Multiple access techniques

Multiple access techniques

- Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.
- The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users.
- For high quality communications, this must be done without severe degradation in the performance of the system.

Duplexing techniques

- In wireless communications systems, it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.
- Duplexing
- FDD
- TDD

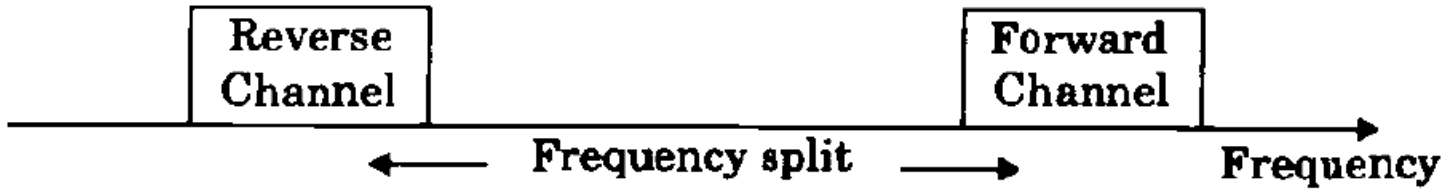
Duplexing techniques

- The forward band provides traffic from the base station to the mobile, and the reverse band provides traffic from the mobile to the base.
- In FDD, any duplex channel actually consists of two simplex channels, and a device called a duplexer is used inside each subscriber unit and base station to allow simultaneous radio transmission and reception on the duplex channel pair.

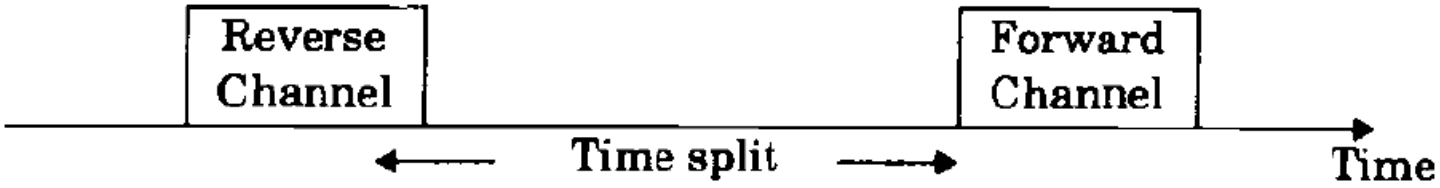
Duplexing techniques

- Time division duplexing (TDD) uses time instead of frequency to provide both a forward and reverse link.
- If the time split between the forward and reverse time slot is small, then the transmission and reception of data appears simultaneous to the user.

Duplexing techniques



(a)



(b)

FDD provides two simplex channels at the same time.
TDD provides two simplex time slots on the same frequency.

Duplexing techniques

- TDD allows communication on a single channel (as opposed to requiring two simplex or dedicated channels) and simplifies the subscriber equipment since a duplexer is not required.
- The duplexing technique of a multiple access system is usually described along with the particular multiple access scheme

Multiple access techniques

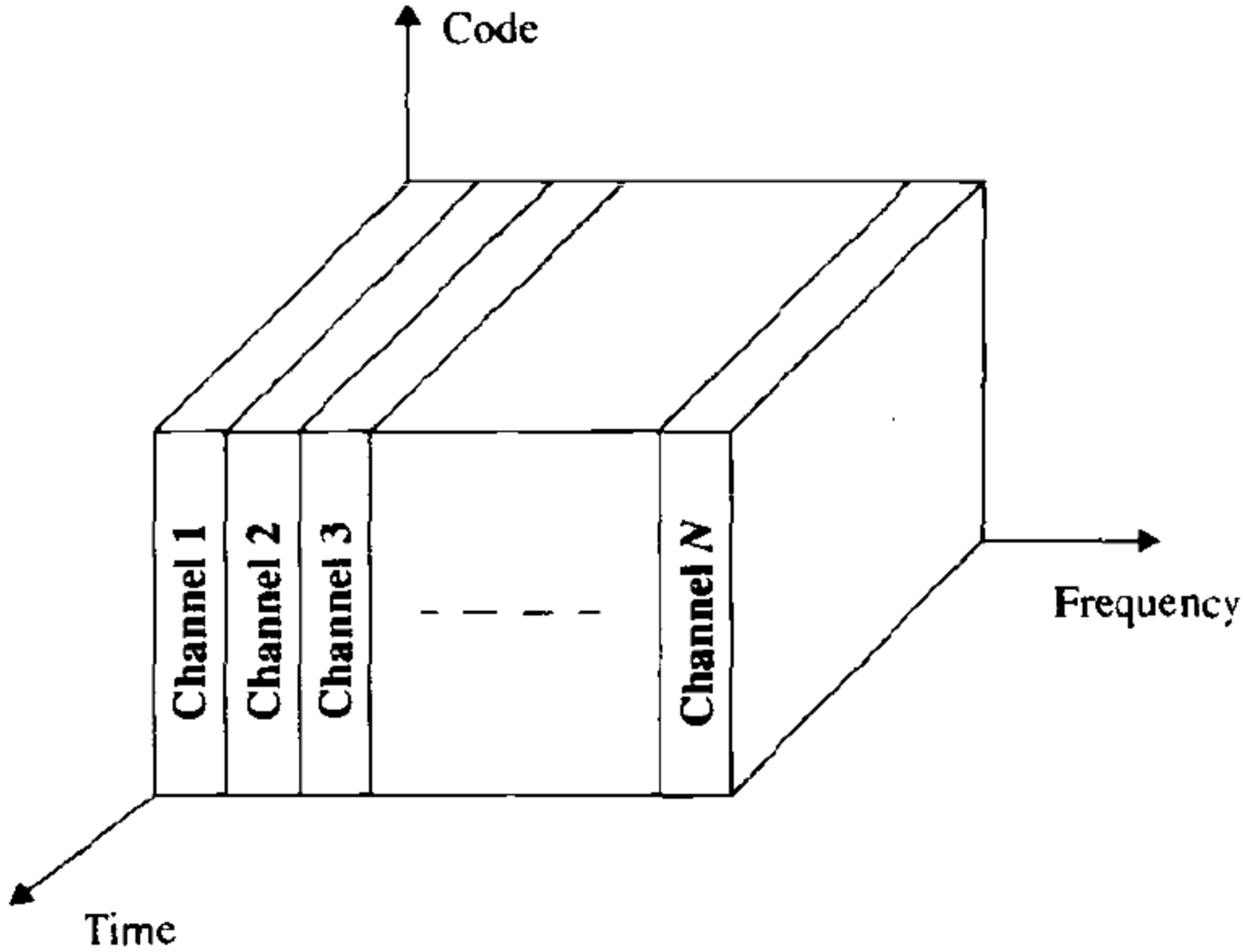
- FDMA
- TDMA
- CDMA
- These techniques can be grouped as narrowband and wideband systems depending upon how the available bandwidth is allocated to the users.

