Cellular Fundamentals 1: Cellular Concept and AMPS

- Cellular Concept and Architecture
- Functionality of Architectural Components
- AMPS Channel Allocation

Reviewing of Previous Lectures

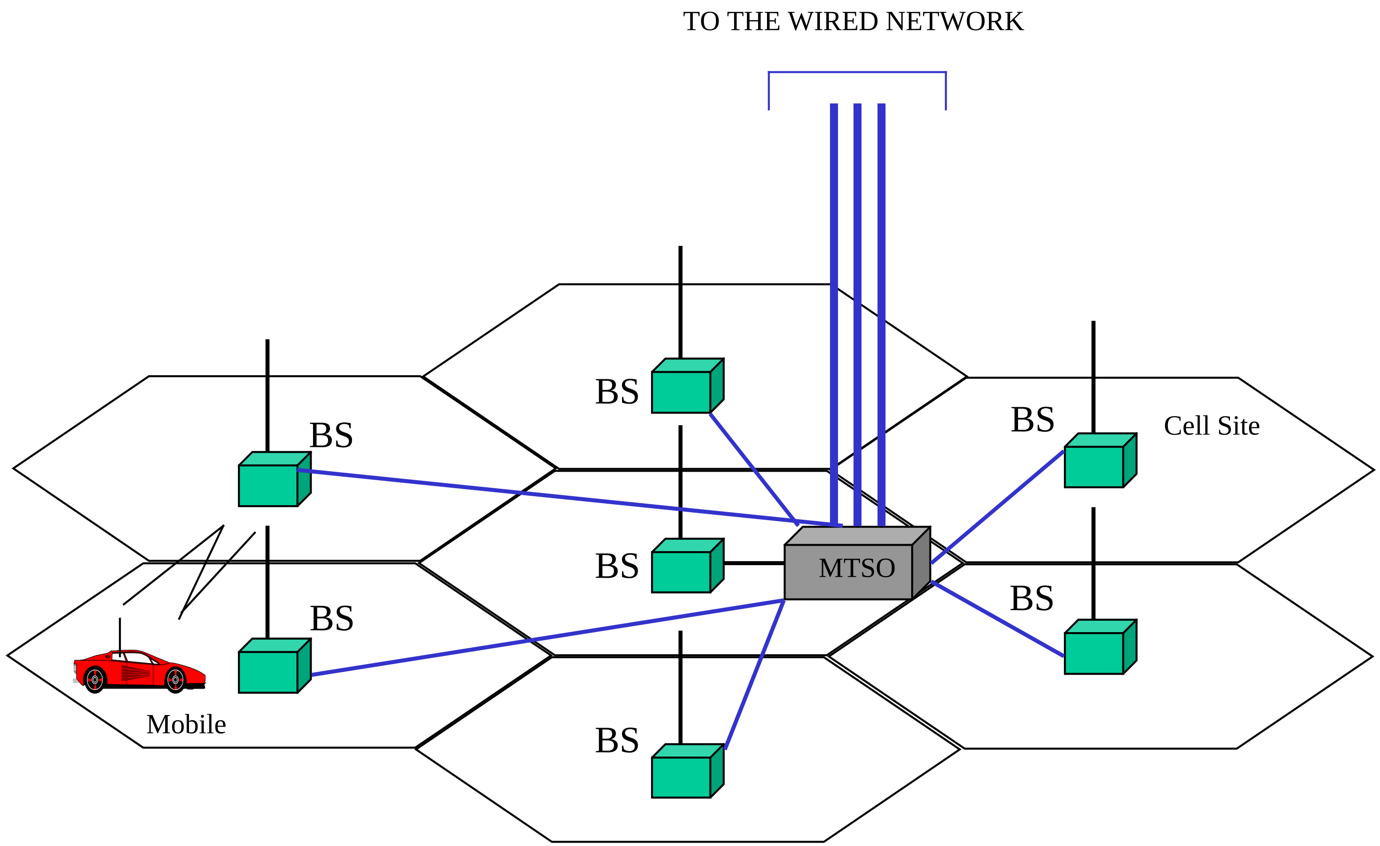
- Radiowave propagation impairments
  - Fadings, Doppler Spread
- Error compensation schemes
- Concept of spread spectrum
  - Direct sequence, Frequency-hopping
- Multiple Access Techniques
  - CDMA, Random Access

