1. AMPLITUDE M0DULATION

1.1 OBJECTIVES

- Examine the main parameters of an amplitude modulated signal
- check the operation of an amplitude modulator
- carry out characteristic measurement on an amplitude modulator
- analyse the spectrum of an amplitude modulated signal.

1.2 INTRODUCTORY INFORNATION

1.2.1 Main aspects

Consider a sine signal $v_m(t)$ with frequency f (fig.1.1):

$v_m(t) = B\cdot\sin(2\pi f\cdot t)$

and another sine signal $v_c(t)$ with superior frequency F:

$v_c(t) = A\cdot\sin(2\pi F\cdot t)$.

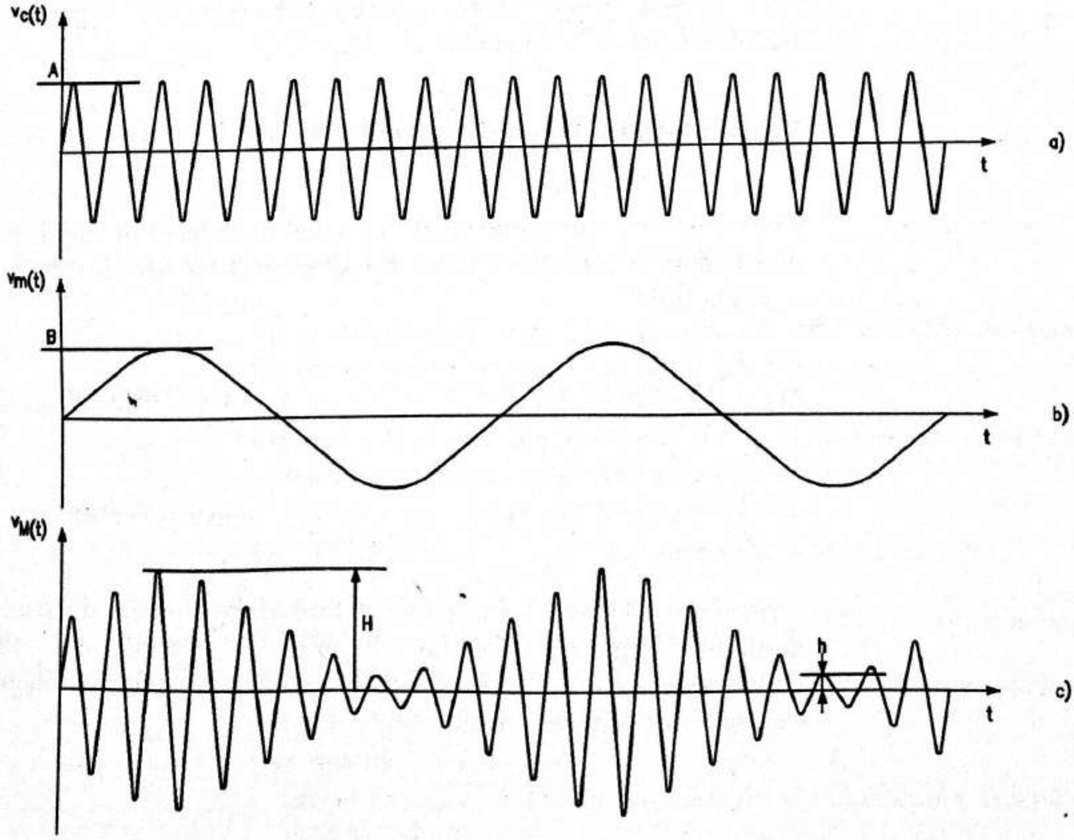

fig.1.1 a) carrier signal b) modulating signal c) modulated signal

The signal $v_m(t)$ is called *modulatring signal*, the signal $v_c(t)$ is called *carrier signal*.

