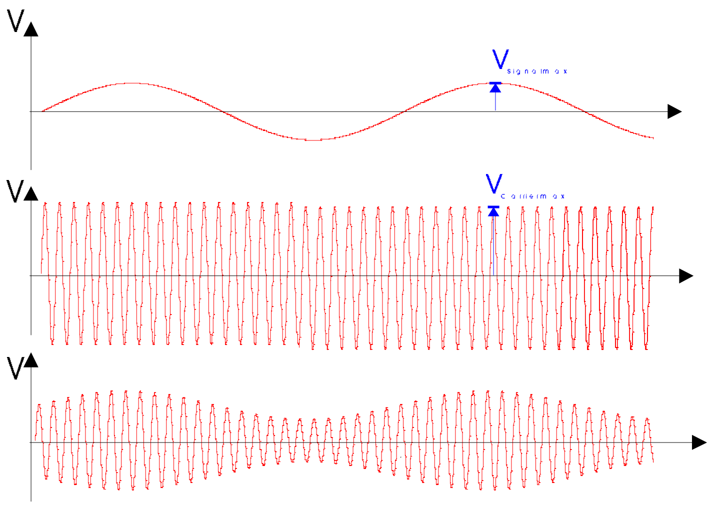
$$V_m = \frac{A\times m}{2}\left(\sin(\omega_c + \omega_{mod}) + \sin(\omega_c - \omega_{mod})\right)$$

where m is the modulation index and A the amplitude of the carrier signal.

d) Modulation index (depth) m

The modulation index (depth) m is defined as the ratio of the peak signal amplitude to the peak carrier amplitude.

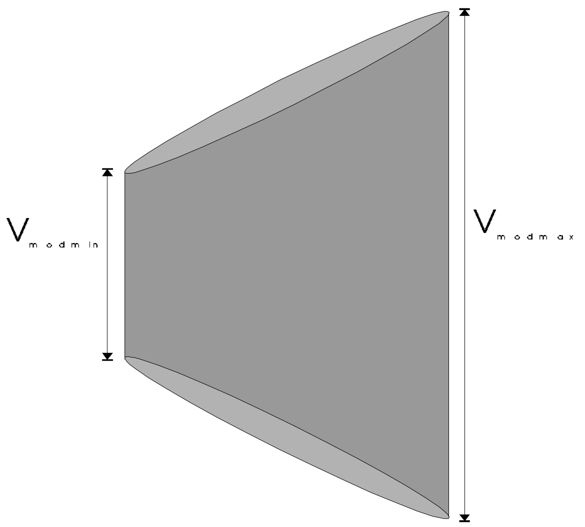
$$m = \frac{\text{peak signal voltage}}{\text{peak carrier voltage}} = \frac{\hat{V}_{\text{Signal}}}{\hat{V}_{\text{Carrier}}}$$



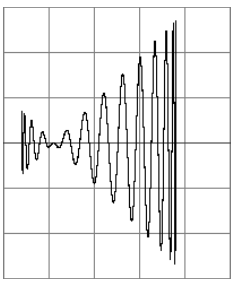
The above figure shows the connection between the modulating signal, the carrier signal and the modulation index m and how to measure via a usual oscilloscope.

Trapezium display

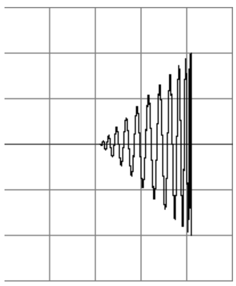
Another easier and more precise way to measure the modulation index is to use an trapezium display. The modulating signal is connected to the X-amplifier and the modulated signal to Y-amplifier of the oscilloscope. By switching the oscilloscope to XY-mode the deflection of the electron ray depends only on the amplitude of the modulating signal and the amplitude of the occurring trapezoid is directly depending of the ratio of carrier to modulating signal.