Cellular Network Organisation

- The organisation of cellular networks was first specified by the Advanced Mobile Phone System – AMPS standard (Bell Systems) in 1979, inside the publication of the Cellular Concept

- A cellular network is composed ideally of hexagonal cells, which represent geographical areas
- **Mobile stations** (MS) allow users to start/receive communications while they move around the cellular network
- **Base stations** (BS) supply frequency channels to mobile stations
- A **mobile switching centre – MSC** (in AMPS was called **mobile telephone switching office – MTSO**) is responsible for the control of the calls and also for acting as a gateway to other telephone/data networks
- The base stations are linked to the mobile switching centre

Cellular Concept Architecture [Mac 79]



Cellular Networks First Main Objectives [Mac79]

- Large subscriber capacity
- Efficient use of the spectrum
- Nationwide compatibility (later worldwide)
- Widespread availability
- Adaptability to traffic density
- Service to vehicles and portables
- Regular telephone services and special services
- Quality of service in telephony
- Affordability

Frequency Reuse

- The essential features of the cellular system that made possible the achievement of the listed objectives were frequency reuse and cell splitting
- frequency reuse : refers to the use of the same frequency carrier in different areas that are distant enough so that the interference caused by the use of the same carrier (co-channel interference) is not a problem
  - The reason for the application of frequency reuse is twofold:
    - Reduce the cost and the size of the transmitters and receivers
      - they can operate using less power (the area to be covered is smaller)
    - Greatly increase the number of simultaneous calls

Cell Splitting

- *Cell Splitting* is the reconfiguration of a cell into smaller cells
- The same network can service different densities of demand for channels
  - Larger cells can serve low demand areas
  - Smaller cells high demand areas
- Cell splitting is a long-term configuration planning that allows the system to adjust to a growth in traffic demand in certain areas, or in the whole network, without any increase in the spectrum

Handoff and Roaming Procedures

- handoff or handover: when a mobile station using a frequency channel needs to change it for another frequency channel
  - Intra-handoff : inside the same cell
  - Inter-handoff: between two cells
  - System inter-handoff: between two cellular systems
- Roaming allows subscribers to initiate or receive calls when visiting a different cellular network

The MSC

- Manage and control the equipments and the connections of the base stations
- Provide PSTN (Public Switched Telephone Network) interface
- Provide a *Home Location Register* (HLR)
- Provide a *Visitor Location Register* (VLR)
- Support intersystem connectivity
- Support call processing functions
- Provide billing, operation, maintenance, and test functions
- Support multiple access technologies (FDMA, TDMA, CDMA)

[Far 96]

The HLR and the VLR

- HLR is a data base for storage and management of subscriber information, which provides and stores
  - Subscriber data
  - Information on the subscriber location and status
  - Mobile identification number
  - Directory number
  - Terminal equipment identification number
  - Subscriber's call related information (duration, long distance destinations, etc.)
- VLR is a dynamic database used to store active (home/roaming) subscriber information associated with the MSC
  - It contains all subscriber data required for the call handling in the current location of the subscriber
  - It stores temporary subscriber information
  - It frequently communicates with HLR to get information

[Far 96]

