Satellite Communication Systems
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Lecture – 01
Introduction

Welcome, so we will talk about satellite communication systems. This is a wireless communication which covers very large area. So, today is the introduction we will try to see why do you need it in such a difficult type of communication and then we will go back to history, most of the textbook we talk about history of US satellite communication. I will also cover what is happening in India, what happened in India and then we will try to see what it is, what we are going to cover in subsequent lectures and a few terms in this process you will learn and maybe a few units you will also learn; let us start.

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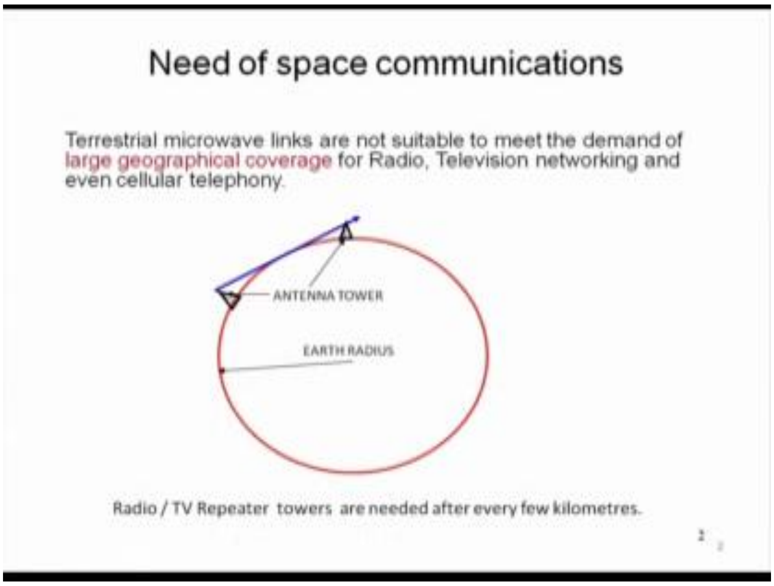

There is a need of space communication; what is the need, it is a wireless communication; terrestrial microwave links are not suitable to meet a large cover large geographical area particularly for radio, television networking even cellular telephony large geographical area. The basic requirement is earth is not flat, earth surface is not flat and micro wave communication; it goes straight line just like light. So, therefore, if there are two towers, the second tower unless it is in the radio visibility it will be not able to receive the signal from the transmitting tower. So, therefore, only a short distance can be covered and you can see that our mobile towers can cover a smaller distance, radio and television earlier days the large towers some of you might have seen in big cities they cover only the city.

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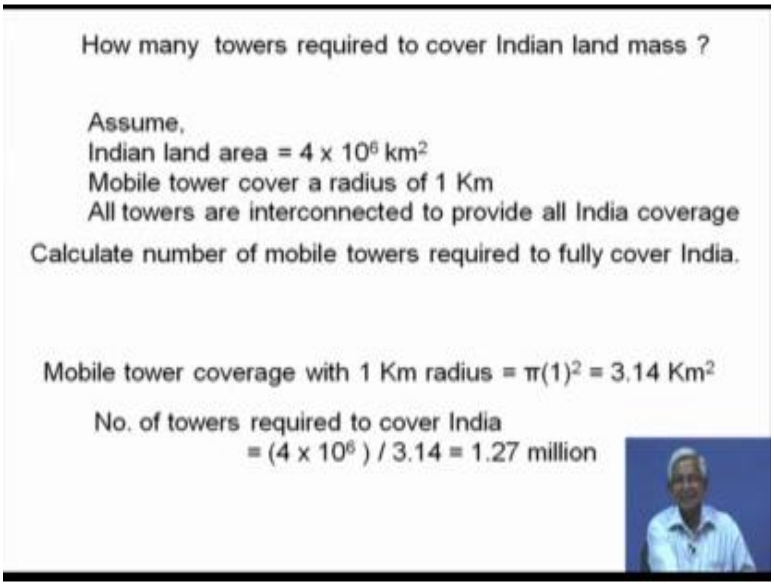

So, therefore, let us do a very small interesting calculation this just for fun; how many cellular towers are required to cover Indian land mass. Let us take very simple type of numbers, let us say Indian land area is about 4 million square kilometers and a mobile can cover with a radius of 1 kilometer, for simplicity and let all the mobile towers are interconnected to provide a all India coverage, a true all India coverage; any geographical place in Indian land mass is covered, let us take this problem.

We have to calculate the numbers of mobile towers required for fully cover India; mobile tower coverage can be calculated pi r square, 1 kilometer radius.

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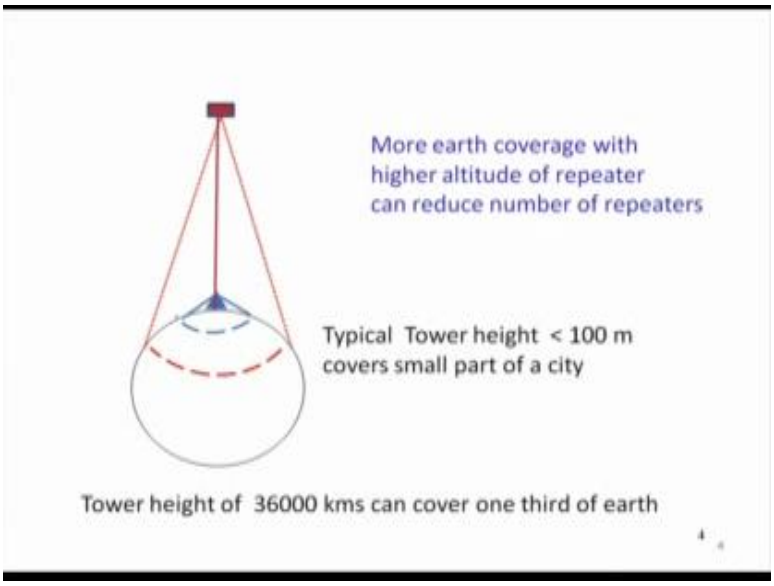

So, it is 3.14 kilometer square and our Indian land area is given as 4 million square kilometer divide by that number and you will get fantastic number 1.27 million towers are required almost like impossible this is just fun calculation. Let us see, normally these towers are less than 100 meters which covers a small part of a city, a town. Now if we really want to cover a larger and larger area, we have to increase the height of the tower and it can be seen that a very long height can cover one third of the path and these top of the tower we can put a repeater.

Now I am first time using a word which is repeater, which receives the micro signal and transmits it back. So, more earth coverage is possible at a higher altitude and that higher altitude; it is roughly calculated as 36000 kilometers from the surface of the earth, we will do all the calculation later, today just we are giving some numbers.

