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Amrita School of Engineering, Coimbatore
B.Tech Missed Midterm – September 2025
5^{th} Semester
Cybersecurity
20CYS301 Digital Communications

Duration: Two hours　　　　Maximum: 50 Marks

Course Outcomes (COs):

CO	**Course Outcomes**
CO01	Understand the fundamental principles of digital modulation and demodulation methods
CO02	Identify and list various issues present in the design of a communication system
CO03	Apply the time domain and frequency domain concepts of signals in data communication
CO04	Design suitable error detection and error correction algorithms to achieve error free data communication
CO05	
CO06	

NOTE to exam invigilator

- Please do NOT permit anyone to leave the desk until the last 30 minute of the exam.

NOTE to students

- Answer ALL questions
- When answering non-problem/proof-based questions, write in bullet points.
- Rough work should be struck out to ensure an evaluator is able to distinguish rough work from solutions.
- Use any colored pen or pencil except red

Formulae

1. Message bandwidth is 50 KHz. It is used to AM-modulate a carrier. Choose one carrier frequency from this list 5 KHz, 50 KHz, 50 MHz. State 1-3 bullet-point reasons for your choice.

In single sideband modulation of bandwidth 100 MHz, how many 10 KHz channels can be supported? Show your calculations.

[5.0] [C01] [BTL2]

50 MHz as carrier frequency must be >> message bandwidth. Else, the transmitted message will be severely distorted. This will make it either impossible to demodulate the transmission or, significantly raise the cost of hardware needed to decode the signal.

of 10 KHz channels = 100*10^3/10 = 10,000 channels.

2. Light speed in vacuum is 3 lac km per second. Max operating frequency of a communication device is 30 GHz. For effective coupling between generated and transmitted energy, antenna length must be $> \frac{1}{10}\lambda$.

Compute the minimum size of the antenna needed.

Submarines when submerged communicate with each other using EM waves or acoustic waves? Justify in 2 bullet points.

[5.0] [C02] [BTL3]

$\lambda_9 = \frac{c}{f} = \frac{3*10^8}{30*10^9} = 1\ cm$. Thus, min antenna length must be $> \frac{1}{10}\lambda$, i.e., $> 1\ mm$.

They communicate with each other using acoustic waves as the antenna size for underwater EM waves is extremely large and also, EM waves are severely attenuated by water.

3. A message with bandwidth 5 MHz is transmitted by AM-modulating a carrier at 5 GHz. Nyquist criteria requires the sampling rate to be at least 2x of the max frequency of the signal. What must be the sampling rate at reception? Justify in 1-2 bullet points.

[5.0] [C02] [BTL3]

Sampling rate must be 10 MHz (2*5 MHz). The answer is NOT 2*(5*10^3+5) MHz or 2*(5*10^3) MHz as before the message signal is sampled, it is demodulated. Demodulation strips off the carrier.

4. Message signal is $m(t) = ae^{(2\pi f_m t)}$. It *a*) frequency modulates and *b*) phase modulates a carrier $c(t) = A_c cos(2\pi f_c t)$. What is the modulated signal?

[5] [C03] [BTL2]

For PM: $\varphi(t) = k_p m(t) = k_p a e^{(2\pi f_m t)}$.

Thus, $u_{PM}(t) = A_c cos\left[2\pi f_c t + k_p a e^{(2\pi f_m t)}\right] = A_c cos\left[2\pi f_c t + \beta_p \cdot e^{(2\pi f_m t)}\right]$

For FM: $\varphi(t) = 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau = 2\pi k_f \int_{-\infty}^{t} ae^{(2\pi f_m t)}d\tau = \frac{a\cdot 2\pi k_f}{2\pi f_m}\cdot e^{(2\pi f_m t)}|_{-\infty}^{t}$

Thus, $\varphi(t) = \frac{k_f a}{f_m}\cdot\left[e^{(2\pi f_m t)} - e^{(2\pi f_m - \infty)}\right] = \frac{k_f a}{f_m}\cdot e^{(2\pi f_m t)}$

Thus, $u_{FM}(t) = A_c cos\left[2\pi f_c t + \frac{k_f a}{f_m}\cdot e^{(2\pi f_m t)}\right] = A_c cos\left[2\pi f_c t + \beta_f \cdot e^{(2\pi f_m t)}\right]$

5. A modulated Quadrature Carrier Multiplexed (QCM) signal that carries messages $m_1(t)$ and $m_2(t)$ is shown here $u(t) = A \cdot m_1(t) \cdot cos(2 \cdot \pi \cdot f_c \cdot t) + A \cdot m_2(t) \cdot sin(2 \cdot \pi \cdot f_c \cdot t)$.

