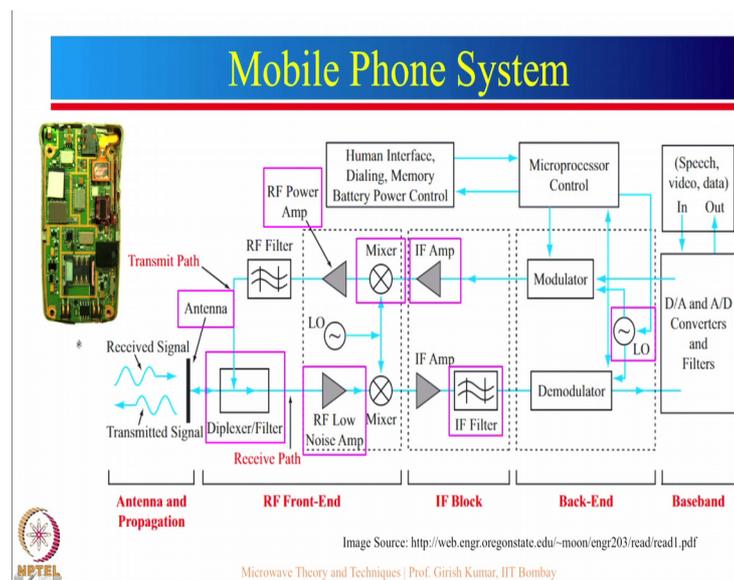


Microwave Theory and Techniques
Prof. Girish Kumar
Department of Electrical Engineering
Indian Institute of Technology, Bombay

Module – 01
Lecture – 03
Microwave Theory and Techniques Introduction – III

Hello, everyone. In the last couple of lectures, we have talked about microwave theory and technique, course outline, different books used, we talked about the microwave transmitter and receiver block diagram, we also talked about microwave components and it was followed by link budget. Today, let just see: what are the different systems we are going to cover in this particular course. So, let us start with something which you all people are used to, your mobile phone.

(Refer Slide Time: 00:53)



So, mobile phone actually speaking you can just see here a simple mobile phone, but in this particular simple mobile phone there are too many things are there. So, let us start from here. So, there is an antenna which is used for transmit as well as received here. So, you are transmitting a signal and receiving a signal. So, now, over here one can see there is a diplexer or filter because the transmitter and receive frequencies are different. So, over here you can see that this is the transmit chain and this is the received chain.

So, we are looked into the transmitter block diagram as well as receiver block diagram. So, you can see there are lot of similarities are there. So, you can say here there is a diplexer filter so, which will only filter out the desired thing. So, it is also known as a double band pass filter. So, one band is for this particular case and this is for the another one not this filter signal comes to the RF low noise amplifier, after that it goes to the mixer we can see here there is a local oscillator, then it comes to IF amplifier, there is a IF filter, there is a demodulator.

And, so, you can see that this block diagram looks very similar to what I had shown you, ok. Let us also look at the transmitter chain again. So, you can see that there is a modulator over here, I will talk about these thing little later modulator then there is an if amplifier there is a mixer based as up conversion. So, this is slightly different then the block diagram with I had shown you, but otherwise you can see that all it is doing it is doing the up conversion. So, here modulation is done at lower frequency and then conversion is done to the higher frequency and this is the RF power amplifier. So, typically for a mobile phone this amplifier may give about roughly 1 watt of output power and in some system it may be even 2 watt output system then it goes through the filter and antenna.

Now, what are these things over here? So, you can see here there is a microprocessor controller which actually have this all this human interface, dialing, memory battery power control and here is the data which you want to send which can be in the form of video data or speech. These things then go to because that may be of signal here could be you can say analog signal that is converted to the digital signal and then through the local oscillator some up conversion is done as I said this is done at a slightly lower frequency and then it is done at a higher frequency.

So, this is what is a general block diagram; However, current mobile phones are much more complicated they have many many more things in there they also have a GPS receiver which is not shown over here. So, this is basically just to give you a general glimpse of the block diagram, but as I said the current mobile phones may have a GPS receiver, they may have accelerometer and so, many things.

(Refer Slide Time: 04:04)



Mobile Phone Jammer / Silencer

Mobile Phone Jammer generates noise, which should be larger than the signal strength in that location.

- Power – Low, medium and high
 - * Low Power – small range
 - * High Power – large range
- Single Band or Multi-Band Jammers
- Omni or Directional Antenna

APPLICATIONS

Colleges, Meeting/Seminar Rooms, Prison, Religious Places, VIP movement, Court, Theater, etc.

