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YouTube search results for "reflection diffraction and scattering in wireless communication".

**1. Reflection**

When Radio waves travelling in between huge buildings or mountain the signal is reflected due to the surface of the structure.

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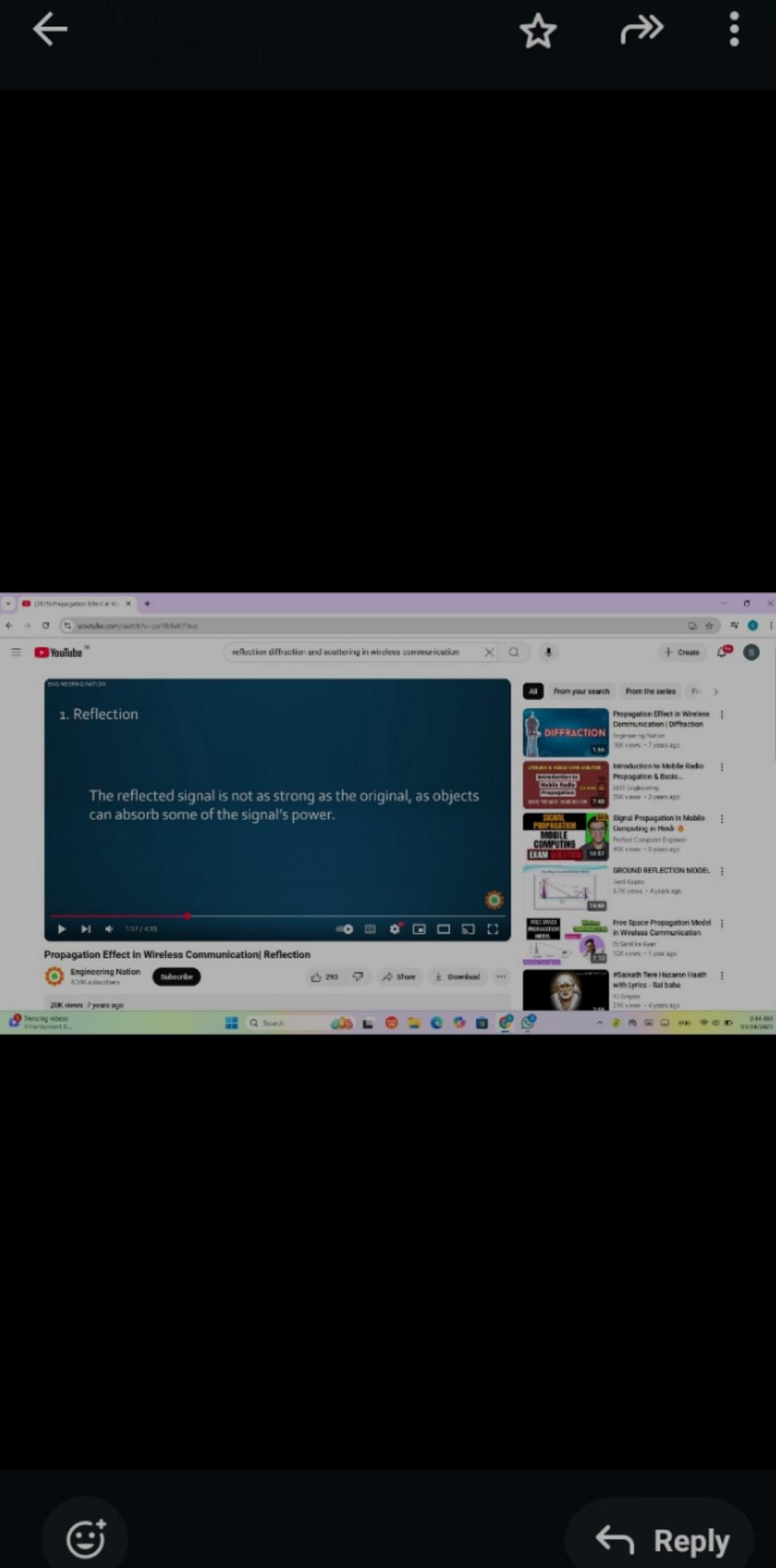
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1. Reflection

Reflection also helps to transmitting radio signals as if there is no straight line or no straight free path available.

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1. Reflection

Signals transmitting from a sender may bounce off the walls of buildings several times before they reach the receiver.

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Reflection, Refraction, Diffraction & Scattering (E&EE)

When a wave hits a smooth object that is larger than the wave itself, depending on the media, the wave may bounce in another direction.

Reflection is the property of a wave to bounce off of a smooth surface and proceed in a direction different from that which was intended.

Light Beam

Mirror

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YouTube reflection, refraction, diffraction & scattering in wireless communication

Reflection Causes

- Buildings & Roads
- Earth's surface
- Doors & Walls
- Metal objects
- Glass
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### 3. Diffraction

Diffraction is very much similar to scattering.

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### 3. Diffraction

Radio waves will be deflected at an edge and propagate in different directions.

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### 3. Diffraction

This can mean that a signal may be received from a transmitter even though it may be "shaded" by a large object between them.

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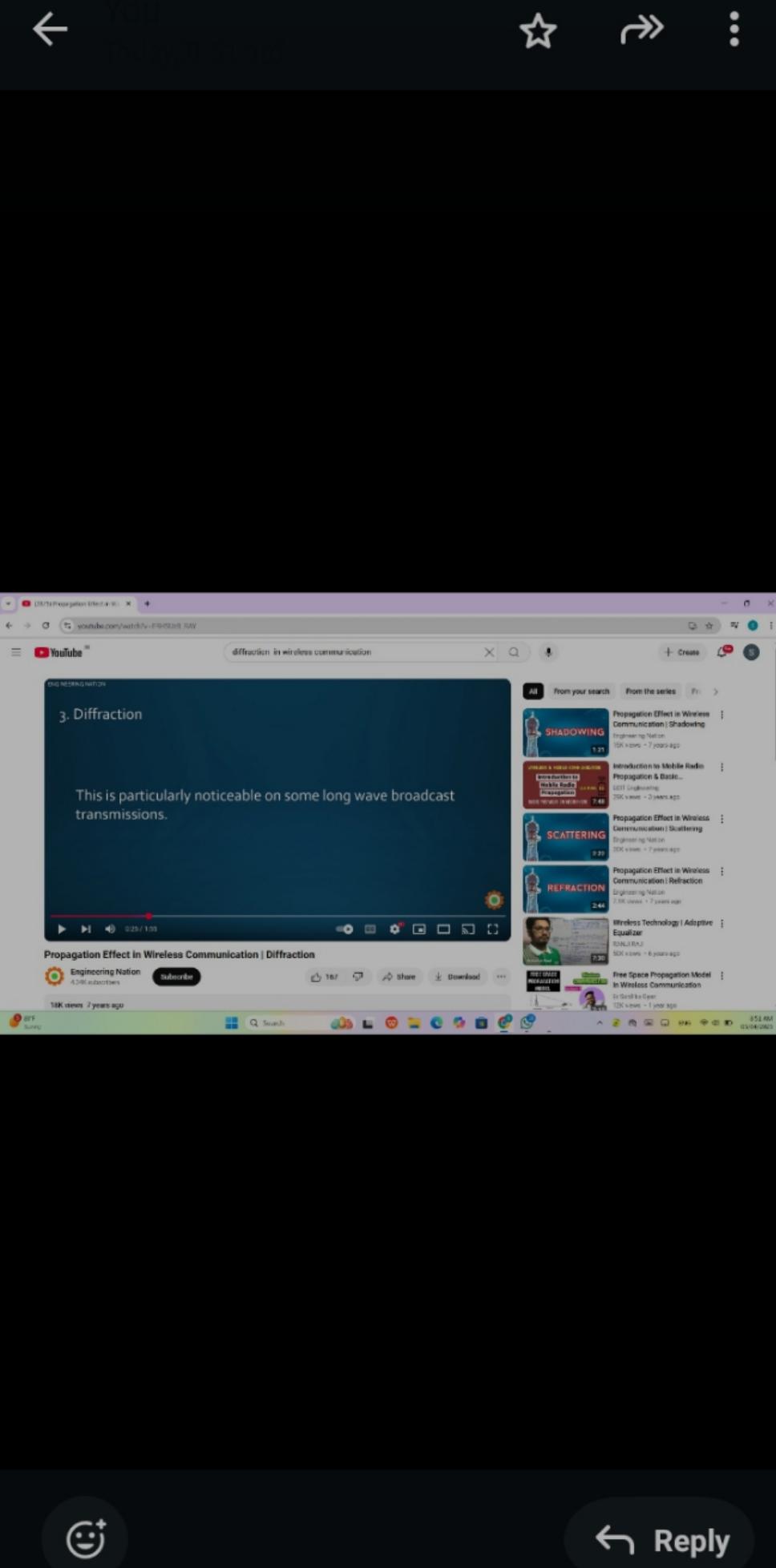
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**3. Diffraction**

For example the BBC long wave transmitter on 198 kHz is audible in the Scottish glens where other transmissions could not be heard.