Rewrite $u(t)$ where $m_3(t)$ and $m_4(t)$ are sent on frequency-modulated carriers.

[5] [C01] [BTL4]

$u(t) = A \cdot m_1(t) \cdot cos(2 \cdot \pi \cdot f_c \cdot t + 2\pi k_{f_c} \int_{-\infty}^{t} m_3(\tau)d\tau) + A \cdot m_2(t) \cdot sin(2 \cdot \pi \cdot f_c \cdot t + 2\pi k_{f_c} \int_{-\infty}^{t} m_4(\tau)d\tau)$.

6. Derive the expression for power of DSB-SC AM message signal $A_c \cdot m(t) \cdot cos(2 \cdot \pi \cdot f_c \cdot t)$. Signal power is $\mathrm{P}[u(t)] = \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} u^2(t)dt$

[7.5] [C01] [BTL3]

$\mathrm{P}[u(t)] = \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} u^2(t)dt = \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} {A_c}^2 m^2(t) C^2(2\pi f_c t)dt$

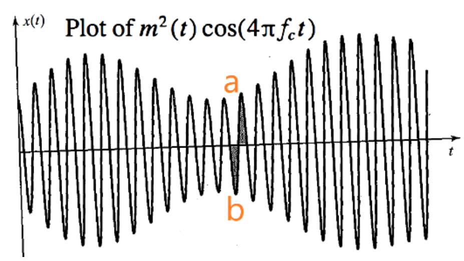
$= \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} \frac{{A_c}^2}{2} m^2(t)[1 + cos(4\pi f_c t)]dt \ldots \because C^2(t) = \frac{[1+C(2T)]}{2}$

$= \frac{{A_c}^2}{2}\left[\lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} m^2(t)dt\right] + \frac{{A_c}^2}{2}\left[\cancel{\lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} m^2(t)cos(4\pi f_c t)dt}\right] \approx \frac{{A_c}^2}{2} P_m$

$\frac{{A_c}^2}{2}\left[\lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} m^2(t)cos(4\pi f_c t)dt\right] \to 0$ because:

a. *The two areas 'a' and 'b' are nearly equal as because $f_m \ll f_c$, the two nearly cancel each other over the period and,*

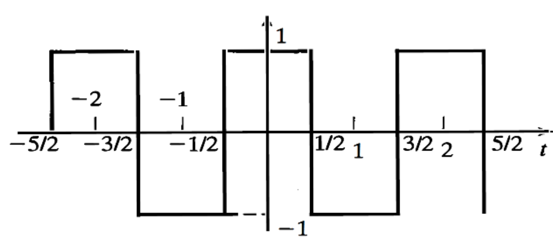
b. *The term is divided by $T \to \infty$.*



7. Derive the expression for fourier transform for the waveform shown. Plug in the values of n=0 and n=6 into the final equation and compute.

The period of the waveform is 2.

$\sin x = x - x^3/3! + x^5/5! \pm O(x^7)$ and $\cos x = 1 - x^2/2! + x^4/4! \pm O(x^6)$



FT for continuous periodic waveform is $X(n) = \frac{1}{T}\int_T \; x(t)e^{-jn\pi t}d\tau$

[7.5] [C03] [BTL4]

$x(t)$ is a periodic signal with $T_0 = 2$.

Thus, $X(n) = \frac{1}{T}\int_{-\frac{1}{2}}^{\frac{3}{2}} x(t)e^{-jn\pi t}d\tau = \frac{1}{2}\int_{-1/2}^{1/2}(1)e^{-jn\pi t}d\tau + \frac{1}{2}\int_{1/2}^{3/2}(-1)e^{-jn\pi t}d\tau$

$= \frac{1}{-2jn\pi}\left[e^{-jn\pi/2} - e^{jn\pi/2}\right] - \frac{1}{-2jn\pi}\left[e^{-jn3\pi/2} - e^{-jn\pi/2}\right]$

$e^{-jn\pi/2} = C(-n\pi/2) + jS(-n\pi/2)$

$\therefore$ **1st term** is $\frac{1}{-2jn\pi}[\cancel{C(\theta)} - jS(\theta) - \cancel{C(\theta)} - jS(\theta)] = \frac{S(n\pi/2)}{n\pi}$

2nd term is $-\frac{1}{-2jn\pi}\left[e^{-jn3\pi/2} - e^{-jn\pi/2}\right] = \frac{1}{2jn\pi}\left[e^{-jn\pi}e^{-jn\pi/2} - e^{-jn\pi/2}\right]$