Multiple access techniques

- Narrowband Systems — The term narrowband is used to relate the bandwidth of a single channel to the expected coherence bandwidth of the channel.
- In a narrowband multiple access system, the available radio spectrum is divided into a large number of narrowband channels.
- Coherence bandwidth (B c) is defined as the range of frequencies over which the channel frequency response can be considered flat.

Multiple access techniques

- Wideband systems — In wideband systems, the transmission bandwidth of a single channel is much larger than the coherence bandwidth of the channel.
- Multipath fading does not greatly affect the received signal within a wideband channel, and frequency selective fades occur in only a small fraction of the signal bandwidth.


Code
Channel 1
Channel 2
Channel 3
Channel N
Frequency
Time

FDMA

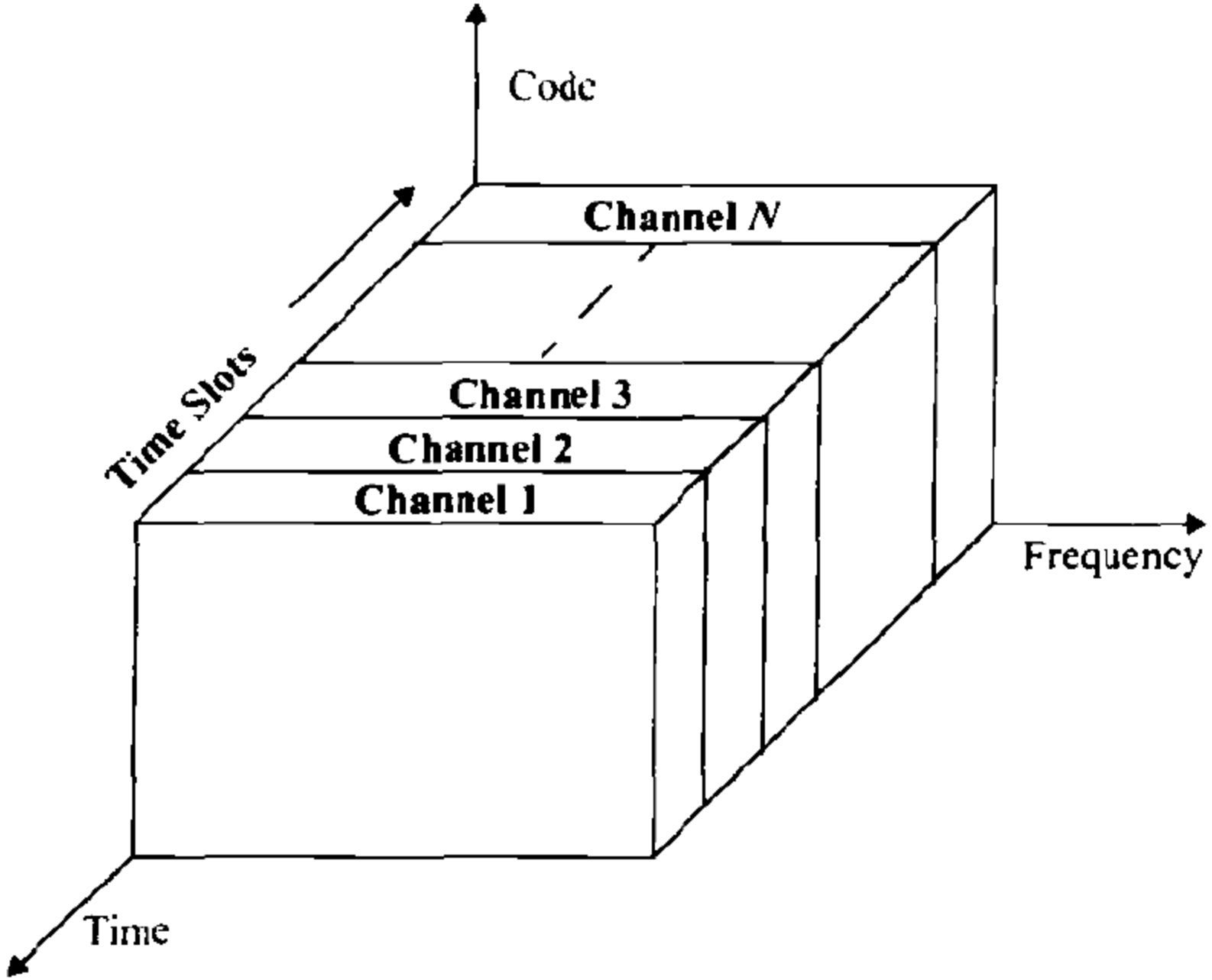
- The FDMA channel carries only one phone circuit at a time. If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity. It is essentially a wasted resource.
- After the assignment of a voice channel, the base station and the mobile transmit simultaneously and continuously.

