Chapter-4

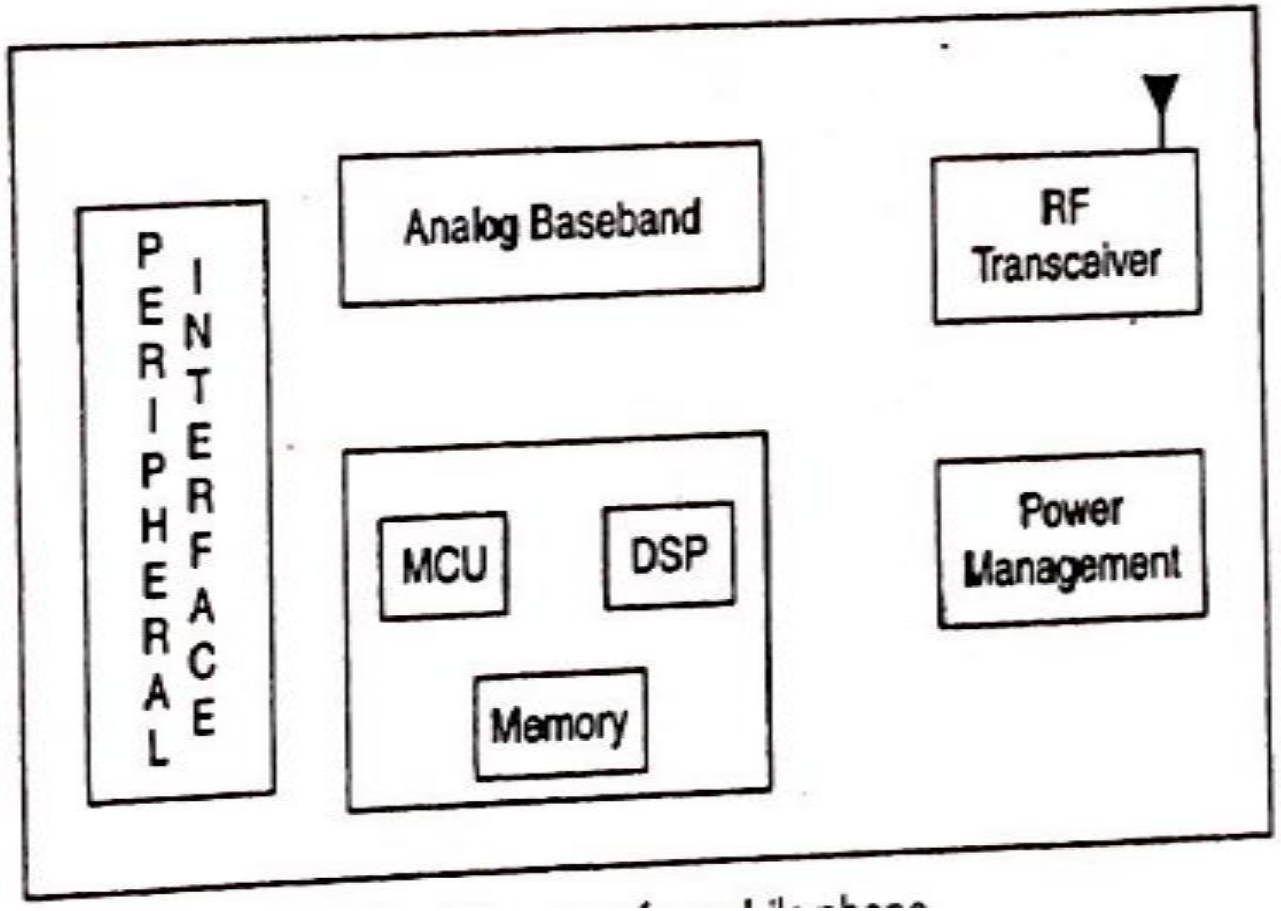
Examples of Embedded Systems

Mobile Phone

- There was a time when mobile phone only had monochromic LCD displays and provide only functions like making calls and texting.
- Today, mobile phones are much more advanced with bright and colorful displays, touch screens and are capable of audio and video processing applications. All this is due to evolution of modern day embedded processors which have powerful processing capabilities and at very high clock rates.

Different Cell Phones

Block Diagram



Block Diagram

- **Central Processing Block:** consist of MCU, DSP and memory. It forms the embedded processor of a mobile phone.
- **RF transceiver:** consisting of RF modem, transmitter, synthesizer and receiver. It uses
  - **low noise amplifier** for boosting signals and
  - **antenna** for transmitting and receiving

Block Diagram

- **Power Management Block** take care of all power related issues of the device.
- **Analog Baseband Block** is responsible for dealing with analog signals coming from microphone and going to speaker.
- **Display:** consists of LCDs, LEDs and other such hardware.
- **Peripheral Interface:** consists of USB port, audio Jack, etc. which facilitates the connection of peripherals to the phone.

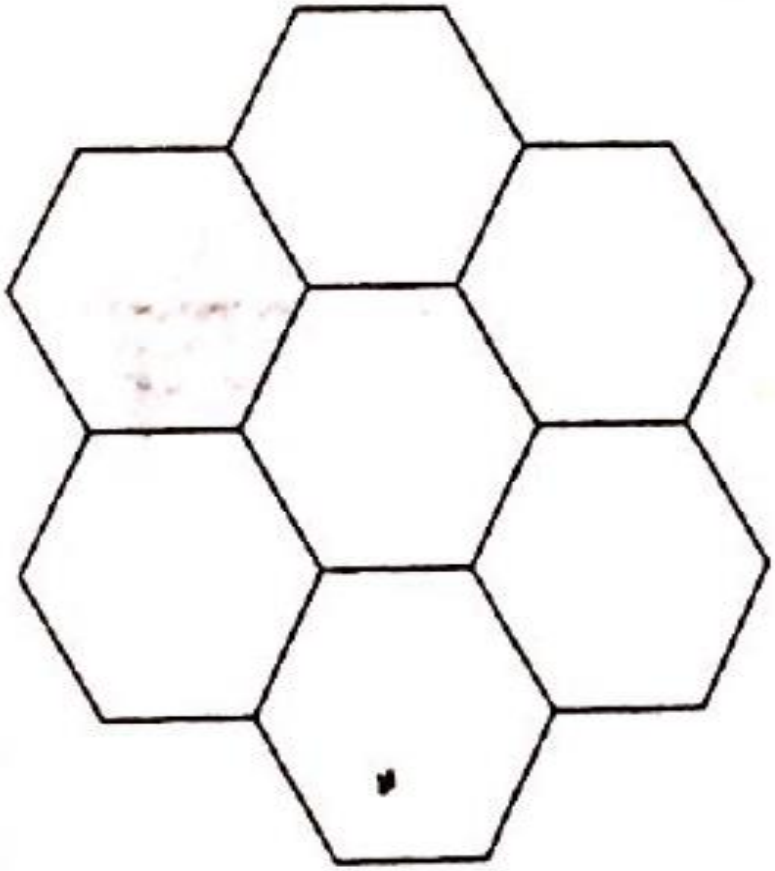
Central Processing Block

- Consists of ARM core based general purpose processors and some co-processor which take care of signal processing.
- The processors use in today's smart phone powerful enough to run operating systems like Linux, Android etc.
- Some of popular processors used in mobile phones are Texas Instruments's OMAP, Samsung's Exynos, Qualcomm's Snapdragon, Apple Inc 's Ax series and Nvidia's Tegra Platform.

Cellular Concept

- The area over which the network has coverage is divided into sub-units called cells. The sub-units are of particular shape –hexagon, square, circle etc.
- Usually hexagonal cells are used. Each cell has a centrally located base station controller which is responsible for handling calls.
- A group of base stations are controlled by a mobile switching center.

Cellular Concept



Multiple Access

- In communication, The same channel is shared by many transmitters for transmitting their messages.
- Types of shared medium access are
  - **FDMA:** each user is allocated a single distinct central frequency with a certain bandwidth around it(for all the time).
  - **TDMA:** Each user is allocated a single time slot during which user can use all the available bandwidth.

