Communication Fundamentals

Modulation
AM Power

Dr. Noor AbdAlkarem Mohammedali

1

Objectives

- **Define the Amplitude Modulation Power.**
- **Explain the power calculation.**
- **Explain The Total Transmitted Power**
- **Explain The Total Transmitted Power in the real world**
- **Activities.**
- **Homework.**

2

2

Amplitude Modulation Power

In radio transmission, the AM signal is amplified by a power amplifier and fed to the antenna with a characteristic impedance that is ideally, but not necessarily, almost pure resistance.

You can see how the power in an AM signal is distributed and calculated by

$$v_{AM} = V_c \cos\omega_c t + \frac{V_m}{2}\cos(\omega_c - \omega_m)t + \frac{V_m}{2}\cos(\omega_c + \omega_m)t$$

carrier — lower sideband — upper sideband

Amplitude Modulation Power

Now, remember that V_c and V_m are peak values of the carrier and modulating sine waves, respectively. For power calculations, r.m.s values must be used for the voltages.

We can convert from peak to r.m.s by dividing the peak value by $\sqrt{2}$ or multiplying by 0.707. The r.m.s carrier and sideband voltages are then:

$$v_{AM} = \frac{V_c}{\sqrt{2}} \cos \omega_c t + \frac{V_m}{2\sqrt{2}} \cos (\omega_c - \omega_m)t + \frac{V_m}{2\sqrt{2}} \cos (\omega_c + \omega_m)t$$

The Total Transmitted Power

The power in the carrier and sidebands can be calculated by using the power formula $P = V^2/R$ where P is the output power, V is the r.m.s output voltage, and R is the resistive part of the load impedance, which is usually an antenna. It is clear that:

$$P_{USB} = P_{LSB} = \frac{\left(V\frac{m}{2}\sqrt{2}\right)^2}{R}$$

5

5

The Total Transmitted Power

The total transmitted power P_T is simply the sum of the carrier power and the power in the two sidebands P_{USB} and P_{LSB} .

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

If we express the sideband powers in terms of the carrier power, the total power becomes:

$$P_T = P_c\left(1 + \frac{m^2}{2}\right)$$

6

6

Example1:

An AM transmitter has a carrier power of 30 W. The percentage of modulation is 85 percent. Calculate:
(a) the total power
(b) the power in one sideband.
Solution:

$$\textbf{a.}\ P_T = P_c\left(1 + \frac{m^2}{2}\right) = 30\left[1 + \frac{(0.85)^2}{2}\right] = 30\left(1 + \frac{0.7225}{2}\right)$$

$$P_T = 30(1.36125) = 40.8\text{ W}$$

$$\textbf{b.}\ P_{SB}\ (\text{both}) = P_T - P_c = 40.8 - 30 = 10.8\text{ W}$$

$$P_{SB}\ (\text{one}) = \frac{P_{SB}}{2} = \frac{10.8}{2} = 5.4\text{ W}$$

7

7

The Total Transmitted Power in the real world

In the real world, it is difficult to determine AM power by measuring the output voltage and calculating the power with the expression $P = V^2/R$. However, it is easy to measure the current in the load. For example, you can use an RF ammeter connected in series with an antenna to observe antenna current. When the antenna impedance is known, the output power is easily calculated by using the formula $P_T = I_T^2 R$ Where $I_T = I_c\sqrt{1 + \frac{m^2}{2}}$

Here Ic is the unmodulated carrier current in the load, and m is the modulation index.

8

8

Example2:

The total output power of an 85 percent modulated AM transmitter, whose unmodulated carrier current into 50Ω antenna load impedance is 10 A.

Solution:

$$I_T = I_c\sqrt{1 + \frac{m^2}{2}}$$

$$I_T = 10\sqrt{1 + \frac{(0.85)^2}{2}}$$

$$P_T = {I_T}^2 R = 136.21502 = 6809\ \text{W}$$

9

9

The Total Transmitted Power in the real world

One way to find the percentage of modulation is to measure both the modulated and the unmodulated antenna currents. Then, by algebraically rearranging the formula above, *m* can be calculated directly:

$$m = \sqrt{2\left[\left(\frac{I_T}{I_c}\right)^2 - 1\right]}$$

10

10

Example3:

An antenna has an impedance of 40 Ω. An unmodulated AM signal produces a current of 4.8 A. The modulation is 90 percent. Calculate (a) the carrier power, (b) the total power, and (c) the sideband power.

