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Module 3.0
Amplitude Modulation (AM)

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Electronic Circuits & Communication Fundamentals
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What is Modulation ?

- Low frequency baseband signal needs <u>shift in frequencies</u> for <u>transmission</u> over channel
- Achieved by <u>superimposing</u> low frequency baseband signal on <u>high frequency carrier</u>
- Shift of low frequency baseband signal to a high frequency carrier signal is <u>modulation</u>
- Done such that <u>one of the characteristics</u> of the carrier varies with the baseband signal
- This is done to <u>retain the characteristics</u> of the baseband signal over the carrier signal

Advantages of Modulation ?

Modulating high frequency carrier signal with low frequency baseband signal :-

- Increases range of communication
- Reduction in the antenna height
- Allows multiplexing of signals
- Avoids mixing of signals
- Improves quality of reception

Advantages of Modulation ?

1. Increases Range of Communication :-

- Frequency of baseband signal is very low & cannot travel long distances by themselves
- When such signals are transmitted, they get heavily attenuated resulting in losses
- Attenuation of signal reduces with increase in frequency, hence can travel long distance
- Thus modulation process increases range of communication by upward frequency shift

Advantages of Modulation ?

2. Reduction in the Height of the Antenna :-

- For efficient transmission of signal, height of antenna should be at least kept at $\lambda/4$
- Here $\lambda = c/f$ where ‘c’ is the velocity of light & ‘f’ is frequency of transmitted signal
- For f = 15 kHz we get λ = 20 km giving height of h = 5 km which is impossible to construct
- For f = 10 MHz we get λ = 30 m giving height of h = 7.5 m which can be easily constructed

Advantages of Modulation ?

3. Allows Multiplexing of Signals :-

- Multiplexing is simultaneous transmission of 2 or more signals over the same carrier
- This is only possible with modulation where carriers can have different high frequencies
- Various baseband signals in audio range of 20 Hz – 20 kHz can easily be transmitted
- For wireless transmission like AM/FM this is helpful in broadcasting several frequencies

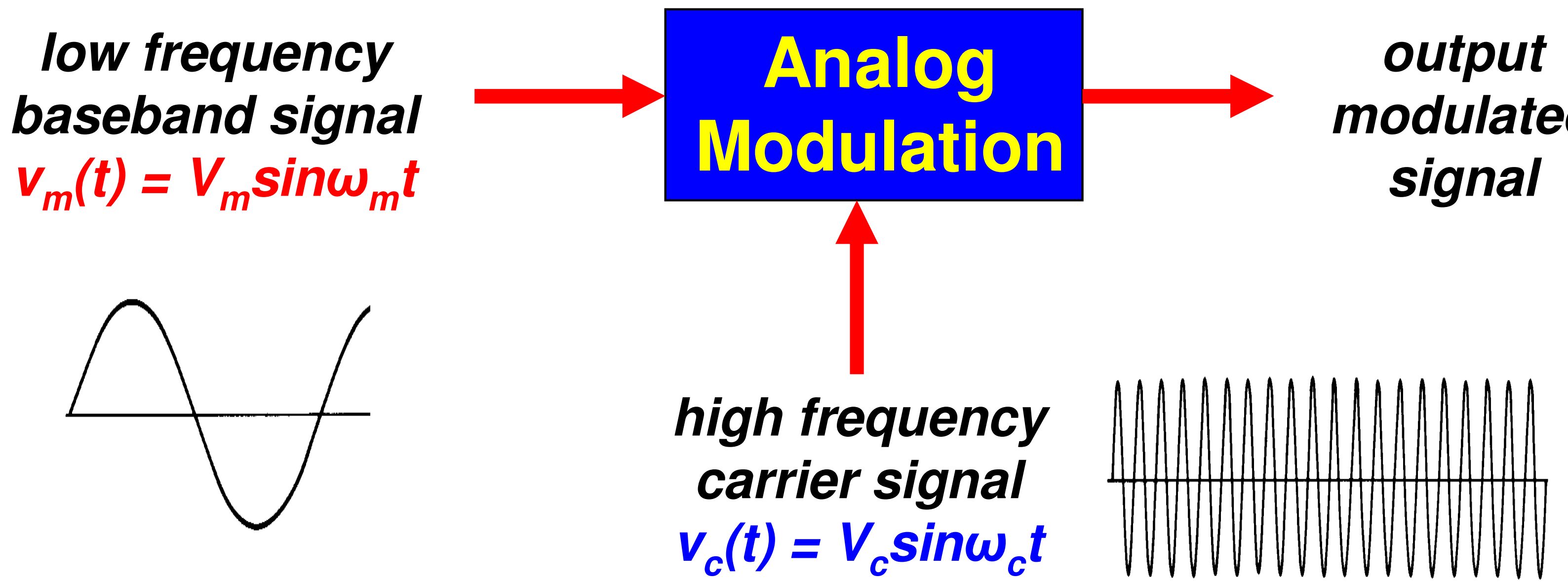
Advantages of Modulation ?

4. Avoids Mixing of Signals :-

- Baseband signals are in the audio frequency range between 20 Hz – 20 kHz
- If they are transmitted directly without any modulation, they will get all mixed up
- Due to this the receiver will not be able to separate out these baseband signals
- Modulation gives them all different carrier frequencies for the transmission process

Definition of Modulation

- Low frequency baseband signal represented by $v_m(t) = V_m \sin\omega_m t$ OR $v_m(t) = V_m \cos\omega_m t$
- High frequency carrier signal is represented by $v_c(t) = V_c \sin\omega_c t$ OR $v_c(t) = V_c \cos\omega_c t$



Definition of Modulation

Analog Modulation is defined as a process in which **one** of the **parameters** (characteristics) of a high frequency **carrier** signal **(amplitude, frequency or phase)** is **varied** proportionally to **instantaneous** amplitude of **modulating** signal, keeping other parameters constant.

- Carrier Amplitude – $V_c \propto v_m(t)$
- Carrier Frequency – $f_c \propto v_m(t)$
- Carrier Phase – $\theta_c \propto v_m(t)$

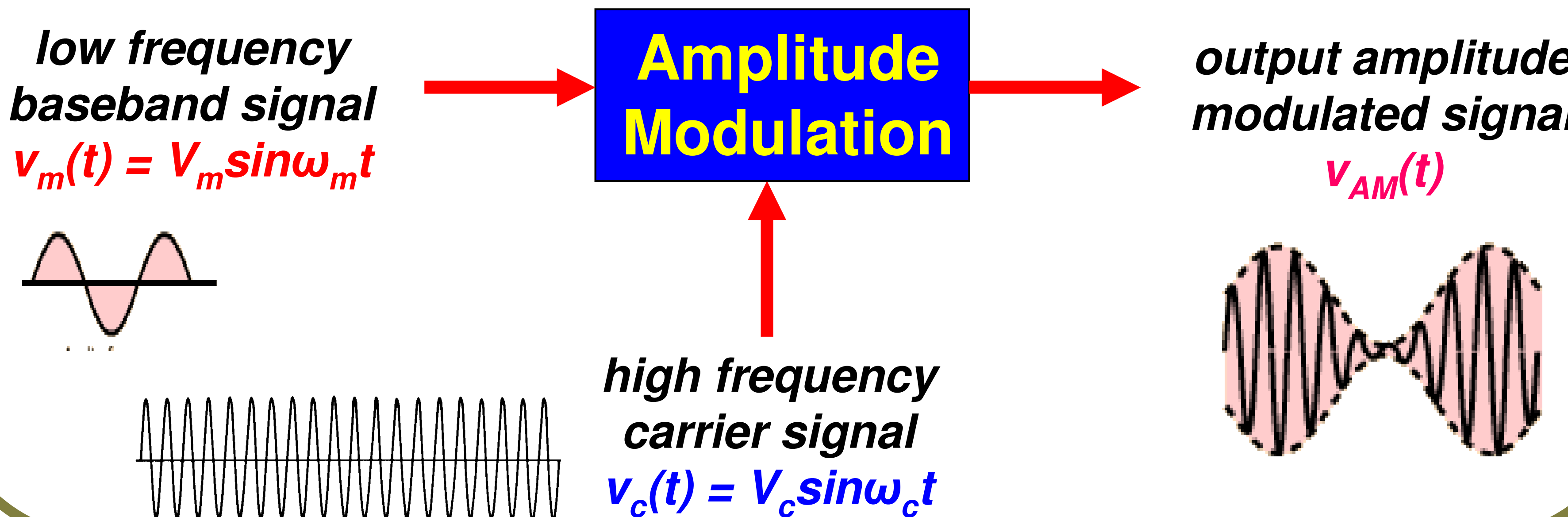
one of them varies while two others remain constant

Types of Analog Modulation

- Amplitude Modulation **(AM)** where the carrier amplitude (V_c) varies
- Frequency Modulation **(FM)** where the carrier frequency $(\omega_c$ or $f_c)$ varies
- Phase Modulation **(PM)** where phase of the carrier (θ_c) varies
- Since phase & frequency are directly related, they are in angular modulation

Amplitude Modulation (AM)

Amplitude Modulation is defined as process in which the **amplitude** of high frequency **carrier** signal is **varied** proportionally to **instantaneous** amplitude of **modulating** signal, keeping **phase** & **frequency** of the **carrier** signal **constant.**



Modulation Index (m_a)

Modulation Index also called as the modulation factor or modulation coefficient (m_a) refers to the depth of modulation of the carrier signal amplitude (V_c) by the instantaneous amplitude of modulating signal $v_m(t)$ & is the simply ratio of peak values of modulating signal amplitude (V_m) to the carrier signal amplitude (V_c)

$$\boxed{m_a = \frac{V_m}{V_c}}$$

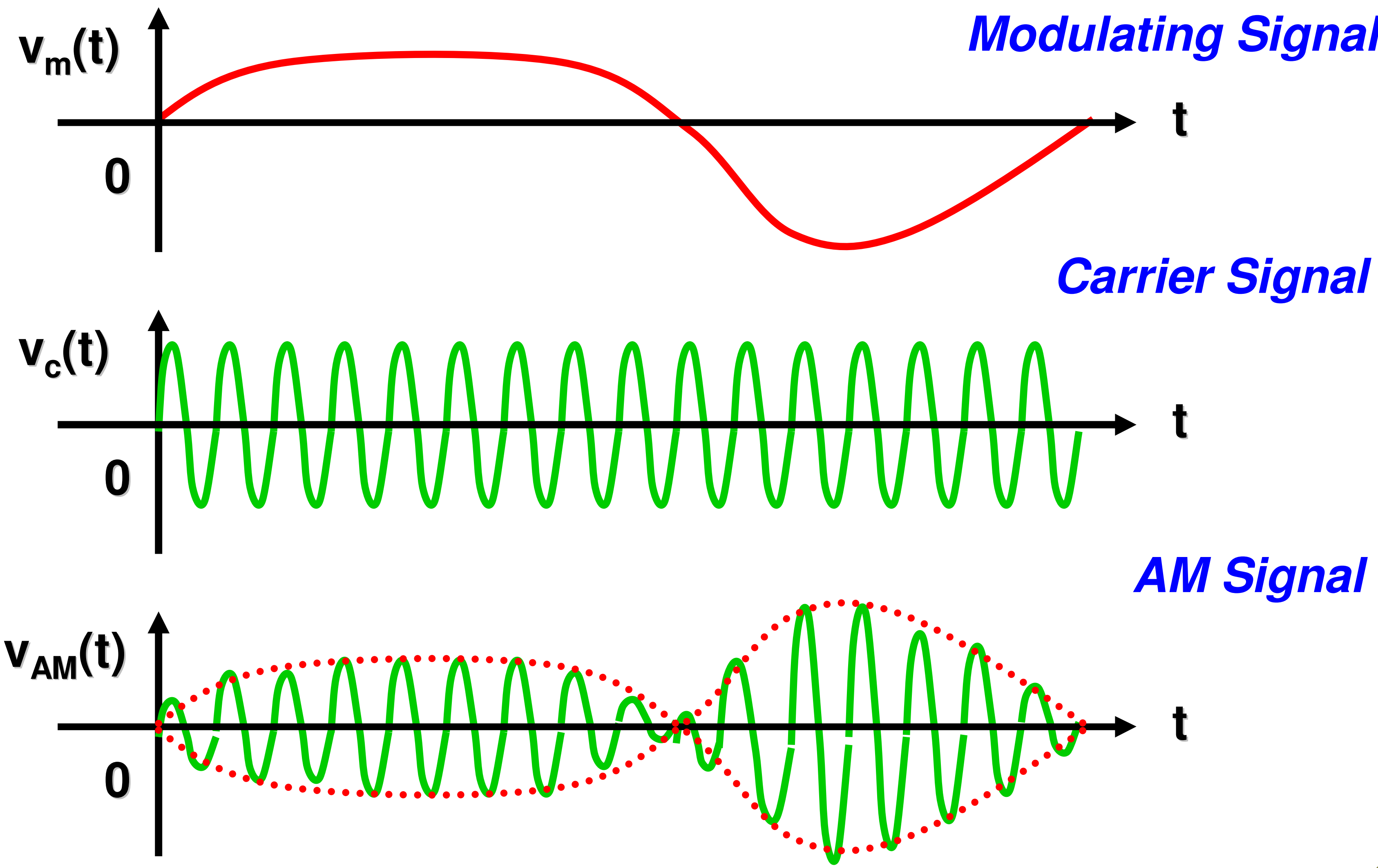
→ mathematical definition of modulation index (m_a)

Modulation Index (m_a)

Modulation Index (m_a) for AM waveform takes one of the following values :-

- When $V_m = 0$ then $m_a = 0$ indicating case of zero (no) modulation being performed
- When $V_m < V_c$ then $m_a < 1$ indicating case of under modulation being performed
- When $V_m = V_c$ then $m_a = 1$ indicating case of critical modulation being performed
- When $V_m > V_c$ then $m_a > 1$ indicating case of over (excess) modulation being performed

Amplitude Modulation (AM)



Modulation Index (m_a)

Modulation Index (m_a) for AM waveform simply is a parameter indicating depth of modulation

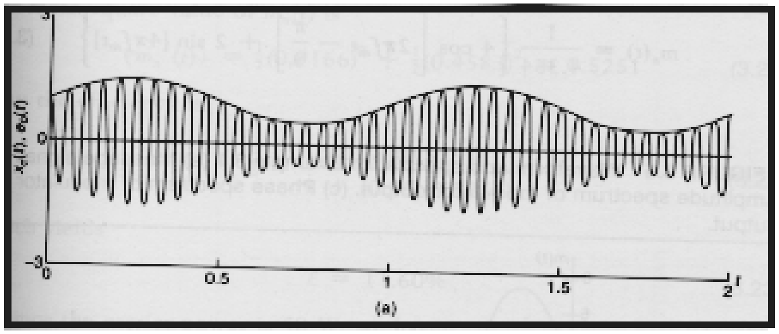
<u>After modulation it is also important to recover modulating signal from amplitude modulated (AM) waveform by removing the carrier signal</u>

Hence the optimum modulation index (m_a) for an AM waveform should be maintained at :-

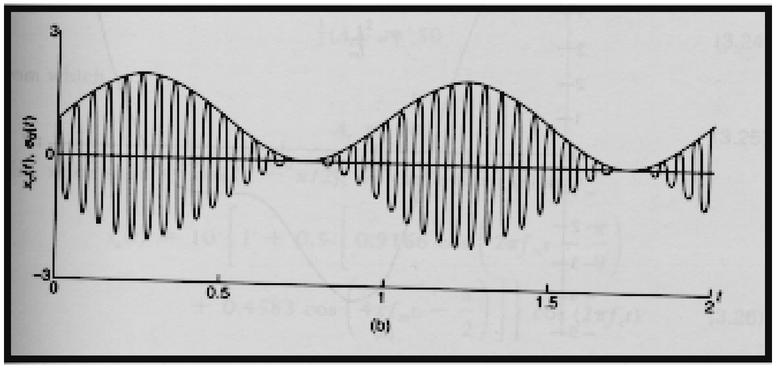
$$\boxed{m_a \leq 1}$$

important so that modulating signal can be easily recovered

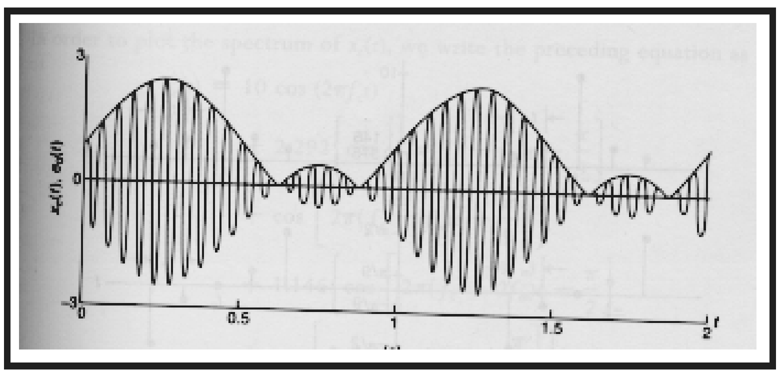
Modulation Index (m_a) values



$\underline{m < 1}$ *hence AM wave is undermodulated*



$\underline{m = 1}$ *hence AM wave is critically modulated*

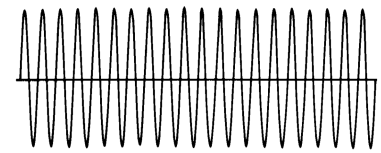


$\underline{m > 1}$ *hence AM wave is overmodulated*

Mathematical Equation of AM wave

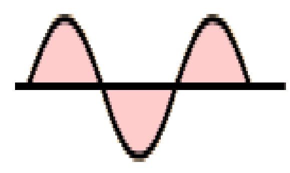
Carrier signal is mathematically represented by the following equation :-

$$v_c(t) = V_c \sin\omega_c t \text{ OR } v_c(t) = V_c \cos\omega_c t$$



Modulating signal is mathematically denoted by the following equation :-

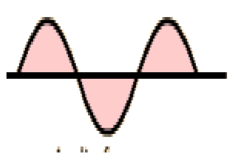
$$v_m(t) = V_m \sin\omega_m t \text{ OR } v_m(t) = V_m \cos\omega_m t$$



Mathematical Equation of AM wave

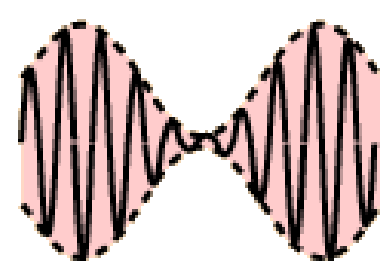
Amplitude Modulation is defined as process in which the **amplitude** of high frequency **carrier** signal is **varied** proportionally to **instantaneous** amplitude of **modulating** signal, keeping **phase** & **frequency** of the **carrier** signal **constant.**

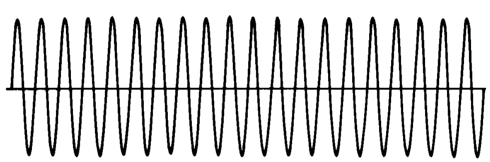
low frequency baseband signal
$v_m(t) = V_m \sin\omega_m t$



Amplitude Modulation

output amplitude modulated signal
$v_{AM}(t)$





high frequency carrier signal
$v_c(t) = V_c \sin\omega_c t$

Mathematical Equation of AM wave

Amplitude modulated (AM) waveform is mathematically represented by :-

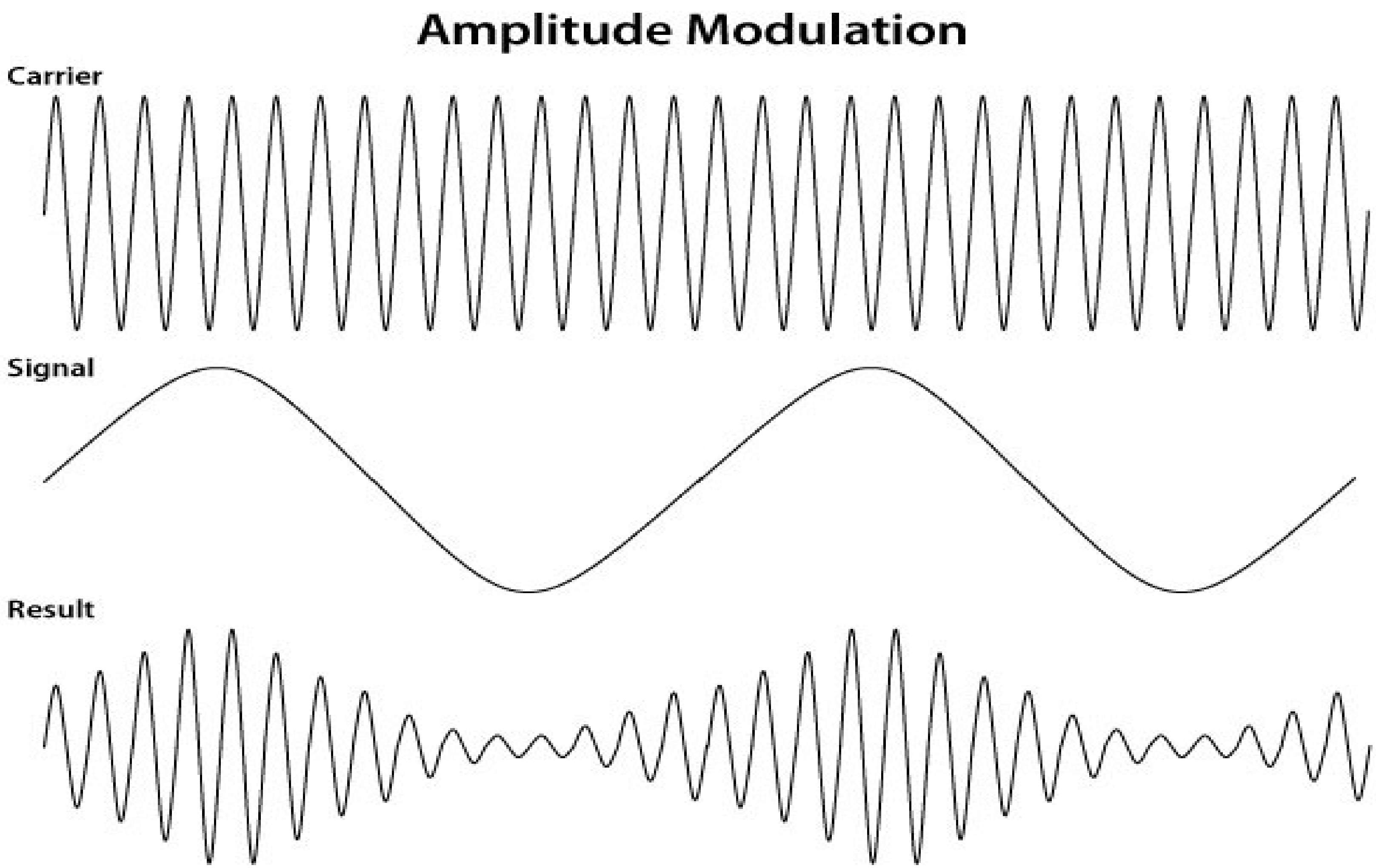
$$\boxed{v_{AM}(t) = V_c\,[\,1 + m_a \sin\omega_m t\,]\,\sin\omega_c t}$$