FDMA

- The bandwidths of FDMA channels are relatively narrow (30 kHz) as each channel supports only one circuit per carrier That is, FDMA is usually implemented in narrowband systems.
- The FDMA mobile unit uses duplexers since both the transmitter and receiver operate at the same time. This results in an increase in the cost of FDMA subscriber units and base stations.
- FDMA requires tight RF filtering to minimize adjacent channel interference.

FDMA

- A US AMPS analog cellular system is allocated 12.5 MHz for each simplex band. If the guard band at either end of the allocated spectrum is 10 kHz, and the channel bandwidth is 30 kHz, find the number of channels available in an FDMA system.
- A cellular system operator is allocated a total spectrum of 5 MHz for deployment of an analog cellular system based on the FDMA technique, with each simplex channel occupying 25 kHz bandwidth. Compute the number of simultaneous calls possible in the system.


Code
Channel N
Channel 3
Channel 2
Channel 1
Time Slots
Frequency
Time

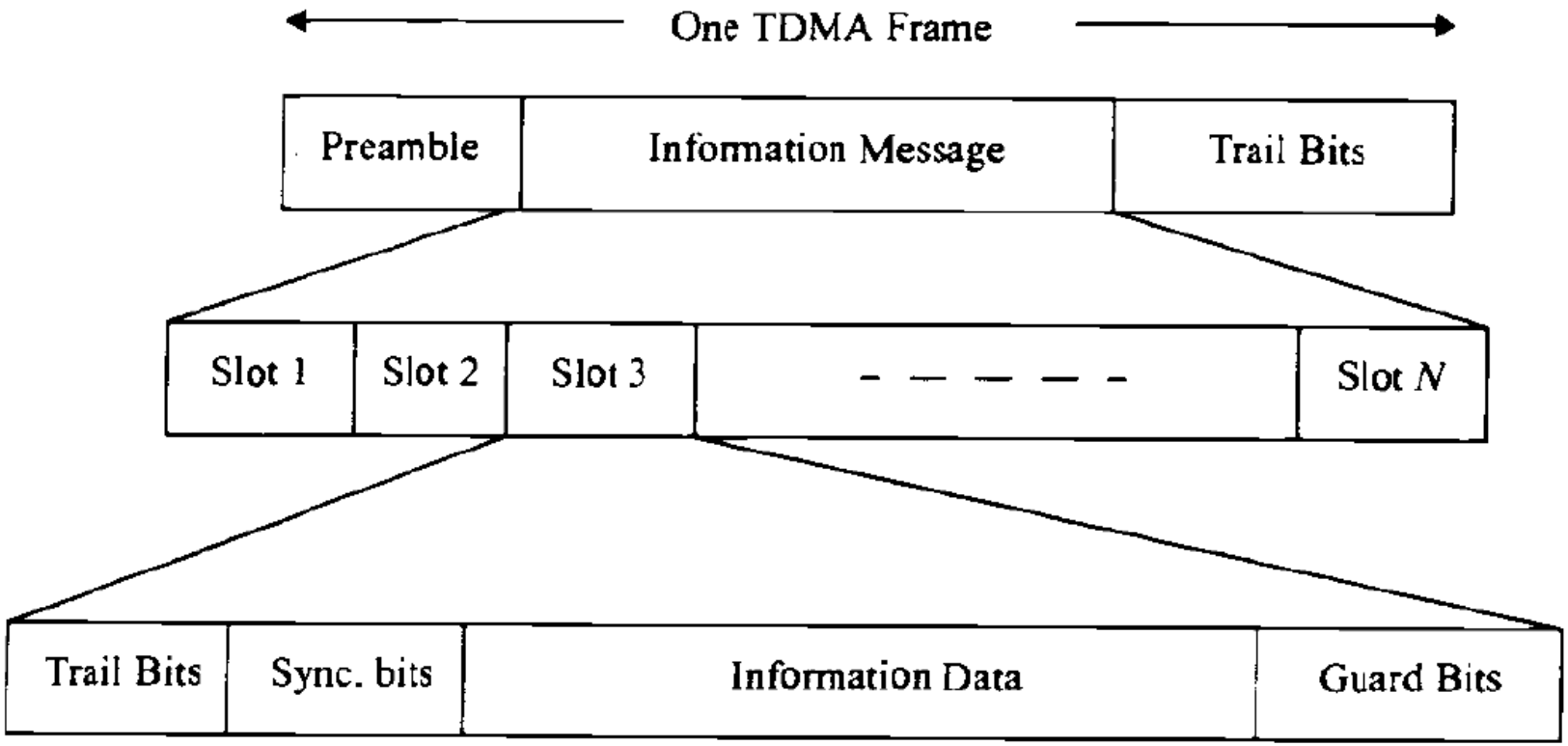
TDMA

- TDMA systems divide the 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, so a channel may be thought of as particular time slot that reoccurs every frame, where N time slots comprise a frame.
- TDMA systems transmit data in a buffer-and-burst method, thus the transmission for any user is non-continuous.

TDMA

- TDMA shares a single carrier frequency with several users, where each user makes use of non-overlapping time slots.
- The number of time slots per frame depends on several factors, such as modulation technique, available bandwidth
- TDMA uses different time slots for transmission and reception, thus duplexers are not required.

TDMA Frame Structure



TDMA

- Consider Global System for Mobile, which is a TDMA/FDD system that uses 25 MHz band for the forward link, which is divided into radio channels of 200 kHz each. If 8 speech channels (time slots) are supported on a single radio channel, find the number of simultaneous subscribers that can be accommodated in GSM, assuming no guard band.

Spread Spectrum Multiple Access

- Spread spectrum multiple access (SSMA) uses signals which have a transmission bandwidth that is several orders of magnitude greater than the minimum required RF bandwidth.
- A pseudo-noise (PN) sequence converts a narrowband signal to a wideband noise-like signal before transmission.

Spread Spectrum Multiple Access

- SSMA also provides immunity to multipath interference and robust multiple access capability.
- SSMA is not very bandwidth efficient when used by a single user.
- Since many users can share the same spread spectrum bandwidth without interfering with one another, spread spectrum systems become bandwidth efficient in a muthple user environment.