Vary the amplitude of the carrier $v_c(t)$ adding the modulating signal $v_m(t)$ to A. You obtain a signal $v_M(t)$ *amplitude modulated*, which can be expressed by:

$v_M(t) = [A+k\cdot B\cdot \sin(2\pi f\cdot t)]\cdot \sin(2\pi F\cdot t) = A\,[1+m\cdot \sin(2\pi f\cdot t)]\cdot \sin(2\pi F\cdot t)$

with k = constant of proportionality

Percentage modulation signal is defined as the value:

$$m = \frac{k\cdot B}{A}\cdot 100$$

With reference to fig.1.lc, the modulation index m can be calculated in this way:

$$m = \frac{H-h}{H+h}\cdot 100\%$$

1.2.2 Spectrum of the modulated signal

With simple trigonometric passages, the relation expressing the modulated signal v_M becomes:

$$V_M(t) = A\cdot \sin(2\pi F\cdot t) + m\cdot \frac{A}{2}\cdot \cos[2\pi\cdot(F-f)\cdot t] - m\cdot \frac{A}{2}\cos[2\pi(F+f)\cdot t]$$

From which we can deduce that the signal modulated in amplitude by a sine modulator consists in three sine components:

$A\sin(2\pi F\cdot t)$	carrier
$m\cdot \frac{A}{2}\cdot \cos[(2\pi(F-f)\cdot t]$	lower side band
$m\cdot \frac{A}{2}\cdot \cos[(2\pi(F+f)\cdot t]$	upper side band

Particularly effective is the representation of the modulated signal into a Amplitude/frequency diagram. Figure 1.2 reports the different components of the AM signal, in the amplitude/frequency diagram as well as the amplitude/time diagram.