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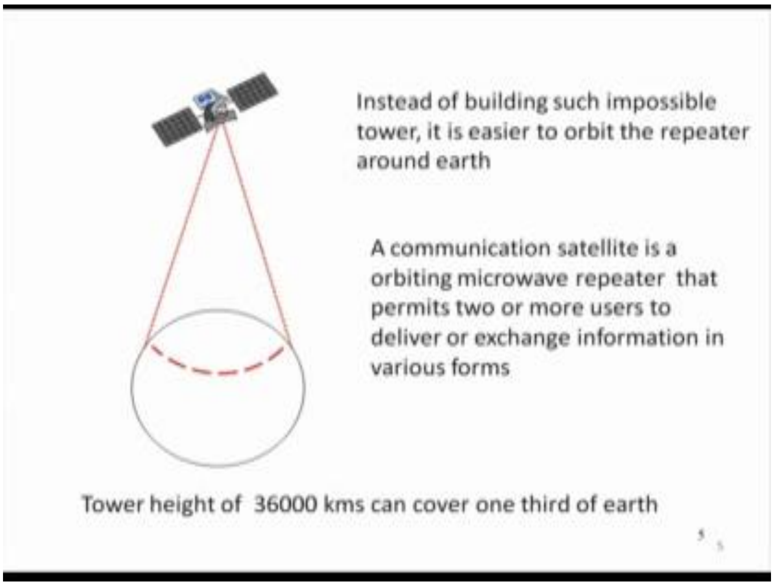

Now, such impossible height of a tower it cannot be realized with today's technology. So, what we did to you show float the repeater; we should float the repeater by the name called communication satellite and that will be floating means it will be orbiting around the earth. So, we should learn about how it can orbit around the earth, instead of simply floating and that will be at 36000 kilometers above the earth surface. So, these repeaters with its radio visibility will permit two or more users, any number of users that is available within its radio visibility to deliver and exchange the information in various forms.

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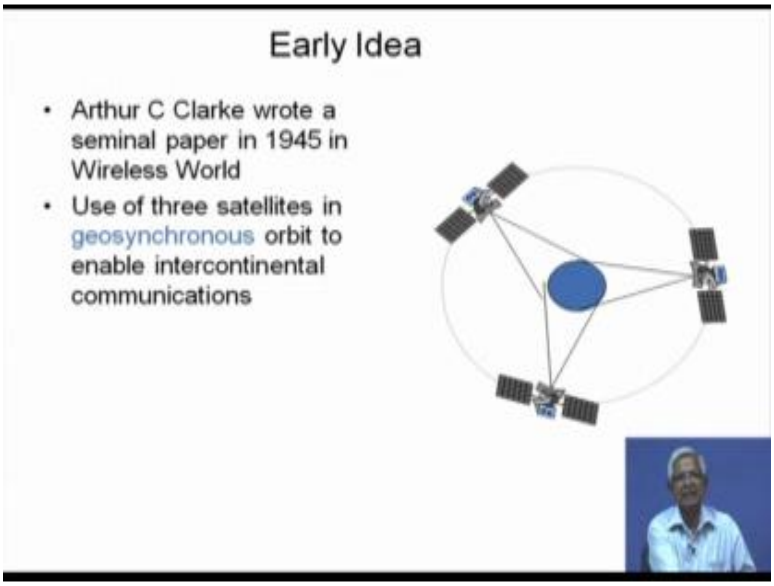

Let us go back to the earlier idea, around world war two time 1945 wireless world Arthur Clarke, a scientist; later he became a novelist. He wrote a seminal paper, did some calculation and he did not use the word satellite, he said a microwave repeater; if it can be floated than 3 such satellites can cover all that earth and these particular height he calculated and said it is called geosynchronous orbit, we will learn more about it later.

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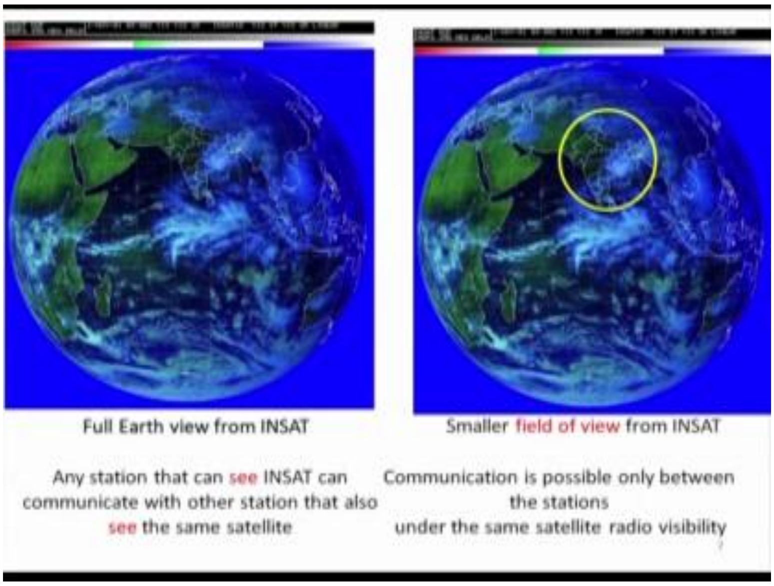

Let us see, India has some satellites it is called INSAT; Indian National Satellite, from the satellite; it is a real picture, if it looks at earth, it looks like this over India and this satellite is placed over above the equator, the full earth view. So anybody, any place from this visibility can see the satellite radio visibility, radio seeing and satellite also can see by the radio. Now if this field of visibility is reduced to Indian land mass, then within that circle what I have put the yellow circle, within that circle the radio visibility is there from the satellite.

So, any user can transmit a signal with the radio visibility of the satellite and within that radio visibility others can receive it; a satellite is nothing, but a repeater it is a smaller field of view. Why it is necessary? Because a larger field of view, you can see most of the part is ocean, so if there is no requirement of the communication with the same person in the ocean, there may be some small requirement you will find, but most of the customers or users are within the land mass and if we specifically use it for India. So, you should cover India, that is a smaller field of view of INSAT and that is communication is possible only within the radio visibility of these stations which are in the radio visibility of the satellite, it is very simple way of telling that.

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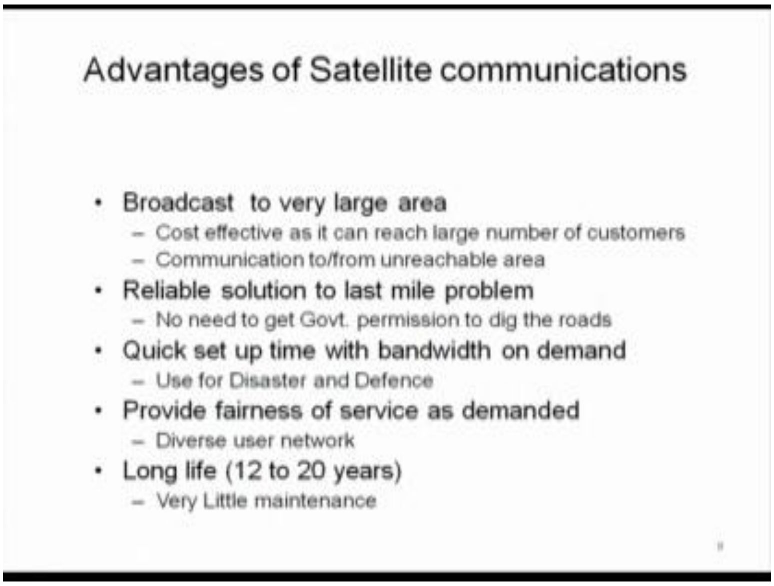

Now, let us see the advantages of these types of communication, the basic advantage it can broadcast to a very large area, it is cost effective, it can reach to a large number of customers with one single repeater. You can remember the example of the tower what we said earlier, large number of towers were required, now it is only one tower and it is a virtual tower.