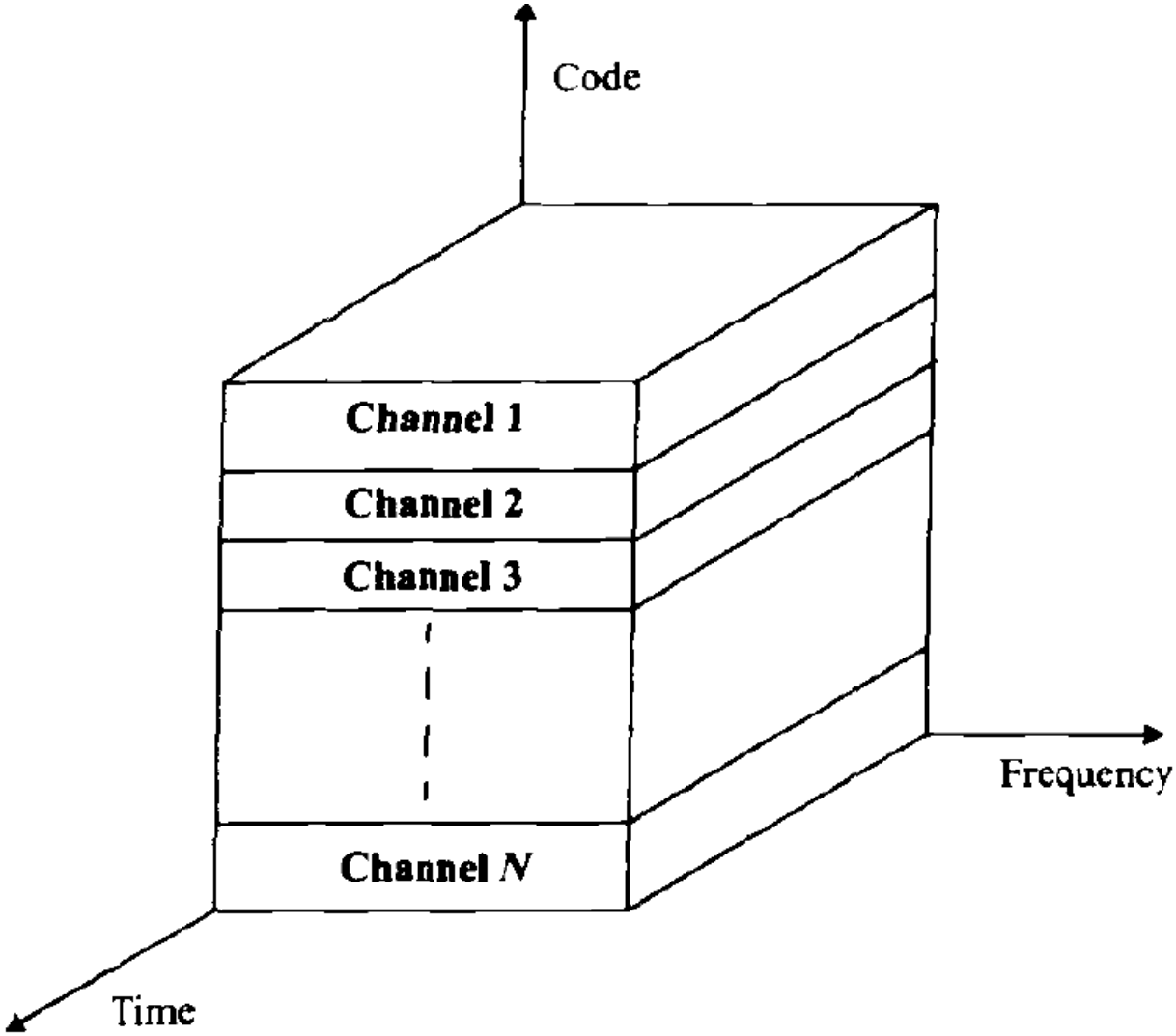
Spread Spectrum Multiple Access

- Frequency hopped multiple access (FH) and direct sequence multiple access (DS). Direct sequence multiple access is also called code division multiple access (CDMA)
- Frequency hopped multiple access (FHMA) is a digital multiple access system in which the carrier frequencies of the individual users are varied in a pseudorandom fashion within a wideband channel.
- The digital data is broken into uniform sized bursts which are transmitted on different carrier frequencies.

Code Division Multiple Access (CDMA)

- In code division multiple access (CDMA) systems, the narrowband message signal is multiplied by a very large bandwidth signal called the spreading signal.
