Advanced Neural Science for Engineers
Professor Hardik J. Pandya
Department of Electronic Systems Engineering, Division of EECS
Indian Institute of Science Bangalore

Lecture 33
Introduction to Biopotentials

Hello everyone, welcome to this class, this class is focused on understanding different biopotentials. Now, what do you mean by biopotentials? So, we talk about ECG in real life or we talk about EMG. Generally, we are all familiar with a term called ECG electrocardiography or electrocardiogram.

But what happens, when we acquire the signals from the brain? So, as a part of this advanced neural science for engineers, it is very important for us to understand that what kind of signal originates from your neurons what are the action potentials versus local field potentials if you want to go into depth, which will be little bit we will touch upon the local field potentials when we talk about micro electrode arrays for implantable devices in rat's brain.

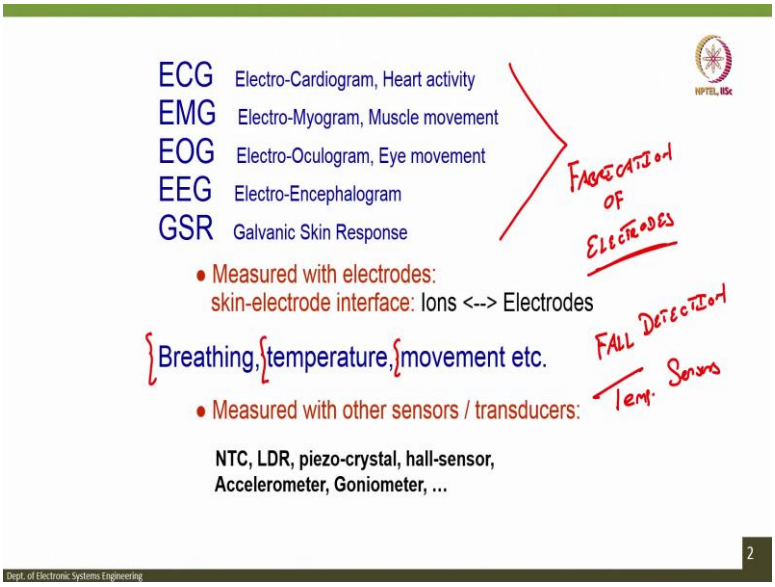
But, in general, we will talk about something called EEG which is electro-encephalogram. Now, like electrocardiogram, we will talk about electro-encephalogram. And then we will see that what kind of systems are used, how the electrodes are placed, how the EEG is acquired. And going forward, we will take an application that if we understand the signals that originates from brain, we can also look into several diseases associated with the brain dysfunction. For example, in case of seizures, they have normal, there are normal data, so when subject is okay. And then you have epileptic subjects.

And in that you have several subtypes, starting with generalized seizure, focal epilepsy or focal seizure, focal to generalized and absence seizure. So, how to identify, what kind of seizures are there from the data acquired from the brain? And currently, how the doctors, they can diagnose or diagnose the type of epilepsy? Are there any gaps? Can we fill those gaps by either creating a code or developing a platform? And, how useful it may be, like we do not want to replace a clinician.

That should not be the intention of developing a technology that replaces people. We develop technology to aid the people. So, all the things that we learn is to aid a clinician to improve the diagnosis to be more accurate than what a person can be because human error always accounts for and you can only do that when you understand the EEG signals. So, with that, if

you see types of signals, then there are ECG signals, EMG signals, EOG signals, EEG signals, GSR.

(Refer Slide Time: 04:05)



So, if you see the screen like I said, ECG, ECG stands for electrocardiogram and it measures the heart activity. Second is if you want to understand the signals arising from the muscle moment, then you can use a technique called electromyogram. If you want to acquire the signals when your eyelids are moving or there is eye moment, then you can use EOG which is electro-oculogram. When the signals are arising from the brain, and you are acquiring those signals, we call it as a electro-encephalogram.