There is one more thing you can see that communication is reaching to the unreachable area; by unreachable, I try to mention that most of you are using mobile phones, cellular telephony; many places when you travel, when you are on highway or railway or some cities, towns you are getting connection, but many other places if you go across smaller villages, across the fields, over the rivers when you go; you do not get the connection. So, these are all unreachable area there also the satellite signal is reaching you have seen just like the view what we showed just now.

Then it is another thing that is a reliable solution to the last mile problem. It is a very interesting thing, last mile problem is from the last exchange to your place, where your computer is there or telephone is there; that is called last mile. That junction problem is a serious problem and with satellite directly; since you are not using any local where or local, no local small transmission where multipath and other effects are coming and satellite is vertically above you, this last mile problem is much less. Now let us see that the last mile problem, if you go by where telephone people, fiber optics people; they need to dig the roads, you do not need to, you do not need to dig the roads because you are located at the sky. It is easy and quick to setup and based on what is the requirement of the bandwidth of our; you can quickly set up and in case of wire communication that is slightly difficult.

Most of the use is in case of disaster when all other communication fails then this satellite communication remains of course, it is required for the defense is unreachable area when you reach then by satellite communication it is possible. It provides the fairness of service as demanded like diverse user network whether you are using television communication, whether you using video conferencing or simple telephone or much simpler data exchange mails. It can be used for different bandwidths on demand and then it has a long life, this repeater is above atmosphere; no disturbance, atmospheric disturbance, aeronautic disturbance; it is much high above. So, its life is much larger, so you do not have to maintain there, so therefore it is very cost effective.

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Just a couple of advantages and let us go back to the early experiments people have tried many things, many things to reach these type of technology to achieve this technology. Initially people said that why not use moon as reflecting surface for the radio waves, it was tried out for some time, but moon is always not visible; sometimes of the day moon is not visible. So, therefore, communication is quite difficult continuous communication and also you need large power to transmit signal, go to moon and it should come back, so high power is required.

People used copper needles in the sky and the copper needles were floating means actually orbiting and reflecting surface was created that also becomes very erroneous and busty in nature, so therefore it was not effective.

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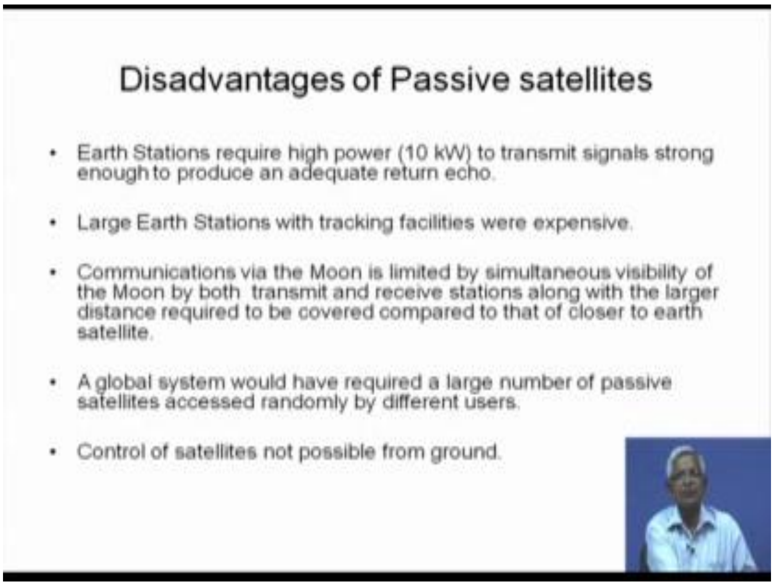

People tried balloon; copper coated balloon, it was tried; balloon name was Echo 1 and Echo 2; two such balloons were launched and that also was tried, not very effective. The disadvantage is very high power is required to transmit from the ground and large earth station, we have to track the facility from where it is to be; it has to be signal is to be reflected then via moon is of course, it is not very comfortable because moon is not available always and the global system would require large number of passive satellites if we use small echo type of satellites.

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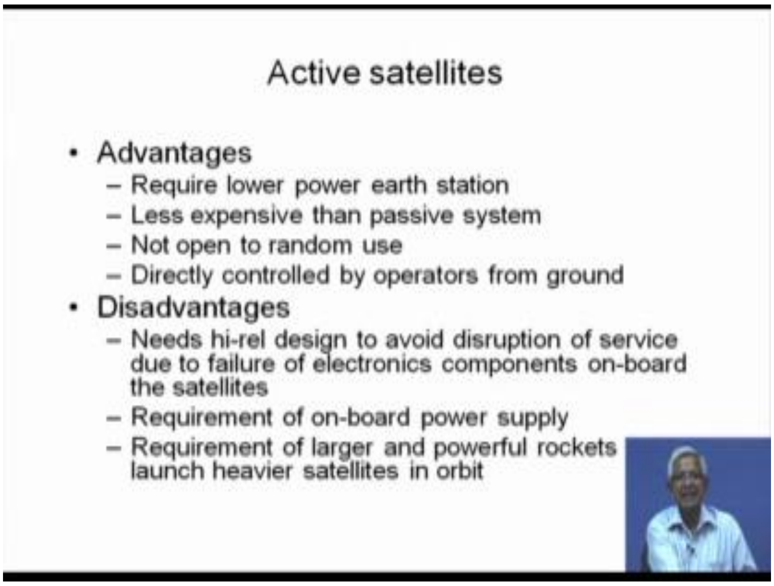

And control of the satellite is not possible because it is passive therefore, people started thinking of active satellite, it has certain basic advantage like it requires lower power earth station because the repeater is there it has a amplifier on board and it is less expensive than a passive system. It is not open for random use, no random transmissions are going and it can be controlled that who is transmitting, who should receive. It can be directly controlled by the operators from the ground and it has also certain disadvantages like, you need high reliable design because in case of electronic component, it feels on board then the whole system fails, it is a single point failure.

So, therefore it has to be high reliable design; we will talk about the reliability much later and then on board power supply is required. So, you make a battery or you need solar power, we will talk about this later and then it needs heavier rocket to launch such a heavy mass, so therefore launching cost is quite high.

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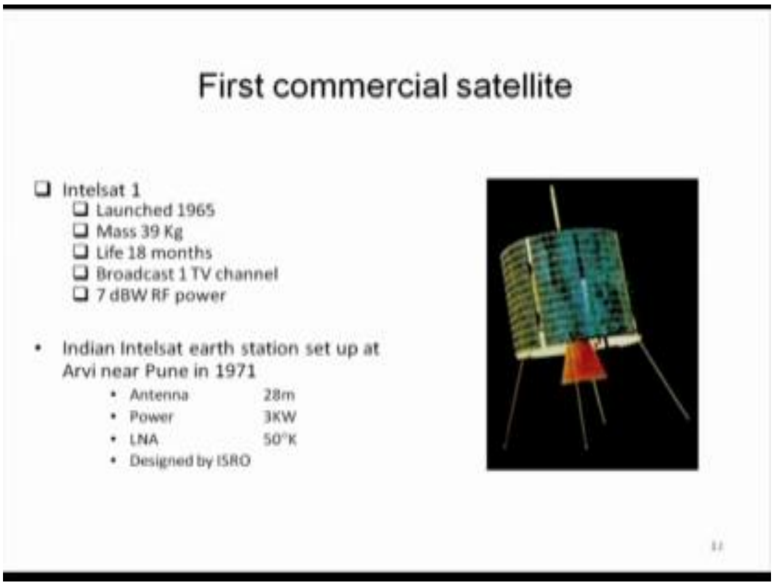

Even with that first commercial satellite, it is called Intelsat 1 was launched in 1965; it has a mass of only nearly 40 kg about; one and half year life time. It could broadcast one TV; analog TV channel and the transmit RF power was 7 dBW RF power, mark dBW this is a power unit in db. When you know convert into direct ratio power, it is equal to 5 watts, this db unit has to be learnt quickly because we will be using it very frequently later.