- The spreading signal is a pseudo-noise code sequence that has a chip rate which is orders of magnitudes greater than the data rate of the message.

Code Division Multiple Access (CDMA)



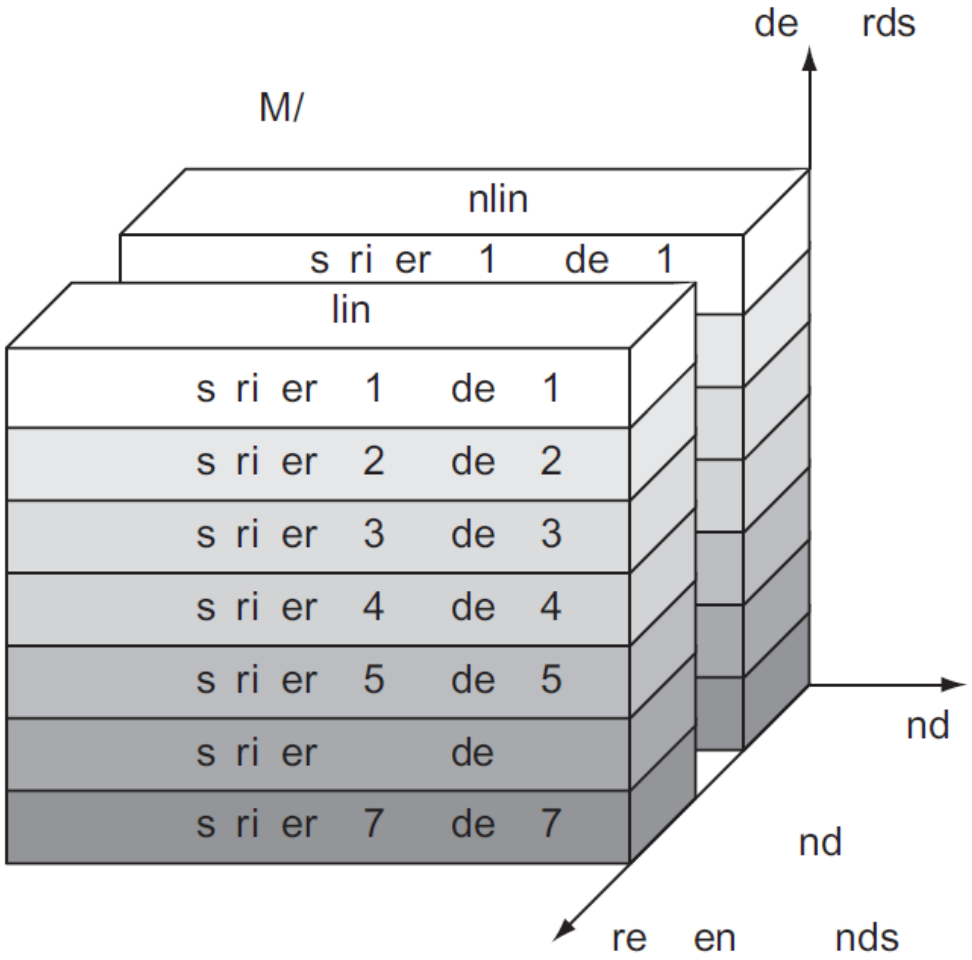
Code Division Multiple Access (CDMA)

- Each user has its own pseudorandom codeword which is approximately orthogonal to all other codewords.
- The receiver performs a time correlation operation to detect only the specific desired codeword.
- All other codewords appear as noise due to decorrelation.
- For detection of the message signal, the receiver needs to know the codeword used by the transmitter.
- Each user operates independently with rio knowledge of the other users.