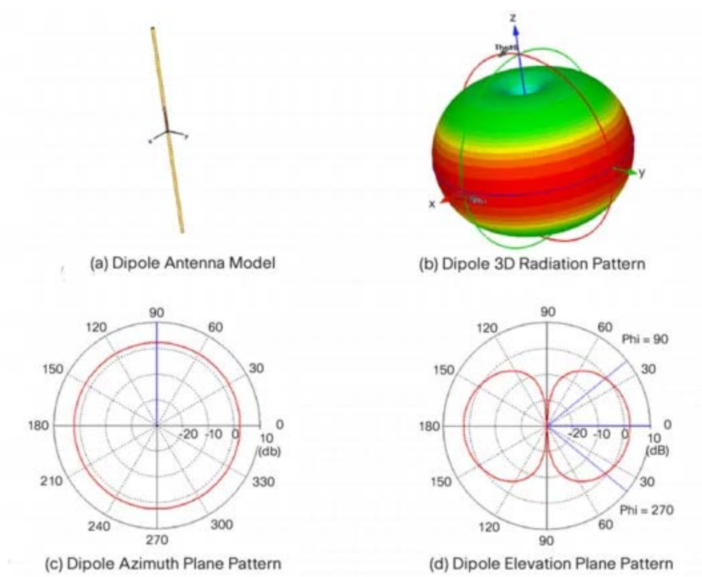
The Base Station

- A base station may establish communication with any mobile station inside its cell coverage area
- Execute functions of control and reconfiguration of base station equipments
- Provide an interface between MSC and the MSs
- Perform transmission and reception of control signals for call establishment and supervision
- Perform measurement of the signal level of a call

[Far 96]

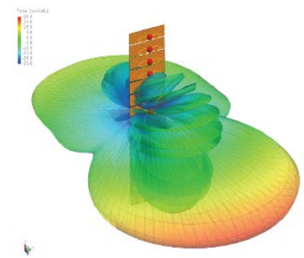
The Base Station

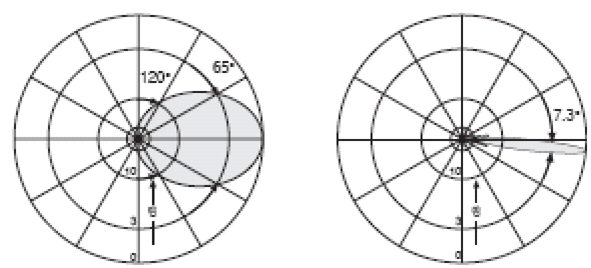
- Cell coverage depends on power, antenna radiation pattern (gain, height, directivity)
- Other types of parameters such as propagation environment, hills, tunnels and buildings greatly affect the overall coverage
- The antenna can be:
  - Omnidirectional (isotropic antenna)
  - Directional antenna: beam angle