So, it was having only 5 watt RF power and corresponding ground station in India which was set up in 1971 has antenna of diameter of 28 meters. So, you can see; such large huge antenna was required on the ground and the ground power requirement was 3 kilo watt, there is a low noise amplifier, we will learn about it later.

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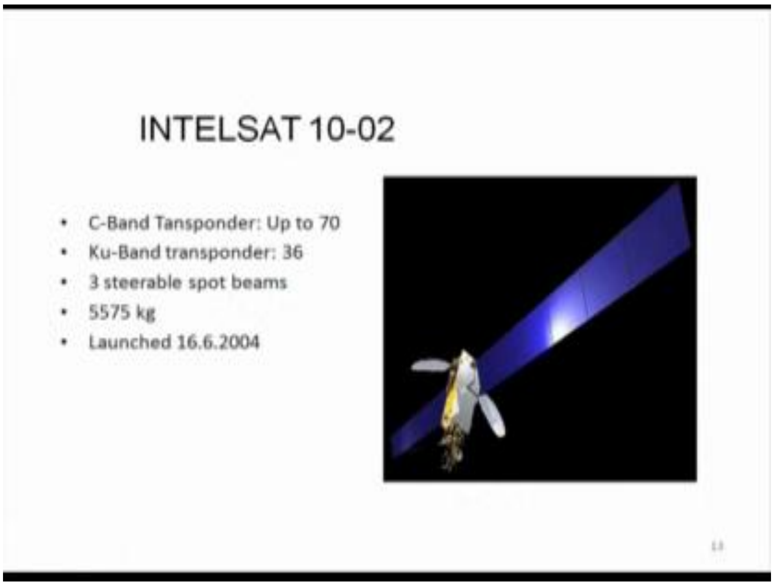

If the noise, the amplifier has to be controlled by reducing the temperature and that was kept at 50 degree Kelvin, that is also another difficult situation and much later the Intelsat 10th generation in the version 2, 10, 0, 2 was launched in 2004, you can see it is 5.5 tones almost it is steerable spot beams and many transponder, a new terminology again transponder which is some form of repeater, I will talk about it later there 36 of them in Ku-band and 70 of them in C-band, this bands also are new terminology we will learn about it later.

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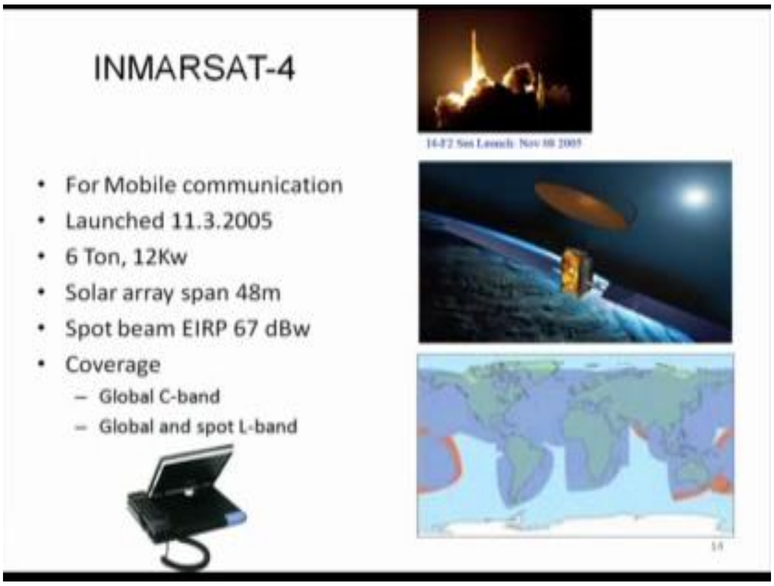

Similarly over the sea, INMARSAT is there, so which is launched in 2005; this is INMARSAT 4, it is 6 ton, 12 kilo watt satellite. It has a solar array of 40 meters, (Refer Time: 15:28) 7 spot beams, these are taken from internet.

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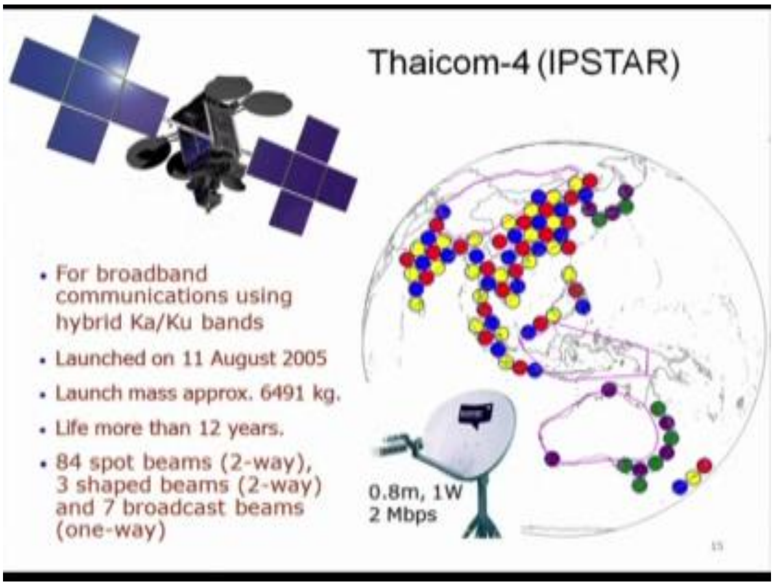

Similarly, another one is IPSTAR right now is existing, it has some many colored spot beams you can see; over India also it is there, it provides service in Ka and Ku band and the 2005 it was launched, it is also 6.4 kg satellite. You can see these are huge satellites and corresponding ground station and now it is reduced to 0.8 meter, 1 watt, 2 megabytes per second.

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Thuraiya is another satellite, mobile phones can be used just is the cellular phone what you use same thing can be used in Thuraiya satellites, it is Arabian satellite.