Code Division Multiple Access (CDMA)

- Self-jamming is a problem in CDMA system. Self-jamming arises from the fact that the spreading sequences of different users are not exactly orthogonal, hence in the despreading of a particular PN code, non-zero contributions to the receiver decision statistic for a desired user arise from the transmissions of other users in the system.
- The near-far problem occurs at a CDMA receiver if an undesired user has a high detected power as compared to the desired user.

CDMA/FDD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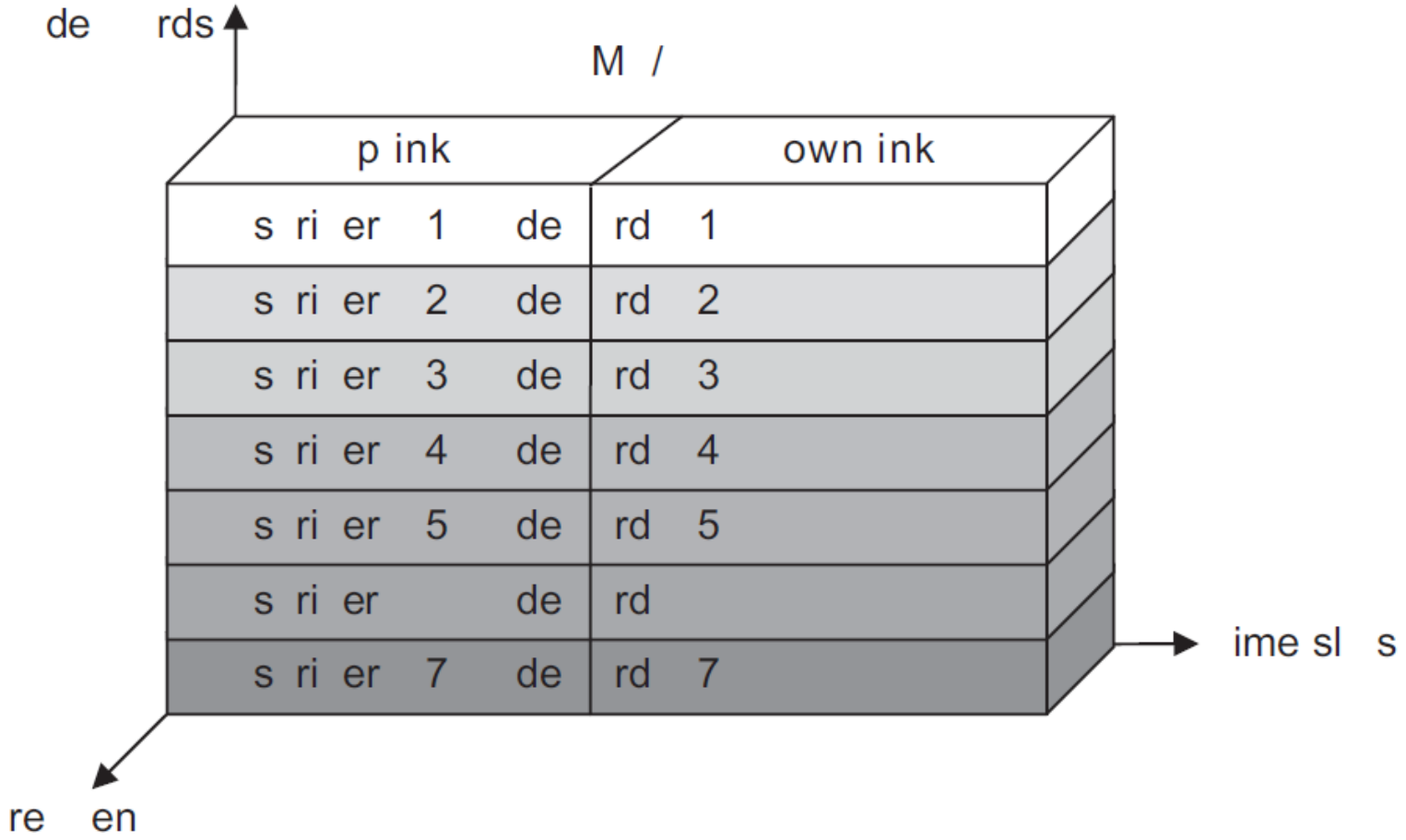
CDMA/TDD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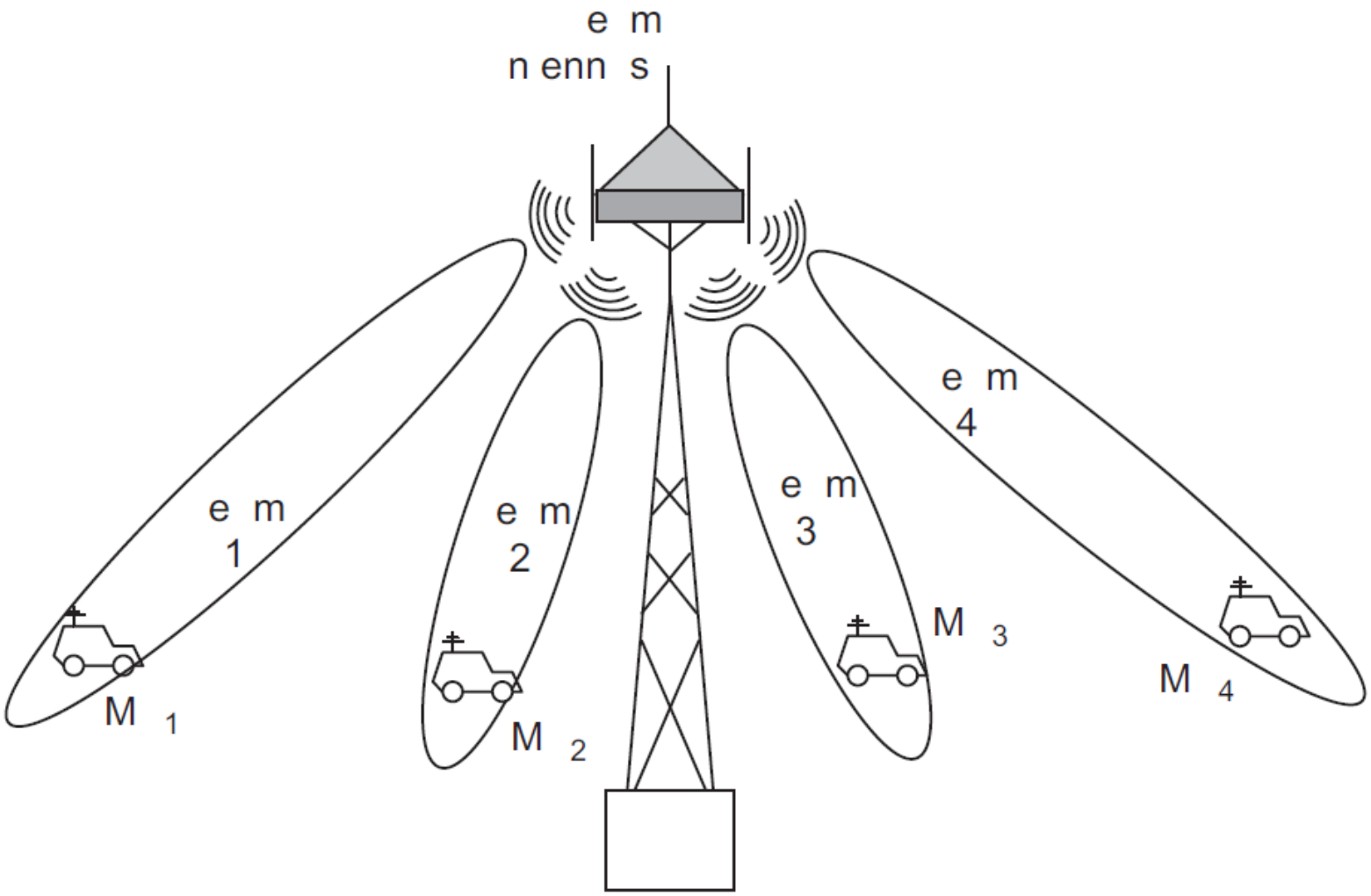
Multiple access techniques in cellular systems

