# Communication Electronics (Lecture 3)

## Modulation Index (m)

Modulation indices are described for various forms of modulation. In AM, modulation index can be defined as the measure of extent of amplitude variation about an un-modulated carrier. As with other modulation indices, the modulation index for amplitude modulation indicates the amount by which the modulated carrier varies around its static un-modulated level. When expressed as a percentage it is the same as the depth of modulation. In other words it can be expressed as:

$$m = \frac{V_m}{V_c}$$

Where,

$V_m$ is the carrier amplitude.

$V_c$ is the peak in the RF amplitude from its unmodulated value.

From this it can be seen that for an AM modulation index of 0.5, the modulation causes the signal to increase by a factor of 0.5 and decrease to 0.5 of its original level.

### Percentage Modulation

A complementary figure to modulation index is also used for amplitude modulation signals. Known as the modulation depth, it is typically the modulation index expressed as a percentage. Thus a modulation index of 0.5 would be expressed as a modulation depth of 50%, etc. However often the two terms and figures are used interchangeably and figures for a modulation index of 50% are often seen where the index is 0.5.

Percentage modulation, %m = $m \times 100 = \frac{Vm}{Vc} \times 100$

The practical value of percentage modulation lies between 0 and 80%. Another way of expressing the modulation index is in terms of the maximum and minimum values of the amplitude of the modulated carrier wave. This is shown in the figure 6-8

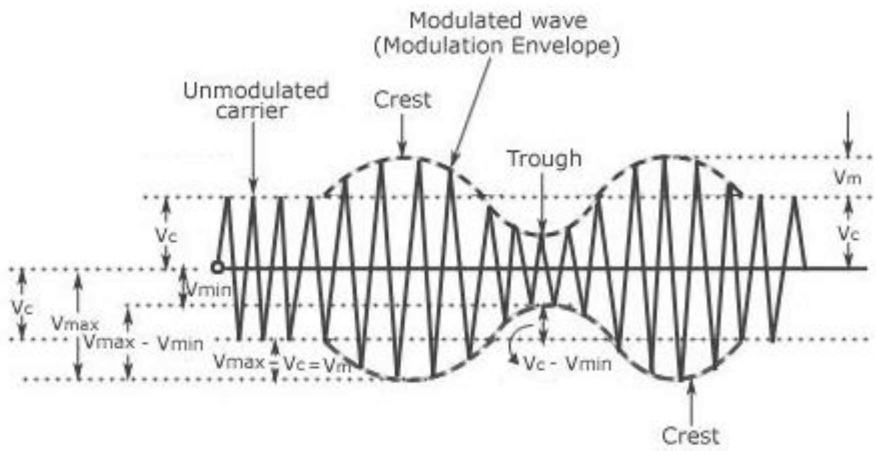



Fig: AM signal for Percentage Modulation Calculation

From above Fig :

$$V_{min} = V_c - V_m \qquad (5)$$

$$V_{max} = V_c + V_m \qquad (6)$$

Adding Equ (5) and (6)

$$Vc = \frac{Vmax + Vmin}{2} \qquad (7)$$

$$Vm = \frac{(Vmax - Vmin)}{2} \qquad (8)$$

Dividing Equ. (8) by (7)

$$m = \frac{Vm}{Vc} = \frac{(Vmax - Vmin)}{(Vmax + Vmin)} \qquad (9)$$

Equation (9) gives experimental way to calculate

**Modulation Index / Modulation Depth Examples**

Typically the modulation index of a signal will vary as the modulating signal intensity varies. However some static values enable the various levels to visualized more easily.

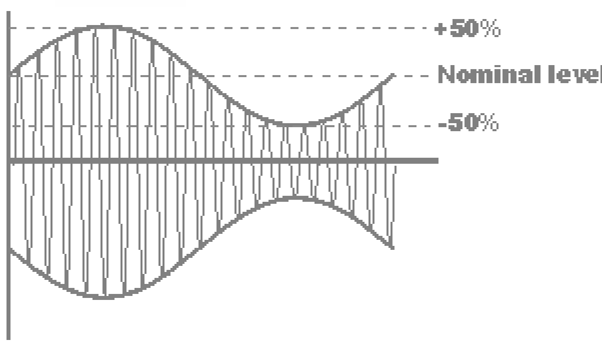



Fig : AM with m = 0.5

When the modulation index reaches 1.0, i.e. a modulation depth of 100%, the carrier level falls to zero and rises to twice its non-modulated level.

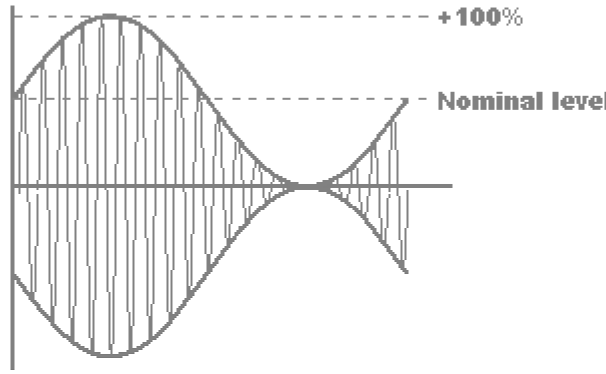
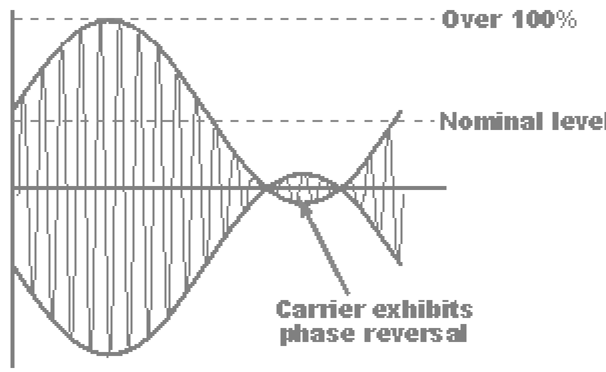
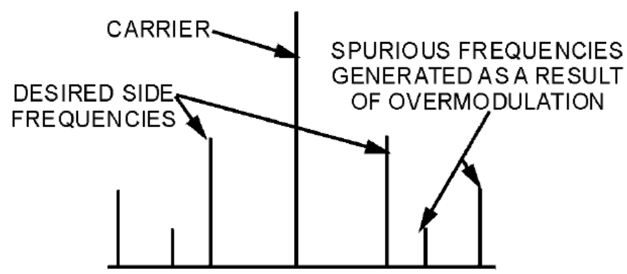