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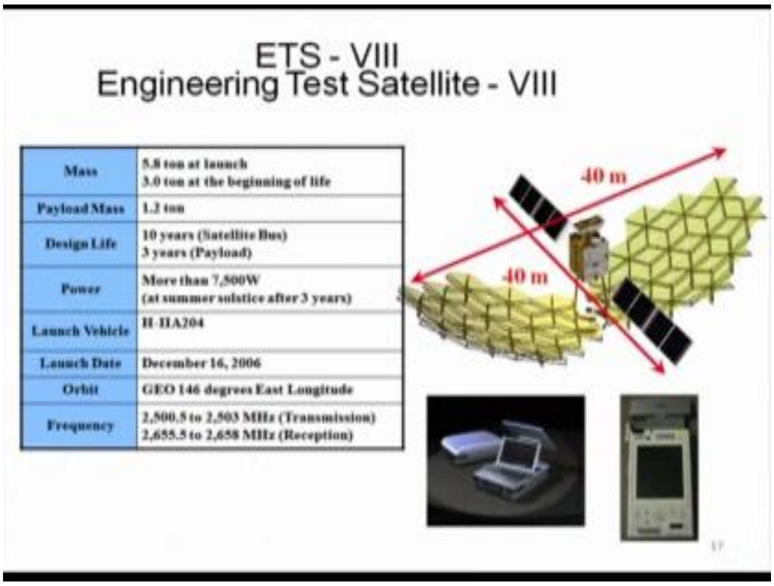

Mass	5.8 ton at launch 3.0 ton at the beginning of life
Payload Mass	1.2 ton
Design Life	10 years (Satellite Bus) 3 years (Payload)
Power	More than 7,500W (at summer solstice after 3 years)
Launch Vehicle	H-IIA204
Launch Date	December 16, 2006
Orbit	GEO 146 degrees East Longitude
Frequency	2,500.5 to 2,503 MHz (Transmission) 2,655.5 to 2,658 MHz (Reception)

Similarly, Japan is have launched another satellite for testing this is; you can see 40 meter antenna diameter, 40 meter span of solar panel; huge 5.5 ton at launch.

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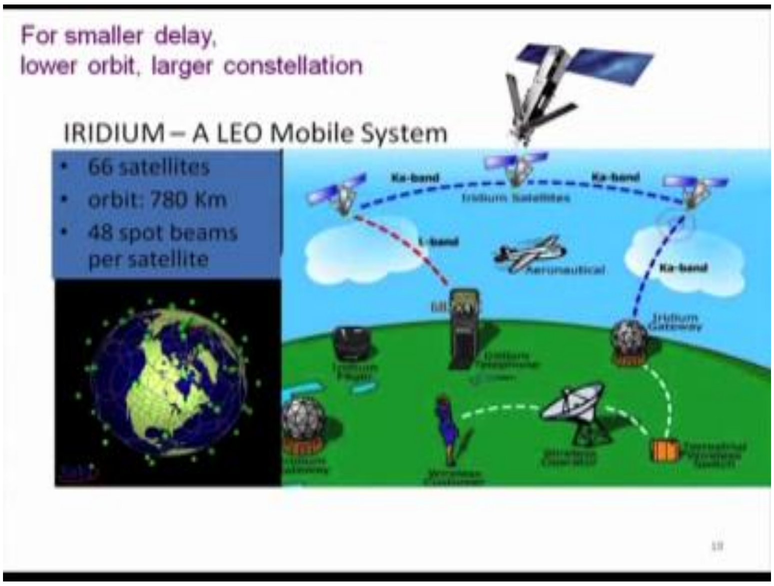

So, such big technologies are there if an much lower of the orbit it is called LEO, 66 satellite constellation was launched by IRIDIUM consortium and each satellite has 48 spot beams anywhere in the world you can communicate via this satellite.

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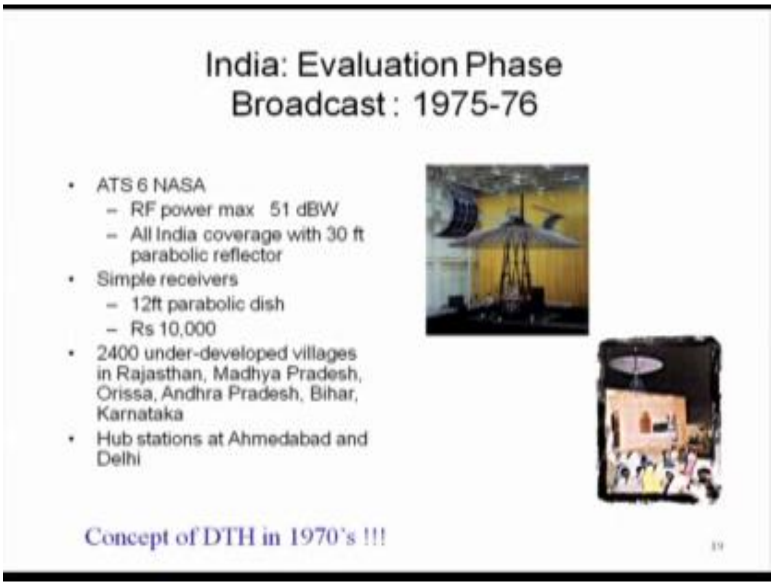

India we had a development phase in 1975-76, we tried with a borrowed satellite from NASA and that was tried with a small parabolic dish of 12 feet diameter, approximately 10000 rupees and it was for school development in villages and you can see that it was tried just like a DTH direct to home in 1970s.

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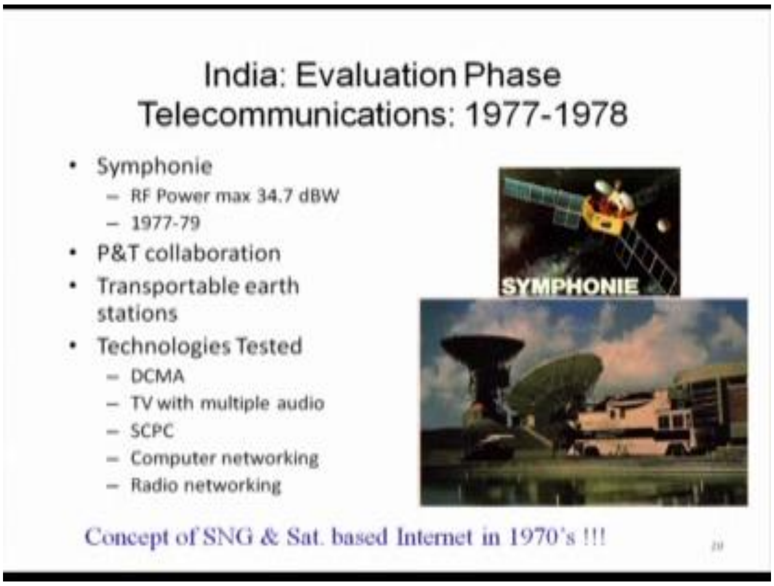

Another evaluation phase we went through, borrowing a satellite Symphonie from Europe that was for post and telegraph; it has a transportable earth station, the communicated picture is there; it is a satellite news gathering terminal.

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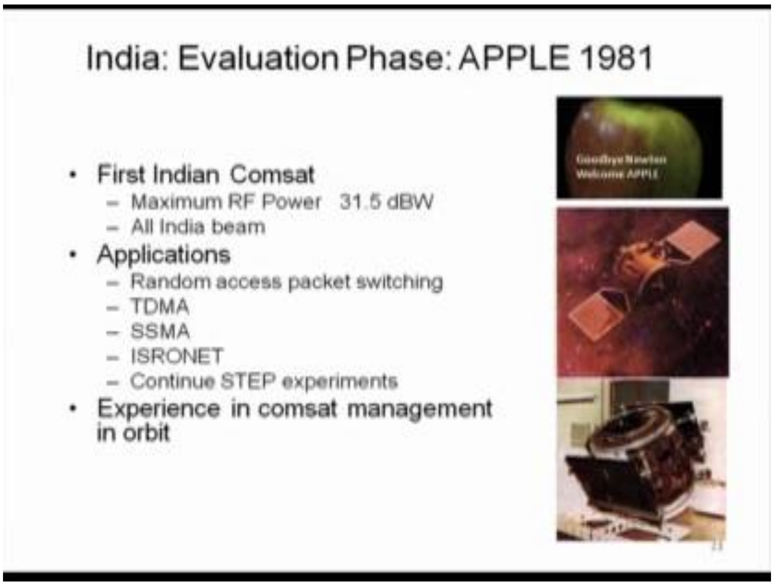

So, those days in 1970s.

