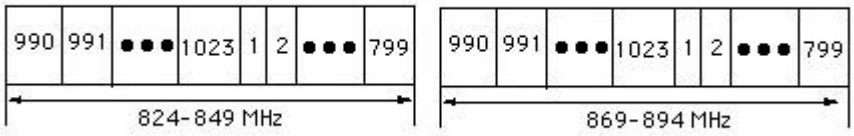
ECECS-611

Microwave Communications

Cellular Telephone Systems

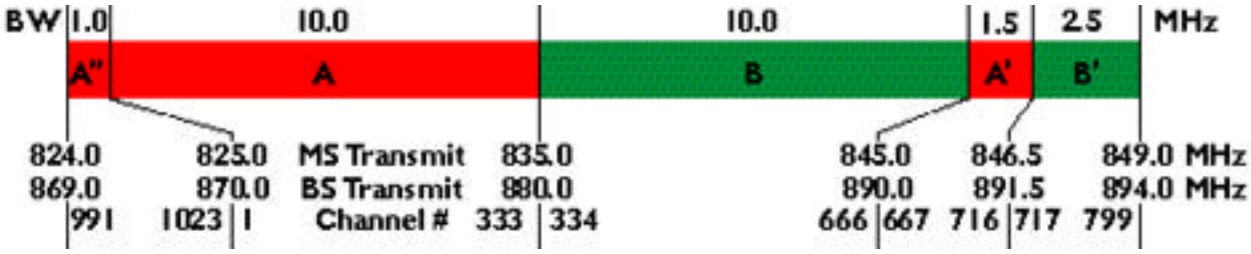
A cellular telephone system provides a wireless connection to the *Public Switched Telephone Network* (PSTN) for any user location within the radio range of the system. Cellular systems accommodate a large number of users over a large geographic area, within a limited frequency spectrum. Cellular radio systems provide high quality service that is often comparable to that of the landline telephone systems.



CDMA Channel Number to CDMA Frequency Assignment Correspondence for Band Class 0

Transmitter	CDMA Channel Number	Center Frequency for CDMA Channel (MHz)
Mobile Station Reverse Channel	1 ≤ N ≤ 799	0.030 N + 825.000
	991 ≤ N ≤ 1023	0.030 (N 1023) + 825.000
Base Station Forward Channel	1 ≤ N ≤ 799	0.030 N + 870.000
	991 ≤ N ≤ 1023	0.030 (N 1023) + 870.000

(Channels 800-989 are unused)



Band Designations for CDMA.

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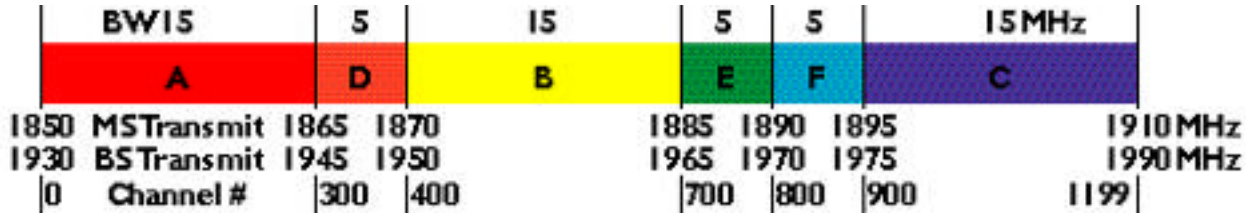

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High capacity is achieved by limiting the coverage of each base station transmitter to a small geographic area called a *cell* so that the same radio channels may be reused by another base station located some distance away. A sophisticated switching technique called a *handoff* enables a call to proceed uninterrupted when the user moves from one cell to another. Figure 1 shows a basic cellular system which consists of *mobile stations*, *base stations* and a *mobile switching center (MSC).* The Mobile Switching Center is sometimes called a *mobile telephone switching office (MTSO),* since it is responsible for connecting all mobiles to the PSTN in a cellular system. Each mobile communicates via radio with one of the base stations and may be handed-off to any number of base stations throughout the duration of a call. The mobile station contains a transceiver, an antenna, and control circuitry, and may be mounted in a vehicle or used as a portable hand-held unit. The base stations consist of several transmitters and receivers which simultaneously handle full duplex communications and generally have towers which support