Fig : AM with m =1.

Any increase of the modulation index above 1.0, i.e. 100% modulation depth causes over modulation. The carrier experiences 180° phase reversals where the carrier level would try to go below the zero point. These phase reversals give rise to additional sidebands resulting from the phase reversals (phase modulation) that extend out, in theory to infinity. This can cause serious interference to other users if not filtered. This effect can easily be detected by tuning a receiver near, but somewhat outside the desired frequency. You would likely be able to tune to one or more of these undesired sideband frequencies, but the reception would be severely distorted, possibly unintelligible. (Without over modulation, no such unwanted sideband frequencies would exist and you would be able to tune only to the desired frequency.) These unwanted frequencies will appear for a considerable range both above and below the desired channel. This effect is sometimes called SPLATTER. These spurious frequencies, shown in Fig (below) (b) causes an interference with other stations operating on adjacent channels. You should clearly understand that over modulation, and its attendant distortion and interference is to be avoided.




(a)




(b)

Fig : AM with m > 1; Over Modulation.(a) Time-domain view

(b) Frequency-domain view.

In addition to the above problems, over modulation also causes abnormally large voltages and currents to exist at various points within the transmitter. Therefore, sufficient overload protection by circuit breakers and fuses should be provided. When this protection is not provided, the excessive voltages can cause arcing between transformer windings and between the plates of capacitors, which will permanently destroy the dielectric material. Excessive currents can also cause overheating of tubes and other components. Ideally, you want to operate a transmitter at 100-percent modulation so that you can provide the maximum amount of energy in the sideband.

However, because of the large and rapid fluctuations in amplitude that these signals normally contain, this ideal condition is seldom possible.

Broadcast stations in particular take measures to ensure that the carries of their transmissions never become over modulated. The transmitters incorporate limiters to prevent more than 100% modulation. Hover they also normally incorporate automatic audio gain controls to keep the audio levels such that near 100% modulation levels are achieved for most of the time.

### Power Relation in AM

In radio transmission, the AM signal is amplified by a power amplifier and fed to the antenna with characteristic impedance that is ideally, but not necessarily, almost pure resistance. The AM signal is really a composite of several signal voltages, namely, the carrier and the two sidebands, and each of these signals produces power in the antenna. The total transmitted power $P_T$ is simply the sum of the carrier power $P_C$ and the power in two side bands $P_{USB}$ and $P_{LSB}$, thus:

$$P_T = P_C + P_{LSB} + P_{USB} \qquad (10)$$

Considering, antenna radiation resistance = R

$$P_c = \left[ \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} \right]$$

$$= \frac{V_c^2}{2R}$$

Each side band has a value of mVc /2 and r.m.s value of mVc/2√2. Hence power in LSB and USB can be written as

$$P_{LSB} = P_{USB} = \left[\frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R}\right] = \left(\frac{m^2}{4}\right)\frac{V_c^2}{2R} = \left(\frac{m^2}{4}\right).P_c$$

$$P_T = \frac{V_c^2}{2R} + \left(\frac{m^2}{4}\right).P_c + \left(\frac{m^2}{4}\right).P_c$$

$$P_T = P_C\left(1 + \frac{m2}{2}\right) \qquad (11)$$

If $I_C$ and $I_T$ are the r.m.s values of unmodulated current and total modulated current and R is the resistance through which these current flows, then

$$\frac{P_T}{P_C} = \left(1 + \frac{m2}{2}\right)$$

$$\frac{I_T^2.R}{I_C^2.R} = \left(\frac{I_T}{I_C}\right)^2$$

$$\frac{I_T}{I_C} = \sqrt{\left(1 + \frac{m2}{2}\right)} \qquad (12)$$

## Power Efficiency in AM

In AM, the carrier term does not carry any information, and hence the carrier power is wasted. The sideband power is useful power which carries intelligence. The total power is the sum of the carrier (wasted) power and the sideband (useful) power. Hence, η, the power efficiency is

$$\eta = \frac{\text{useful power}}{\text{total power}} = \frac{P_{SB}}{P_{C+}\ P_{SB}}$$

$$= \frac{(m^2/2)P_C}{P_C\left(1+\frac{m^2}{2}\right)}$$

Let m = 1, In this situation

$$\eta = 0.33$$

Thus, the efficiency of conventional AM is only 33%, which is very poor. The above relation also expresses that if the carrier is suppressed; only the sideband power remains. As this is only $(m^2/2)P_C$ , a two-third saving is affected at 100% modulation, and even more is saved as the depth of modulation is reduced. Among two sidebands, if one of the sideband is also suppressed, the remaining power is $P_C(m^2/4)$, further saving of 50% over carrier suppressed AM.