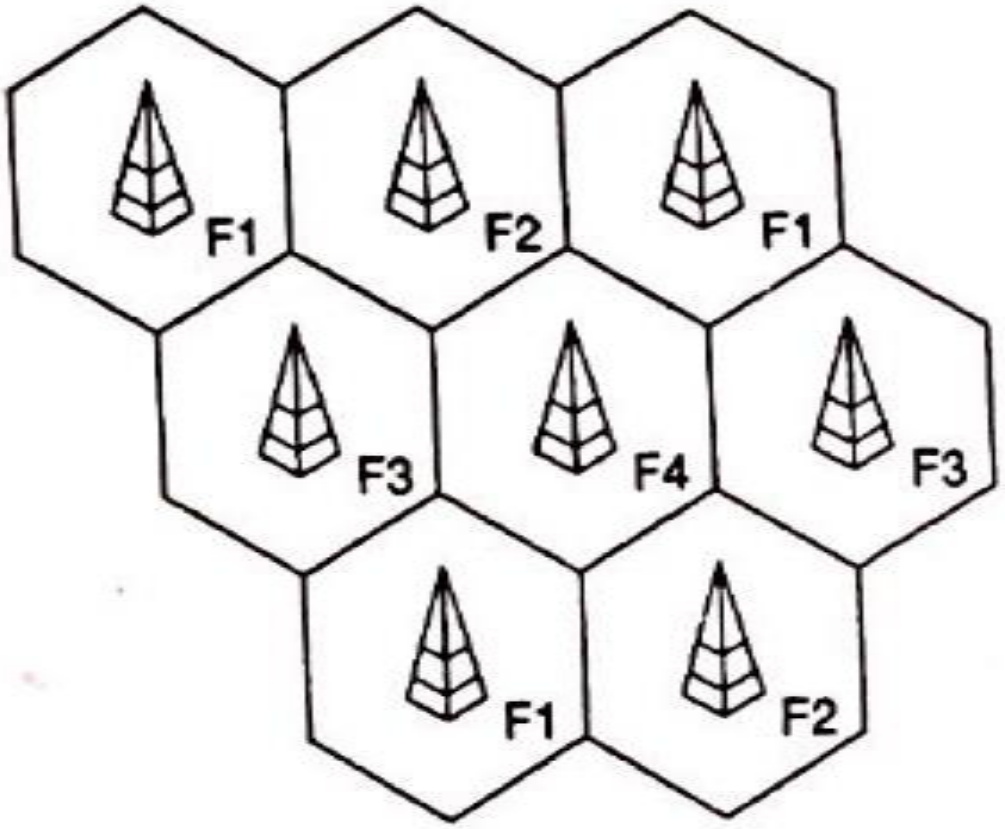
Multiple Access

- Today's cellular networks use combination of FDMA and TDMA.
  - Usually there are multiple antennas in a base station.
  - Each of the antenna will have transceiver units.
  - Each of the transceiver units is assigned a frequency .
  - Each of the frequency channel is divided into timeslots.
  - When a person makes a call using his cell phone , the call is handled by the nearest base station .

Multiple Access

- The call is assigned a time slot on one of the frequency on one of the antenna.
- the call gets connected to the PSTN or another base station depending on whether call is made to landline telephone or another mobile phone.

Frequency Re-use



Frequency Re-use

- As power of signal varies inversely with square of the distance from signal source, signal transmitted by base station dies out after a certain distance.
- This allows us to use the same frequency for two other base stations which are at a minimum distance from each other. This is called frequency re-use.

Frequency Re-use

- This may not possible for two adjacent base stations as there might be locations where signals from both base stations arrive with power generated greater than power required. This type of interference is called co-channel interference. This is prevented by utilizing frequency re-use only after a certain minimum distance.
- with a couple of frequencies, a service provider can provide coverage to large area using frequency re-use.

Hand- off

- Consider a person is talking on the phone and is travelling. If he moves out of the cell one would expect the call to be dropped by the base station.
- Handoff is used to take care of this situation and ensure that the call is not dropped.
- The base station near the previous position of the person will communicate with the base station near the new position of the person, and effectively handover the call to new base station.

Spread Spectrum Techniques

- Signals which are limited to a certain bandwidth are spread across a wider band width.

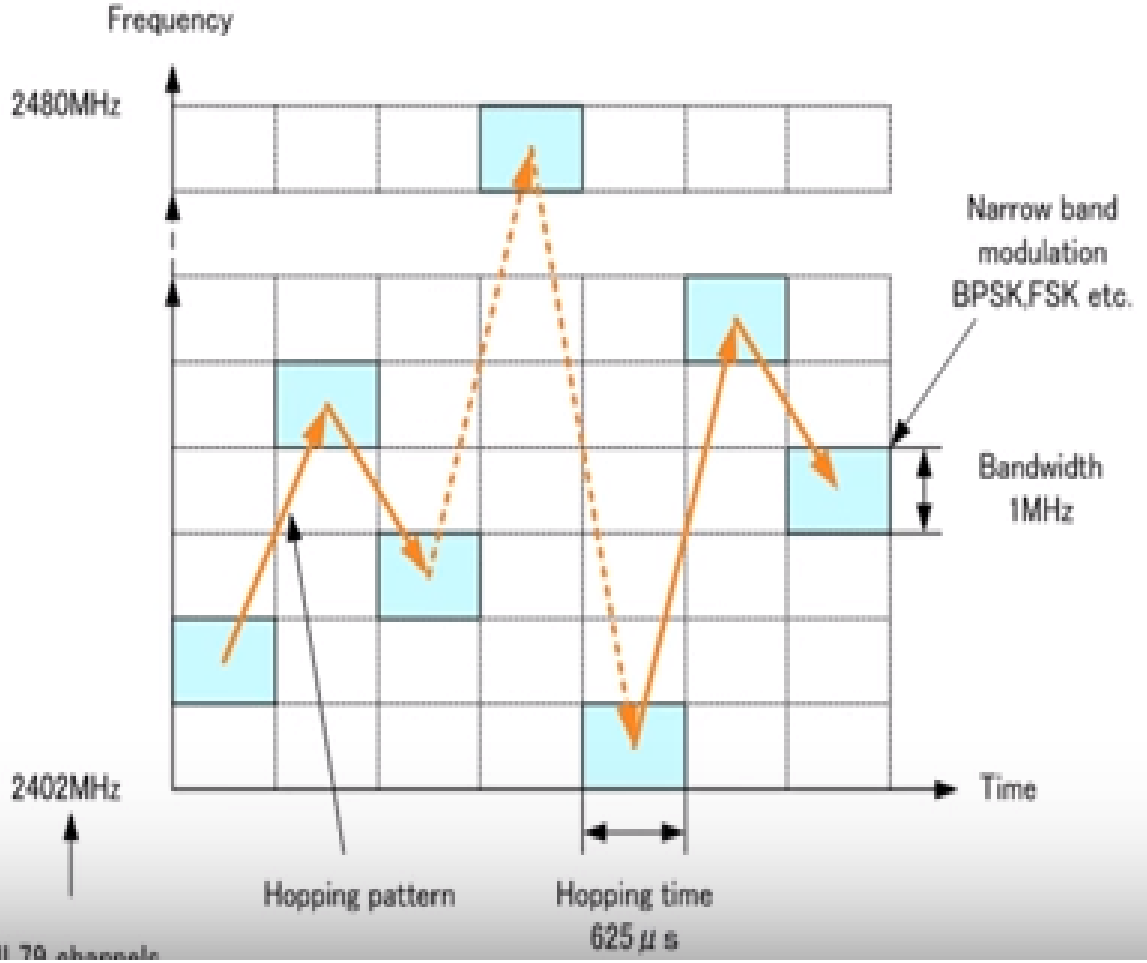
Types of spread spectrum

- **Frequency hoping Spread spectrum**: It is a technique in which the frequency assigned to the base station is changed frequently among a set of frequencies . The switching of frequencies is done according to pseudo-random sequence known only to sender and receiver.

Sender don't use single frequency to transmit data. Multiple frequency is used for transmission.

Sender send data using frequency f1 for 625 micro second and then change frequency.

Different-2 sender use different-2 frequency patter.



Let's say sender A want to send some data. Hopping sequence for A is F1,F5,F3,F8

Spread Spectrum Techniques

- **Direct Sequence Spread Spectrum :** The signal is multiplied by a pseudo-random sequence which is known only to the sender and the receiver.
- At the receiver side, the correlation of received signal with pseudo-random is determined to demodulate the signal. This process is known as de- spreading and it relies on orthogonality of pseudo-random sequences. This is basis for CDMA.