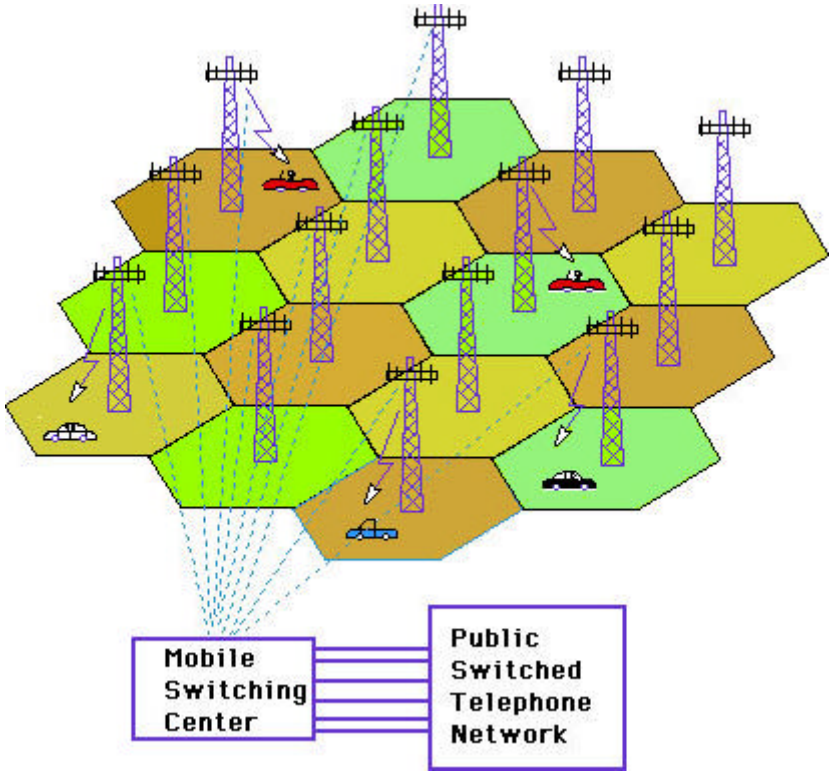


Figure 1. Cellular System. The towers represent base stations which provide access between the mobile users and the Mobile Switching Center (MSC)

several transmitting and receiving antennas. The base station serves as a bridge between all mobile users in the cell and connects the simultaneous mobile calls via telephone lines or microwave links to the MSC. The MSC coordinates the activities of all of the base stations and connects the entire cellular system to the PSTN. A typical MSC handles 100,000 cellular subscribers and 5,000 simultaneous conversations at a time, and accommodates all billing and system maintenance functions, as well. In large cities, several MSCs are used by a single carrier.

Communication between the base station and the mobiles is defined by a standard common *air interface* (CAI) that specifies four different channels. The channels used for voice transmission from the base station to mobiles are *called forward voice channels (FVC)* and the channels used for voice transmission from mobiles to the base station are called *reverse voice channels (RVC).* The two channels responsible for initiating mobile calls are *the forward control channels (FCC) and reverse control channels (RCC).* Control channels are often called *setup channels* because they are only involved in setting up a call and moving it to an unused voice channel. Control channels transmit and receive data messages that carry call initiation and service requests, and are monitored by mobiles when they do not have a call in progress. Forward control channels also serve as beacons which continually broadcast all of the traffic requests for all through mobiles in the system. Supervisory and data messages are sent in a number of ways to facilitate automatic channel changes and handoff instructions for the mobiles before and during a call.