S. No.	*Type of cellular system*	*Standard*	*Multiplexing technique*	*Multiple access technique*
1.	1G Analog Cellular	AMPS	FDD	FDMA
2.	US Digital Cellular	USDC	FDD	TDMA
3.	2G Digital Cellular	GSM	FDD	TDMA
4.	Pacific Digital Cellular	PDC	FDD	TDMA
5.	US Narrowband Spread Spectrum Digital Cellular	IS-95	FDD	CDMA
6.	3G Digital Cellular	W-CDMA	FDD/TDD	CDMA
7.	3G Digital Cellular	Cdma2000	FDD/TDD	CDMA

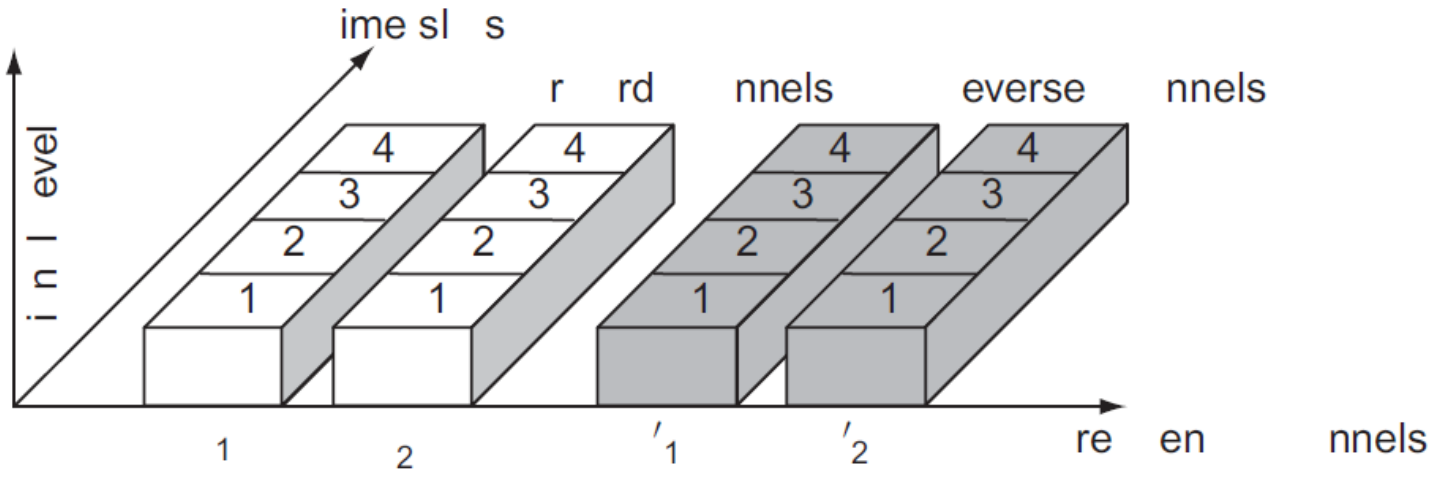
SPACE DIVISION MULTIPLE ACCESS

- If the transmit and receive antenna could be focused directly at the other end of the link, then this would provide a number of improvements such as
- Reduction in the total transmitted power as all power would be transmitted in the desired direction only
- Reduction in the amount of interference generated by each transmitter because total transmit power is reduced and localized
- Receiving a stronger signal by the receiver due to directional antenna gain and less interference

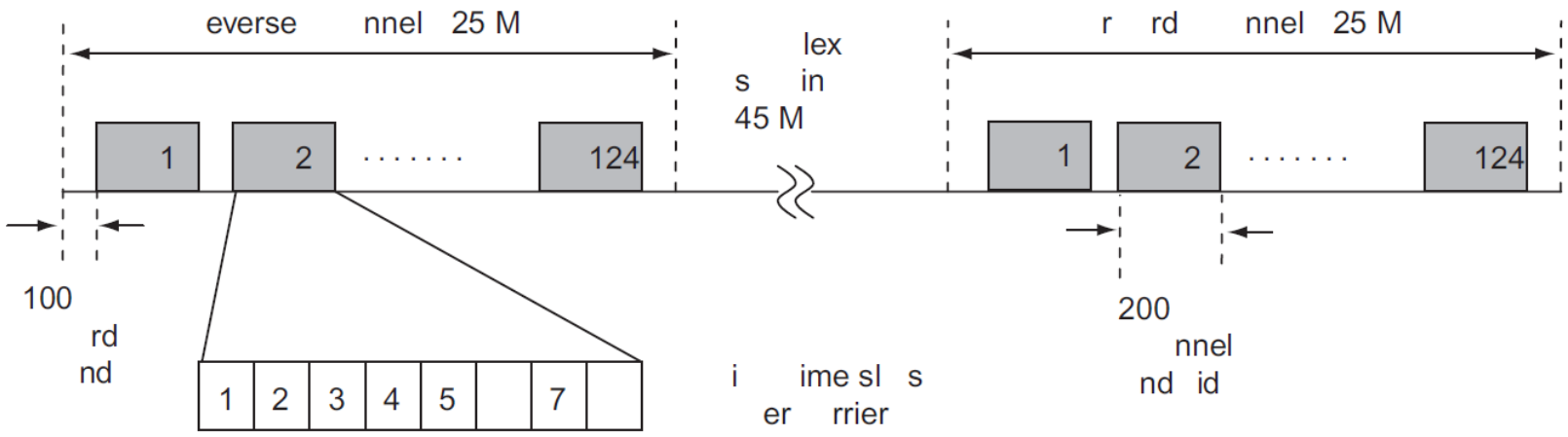
SPACE DIVISION MULTIPLE ACCESS



Hybrid TDMA/FDMA



Hybrid TDMA/FDMA



Hybrid TDMA/DSMA

- In a hybrid time division direct sequence multiple access (TDMA/DSMA) technique, each cell is using a different spreading code (DSMA employed between cells) that is conveyed to the mobile subscribers operating in its coverage area.
- Inside each cell (inside a DSMA channel), TDMA is employed to multiplex multiple mobile subscribers.

Hybrid TDMA/DSMA

- A particular time slot in a TDMA frame is allocated to one mobile subscriber per cell.
- Only one mobile subscriber transmits in each cell at any time.
- This results in significant reduction of near–far effect.

Hybrid TDMA/FHMA

- In the hybrid TDMA/FHMA technique, the mobile subscriber can hop to a new frequency at the beginning of every TDMA frame.
- At each time slot, the mobile subscriber is hopped to a new frequency according to a pseudorandom hopping sequence.
- Each successive TDMA frame in a given channel is carried on a different carrier frequency

Hybrid DSMA/FHMA

- In the hybrid DSMA/FHMA technique, the signals are spread using spreading codes (direct sequence signals are obtained), but these signals are not transmitted over a constant carrier frequency; they are transmitted over a frequency-hopping carrier frequency. The centre frequency of a direct sequence modulated
- signal is made to hop periodically in a pseudorandom manner.

Hybrid FDMA/DSMA

- In the hybrid FDMA/DSMA technique, the available wideband frequency spectrum is divided into a number of narrowband radio channels.

Hybrid SDMA with FDMA/TDMA/CDMA

- When SDMA is used with FDMA as well as TDMA (SDMA/ FDMA/TDMA), the higher carrier-to-interference value can be exploited for better frequency channel reuse.
- When SDMA is used with TDMA as well as DSMA (SDMA/TDMA/DSMA), different service areas can be covered by the individual antenna beam, thereby providing a similar effect as obtained by frequency reuse.