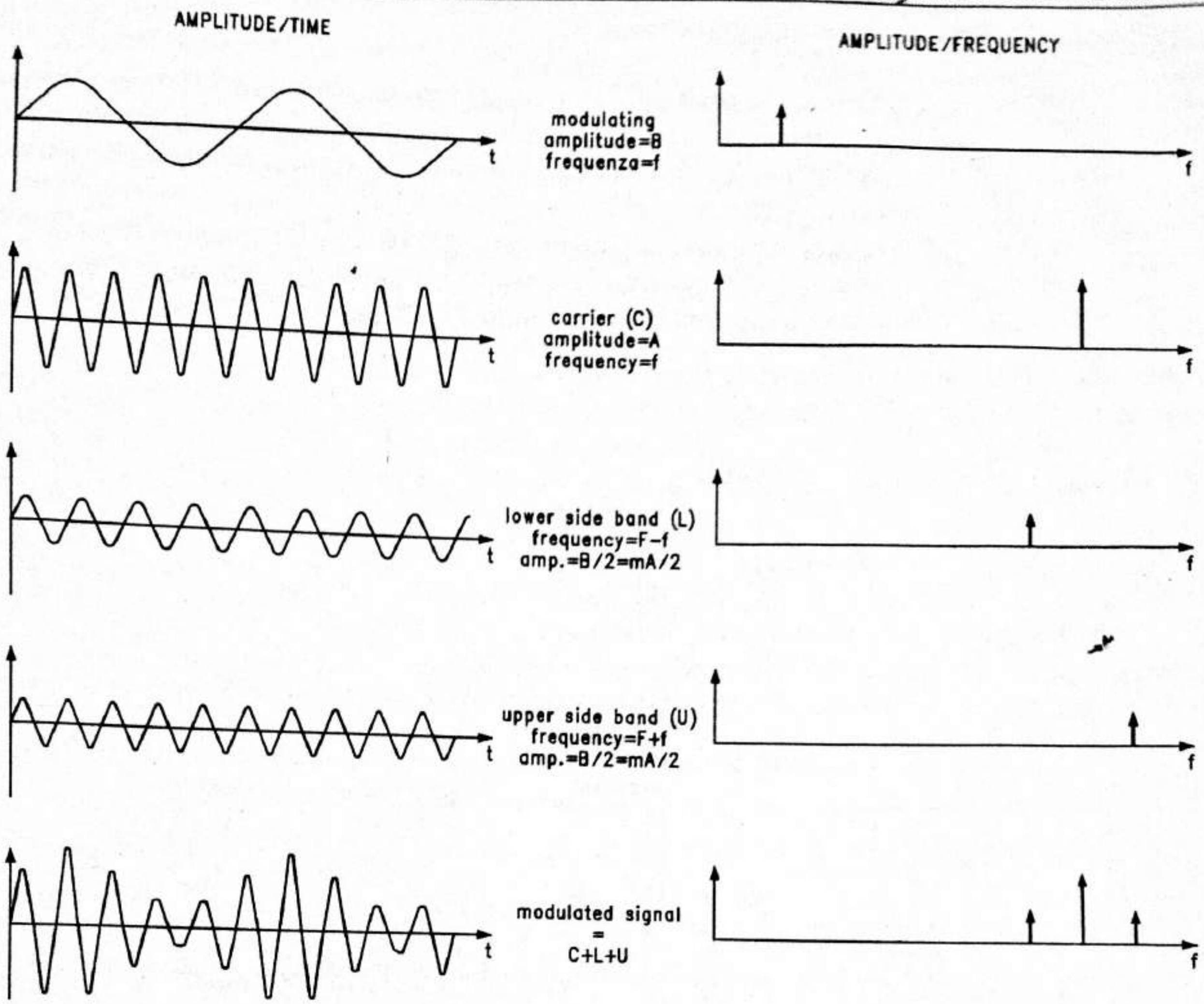

fig. 1.2

1.2.3 Power of the modulated signal

The total power of an AM signal is the sum of the contributes related to the carrier and to the upper and lower side bands.

Considering a sine modulating signal and a load resistance R, the different components supply the following powers:

$P_C = A^2/2 \cdot R$	power associated to the carrier
$P_L = (m.A)^2/8 \cdot R$	power associated to the lower side band
$P_U = (m.A)^2/8 \cdot R$	power associated to the lower side band

It is important to note that:

- the power associated to the carrier is fixed and does not depend on the modulation
- the power associated to each side band depends on the index of modulation, and reaches at max. the 25% of the power of the carrier (50% the two side bands together).

1.2.4 Non-sinusoidal modulating signal: spectrum

Consider a modulating signal not constituted by a single sine wave, but a generic signal with frequency spectrum ranging between f_1 and f_2. With the amplitude modulation this spectrum is moved aver and under the carrier (fig.1.3).
It is evident that the larger is the spectrum of the modulating signal, the larger is the band Bw occupied by the modulating signal. Bw results equal to the double of the modulating signal:

$$Bw = 2 \cdot f_2$$

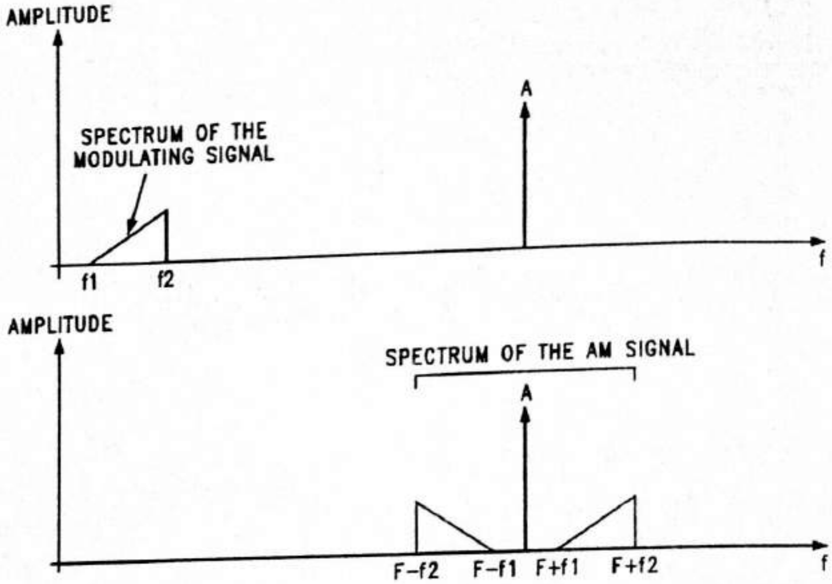

fig. 1.3

1.2.5 Amplitude Modulation Generation

The circuits used to generate an amplitude modulation must vary the amplitude of a high frequency signal (carrier) as function of the amplitude of a low frequency signal (modulating signal).