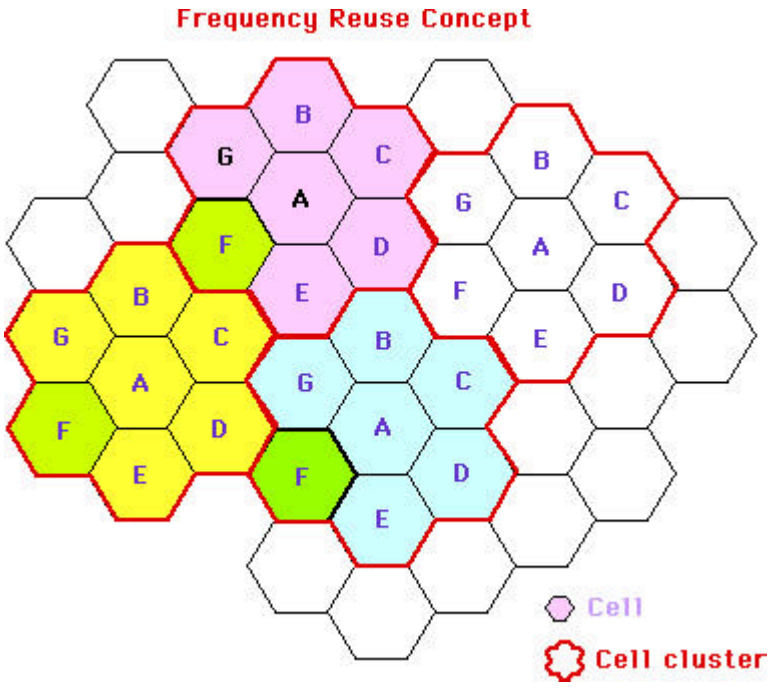


Figure 2. Cells within the same letter use the same set of frequencies. A cell cluster is outlined in bold and is replicated over a coverage area. In this example, the cluster size, N, is equal to seven, and the frequency reuse factor is 1/7 since each cell contains one-seventh of the total available channels.

Example 1

Cellular systems rely on the frequency reuse concept, which requires that the forward control channels (FCCS) in neighboring cells be different. By defining a relatively small number of FCCs as part of the common air interface, cellular phones can be manufactured by many companies which can rapidly scan all of the possible FCCs to determine the strongest channel at any time. Once finding the strongest signal the cellular phone receiver stays "camped" to the particular FCC. By broadcasting the same setup data on all FCCs at the same time, the MSC is able to signal all subscribers within the cellular system and can be certain that any mobile will be signaled when it receives a call via the PSTN.

Example 2.

If the total of 33 MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex voice and control channels, compute the number of channels available per cell if a system uses (a) 4-cell reuse, (b) 7-cell reuse (c) 12-cell reuse. If I MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels in each cell for each of the three systems.

Solution to Example 2

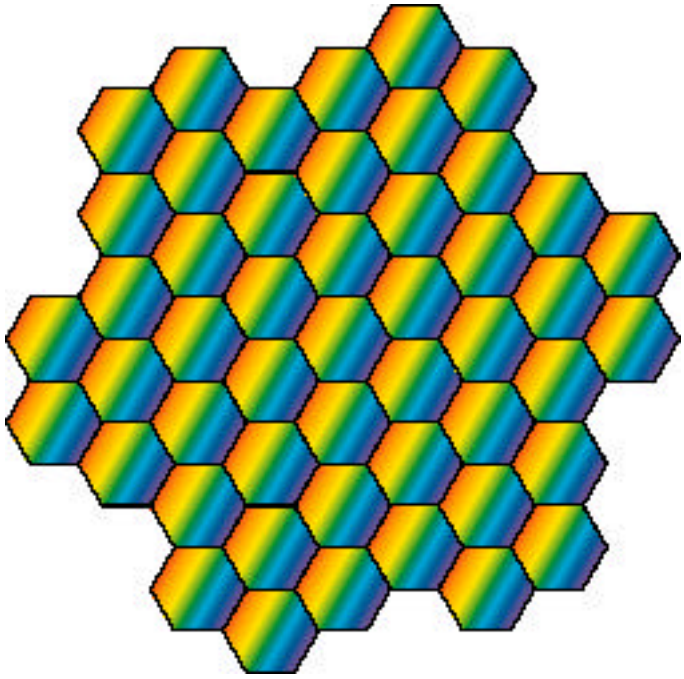
Given total bandwidth = 33 MHz. Channel bandwidth = 25 kHz x 2 simplex channels = 50 kHz/duplex channel. Total available channels = 33,000/50 = 660 channels

(a) For $N = 4$,
total number of channels available per cell = 660/4= 1 65 channels

(b) For $N = 7$,
total number of channels available per cell = 660/7= 95 channels

(c) For $N = 12$,
total number of channels available per cell 660/12 = 55 channels.

A 1 MHz spectrum for control channels implies that there are 1000/50 = 20 control channels out of the 660 channels available. To evenly distribute the control and voice channels, simply allocate the same number of channels in each cell wherever possible. Here, the 660 channels must be evenly distributed to each cell within the cluster. In practice, only the 640 voice channels would be allocated, since the control channels are allocated separately as I per cell. (a) For $N = 4$, we can have 5 control channels and 160 voice channels per cell. In practice, however, each cell only needs a single control channel (the control channels have a greater reuse distance than the voice channels). Thus, one control channel and 160 voice channels would be assigned to each cell. (b) For $N = 7$, 4 cells with 3 control channels and 92 voice channels, 2 cells with 3 control channels and 90 voice channels, and I cell with 2 control channels and 92 voice channels could be allocated. In practice, however, each cell would have one control channel, four cells would have 91 voice channels, and three cells would have 92 voice channels. (c) For $N = 12$, we can have 8 cells with 2 control channels and 53 voice channels, and 4 cells with 1control channel and 54 voice channels each. In an actual



For CDMA, the rainbow cells indicates that the entire 1.25 MHz passband is used by each user and the same passband is reused in each cell.

system, each cell would have 1 control channel, 8 cells would have 53 voice channels, and 4 cells would have 54 voice channels.