While the galvanic skin response GSR is used for several factors in fact a lot of research is going around to understand the change in the GSR with respect to stress and the GSR in particular or in particular all these techniques are used with electrodes where the skin electrode interfaces.

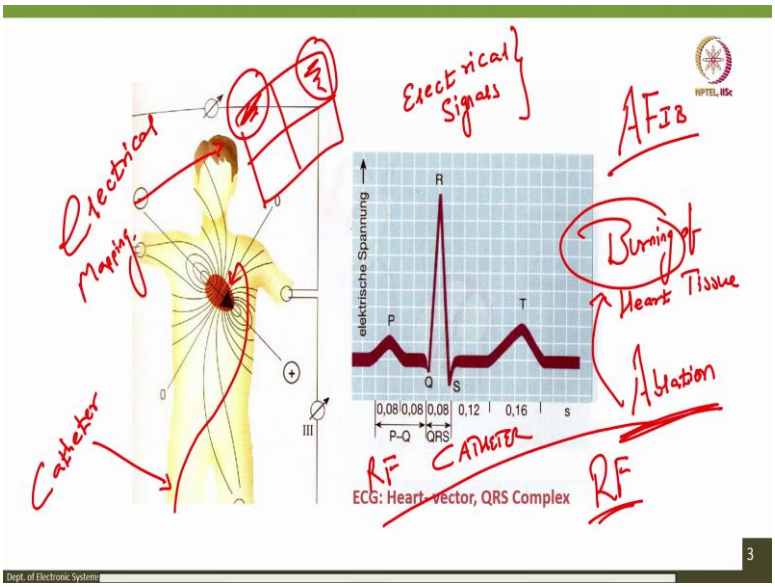
So, there is the ions and electrodes interfacing and exchanging which causes the, which is the technique, but in all this technique, you will see that there is there is a use of electrodes that means fabrication of electrodes is the heart of all these techniques, the other things that we generally measure is the rate of breathing, temperature of the body and the non or un-voluntary moments even in this voluntary moment we can measure those for example, if it is a fall detection if you talk about a watch that can measure the fall detection that means that the watch has accelerometer.

Same thing if you want to measure the temperature that means the band or watch should have temperature sensors. Same thing goes for breathing and so, on. So, the point is that in any case in every case when we talk about measuring something most of the time the

measurement is done with respect to one kind of sensor or other. And that is what is the intent of this course of teaching the fabrication of those sensors.

So that it can be used for the neuroscience application. Now, several kinds of sensors are available for example LDR, NTC, accelerometer goniometer, visual crystal hall sensors and so on so forth there is an endless list of these sensors.

(Refer Slide Time: 07:57)



Generally, this is these are the waveforms that in a continuous fashion we see on the screen in in movies and serials, where there are multiple electrodes that are placed on the chest of a patient and the ECG is measured. So, there are several waves one is PQ wave, then there is a QRS wave and then there is a ST wave, but the main thing is QRS and of course relation with respect to the PQ, this is where the abnormality of the heart can be measured.

Now, generally when the heart starts pumping faster, we call it as arrythmia. But in certain cases, the heart starts pumping unevenly when there is uneven heart moment it is called atrial fibrillation.

Now, this atrial fibrillation can be generated by medicines but the treatment also involves the burning of tissue, burning of heart tissue, this short form is called AFIB, atrial fibrillation, in that the doctor will place a catheter is a tube into the heart through here goes to the heart. It measures electrical signals and if there is a misfiring of the signals, if there is the signal uniformity is not maintained, then we can get or they can see in which region of the heart the misfiring of signal is happening that is called electrical mapping again, I am repeating when the heart starts pumping unevenly, if it is faster, then it is called arrhythmia.

And if there is a slow and fast bits of heartbeats are there it is called atrial fibrillation. In atrial fibrillation the treatment is generally medicine and most of the cases a person has to go for a burning of the heart tissue. Now, which area of the heart tissue needs to be burn? This burning in a medical term is called ablation.