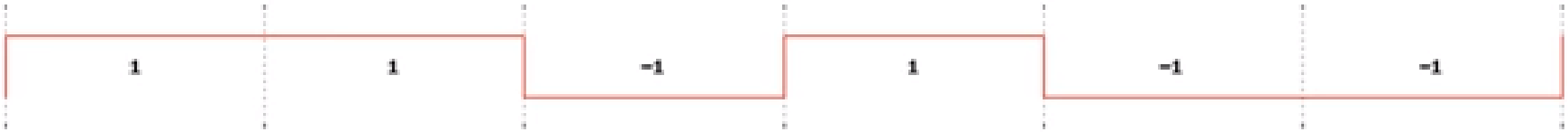
Direct Sequence Spread Spectrum

For the duration of every message bit, the carrier is modulated following a specific sequence of bits (known as chips). The process is known as "chipping" and results in the substitution of every message bit by (same) sequence of chips.

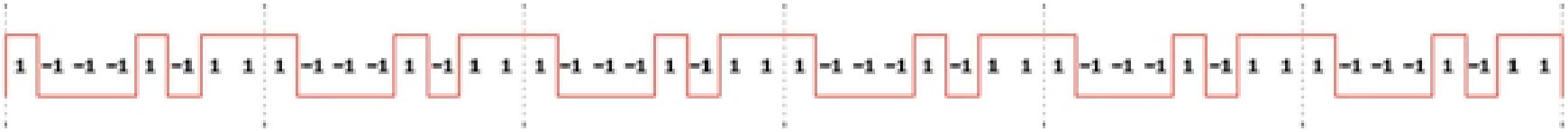
Spreading code example (100101)
0 is represented as -1
Spreading code is now (1,-1,-1,1,-1,1)

Direct Sequence Spread Spectrum

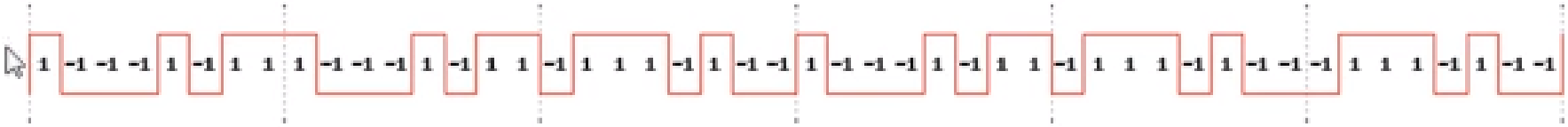
Low-Bandwidth Signal:



High-Bandwidth Spreading Code:

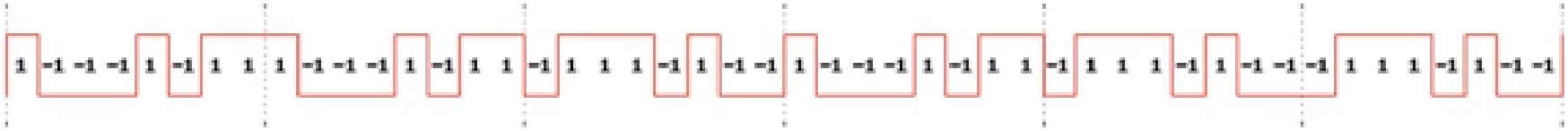


Mix is a simple multiply

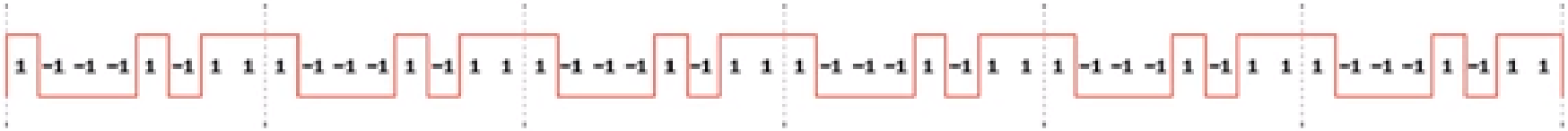


DSSS

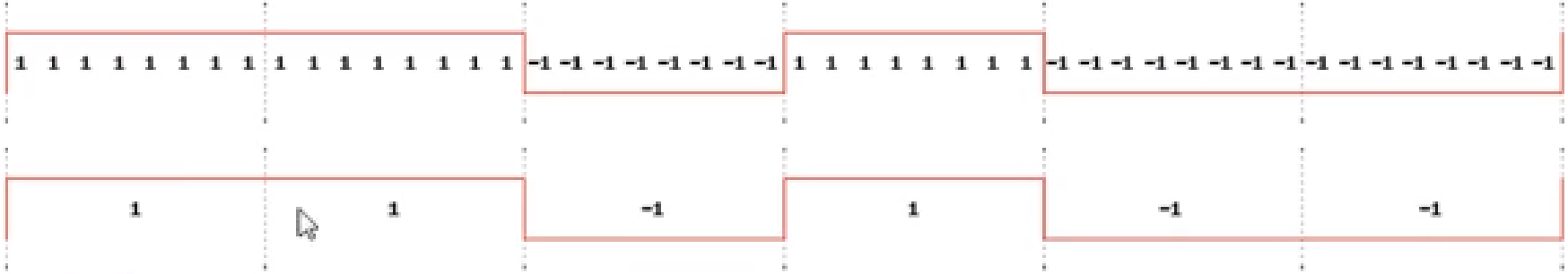
To Decode / Receive, take the signal:



Multiply by the **same** Spreading Code:



… to get …



Advantages

- **Narrow Interference**: Consider the case when there is some interference around a certain frequency. If the frequency allotted to all the base stations are fixed, the base station allotted this particular frequency will have same value of interference.
- If the frequencies are switched from time to time this narrowband interference gets averaged over all the base stations and hence each of the base station receives only a small amount of interference. This is known as spread spectrum technique. This helps to take care of jamming noise.

Advantages

- **Eaves dropping**: The frequency switching take place according to a pseudo- random sequence known only to sender and receiver.

Third person eavesdropping on communication is impossible without knowing the pseudo random sequence. This helps in making communication secure.

Set Up and Maintenance

- It is an extensive and complicated process.
- Mobile service providers outsource the engineering aspects of their mobile networks to telecommunication companies like Ericsson, Nokia-Siemens, huawei etc. Companies are responsible for setting up BSCs, MSCs, user databases etc.

Conclusion

- The modern mobile phone is no longer ‘just a phone’. Multitudes of applications run on it and many important aspects of life banking, for instance , find mobile phone and mobile communication to be safe and secure. The future will definitely bring many more solutions to be handled by mobile phones.

Automotive electronics

- The earlier electronic equipments to be used in automobiles were AM radios and 2-way radios.
- With invention of IC , there are major developments in the field of automotive electronics.

Automotive electronics

- Electronic systems today are involved in almost every aspect of the car. They are used for
- safety purposes
- Better driving comforts
- Fuel usage efficiency
- The industry is constantly driven by consumer demand and, great deal of advancement is still happening in this field.

Automotive electronics

- The electronic system inside an automobile are controlled by electronic control units.
- There are about 50 to 100 ECUs in modern car. These ECU mainly consists of a microprocessor and necessary software stored on EEPROM.
- Any faulty or delayed reading can potentially harm passengers of the automobile, the sensor inputs are processed in real time. Os assigns hard deadlines to the applications.

Electronic fuel Injection

- EFI is a mechanism for regulating amount of fuel supplied to the engine for combustion.
- Prior to development, it was done by a carburetor and a floating mechanism.
- The floating mechanism would regulate amount of fuel supplied to engine.
- The carburetor would evaporate the fuel so that it mixes with air for combustion.

Electronic fuel Injection

- EFI mechanism on the other hand measures the fuel through a tiny nozzle under high pressure to atomize it.
- It gives only proper amount of fuel needed for engine.