How a Cellular Telephone Call is Made?

When a cellular mobile phone is turned on and is not yet engaged in a call, it first scans the group of forward control channels to determine the one with the strongest signal, and then monitors that control channel until the signal drops below a usable level. At this point it again scans the control channels in search of the strongest base station signal. For each cellular system, the control channels are defined and standardized over the entire geographic area covered and typically make up about 5% of the total number of channels available in the system (the other 95% are dedicated to voice and data traffic for the end-users). Since the control channels are standardized and are identical throughout different markets within the country or continent, every phone scans the same channels while idle. When a telephone call is placed to a mobile user, the MSC dispatches the request to all base stations in the cellular system. The *mobile identification* number (MIN), which is the subscriber's telephone number, is then broadcast as a paging message over all of the forward control channels throughout the cellular system. The mobile receives the paging message sent by the base station which it monitors, and responds by identifying itself over the reverse control channel. The base station relays the acknowledgment sent by the mobile and informs the MSC of the handshake. Then, the MSC instructs the base station to move the call to an unused voice channel within the cell (typically, between ten to sixty voice channels and just one control channel are used in each cell's base station). At this point the base station signals the mobile to change frequencies to an unused forward and reverse voice channel pair, at which point another data message (called an *alert)* is transmitted over the forward voice channel to instruct the mobile telephone to ring, thereby instructing the mobile user to answer the phone. All of the sequence of events occur within a few seconds and are not noticeable by the user.

Once a call is in progress, the MSC adjusts the transmitted power of the mobile and changes the channel of the mobile unit and base stations in order to maintain call quality as the subscriber moves in and out of range of channels so that the mobile unit may be controlled by the base station and the MSC while a call is in progress.

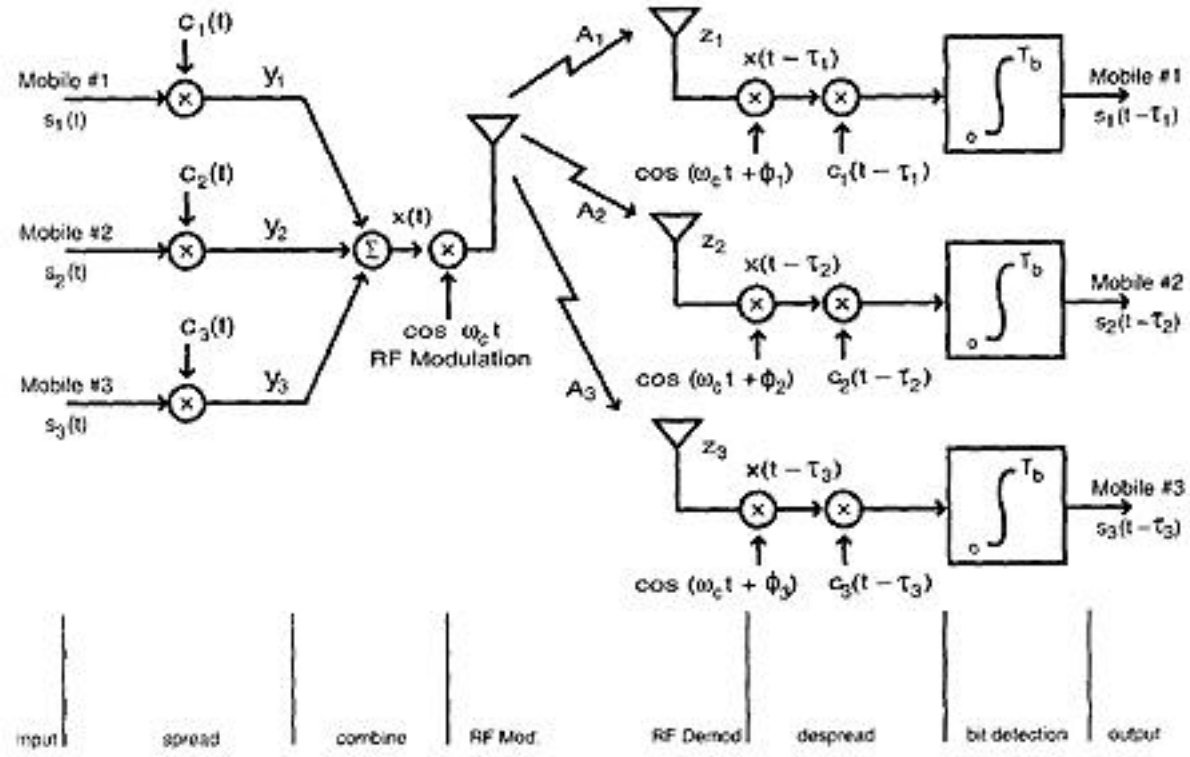
When a mobile originates a call, a call initiation request is sent on the reverse control channel. With this request the mobile unit transmits its telephone number *(MIN), electronic serial* number (ESN), and the telephone number of the called party. The mobile also transmits a *station class* mark (SCM) which indicates what the maximum transmitter power

