Amplitude Modulated Systems

- Communication is process of establishing connection between two points for information exchange.
- Channel refers to medium through which message travels e.g. wires, links, or free space.
- Information is called baseband signal/modulating signal.
  **Example:** Audio signal 30 Hz to 20 KHz
  Tone – single frequency
- Modulation is the requirement of communication systems. It is a process by which some characteristic of carrier signal is varied according to instantaneous value of modulating signal.

**Types of Modulation:**

- **Continuous wave (CW) modulation:** Carrier waveform is continuous.
- Example: Amplitude and Angle modulations,
- **Pulse modulation:** Carrier is pulse type:
  - Pulse Analog Modulation: PAM, PWM, PPM
  - Pulse Digital modulation: PCM, DM, DPCM
- **Digital Modulation Schemes:** Used for data transmission; ASK, FSK, PSK
Need for Modulation?

(i) **Multiplexing:** Simultaneous transmission of multiple messages. If transmitted without modulation they will interfere.

(ii) **Size of antenna:** audio frequency: 30Hz – 20 KHz
(a) For 30Hz, $\lambda = 10,000$ KM, Antenna size $\lambda / 4 = 2500$ Km (Impractical)
(b) For 1 MHz carrier, $\lambda = 300$m, Antenna $\lambda / 4 = 75$m (Big)
(c) For 100 MHz carrier, $\lambda = 3$m, Antenna $(\lambda / 4) = 7.5$m (Practical).

(iii) **Narrow banding:** If baseband signal (50 Hz-20 KHz) is transmitted directly one needs very wide band antenna. Frequency translation improves a lot typical 1:200 ratio of band edge reduces to 1:1.01 for frequency range of 1 MHz.

Amplitude Modulation (Conventional AM)

- Amplitude of carrier is changed with respect to modulating signal.
- It is linear modulation.

Carrier wave $e_c = E_c \cos \omega_c t$
Modulating signal $e_m = E_m \cos \omega_m t$
Modulated signal $s(t) = E_c \left[ 1 + \frac{E_m}{E_c} \cos \omega_m t \right] \cos \omega_c t$

Where, modulation index $(\mu) = \frac{E_m}{E_c}$
\[ s(t) = E_c \cos \omega_c t + \frac{\mu E_c}{2} \cos(\omega_c - \omega_m) t + \frac{\mu E_c}{2} \cos(\omega_c + \omega_m) t \]

Three components

(i) Carrier frequency with amplitude \( E_c \)
(ii) Upper sideband \((\omega_c + \omega_m)\) with amplitude \( \frac{\mu E_c}{2} \)
(iii) Lower side band \((\omega_c - \omega_m)\) with amplitude \( \frac{\mu E_c}{2} \)
Experimental Determination of Modulation Index ($\mu$):

Minimum amplitude of AM wave $V_{\text{min}} = (E_c - E_m)$

Maximum amplitude of AM wave $V_{\text{max}} = (E_c + E_m)$

So, $\mu = \frac{(V_{\text{max}} - V_{\text{min}})}{(V_{\text{max}} + V_{\text{min}})}$ (From the waveform on CRO)
Power in AM wave:

(a) Conventional AM (DSB FC)

\[ P_{AM} = \frac{E_{car}^2}{R} + \frac{E_{LSB}^2}{R} + \frac{E_{USB}^2}{R} \quad \text{where all voltages in RMS and} \ R \ \text{is resistance of antenna} \]

\[ E_c = \frac{E_c}{\sqrt{2}} \]

\[ P_{LSB} = P_{USB} = \frac{E_{LSB}^2}{R} = \frac{\left(\frac{E_c}{\sqrt{2}}\right)^2}{R} = \frac{\mu^2 E_c^2}{8R} \]

\[ P_{AM} = \frac{E_c^2}{2R} + \frac{\mu^2 E_c^2}{2R} + \frac{\mu^2 E_c^2}{2R} \quad (\text{Resistance} \ R \ \text{can be taken as unity}) \]

\[ \frac{P_{AM}}{P_c} = \frac{P_T}{P_c} = \left(1 + \frac{\mu^2}{2}\right) \quad \text{OR} \quad P_{DSBFC} = \left(1 + \frac{\mu^2}{2}\right) P_c \quad \& \quad \eta = \frac{P_{SB}}{P_T} = \frac{\mu^2}{(2 + \mu^2)} \]

For \( \mu = 1, \quad \eta = 33.3\% \)

If modulated by several tones then overall modulation index is given by

\[ \mu_t = \sqrt{\mu_1^2 + \mu_2^2 + \cdots} \]
(b) **Double side band suppressed carrier system (DSBSC)**

Most of the power in conventional AM is contained in carrier.

Major saving of carrier in this systems.

Efficiency of suppressed carrier (SC) system is 100%.