Advantages of EFI over carburetor

- EFI prevents the flooding of engine by not allowing too much fuel into the engine.
- EFI is more efficient and emission- friendly.
- With EFI, same hardware can be used for diesel and petrol engines, which is not in case of carburetors

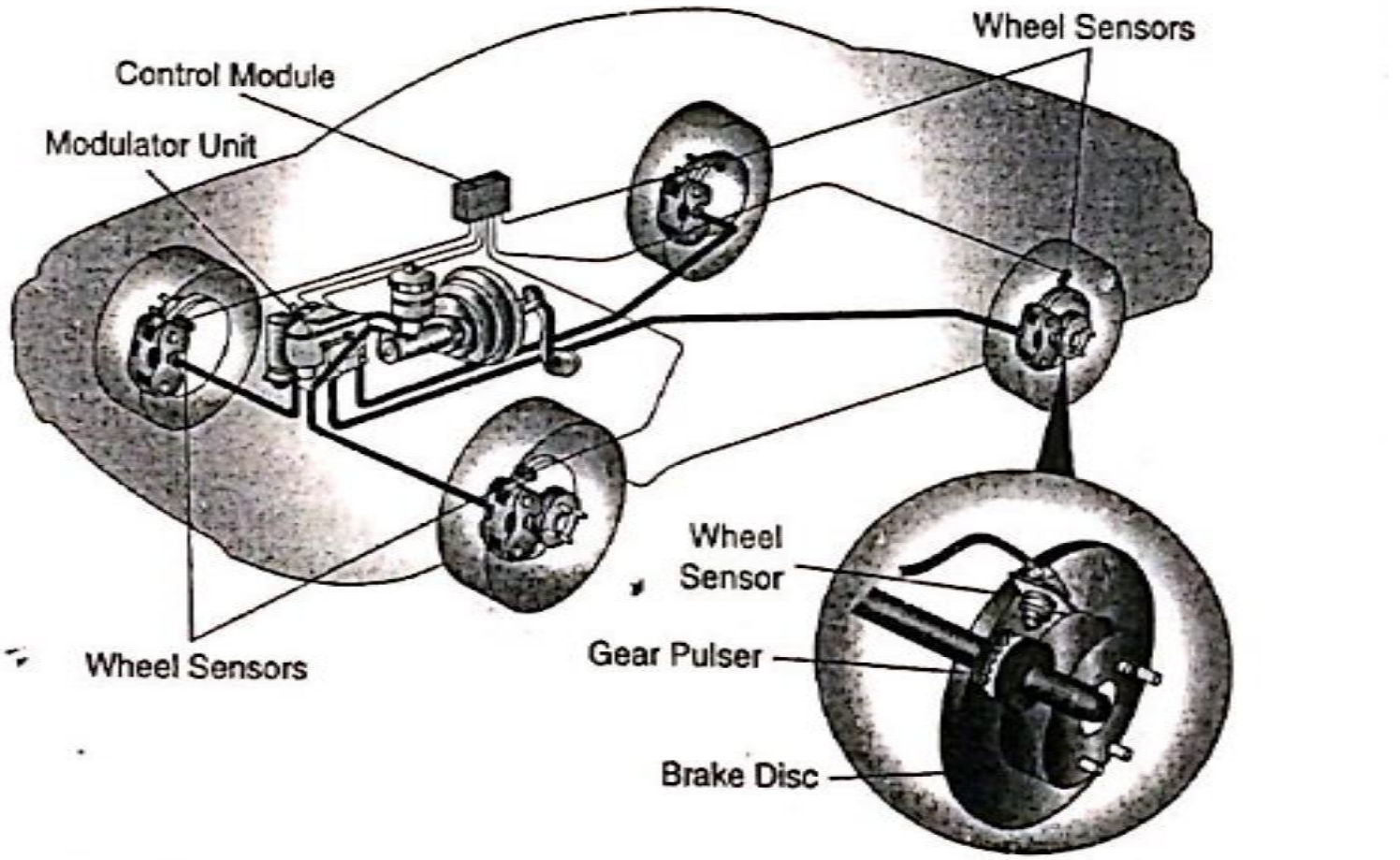
Anti-lock Braking System(ABS)

- ABS is mechanism to prevent skidding due to locking up of wheels.
- Consider a situation in which vehicle is moving at a high speed and is suddenly confronted by an obstacle in its path.
- In a moment of panic, the driver applies a full brakes and turns the steering with the intention of turning the vehicle away from the obstacle.

Anti-lock Braking System(ABS)

- As driver applied full brakes , the wheels are locked up and skidding on the road.
- As a result, wheels does not change direction but skids in direction of obstacle.
- An ABS consists of ECU, wheel sensors and hydraulic brakes.

Anti-lock Braking System(ABS)



Anti-lock Braking System(ABS)

- The wheel sensors inform ECU about the speed of wheels. The speed of wheels relative to each other is important and hence differentials are analyzed.
- Whenever a wheel is moving significantly slower or faster than other wheels, ABS applies hydraulic brakes appropriately.
- If one wheel is moving faster than other wheels, ABS increases the brakes applied on this wheel and if one is moving slower ABS decreases brakes applied on wheels.

Anti-lock Braking System(ABS)

- After few accelerations and decelerations all wheels having same speed
- Main advantage of ABS is that
- it prevents wheel locks-up and hence gives driver steering control, even after application of full brake. Reduces risk of accident
- ABS added advantage of less braking distance as compared to vehicles without ABS
- Braking distance also depends on road conditions.

Electronic Stability Control

- It provides driver better control of vehicle. It has wheel sensors and braking mechanisms similar to ABS. It also has a steering wheel orientation sensor and gyroscopic sensor.
- The gyroscopic sensor detects directional changes of the vehicle.
- ECU of ESC checks if vehicle is moving in direction the driver intends to move , whether the gyroscopic sensor senses the vehicle in direction of steering wheel orientation or not.

Electronic Stability Control

- If they agree with each other , ESC does not intervene.
- If they donot match, the ESC applies brakes appropriately on wheels so that vehicle moves in the direction intended by driver. ESC work on any surface.

Adaptive Cruise control

- Cruise control is mechanism in which vehicle speed is maintained at constant value without driver having to keep his foot on accelerator pedal.
- This can be useful for drivers while driving through highways with low traffic levels.
- ordinary cruise control is not very useful in significant amount of traffic

Adaptive Cruise control

- Modern mechanism take into account other vehicles in front of them. These mechanisms are called adaptive cruise control mechanisms.
- Adaptive cruise control units consists of ECU, RADAR. When there is no vehicle in front, adaptive cruise control behaves like normal cruise control . when there is a vehicle in front adaptive cruise control comes into play

Adaptive Cruise control

- With the help of RADAR sensor, ECU measures the speed and distance of vehicle ahead and accordingly accelerates or decelerates. ‘this ensures that the vehicle is at safe distance from vehicle in front.
- Another type of cruise control called ‘**hill descent control**’ helps the driver descending down hilly roads in difficult terrain. The control mechanism applies brakes appropriately to drive downhill without the driver having to apply brakes.

Airbag deployment

- Airbag are to be deployed whenever there is an automobile collision . They prevent the passengers in the vehicle from hitting inside of car-window , dash board etc.
- this mechanism make use of speed sensors and impact sensors. Whenever there is a sudden decrease in speed of vehicle in very small amount of time, large amount of deceleration , it indicates a collision. The impact sensor may also report a collision. In either case the ECU actuates

Airbag deployment

- The ignition of a gas generator. This gas is nitrogen which then inflates a nylon fabric bag. The airbags thus deployed preventing injury.

Automatic Navigation System

- It provides a lot of useful information to the driver. It provide real-time information about routes, traffic congestion etc.
- These system consist of ECU, gyroscopic sensor and GPS.
- GPS makes use of satellites in space to triangulate the position of vehicle.
- The gyroscopic sensor is used to detect the direction in which vehicle has turned.

Automatic Navigation System

- These system also provide details about driving restrictions signboards, nearby fuel stations etc.
- the current position of vehicle is known to ECU using GPS.
- The software has knowledge of all routes. When use enters the destination details into system using the user interface, the ECU finds the shortest path from current point to destination.
- once the driver has selected the route it shows the driver the path to be taken and also informs the driver when and where the turn is to be taken.

Automatic Navigation System

- If driver takes wrong turn, the system recalculates and finds the shortest route from point to the destination
- The modern version of navigation system also show traffic details. These details are usually communicated in real-time to navigation system using blue tooth or such wireless communication protocols.

