

October 31, 2023, Deadline: Nov 03, 2023

L01-03, SLIDE 17

The central carrier frequency is 2.4 GHz; 2.35 to 2.45 GHz.  
Message signal has bandwidth of 10 KHz.

1. How many users can operate simultaneously with SSB AM modulation?

1) Central carrier frequency = 2.4 GHz  
Range = 2.35 - 2.45 GHz  
Message signal bandwidth = 10 kHz.  
For SSB AM modulation, only one of the sideband is transmitted.

Bandwidth for each user = Bandwidth of message signal

No. of users =  $\frac{\text{Total Bandwidth}}{\text{Bandwidth per user}} = \frac{2.45 - 2.35 \text{ GHz}}{10 \text{ kHz}}$

$\frac{100 \text{ MHz}}{10 \text{ kHz}} \Leftarrow = \frac{0.1 \text{ GHz}}{10 \text{ kHz}}$

$[100 \times 10^6] / [10 \times 10^3] = 10^4$

= 10,000 users

2. How many users can operate simultaneously with DSB AM modulation?

2.) No. of users operating simultaneously with DSB-AM modulation →

Both the sidebands are transmitted. Therefore, the bandwidth for each =  $2 \times 10$

$$= 20 \text{ kHz}$$

correct but too much of writing ...

$$\begin{aligned} \text{No. of users} &= \frac{\text{Total Bandwidth}}{\text{Bandwidth per user}} \\ \text{DSB bandwidth is 2x of that of SSB. Thus, \# of supported users is half, which is } 10000/2 &= \\ 5,000 \text{ users} &= \frac{100 \text{ MHz}}{20 \text{ kHz}} \\ &= 5,000 \text{ users} \end{aligned}$$

3. How many users can operate simultaneously with SSB AM modulation if a 2 KHz guard band is needed?

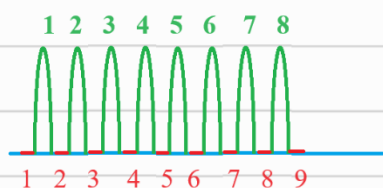
4. How many users can operate simultaneously with DSB AM modulation if a 2 KHz guard band is needed?

4.) DSB AM with guardband  
Bandwidth per user =  $(20 + 2) \times 2$   
(for n+1 guardbands) = 24 kHz

$$n(\text{users}) = \frac{0.1 \times 10^6 \text{ kHz}}{24 \text{ kHz}}$$

$$\approx 4166.67$$

$$= 4166 \text{ users}$$



5. If duty cycle is 250 ms, i.e., one is allowed to transmit only for 250 ms then how many users can be supported in each case?

Q5 sol) Duty Cycle = 250 ms = 0.25 seconds  $\Rightarrow$  Time Division Multiplexing (TDM).

$\rightarrow$  The no. of users can be divided by the duty cycle.

$$\begin{aligned}\rightarrow \text{SSB AM Modulation} &= \frac{\text{No. of users}}{\text{Duty Cycle}} = \frac{10,000}{0.25} \\ &= 10,000 \times 4 = 40,000 \text{ users}\end{aligned}$$

6. In which of the 8 cases above are we doing time-division multiplexing?

6. In case 5, we are doing time division multiplexing because we are dividing the time into slots & allowing each user to transmit in their allocated slots.

All cases in case 5. NOTE: justification has NOT been asked!



7. If the signals were not AM-modulated by FM-modulated, assuming  $\beta$  is 3, how many users can operate simultaneously if receiver cannot operate correctly if the filtered signal power must be  $> 98\%$  of the received signal power?

7. FM modulation

$\beta = 3$  (modulation index)  $f_m = 10 \text{ kHz}$

The BW of a FM signal can be calculated using Carson's rule which states that nearly all ( $\sim 98\%$ ) of the power of an FM signal is contained within a BW  $= 2(\Delta f + f_m)$

$\Delta f = \beta \cdot f_m$

$= 3 \cdot 10 = 30 \text{ kHz}$

**1ST RESPONSE IS TOO LONG**

Substituting into Carson's rule

$BW = 2(\Delta f + f_m)$

$= 2(30 + 10) = 80 \text{ kHz}$

So, no. of users that can operate simultaneously would be:

No. of users  $= \frac{\text{Total BW}}{\text{B.W per user}} = \frac{100 \text{ MHz}}{80 \text{ kHz}} = 1250$  users

$$\beta c = 2[1 + \beta f] f_m. \text{ Thus, } \beta c = 2[1 + 3] 10 \cdot 10^3 = 80 \text{ KHz}$$

$$\# \text{ of users: } [100 \text{ MHz} / 80 \text{ KHz}] = 1,250.$$

8. Speed of light in vacuum is 3 lac km/s.  
 Speed of light in sea water is 2.25 lac km/s.  
 Speed of sound in sea water is 1.5 km/s.

For a submarine, assuming transmissions are at 800 MHz in the electromagnetic spectrum and 500 Hz for sound, what is the minimum length of each antenna given that for efficient coupling of generated to transmitted EM energy, antenna must be  $> 1/10 \lambda$ .

$$\lambda = \frac{c}{f}$$

$$\lambda(\text{seawater}) = \frac{2,25,000 \text{ km/s}}{800 \text{ mhz}}$$

$$= 0.28125 \text{ m}$$

$$\text{Minimum Antenna Length} = 1/10 \times \lambda$$

$$= 1/10 \times 0.28125 \text{ m}$$

$$28.13 \text{ mm} \Rightarrow \underline{\underline{2.8125 \text{ cm}}}$$

Similarly

Speed of sound in water is 1.5 km/s

$$\frac{1.5,000 \text{ km/s}}{500 \text{ mhz}}$$

Sound F is 500 Hz

$$\Rightarrow 0.003 \text{ m}$$

$$\lambda = [1.5 \times 10^3] / 500 = 30 \text{ meter}$$

$$\therefore 1/10 \times 0.003 \text{ m}$$

Thus, antennae length must be  $30/10$

$$= 3 \text{ meter} = 0.0003 \text{ m}$$

$$= \underline{\underline{0.3 \text{ mm}}}$$