OR

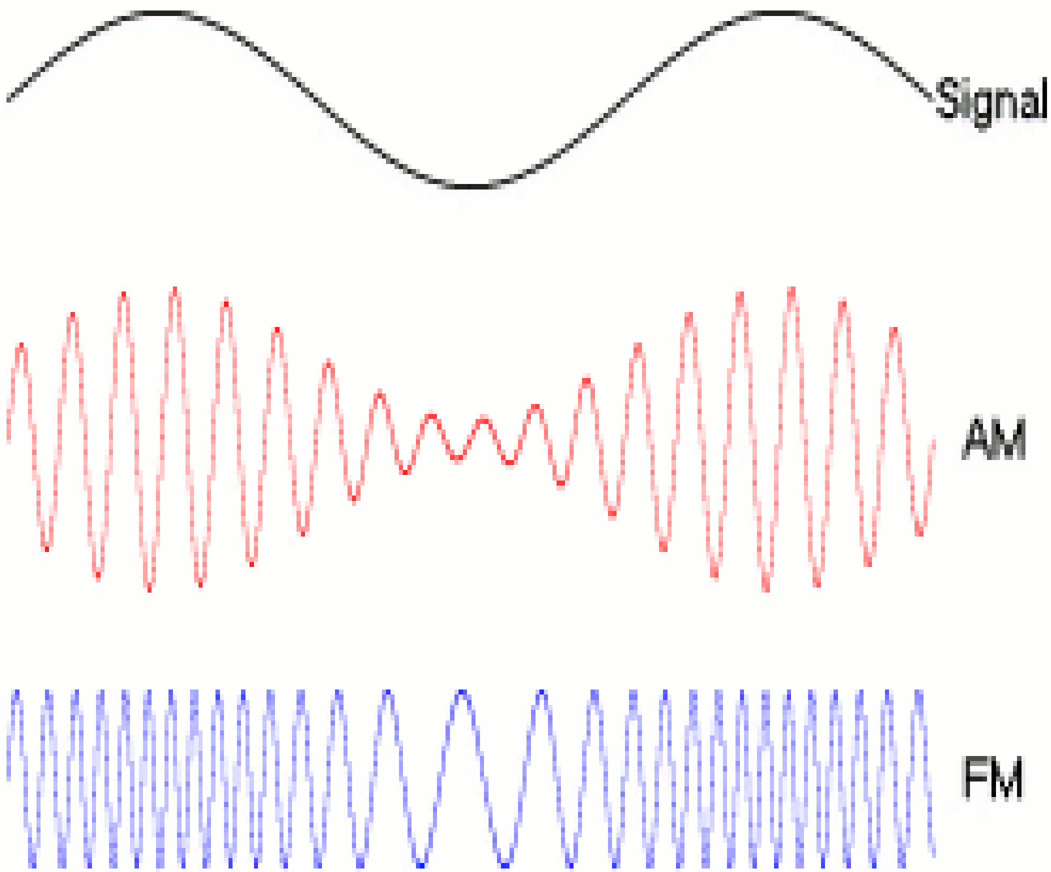
$$\boxed{v_{AM}(t) = V_c\,[\,1 + m_a \cos\omega_m t\,]\,\cos\omega_c t}$$

please refer to your notebook for the complete derivation

Graphical Representation of AM wave



Graphical Representation of AM wave

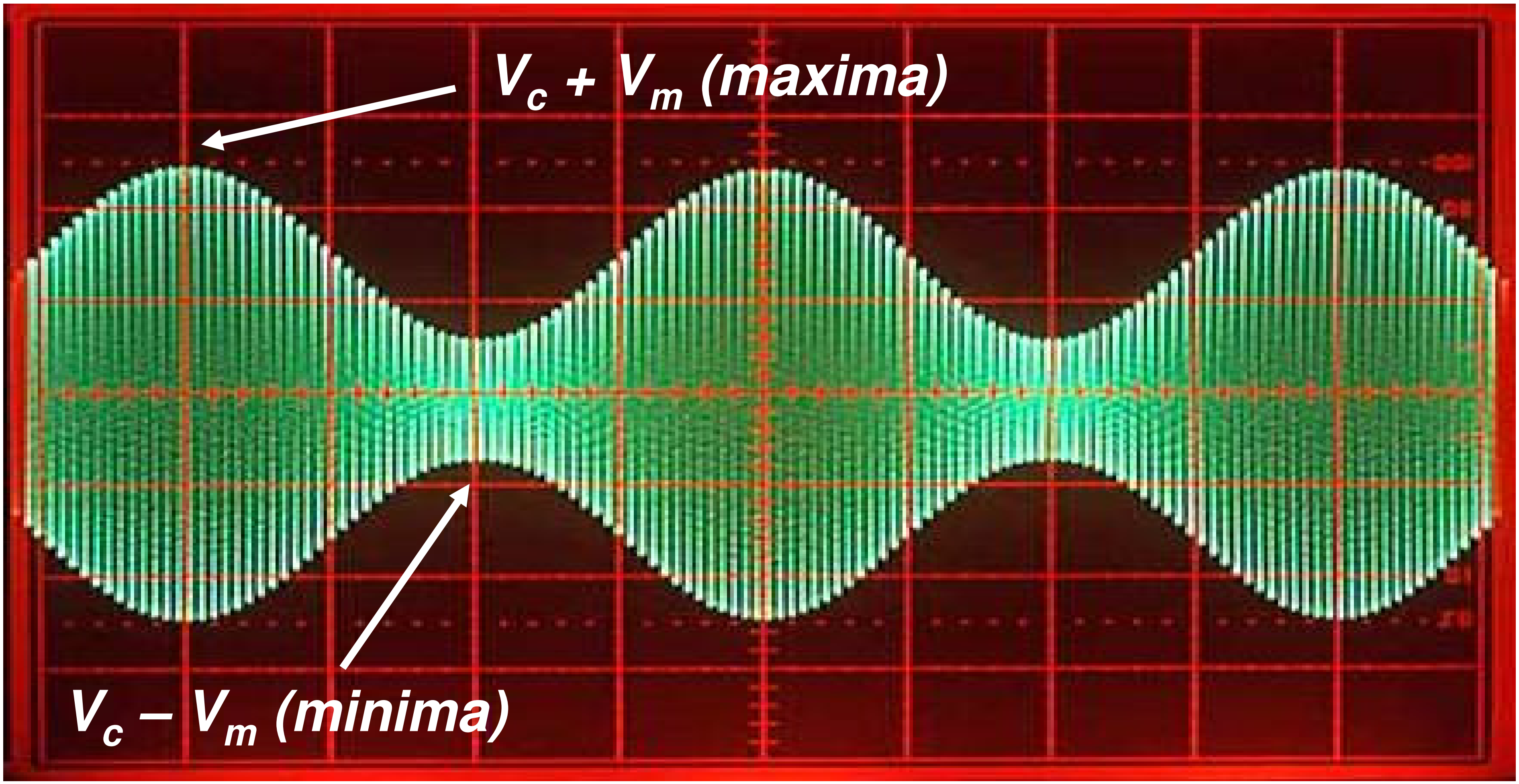


modulating or baseband signal

amplitude variations in V_c due to $v_m(t)$

frequency variations in ω_c due to $v_m(t)$

Graphical Representation of AM wave



Amplitude Modulated (AM) wave on CRO

Frequency Spectrum of AM wave

Amplitude modulated (AM) waveform is thus mathematically represented by :-

$$v_{AM}(t) = V_c\,[\,1 + m_a \sin\omega_m t\,]\,\sin\omega_c t$$

OR

$$v_{AM}(t) = V_c\,[\,1 + m_a \cos\omega_m t\,]\,\cos\omega_c t$$

please refer to your notebook for the complete derivation

Frequency Spectrum of AM wave

Amplitude modulated (AM) waveform is thus mathematically represented by :-

$$v_{AM}(t) = V_c \cos\omega_c t \rightarrow \text{carrier frequency component}$$

$$+ \frac{m_a V_c}{2}\cos(\omega_c + \omega_m)t \rightarrow \text{upper side band (USB)}$$

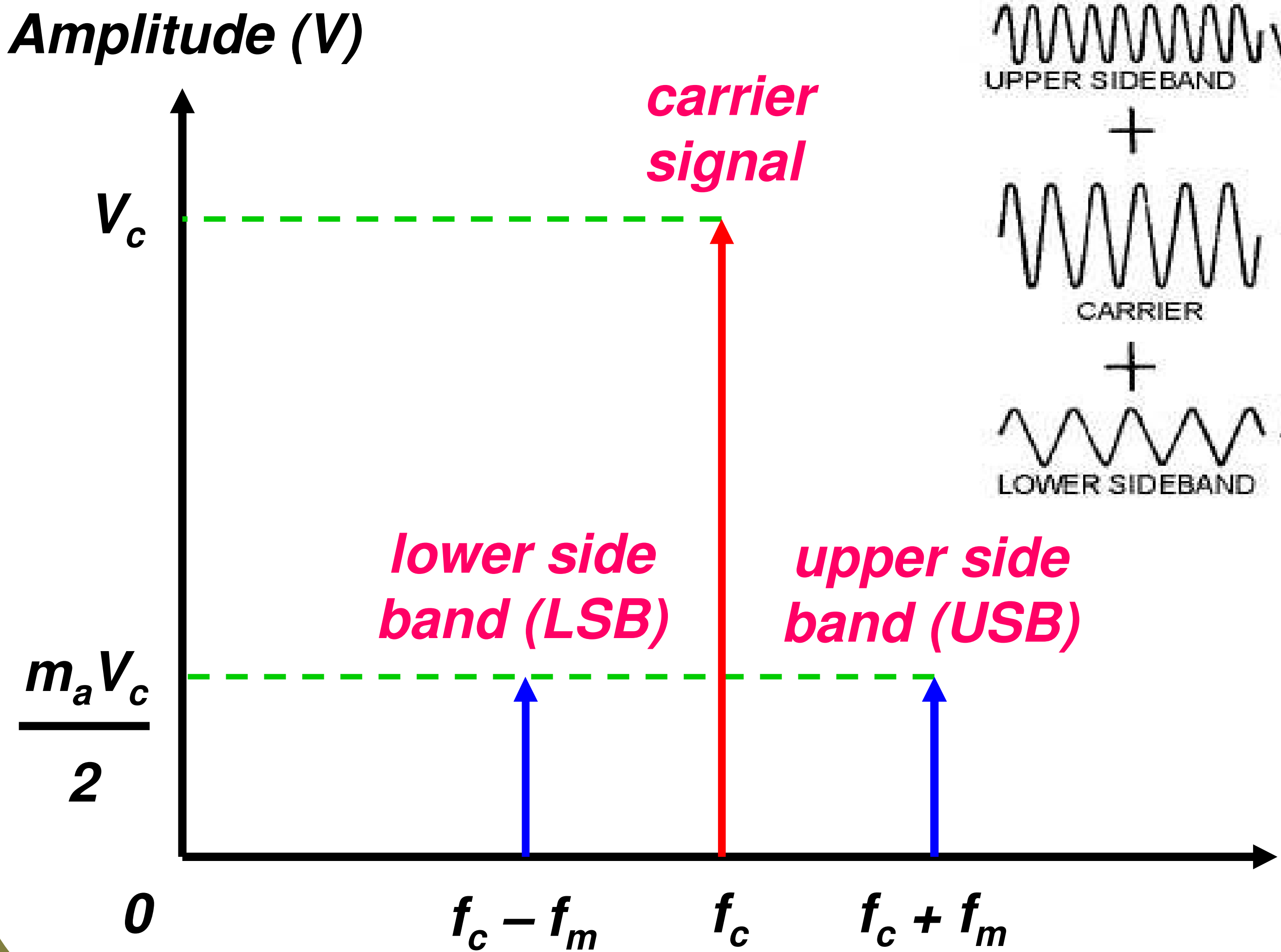
$$+ \frac{m_a V_c}{2}\cos(\omega_c - \omega_m)t \rightarrow \text{lower side band (LSB)}$$

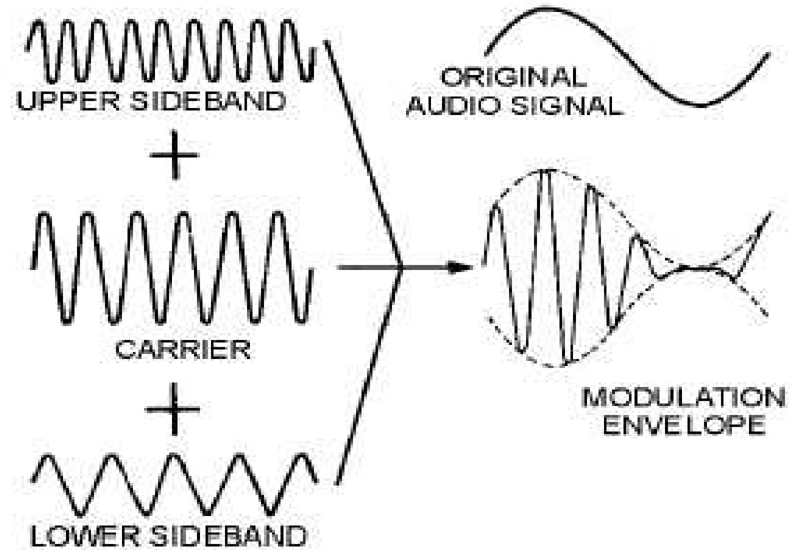
Frequency Spectrum of AM wave

Amplitude modulated (AM) waveform is thus composed of the following components :-

- **Carrier Signal itself, having an amplitude of V_c & frequency of f_c Hz**
- **Upper Sideband (USB) having amplitude of $m_a V_c/2$ & a frequency of $f_c + f_m$ Hz**
- **Lower Sideband (LSB) having amplitude of $m_a V_c/2$ & a frequency of $f_c - f_m$ Hz**

Frequency Spectrum of AM wave





Power Distribution in AM Wave

Amplitude modulated (AM) waveform is thus mathematically represented by :-

$$v_{AM}(t) = V_c \cos\omega_c t$$ → *carrier frequency component*

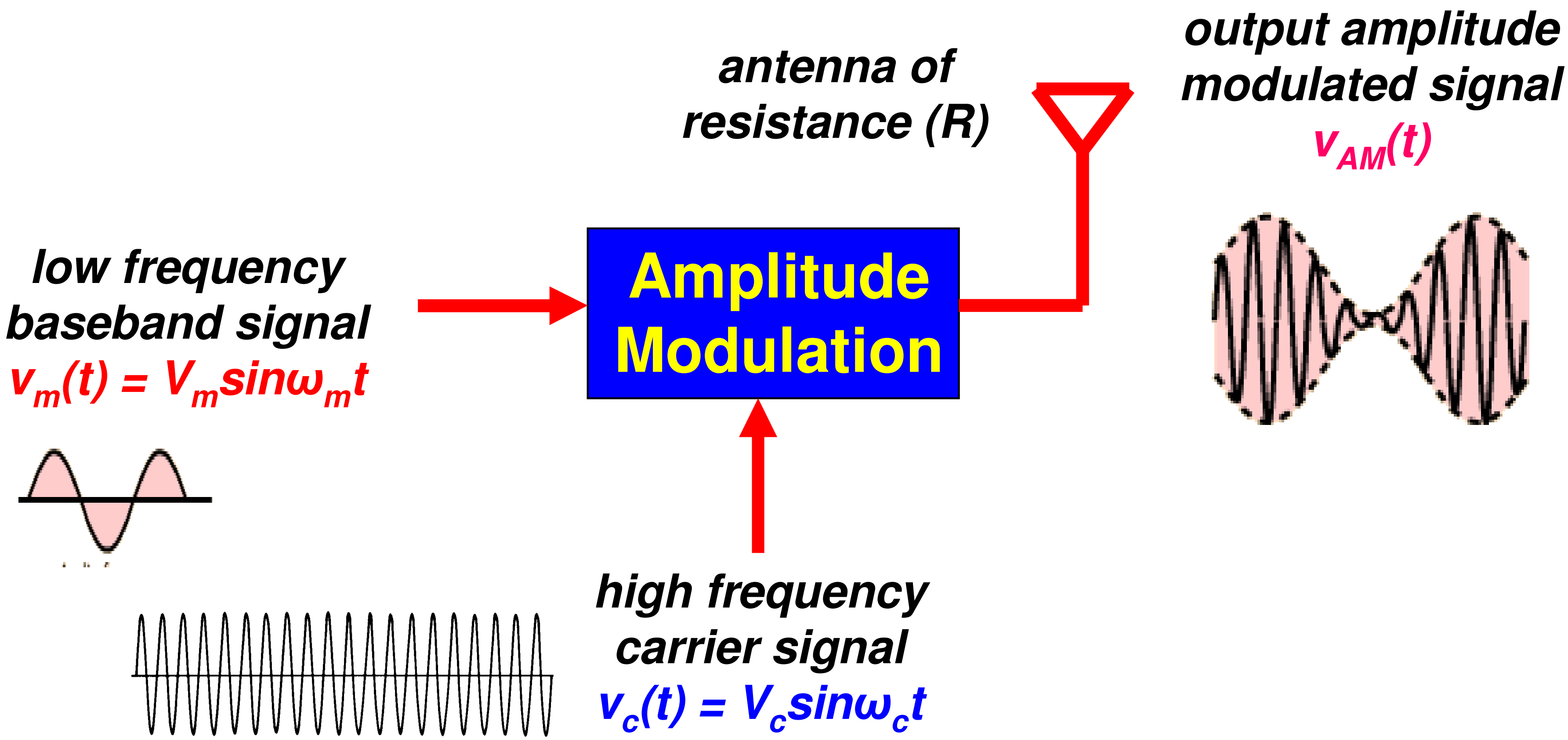
$$+$$

$$\frac{m_a V_c}{2}\cos(\omega_c + \omega_m)t$$ → *upper side band (USB)*

$$+$$

$$\frac{m_a V_c}{2}\cos(\omega_c - \omega_m)t$$ → *lower side band (LSB)*

Power Distribution in AM Wave



Power Distribution in AM Wave

Power contained (P_T) in amplitude modulated (AM) waveform is the total sum of :-

1. **Power in the carrier signal (P_C)**
2. **Power in the upper sideband (P_{USB})**
3. **Power in the lower sideband (P_{LSB})**

$$\boxed{P_T = P_C + P_{USB} + P_{LSB}}$$

Power Distribution in AM Wave

Carrier Power (P_C) :-

$$P_C = \frac{V_c^2}{2R} \rightarrow (2)$$

USB Power (P_{USB}) :-

$$P_{USB} = \frac{m_a^2 V_c^2}{8R} \rightarrow (3)$$

LSB Power (P_{LSB}) :-

$$P_{LSB} = \frac{m_a^2 V_c^2}{8R} \rightarrow (4)$$

Power Distribution in AM Wave

Power in sidebands (P_{USB} & P_{LSB}) can easily be expressed in terms of carrier power (P_C) :-

$$\underbrace{\boxed{P_{LSB} = P_{USB} = \left(\frac{m_a^2}{4}\right)\left(\frac{V_c^2}{2R}\right) = \left(\frac{m_a^2}{4}\right)P_C}}$$

please refer to your class notes for the derivation

Power Distribution in AM Wave

The total power (P_T) can now be expressed by the following equation as shown below :-

$$P_T = P_C + P_{LSB} + P_{USB} \longrightarrow 6$$

$$P_T = P_C + \left(\frac{m_a^2}{4}\right)P_C + \left(\frac{m_a^2}{4}\right)P_C \longrightarrow 7$$

$$P_T = P_C + \left(\frac{m_a^2}{2}\right)P_C \longrightarrow 8$$

Power Distribution in AM Wave

The total power (P_T) can now be expressed by the following equation as shown below :-

$$\boxed{P_T = P_C\left(1+\frac{m_a^2}{2}\right)}$$

please refer to your class notes for the derivation

Power Distribution in AM Wave

$$\frac{P_T}{P_C} = 1 + \frac{m_a^2}{2}$$

$$\frac{m_a^2}{2} = \frac{P_T}{P_C} - 1$$

$$m_a^2 = 2\left(\frac{P_T}{P_C} - 1\right)$$

Representation of modulation index (m_a) in terms of the total power (P_T) & carrier power (P_C)