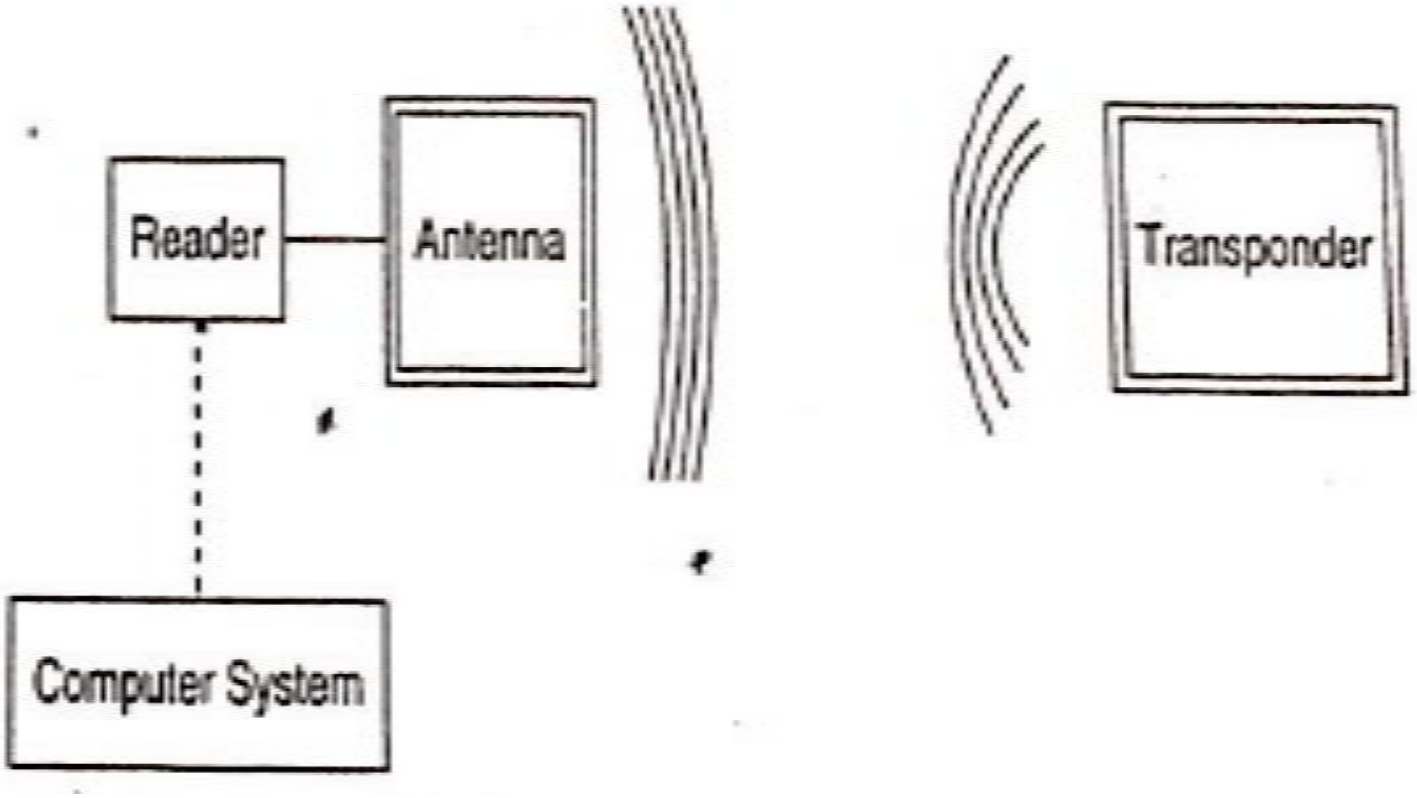
Automatic Navigation System

- High end cars have electronic controls for almost everything right from door locking to engine starting key.
- The no. of processors used in S class Mecedes Benz is likely to be, more than 100. these processor circuits are interconnected by buses like CAN, LIN, MOST and flex-Ray. Automobile industry is one of biggest users of embedded system.

Radio Frequency Identification(RFID)

- Radio frequency identification is method of identifying, tracking or verifying objects/ persons with help of electronic tags are capable of receiving and transmitting radio frequencies and are called RFID tags or RFID labels. The ID information from these tags is obtained using RFID readers.
- The system consists of a reader, tag and antenna.

Radio Frequency Identification(RFID)



Radio Frequency Identification(RFID)

- Each RFID tag consists of a transmitter and receiver called a transponder because it ‘transmits and responds’ .
- The RFID transmits a signal to interrogate the tag. The tag receives the signal and responds by transmitting its identity information.
- The system then takes action based on this information.

Radio Frequency Identification(RFID)

- The action may be simply to display a number / name on a handheld device, or it may be the information is passed on to a system for authentication/counting of a person etc.
- Three general bands:
- Low Frequency from 125 KHz to 134 KHz
- High Frequency at 13.56MHz
- Ultra High frequency 860 to 930 MHz

Radio Frequency Identification(RFID)

Frequency use depends on

- Regulations in particular country
- Frequency band also influences the practical size of antenna and power transmission that can be used.

RFID Architecture

RFID TAG:

- Transponder –a combination of transmitter and receiver, which is designed to receive a specific radio signal and automatically transmit a reply.
- Transponder listens for a radio signal and sends a signal of its own as a reply.
- More complicated system may send a letter or digit back to the source .

RFID Tag

- Advanced system do a calculation or verification and include encryption to prevent eavesdroppers from obtaining information being transmitted.
- RFID tag consists of
  - Encoding/Decoding circuitry
  - Memory
  - Antenna
  - Power Supply
  - Communication Control

RFID TAG

- A tag can take almost any physical form like cards, keys, rods etc. as desired to perform the required function.
- Design may be influenced by type of antenna which may be dependent on frequency used for the system.

RFID advantages over barcode

- RFID can be used to read multiple tags at a time where as bar code can read only one item at time
- RFID tags can be read even if the tagged object is inside a box or a cover, or other situation when there is no line of sight. Barcode requires the code to be scanned in line of the sight.

RFID tag types

- Two types:
- Active: The active tags need a battery for power
- Passive: make use of power of signal transmitted by the RFID reader.
- This prevents unnecessary power wastage during idle hours.

RFID Reader

- Transceiver: transmitter plus receiver
- Named reader by virtue of its function of querying the tag and reading data from it.
- Handheld systems have reader and its antenna together as one unit, while larger systems usually separate antenna from the reader.

RFID Reader

Consists of :

- A system interface such as RS-232 serial port or Ethernet Jack
- Cryptographic encoding or decoding circuitry
- A power supply or battery
- A communication control circuit

RFID Applications

- Supply-chain product tracking
- Season parking tickets
- Toll booths
- Transportation Services
- Public Transit(metro, railway etc.)
- Hospitals and museums
- Person Authentication

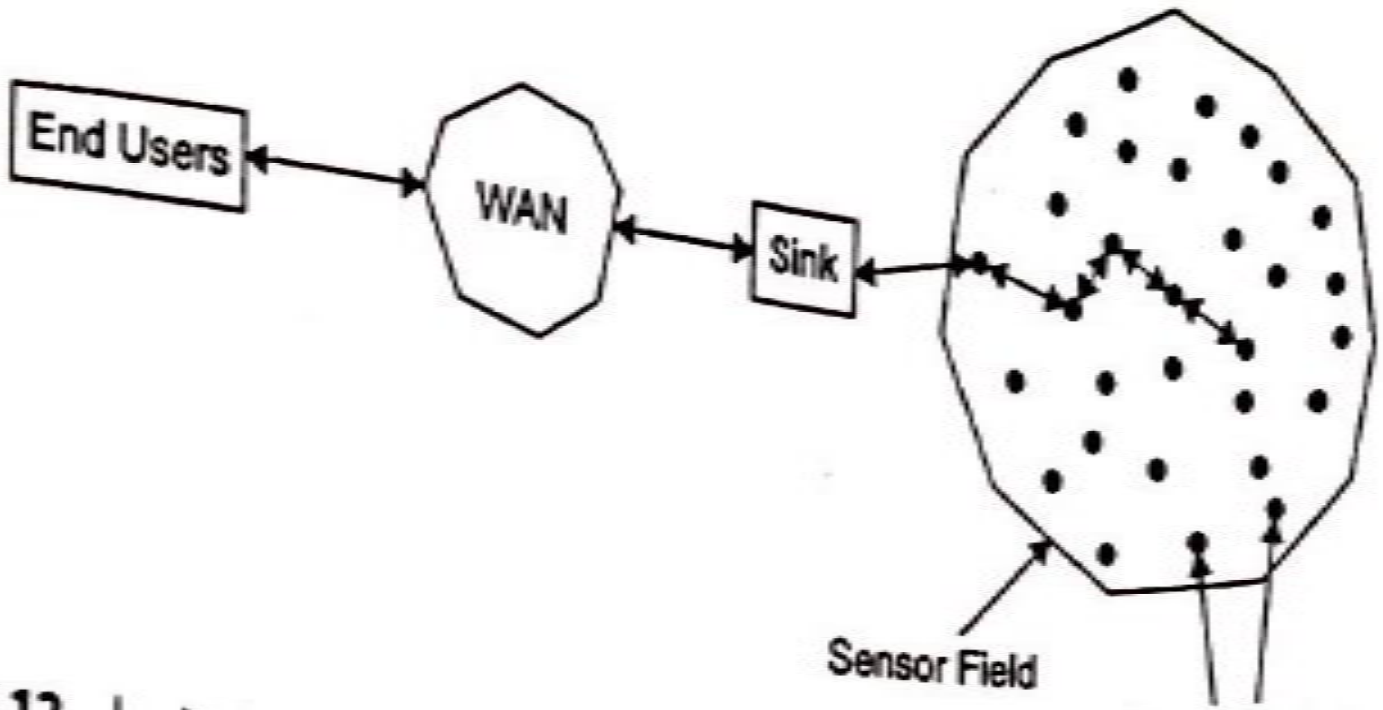
RFID

- The reader receives the information from RFID tag. The reader may be self- contained and may store information internally, But it my be part of localized system such as an authentication system or large local area network(LAN) or wide area network (WAN). Readers that send data to a LAN, do so by using a data interface such as Ethernet or RS-232.