 NPTEL

Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay

So, now when there are too many mobile phones are there. There is a requirement for jammer also. So, first of all what is a jammer? In fact, we also gave a name as silencer. So, what is a mobile phone jammer? Basically, it generates noise which should be larger than the signal strength in that particular location. So, if the noise is larger than the signal received by the mobile phone will get confused and hence it will actually show that there is a no network available.

Now, there can be different types of mobile phone jammer. It can be a low power, medium power, high power basic proposes. A low power jammer will have a small range; a high power jammer will have a larger range. It all depends upon whether you want to do jamming only in a small room or in a big hall or you want to even do a jamming at several you know concerts or even for you can say military convey they actually do a jamming for several hundreds of meter range also.

Now, this jammers can be single band jammer or multi band jammer; that means, either you have just jamming only one particular band or multiple band you are doing. Now, antennas can be two type omni directional antenna which will actually speaking omni directional antenna has a radiation pattern which radiates in this particular direction equally, but in the vertical direction radiation is not their. It has a radiation pattern in this particular fashion which makes a figure of 8. So, when we talk about antenna will talk

more about it. Directional antennas are antennas which send signal in a particular direction.

So, where do we need to use mobile phone jammer? There are lots of application. So, I will actually first start with the prison. Now, these days there are several jails where prisoners are actually able to smuggle in the mobile phones and then they do anti-social activities even though they are in the prison. So, we need to install jammers in the prison. Now, colleges many colleges these days are installing jammers specially during the exam time when if you had seen Munna Bhai, MBBS movie; in that movie one of the hero actually uses mobile phone for cheating purposes. In fact, that has created lot of problems. So, many colleges now have started installing jammers and also students are using mobile phones in the colleges so, they are not concentrating on their studies and hence many colleges are also installing jammers.

In meeting seminar rooms I mean meeting is going on and somebody's mobile phone rings. So, of course, it is a nuisance. So, many times they install these jammers. Even in religious places let us say if we are going to some place to do [FL] and some mobile phone rings, it is very annoying. Now, VIP movement is require jammer because these days many of the bombs are getting triggered by remotely mobile phone. So, even in the court and theatre people have started installing jammer. So, jammers have lot of applications that way.

(Refer Slide Time: 07:21)

Signal Enhancer / Repeater

Signal Enhancer amplifies the weak signal present in that area

- Single or Multi – Band
- Gain and Power – Low, medium and high
- Omni or Directional Antenna

APPLICATIONS

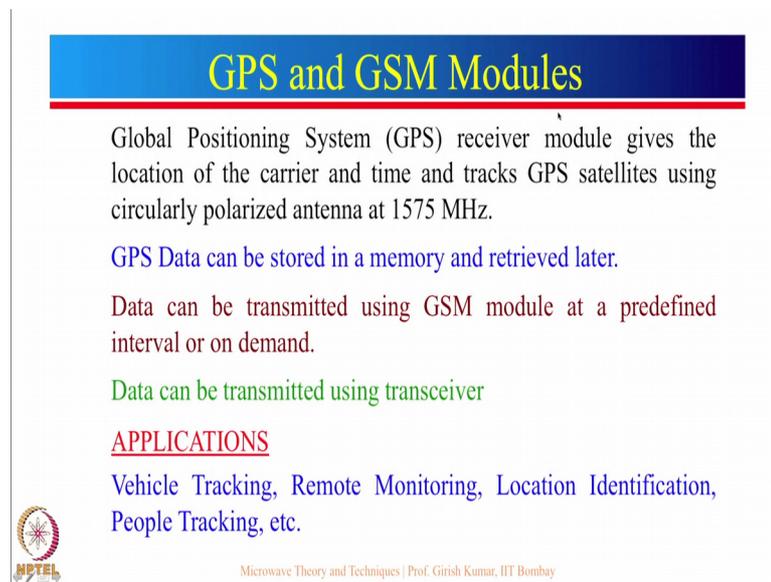
Room, Hall, Open Space, Vehicle, Lift, Garage, Parking Lot



Now, this is signal enhancer and repeater. Signal enhancers and repeaters are basically nothing, but the deviser which amplify the weak signal in a given particular area. Now, these signal enhancers again can be a single band or multi-band, it can have a gain and power it can be low medium high depending upon in how much area you want to amplify the signal, again it may have omni or directional antenna.