As a result the long wave transmissions can be heard in many more Places.

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3. Diffraction

Diffraction is more pronounced when the obstacle becomes sharper and more like a "knife edge".

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Chapter Name : Mobile Radio Propagation  
Topic Name : Scattering

Scattering occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength and where the number of obstacles per unit volume is large.

- Follows same principle as diffraction
- Causes the transmitter energy to be radiated in many directions
- E.g. foliage , street sign , lamp post

Scattering - Mobile Radio Propagation - Mobile Communication System

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scattering means with example in wireless communication

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2. Scattering

What is Scattering in Radio Signals ?

Scattering is the loss of signal caused by the diffusion of a signal, where the diffusion itself is caused by microscopic variations in the transmission medium.

Scattering typically happens when a radio signal hits an impurity in Environment.

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2. Scattering

Dust, humidity, unevenness and other qualities in a material can cause a signal to scatter in all directions. This can have a significant impact on signal integrity and strength.

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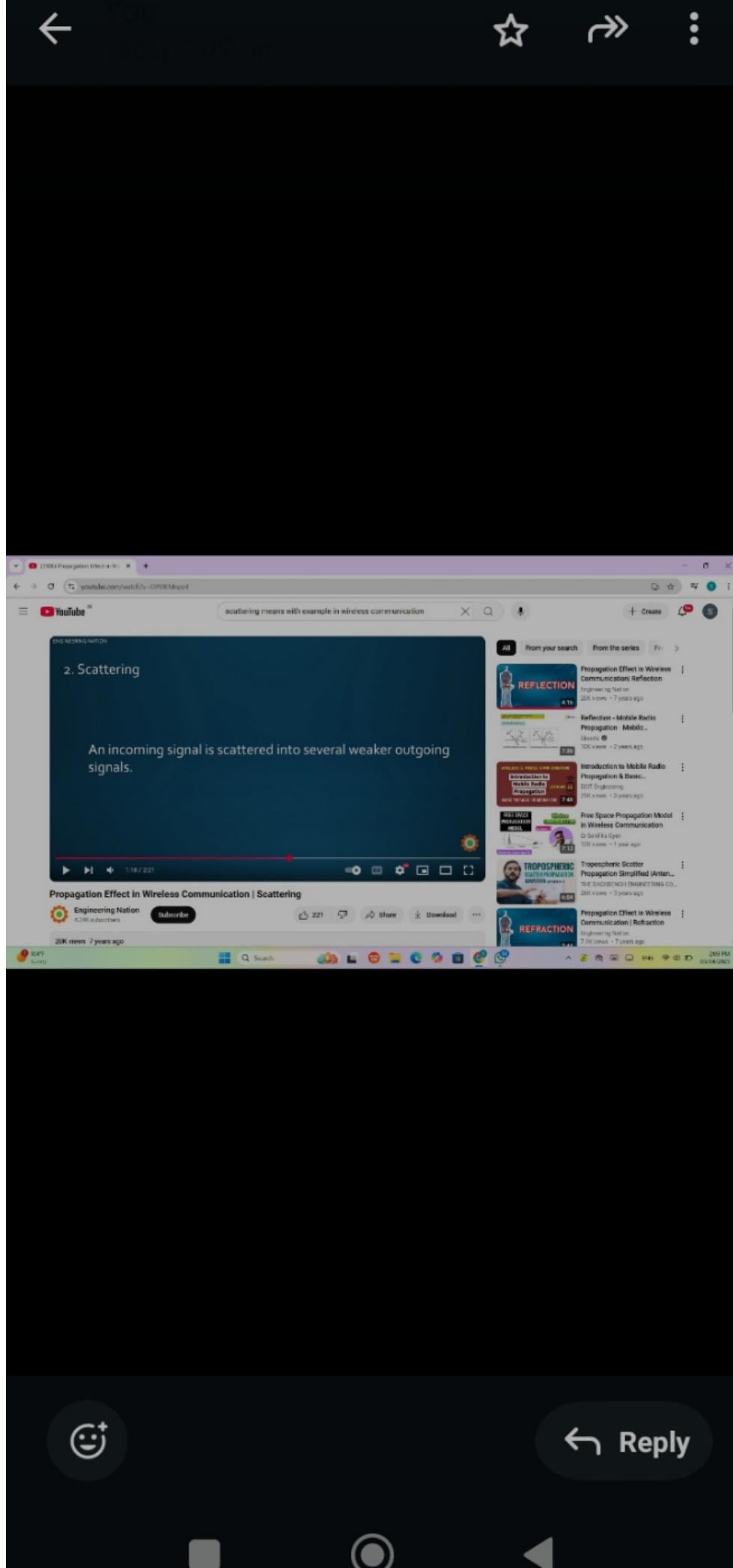
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**Propagation Basics: 1**

- **Diffraction**
  - When the radio path between transmitter and receiver is obstructed by a surface that has sharp **irregularities or edges**.
  - This is the reason why radio signals travel in urban and rural areas without a line of sight.
- **Scattering**
  - When the medium has objects that are **smaller or comparable to wavelength** of the signal.
  - Objects include water droplets, rough surface, rain drops, snow.
  - It depends on the wavelength heavily eg. Rain drops will interact with **millimetre wavelength** but won't be that effective when 900 MHz carrier frequency is used.

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- **Diffraction**
  - When the radio path between transmitter and receiver is obstructed by a surface that has sharp **irregularities or edges**.
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Occurs when the radio path between the transmitter and receiver is obstructed by a surface that has a sharp irregularities(edges)

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Occurs when the radio path between the transmitter and receiver is obstructed by a surface that has a sharp irregularities(edges)

The phenomenon of diffraction can be explained by Huygens's principle

Which states that all points on a wave front can be considered as point sources for the production of secondary wavelets

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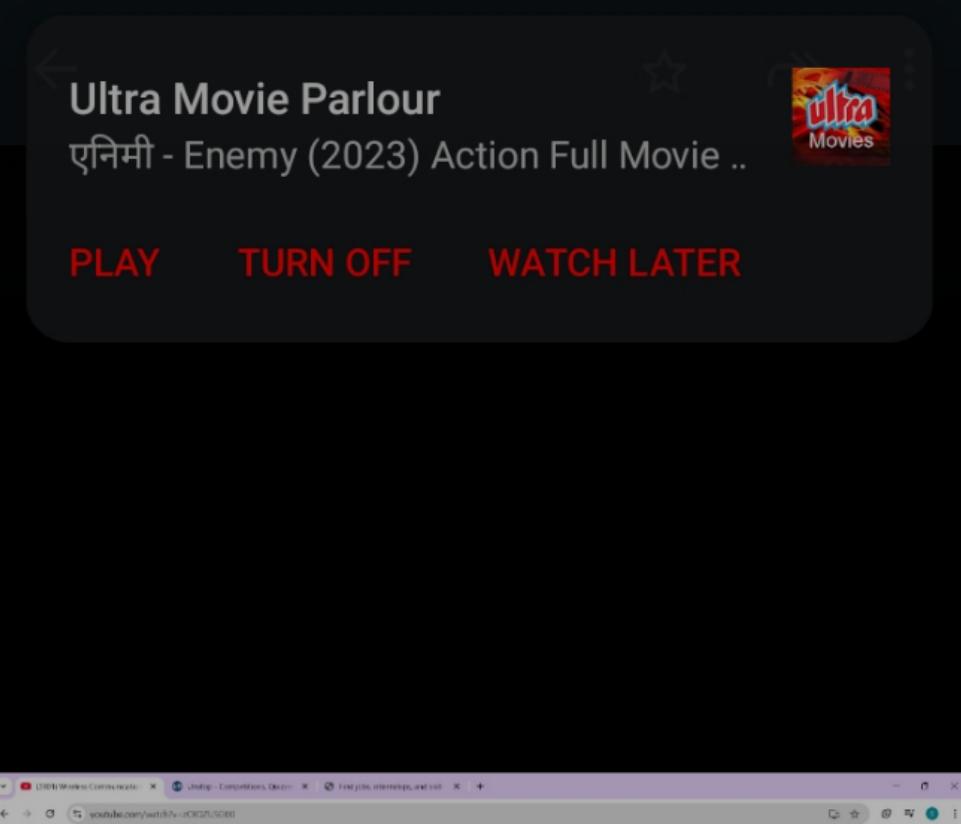
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Topic Name : Diffraction

Fresnel-Kirchoff diffraction parameter  $\nu$  which is given by

$$\nu = h \sqrt{\frac{2(d_1 + d_2)}{\lambda d_1 d_2}}$$



YouTube search results for "fading in wireless communication".