Wireless Sensor Network(WISENET)

- A wireless network consisting of sensors meant for monitoring environmental conditions like temperature, pressure, humidity, level of gases etc.
- They can also be used for auditory or visual monitoring. This information is then transmitted to main database. These networks are of great use in monitoring environmental conditions in places which are not easily accessible.

Wireless Sensor Network(WISENET)



e 4.12 | A wireless sensor network

Wireless Sensor Network(WISENET)

- A WISENET node consists of a
  - wireless transceiver,
  - antenna,
  - microcontroller and battery.
- The nodes communicate with each other and information finally reaches the sink node.
- The sink node connected to WAN and hence reaches the end user.
- WISENET uses ZigBee and IEEE 802.15.4.

Wireless Sensor Network(WISENET)

- The algorithms used in WISENET such that it minimizes the power consumption.
- First operating system specially designed for WSN is TinyOS
- As software is mainly responsible only for processing the sensor reading and transmitting the data packets, it need not to be functioning all the time.
- TinyOS makes use of event- driven programming.

Wireless Sensor Network(WISENET)

- There are event handlers associated with each task.
- Whenever an event comes up, OS assigns the event handler to handle the task.

Applications

Vehicle Tracking

Energy Monitoring

Robotics

- It is field of design and development of devices which can perform tasks on their own or with guidance.
- The devices which perform these tasks are called robots.
- Robots are subset of embedded systems. A robot is mechanical system which has a sense of purpose.

A typical robot can

- Can sense its environment
- Can manipulate things in its environment
- Has intelligence embedded in it
- Has motion or translation in one or more axes

The working of robot

- Three main phases:

Perception: obtaining information about the environment. This is done by sensors.

E.g. vision, sound etc.

Processing: The processor processes the input data from the sensor and generates the necessary control signals to be sent to actuators which executes the necessary actions.

The working of robot

- **Action:** Implementation of commands given by the processor.

e.g. motor, video, sound etc.

Sensors

Some of sensors used by robots are

- **Vision:** robotic vision is mainly computer vision captured using CMOS and CCD(charged Couple Device) array . The pixel information of the image is then processed by the processor.
- **Sound:** Robots which respond to audio signals have a microphone to gather input data which is processed by processor. Highly efficient algorithms have been developed for speech recognition applications.

Sensors

- **Tactile sensors:**

Robots which responds to touch, make use of tactile sensors for input data. These sensors have certain impedance measuring devices which helps in detecting tactile information.

Actuators

Actuators used by robots are;

- **Motors:** Motors are used to do mechanical functions like turning wheels, pumping water, move in any direction etc.
- **Video and audio:** Robots can also provide visual and auditory data using LCD displays and speakers respectively.

Embedded Intelligence

- All robots have some degree of intelligence attached to it. The intelligence to be embedded in a robot depends on its intended application as well as on degree of sophistication and precision to which it is to perform.

e.g. Mobile Robot

To perform its intended applications it needs

- Sensors to sense its environment and to move accordingly
- Actuators for performing the movement, and the assigned task
- A control algorithm for moving and performing the intended task
- Communication system(optional, depending on application)

Types of Robots

- **Stationary robots** are stationary as a whole but have moving parts like a robotic arm . Such arm used for picking up objects like and /or perform similar activities.
- **Mobile robots:** have capability to move around in their environment and are not fixed to one physical location.
- **Humanoid robots** are those which have an appearance similar to human beings

Open loop and closed loop System

- Open loop System:

Action phase is executed based on perception phase but perception phase is not influenced by action phase.

Eg consider a robot which translates from English to French. It has microphone as sensor and speaker as actuators. The robot takes in data in English via microphone, translate it using its processor and gives the output in French via speaker.

Closed loop system

- Perception phase is also made dependent on previous action phase, the loop becomes closed and hence there is feed back mechanism in the system.
- E.g. consider a mobile robot which follows a red-colored ball. It has a video camera as a sensor and motor as actuator to drive its wheels.
- The robot takes in visual data via camera, finds location of red-ball using the algorithm burned in the processor and turns the wheel in such a way that robot is still following the ball.

Closed loop system

- The simplest algo would be to ensure that the ball is always at the center of image captured by the camera. Whenever the ball moves away from the center, the current image seen by the robot(current ‘perception’ phase) is dependent on the direction in which the robot moved in the previous instant(previous ‘action’ phase) .

Designing an autonomous Robotic System

- An autonomous robot can perform task in unstructured environments without continuous human guidance.
- Different robots can be autonomous in different ways. An autonomous robot is an assembly of mechanical and electronic elements with artificial intelligence embedded in it.

Designing an autonomous Robotic System

- The mechanical structure of a robot must be controlled to perform tasks. The control of a robot involves various aspects such as path planning, pattern recognition, obstacle avoidance etc.

Steps for Designing an autonomous Robotic System

- Identify various cost-effective applications
- Study various algorithm which can perform this job efficiently
- Test the chosen algorithm using modeling techniques
- Design the hardware and software
- Choose the right sensors and actuators
- Integrate the whole system and test it

Biomedical Applications

Embedded systems are being used in a variety of medical applications.

- **X-ray:** X-ray machines used to be analog devices. The x-rays generated from source are projected on to a film sensitive to a radiation after passing it through the body part to be examined. Earlier film had to be developed to obtain the image.

Biomedical Applications

- In digital x-ray machines Flat Panel Detector sensors replace the film. The analog output of sensors are amplified and fed to ADCs which convert them into digital codes and pass it on to digital modules which process the information and generate the image from it.

MRI(Magnetic Resonance Imaging)

- Here magnetic waves generated by nuclei immersed in a strong magnetic field and disturbed by RF pulse at their resonant frequency. This is sensed by coils and this information is processed to obtain the information.

Biomedical Applications

- CT(computed Tomography): uses x-rays to generate 3D images of body by rotating sensor-detector pair around the body and taking multiple images at various angles.
- Pulse oximetry: Red and Infrared light is passed through user's finger or earlobe and transmitted light is sensed and processed to obtain information about oxygen content in the blood and pulse rate.

Blood Glucose measurement

- A drop of blood is placed on special strip and strip is loaded into a device. The device applies various electrical inputs to strip and measures some quantity like charge passed through strip or its resistance to measure glucose level in blood.

Pedometer

- Devices that can be embedded in special purpose shoes or carried /worn by the user can count the number of footsteps.
- This can be used by athletes to monitor their performance. Such devices might use accelerator or pressure sensors to obtain the input signal, which is then filtered and processed to give the required information.

Biomedical Applications

- **Wearable Medical devices**: Compact light weight systems that can monitor important health parameters and transmit them for observation are being developed.
- **Emergency Alert System:** Systems are available that can monitor vital characteristics of person and alert others in case of a problem.

Useful incase of elderly and infirm who are prone to dangers like falling or conditions like cardiac arrest.