So, what are the applications? So, I will actually start first in general that many hotels actually speaking have in-building solution. So, in-building solution consists of lot of power dividers, couplers, filters, antennas and repeaters. So, that is how they are able to give signal in almost every possible room. But, so, here any room or any hall wherever there is a no signal sometimes in the open space there is a possibility that signal may be weak or in vague. Inside the lift you know that if it is specially a metallic lift you might have notice that your mobile phone does not work, and garage or parking lots specially underground parking lot signal is very very weak. So, they do install signal enhancers over there.

(Refer Slide Time: 08:47)



GPS and GSM Modules

Global Positioning System (GPS) receiver module gives the location of the carrier and time and tracks GPS satellites using circularly polarized antenna at 1575 MHz.

GPS Data can be stored in a memory and retrieved later.

Data can be transmitted using GSM module at a predefined interval or on demand.

Data can be transmitted using transceiver

APPLICATIONS

Vehicle Tracking, Remote Monitoring, Location Identification, People Tracking, etc.

 NPTEL

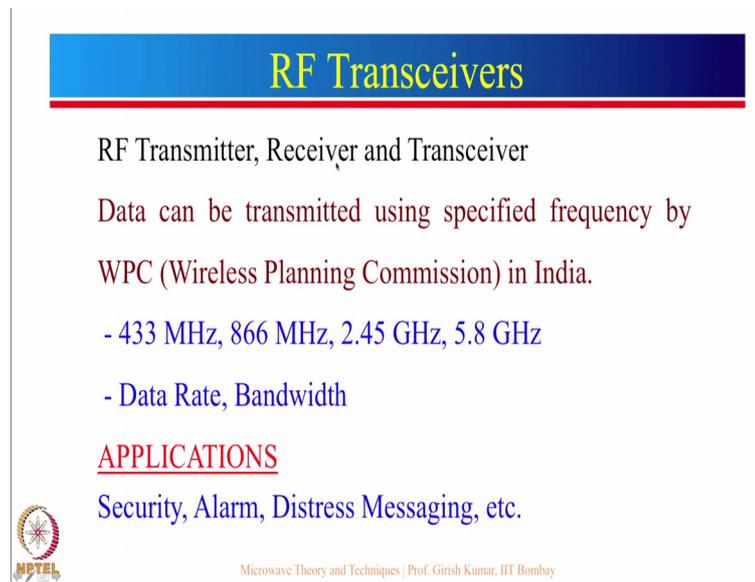
Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay

GPS and GSM modules: now, GSM modules of course, are there inside the mobile phone even many mobile phones have GPS. But, these now days these are separately available also. So, you can by separately GPS module, you can buy separately GSM modules. In fact, nowadays even combined GPS and GSM modules are also available. So, GPS works at a frequency of 1575 megahertz and the bandwidth is plus minus 10

megahertz. So, GPS can be used for many many application. So, for example, you can say GPS data in a memory and you can retrieve it later or you can transmit the data using GSM module or you can transmit using transceivers.

There are several applications are there of course, these days people do car booking and other thing also so, which has a location finder. So, which actually has a GPS and other thing, but. So, in generally you can use it for vehicle tracking remote monitoring location identification, even some people use it for people tracking also.

(Refer Slide Time: 09:55)



RF Transceivers

RF Transmitter, Receiver and Transceiver

Data can be transmitted using specified frequency by WPC (Wireless Planning Commission) in India.

- 433 MHz, 866 MHz, 2.45 GHz, 5.8 GHz
- Data Rate, Bandwidth

APPLICATIONS

Security, Alarm, Distress Messaging, etc.

 NPTEL

Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay

Now, RF transceivers, what is a RF transceivers? Basically, you can say mobile phone in an example of RF transceiver. So, RF transceiver consist of transmitter, receiver so, the combination of this is known as transceiver; you can see that trans coming from here and this part is coming from here. So, by using RF transceiver one can transmit the data at a specified frequency.

Now, in India we have to use wireless planning commission and this comes under the umbrella of DOT which is department of telecommunication. In USA the corresponding body is FCC. Now, in India RF transmitters transceivers are there 433, 866, 2.45, 5.8, but I just want to mention here 433 megahertz band has not in approved in India, but almost you can say majority of the other countries do use 433 megahertz as transceiver, but this is not allowed in India as of now. Of course, when you are talking about transceiver what are the important things, what is the data rate, at which you can transmit and what is the

bandwidth allocated for that particular band. And, of course, there are many applications are there. You can use a for security purpose, you can use for sending alarm or you can use for distress messaging and so on.