Video thumbnail: Wireless Communication | Fading & Types of Fading | In Short | IPU Exam | Get Set Study

Video details: 0:52 / 4:48

Description: Q2. What is fading ? Types of fading ?

Time Variation of Received signal power due to change in transmission medium or path is called "fading".

Reason of fading: Path loss, multipath propagation, Rayleigh scattering.

Graph: A graph showing Signal Strength (dBm) on the Y-axis and Distance on the X-axis. The signal strength fluctuates over time, with a note "fading" pointing to the graph.

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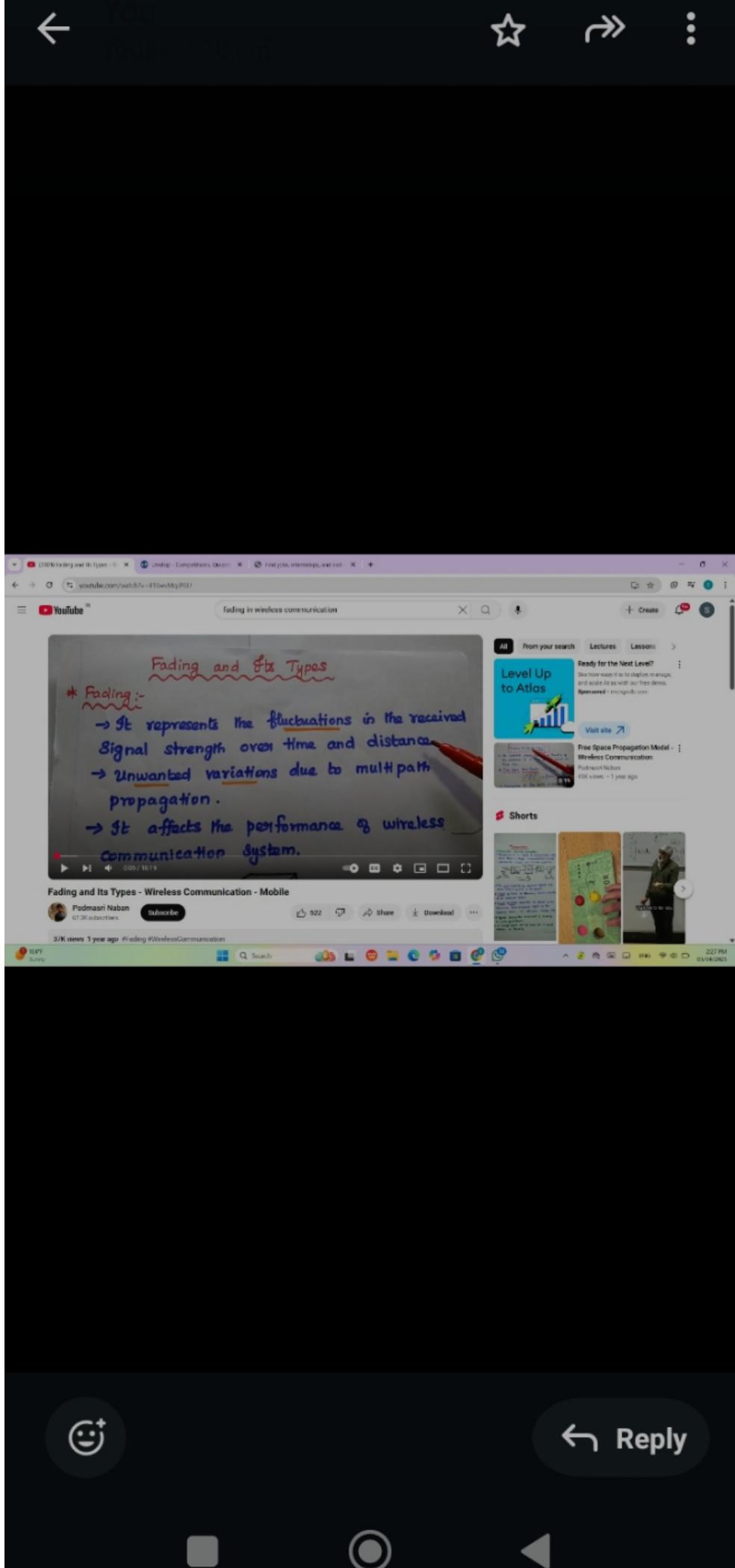
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YouTube "fading in wireless communication"

The diagram illustrates the types of fading in wireless communication:

- Large-Scale Fading** (Large distance: Several 100s (or) 1000s meters):
  - Path Loss
  - shadowing
- Small Scale Fading** (short distance: a few cms to a few meters):
  - Multipath spread
  - Doppler Spread

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Path Loss shadowing

Multipath spread

Doppler Spread

Flat fading

$B_s < B_c$

$T_s < T_c$

Frequency Selective fading

$B_s > B_c$

$T_s > T_c$

Fast Fading

$T_s > T_c$

$B_s < B_D$

Slow Fading

$T_s < T_c$

$B_s > B_D$

↳ Delay spread.

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Large-Scale fading

- \* Variations occur over large distance (ie) Several hundreds or thousands meters
- \* Path Loss & shadowing
- \* Long term variation in the signal caused

Small-Scale fading

- \* Variations occur over short distance (ie) a few cms to a few meters
- \* Multipath & Doppler spread
- \* Short term variation in the signal strength

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\* It affects the entire Signal | It affects the individual Symbols.

\* Time variation is slow | Time variation is rapid.

\* It reduces the overall received signal power | It causes interference distortion

\* It can be mitigated using: Equalization

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\* It affects the entire signal  
\* Time variation is slow  
\* It reduces the overall received signal power  
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It affects the individual symbols.  
Time variation is rapid.  
It causes interference distortion  
↳ Equalization

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**\* Path Loss & Shadowing**

\* Long term variation in the signal caused by the mobile unit moving into the Shadow of surrounding objects.

**\* Multipath & Doppler spread**

Short term variation in the signal strength caused by the multipath propagation.

\* It affects the entire system.

It affects the individual user.

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The video player shows a handwritten note on a whiteboard:

* Time variation is slow	Time variation is rapid.
* It reduces the overall received signal power	It causes interference distortion
* It can be mitigated using: ↳ Power control ↳ Antenna placement ↳ diversity methods	↳ Equalization ↳ Diversity ↳ Adaptive mechanisms.

Video controls: 7:33 / 10:19

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**Fast Fading**

- \* Channel variation is faster than Baseband Signal Variation
- \* It varies quickly with the frequency
- \* It occurs due to High Doppler Spread

**Slow Fading**

- \* Channel variation is slower than Baseband Signal Variation
- It does not vary quickly with frequency
- It occurs due to Low Doppler Spread

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YouTube "fading in wireless communication"

The video shows a handwritten note on a whiteboard comparing two types of fading based on symbol period ( $T_s$ ) and coherence time ( $T_c$ ):

$T_s$ varies quickly with frequency	It does not vary quickly with frequency
* It occurs due to <u>High Doppler spread</u>	* It occurs due to <u>Low Doppler spread</u>
* $T_s > T_c$ $T_s \rightarrow$ Symbol period $T_c \rightarrow$ Coherence Time of the channel + The channel impulse response changes at a slow rate	* $T_s \ll T_c$ + The channel impulse response changes at a rapid rate

Below the note, there is a red marker pointing to the text "The channel impulse response changes at a rapid rate".

Video details:  
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YouTube "fading in wireless communication"

The video player shows a handwritten note on a whiteboard:

* Time variation is slow	Time variation is rapid.
* It reduces the overall received signal power	It causes interference distortion
* It can be mitigated using: ↳ Power control ↳ Antenna placement ↳ diversity methods	↳ Equalization ↳ Diversity ↳ Adaptive mechanisms.