(a) Dipole Antenna Model (b) Dipole 3D Radiation Pattern

(c) Dipole Azimuth Plane Pattern (d) Dipole Elevation Plane Pattern



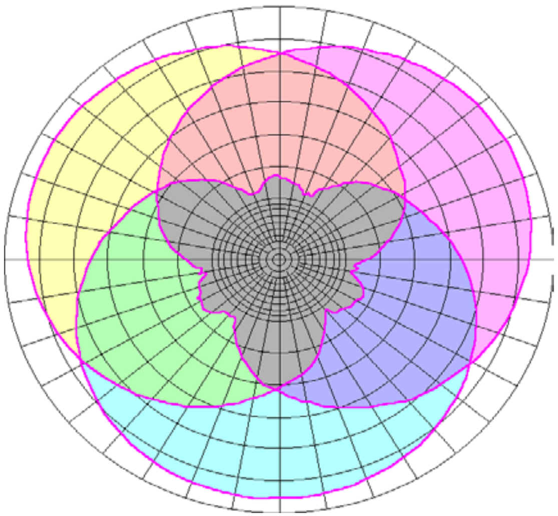


Horizontal Pattern Vertical Pattern

Directional Antennas for Sectorised Cells

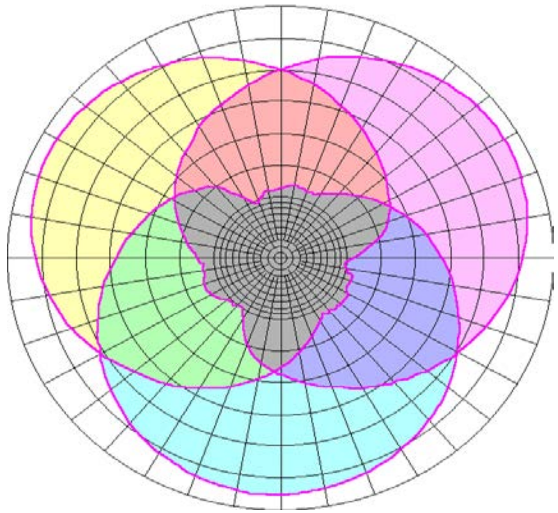
Sector Selection Trade Offs

90° Sectors



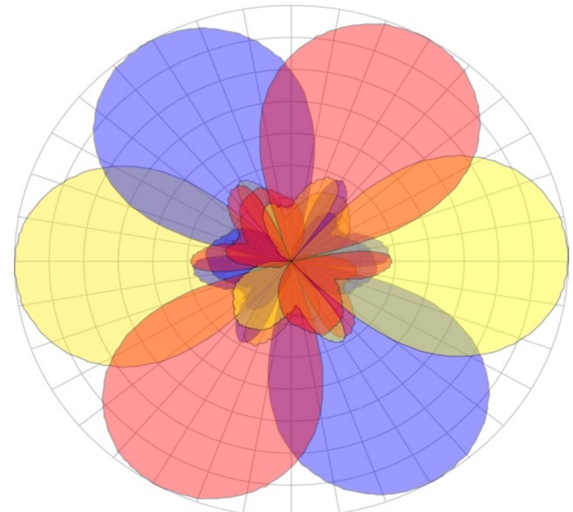
- Large areas of intersector overlap
- Small area of between sector null

60° Sectors



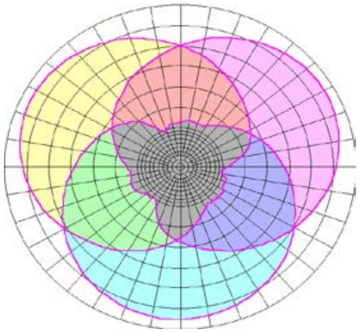
- Reduced area of intersector overlap
- Larger area of between sector null

30° Sectors



- Significant reduction of intersector overlap
- Larger nulls
- More difficult commercial deployment

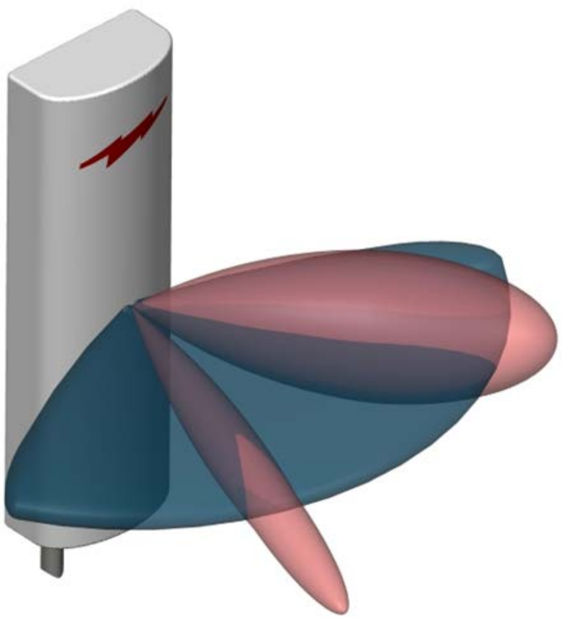
Capacity Improvements Enabled By Base Station Antennas

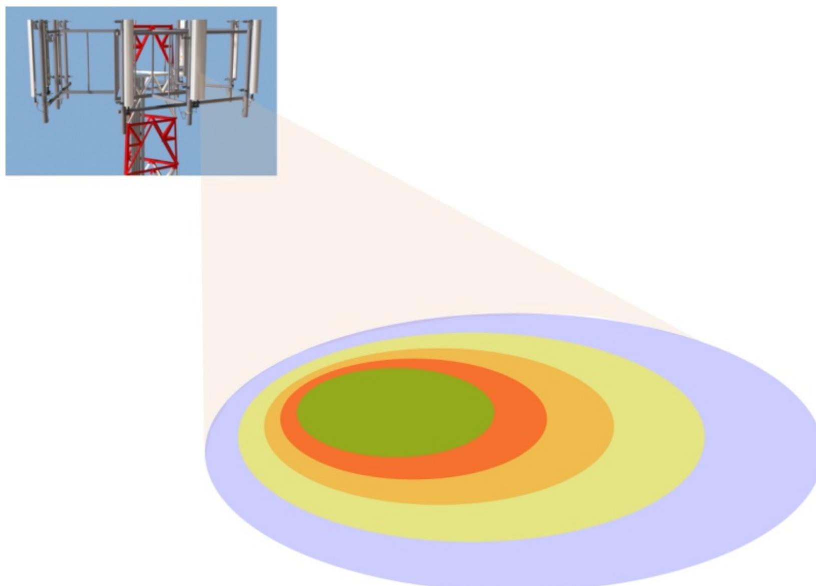


- Improved, tighter RF containment in the Az plane
- Precise pattern control in the El plane
- Excellent suppression of intermodulation
- Agility and flexibility in real time