(Refer Slide Time: 11:34)

RFID (Radio Frequency Identification)

Active and Passive Tags, Reader

Standard Frequency - WPC

- 125 KHz, 13.56 MHz, 866 MHz, 2.45 GHz, 5.8 GHz

APPLICATIONS

Retail, Library Management,
Vehicle License Plate, E-Passport,
Product Tracking, Animal Tracking,
Electronic Toll Collection, etc.

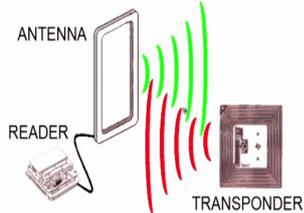


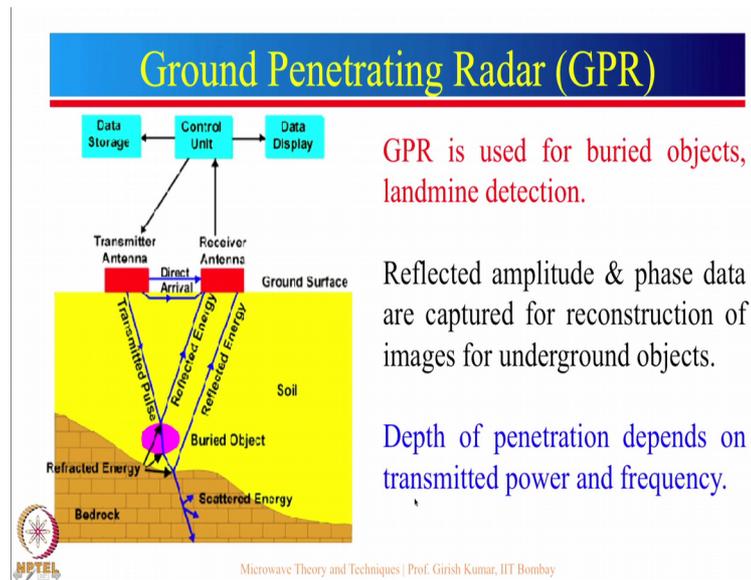
Image Source: <http://ashtopustech.com/products/rfid/>

Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay

And, RFID I am sure many of your familiar with radio frequency identification might have use active or passive tag. So, you can just see here this is a passive tag over here, you can see a simple one there is a this is one is a RF reader, through the RF reader antenna is there. So, in this particular case we transmit the signal and what passive tag really implies that there is a no battery. So, what happens, it gets the signal through this transmitter power and that signal is converted to dc voltage and then it sends back the signal and that is how the identification takes place. In case of active tag this may actually have it is own battery. So, the advantage of having a battery is that the range is much larger the disadvantage is of course, you need a battery and the battery needs to be change at different times.

So, there are several frequencies which have been approved by WPC wireless planning commission in India. So, 125 kilohertz, 13.56 megahertz, 866 megahertz, 2.45 gigahertz, 5.8; So, you can really see there is a huge spectrum starting from kilohertz up to gigahertz. So, that is why there are lots of applications are there. So, it can be used in the retail, it can be used for library management, vehicle license plate, E-passport, product tracking, animal tracking, electronic toll collection and so on.

(Refer Slide Time: 13:01)



So, let us talk about ground penetrating radar. What is a ground penetrating radar? In a very simple manner what we have here this is a transmitting antenna which is sending the signal down and the let us say there is an objects and the wave gets reflected from this particular object and this is the receiver antenna. So, what it does here this is used for buried objects, it can be used for landmine detection, buried objects can be even it can be a gold, it can be just buried copper cables or it can be a you know buried steel and so on.

So, basically what the principle is that reflected amplitude and phase are captured for reconstruction of images for underground object. So, in fact, this you can even thing about it is a part of microwave imaging also. So, how much is the depth one can go through that actually depends upon the depth of penetration depends on the transmitted power and frequency. So, just you give you a general idea if the frequency is around 1 gigahertz the depth of penetration can be about 40 to 50 centimeter, but if you want a larger depth then you have to use lower frequencies.

So, radar systems are of course, used for defense systems. So, I am not talking about the defense system right now. Most of the time they are secrete things. So, let us now talk about the secrete things. So, what are the public domain things, let us talk about that.

(Refer Slide Time: 14:39)

Radar Systems for Automobiles

10 GHz / 24 GHz Radar System

- To measure speed of the vehicle (5 km/s to 200 km/s)
- To measure length of the vehicle (0.1 m to 10's of m)

Extremely Sensitive – can detect even hand movement

77 GHz Radar System

Collision Avoidance for the vehicle



Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay

So, these days radar systems are being used for many automobile applications. So, we have some of this lower frequency region compared to this it is lower of course, otherwise 10 gigahertz or 24 gigahertz are very high frequency; Just to give you a little bit of a perspective most of the mobile phones work at 1 to 2 gigahertz, Wi-Fi works at 2.45 gigahertz. So, 10 gigahertz is definitely larger than that. But, now this 10 gigahertz or 24 gigahertz radar systems, these are actually being used to measure speed of the vehicle.