Video controls: 7:33 / 10:19

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The channel impulse response changes rapidly within the symbol duration.

\*  $B_s < B_D$

$B_s \rightarrow$  Bandwidth of the transmitted signal

\*  $B_s > B_D$

$B_D \rightarrow$  Bandwidth of the channel

Doppler spread.

Amplitude

Fast Fading

The channel impulse response changes at a rate slower than the transmitted symbol.

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Compare reflection vs refraction

Reflection vs Refraction Comparison Table

Feature	Reflection	Refraction	Scattering
Definition	When light bounces off a surface	Bending of waves around edges or through curved openings	Spreading of waves in different directions by tiny particles
Cause	Comes from a point source and wave	Exposure when obstacles or curves are present	Interaction with small particles on irregular surfaces
Wave Behavior	Reverses direction	Changes direction to bend	Changes direction randomly
Predictability	Highly predictable	Moderately predictable	Low predictability
Example (Solid)	Light reflecting from a surface	Light bending around a sharp edge	Shiny stars appearing at night
Example (Liquid)	Light reflects off water	Light bends around a corner	My red hand being
Wavelength Impact	Negligible impact	More noticeable with longer wavelengths	Decreases with smaller particles
Matter Required	Smooth surface needed	Opening or edge needed	No specific matter required

Let me know if you want a diagram to visualize the differences too!

(9) (10) (11) (12) (13) (14)

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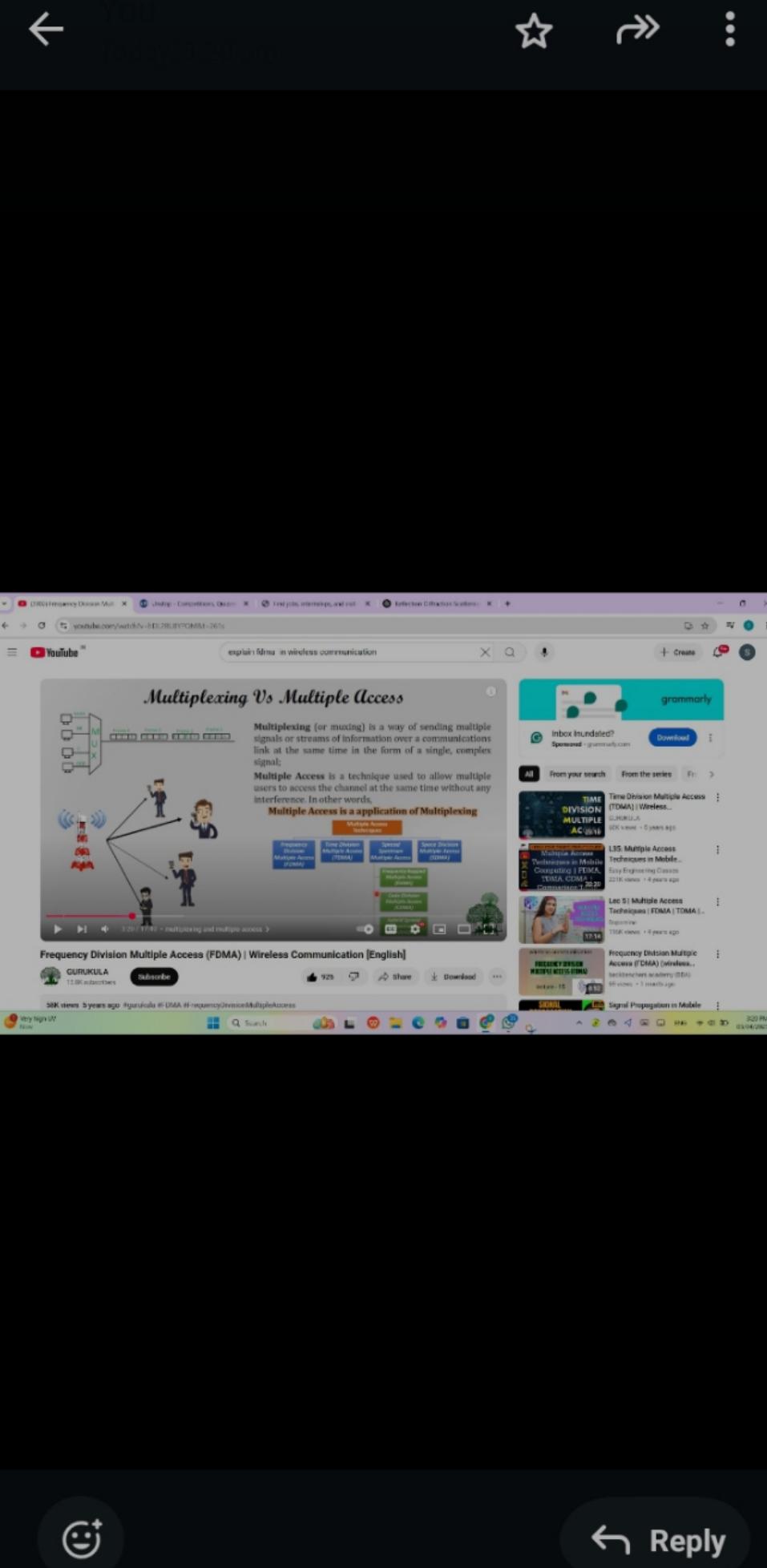
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Frequency Division Multiple Access - FDMA

GUURUKULA

Frequency Division Multiple Access (FDMA) | Wireless Communication [English]

Time

Guard Bands To avoid interference

CHANNELS

USER 1

USER 2

USER 3

CHANNEL 1

CHANNEL 2

CHANNEL 3

CHANNEL N

Frequency

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explain fdma in wireless communication

## FDMA

- FDMA Assigns individual channels to individual users
- Each user is allocated a unique frequency band or channel
- The channels are assigned on demand by the users
- The same frequency is not allotted for 2 different users.
- The bandwidth of FDMA channel is relatively narrow (30Khz)
- FDMA are usually implemented in narrow band systems
- The amount of inter symbol interference is low and thus No equalization is required in FDMA narrow band systems
- FDMA is continuous transmission systems where as it required less Overhead compared to TDMA
- FDMA uses Duplexers since both the transmitter and receiver operates at the same time. This results in Increase in COST of FDMA
- FDMA requires tight RF filtering to minimize adjacent channel interference

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Non Linear Effects in FDMA

- In FDMA, Many channels share the same antenna at the base station.
- In order to get the Maximum Power Efficiency the Power Amplifiers and Power Combiners are operated at (or) near Saturation Region
- At (or) near Saturation Region the Power amplifiers and power combiners are Non Linear.
- These non linearities causes signal spreading in the frequency domain and generate Intermodulation (IM) Frequencies.
- These Spreading will interfere with adjacent channels causing adjacent channel interference.

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Capacity of FDMA

- The number of channels that can be simultaneously supported in FDMA systems is given by

$$N = (B_t - 2 B_{\text{guard}}) / B_c$$

- Where
  - $B_t$  is the total spectrum allocation
  - $B_{\text{guard}}$  is the guard band allocation at the edge of allocated spectrum
  - $B_c$  is the channel bandwidth

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Advantages of FDMA

Advantage	Description
Simple implementation	FDMA is easy to implement compared to orthogonal systems.
Low cost	Since it uses a single channel, there is no need for expensive equipment.
Dedicated bandwidth	Each user has a dedicated channel for reducing interference between users.
No signal noise interference	Under TDMA, FDMA does not experience signal noise interference.
Stable performance	Stable performance is maintained even under varying transmission line conditions.

Disadvantages of FDMA

Disadvantage	Description
Uneven bandwidth utilization	Freq. hopping utilization may lead to underutilization of bandwidth.
Selectivity	FDMA cannot filter multiple signals effectively.
Interference	FDMA signal bands interfere with each other and with others.
Implementation complexity	Resource intensive and complex hardware for precise frequency selection.
Scalability issues	Limited number of channels restricts the number of simultaneous users.