With Features such as

- RET(Remote Electronic Tilting) enabled
- Various degrees of beam steering





The Mobile Station

- It contains a control unit, a transmitter/receiver and an 'omni-directional' antenna
- It transmits and receives control and traffic signals
- Its Electronic Serial Number(ESN: 32-bit binary stored in ROM at time of manufacture) may be used as protection against stealing or misuse
- Each mobile station has a Mobile Identification Number(MIN: directory number assigned by operating company)
  - identifies uniquely the mobile station inside the cellular system

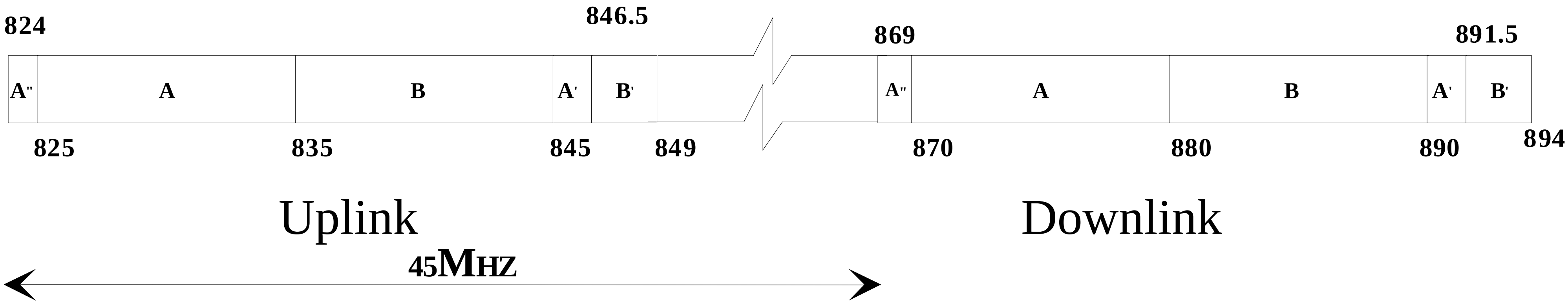
Channels and Spectrum

- The cellular system is fully automated, the user takes no action other than placing or answering a call
- Two types of channels are available between the mobile station and the base station
- Control Channels (Digital – FSK)
  - used to exchange system information (identify mobile stations, grant traffic channels, synchronisation, handoff, etc.)
  - *forward control channel* (FOCC)
  - *reverse control channel* (RECC)
    - also called *access channel*
- Traffic Channels (Analog – FM)
  - Carry a voice or data connection between users
  - *forward traffic channel (FTC)*
  - *reverse traffic channel (RTC)*