In an AM transmitter we speak of:

- *high level modulation,* if the modulation is carried out directly in the last power stage, which is generally an amplifier in class C
- *low frequency modulation,* when the modulation is carried out by stages which are before the final power amplifier.

Semiconductor devices can be used, in case of low power, or valve ones, when the required power are high.
In the circuit used for the exercises, the amplitude modulation is generated by a differential amplifier, which gain is varied by the modulating signal. This circuit, contained in the integrated circuit LM1496, can be used also to generate the amplitude modulation with suppressed carrier, object of another exercise.

1.3 EXERCISE

Reguired material

- modules T10A-T10B
- power supply +1-12 Vdc
- oscilloscope.

1.3.1 Exercise 1: Modulator Operation

1. Carry out the connections between modules T10A and T10B, as indicated in fig.1.4. Power the modules with ±12V and carry out the following presetting:
   - FUNCTION GENERATOR: sine (J1); LEVEL about 0.5 Vpp; FREQ. about 1 kHz
   - VCO2: LEVEL about 1 Vpp; FREQ. about 450 kHz
   - BALANCED MODULATOR 1: CARRIER NULL completely rotated clockwise or counter clockwise, so to "unbalance" the modulator and to obtain an AM signal with not suppressed carrier across the output; OUT LEVEL in intermediate position.