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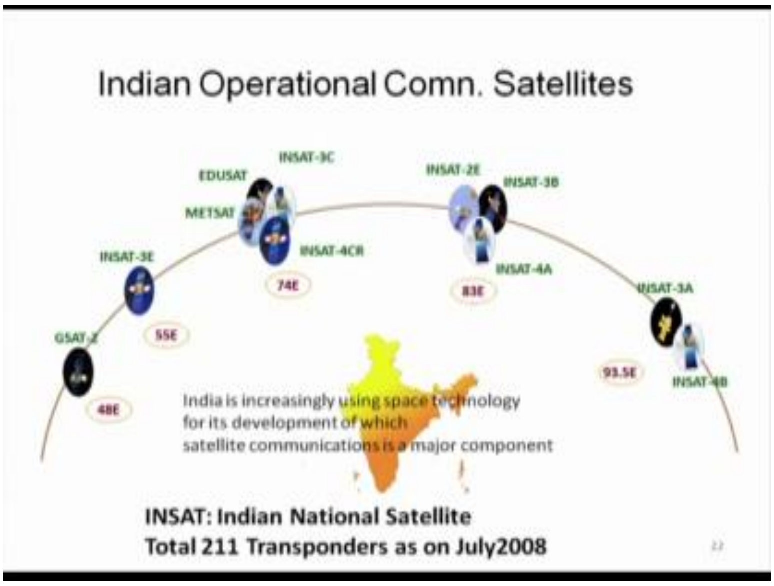

We have tried many evaluations and later we launched our own satellite called apple and that was the first commercial, first Comsat payload; communication satellite payload, lot of experimentation was done and subsequently we launched Indian National Satellites and 2008, we had almost 211 transponder and many such satellites at different places in the orbit seen and the almost now similar number of satellites are there.

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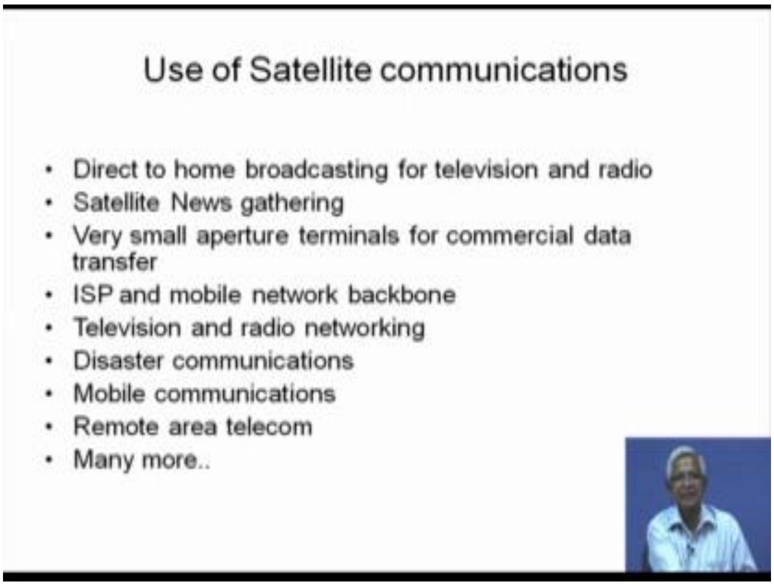

Now, satellite communication can used for direct to home broadcasting to television radios or news gathering, very small aperture terminal, internet service provider and mobile network backbone, television, radio networking, disaster communication, mobile communication, remote area communication lot of things.

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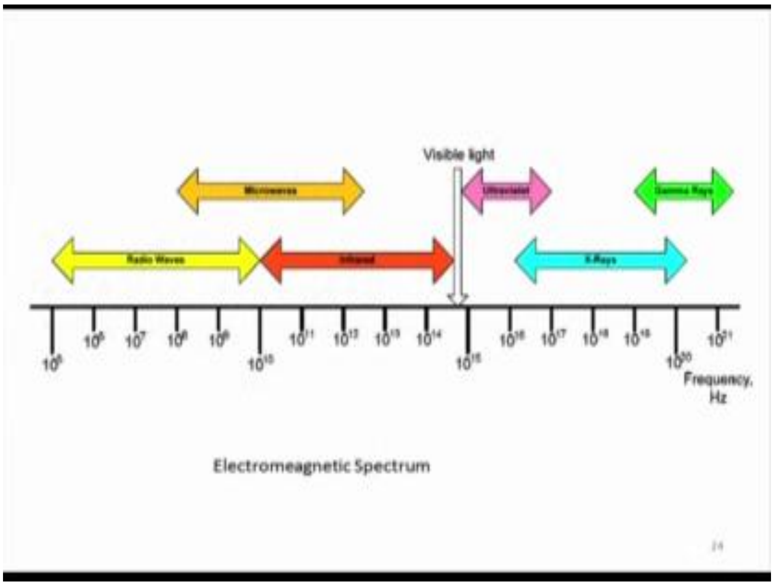

Normally these are the bands where you can see the yellow color top microwave, that band is used for satellite communication and you can see in this table; frequency bands which are available towards the bottom 30 gigahertz, 3 gigahertz to 30 gigahertz is super high frequency satellite microwave is covered in that.

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Common Freq. Bands and typical applications

Frequency Band	Name	Applications
< 3 kHz	Extremely Low Frequency (ELF)	Submarine communications
3 kHz - 30 kHz	Very Low Frequency (VLF)	Marine communications
30 kHz - 300 kHz	Low Frequency (LF)	AM Radio
300 kHz - 3 MHz	Medium Frequency (MF)	AM Radio
3 MHz - 30 MHz	High Frequency (HF)	AM Radio
30 MHz - 300 MHz	Very High Frequency (VHF)	FM Radio, TV
300 MHz - 3 GHz	Ultra High Frequency (UHF)	TV, cellular, wireless systems
3 GHz - 30 GHz	Super High Frequency (SHF)	Satellites
30 GHz - 300 GHz	Extra High Frequency (EHF)	Satellites, radars

There is the international telecommunication union is standardizes this natural resource of wireless communication.

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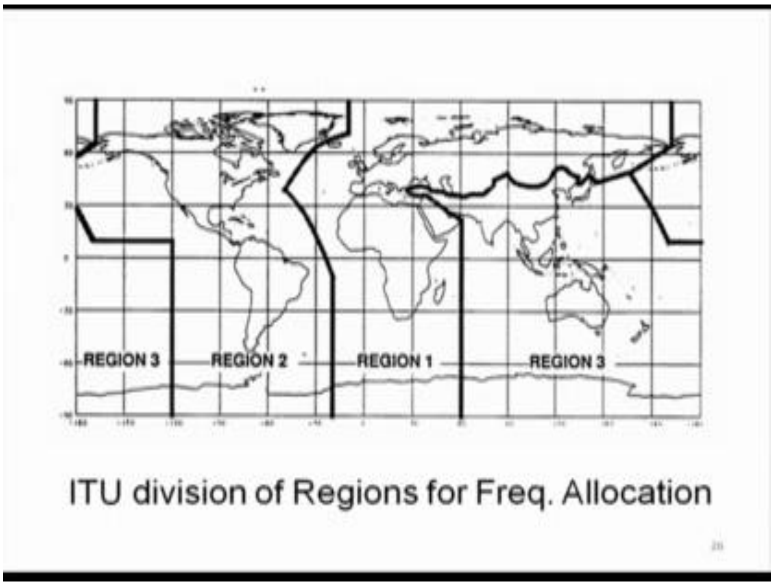

We are divided the world into region 1, 2, 3 and India falls in region 3 and they provide a table, the table one page I have shown here.