Modulation Index (m_a) calculation

Modulation Index (m_a) can be calculated from the power equation as shown below :-

$$\boxed{m_a = \sqrt{2\left(\frac{P_T}{P_C} - 1\right)}}$$

please refer to your class notes for the derivation

Transmission Efficiency (η) in AM

- Transmission efficiency (η) is defined as the ratio of the useful power to the total power
- In AM, frequency spectrum consists of both sidebands (USB & LSB) with carrier signal
- Information (modulating signal) is present in only both sidebands & NOT in carrier signal
- Hence useful transmitted power is only that of the sidebands (P_{USB} & P_{LSB})
- Carrier transmission results only in wastage of power (P_C) since NONE of it is useful

Transmission Efficiency (η) in AM

Transmission Efficiency (η) is expressed in the context of definition as :-

$$\eta = \frac{\textit{Useful Power in AM}}{\textit{Total Power in AM}}$$

$$\boxed{\eta = \frac{P_{USB} + P_{LSB}}{P_T}}$$

basically defined as ratio of the sidebands power to total power

Transmission Efficiency (η) in AM

$$\eta = \frac{P_{USB} + P_{LSB}}{P_T}$$

$$\eta = \frac{\left(\frac{m_a^2}{4}\right)P_C + \left(\frac{m_a^2}{4}\right)P_C}{P_C\left(1 + \frac{m_a^2}{2}\right)}$$

please refer to your class notes

$$\eta = \frac{\left(\frac{m_a^2}{2}\right)P_C}{P_C\left(1 + \frac{m_a^2}{2}\right)}$$

$$\eta = \frac{\left(\frac{m_a^2}{2}\right)}{\left(1 + \frac{m_a^2}{2}\right)}$$

Transmission Efficiency (η) in AM

Transmission Efficiency (η) is expressed in the terms of modulation index (m_a) as :-

$$\underbrace{\boxed{\eta = \frac{m_a^2}{2 + m_a^2}}}$$

please refer to your class notes for the derivation

Transmission Efficiency (η) in AM

Transmission Efficiency (η) is expressed in the terms of modulation index (m_a) as :-

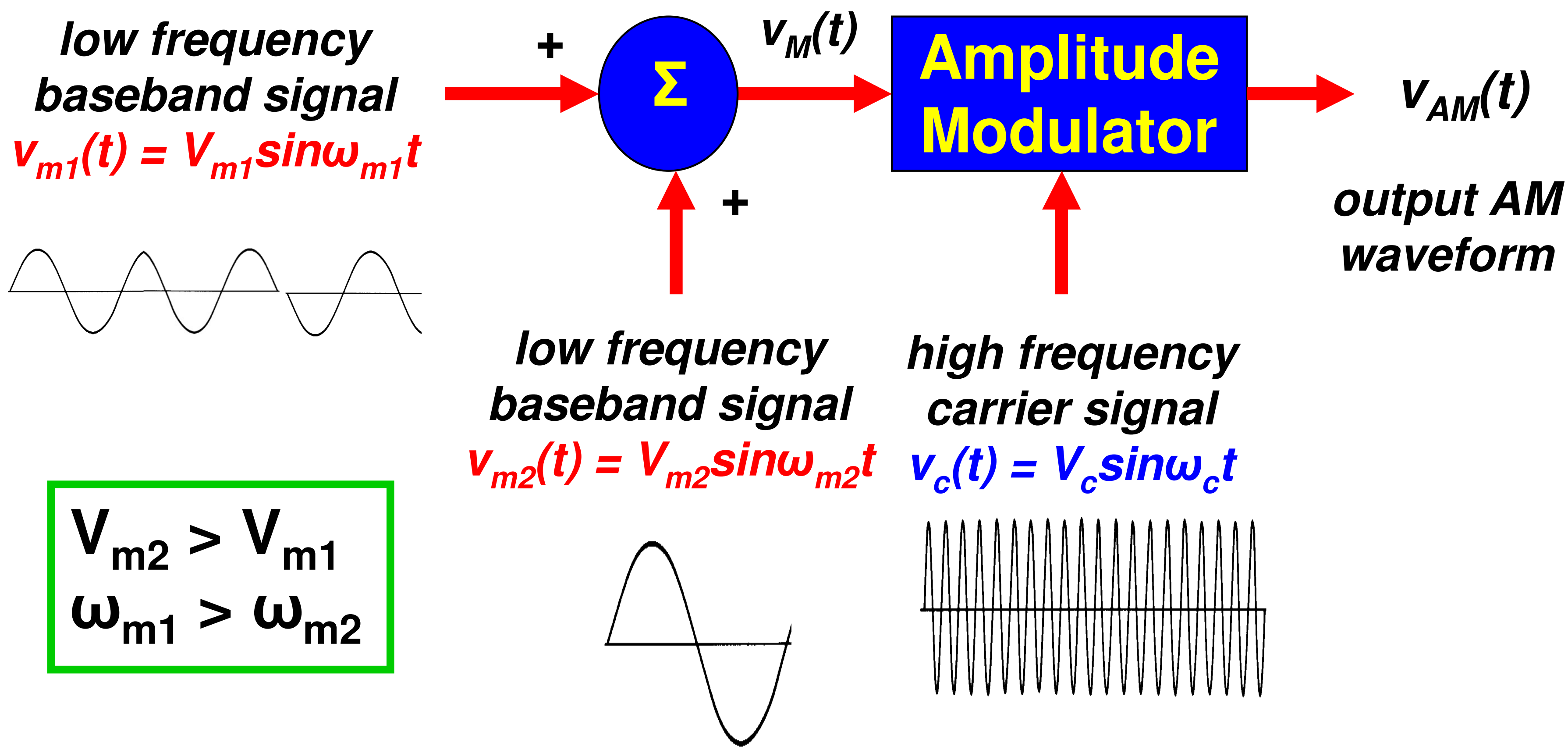
$$\eta = \frac{m_a^2}{2 + m_a^2}$$

assume $m_a = 1$ for critical modulation

$$\eta = \frac{(1)^2}{2+(1)^2}$$

$$\boxed{\eta = \frac{1}{3} = 33.33\%}$$

AM of Multiple Baseband Signals



$V_{m2} > V_{m1}$
$\omega_{m1} > \omega_{m2}$

refer to your class notes for complete description, derivation & analysis of the frequency spectrum

AM of Multiple Baseband Signals

Overall equation of the AM waveform is given by the following as shown below :-

$$\boxed{v_{AM}(t) = V_c[1 + m_{a1}cos\,\omega_{m1}t + m_{a2}cos\,\omega_{m2}t]cos\,\omega_c t}$$

refer to your class notes for complete description, derivation & analysis of the frequency spectrum

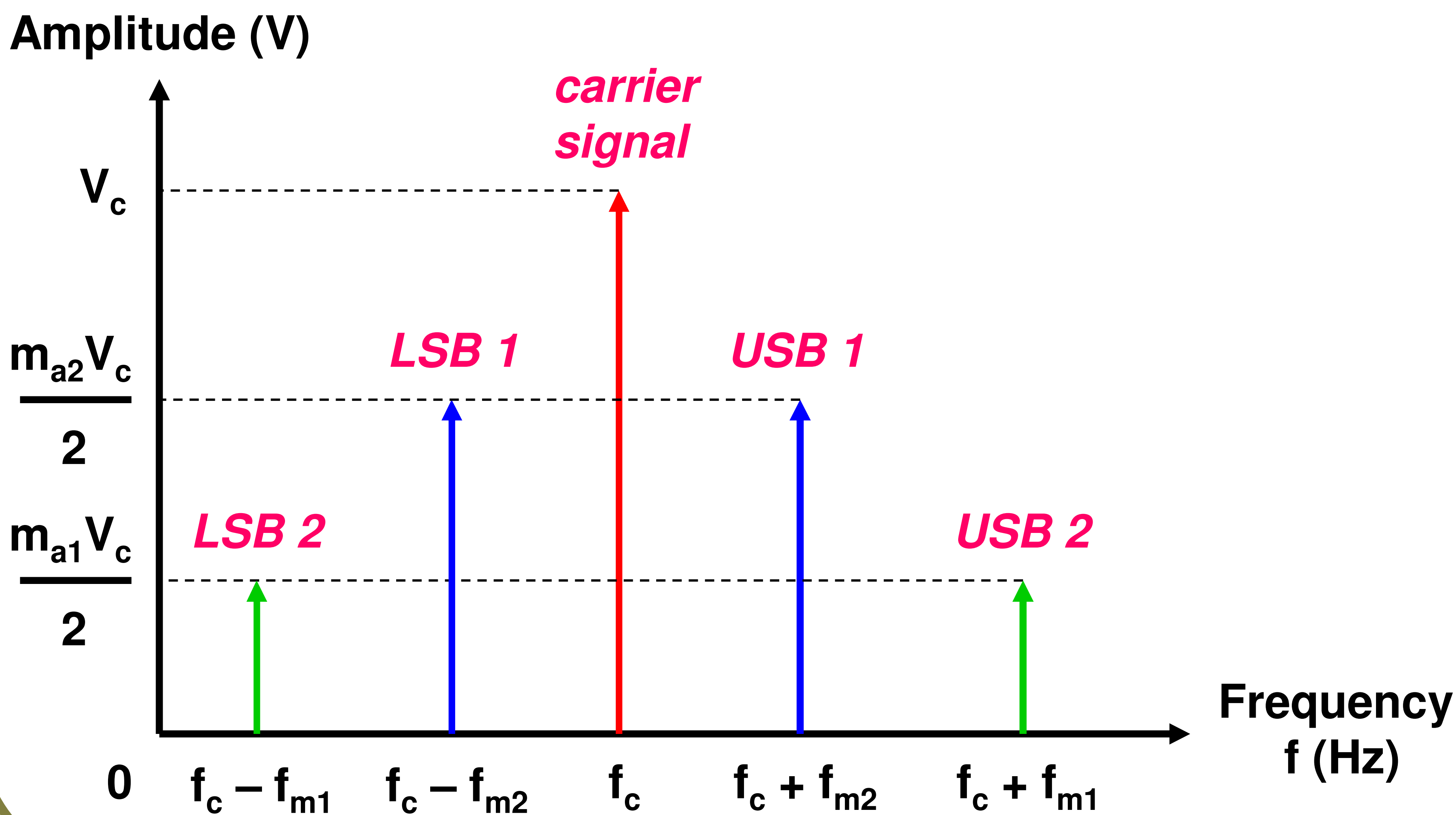
AM of Multiple Baseband Signals

Frequency spectrum representation of the AM waveform is given by following equation :-

$$v_{AM}(t) = V_c \cos\omega_c t + \frac{m_{a1}V_c}{2}\left[\cos(\omega_c + \omega_{m1})t + \cos(\omega_c - \omega_{m1})t\right]$$
$$+ \frac{m_{a2}V_c}{2}\left[\cos(\omega_c + \omega_{m2})t + \cos(\omega_c - \omega_{m2})t\right]$$

refer to your class notes for complete description, derivation & analysis of the frequency spectrum

Frequency Spectrum of AM wave



AM of Multiple Baseband Signals

Overall modulation index (m_T) is expressed in terms of individual modulation index values :-

$$\boxed{m_T = \sqrt{m_{a1}^2 + m_{a2}^2 + m_{a3}^2 + \ldots}}$$

please refer to your class notes for the derivation

AM of Multiple Baseband Signals

The total power (P_T) can now be expressed by the following equation as shown below :-

$$\boxed{P_T = P_C\left(1+\frac{m_T^2}{2}\right)}$$

please refer to your class notes for the derivation

Types of Amplitude Modulation (AM)

- Dual Sideband Full Carrier (DSBFC)
- Dual Sideband Suppressed Carrier (DSBSC)
- Single Sideband Modulation (SSB)
- Independent Sideband Modulation (ISB)
- Vestigial Sideband Modulation (VSB)

Please refer to your class notebook for mathematical analysis & derivations

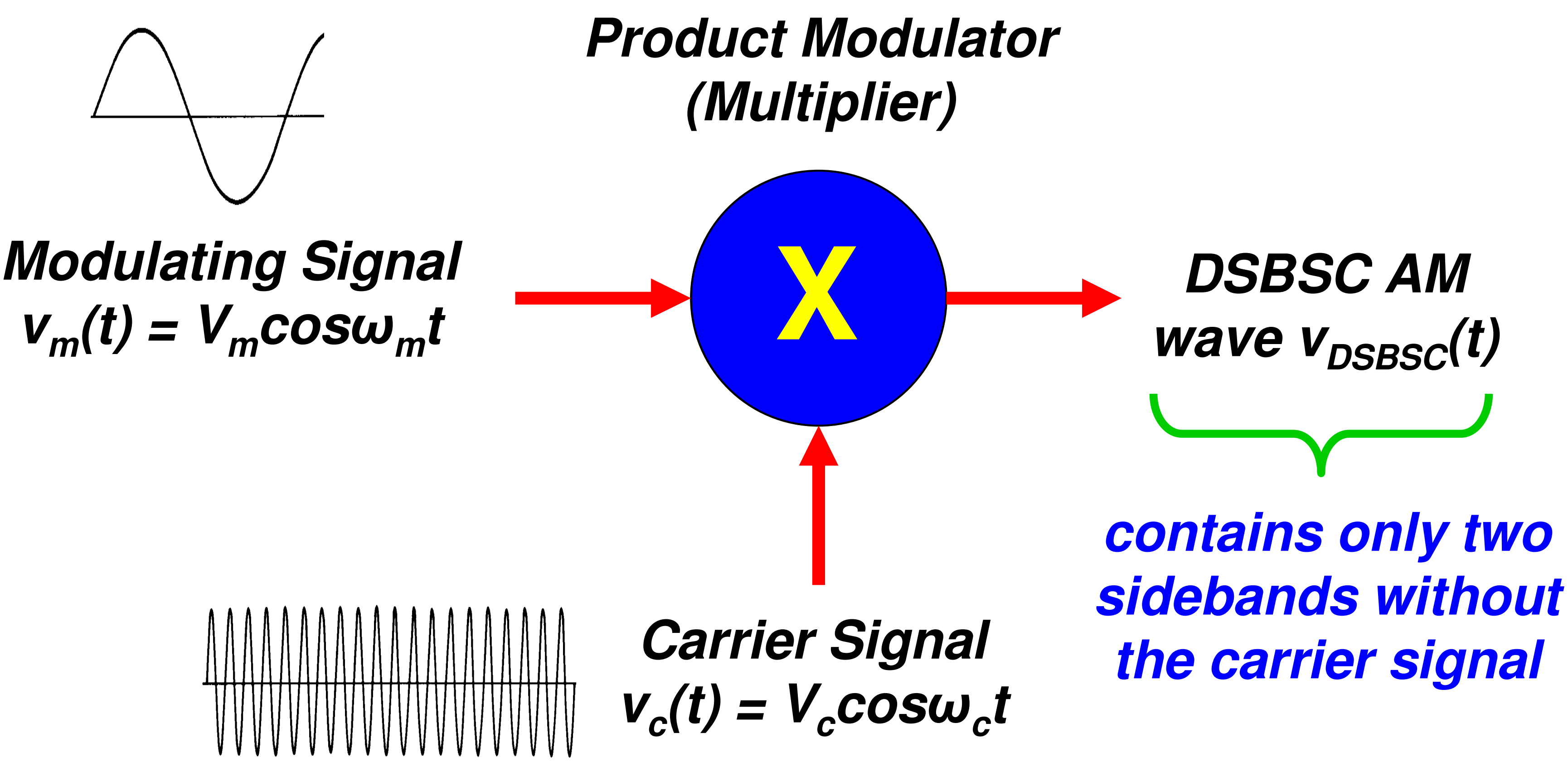
How is DSBSC better than DSBFC ?

ADVANTAGES OF DSBSC OVER DSBFC :-

1. **Power is wasted as the carrier contains no information and each of sideband carries the same information independently**
2. **The double sideband suppressed carrier (DSBSC) is introduced to eliminate the carrier & hence improve the power efficiency**
3. **It is a technique in which it is transmitting both the sidebands without the carrier (the carrier is being suppressed or removed)**

DSBSC – The Principle of Operation

Mathematical Model of DSBSC :-



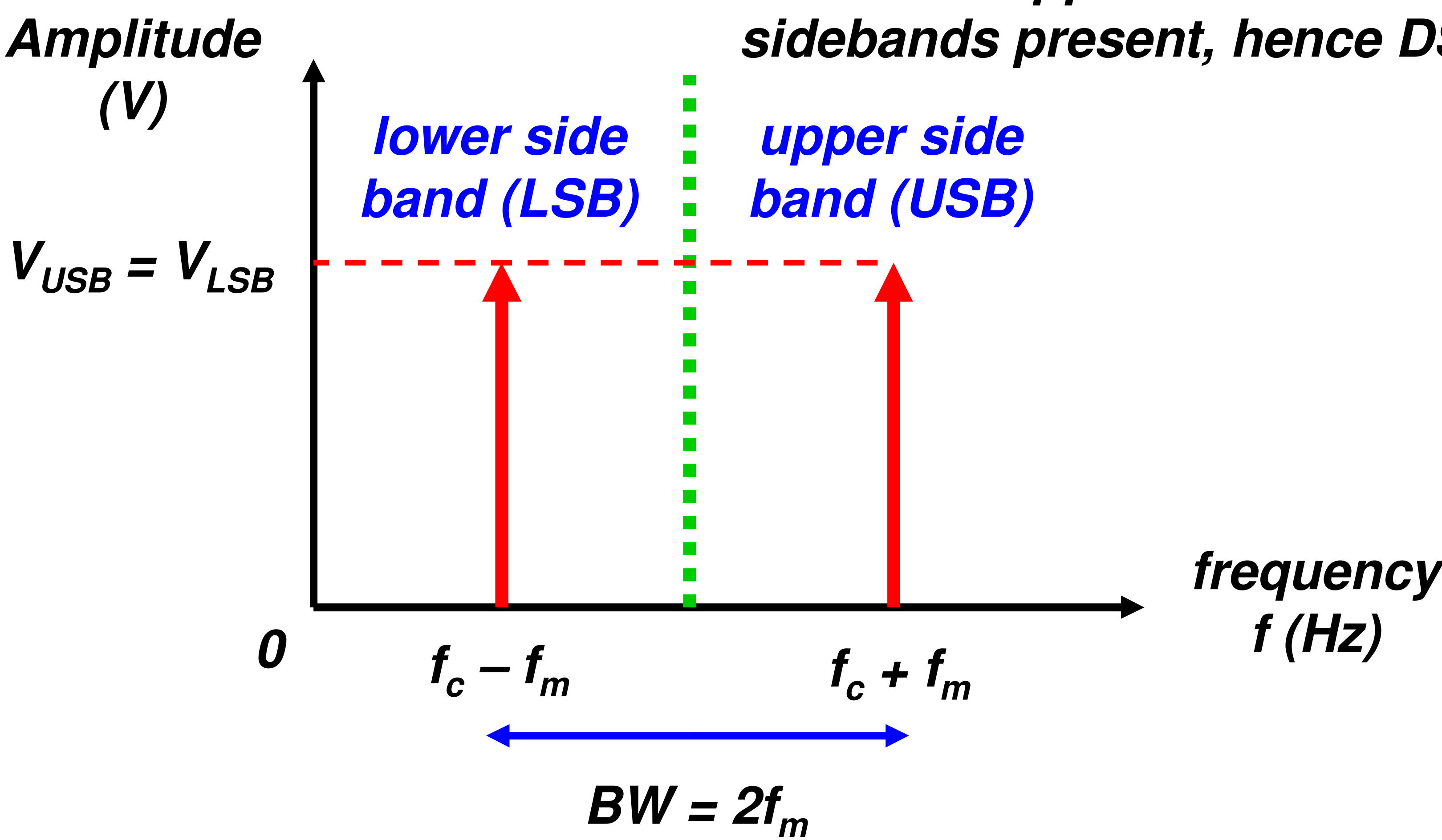
DSBSC – The Principle of Operation

$$
\begin{aligned}
v_{DSBSC}(t) &= V_c V_m \cos\omega_c t \cos\omega_m t \\
&= \frac{V_c V_m}{2}\left[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t\right] \\
&= \underbrace{\frac{V_c V_m}{2}\cos(\omega_c + \omega_m)t}_{\text{upper sideband component (USB)}} + \underbrace{\frac{V_c V_m}{2}\cos(\omega_c - \omega_m)t}_{\text{lower sideband component (LSB)}}
\end{aligned}
$$

From above equation it can be easily seen that carrier is suppressed, leaving only USB & LSB

DSBSC – The Frequency Spectrum

carrier is suppressed but both the sidebands present, hence DSBSC



Total Power Saved in DSBSC

Total power saved in DSBSC is expressed in the context of definition as :-

$$PS = \frac{\textit{Power Saved in AM}}{\textit{Total Power in AM}}$$

$$\boxed{PS = \frac{P_C}{P_T}}$$

basically defined as ratio of the carrier power to total power

Total Power Saved in DSBSC

$$PS = \frac{P_C}{P_T} \Rightarrow PS = \frac{P_C}{P_C\left[1+\frac{m_a^2}{2}\right]}$$

please refer to your class notes

$$PS = \frac{1}{\left[1+\frac{m_a^2}{2}\right]} \Rightarrow PS = \frac{2}{2+m_a^2}$$