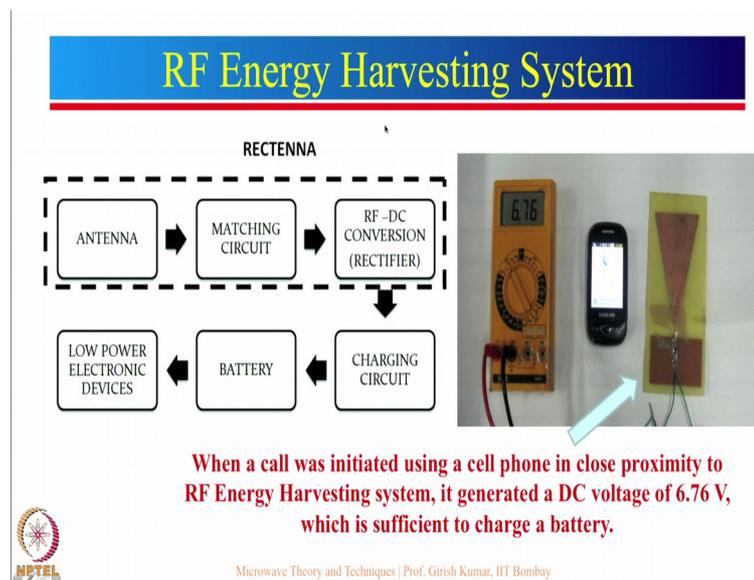
So, you might be familiar with the speed gun. So, basically speed guns are nothing, but used to monitor the speed of the vehicle and majority of the police would have these kind of a speedometer, so that they can actually find out who is driving very fast and of course, then you may get a ticket of course, in India speedometers are not very popular, but abroad almost all the other countries do have police vehicles which actually have these radars to measure the speed.

But, here I am talking about one additional application and that is to measure length of the vehicle. So, there are now these 10 gigahertz 24 gigahertz radar systems. So, not only they can measure this speed of the vehicle they can also measure the length of the vehicle. So, in fact, we have worked on some of this system. So, where we could actually speaking what we did that we actually put this particular radar system next to the highway and we went early morning around 6:30 am and we could actually see that you know when a Maruti car goes or a bigger car goes or a truck goes so, you get actually a

larger signature and with this particular thing then you can measure the speed as well as length of the vehicle. In fact, when we were doing the testing we found these to be extremely sensitive also and we can even detect hand movement also, but of course, the distance is up to only about 5 to 10 meter.

Now, these days many automobiles specially high end automobiles and of course, driver less automobiles are using 77 gigahertz radar system and these are again now collision avoidance for the vehicle. And recently now, all these things are also available in the modulated form. So, you can actually speaking by the module in fact, 77 gigahertz module is just approximately about 10 centimeter by 10 centimeter size you can see it is really small and you can actually mount in the vehicle. And majority of all these driver less vehicles do have that as I mentioned some of the high end vehicles like high end Mercedes they do have these kind of a high power radars.

(Refer Slide Time: 17:44)



Then, this is the again a becoming a very very important topic which is a RF energy harvesting system. So, why it is important first of all I tell you these days in the atmosphere we have too many RF signals, we have too many cell towers working at CDMA, GSM 900, 1800 then 3G, 4G we have Wi-Fi modems almost everywhere these days, we have a Wi-Fi enabled airports Wi-Fi enabled colleges, Wi-Fi enabled railway stations, now they are talking about Wi-Fi enabled city. So, these signals are available almost everywhere.

So, what is this RF energy harvesting system; that you can use some of this available signal in the available in the environment or you can actually use this as a standalone unit also. So, first of all let me just tell you quickly the block diagram. So, what RF energy system has? It has an antenna then along with an antenna, there is a matching circuit in between, basically this circuit is required what we generally need is an antenna should receive the signal and that should go to RF to DC conversion, but the rectifier input impedance is very different then the antenna impedance. Hence we need a loss less matching circuit and in this particular course we will talk about lot of different type of loss less matching network. So, this combination again part comes from rectifier and this part is coming from antenna. So, that is how the term is rectenna.