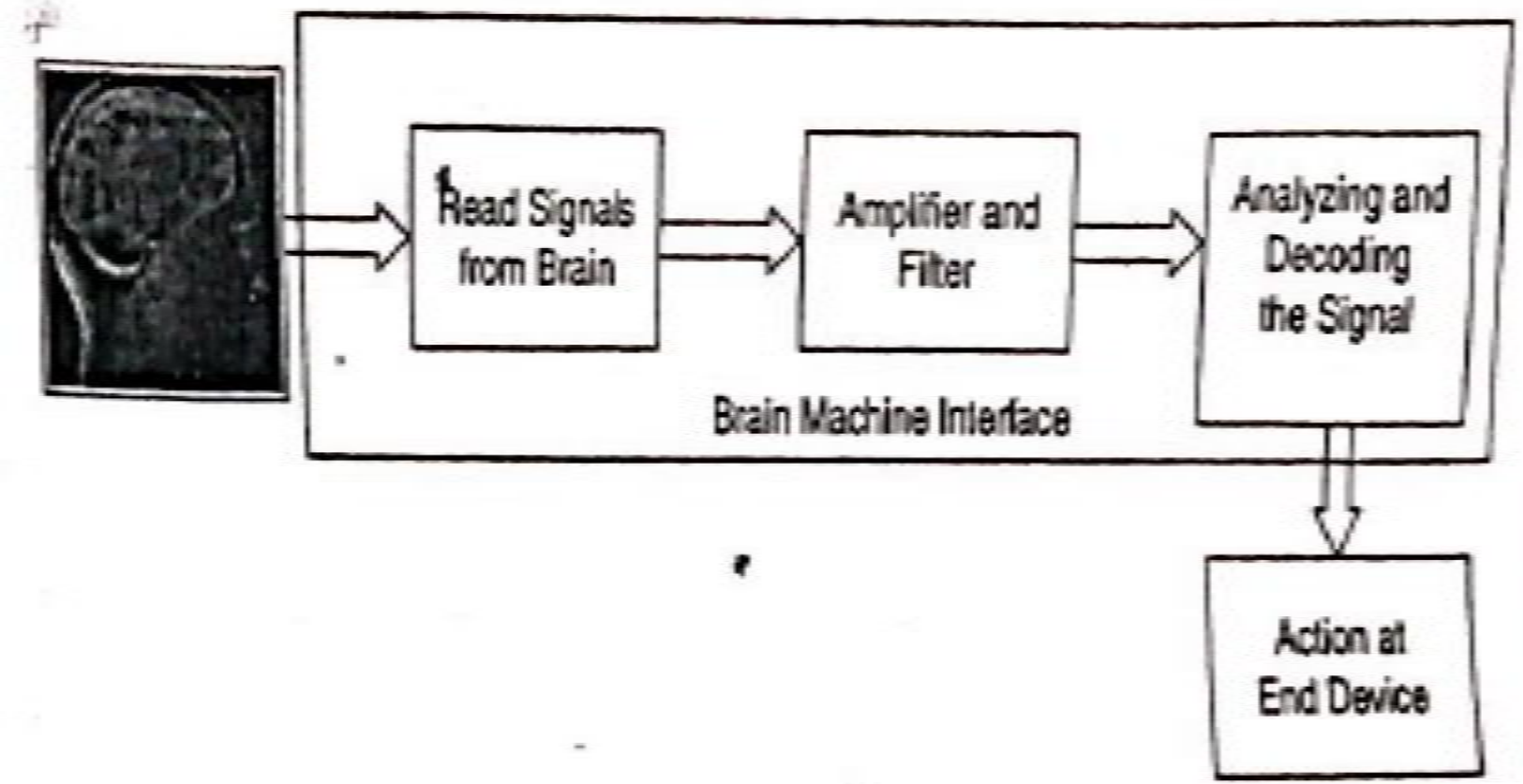
Biomedical Applications

- **Wheel Chairs:** Wheel chairs with lots of flexibility of movement and control and a lot of features are now manufactured.
- **T**he complete control of chair is done by high end processors with signal processing capabilities and running very sophisticated algorithms for locomotion.

Brain Machine Interface

- A technology which would enable one to control objects without physically interacting with them but could control them by just a thought
- Many such devices have translated human thought into prosthetic arm movements, computer cursor movements etc. This realized using what is called Brain- machine interface.

Block Diagram



Brain-Machine Interface

- BMI is a communication channel between human brain and an external device. It serves as an interpreter or translator which translates human thought into corresponding action.
- BMI Stages
  - Signal Reading Stage
  - Amplifier and filter Stage
  - Analysis and Decoding Signals

Signal Reading Stage

Two methods are adopted

I. **Non-Invasive**

Electroencephalography(EEG):

- EEG offers a non-invasive technique for reading brain activity, i.e. reading signal without placing electrodes or any such devices inside human body.
- No surgery required to connect a BMI to a person using EEG.

Signal Reading Stage

- Only the signals which are obtained at the scalp can be read using EEG.
- These signals are highly attenuated by the skull when they reach the scalp.
- These reason make the signal obtained at the scalp weak and highly distorted.
- We need very high gain amplifiers to boost the signal and filters to remove noise.

Signal Reading Stage

- Difficulty with this method is that no non-invasive technique currently exists that approaches the spatial resolution needed to extract the finest neural details.
- Fig shows no. of electrodes placed on a scalp.

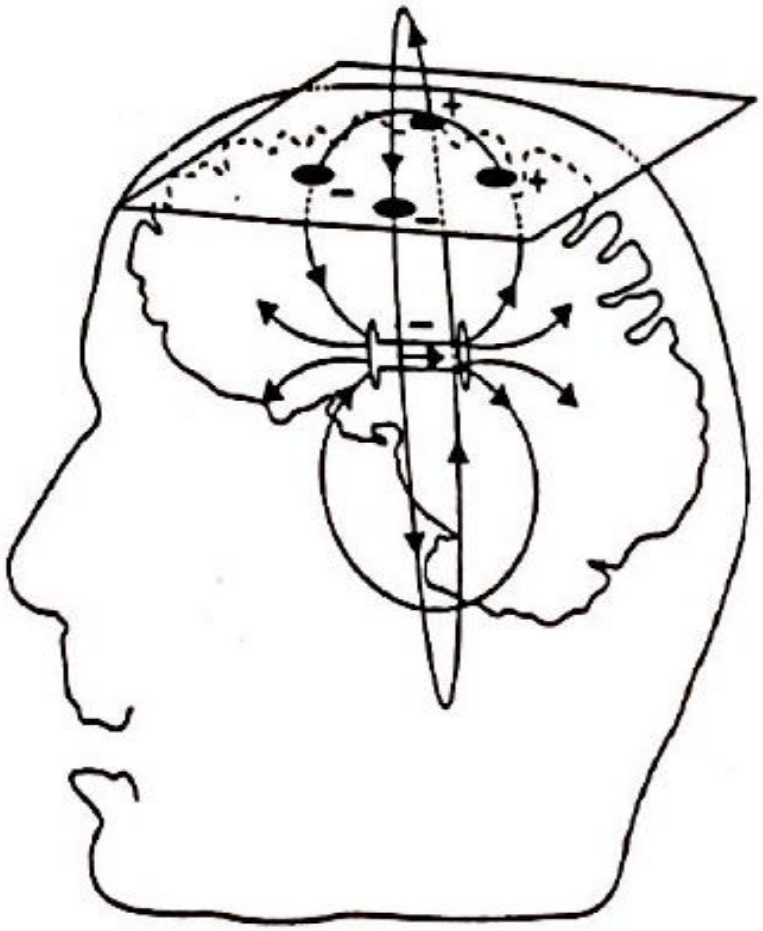
Signal Reading Stage

Spatial Resolution

- Spatial resolution is measure of the ability of reading stage to differentiate between signals from two very close parts of the brain.
- Different signals come from different points on the brain surface which are often close to each other.
- As signals are read from context directly, the attenuation caused by the skull is avoided.

II. Invasive(Electrocorticography ECoG)

- ECoG is an invasive approach that is electrodes have to be surgically implanted inside the person's head
- Fig shows the signal inside the brain which are to be extracted and the precise method is to place electrodes inside the brain.



Amplifier and Filter Stage

- The signals obtained from the scalp or context are weak and need to be amplified.
- In EEG differential amplifiers are used.
- These amplifiers have range of 60 dB to 100 dB i.e. voltage gain of 1000V/V to 100,000 V/V.
- This would facilitate strengthening of signal of micro volt to milli volt range.

Amplifier and Filter Stage

- The EEG/ECoG signal obtained are not only weak but is also corrupted with lots of noise.
- In order to decode the brain wave it is very important that signal passed through a filter first and then only analysed.
- Analysing an EEG signal directly is like listening to bad telephone .
- After amplification the brain waves are passed through a filter with cut-off frequency usually near 30-70HZ range.

Amplifier and Filter Stage

- Filters used here are very accurate as there are all sorts of noise in the signal.
- Sometimes, a notch filter is also used with notch at supply frequency i.e. the frequency at which supply voltage operates.
- This is done to avoid any noise creeping into system via power supply.