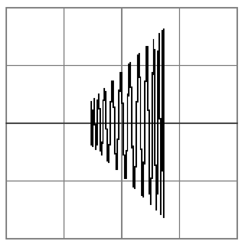
1.)



2.)



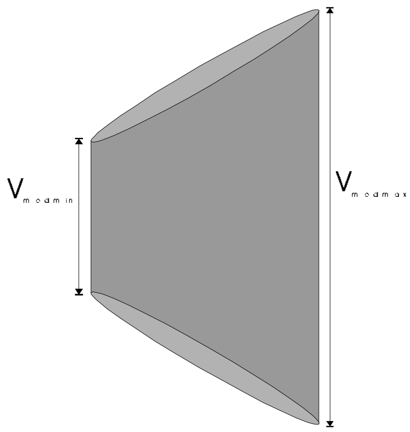
3.)



The above figures show three different values of the modulation index m.
1.) overmodulated (m>100%)
2.) fully modulated (m=100%)
3.) mid modulation (m= ca.30%)

The modulation depth via the trapezium display is calculated by:

$$m = \frac{V_{mod\,max} - V_{mod\,min}}{V_{mod\,max} + V_{mod\,min}}$$



4. Lab Equipment

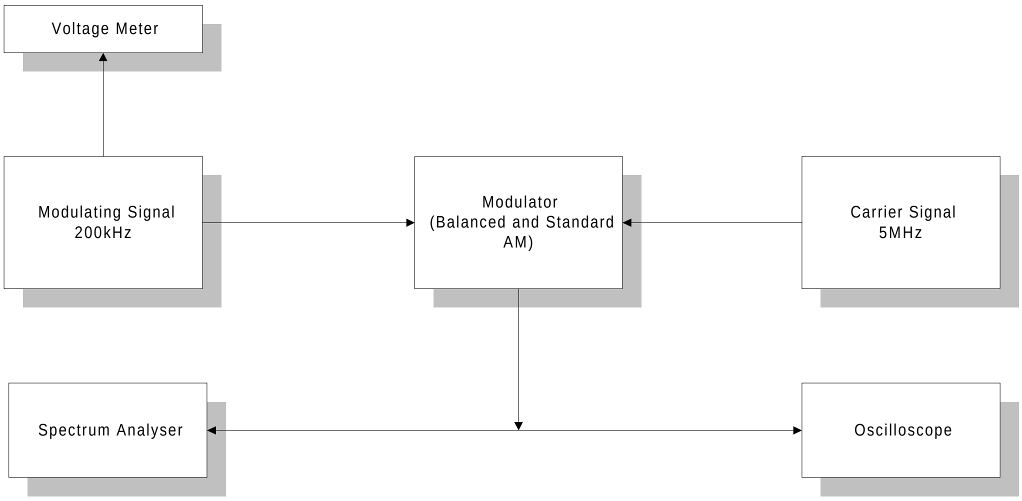


figure 3 - Lab Equipment

The Lab Equipment consists of a modulator for standard and balanced AM, two sinewave generators for the modulating and the carrier signal, a standard oscilloscope, a HP spectrum analyser and a Fluke voltage meter to measure the amplitude of the carrier signal.
This could not be done exactly with the provided measuring instrument, because it's higher cut-off frequency is 20kHz and not as needed 200kHz.

5. Lab Objectives

The objectives of the Lab were
a) To measure depth of modulation by trapezium display
b) To measure depth of modulation using a spectrum analyser
c) To observe the time domain descriptions of conventional and double sideband carrier signals and relate this to frequency domain results.