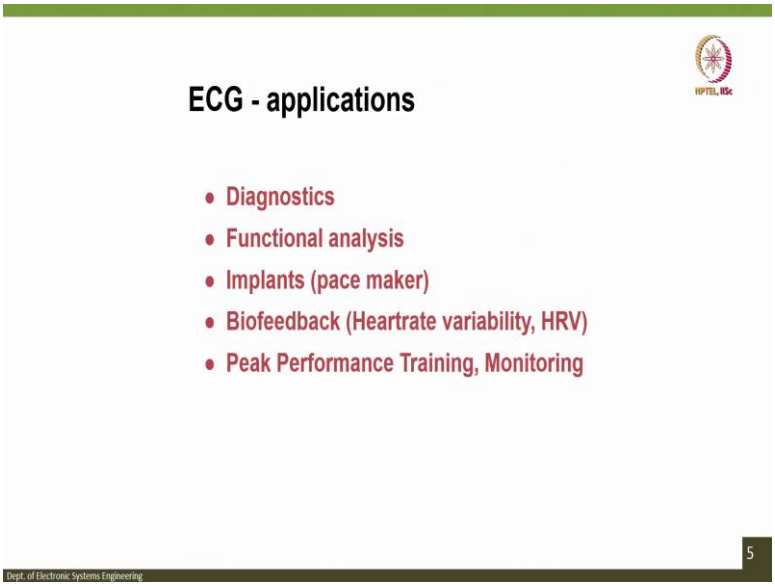
And first is that tube, which we call as a catheter is inserted through the groins and it is the heart and the tube has a insert at the tip to measure the electrical activity from different regions of the heart. So, that is what is called electrical mapping. So, some region will show some kind of extra electrical activity. Now, what the surgeon will do is they will insert another catheter and burn these tissues, this burning is called ablation.

If you burn the tissue, the tissue will not conduct and the rhythm of the heart can be regained. Now, when I say burning of a heart or burning of a tissue does not mean that you burn the entire section of the heart, is only a small portion of the heart tissue which is burned and that small portion is the is the culprit in a way that the misfiring of the signals are happening.

Now, ablation or burning of the heart tissue can be done by a catheter that much we known. But, how to ablate it? So, we use something called radiofrequency that is why it is called RF ablation. What is radiofrequency? Radiofrequency when we apply to the tissue it will start heating the tissue and ultimately causing the burning of the tissues, tissue will not conduct and the activity will be regained.

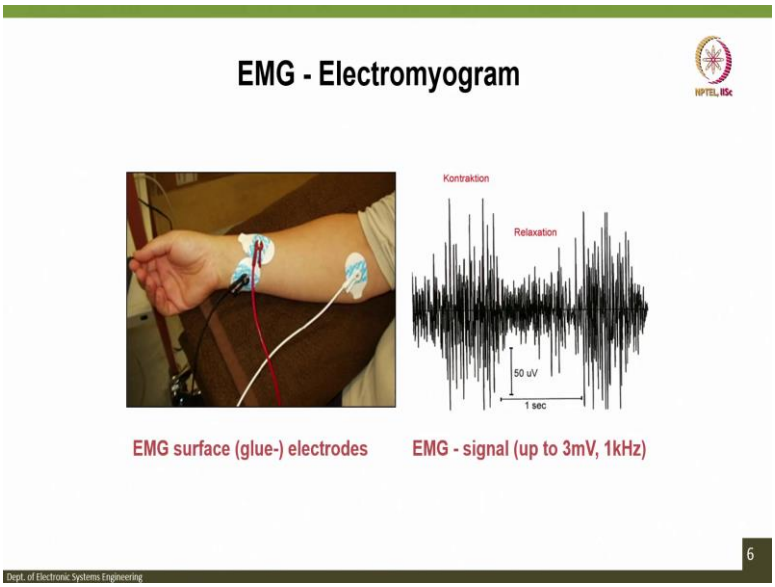
The catheter, since we are using is called catheter ablation, but since we are using radiofrequency is called radiofrequency catheter ablation, RF ablation radiofrequency catheter ablation, and that is how the activity of the heart is regained. Now, this is the use of understanding the signals through the ECG. Because if we know the signals are not rhythmic the signals are uneven. The signals have some fault either in the PQ or QRS, then from that the patient's heart, health of the heart can be determined. That is the use of ECG.