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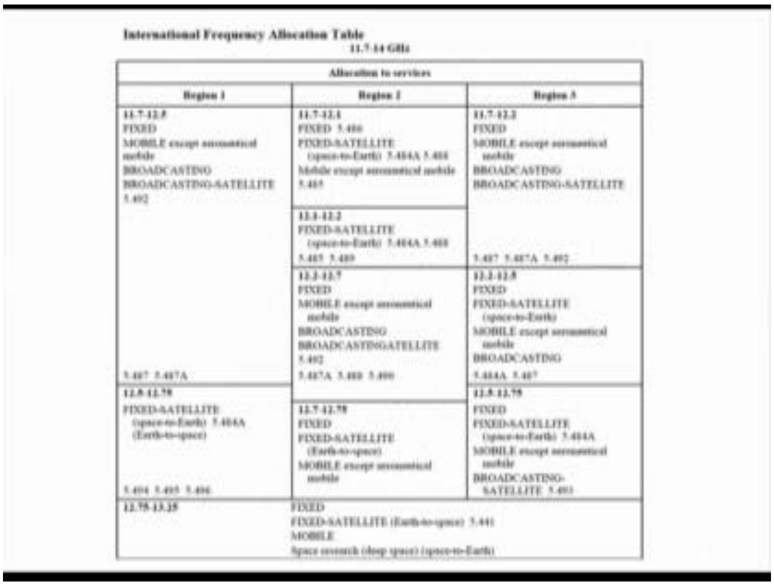

International Frequency Allocation Table

11.7-14 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
11.7-12.5 FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTING-SATELLITE 5.492	**11.7-12.1** FIXED 5.486 FIXED-SATELLITE (space-to-Earth) 5.484A 5.488 Mobile except aeronautical mobile 5.485	**11.7-12.2** FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTING-SATELLITE
	12.1-12.2 FIXED-SATELLITE (space-to-Earth) 5.484A 5.488 5.485 5.489	5.487 5.487A 5.492
5.487 5.487A	**12.2-12.7** FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTINGATELLITE 5.492 5.487A 5.488 5.490	**12.2-12.5** FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile BROADCASTING 5.484A 5.487
12.5-12.75 FIXED-SATELLITE (space-to-Earth) 5.484A (Earth-to-space) 5.494 5.495 5.496	**12.7-12.75** FIXED FIXED-SATELLITE (Earth-to-space) MOBILE except aeronautical mobile	**12.5-12.75** FIXED FIXED-SATELLITE (space-to-Earth) 5.484A MOBILE except aeronautical mobile BROADCASTING-SATELLITE 5.493
12.75-13.25	FIXED FIXED-SATELLITE (Earth-to-space) 5.441 MOBILE Space research (deep space) (space-to-Earth)	

Where the bands are shown, you can see region 3 bands; where you can see fixed satellite service space to earth. Similarly, fixed satellite service, mobile service, broadcasting satellite service different bands are given which are allowed for communication from space to earth or earth to space.

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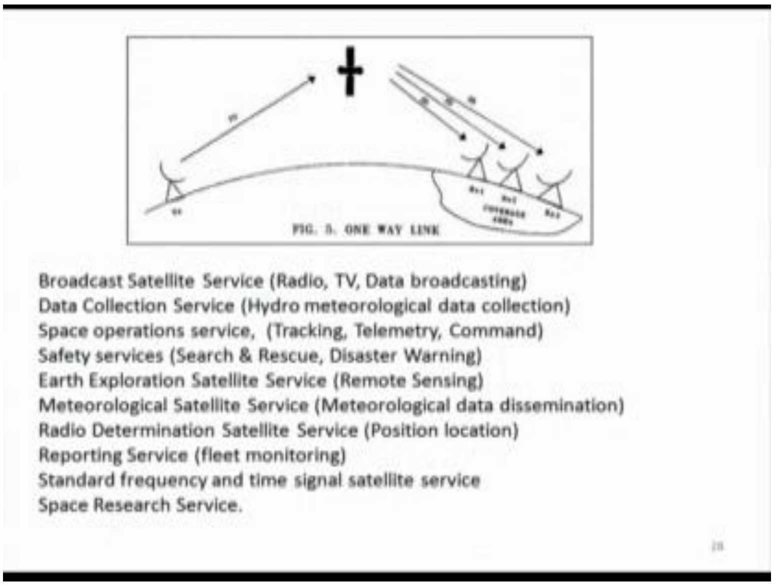

For one way, it can be used there is a big list I have provided, it is for broadcast satellite service, data collection service, space tracking operation service etcetera. Similarly, two ways it can be used for fixed satellite service, mobile satellite service, news gathering service.

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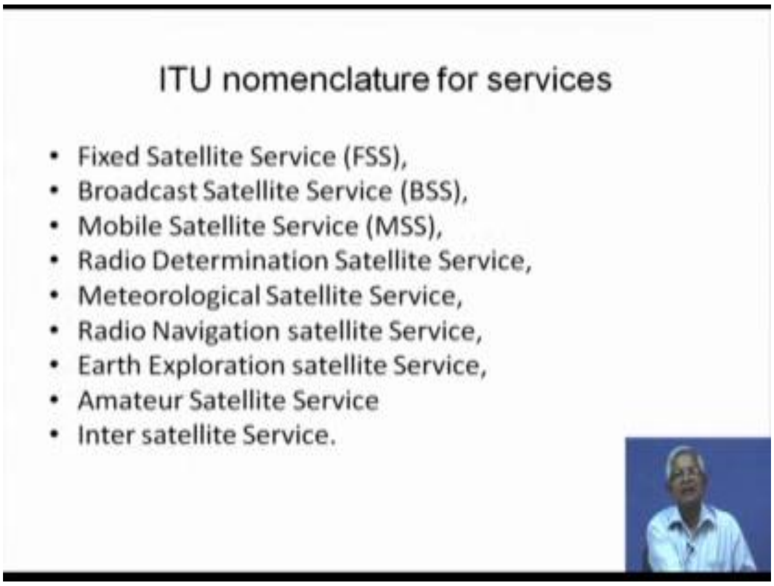

So these terms what I am using is listed by ITU nomenclature on Fixed Satellite Service; FSS, Broadcast Satellite Service; BSS, Mobile Satellite Service; MSS like that there is a big list of that, so these are the terminologies we will be using frequently.