Analysing and Decoding the signals

- It has important job of analysing the signals, finding out what they are meant for and generating the necessary control signals to realize the corresponding movement/action in the end device.

Parameters with the help of which brain waves are analysed

I. Location of Electrode:

- Location on the brain from where waves are read.
- Different parts of brain have different functions.
- Signal received from visual context of brain are associated with vision, where as signals received from motor context of brain are associated with voluntary limb movements.
- Spatial resolution is important concept in this context.

Parameters with the help of which brain waves are analysed

II. **Frequency of Signal:**

- frequency of brain waves tell us the class to which it belongs to(theta, alpha, beta, gamma etc.)
- This in turn gives us the information about the kind of activity taking place in the brain.

Parameters with the help of which brain waves are analysed

- e.g. alpha waves(8-12hz) are obtained while closing or opening of the eye.
- When a person is in alert state, beta waves (12-30 hz) are obtained.
- Gamma waves(30-100 hz) are obtained during memory match

Parameters with the help of which brain waves are analysed

III. **Strength of signal:**

power of signal is different for different types of brain activity.

e.g. while opening eyes lower power alpha waves are obtained, where as while closing high power signals are obtained.

This is one of easiest method for decoding brain waves.

Parameters with the help of which brain waves are analysed

- Consider a robot which can move forward or backward. Closing and opening of the eyes can serve as ‘indicator thoughts’ in order to tell BMI to generate necessary control signals to make robot move backward or forward.
- This algo is simple actual algos can be very complex
- The complexity increased manifold as brain waves are subjective i.e. varies from person to person
- to develop a BMI which can be used on any person is impossible

Parameters with the help of which brain waves are analysed

- The BMI has to fully understand the person before actually being effective in aiding the person.
- for this to happen, the person and BMI have to adapt to each other
- BMI has to understand the individual patterns characterizing the mental tasks executed by the subjects.

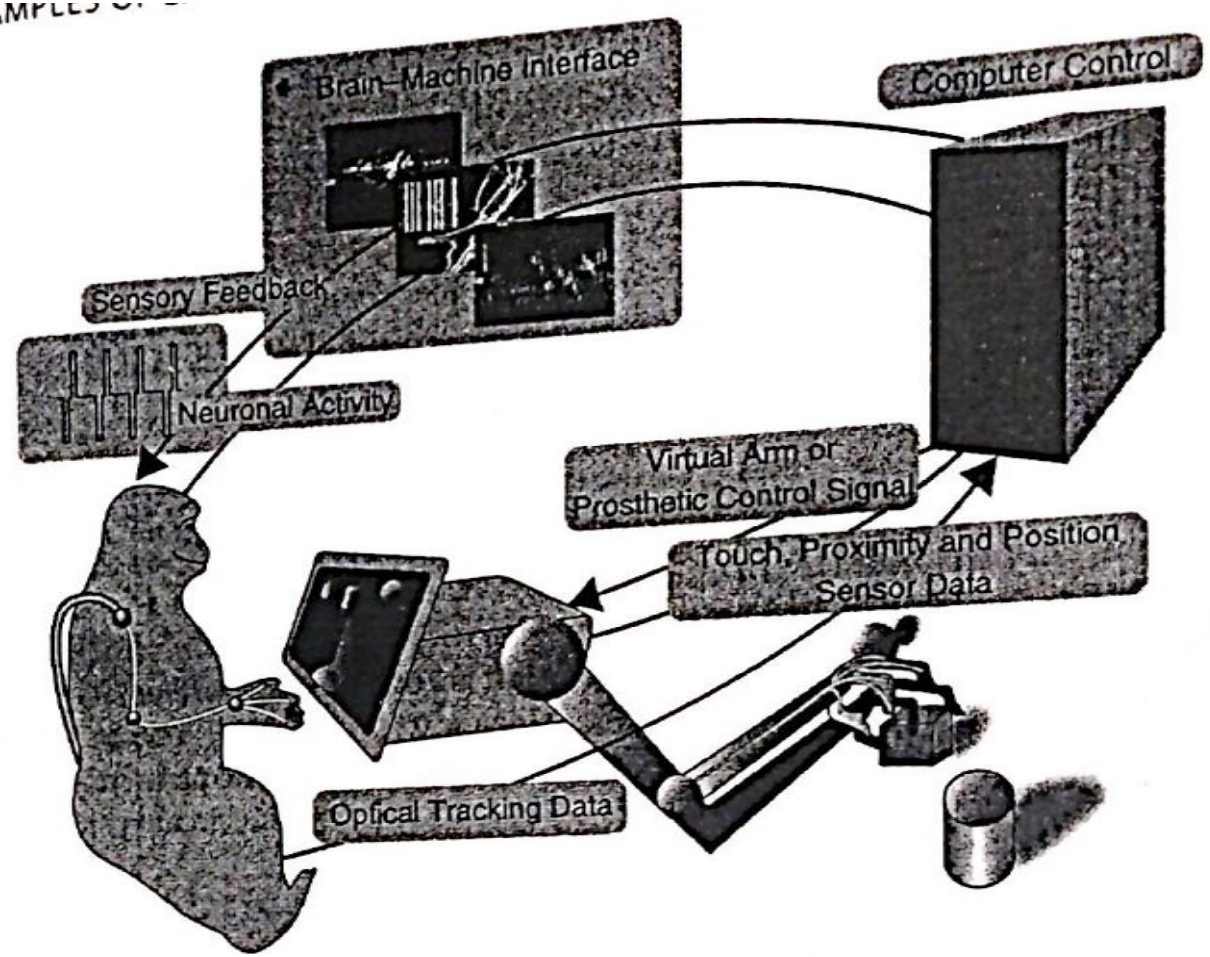
Parameters with the help of which brain waves are analysed

- On the other hand, subject has to modulate his brain waves voluntarily through feedback to generate distinct wave patterns.
- This requires an adaption time wherein the subject is to visualize about necessary action bring executed and his/Her bran waves are recorded.
- this is done no. of times to get distinct wave patterns which are fed into BMI as indicator for the necessary action.

End Device

- The end device may be a robot, a prosthetic limb a computer cursor etc.
- In case of a computer cursor, the patient mentally visualizes the cursor moving to the target.
- BMI understands this signal and then generates necessary signals to make the computer cursor move to target
- For brain- machine interface to understand signal house of practice is required.
- BMI has to be trained to decode the signals correctly.

EXAMPLES O


Brain–Machine Interface
Computer Control
Sensory Feedback
Neuronal Activity
Virtual Arm or
Prosthetic Control Signal
Touch, Proximity and Position
Sensor Data
Optical Tracking Data

End Device

- The end device may be Prosthetic limb. In this case corresponding movement is generated in prosthetic limb
- some times BMIs are used to provide alternative neural pathways for persons whose neural pathways have been damaged
- Consider a case when the muscles near the elbow part of arm are damaged.
- The signals from the brain cannot reach the hand part of arm due to blockage caused by damaged muscles.

End Device

- A BMI can easily solve the problem by providing an alternative pathway between the brain and human hand.
- Here the end device is not a prosthetic object or robot, but a human organ

Important Milestone

- In 200, a man named jens Neumnn had his vision restored using a BMI.
- Jens Neumnn had lost his eyesight during adulthood. The device was in the form of camera attached to one of the glasses of his spectacles.
- The images captured by camera were processed and sent to visual cortex.
- Scientists targeted the 177 brain cells in the cortex which interpret the image falling on the retina of the eye.

Important Milestone

- The implant however offered only black-and-white vision and at a low frame rate.
- Inspite of this, he was able to drive slowly in the parking lot of the research centre where he was given the BMI.
- BMI technology for motor neuro-prosthetics created a whole new benchmark with BrainGate BMI implanted into Matt Nagle's brain in 2005.

Important Milestone

- Matt was paralysed neck down after his spinal cord had been severed, as a result of stabbing. It was done as part of first nine-month human trial of cyber-kinetics neuro-technology's BrainGate chip-implant.
- A 96 electrode BMI was implanted into his cortex. It required him some months to initially adapt to the BMI.
- His signals were read and were then used for moving a computer cursor.

Important Milestone

- He could utilize the full functionality of computer cursor including left-click, right-click etc.
- He could then check email, turn on/off tv, lights etc.
- He also become the first person to move a prosthetic hand with his thoughts.

These examples indicate that BMI seems to be quite promising, though many hurdles are left to be crossed before it can be made really useful.