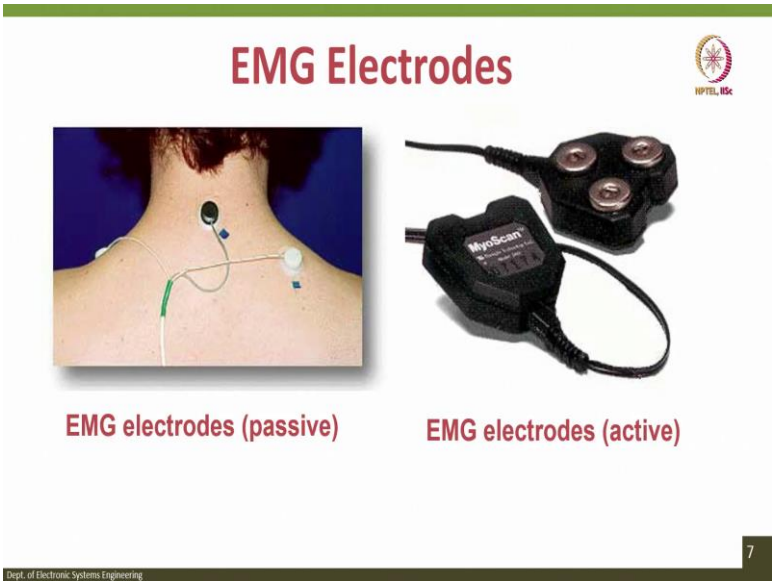
(Refer Slide Time: 14:26)



And if you can acquire the ECG signals faithfully then you can use it for several applications. The first one would be diagnostics. The second one is functional analysis. If you understand that the heart is not able to pump then you can have implants like pacemaker. You can measure the heart rate variability or HRV also known as HRV. And for athletes or for even us, if you are engaged in the physical exercise in the training, then you can monitor the health of the heart by measuring the ECG signals.

(Refer Slide Time: 15:30)



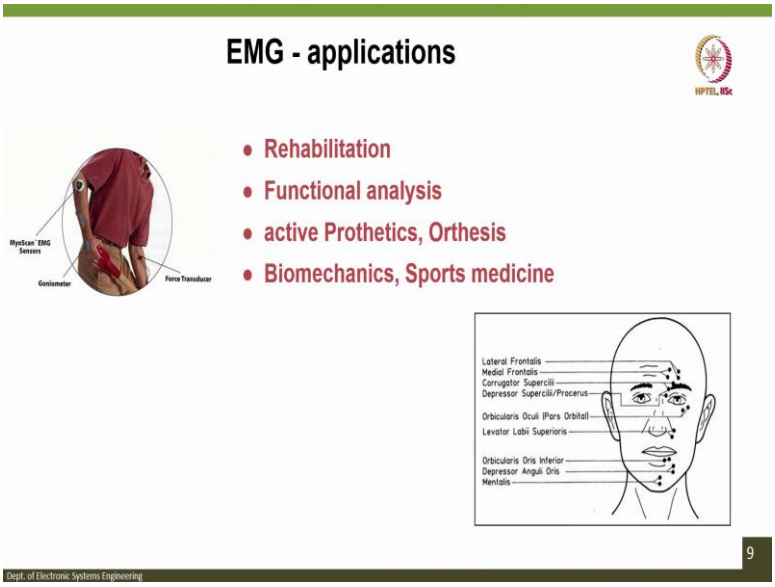


Now, let us not spend too much time on ECG because our interest is in EEG. But let us touch upon a term called electromyogram. Electromyogram, as you can see from the image is a technique to acquire the signals from the muscles it is used heavily for prosthetics and again, if you see that the way to acquire the signals from the muscles is using the electrodes, and this electrodes are on the surface that is why we call it as a EMG surface electrodes when the muscle will contract and relax there is a change in the signals that are produced that is produced by those muscles.