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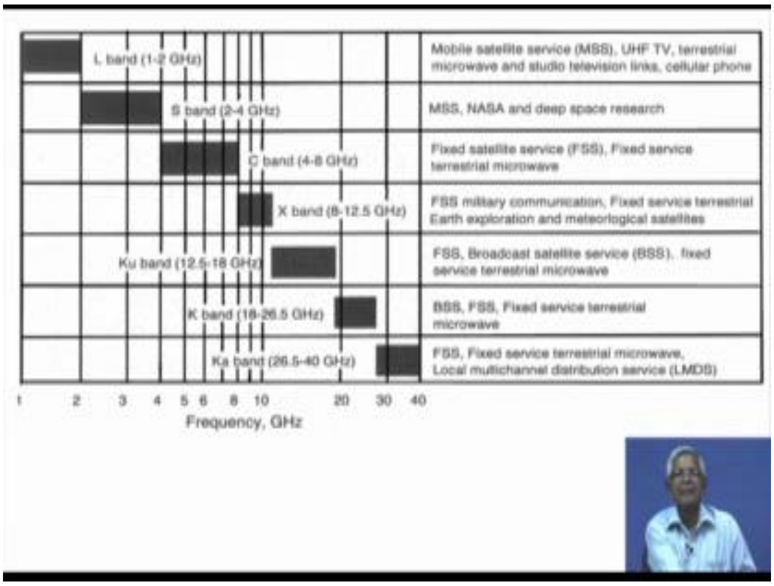

And the bands in very common general term, it is used for satellite communication is L band, it is 1 to 2 gigahertz, S band 2 to 4 gigahertz, C band 4 to 8 gigahertz. Particularly what we see in our regular daily life is direct to home television, cable t v as well as the fixed satellite communication which is in Ku band 12.5 to 18 gigahertz, that is for FSS, Fixed Satellite Service and Broadcast Satellite Services; BSS is also allowed in a band which is between 18 to 26 gigahertz and Ka band is for fixed satellite service, 26.5 to 40 gigahertz, these are roughly these are the bands, the details are shown like the previous page I have shown, there is a radio regulation.

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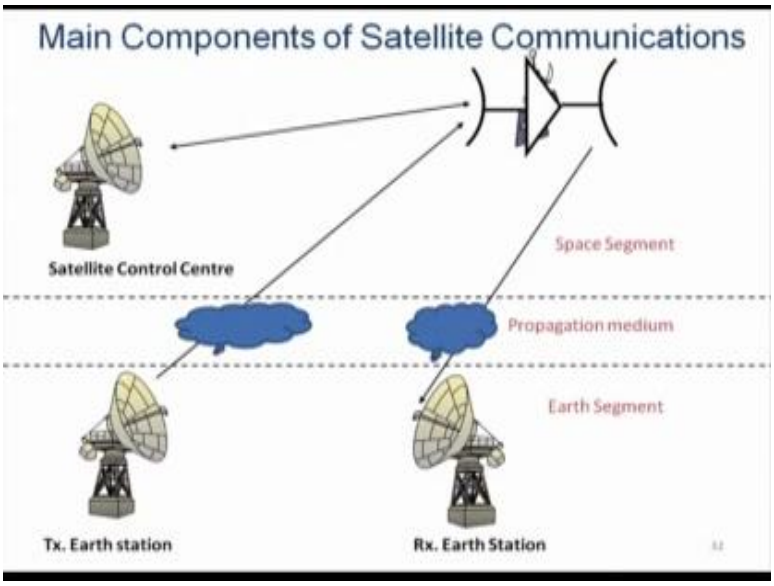

The main component of satellite communication is a space segment, which is a satellite as well as controlling part of the satellite is called satellite control center. Space segment consists nothing, but the receiver, amplifier and transmitter that is all; it is a repeater and there will be ground segment, which will be communicating to these trans-receiver and the satellite, a transmitter station receives station, a station who I have shown here pictorially sketch, a large station it could be very small station and coming in between medium which is the propagation medium through which the signal will pass.

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	Topics
1.	Orbit
2	Space segment
3.	Ground segment
4	Propagation effect
5	Link Budget
6	Multiple Access
7	Issues: Nonlinearity, Synchronisation, effect on higher layer
8	Regulations and Standards

So, we will learn about how to put the satellite into that space, then what should be there inside the space segment, what is there in the propagation media and what is there in the ground segment. So, our topics subsequently will be, we will learn about orbit where the arbitrary dynamics of the satellite, the velocity, the orbital height, how it can be calculated, how it can be placed in the orbit; we will learn about it in subsequent couple of classes.

Then we will talk about the space segment inside the satellite what is there and then we will talk about the other things like ground segment propagation effect. The link budget is very important, I may advance the link budget a little early and link budget is how much hour it should transmit from the satellite as based from the ground, based on your significant noise criteria and since it is covering very large area, we will talk about multiple access, multiple users can access the satellite and there are certain technical issues that we will discuss, which is about the non-linearity, about the synchronization, about the effect from this physical layer to the higher layer, that is data link layer and the transport layer, network layer, so that also we will discuss. We will discuss about the regulation and certain and standards.

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Now, what we learnt till now is; Satcom is a form of wireless communication which covers a large geographical area. Also we learnt that; these communication satellites generally are used in the microwave band and it can be called as a microwave repeater.

We have seen a very briefly early history of Satcom internationally and in India and certain technical terms like BSS, MSS, FSS and DTH, DB; DBW these are the certain terms we have used and we have seen what is the international frequency band that is used for this services and some technical units like; DBW and gigahertz these are the certain things we have used.

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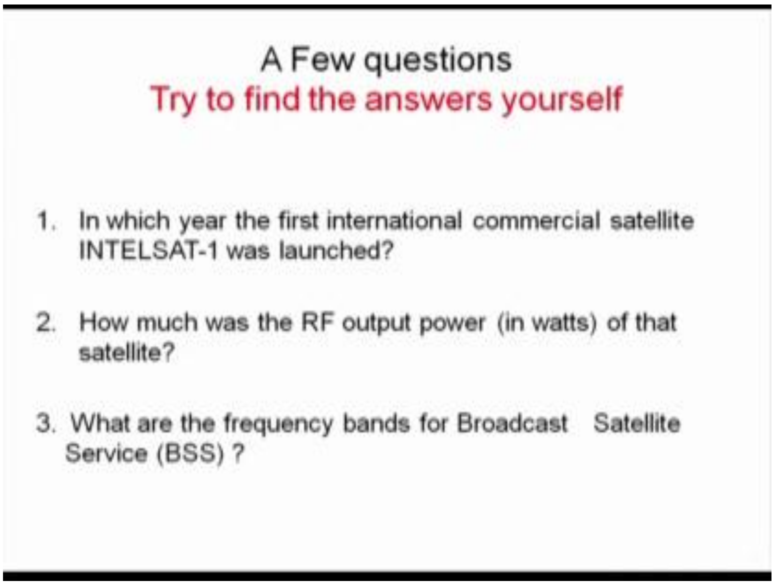

Now, I will leave certain questions for you to go through these video and try to answer yourself. I will not give the answer; you can see the answer in the video itself; In which year the first international commercial satellite INTELSAT-1 was launched? How much was the RF output power in watts of that satellite? Remember I am that asking in watts, how much it is and; what are the frequency bands for Broadcast Satellite Service - BSS you go through these video and try to answer with yourself right.

Thank you very much for today and next class onwards, we will start about the technical issues, about the orbits and how the satellites behave in the orbit, what is the effect of the orbit for our communication purpose and then we will go into the space segment and link budget.

Thank you very much.