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Time Division Multiple Access - TDMA

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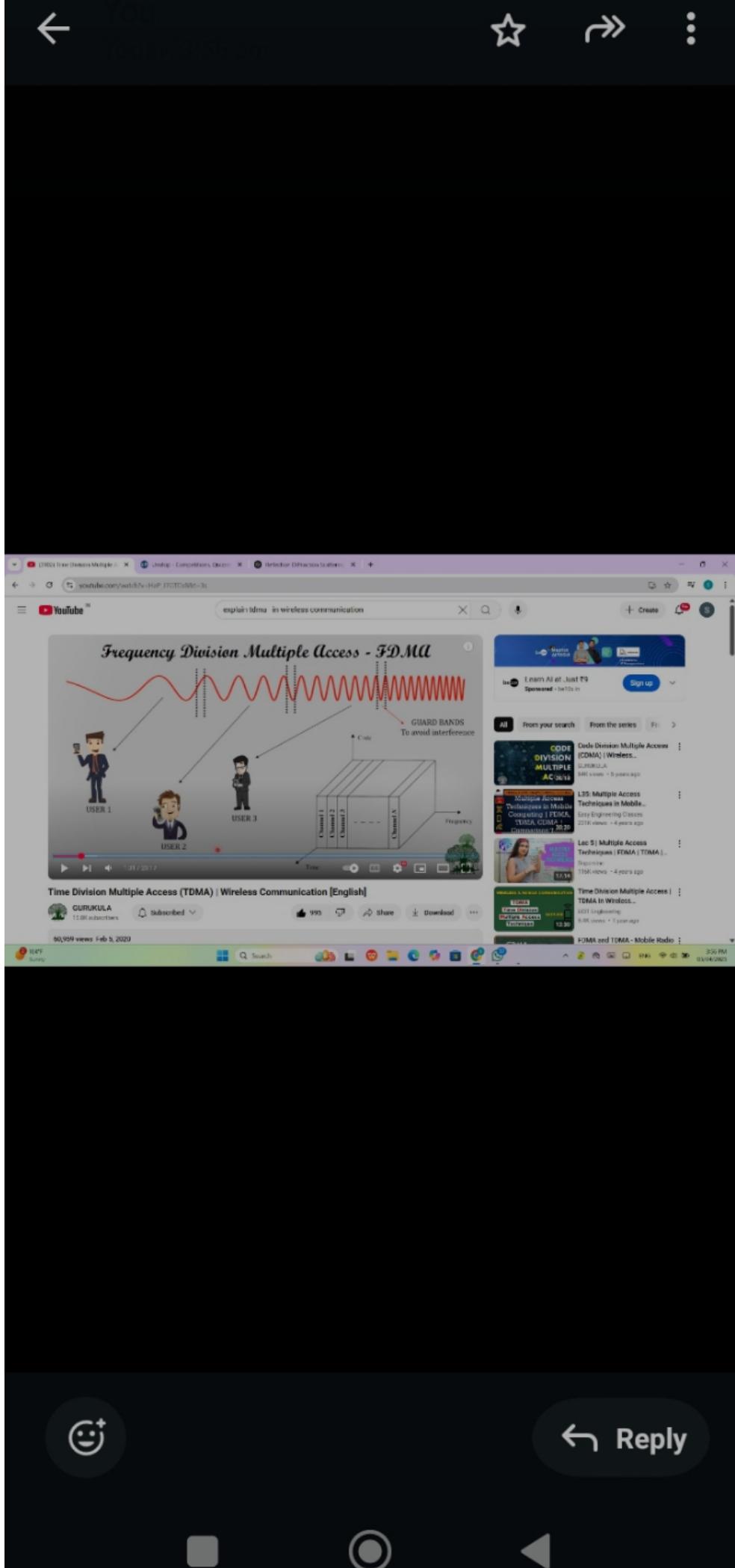
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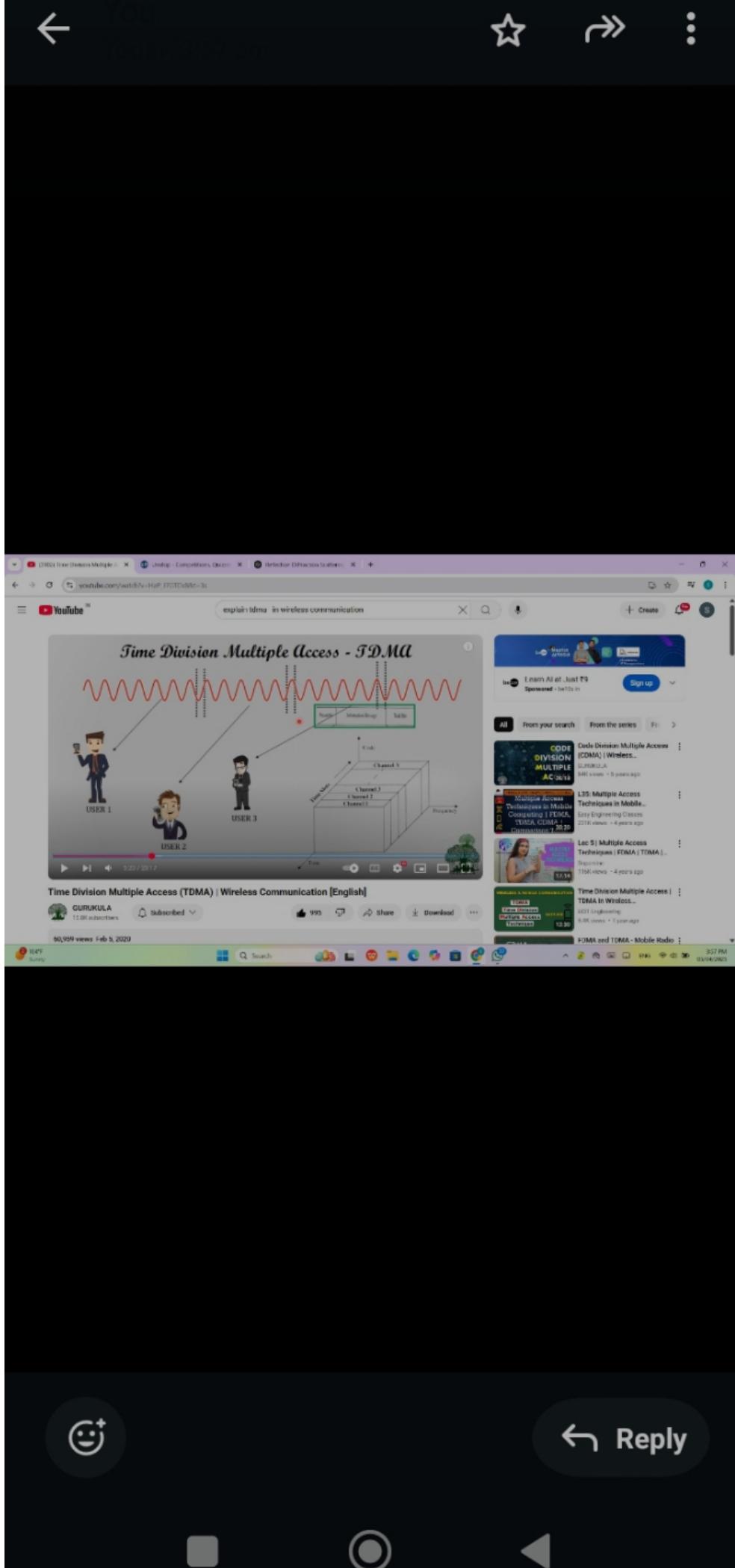
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The screenshot shows a mobile phone interface with a dark theme. At the top, there is a navigation bar with a back arrow, a star icon, a right arrow, and a three-dot menu icon. Below this is a large black rectangular area, likely a placeholder for a video or a blank screen. Underneath is a YouTube video player window.