So, when you contract it, it can be as high as three millivolts which is measured around one kilo hertz and there is a sudden reduction in the voltage as soon as you relax it. So, the contraction and relaxation would result in a signal and that can be measured using glue electrodes that we call as a EMG.

These are some of the EMG electrodes that you can see on the left side this is a passive one that means it does not apply any voltage just acquire the signal and the right side those are active electrodes from MyoScan you just look into a Google Sheet saying MyoScan you will understand how these electrodes are used. Active means when you apply a signal and you measure the corresponding signals. So, let us now see the video which shows that how these EMG signals are acquired.

(Refer Slide Time: 17:57)



So, you can understand that the EMG signals are applied or acquired and the applications can be can be many, the first one is rehabilitation, when you need to understand that a person is suffering from a stroke or a person is suffering from spinal cord injury and when the person is recovering, then the whether the recovery is progressing or not. If you if you send a signal like if you think about moving your hand and the hand is moving correctly, if you contract your contract your palm and relax your palm then relax your hand contact your hand then what happens is the signals would come faithfully or we can acquire the signals faithfully.

But in case of the difficulty in the muscle moment, because if the motor area is affected, then this will not happen. But you can measure those changes in the signals with the help of EMG electrodes. And that is why it can be used for rehabilitation application.

The second application is functional analysis whether a person is functioning well. The third application can be active Prosthetics, Orthesis. It can be used if you know the how to acquire the EMG signal. The application can also be the area of biomechanics and sports medicine.

On the right-hand side, right bottom you can see a face and from there you can see that so many regions from a human's face can be used to measure the signals so, many area from the human face can be used to measure the signals which we call as EMG signals.

(Refer Slide Time: 20:15)

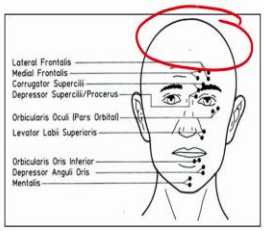
EEG: Electroencephalogram

EEG

- **Electroencephalogram** or **EEG** is commonly used in medical and research areas to record the biopotentials from brain placing electrodes on the scalp.
- It reflects electrical activity of brain.
- It gives high temporal resolution (m sec) and low spatial resolution.
- Vladimirovich (1912) recorded EEG from animal model (dog)
- Cybulski (1914) first recorded EEG signal of induced seizures
- Berger (1924) recorded **first EEG signal from human** and coined the term 'electroencephalogram'.

EMG - applications

- Rehabilitation
- Functional analysis
- active Prothetics, Orthesis
- Biomechanics, Sports medicine