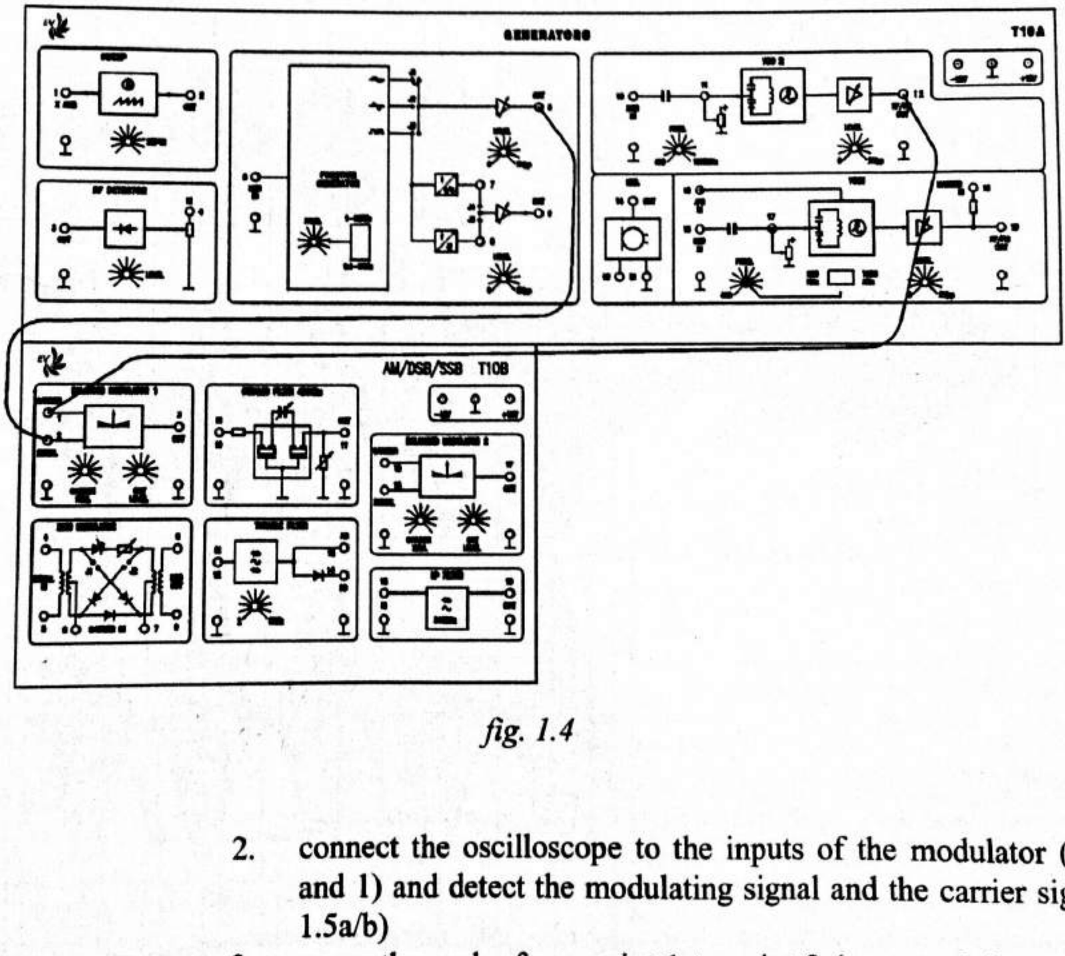

fig. 1.4

2. connect the oscilloscope to the inputs of the modulator (points 2 and 1) and detect the modulating signal and the carrier signal (fig. 1.5a/b)
3. move the probe from point 1 to point 3 (output of the modulator), where a signal modulated in amplitude is detected (fig.1.5c). Note that the modulated signal envelope corresponds to the waveform of the modulating signal
4. vary the amplitude of the modulating signal and check the 3

following conditions: modulation percentage lower than the 100% (fig.1.5c), equal to the 100% (fig.1.5d), superior to 100% (overmodulation, fig.1.5e)

5. vary the frequency and waveform of the modulating signal, and check the corresponding variations of the modulated signal
6. vary the amplitude of the modulating signal and note that the modulated signal can result saturated or overmodulated.