**Video Title:** Time Division Multiple Access - TDMA

**Description:**

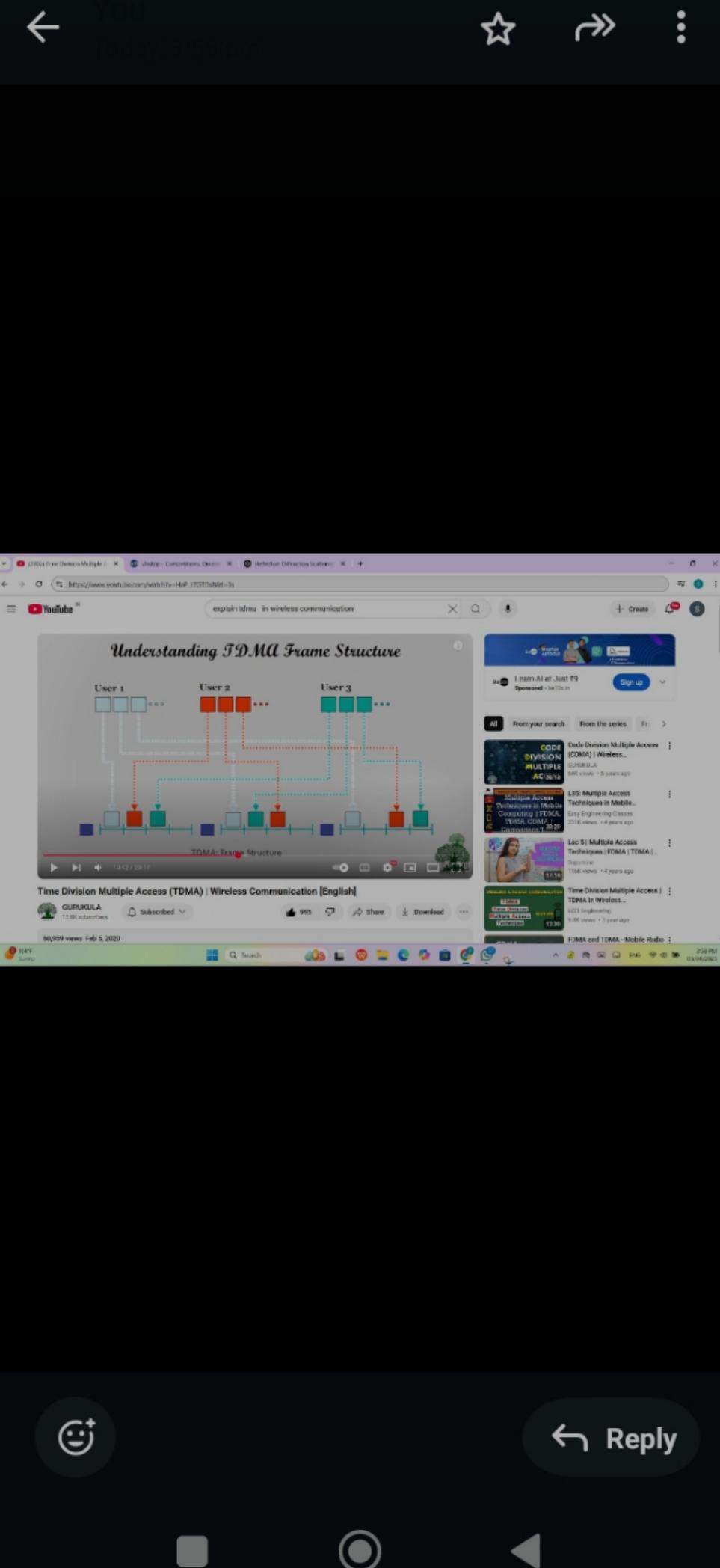
- TDMA divides the entire radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive.
- Each user occupies a cyclically repeating time slot.
- TDMA System transmits data in Buffer and Burst method. This makes the transmission a discontinuous one.
- Hence this makes the TDMA Systems more suitable for Digital Systems.
- Systems use TDMA/TDD or TDMA/FDD methods for Duplexing and Multiple Accessing.
- In TDMA/TDD – The Single Frame will be used as forward link for half of the duration and as reverse link on another half period.
- In TDMA/FDD – 2 Different Frames will be used for Forward and Reverse Link but the carrier frequency will be different.

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**Bottom Bar:** A circular icon with a smiley face and a plus sign, a reply button with a left arrow and the word "Reply", and standard Android navigation icons (back, home, recent apps).



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YouTube explain tdma in wireless communication

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Time Division Multiple Access - TDMA

Preamble:

- ✓ Consists of Address and Synchronization bits which is used by base stations subscribers to identify each others.

Information Message:

- ✓ Contains multiple slots of user information
- ✓ Each slot will have
  - ✓ Trail Bits
  - ✓ Sync Bits
  - ✓ Information
  - ✓ Guard Bits

Figure 2.4 TDMA frame structure: The frame is cyclically repeated over time.

Trail Bits

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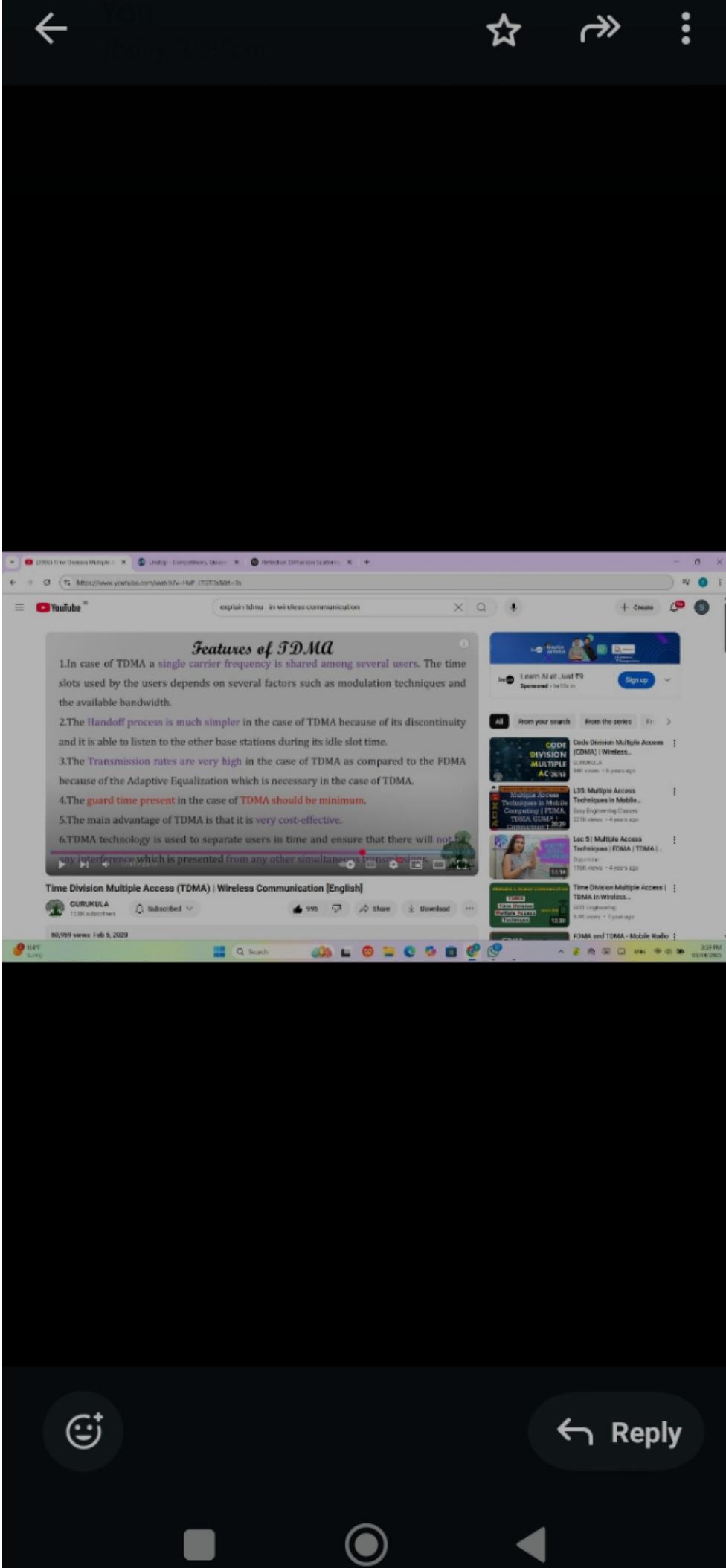
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### Efficiency in TDMA

- Calculation of Efficiency becomes trivial as TDMA uses high Overhead than compared to FDMA.
- The efficiency of TDMA System is a measure of the percentage of transmitted data that contains information as opposed to providing overhead for the scheme.