6. The Lab

a) Measuring of the modulation depth via oscilloscope

First part of the lab was to measure the depth of standard amplitude modulation using the spectrum analyser at different amplitudes of the modulating signal.
The following table shows the measured values for different modulation depths. The modulation index was read out from the spectrum analyser as ratio peak signal amplitude to peak carrier amplitude.

m/% (from Spectrum Analyser)	V_{Sig}
100	**68**
75	**52**
50	**30**
25	**16**
0	**0**

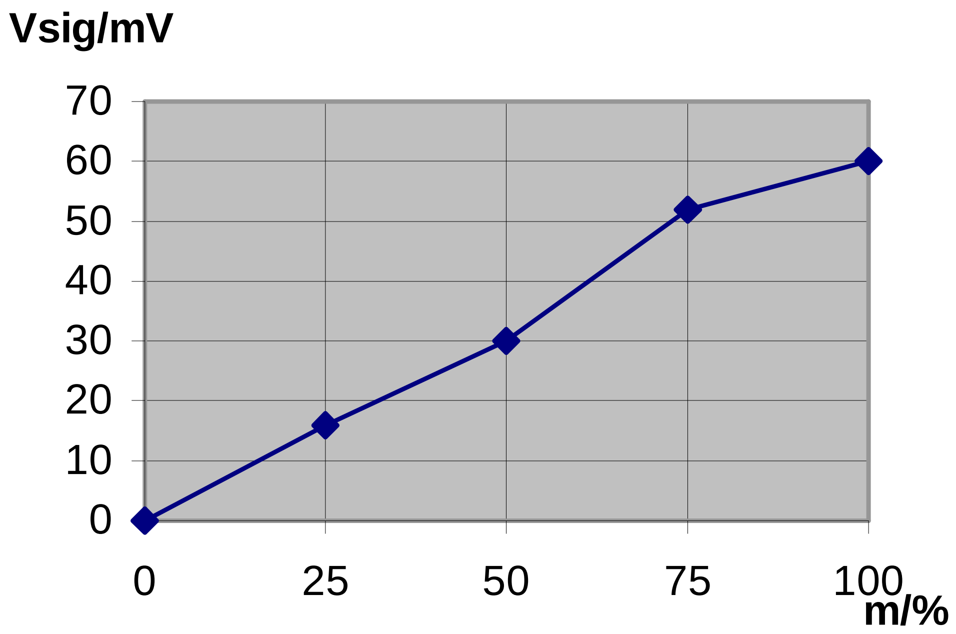


figure 4 - Modulation depth graph

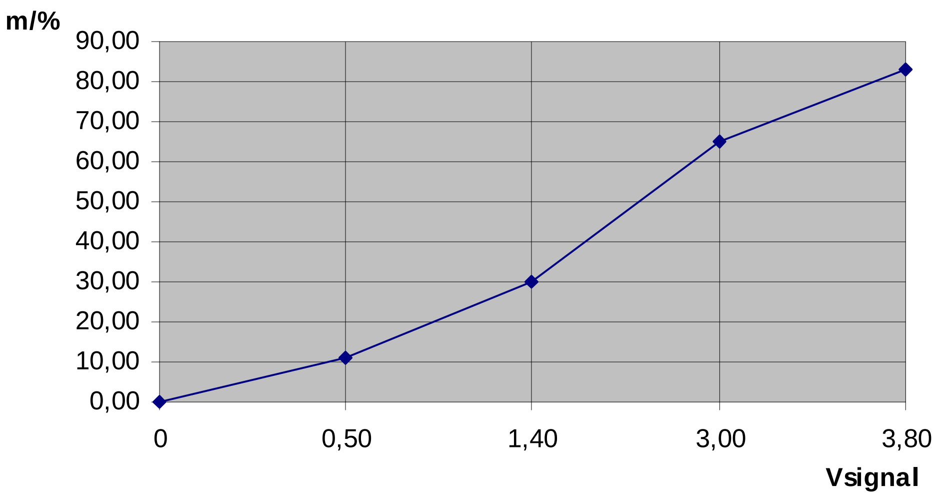
Figure 4 shows the amplitude of the sideband (Vsig) over the modulation depth m. For best modulating results the connection between these both should be linear to prevent modulation interferences.