$= \frac{e^{-jn\pi}}{2jn\pi}\left[e^{-jn\pi/2} - e^{+jn\pi/2}\right] = \frac{e^{-jn\pi}}{2jn\pi}[-2jS(n\pi/2)] = \frac{-e^{-jn\pi}}{n\pi}[S(n\pi/2)]$

Thus, total term is $\frac{S(n\pi/2)}{n\pi}$ - $\frac{e^{-jn\pi}[S(n\pi/2)]}{n\pi} = \frac{S(n\pi/2)}{n\pi}\left[1 - e^{-jn\pi}\right]$

$= \frac{S(n\pi/2)}{n\pi}\left[1 - \left(C(-n\pi) + jS(-n\pi)\right)\right] = \frac{S(n\pi/2)}{n\pi}[1 - C(n\pi)]$

If n is even then, 0

If n is 1 then, $\frac{2}{\pi}$ If n is 3 then, $\frac{-2}{2\cdot\pi}$, etc.

If n is 0 then, in the limits, $\frac{(n\pi/2-(n\pi/2)^2/2!+\cdots-\cdots)}{n\pi}[1 - 1 + (n\pi)^3/3! - \cdots + \cdots]$

$= [1 - n\pi/2/2! + \cdots - \cdots]\cdot[(n\pi)^2/3! - \cdots + \cdots]$ which, in the limits, is 0 because of 2nd term.

Thus, the value is 0 where n = 0 and 0 where n= 6.

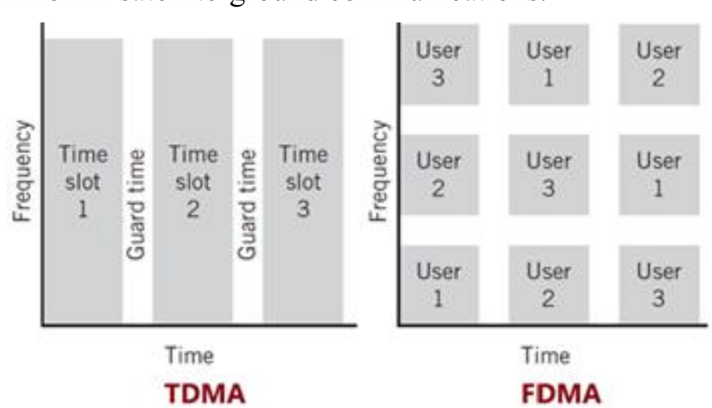
8. The figure shows usage of spectrum across time and frequency for TDMA and FDMA.

Spatial division multiple access (SDMA) is common in satellite-ground communications.

Does SDMA have guard bands across time axis?

Does SDMA have guard bands across frequency axis?

It is designed to support 3000 drones operating at a max speed of 40 m/s. The speed limit is due to the need for sufficiently fast communication needed between the ground control station and the drones (drones are all remotely piloted).



To support the same number of drones operating in the region, with max drone speeds reaching 60 m/s, should we

i. double the guard bands along time axis but not along frequency axis
ii. double the guard bands along frequency axis but not along time axis
iii. double the frequency bands
iv. use faster hardware

Write 1-2 bullet points on each of the statements whether that should be done and why, or why not.

[10.0] [C02] [BTL2]

i. Increasing the # of guard bands along time axis will reduce the # of time slots available per second. This will in turn reduce the # of drones that can be supported.
ii. Same response as i.
iii. Doubling the # of frequency bands will help support more drones. But to support faster drones, what is needed is increase in # of time slots as per second so allocated time slot sequence once handed over can be regained faster. So, one can utilize the doubled # of frequency bands to park more drones there and then, thereby, effectively, have double the # of time slots available.
iv. Faster hardware will allow one to communicate faster with faster switchovers with users and this can also be a solution, perhaps better as doubling bandwidth may not even be feasible due to regulatory limitations.

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Course Outcome /Bloom's Taxonomy Level (BTL) Mark Distribution Table

CO	Marks	BTL	Marks
CO01	**22.5**	BTL 1	**0.0**
CO02	**15.0**	BTL 2	**15.0**
CO03	**12.5**	BTL 3	**17.5**
CO04	**0.0**	BTL 4	**17.5**
CO05		BTL 5	
CO06		BTL 6	

Bloom's Taxonomy Levels (attached for reference)

Level 1 – Remember | Level 2 – Understand | Level 3 – Apply | Level 4 – Analyze |

Level 5 – Evaluate | Level 6- Create