Total Power Saved in DSBSC

Total Power Saved (PS) is expressed in terms of the modulation index (m_a) as :-

$$\boxed{PS = \frac{2}{2 + m_a^2}}$$

please refer to your class notes for the derivation

Total Power Saved in DSBSC

Total Power Saved (PS) is expressed in terms of the modulation index (m_a) as :-

$$PS = \frac{2}{2 + m_a^2}$$

assume m_a = 1 for critical modulation

$$PS = \frac{2}{2 + (1)^2}$$

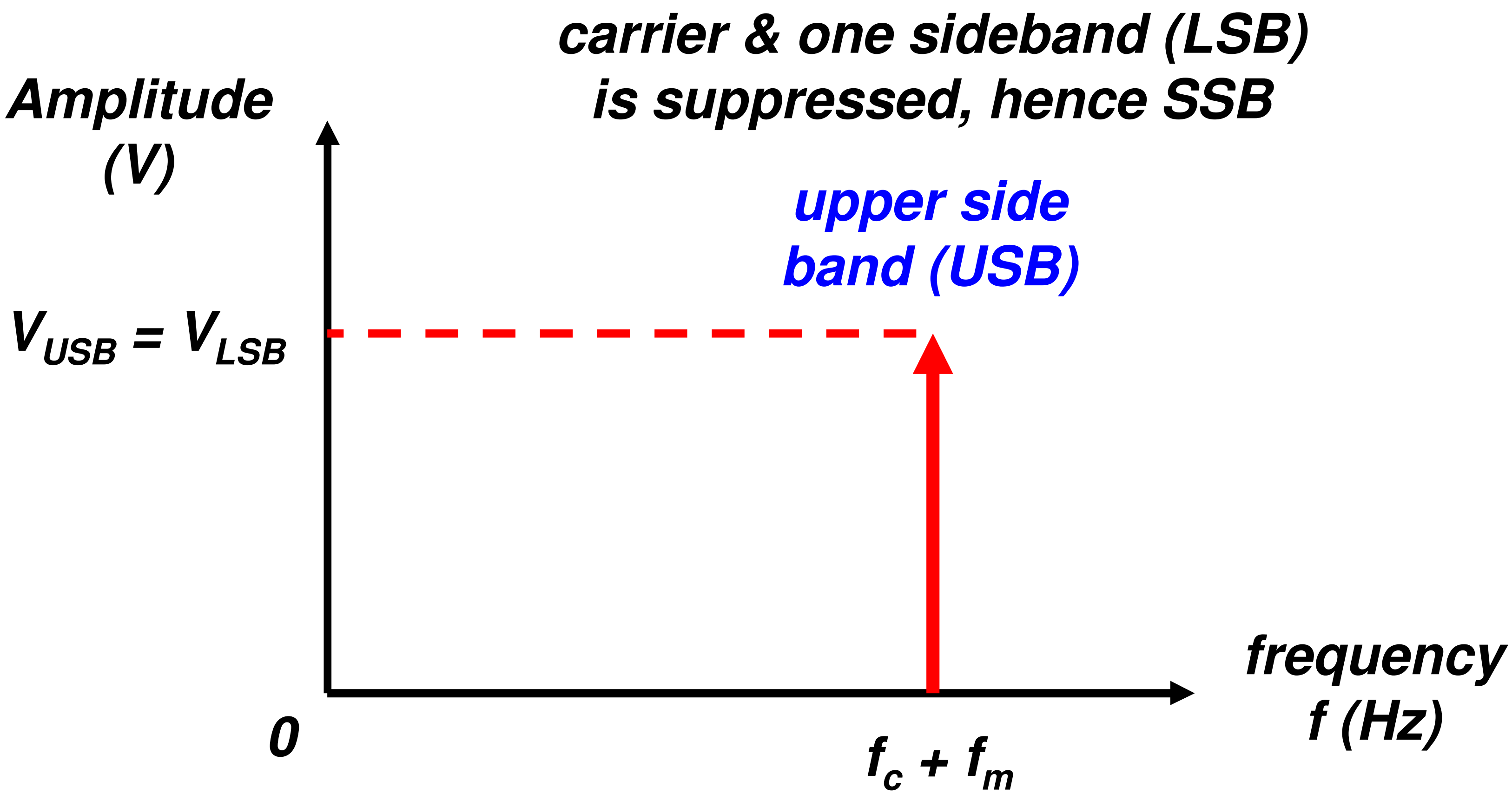
$$\boxed{PS = \frac{2}{3} = 66.67\%}$$

How is SSB better than DSBSC ?

ADVANTAGES OF SSB OVER DSBSC :-

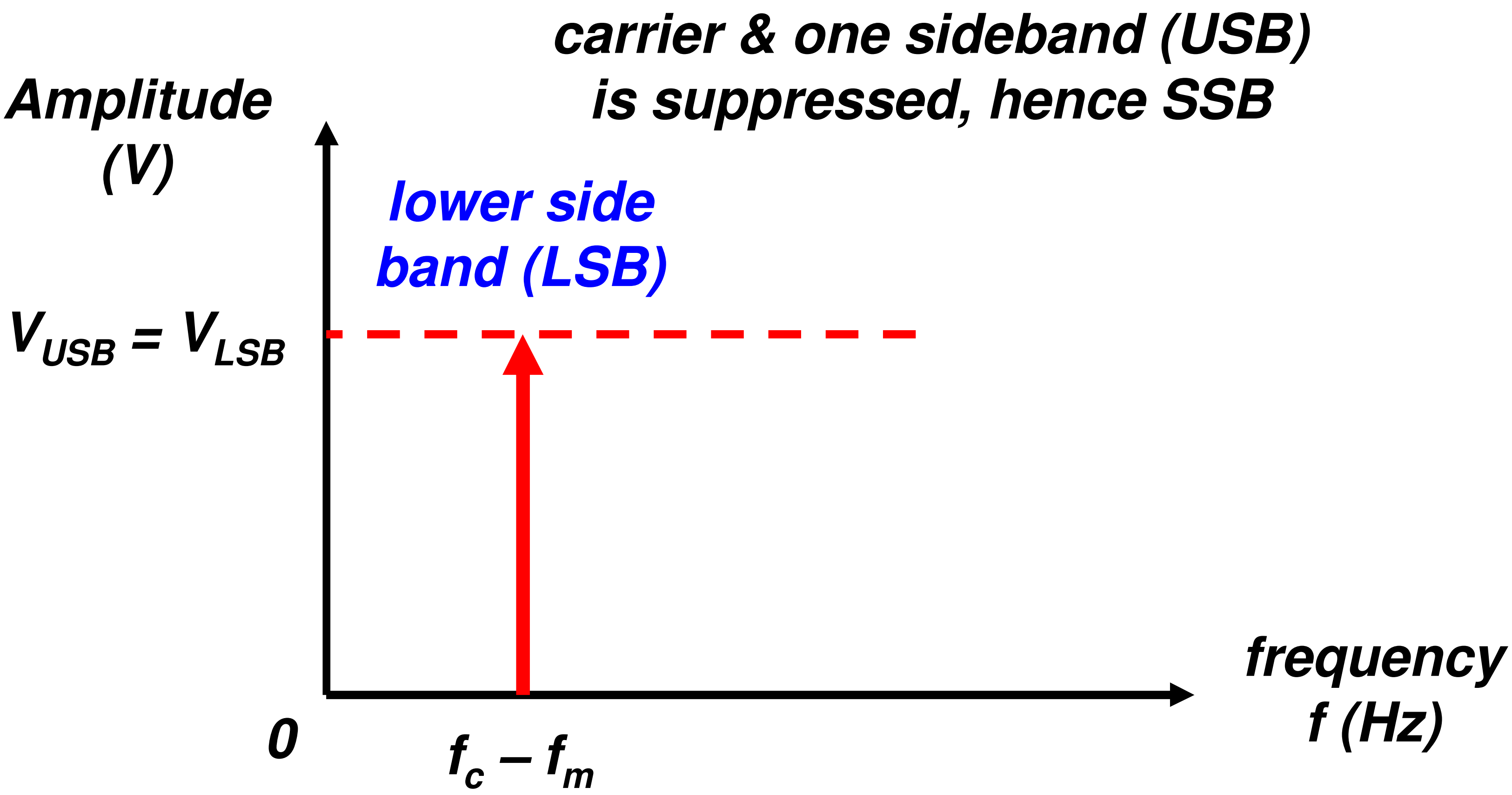
1. Power saving is higher in SSB as compared to DSBSC, only one sideband is transmitted
2. Bandwidth reduces to half, hence compared to DSBSC, bandwidth of SSB is only f_m Hz
3. As bandwidth reduces to half, more number of channels can now be easily transmitted
4. This gives an advantage in saving power & bandwidth compared to DSBSC & DSBFC

SSB – The Frequency Spectrum



$\boxed{BW = f_m}$

SSB – The Frequency Spectrum



$\boxed{BW = f_m}$

Total Power Saved in SSB (SC)

Total power saved in SSB (SC) is expressed in the context of definition as :-

$$PS = \frac{\textit{Power Saved in AM}}{\textit{Total Power in AM}}$$

$$\boxed{PS = \frac{P_C + P_{SB}}{P_T}}$$

defined as ratio of carrier + sideband power to total power

Total Power Saved in SSB (SC)

$$PS = \frac{P_C + P_{SB}}{P_T} \Rightarrow PS = \frac{P_C + \left[\frac{m_a^2}{4}\right] P_C}{P_C \left[1 + \frac{m_a^2}{2}\right]}$$

please refer to your class notes

$$PS = \frac{1 + \frac{m_a^2}{4}}{1 + \frac{m_a^2}{2}} \Rightarrow PS = \frac{4 + m_a^2}{2(2 + m_a^2)}$$

Total Power Saved in SSB (SC)

Total Power Saved (PS) is expressed in terms of the modulation index (m_a) as :-

$$\boxed{PS = \frac{4 + m_a^2}{2(2 + m_a^2)}}$$

please refer to your class notes for the derivation

Total Power Saved in SSB (SC)

Total Power Saved (PS) is expressed in terms of the modulation index (m_a) as :-

$$PS = \frac{4 + m_a^2}{2(2 + m_a^2)}$$

assume m_a = 1 for critical modulation

$$PS = \frac{4 + (1)^2}{2[2 + (1)^2]}$$

$$\boxed{PS = \frac{5}{6} = 83.33\%}$$

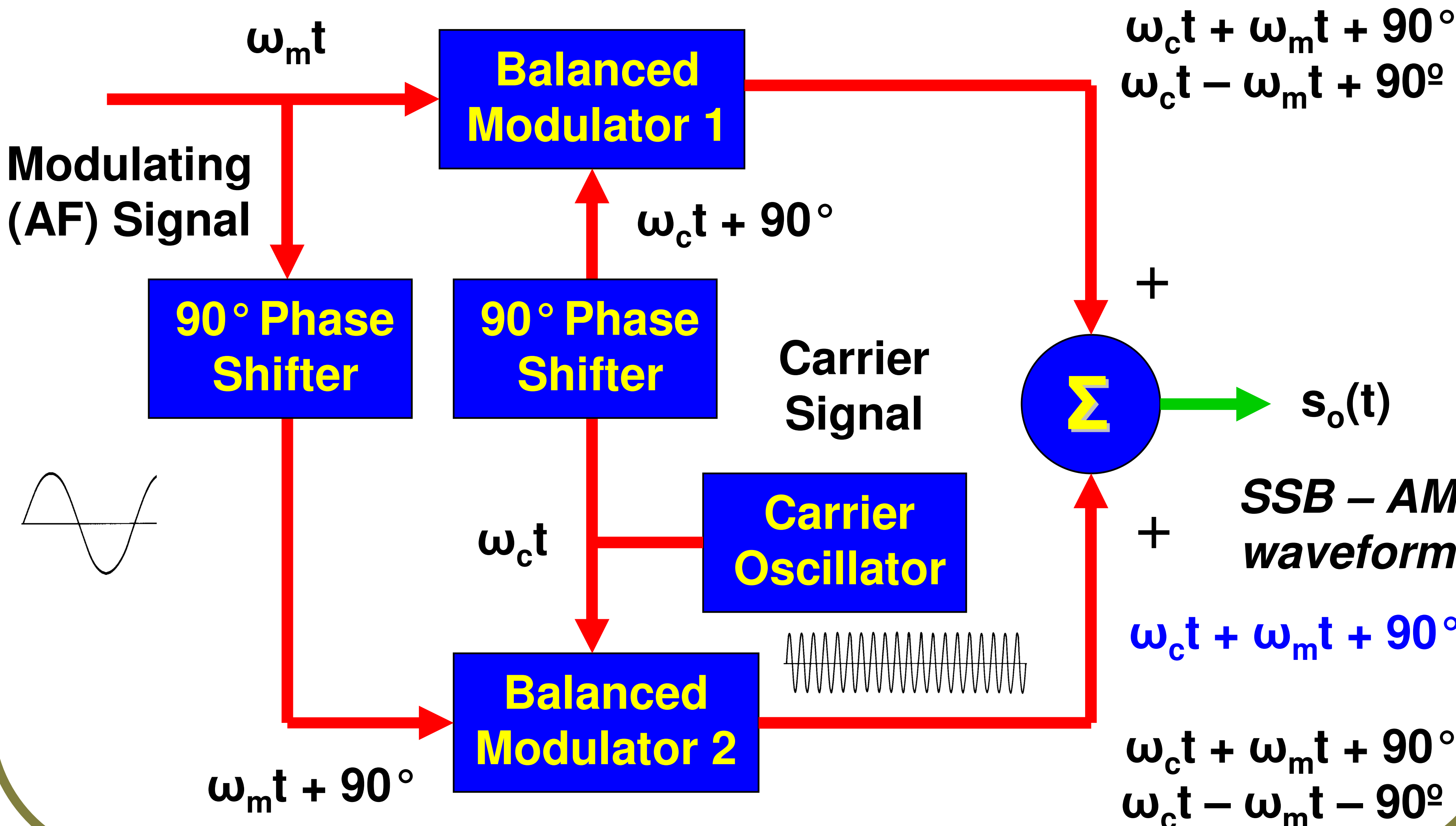
DSBSC – Methods of Generation

Single Sideband Suppressed Carrier AM (SSB) can be generated as follows :-

- **The Filter (USB/LSB) Method**
- **The Phase Shift Method**
- **The 'Third' Method (Weaver's Method)**

Please refer to your class notebook for analysis, derivations & theory

Single Sideband (SSB) Generation – The Phase Shift Method



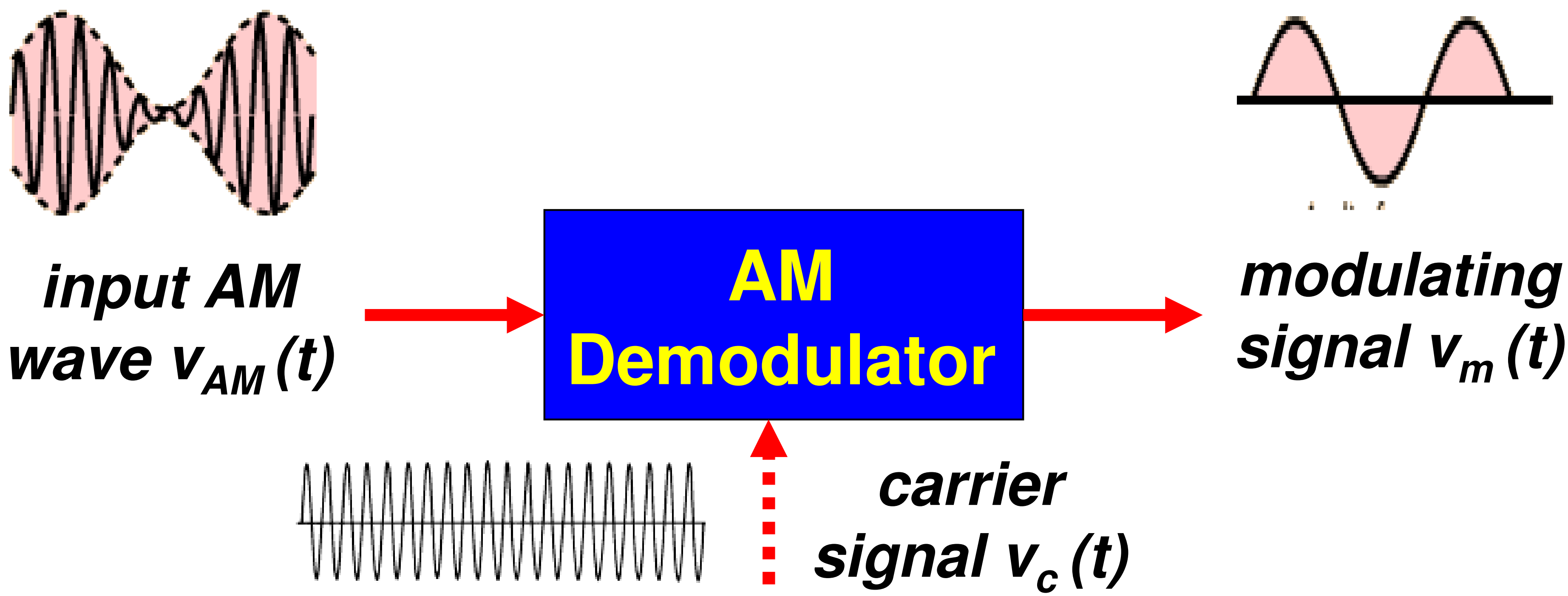
Functions of Radio Receivers

- To select a desired RF frequency (AM/FM) & to reject other unwanted frequencies
- Suitably amplify selected / tuned RF (AM/FM) channel (frequency or station)
- Detect the modulating signal (original) from the AM/FM waveform, removing the carrier
- Amplify recovered modulating signal from AM/FM wave to drive the loudspeaker
- Perform this function with almost zero or a minimum amount of distortion in o/p signal

Concept of Demodulation

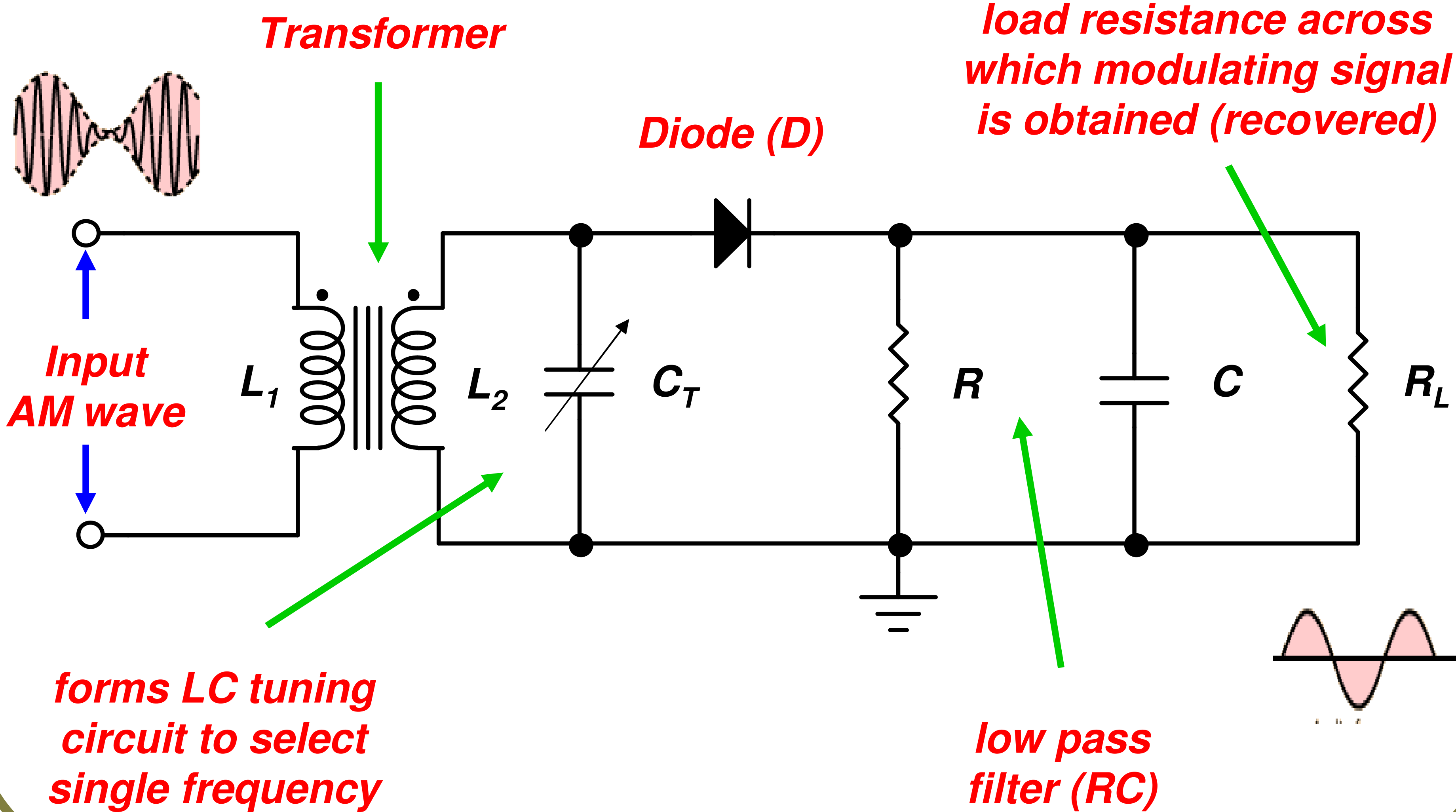
- Demodulation is the recovery of the original modulating signal $v_m(t)$ back from AM wave
- Involves extracting (removal) of modulating signal $v_m(t)$ from the AM wave at receiver
- Consists of the following steps :-
  - ✓ AM/FM Wave Detection (Tuning)
  - ✓ Received RF Signal Amplification
  - ✓ Carrier Separation (Demodulation)
  - ✓ Filtering Process (LPF)
  - ✓ Amplification & Signal Conditioning