It is at the cost of expensive and complex receiver

\[ s(t) = m(t) \cos \omega_c t = \mu E_c \cos \omega_m t \cos \omega_c t \]

\[ P_{DSBSC} = P_{USB} + P_{LSB} \]

\[ P_{USB} = P_{LSB} = \frac{\mu^2 E_c^2}{8R} \]

\[ P_{DSBSC} = \frac{\mu^2 E_c^2}{4R} = \frac{\mu^2}{2} P_c \]

Used in commercial radio broadcasting.
(c) Single sideband suppressed carrier (SSBSC)

\[ P_{SSB} = \frac{E_{LSB}^2}{R} = \frac{E_{USB}^2}{R} \]

\[ P_{LSB} = P_{USB} = \frac{E_{SB}^2}{R} \]

\[ P_{SSB} = \frac{\mu^2}{4} \frac{E_c^2}{2R} = \frac{\mu^2}{4} \cdot P_c \]

Used in point to point communication
Vestigial Sideband (VSB):-

It is also called asymmetric sideband system. It is a clever compromise between DSB & SSB.

In VSB BW is $\approx 25\%$ higher than SSB.

An attractive option for TV broadcast. Total BW of TV channel is now 6 MHz instead of 9 MHz.
AM Modulators

- Modulation translates the message spectrum upward in frequency and demodulation is downward frequency translation.
- Upward frequency translation achieved by multiplier.

Types of Modulators

- Multiplier Modulator: Using analog multiplier
- Nonlinear Modulators: Using nonlinear devices like diode
- Switching Modulator: Multiplication operation can be achieved by simple switching operation.
- Balanced Modulator or Ring Modulator: Used for generation of DSB-SC wave. It suppresses unwanted carrier.
- SSB generation: Using analog multiplier & BPF. It can be also be used for VSB

AM Demodulation or Detection: To extract baseband signal from conventional AM. DSB-SC and SSB modulation require coherent detection (complex in nature)

Two Types of AM Detectors

- Square law detector: For low level modulated signals (<1V), square law region of diode characteristic is used. This circuit gives distortion.
- Linear diode detector or peak detector or envelope detector: Extracts envelope of AM wave. It is simple and cheap (one diode, one capacitor) and one resistor
Operation of Envelope Detector
When AM wave amplitude increases capacitor voltage is increased. When input falls, capacitor voltage is reduced (discharged through R).

Choice of time constant
- To keep RC large compared to period of carrier wave to reduce fluctuations in detected envelope. If it is too high discharge curves is horizontal, the negative peak may be missing. This distortion is called diagonal clipping, so it is chosen as

\[
\frac{1}{f_m} \gg \tau(RC) \gg \frac{1}{f_c}
\]

Above condition is possible only if \( f_c \gg f_m \)
AM Receivers:

Tuned Radio Frequency Receivers (TRF):

- Cheap and simple
- Satisfactory at Medium frequency but poor at radio frequencies

Super heterodyne Receiver: Uses the principle of heterodyning (mixing)
Advantages:

➤ No variation in bandwidth
➤ High sensitivity and selectivity
➤ High adjacent channel rejection

Disadvantage: Suffers from image frequency problems

Image Signal

\[ f_{ci} - \text{Image frequency} \]
\[ f_c - \text{Signal frequency} \]
\[ f_i - \text{Local oscillator frequency} \]

\[ f_i - f_c = f_i \]

Or \( f_c = (f_i - f_i) \)

Image frequency \( f_{ci} = (f_i + f_i) \)

\[ f_{ci} = f_c + f_i + f_i = (f_c + 2f_i) \]

Image signal should be rejected in RF stage only.
### Comparison of AM Systems

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional AM</th>
<th>DSBSC</th>
<th>SSB</th>
<th>VSB</th>
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<tbody>
<tr>
<td>1. Carrier suppression</td>
<td>No</td>
<td>Fully</td>
<td>Fully</td>
<td>No</td>
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<td>2. Side band suppression</td>
<td>No</td>
<td>No</td>
<td>One sideband</td>
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<td>Completely</td>
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<td>3. Bandwidth</td>
<td>2f</td>
<td>2f&lt;sub&gt;m&lt;/sub&gt;</td>
<td>f&lt;sub&gt;m&lt;/sub&gt;</td>
<td>f&lt;sub&gt;m&lt;/sub&gt; &lt; BW &lt; 2f&lt;sub&gt;m&lt;/sub&gt; (between SSB and SSBSC)</td>
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<td>4. Cost &amp; complexity</td>
<td>Huge cost and</td>
<td>Simple Transmitter</td>
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<td></td>
<td>complexity in</td>
<td>but costly receivers</td>
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<td>5. Use</td>
<td>Commercial Radio</td>
<td>Commercial</td>
<td>Point to point</td>
<td>TV</td>
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<td>radio broadcast</td>
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