Frame Efficiency ( $\eta_f$ ) is calculated by

$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\%$$

$b_{OH}$  - Number of overhead bits per frame  
 $b_T$  - Total Number of Bits per Frame

$b_{OH} = N_r B_r + N_t B_p + N_l B_g + N_g B_e$   
 $N_r$  - Number of reference burst per frame  
 $B_r$  - Number of overhead bits per reference burst  
 $N_t$  - Number of Traffic Burst per Frame  
 $B_p$  - Number of Overhead bits per Preamble in each slot  
 $N_l$  - Number of Equivalent bits in each guard time interval  
 $B_g$  - Channel Bit Rate

Time Division Multiple Access (TDMA) | Wireless Communication [English]

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Number of Channels in TDMA Systems

The number of TDMA Channels slots that can be provided in a TDMA system is found by multiplying the **number of TDMA slots** per channel by the **number of channels available**.

$$N = \frac{m(B_{tot} - 2B_{guard})}{B_c}$$

*m – maximum number of TDMA users supported in channel*

It is also important to note that the 2 Guard Bands, one at the lower end and other at the higher end of the allotted frequency are required to ensure the users at the edge do not “bleed over” into an adjacent radio channels

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### Advantages of TDMA

Advantage	Description
Efficient bandwidth usage	Using a lower than the entire frequency band simultaneously.
Less interference	Since users transmit at different times, there's reduction of channel interference.
Power efficiency	Time can be used efficiently based on demand.
Lower power consumption	Device can power consumption than time slot using battery (e.g., in mobile).
Supports digital signals	Works well with digital data and supports encryption and compression.

### Disadvantages of TDMA

Disadvantage	Description
Signal degradation	Because signals are being transmitted simultaneously.
Time slot wastage	If a user has no data to send, then it results in unnecessary waste.
Latency	Latency is always constant for the same slot, especially in uplink.
Complex implementation	Requires complex, expensive and redundant hardware management and synchronization.
Not ideal for continuous	Not suitable for continuous signals like analog voice or unstructured buffering.

Get me some if you'd like a TDMA vs CDMA comparison chart too!

Send anything

800 PM 03/04/2025



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Reflection Diffraction Scattering

### Advantages of TDMA

Advantage	Description
Efficient bandwidth usage	Multiple users share the same frequency by taking turns (time slots).
Less interference	Since users transmit at different times, there's reduced co-channel interference.
Dynamic allocation	Time slots can be allocated flexibly based on user demand.
Lower power consumption	Devices can power down between their time slots, saving battery (e.g., in mobile).
Supports digital signals	Works well with digital data and supports encryption and compression.

### Disadvantages of TDMA

Disadvantage	Description
Strict synchronization	Requires precise timing between transmitter and receiver.
Time slot wastage	If a user has no data to send, their time slot remains unused.
Latency	Small delay as users must wait for their time slot, especially in high-traffic.
Complex implementation	Requires complex hardware and software to manage time slots and synchronization.
Not ideal for continuous	Not suitable for continuous signals like analog voice without added buffering.

Let me know if you'd like a TDMA vs FDMA vs CDMA comparison chart tool

Ask anything

ChatGPT can make mistakes. Check important info.

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TDMA (Time Division Multiple Access)

→ Available spectrum is partitioned into narrow frequency bands or channels which in turn are divided into no. of time slots.

→ In each slot only one user is allowed to either transmit or receive.

Features: Single carrier freq is used for several users, Duplexers not required, Data

FDMA (Frequency Division Multiple Access)

CDMA (Code Division Multiple Access)

L35: Multiple Access Techniques in Mobile Computing | FDMA, TDMA, CDMA | Comparison Table

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**CDMA** (Code Division Multiple Access)

- Message Signal is multiplied by a very large bandwidth Signal
- Called Spreading Signal (PN CODE)
- All user uses Same Carrier frequency and transmit simultaneously.
- Each user has its own PN Code.
- No Guard Bands are required.

Features:

$$\begin{aligned} S_1(C_1) d_1 &= c_1 \times d_1 \\ S_2(C_2)d_2 &= c_2 \times d_2 \\ S_3(C_3)d_3 &= c_3 \times d_3 \\ S_4(C_4)d_4 &= c_4 \times d_4 \end{aligned}$$

(C<sub>1</sub>d<sub>1</sub>) + (C<sub>2</sub>d<sub>2</sub>) + (C<sub>3</sub>d<sub>3</sub>)

L35: Multiple Access Techniques in Mobile Computing | FDMA, TDMA, CDMA | Comparison Table

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explain cdma in wireless communication

Code Division Multiple Access (CDMA)

Spread spectrum Tech.

It allows many users to occupy the same time & freq allocation in a given band / space.

It is a form of direct sequence spread spectrum communication.

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Benefits:

- Out standing Voice call Quality,
- greatest coverage for lower cost
- More data, longer talktime, long battery life.
- fewer dropped calls, Improved Security & privacy
- Greater Capacity, Reduced background noise

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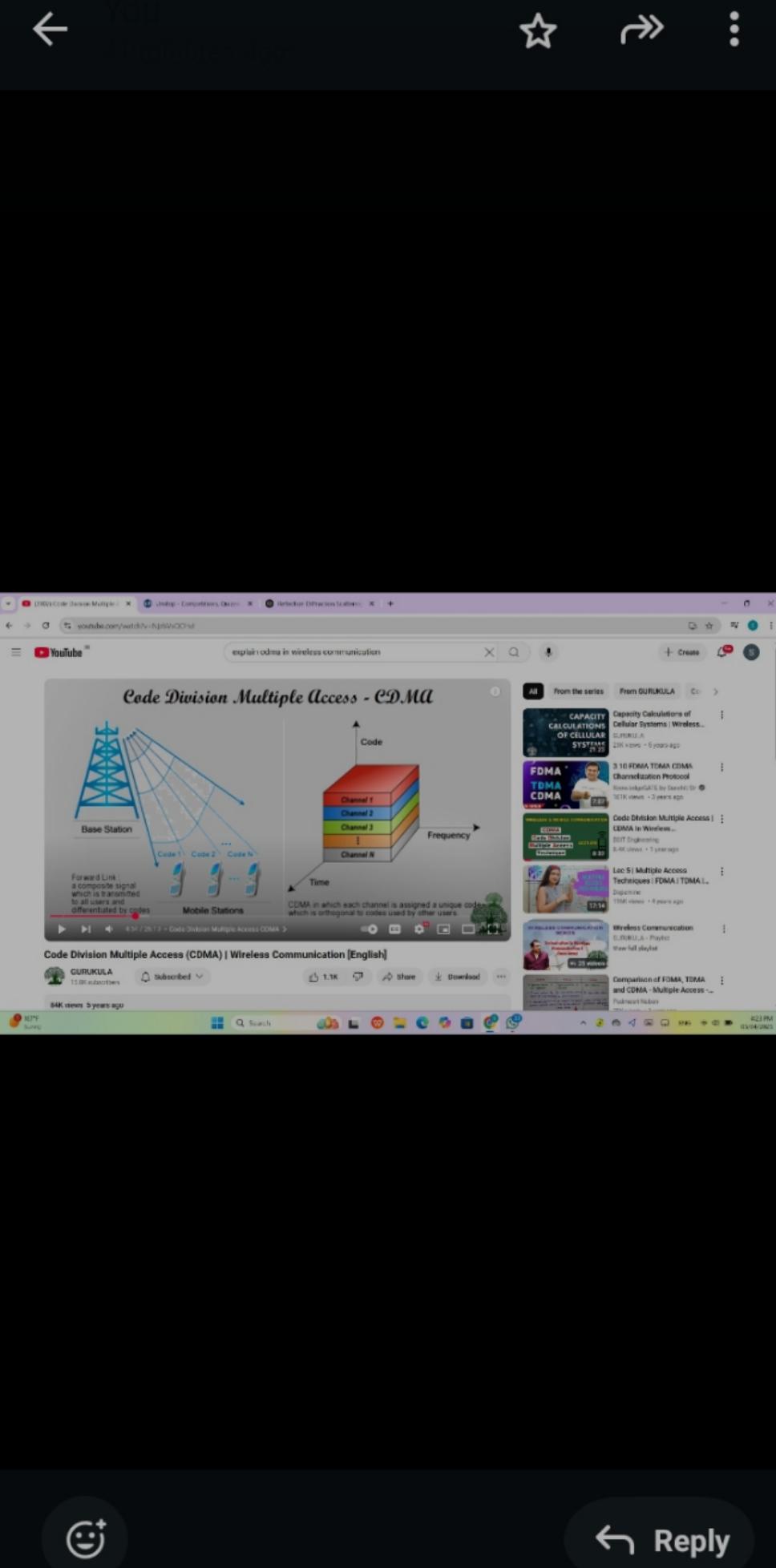
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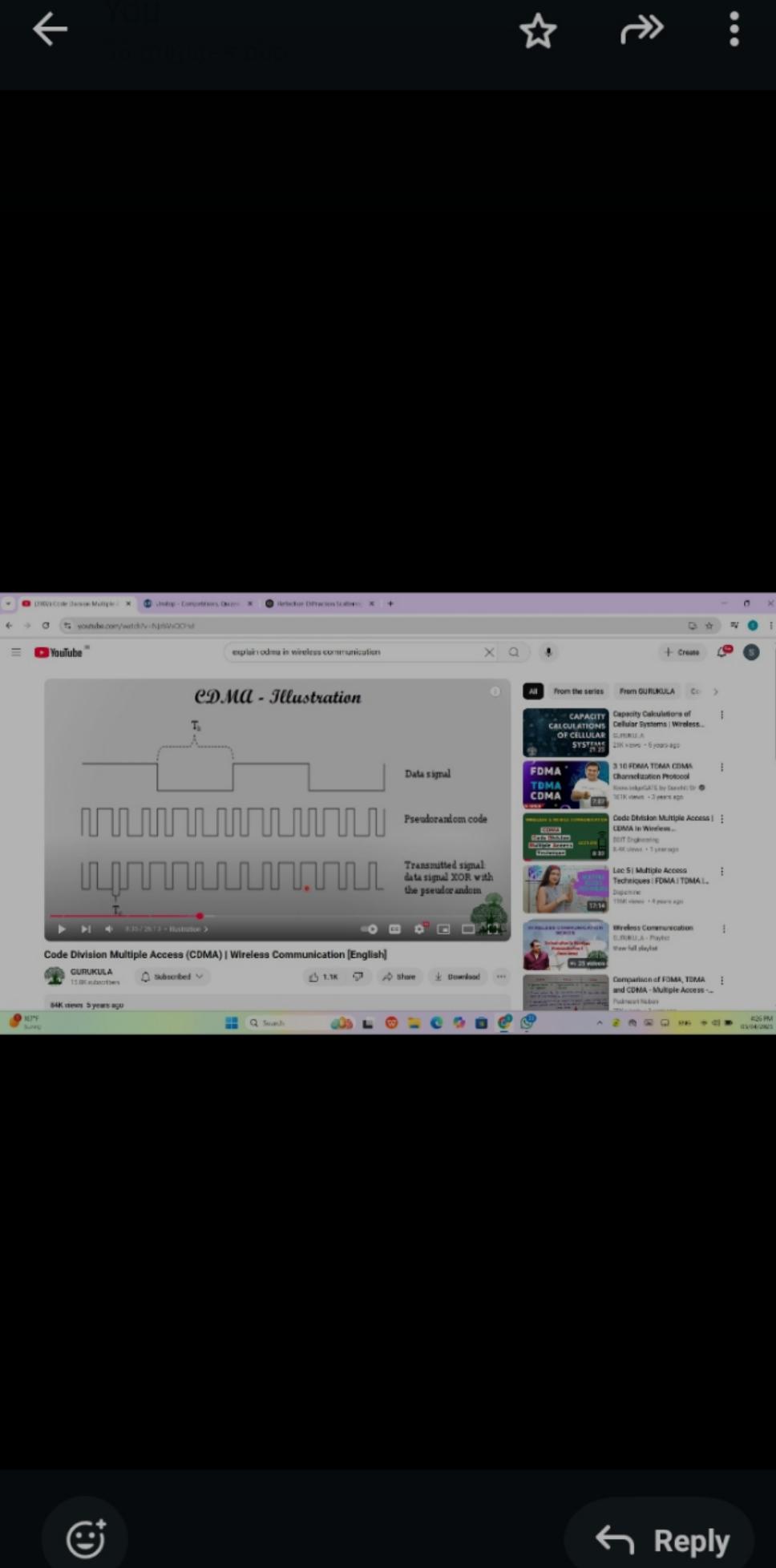
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Code Division Multiple Access - CDMA