Concept of Demodulation (AM)

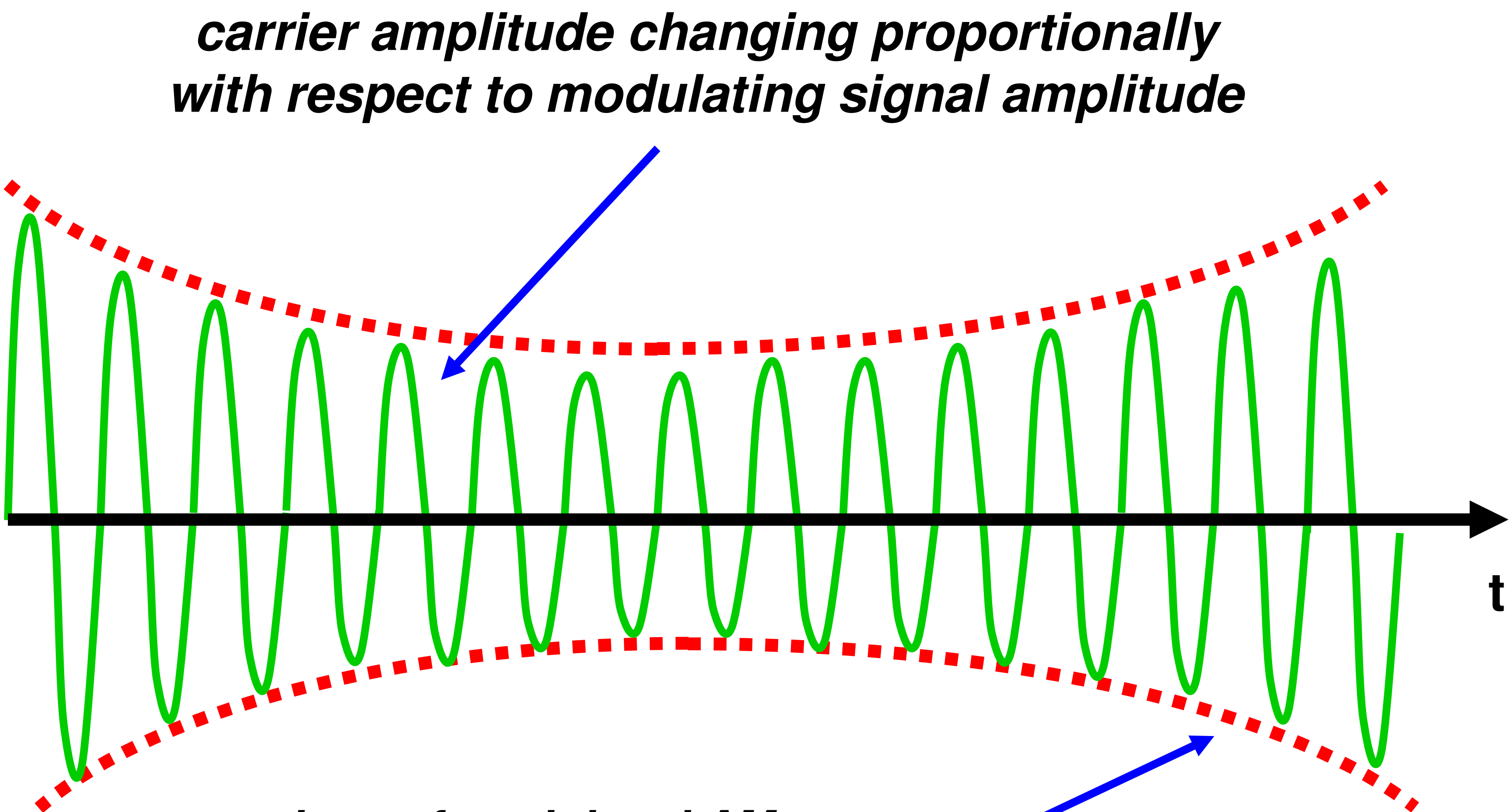


- **Coherent** Demodulation – Carrier signal is **required**
- **Non Coherent** Demodulation – Carrier signal **not required**

The (AM) Diode Detector



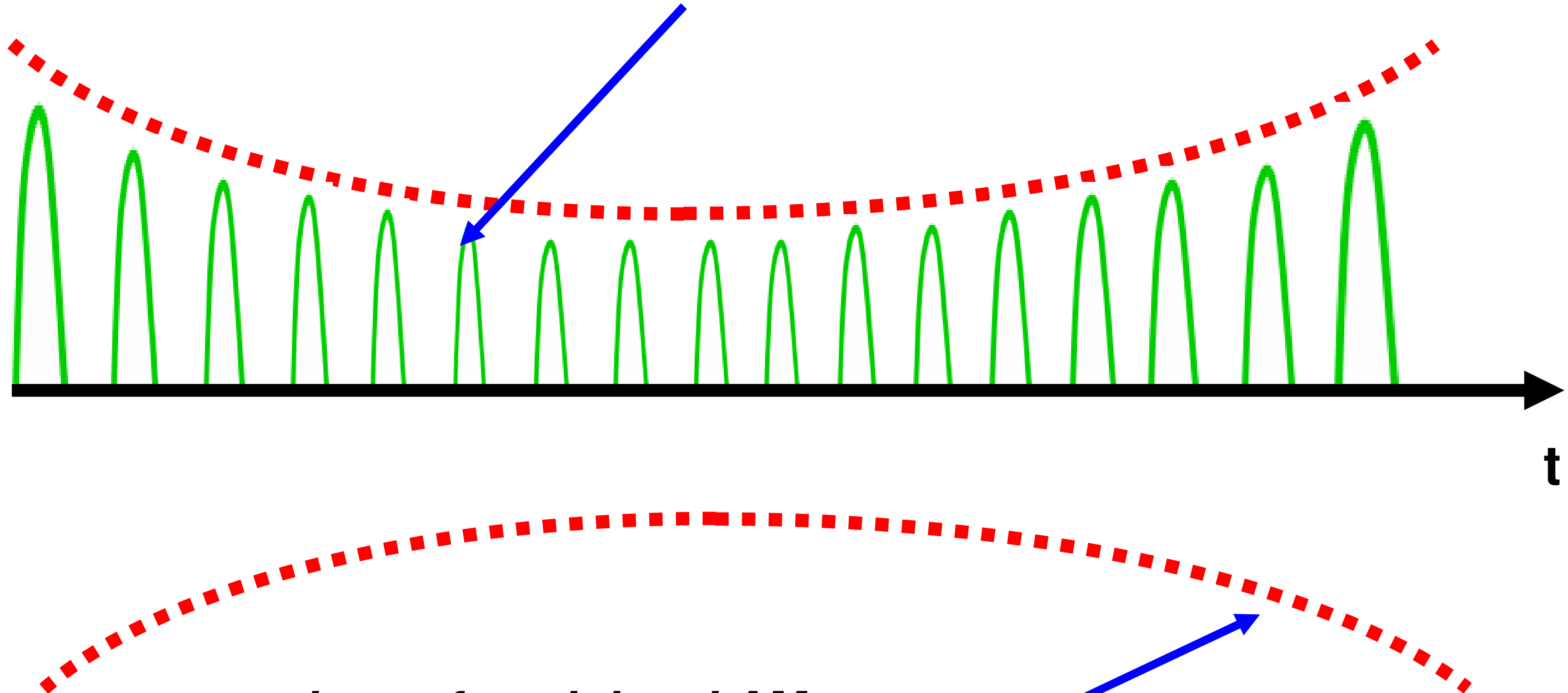
The (AM) Diode Detector – 1. Input Amplitude Modulated (AM) Wave



$$v_{AM}(t) = V_c\,[\,1 + m_a \cos\omega_m t\,]\cos\omega_c t$$

The Diode Detector –
2. Output of the Diode (D) +ve HWR

Diode (D) eliminates the negative half cycle of AM wave, giving positive pulses of varying amplitude

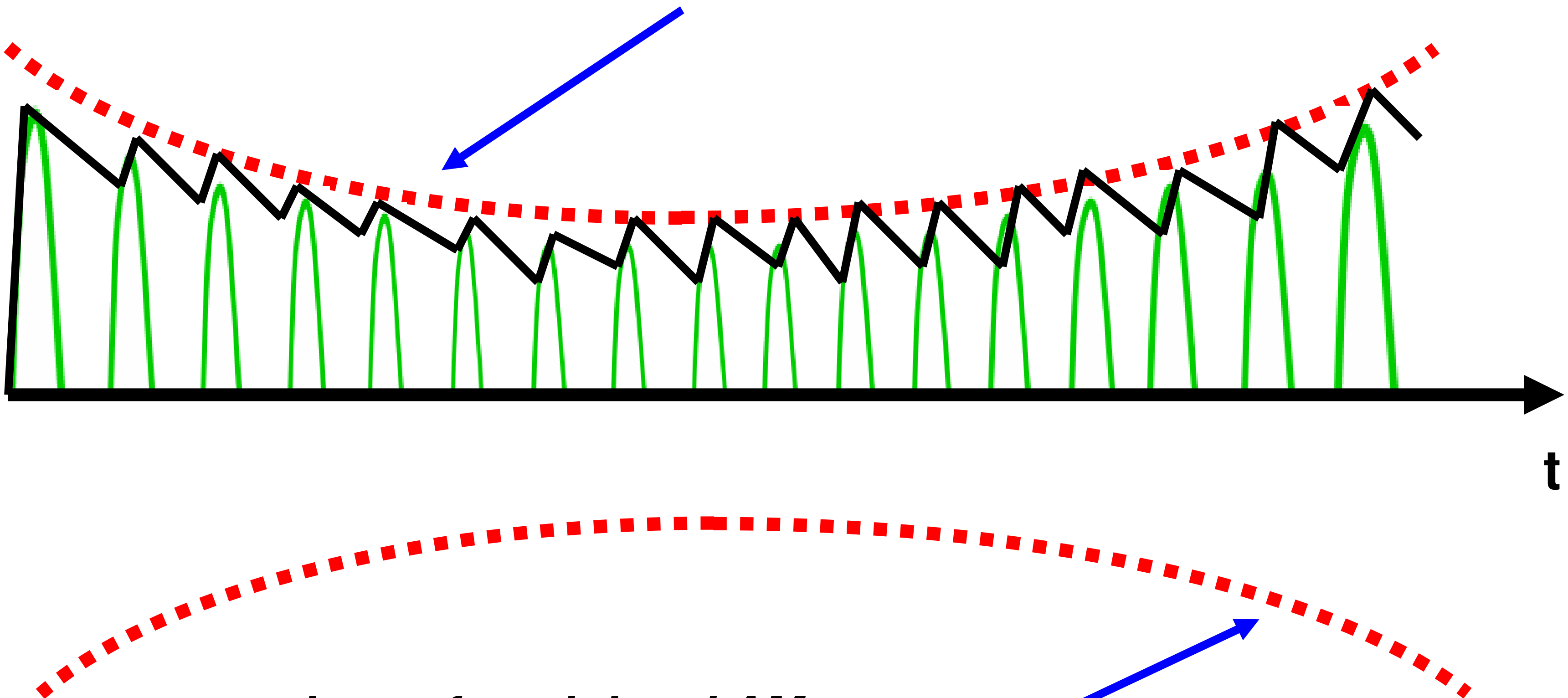


envelope of modulated AM wave

$$v_{AM}(t) = V_c\,[\,1 + m_a \cos\omega_m t\,]\cos\omega_c t$$

The Diode Detector –
3. Output of the low pass RC Filter

low pass RC filter allows C to charge up for each +ve peak of input signal & hold the voltage until next peak

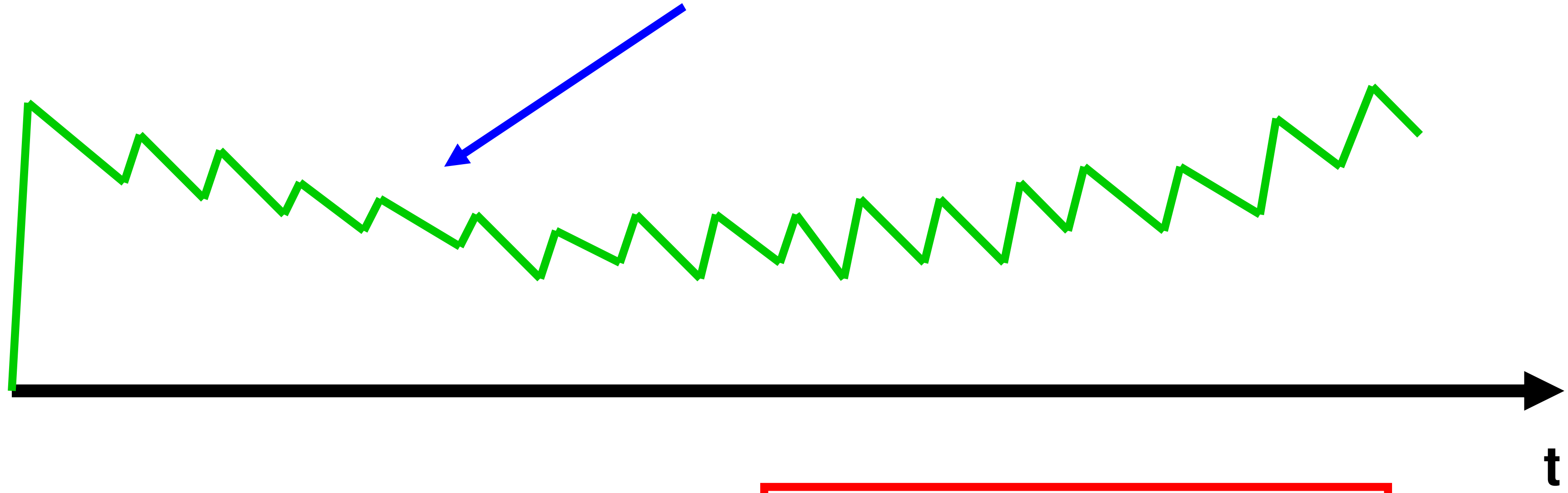


envelope of modulated AM wave

$$v_{AM}(t) = V_c\,[\,1 + m_a \cos\omega_m t\,]\cos\omega_c t$$

The Diode Detector –
4. Demodulated AM wave (modulating)

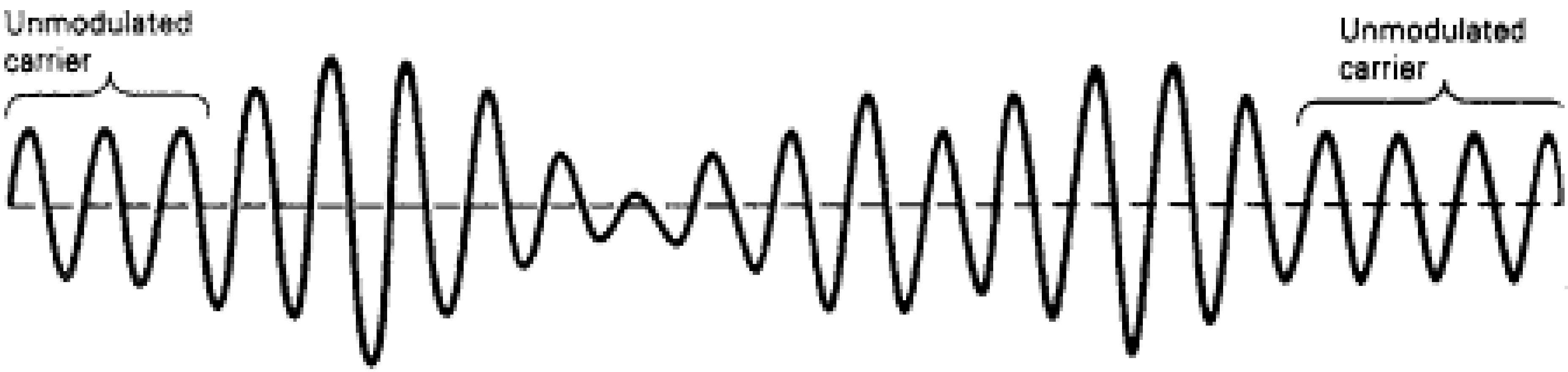
final output results in highly pulsating positive wave having amplitude proportional to modulating signal



for successful demodulation, values of RC should be chosen as per following condition :-

$$RC \geq \frac{1}{\omega_m}\sqrt{\frac{1-m_a^{\,2}}{m_a^{\,2}}}$$

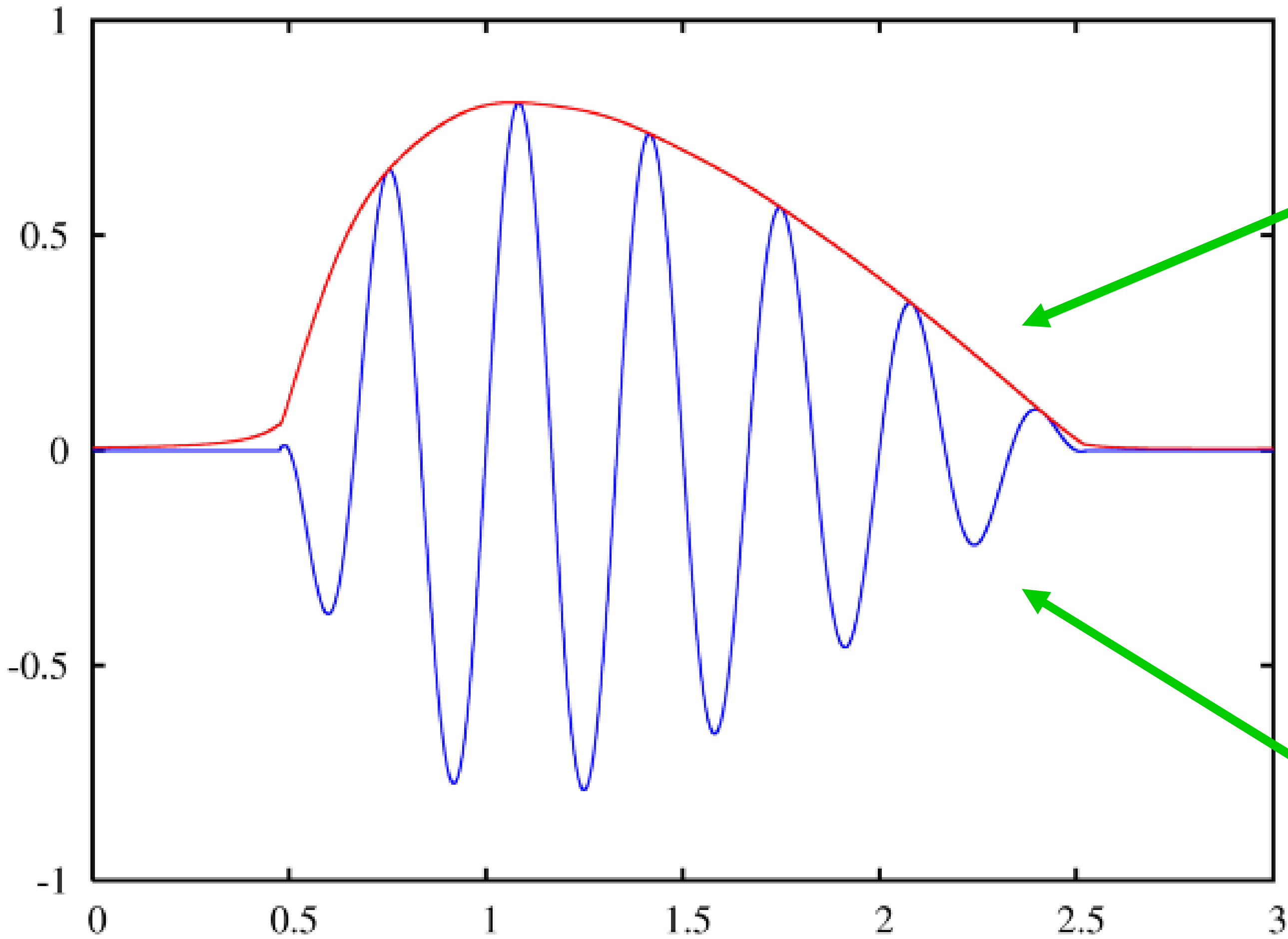
The Diode Detector – An Example
The AM Demodulation Process