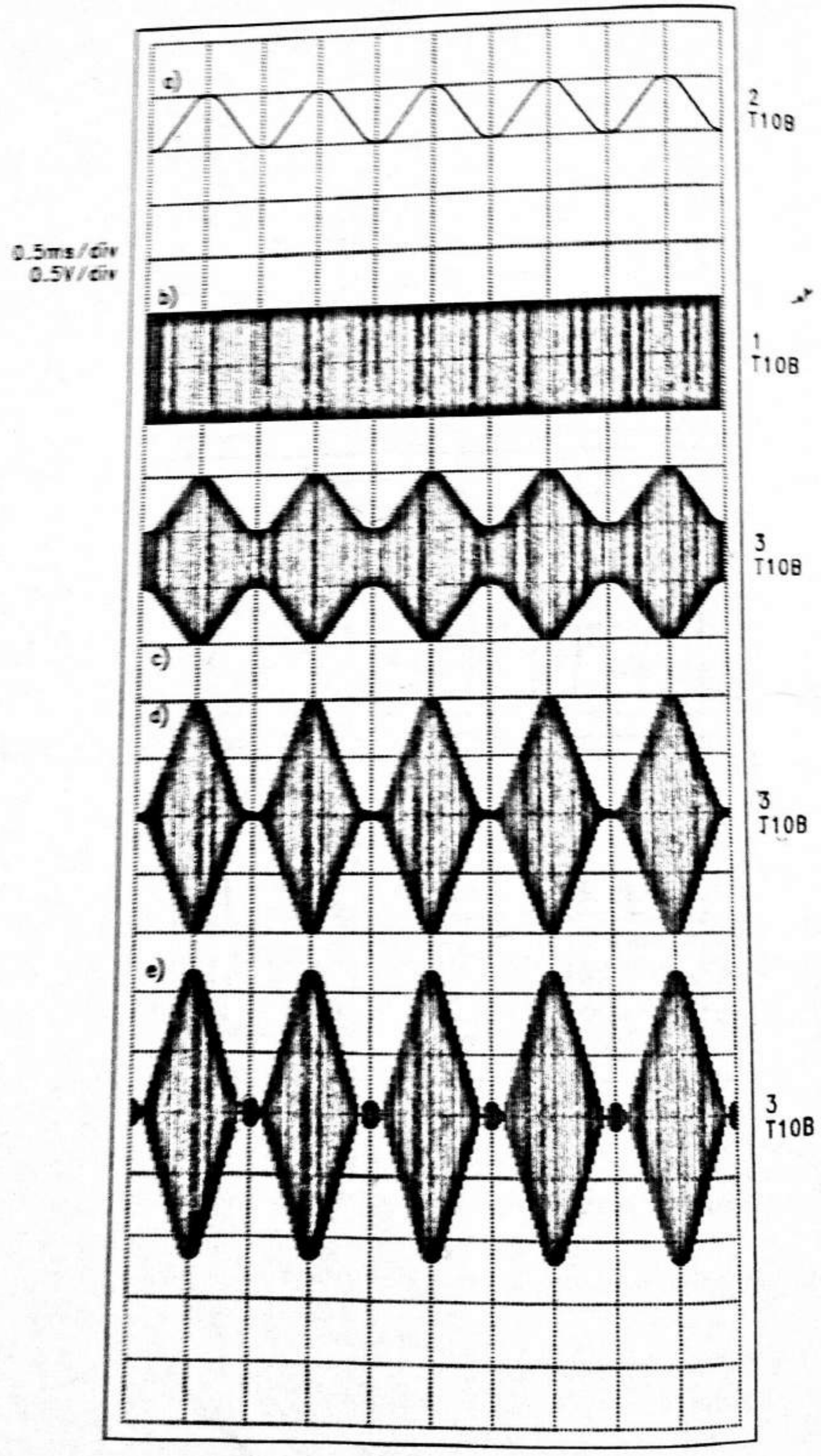

fig. 1.5 Wave-forms of the AM modulator

1.3.2 Exercise 2: Modulation Index

7. Set the modules as in the last point 1
8. using the oscilloscope measure (fig.1.6):
   - the amplitude B of the modulating signal (point 2 of T10B)
   - the amplitudes H and h of the modulated signal, and the amplitude C of the envelope of the modulated signal (point 3 of T10B)
9. calculate the constant k of the modulator, equal to: k=C/B You find a value a little over 1
10. calculate the amplitude A of the carrier, equal to:

$$A = \frac{H+h}{2}$$

11. calculate the percentage index of modulation m, equal to:

$$m = \frac{H-h}{H+h} \cdot 100\%$$

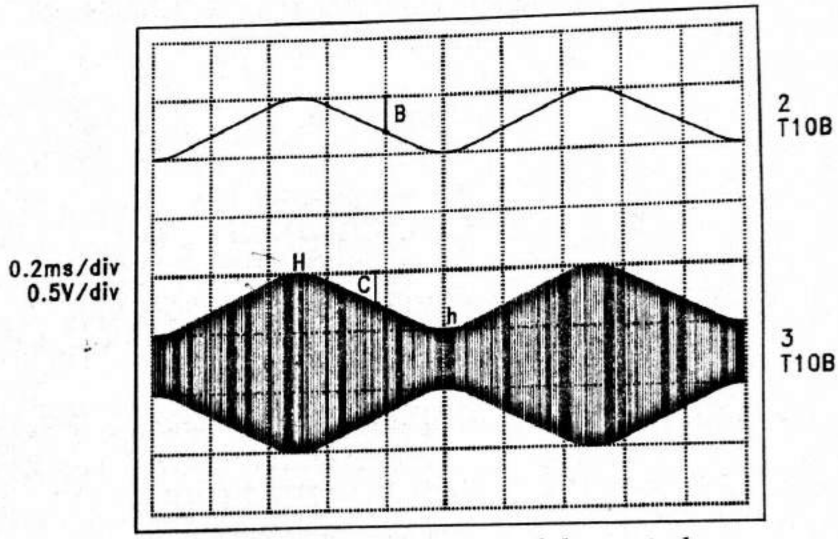

fig. 1.6 : Calculation of the modulation index

1.3.3 Exercise 3: Linearity of the Modulator

12. Set the modules as in the last point 1
13. set the oscilloscope in X-Y mode (X=0.2V/div, Y1V/div). Connect the modulating signal (2 of T10B) to the axis X, and the modulated signal (3 of T10B) to the axis Y
14. on the diagram there is a trapezium similar to the one of fig.1.7a; this supplies the behaviour of the envelope of the modulated signal as function of the modulating signal amplitude. The display method points out the eventual non linearity or distortions of the modulated signal. Increase the amplitude of the modulating signal and observe how the saturation and the overmodulation of the modulated signal are displayed (fig.1.7b)