- In CDMA systems, the narrow band message signal is multiplied with large bandwidth signal called the "Spreading Signal".
- These spreading signals are nothing but the PN Sequences whose chip rate is larger than the data rate of the message.
- CDMA uses same carrier frequency to modulate all the users and also it allows all the users to transmit simultaneously.
- Each user has his own pseudorandom code word which is approximately orthogonal to all other code words,
- To ensure multiple users on a CDMA system cause minimal mutual interference the spreading codes must be orthogonal.
- The receiver performs the time correlation function so that all other signals appears uncorrelated. However the receiver should know the code word to decrypt the message signals.
- In CDMA systems the power of the user determines the noise floor of the entire system. Failing to incorporate the proper power control leads to Near Far Problem.
- Lo. users with low power will not get a chance to connect to the base station thereby left unserve.

Code Division Multiple Access (CDMA) | Wireless Communication [English]

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explain cdma in wireless communication

**CDMA – Pros and Cons**

- Unlike TDMA and FDMA, CDMA has a soft limit on the capacity of number of users. Increasing the number of users in the system will lead to increased power.
- There is no absolute limit on the number of users to be added but rather, the system performance gets degrades for all users.
- Multipath fading is considerably reduced as the signal spreads over a large bandwidth.
- Channel data rates are very high in CDMA systems.
- Symbol period is very less than the channel delay spread hence any delayed signal for the duration more than one chip is considered as noise.
- RAKE Receivers are used to improve the reception by collecting time delayed versions of the required signal.
- Self jamming is problem in CDMA which arises when the PN sequence are not orthogonal. (causes interference between the users)
- Near Far problem arises when the power levels of undesired user are higher than the power levels of desired user.

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Near - Far Problem

- **Channel Capacity:** According to Shannon's Theorem, SNR & Channel Capacity are directly proportional to each other. Lower the SNR, Lower the Capacity.
- **Service Degradation:** The service quality degrades due to low SNR due to higher interference caused by the UE's at the cell edge transmitting at higher power in order to maintain good SNR at the Base station.
- **Battery Drain:** This will have an impact on the battery life of the User far from the Base Station. Because it has to transmit at higher power in order to maintain good SNR at the Base station.

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SNR - Signal to noise ratio

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YouTube "explain cdma in wireless communication"

### Capacity of CDMA systems

- The capacity of CDMA system is interference limited as opposed to bandwidth limited in FDMA and TDMA systems.
- Thus any reduction in the interference will cause linear increase in CDMA systems.
- The number of users that can access the system is given by,

$$N = 1 + \frac{W/R}{E_b/N_0} - (e^2/3)$$

W/R → Processing Gain  
η → background thermal noise  
S → Power of each user  
N → Number of Users

Code Division Multiple Access (CDMA) | Wireless Communication [English]

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Comparison of FDMA, TDMA and CDMA - Multiple Access - FDMA vs TDMA vs CDMA

Frequency Division Multiple Access (FDMA)	Time Division Multiple Access (TDMA)	Code Division Multiple Access (CDMA)
# FDMA shares a single Bw among multiple stations by dividing it into sub-channels.	# It shares the time slot & transmission through satellite.	CDMA shares both Bw and time among multiple stations with <u>Separate unique code</u> .
# Each station is allocated with <u>frequency band</u> for all the time to send data	# There is a <u>time slot</u> given each station to transmit data	# It allows each station to transmit data over the entire frequency <u>all the time</u> .
# Codeword is not required	# Codeword is not required	# Each user is assigned with a unique code sequence.

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Comparison of FDMA, TDMA and CDMA - Multiple Access - FDMA vs TDMA vs CDMA

YouTube video player showing a comparison chart and diagrams of FDMA, TDMA, and CDMA.

The chart compares three methods:

- FDMA:** Sub-channels by separating the frequency band into sub-channels.
- TDMA:** Through Satellite. There is a time slot given to each station to transmit data.
- CDMA:** Multiple stations with Separable unique code. It allows each station to transmit data over the entire frequency all the time.

Below the chart, there are diagrams illustrating the data transmission process for each method.

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explain cdma in wireless communication

FDMA	TDMA	CDMA
* Synchronization is not required	Synchronization is required	not required
* It uses continuous signals for data transmission	It uses signals in bursts for data transmission	It uses digital signals.
* It requires guard bands between adjacent bands	It requires the guard time of the adjacent time slots	CDMA requires both guardband and guard time
* Low data rate	Medium data rate	High data rate
* Limited cell capacity	Restricted cell capacity	No capacity restriction
		Low cost

Comparison of FDMA, TDMA and CDMA - Multiple Access - FDMA vs TDMA vs CDMA

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