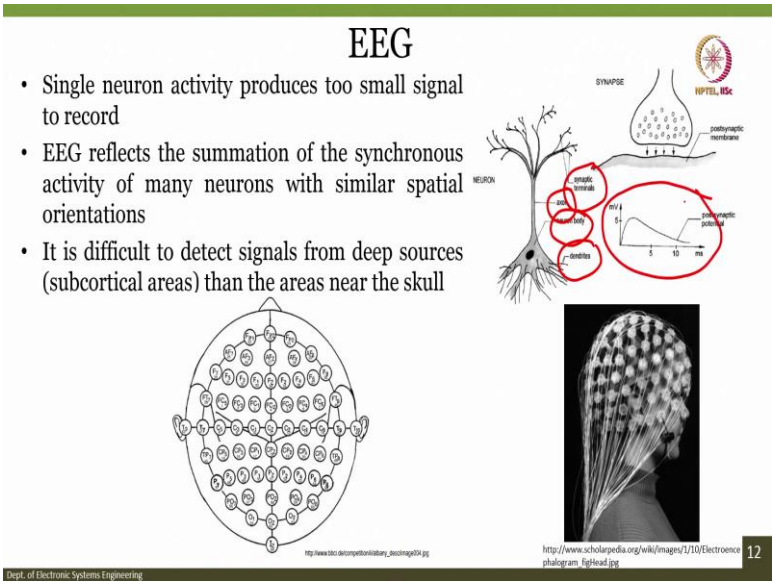


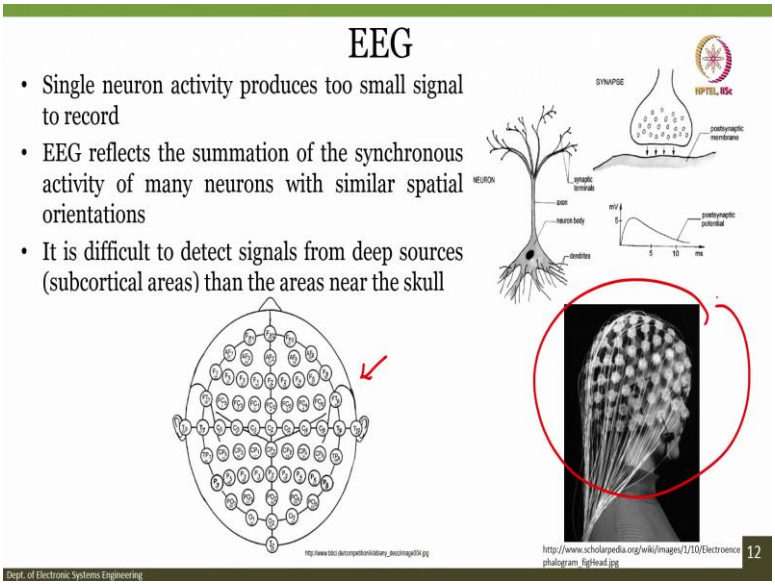
Now, let us draw our attention to a term called EEG which stands for electroencephalogram. So, the term EEG or electroencephalogram is commonly used in medical and research areas to record the bio potential from brain placing electrodes on the scalp.

So, what does it mean? This is the region on which we put the electrodes and the signals are rising from the brain by placing the electrodes on the scalp. What does it reflect? The EEG reflects the activity of the brain. EEG gives us a high temporal resolution of some milliseconds and low spatial resolution. In 1912 Vladimirovich or Vladimir-rovich is the person who recorded the EEG from an animal model and that was a dog.

Cybulski in 1914 recorded the first seizures. And, Berger in 1924 recorded first EEG signal from human and coined the term electroencephalogram. So, in a way it is not too old a technique but not too new as well, is not it. But the activity of the brain is very important to understand because there are several applications in EEG and we will look into those.

(Refer Slide Time: 23:13)