Input AM waveform

Demodulated output waveform

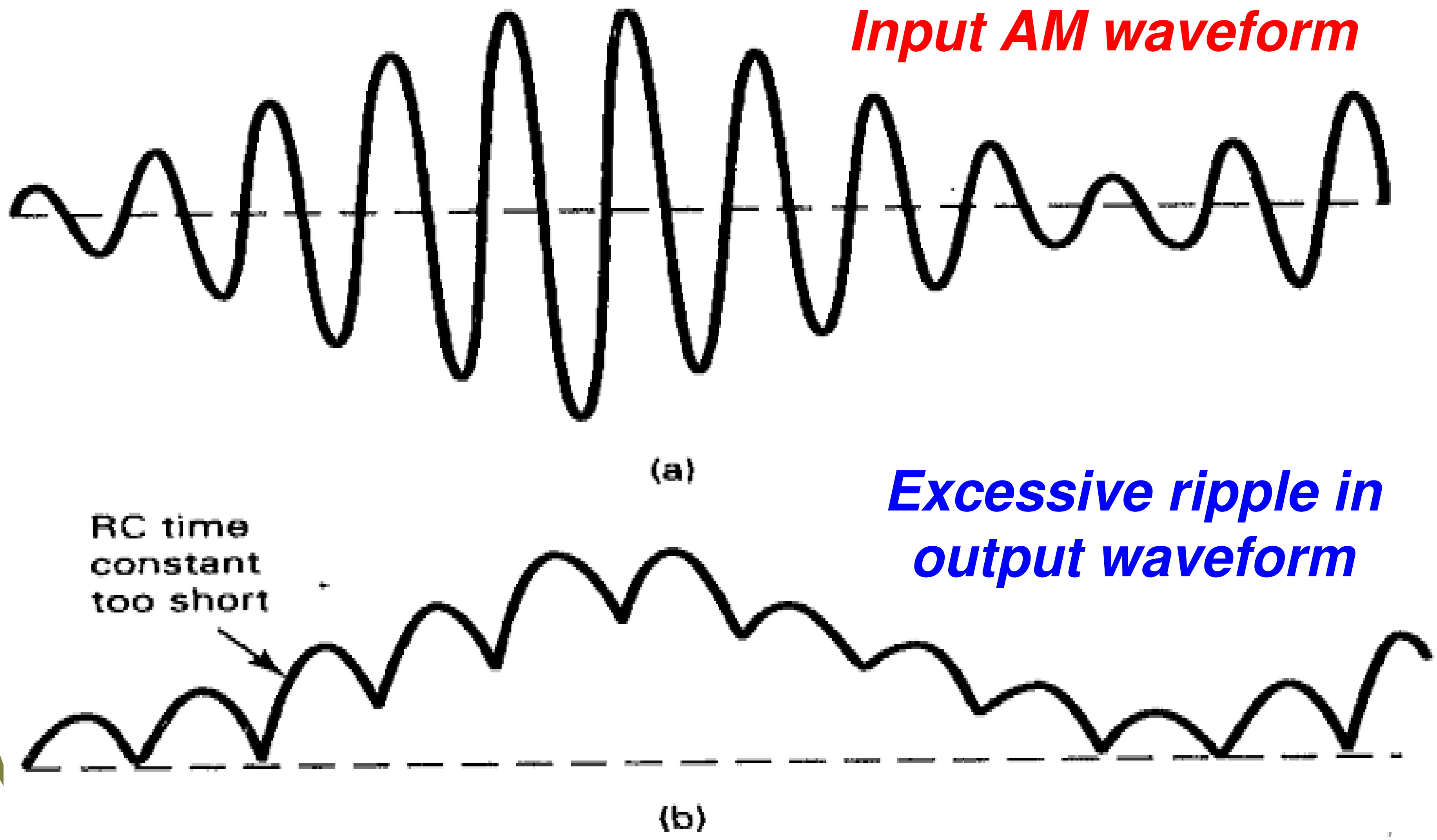
Example of Optimum AM Demodulation



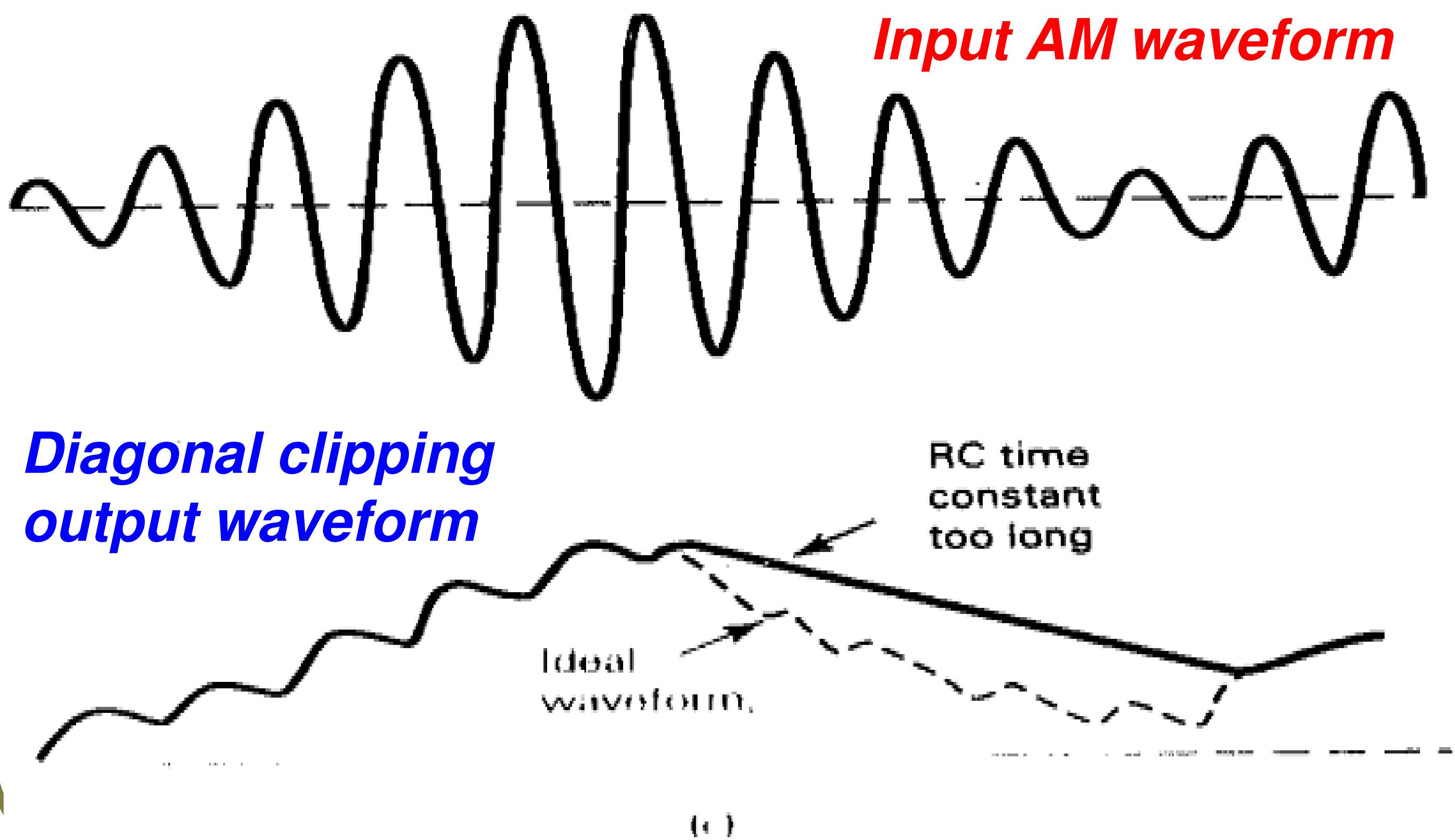
output of the diode detector

modulated AM wave

Distortion in AM Demodulation – 1



Distortion in AM Demodulation – 2



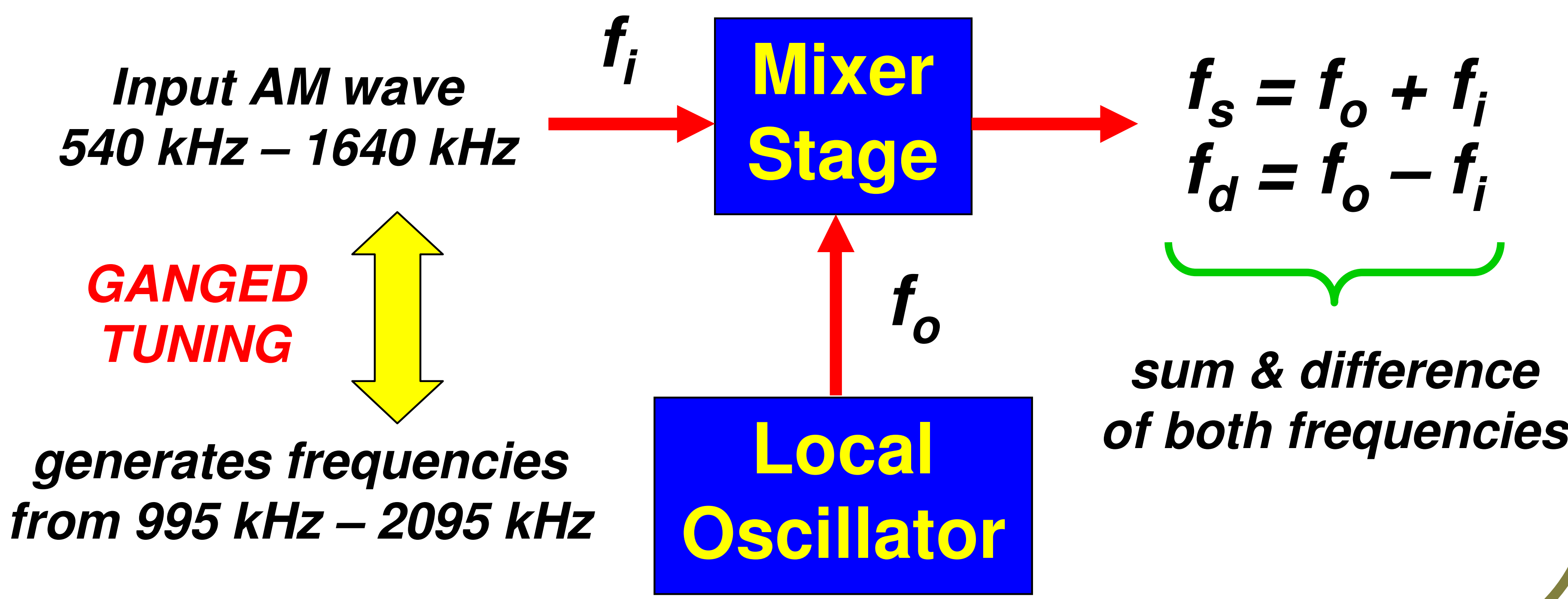
Distortion in AM Demodulation

- **Negative Peak Clipping –** occurs on account of over, excessive modulation at transmitter where a negative part of signal is clipped off
- **Diagonal Clipping –** occurs when ‘R’ is high causing ‘C’ to discharge very slowly, thereby missing a few peaks in the entire process
- **Excessive Spikes –** occurs when ‘R’ is less, causing ‘C’ to rapidly discharge, creating a spike-like appearance in detected envelope

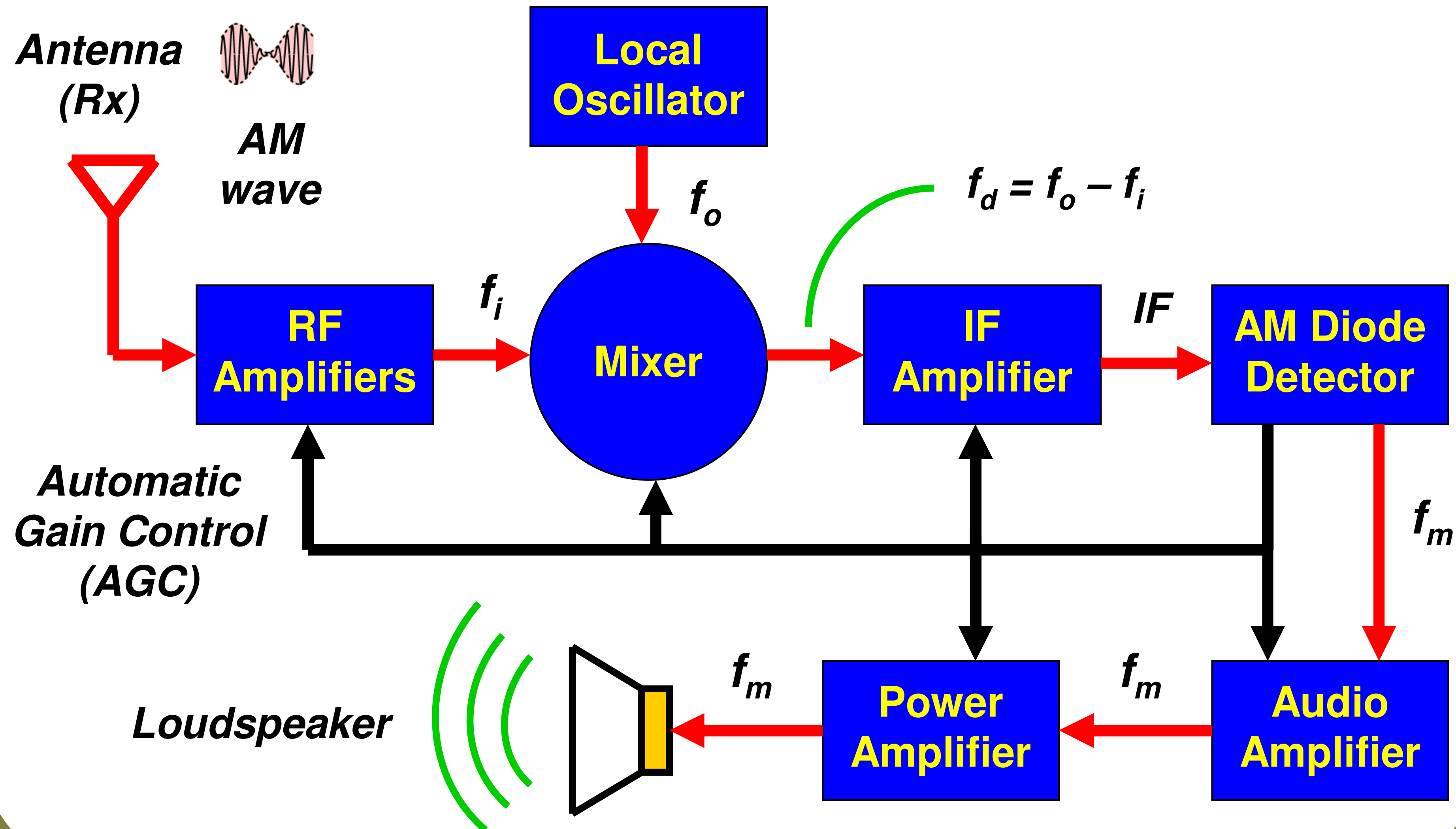
Refer class notes for waveforms of each case

The Superhetrodyne Principle

The superhetrodyne process involves mixing of two different frequency signals such that the output is a sum & difference of both the input signal frequencies



The AM Superhetrodyne Receiver



The AM Superhetrodyne Receiver

Block Diagram Description :-

- Input RF amplifier stages, all tuned together used to select & amplify the input frequency
- AM diode detector used to demodulate AM wave to recover modulating signal $v_m(t)$
- Audio amplifier amplifies the modulating received signal (increases the amplitude)
- Power amplifier raises the power level to a sufficient stage to drive the loudspeakers

The AM Superhetrodyne Receiver

Block Diagram Description :-

- **RF amplifier stages designed for frequency selection between 540 kHz to 1640 kHz**
- **Local oscillator tuning mechanically linked with RF amplifier from 995 kHz to 2095 kHz**
- **Mixer produces a single constant frequency (IF) of 455 kHz over entire AM tuning range**
- **IF amplifier is narrow-band amplifier having high selectivity to select only IF frequency**

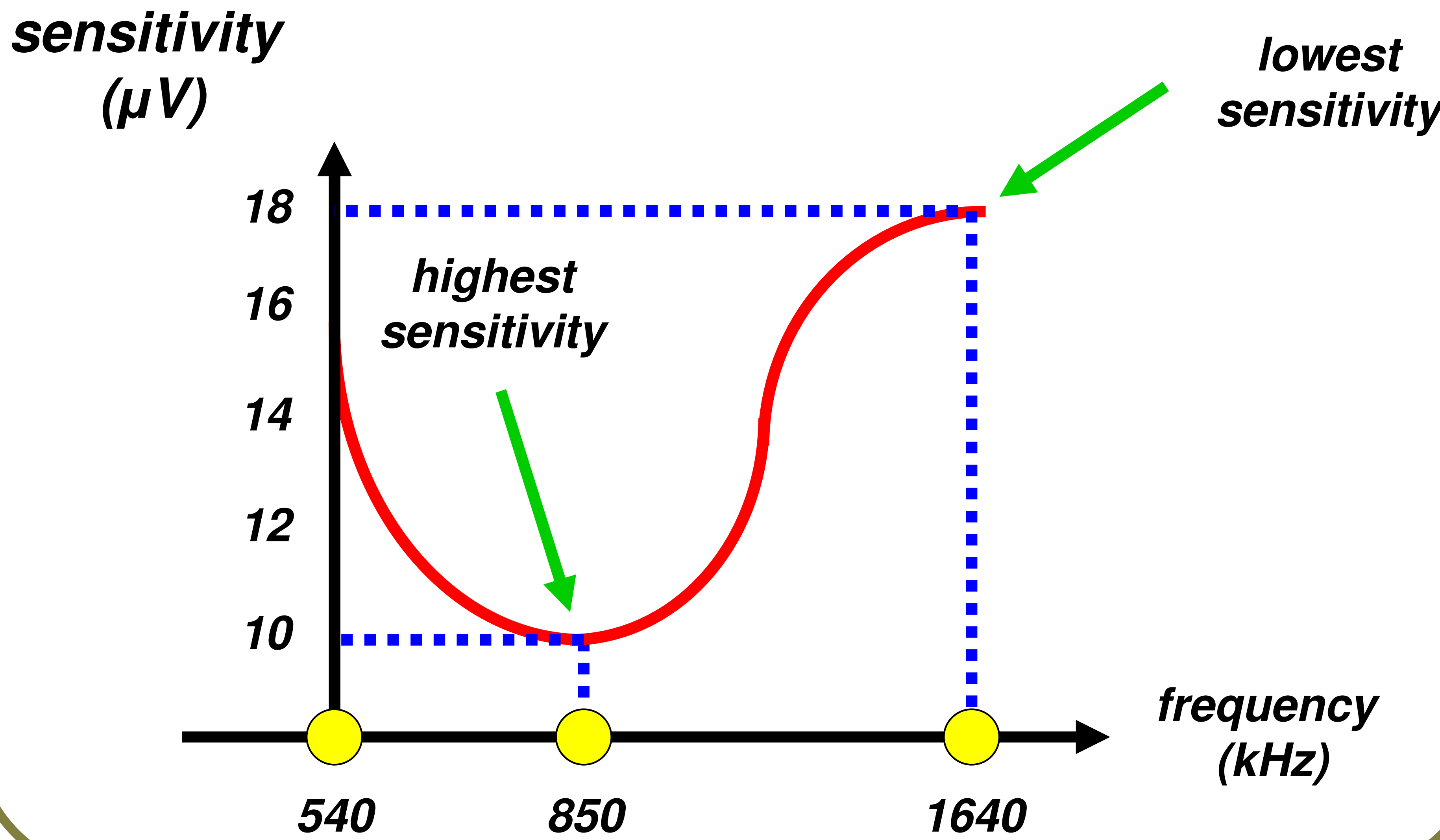
Characteristics of Radio Receiver

Radio Receiver Parameters (Factors) :-

- Sensitivity
- Selectivity
- Fidelity
- Image Frequency & it's rejection
- Double Spotting Effect

these parameters determine how good a radio receiver is in terms of performance

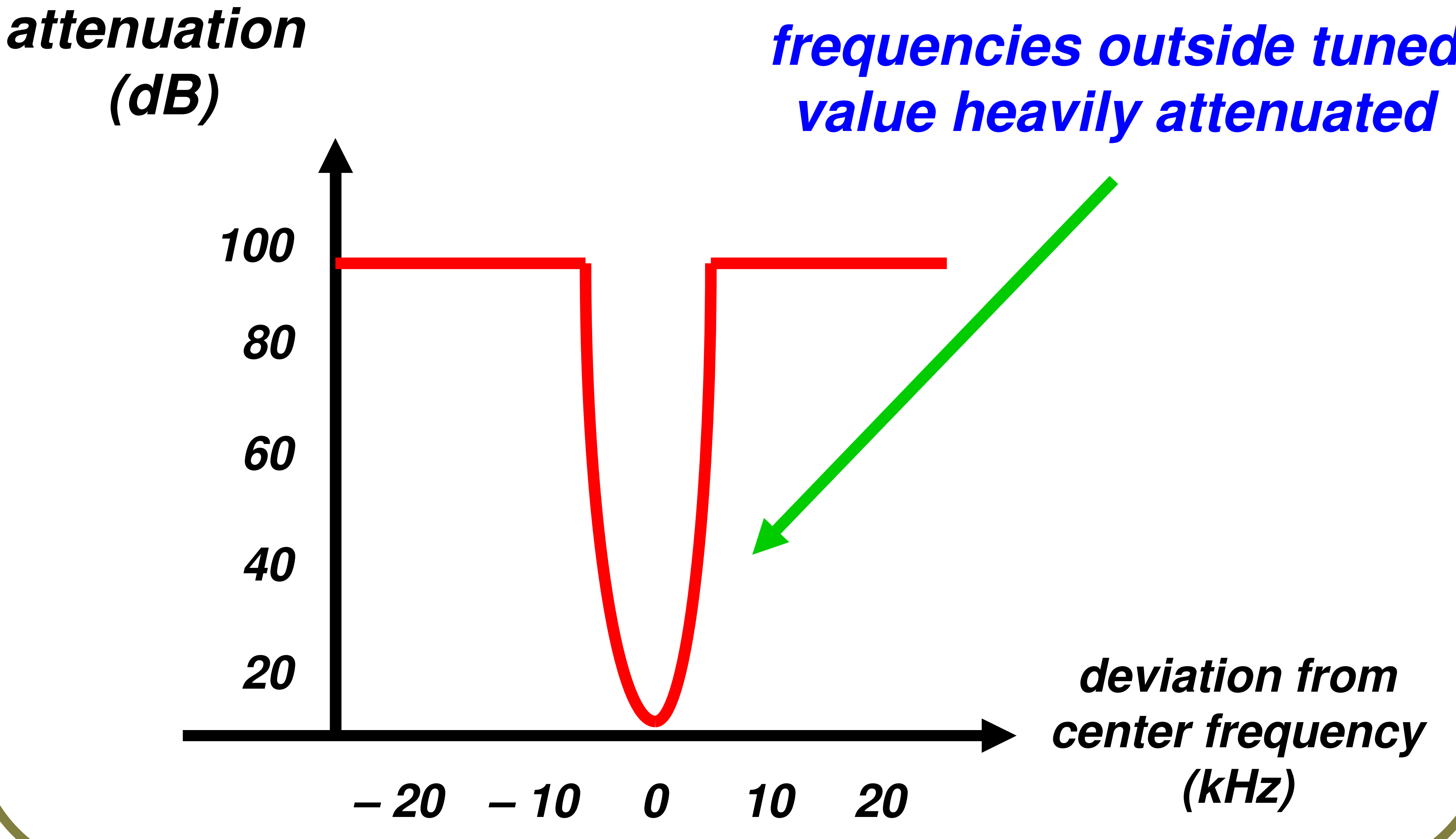
1. Sensitivity



Characteristics of Radio Receiver – 1. Sensitivity

- Sensitivity of a radio receiver is the ability of the receiver to amplify weak signals
- It refers to the minimum amount of voltage at the input to produce a standard output
- Standard output in terms of power is 50 mW or, in terms of voltage, a few µV value
- Often expressed in dB or µV since receiver is more sensitive for lower input signals
- Depends upon the gain of the input or initial RF amplifier stages (should be high)