So, this now RF to dc conversion we got a DC voltage over here that can go to the charging circuit which can charge a battery or it can be use for low power devices also. So, may not require for example, as I said RFID really speaking does not have any battery, but it actually uses straight way. In fact, RFID would not have any of these thing RFID at this particular point only it will go to the circuit which will send the signal.

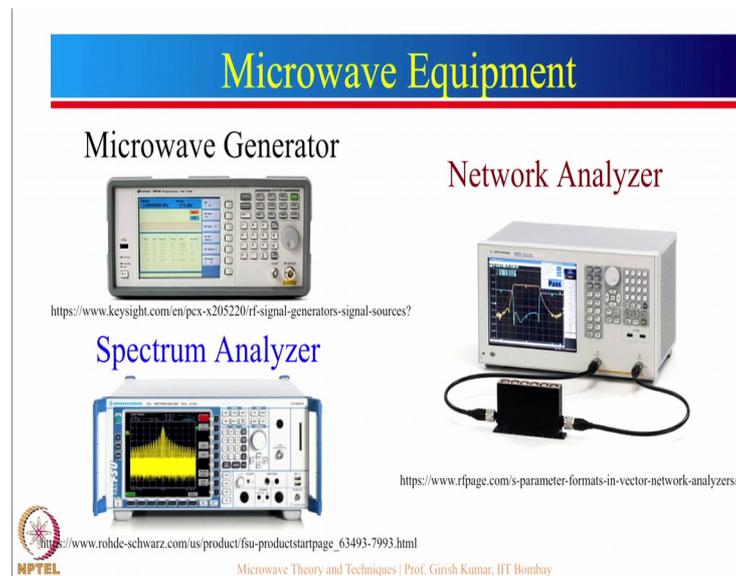
So, now we have designed these particular circuits. So, just to show you here one of the example. So, here we have actually designed a broadband monopole antenna. Why broadband? so that we can receive the signal, right from CDMA which starts around 800 megahertz up to Wi-Fi which is 2.5 gigahertz. So, we designed this broadband antenna and then this portion what you see over here that has actually RF to DC conversion as well as matching circuit.

So, all of that fits over here, and you can see the size idea you can get there is a mobile phone over here. So, now, just to give the demonstration here then a mobile phone starts ringing. So, we initiated a call from here, this antenna receive the signal and now you see what is the DC voltage measure by this that is 6.76 volt that is huge voltage which is sufficient to charge a battery.

Now, just you tell you what we also did. So, we made multiple units of this. So, we put one unit on this side and we put another unit over here and we took this DC's output of this and DC output of this and we put combine and over here we got more than 13 volt. So, that means, you can put one a rectifier circuit here another rectenna or RF energy harvesting system and put a mobile phone. So, if you actually speaking put mobile phone

in the speaker mode so, while you are talking speaker mode you can use this voltage and you can even use this voltage to charge a battery. So, that would be a simple thing for mobile phone, but this particular thing can also be taken next to the cell tower and in fact, we have done some of these experiments also. So, when we talk about energy harvesting system we will talk about some of these things in more detail.

(Refer Slide Time: 21:50)



Let us look at what are the different types of microwave equipment. So, we have a something like a microwave generator. There are varieties of microwave generators are there. There are microwave generators may give output of only up to one gigahertz or up to 3 gigahertz or 10 gigahertz or 20 gigahertz of course, there are microwave generators at 100 gigahertz also. Then, these microwave generators may have other features also they may have things like amplitude modulation built in or frequency modulation or it may have a digital modulation built in two way. So, that you know one view get an output you can get a modulated signal output also.

So, here in general microwave generator you can change the frequency from a low frequency value to a higher frequency; low frequency can be in kilohertz also up to gigahertz and the output power also can be changed from a very small value which can be even let us say minus 100 dB to up to even plus 10 to plus 20 dBm also.

Now, then there is a spectrum analyzer. Basically, spectrum analyzer is a equipment which measures the spectrum of a given signal. So, what you see over here that here is a

signal is present over here and this is nothing, but a noise floor. So, again in spectrum analyzer majority of the time what should do you actually set the start frequency and the stop frequency and then you can see the spectrum of a given signal.

So, then we have a network analyzer. So, basically network analyzer is used to measure the S-parameters of a device S-parameters also we will discuss in more detail, but just in a simple form suppose if this device is an amplifier. So, we connect the input over here we connect the output over here. So, you can actually measure the gain of the amplifier.