Solution:

a) $P_c = I_c{}^2 R = 921.6\ \text{W}$

b) $I_T = I_c \sqrt{1 + \frac{m^2}{2}} = 5.7\ \text{A}$

c) $P_T = I_T{}^2 R = 1295\ \text{W}$

d) $P_{SB} = P_T - P_c = 373.4\ \text{W}$ (186.7 W each sideband)

11

11

Homework:

The transmitter in Example 3 experiences an antenna current change from 4.8 A unmodulated to 5.1.
What is the percentage of modulation?

Solution:

12

12

Homework:

What is the power in one sideband of the transmitter in Example 3?

Solution:

14

14

Transmission Efficiency of AM Signal

The transmission efficiency η of AM signal can be calculated as follow:

$$\eta = \frac{P_{SB}}{P_T} \times 100\%$$

$$= \frac{\frac{m^2 P_c}{2}}{P_c\,(1+\frac{m^2}{2})} \times 100\%$$

$$= \frac{m^2}{2\,(1+\frac{m^2}{2})} \times 100\%$$

$$\eta = \frac{m^2}{2+m^2} \times 100\%$$

15

15

Example 5:

For AM signal:
a) Calculate the transmission efficiency if m=0.5.
b) Show that the maximum efficiency =33.33% if m=1.

Solution:

$$a)\ \eta = \frac{m^2}{2+m^2}\times 100\% = \frac{0.5^2}{2+0.5^2}\times 100\% = \frac{0.25}{2+0.25}\times 100\% = 11.11\%$$

$$b)\ \eta = \frac{m^2}{2+m^2}\times 100\% = \frac{1^2}{2+1^2}\times 100\% = \frac{1}{2+1}\times 100\% = 33.33\%$$

16

16

Example 6:

The output signal from an AM modulator is:
s(t) = 5cos(1800π t) + 20cos (2000π t) + 5cos (2200π t)
(a) Determine the modulation index.
(b) Determine the ratio of the power in the sidebands to the power in the carrier.

Solution: Re-arranging this equation and comparing it with AM general equation:

$$s(t) = 20\cos(2000\pi t) + 5\cos(1800\pi t) + 5\cos(2200\pi t)$$

$$v_{AM} = V_c \cos \omega_c t + \frac{V_m}{2}\cos(\omega_c - \omega_m)t + \frac{V_m}{2}\cos(\omega_c + \omega_m)t$$

17

17

Continue to Example 6:

(a) Determine the modulation index.
(b) Determine the ratio of the power in the sidebands to the power in the carrier.

It is clearly that,

a) $V_c = 20$ V, $\frac{V_m}{2} = 5$ (i.e, $V_m = 10$)

$$m = \frac{V_m}{V_c} = \frac{10}{20} = 0.5$$

b) $\frac{P_{SB}}{P_C} = \frac{\frac{m^2 P_c}{2}}{P_C} = \frac{m^2}{2} = \frac{0.5^2}{2} = 0.125$

18

18

Homework:

AM waveform has sidebands power equal to 18% of the carrier power.
Determine:
(a) The modulation index m.
(b) Transmission efficiency.
(c) Carrier power if the amplitude of the modulating signal is 6V.

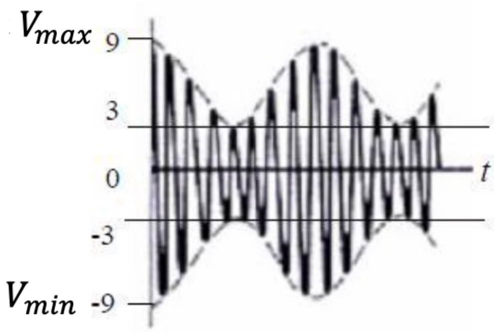
Solution:

19

19

Homework

A sinusoidally modulated ordinary AM waveform is shown below.



Determine:
(a) The modulation index.
(b) The transmission efficiency.
(c) The amplitude of the carrier which must be added to attain a modulation index of 0.3.

20

20

Thank you …

21

21