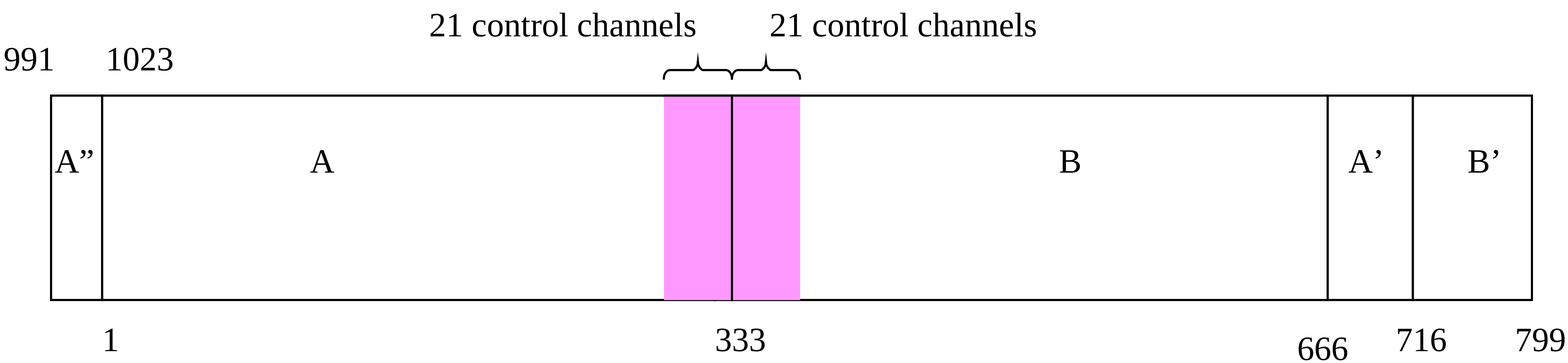
AMPS Spectrum Allocation

- Cellular communication is full-duplex/FDD
- The frequency band is divided between both communication paths
  - 25 MHz is allocated to the *forward path* or *downlink,* which is the path from the base station transmitter towards the mobile terminal receiver
  - 25 MHz is allocated to the *uplink* or *reverse path* in the opposite direction
- The paths are separated by a 45 MHz guard band in order to avoid interference between the transmission and reception channels.
- The frequency band is also divided into A band and B band among two service providers. Each has 25MHz bandwidth.

AMPS Spectrum Allocation



- Bands are divided into 30kHz channels
  - 333 channels per band: (A:1-33) and(B: 334-666) in the Non Expanded Spectrum (NES)
  - 83 channels per band: (A':667-716)+(A":991-1023) and (B':717-799) in the Expanded Spectrum (ES)



AMPS Channel Allocation

- The frequency allocation is related to the number of the channel. The top end frequency of the band is:
  - Dowlink Frequency = (0.03N +870) MHz (N < 800)
    or 0.03(N − 1023) + 870 MHz (N > 990)
  - Uplink Frequency = (0.03N + 825) MHz (N < 800)
    or 0.03(N−1023) + 825 MHZ (N > 990)
    - Where N is the channel number (N = 1,2,3 ..., 1023)

AMPS Channel Allocation Examples

To find the band of following channel pair

- For the channel pair number 6:

– Dowlink Frequency = (0.03x6 +870) MHz = 870.18 MHz ($N < 800$)

– Uplink Frequency = (0.03x6 + 825) MHz = 825.18 MHz ($N < 800$)

  - Channel 6 will occupy a band from 870.15 to 870.18 (downlink)
  - Channel 6 will occupy a band from 825.15 to 825.18 (uplink)

- For the channel pair number 995:

– Dowlink Frequency = 0.03(995 –1023) + 870 MHz = 869.16 MHz ($N > 990$)

– Uplink Frequency = 0.03(995 –1023) + 825 MHZ = 824.16 MHz ($N > 990$)

  - Channel 995 will occupy a band from 869.13 to 869.16 (downlink)
  - Channel 995 will occupy a band from 824.13 to 824.16 (uplink)

Class Quiz

- Why is the cellular architecture invented?
- How does the cellular network work?
- How is AMPS channel allocated?

Reading References

- [Far96] Saleh Faruque. Cellular Mobile Systems Engineering. *Mobile Communication Series*. Artech House Publishers. ISBN 0-89006-518-7.1996.
- [Lee 95] William C. Y. Lee. Mobile Cellular Telecommunications: Analog and Digital Systems. Second Edition. McGraw-Hill, Inc. ISBN 0-07-038089-9. 1995.
- [PK] Kaveh Pahlavan and Prashant Krishnamurthy. Principles of Wireless Networks. *Prentice Hall*. ISBN 0-13-093003-2, 2002.
- [Mac 79] V. H. Mac Donald. Advanced Mobile Phone Service: The Cellular Concept. *The Bell System Technical Journal*, volume 58, number 1, pages 15-41, January 1979.
- [WS] William Stallings. Wireless Communications and Networks. *Prentice Hall*. ISBN 0-13-040864-6, 2002.