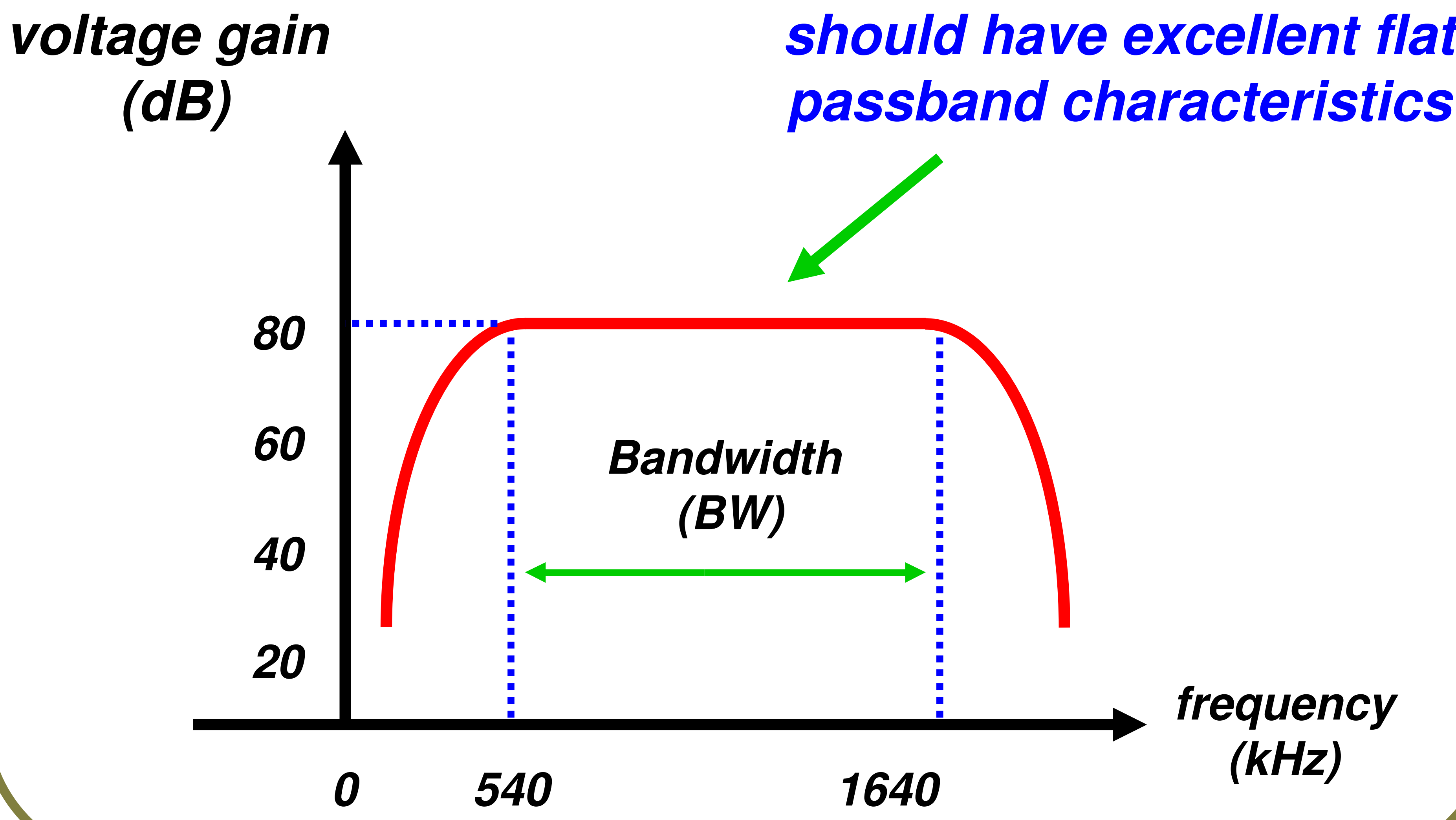
2. Selectivity



Characteristics of Radio Receiver – 2. Selectivity

- Selectivity of radio receiver is the ability of the receiver to reject unwanted signals
- It is expressed as curve, shows attenuation by receiver to frequencies near tuned value
- For some good adjacent channel frequency rejection, selectivity curve should be sharp
- It depends upon the frequency response of the mixer, RF & IF amplifier stages
- Practically not possible to have sharp curve for selectivity (only under ideal conditions)

3. Fidelity



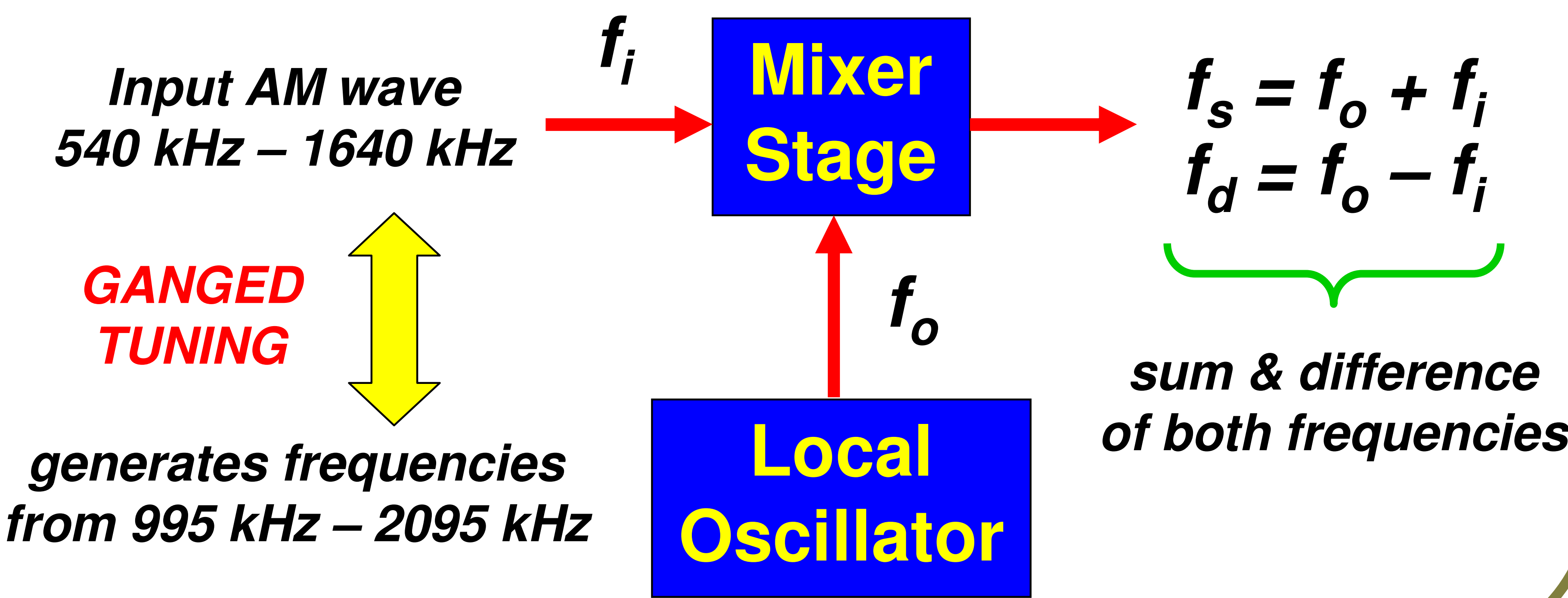
voltage gain
(dB)
should have excellent flat passband characteristics
80
60
40
20
Bandwidth
(BW)
frequency
(kHz)
0
540
1640

Characteristics of Radio Receiver – 3. Fidelity

- Fidelity of radio receiver is the ability of the receiver to amplify equally all frequencies
- It should have a constant value of gain (A_V) in the bandwidth of the entire tuning range
- The frequency response of the AF & the RF stages should be maximally flat as possible
- Critical parameter to achieve a good fidelity is frequency response & gain of AF stage
- These amplifiers should also have a good tuning characteristics for good fidelity

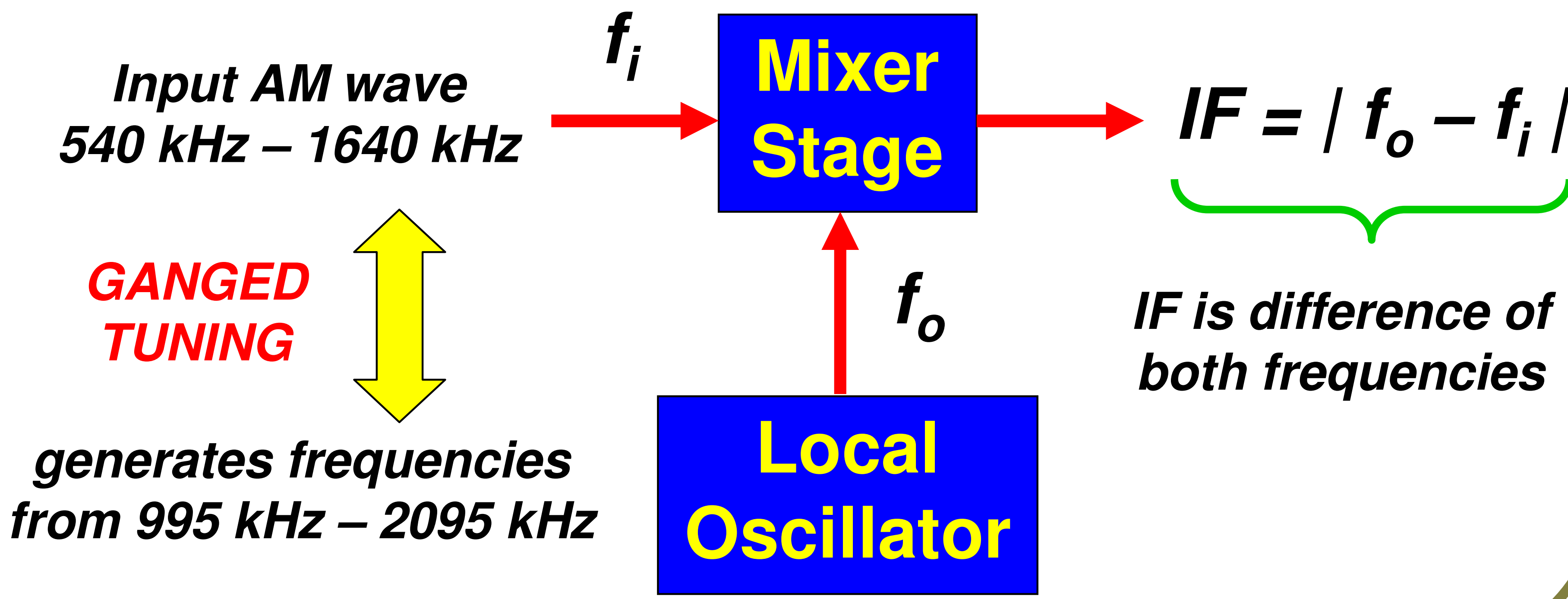
The Superhetrodyne Principle – 1

The superhetrodyne process involves mixing of two different frequency signals such that the output is a sum & difference of both the input signal frequencies



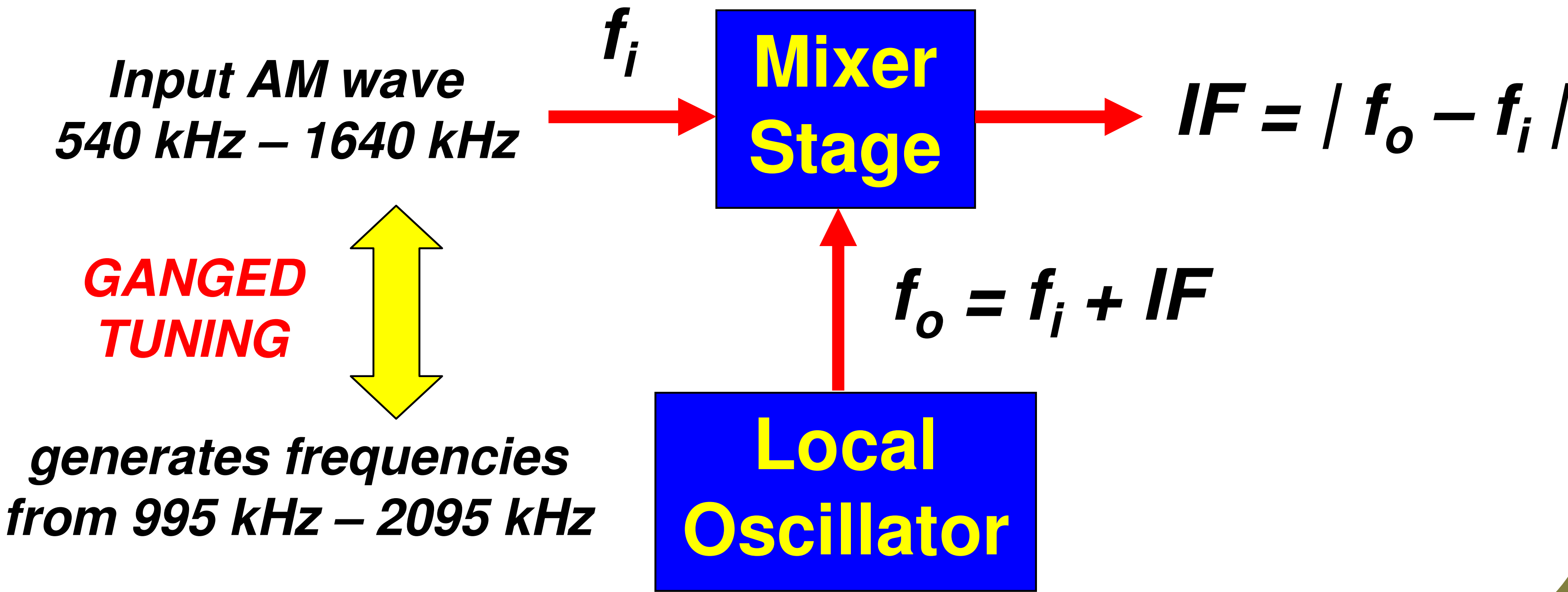
The Superhetrodyne Principle – 2

The superhetrodyne process involves mixing of two different frequency signals such that the output is a sum & difference of both the input signal frequencies



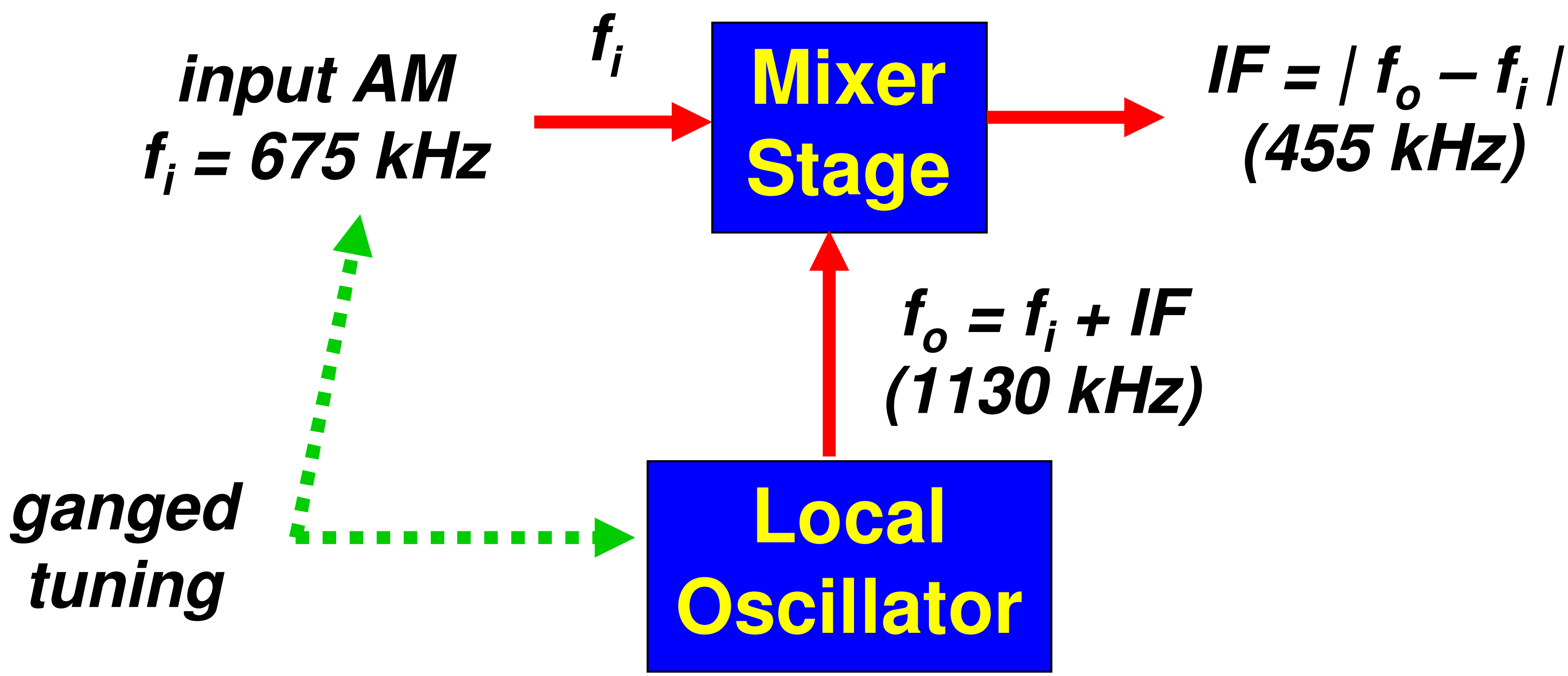
The Superhetrodyne Principle – 3

The superhetrodyne process involves mixing of two different frequency signals such that the output is a sum & difference of both the input signal frequencies



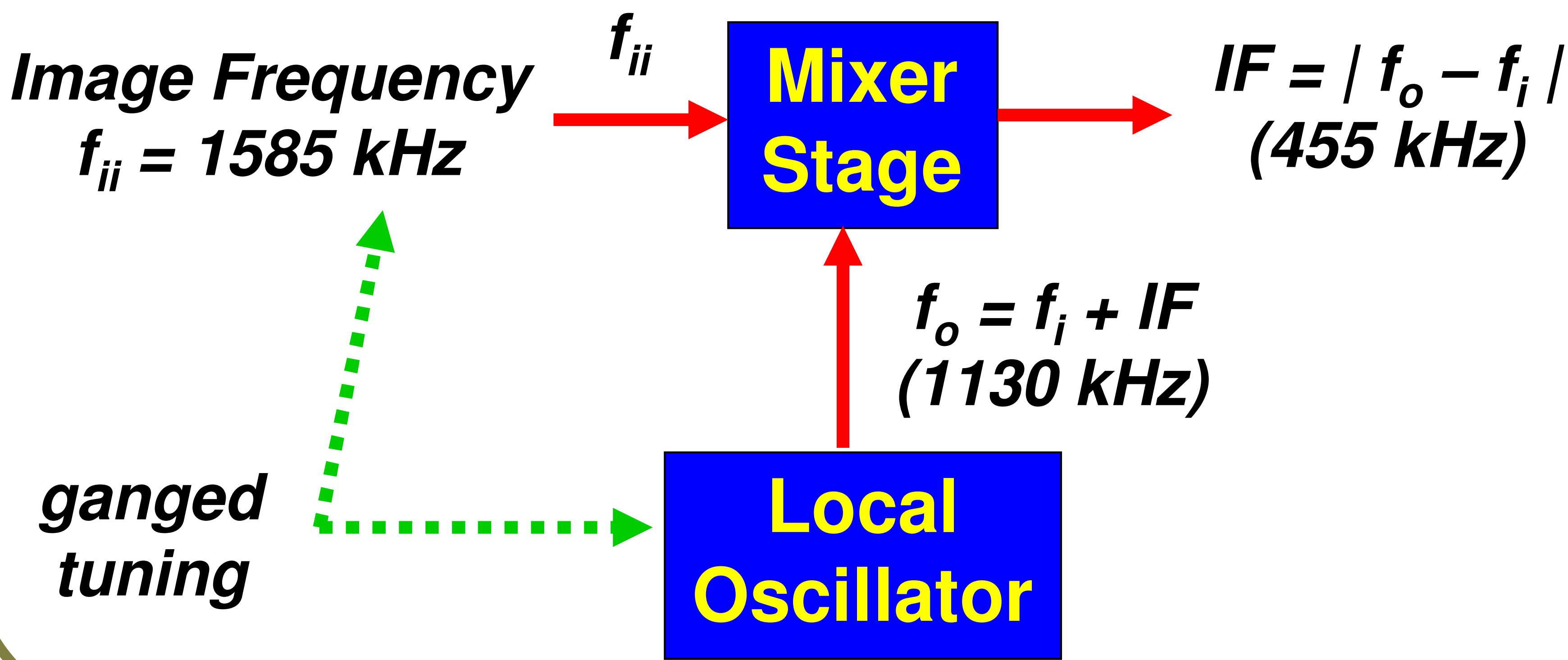
Characteristics of Radio Receiver – 4. Image Frequency & Rejection