level is for the particular user. The cell base station receives this data and sends it to the MSC. The MSC validates the request, makes connection to the called party through the PSTN, and instructs the base station and mobile user to move to an unused forward and reverse voice channel pair to allow the conversation to begin.

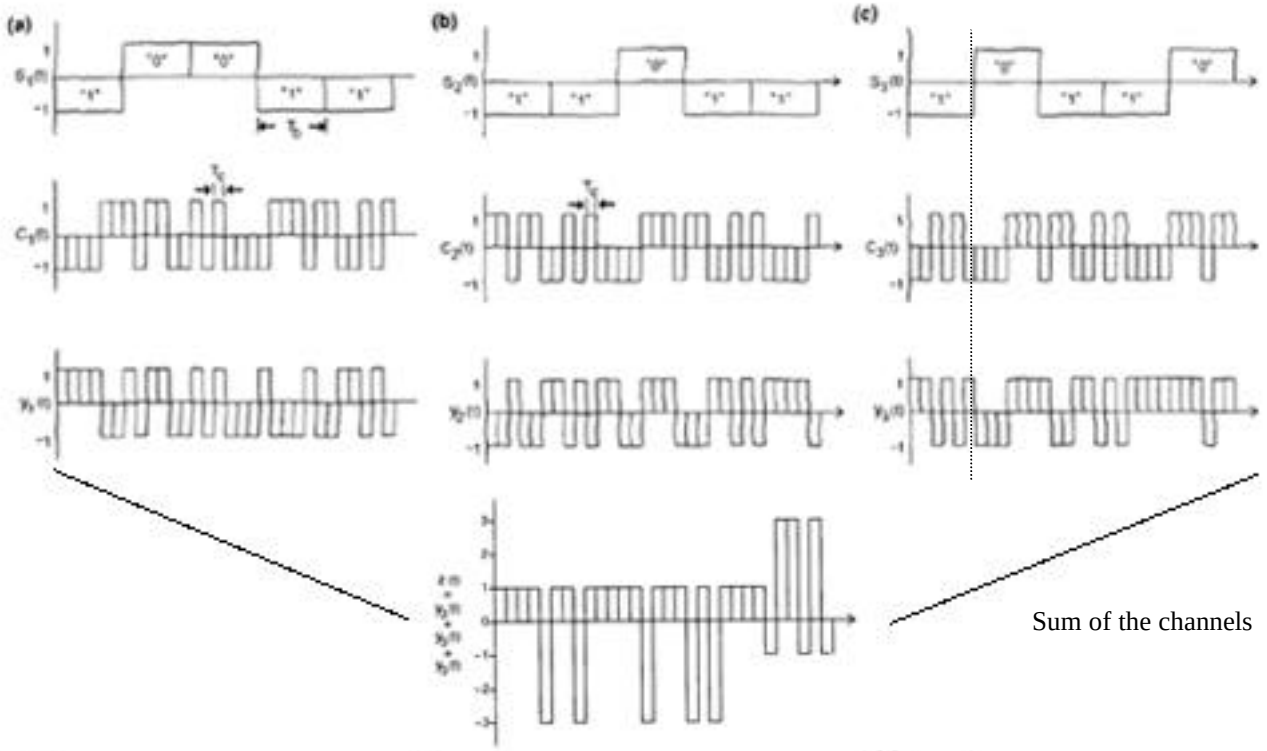
All cellular systems provide a service called roaming, This allows subscribers to operate in service areas other than the one from which service is subscribed. When a mobile enters a city or geographic area that is different fi7om its home service area, it is registered as a roamer in the new service area. This is accomplished over the FCC, since each roamer is camped on to a FCC at all times. Every several minutes, the MSC issues a global command over each FCC in the system, asking for all mobiles which are previously unregistered to report their MIN and ESN over the RCC. New unregistered mobiles in the system periodically report back their subscriber information upon receiving the registration request, and the MSC then uses the MIN/ESN data to request billing status from the home location register (HLR) for each roaming mobile. If a particular roamer has roaming authorization for billing purposes, the MSC registers the subscriber as a valid roamer. Once registered, roaming mobiles are allowed to receive and place calls fi7om that area, and billing is routed automatically to the subscriber's home service provider.