Now, if you have done the simple experiment in the analog circuits lab. So, what do you do you give a input signal through let us say generator and then you measure this particular output signal let us say an oscillasso. So, generally speaking to get the frequency response measure so, what you do? So, let us say you want to do frequency response from 1 kilohertz to 20 kilohertz, you will give 1 kilohertz you measure there you give 2 kilohertz then measure the value, then 3 then up to 20 and then you will set down and plot the graph.

Well, network analyzer does all of those things in a very simple manner all you need to do it is you give the start frequency you give the end frequency you give the step frequency and then you connect this particular thing of course, before connecting you have to do one thing. You have do the calibration over here, the calibrations are in the form of short circuit open circuit and match load.

So, once you do this particular calibration network analyzer is ready to do the testing and you connect that and you will straight way get the plot you will get the plot of reflection coefficient also you will get the plot for transmission coefficient. So, what is reflection coefficient that will tell you; what is the reflected power, transmission coefficient will tell you what is the transmitter power. So, this can be used to let us say characterize a amplifier or let us say filter or coupler or divider and so on and so forth.

(Refer Slide Time: 25:35)

High Power Microwave Systems

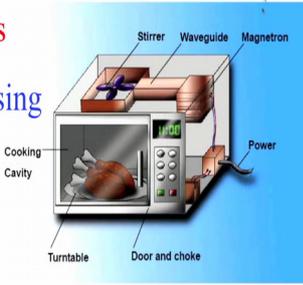
Communication Range is increased

Microwave Heating Applications

- Cooking, Drying, Food Processing
- Hyperthermia

Microwave Bomb

Microwave Weapon



http://www.cfs.gov.hk/english/programme/programme_rafs/programme_rafs_ft_01_02_mcf.html

Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay



Now, let us look at various high power microwave system. So, of course, what you are familiar with the simple microwave oven. So, you can see a typical block diagram of a microwave oven. So, we can see here there is a power supply, there is a transformer which goes to magnetron that magnetron generates a microwave frequency at 2.45 gigahertz through the waveguide it goes over here and let us actually going in to the cavity where multiple reflection takes place.

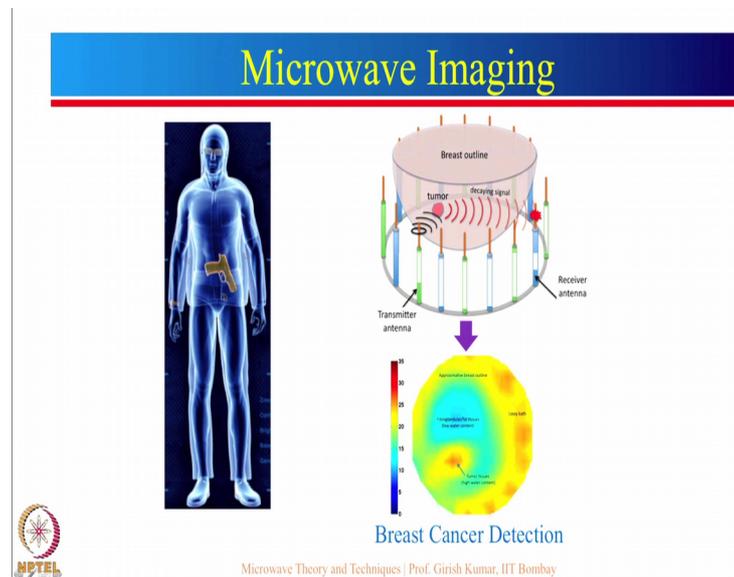
Now, there may be a stirrer over here or there can be a turntable sometimes there may be both, so that there is a uniform heating of the food which is kept in there, but however, high power microwave systems are used also let us say communication range is increased, just to tell you some of the defense system may even use 1 mega watt of power also. And, of course, microwave heating as I mention you may be familiar with the microwave oven, but there are many other applications are there it can be use for cooking it can be use for drying it can be use for food processing it can be even use for hyperthermia.

And, of course, an extremely high power microwave can be use as microwave bomb alright. So, the what bomb does if this one actually basically microwave bomb transmits a very high power of small pulse which has actually a very wide bandwidth and this actually is used to destroy all the receivers. So, once a microwave bomb is put most of

the receivers which actually work at a very low received power when they receive this very high power these receiver input signal get burned.