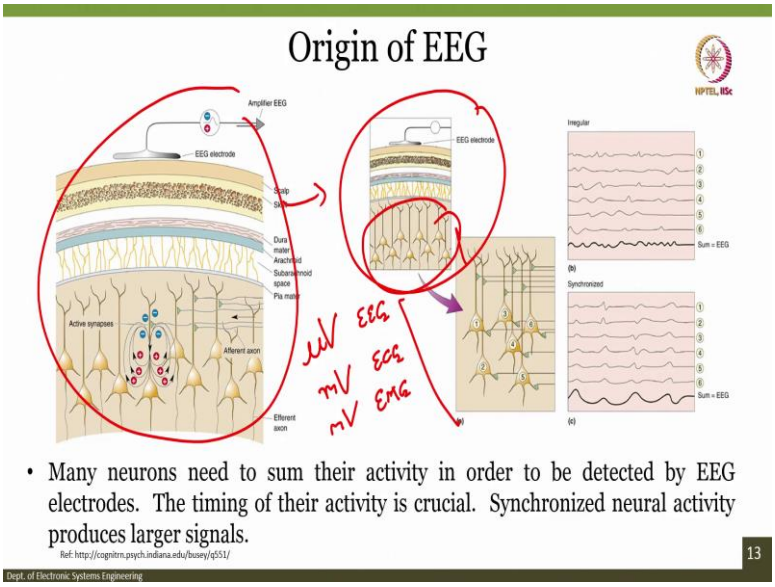


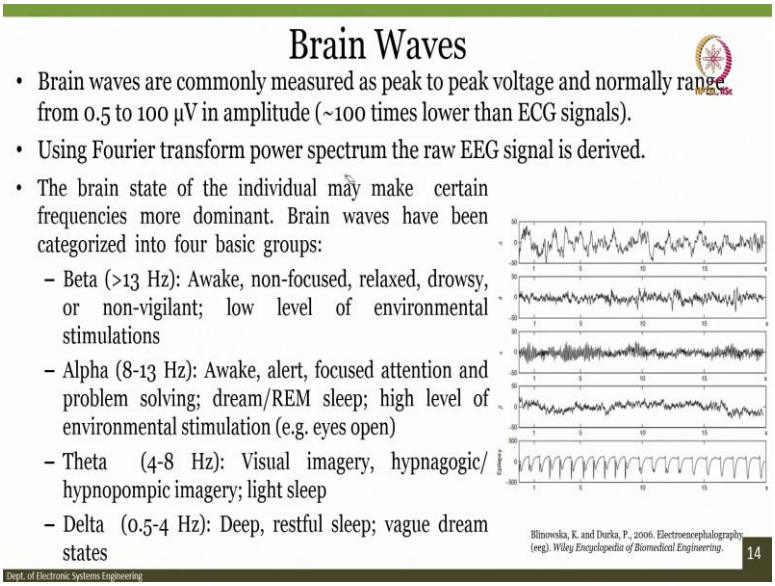
So, the single neuron activity produces two small signal to record. If you just go to single neuron activity, sometimes people call these action potentials. It is a very small signal to record and you have to have a very sophisticated device to record those. But when you go for EEG as a term then it reflects the summation of the synchronous activity of many neurons with a similar spatial orientation.

The another important thing is that it is difficult to detect signals from deep sources like subcortical areas and the areas near the skull. So, if you see if you have a neuron, the neuron has the synaptic terminals, it has axon it has near and bodies and it has dendrites and each synaps is connected to the postsynaptic membrane. And you can see that the postsynaptic potential that arises from the postsynaptic membrane in a few milliseconds you can see in this particular schematic.

This is the schematic of 10-20, the electrodes are placed in 10-20 mechanism. We have the frontal lobe, parietal lobe, temporal lobe, occipital lobe and central lobe. So, if you see this one, the electrons are placed in 10-20 mechanism to acquire the signal.

(Refer Slide Time: 25:32)