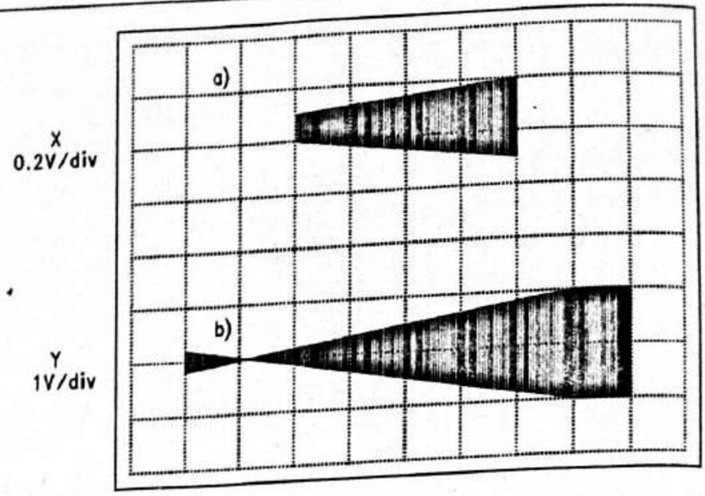

fig. 1.7 Linearity of the modulator

1.3.4 Exercise 4: Spectrum of the AM Signal

Refer to the "Appendix A" far the explanation of the operating principle of the spectrum analyser.

15. Carry out the connections between modules T10A and T10B, as shown in fig.1.8. Power the modules with ±12V and carry out the following presetting:
    - FUNCTION GENERATOR: sine wave (JI); LEVEL about 0.5 Vpp; FREQ. about 10 kHz
    - VCO2: LEVEL about l Vpp; FREQ. about 450 kHz
    - VCO1: LEVEL about 2 Vpp; shifter on 1500kHz; FREQ. about 900 kHz
    - SWEEP: DEPTH almost completely counter clockwise
    - RF DETECTOR: LEVEL completely clockwise
    - BALANCED MODULATOR 1: CARRIER NULL rotated completely clockwise or counter clockwise, so that an AM signal is obtained across the output; OUT LEVEL in intermediate position
    - BALANCED MODULATOR 2: CARRIER NULL in central position, so that the circuit operates as frequency converter (balanced modulator with suppressed carrier); OUT LEVEL in intermediate position
    - trimmer of the CERAMIC FILTER completely clockwise
16. set the oscilloscope in X-Y (X=0.2V/div, Y=50mV/div). Connect the SWEEP generator (1 of T10A) to the axis X, and the detected signal (3 of T10A) to the axis Y
17. vary the frequency of the carrier (VCO2) until the oscilloscope shows a representation similar to the one of fig.1.9. To obtain the best wave adjust: the deviation of the SWEEP generator (DEPTH); the pass band of the ceramic filter (variable capacity); the CARRIER NULL of the balanced modulator 2

18. the wave-form represents the spectrum of the AM signal, consisting in the carrier and the 2 side bands
19. vary frequency, amplitude and waveform of the modulating signal and examine the variations on the spectrum.