b) Measuring of the modulation depth via trapezium display

Another more exact way of measuring the modulation depth is the trapezium display. The modulating signal is fed into the X-input of the oscilloscope and the modulated signal to the Y-input. Then the oscilloscope is set to the XY-mode.
(See also 3d) Modulation index (depth) m)

$$m = \frac{V_{\text{mod max}} - V_{\text{mod min}}}{V_{\text{mod max}} + V_{\text{mod min}}}$$

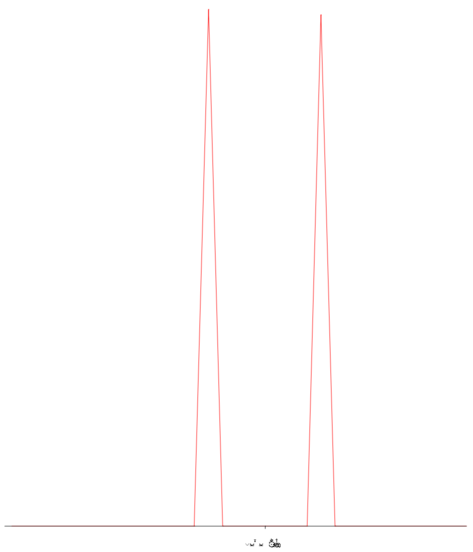
V_{min}/DIV	V_{max}/DIV	m/%
0.4	**4.2**	**83**
0.8	**3.8**	**65**
1.6	**3.0**	**30**
2	**2.5**	**11**
2.25	**2.25**	**0**

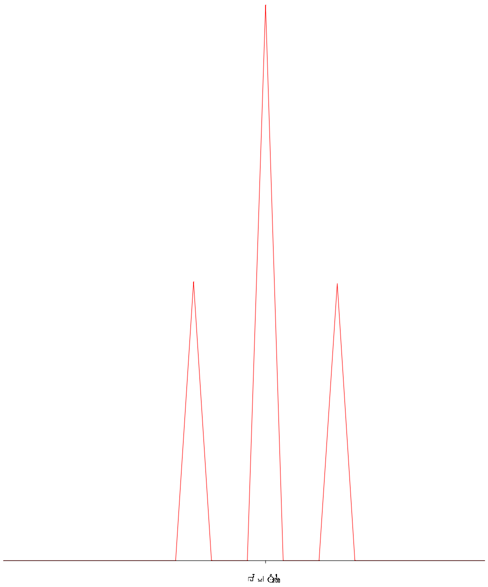


The above graph shows the modulation depth versus the signal amplitude obtained from the trapezium display.
The trapezium display is much more exactly than the obtaining of the modulation index via an oscilloscope in time mode.

c) Standard and balanced amplitude modulation

Like shown in c) Balanced Amplitude Modulation the carrier can be switched off and on by adding a DC-unbalance to the modulating signal. On transmission of standard amplitude modulation a large part of the transmission power is needed only for the carrier.
So professional amplitude modulating systems work wit balanced amplitude modulation, which sometimes is called suppressed carrier AM. The carrier is only needed for better transmission of very low frequent signals and for rectifier demodulation.





a) Balanced b) Standard AM (Spectral Plots)

The two figures above show the output plots of the spectral analyser with balanced and unbalanced AM.
The sidebands are both located at 4.8MHz and 5.2MHz. The modulation depth m is 50%.

7. Conclusion

Although amplitude modulation is used since the first days of the 20th century, it is still very popular. The advantages of AM are the easy and cheap way of realisation and the little consumption of bandwidth. The disadvantages are the poor signal to noise ratio and the proneness to amplitude distortions.
An important part of amplitude modulation is the measuring of the modulation depth m. The modulation depth can be either determined by directly obtaining the ratio of the modulating and the carrier signal or to obtain the modulation depth via a trapezium display. The trapezium display is more exactly, because the modulation depth is directly readable from the oscilloscope's screen.
Linear modulation is very nessesary to obtain a not interfered signal at the receiver.