CDMA (from Ref c)

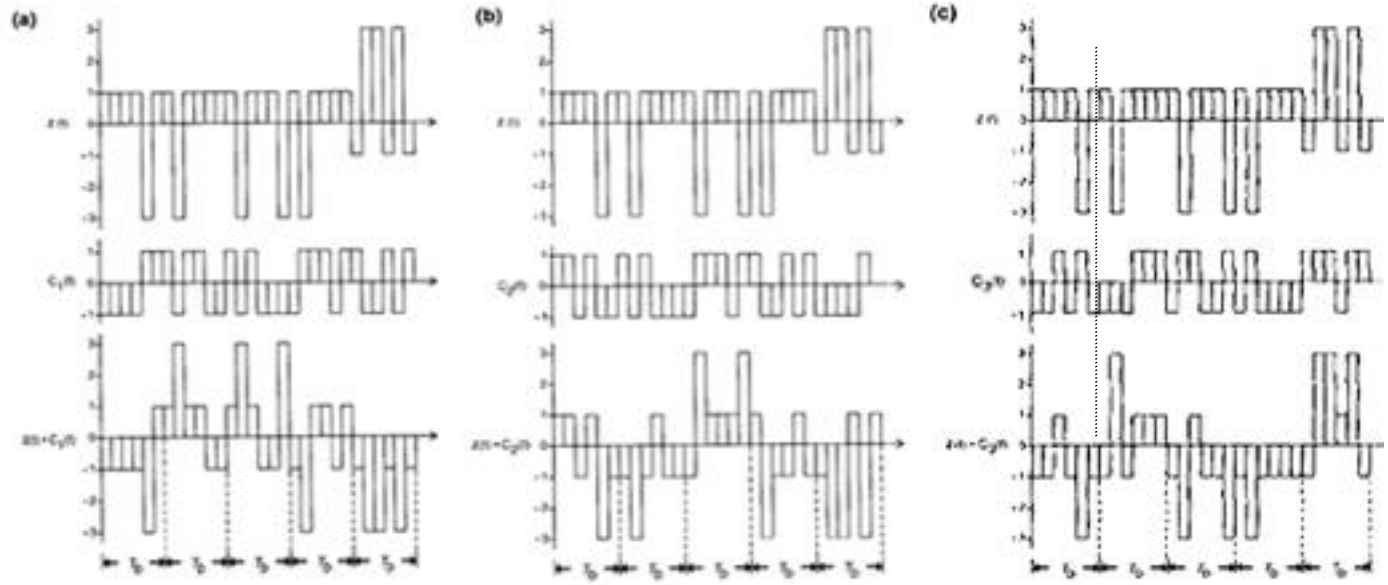
Multi-user DS CDMA, Downlink system
S's are signals
C's are codes for each channel
The code frequency is 6 times higher that the digital signal frequency.



Multiuser DS CDMA—Downlink System (From Ref.c)



Sum of the channels



	T_b	$2T_b$	$3T_b$	$4T_b$	$5T_b$
Value of integration at the end of bit period	-6	4	-8	-8	8
Bit Value	1	0	1	1	0

For channel (c)

References:

(a)***Wireless Communications, Principles and Practice,*** T.S.Rapport, IEEE Press, 1996
(b) http://www.ttl.nectec.or.th/IMT2000/Dowload/CDMA2000/20002.pdf
(c) ***Wireless Network Evolution 2G-3G***, Vijay K. Garg, Prentice Hall, (2001)