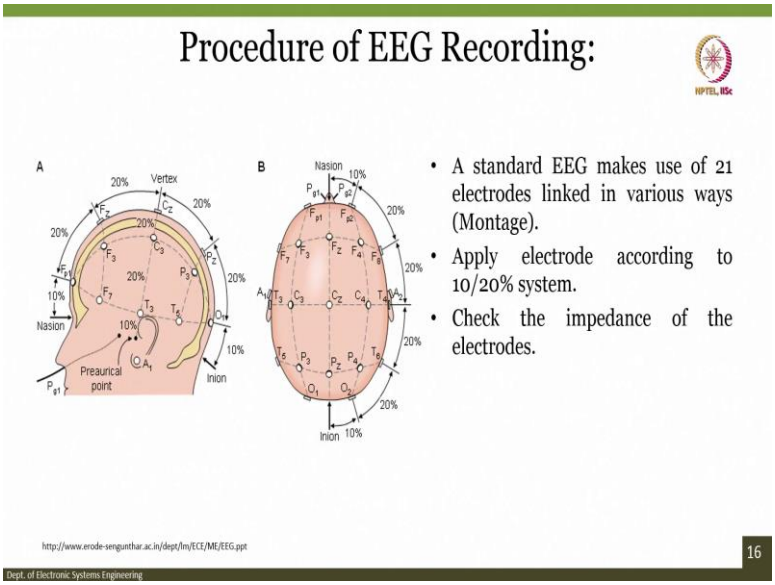
So, if you understand exactly where the electrical signals are arising, then these are the efferent axons and active synapses, there is a pia mater, subarachnoid space, there is a dura mater, arachnoid on that there is a skull on that there is a scalp on which we are placing the EEG electrodes and since the signal is very small compared to ECG, the signal from ECG is millivolts the signal from EMG is millivolts, sorry but the signals from EEG is only microvolts, since the signals as small we can amplify them with the help of the subsequent step in which there is a electronic module with an amplifier to amplify the EEG signals which are in micro volts range.

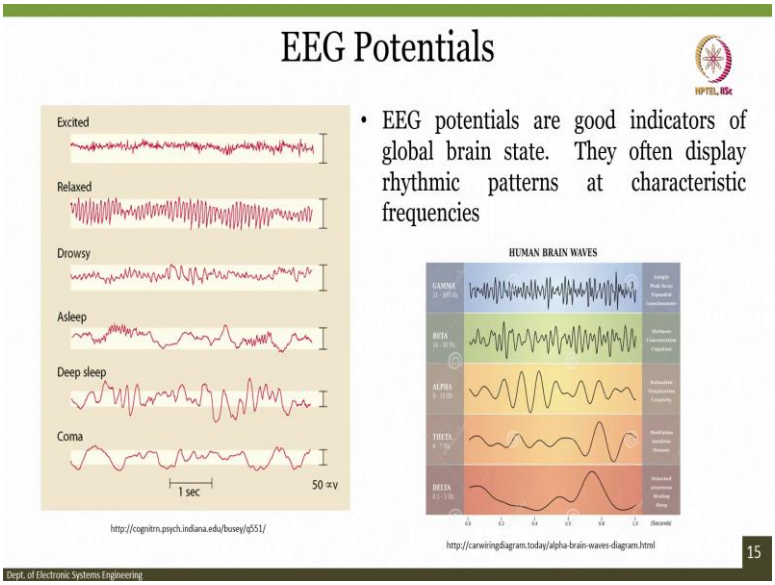
So, the same thing here this entire thing and if you go further in this region then what you will see that the efferent neurons, efferent axons how they are associated and you can very

clearly see that synchronized EEG versus irregular EEG you can easily understand through the data obtained using the 10-20 system. So, many neurons need to sum their activity in order to be detected by EEG electrodes the timing of the activity is very crucial and synchronization or synchronized neural activity produces large signals.

So, this much we understood about the origin of the EEG which is electroencephalogram. So, next one, so let us the top here, and we will focus on the origin on the application like how what are the brainwaves, and how we can use this brainwaves for ECG, EEG potentials.

(Refer Slide Time: 28:31)





And what are the procedures for EEG recording and so on and so forth in the next class. So, I will stop here because I do not want to overwhelm you with a lot of EEG, EEG things, but I

hope that in a short period for this particular class, we do understand or we learn that there are different biopotentials.

Biopotentials from the eyes, from the heart from the muscles, from the brain, and how exactly the signals are arising. And once the EEG which is in micro volts, we need to amplify those signals with the help of the amplifier. So, let us meet in the next class and see how we can utilize the brain waves for several applications. Till then you take care, bye for now.