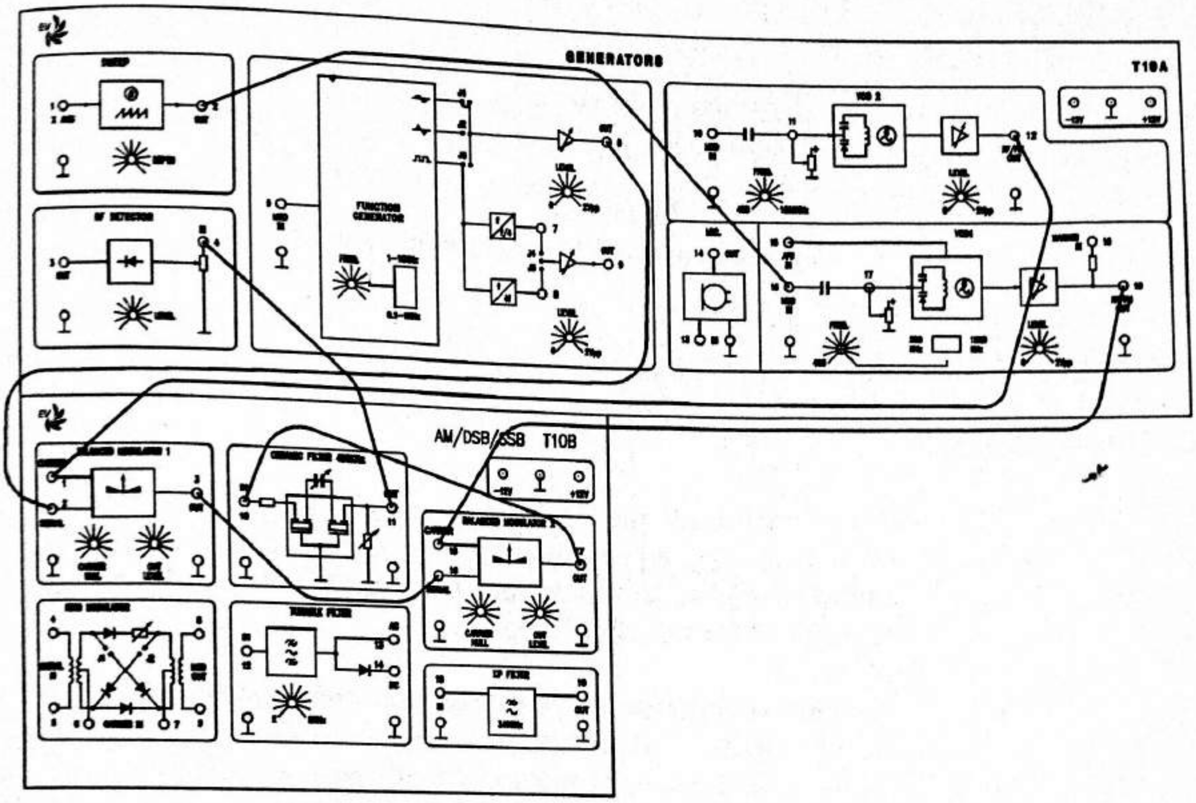

fig. 1.8

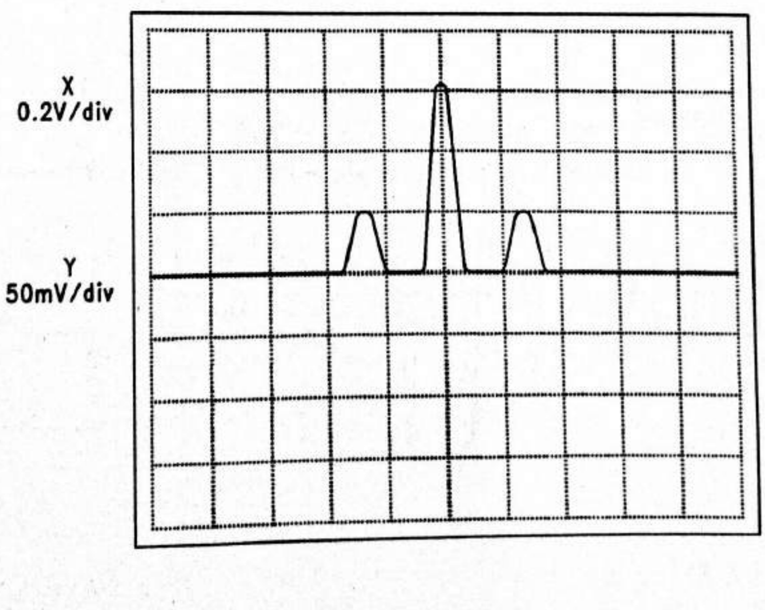

fig. 1.9 : Spectrum of the AM signal