- ✓ ***Receiver tuned to receive f_i = 675 kHz***
- ✓ ***Local Oscillator output f_o = 1130 kHz (ganged)***
- ✓ ***Intermediate Frequency (IF) = 1130 – 675 = 455 kHz***



Characteristics of Radio Receiver – 4. Image Frequency & Rejection

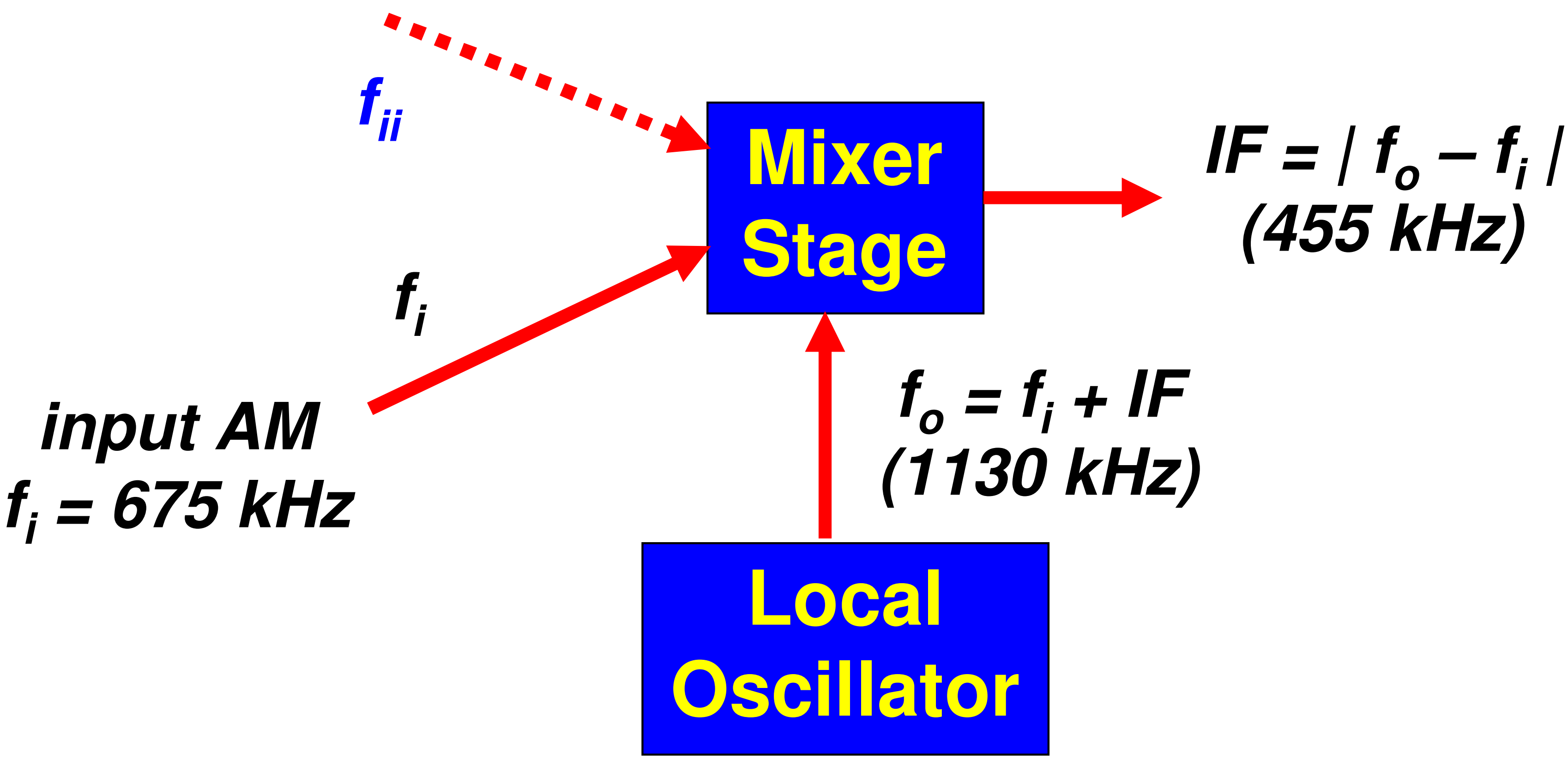
- ✓ *Image Frequency* $f_{ii} = f_i + 2IF = 1585$ *kHz*
- ✓ *Local Oscillator output* $f_o = 1130$ *kHz (ganged)*
- ✓ *Intermediate Frequency (IF) = |1130 – 1585| = 455 kHz*



Characteristics of Radio Receiver – 4. Image Frequency & Rejection

Image Frequency
f_{ii} = 1585 kHz

both signals f_i & f_{ii} are together received at mixer stage input



Characteristics of Radio Receiver – 4. Image Frequency & Rejection

Image Frequency Equation :-

$$\boxed{f_{ii} = f_i + 2IF}$$

Image Frequency Rejection Ratio :-

$$\boxed{\alpha = \sqrt{1 + Q^2 \rho^2}}$$

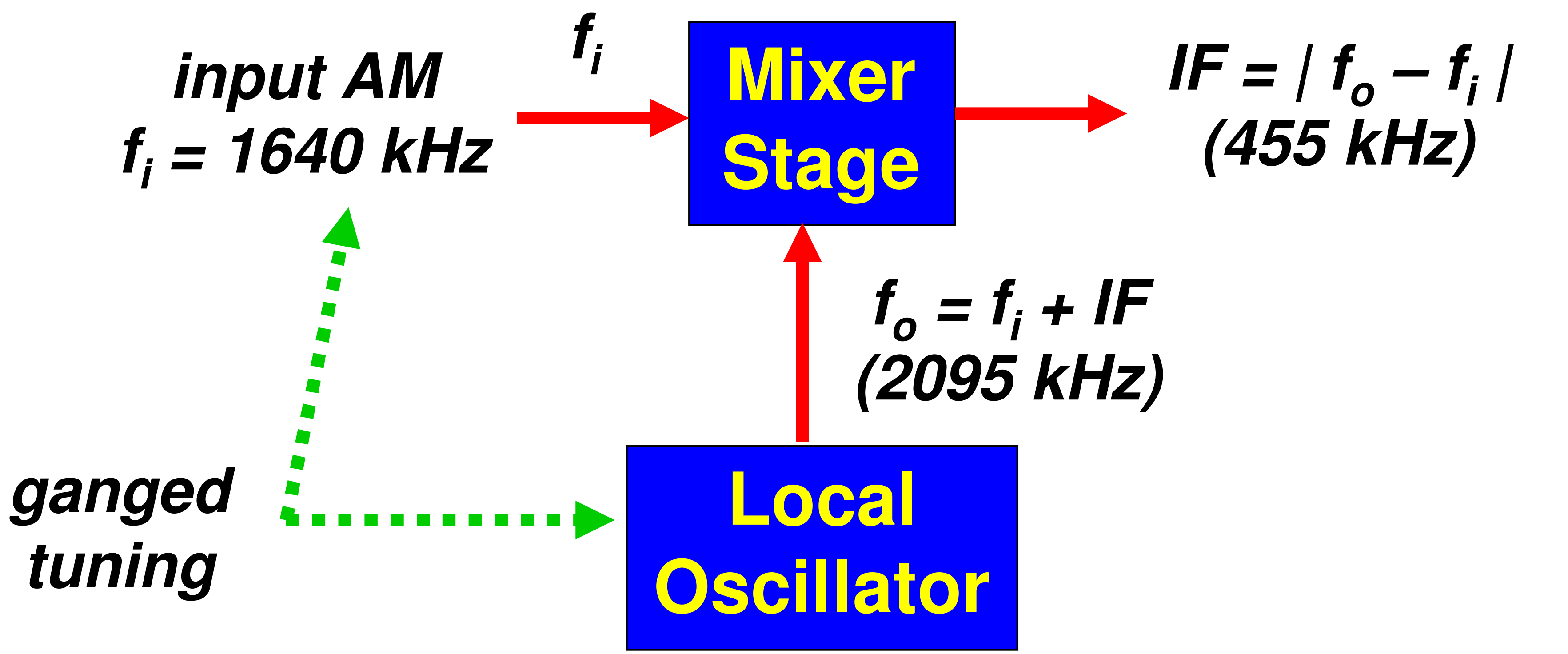
where $\rho = \dfrac{f_{ii}}{f_i} - \dfrac{f_i}{f_{ii}}$ ***& Q = Quality Factor***

Characteristics of Radio Receiver – 4. Image Frequency & Rejection

- **Image frequency is problem of receiving two radio stations together on same dial point**
- **If f_i = 675 kHz then f_o = 1130 kHz & f_i selected as IF = $|f_o - f_i|$ = 455 kHz for that radio station**
- **However another frequency at f_{ii} = 1585 kHz is selected as IF = $|f_o - f_{ii}|$ = 455 kHz also !**
- **Both frequencies f_i & f_{ii} are simultaneously given at the input to the mixer stage**
- **Though f_o = 1130 kHz, input frequency (f_i) & its image (f_{ii}) are applied to mixer input**

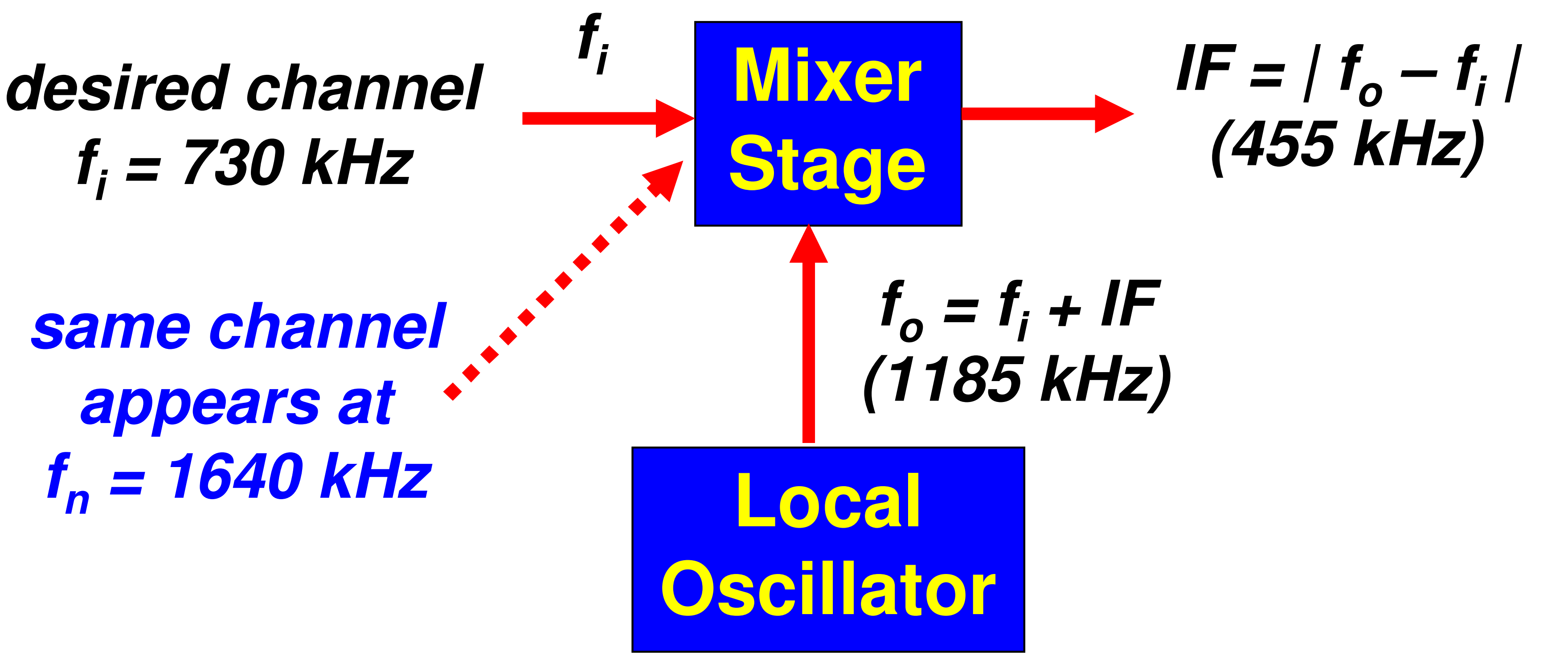
Characteristics of Radio Receiver – 5. Double Spotting Effect

- ✓ ***Local oscillator output f_o = 2095 kHz***
- ✓ ***Input frequency (selected) f_i = 1640 kHz***
- ✓ ***Intermediate Frequency (IF) = 2095 – 1640 = 455 kHz***

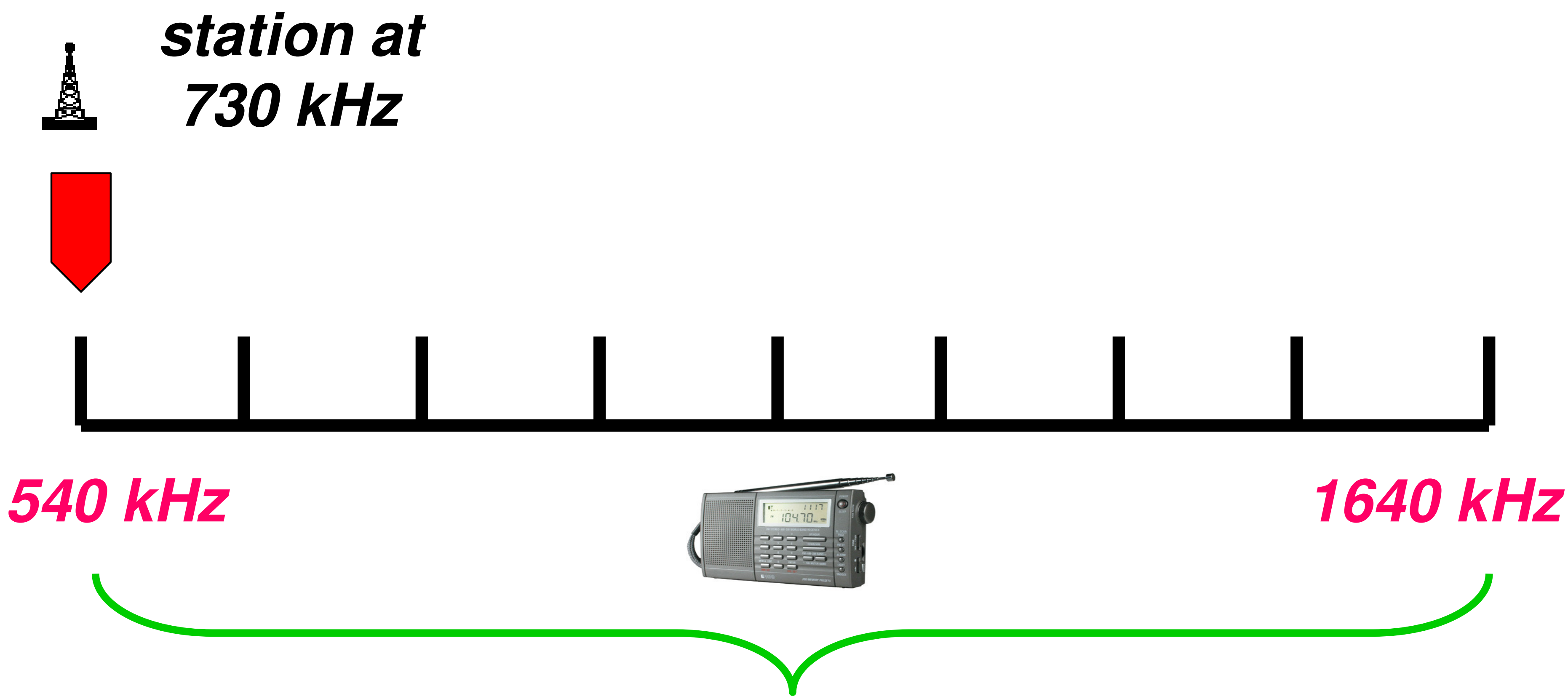


Characteristics of Radio Receiver – 5. Double Spotting Effect

- ✓ *Local oscillator output f_o = 1185 kHz*
- ✓ *Input frequency (selected) f_i = 730 kHz*
- ✓ *Intermediate Frequency (IF) = 1185 – 730 = 455 kHz*

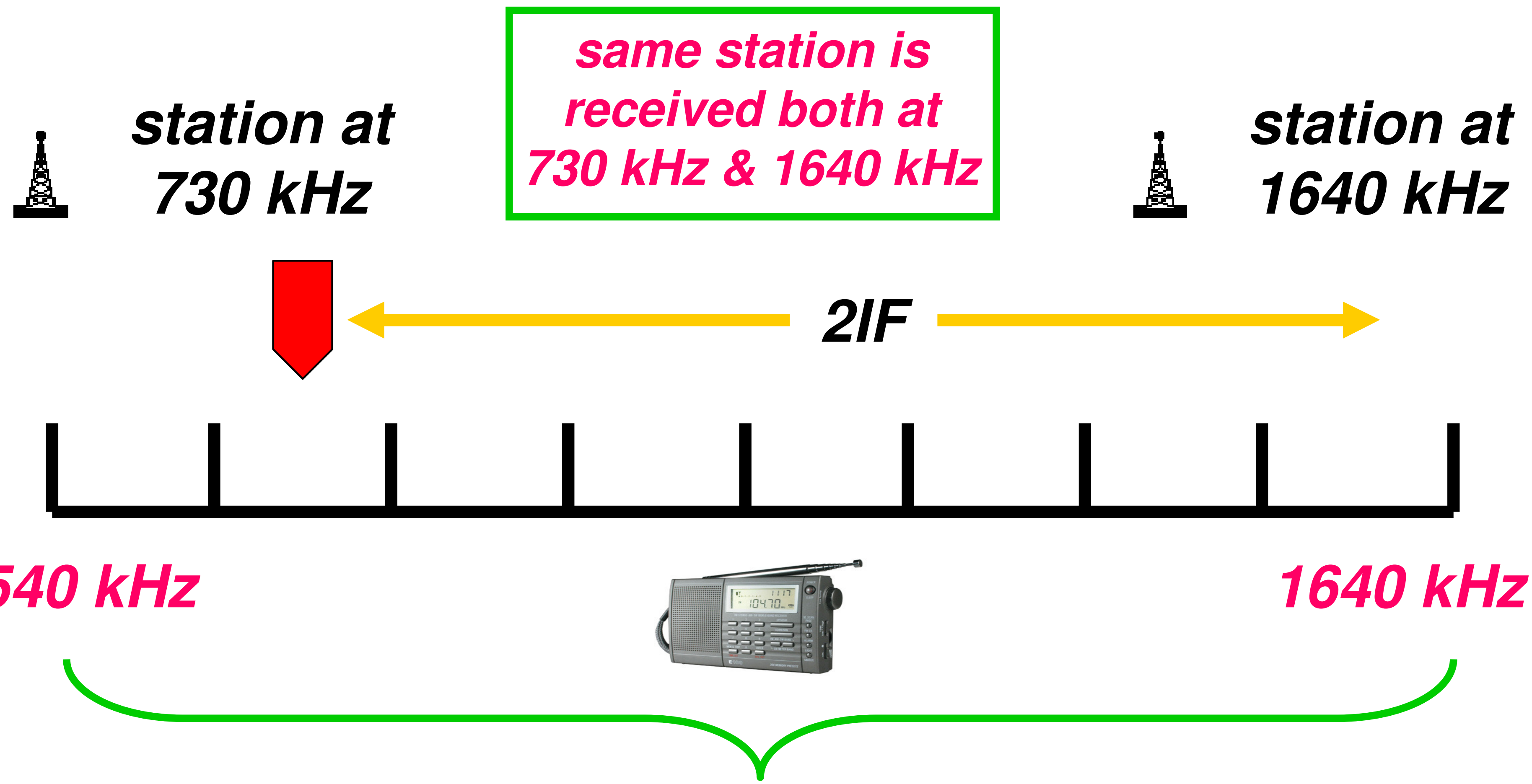


Characteristics of Radio Receiver – 5. Double Spotting Effect



Standard (MW) AM Receiver Tuning Dial

Characteristics of Radio Receiver – 5. Double Spotting Effect



Standard (MW) AM Receiver Tuning Dial

Characteristics of Radio Receiver – 5. Double Spotting Effect

- Double spotting means the same signal gets picked at two different points of receiver dial
- Tuning f_o = 2095 kHz, f_i = 1640 kHz selected since IF = $|f_o – f_i|$ = 455 kHz (radio station)
- Radio station at f_i = 1640 KHz appears again at f_o = 1185 kHz, when f_i = 730 kHz
- This is due to fact that intermediate freq. (IF) is still maintained at IF = $|f_o – f_i|$ = 455 kHz
- Hence the radio station (channel) appears at both frequencies, f_i = 730 kHz & 1640 kHz