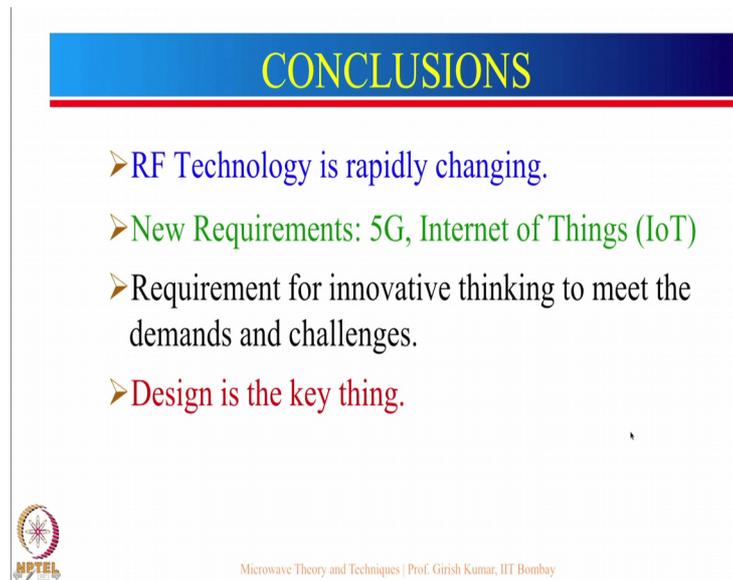
Now, microwave weapon is now reality where what they do, they use high power microwave director towards a certain segment and the in fact it has been now commercial used for crowd dispersal. So, you know that for crowd dispersal people do use tear gas or they use water canon and here they have use high power microwave at millimeter wave frequency and by transmitting that people feel the burning sensation and they run away.

(Refer Slide Time: 27:53)



Microwave imaging is now again becoming a very very important thing. So, here you can actually see that this person has concealed the gun inside the cloth, but just by looking at the image of that particular thing you can see that the gun is reveal. Now, microwave imaging can also be use in the medical things. So, here is a one of the example where it can be use for breast cancer detection and there are many other applications are there.

(Refer Slide Time: 28:17)



CONCLUSIONS

- RF Technology is rapidly changing.
- New Requirements: 5G, Internet of Things (IoT)
- Requirement for innovative thinking to meet the demands and challenges.
- Design is the key thing.

 Microwave Theory and Techniques | Prof. Girish Kumar, IIT Bombay

So, in conclusion I would like to mention that RF technology is rapidly changing lots of new advances are happening and specially now with the new 2 requirements which are coming up and that is 5G and IoT which full form is Internet of Things, just you tell you that 5G internet of things has been projected by the industry people as 7 trillion dollar market, and just to tell you that as of now, India's GDP is around 2 to 3 trillion dollar. So, you can imagine 7 trillion dollar is huge amount of money. So, there will be lots of things happening. So, I want to mention as per as India is concerned we miss the bus for 2G, 3G, 4G.

So, all those things are getting imported in India. In fact, today India is one of the largest importer of let us say apple phone. In fact, in India we have about 100 [FL] cell phone subscribers and only 10 [FL] cell phones are being manufacture in India. So, 90 [FL] or may be half of that 50 [FL] even if we say which are being imported and if you take an average price of 4000 rupees per mobile phone we are totally you know we are importing about 2 lakh [FL] rupees worth of mobile phone and then all the infrastructure mobile phones and other thing are being imported.

So, now a 5G an internet of things if that is going to be let us say 7 trillion dollar market then Indian market itself may be touching one trillion dollar and that is like half to one third of the Indian economy. So, I think all the people all the professors, all the researchers, all the industry people and students they should really seriously focus on

microwave technology, so that we should start designing in India and if we design in India then only we can make in India. So, make in India will be only successful if you do design in India.

So, we really in fact, if these things are manufactured in India it will create lots of jobs in the manufacturing sector, it will create lots of job in the design. So, all you engineers will get good possible job, all you professors may get consultancy project and all the engineers you have your hands full. So, I would like to mention that there is a requirement for innovating thinking to meet the demands and challenges and design is of course, the key thing and the design can be in two different segments one thing is design would be which would be a low cost design. So, that would be very very important to complete with the rest of the world.

The second thing is design could be that frontier technology you develop new technology. So, design can be from let us say low end to a very high end also. So, in this particular course we are going to look at different types of design and at different times I will tell you about what are the low cost design and where we need a high cost design specially when it comes to the defense and space application, where performance is much more important and when we talk about commercial application then the cost is more important. So, we have to maintain a balance when we are doing the design of different component.

So, now, of course, in the next lecture I am going to first talk about microwave hazards because before you design anything whether it is a electronic product or whether let us say your designing a bridge or the road you have to understand what are the safety requirements for that. So, in the next lectures I am going to talk about what are the health hazards possible because of the microwave radiation and what precautions need to be taken.

Thank you very much, bye.