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Satellite Communication
(Editorial article)

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Abstract: The Article recalls the historical background of Satellites for communication in the Global scenario. It takes cognizance of the beginning of Satellite communication Applications in the country with SITE & STEP, followed by Satellites for Communication, its growth from Experimental to operational phase. The article discusses the distinctive advantages of Satellite Communication. It then outlines the Technology involved, its evolution with time, the present status and future prospects and challenges. A list of various applications in day to day life in the country is presented. It concludes with an observation that Satellite Communication has carved out a niche space for itself and hence will not fade into obscurity. The SatCom technology will only keep improving to make it more attractive for the users. At best, it will co-exist with the other terrestrial systems.

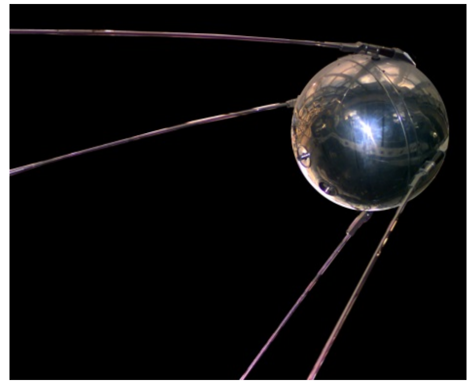

Fig 1 Sputnik-1

Fig 2 Telstar-1

I HISTORICAL BACKGROUND

Ever since Mankind entered into the Satellite Era in late 1957 with the launch of Russian Sputnik-1, there was no looking back to the development of Satellite technology and its applications, Satellite Communication in specific. Telstar 1, developed by the American Telephone and Telegraph Company (AT&T), was the world's first active communications satellite. Launched in mid 1962 by a Delta rocket, AT&T used this satellite to test basic features of communications via space.

In India, Satellite Communication Applications began ahead of the realization of a communication Satellite. The Applications referred here, are the yearlong SITE (Satellite Instructional Television Experiment) which began in mid 1975 and the STEP (Satellite Telecommunication Experiments Project) which was a two year program from 1977. Both these applications projects used foreign satellites, namely the American ATS-6 for SITE and the Franco-German Symphonie satellite for the STEP projects respectively.

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Fig 3 ATS-6

Fig 4 Symphonie

The APPLE (Ariane Passenger Payload Experiment) satellite was India's very first indigenously designed and built experimental communication satellite. It was launched by the third of the three developmental flights of ESA's Ariane vehicle from Kourou on June 19, 1981 and had a life of about 2 years. It carried experimental payloads in VHF and C-Bands and they were used only for gaining experience in the realisation and operationalization of our own communication satellite in orbit and conduct experiments with the communication payloads.

Fig 5 APPLE Satellite

However, the demonstrated space applications of SITE and STEP were transformed into practical, operational systems through the INSAT-1 (Indian National Satellite System), which became operational in the year 1982. With the launch of multipurpose INSAT-1A & 1B, India established its own operational communication satellite systems to deliver Telecommunication, TV & Radio broadcasting as well as Meteorological services.

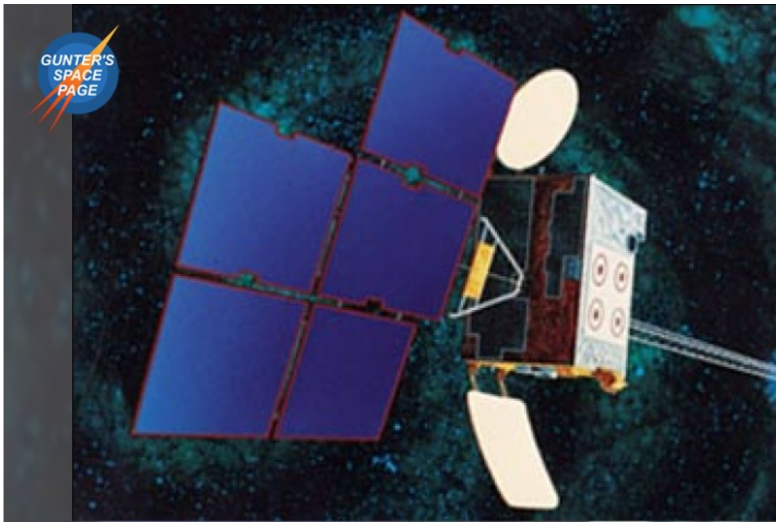

Fig 6 INSAT-1 Series Satellite

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Way before this time line, several other commercial communication satellites were providing operational services like the Early Bird (also known as Intelsat-1) in April 1965 and the follow on Intelsat series in the subsequent years. To begin with, their services were available to the western world and later the services were made available globally. Thus Intelsat became the first global satellite service provider.

Referring back to India's INSAT-1 System, the multipurpose satellites (a series of 4 satellites) were sourced from an American company, which were built as per our own service requirements and specifications. In parallel, India designed and built its own advanced communication satellite with multiple payloads in UHF, C and S Bands. This series of satellites termed as INSAT-2 came into being in the second half of 1992 with the operationalization of INSAT-2A. From then onwards India progressed in leaps and bounds in realizing dozens of such satellites, improving the technologies, payload capabilities and services.

Fig 7 One of the Indigenous INSAT / GSAT Satellite

II SATELLITE COMMUNICATION AND THEIR ADVANTAGES

The concept of sellite communication from a Geostationary orbit was first introduced in 1945 by the science fiction writer Arthur C. Clarke in his article "Extra-Terrestrial Relays" published in Wireless World magazine. In this article, he proposed the idea of using geostationary satellites as communication relays to transmit signals across the world. He propounded that a satellite placed at an altitude of 36,000 Kms (35,786 to be precise) above the Earth will appear to be stationary from a point on the Earth. If three such Relays are kept 120 deg apart, communication around the globe (except the Northern latitude and Polar Regions) is possible. 20 years later, this prophesy came to be true with the realization of Early Bird satellite. It is this principle that made several countries race with each other to get allotted the much valued orbital slot(s) in the geostationary arc for their satellites resulting in hundreds of geostationary communication satellites around the globe, starting with 3 deg separation between the satellites and progressing reducing to 2 deg and 1.5 deg and further to operate them in co-located mode with the use of advanced techniques such as use of orthogonal polarizations, spaciously separated coverage areas, highly shaped beam coverage without causing interference to each other's service etc.

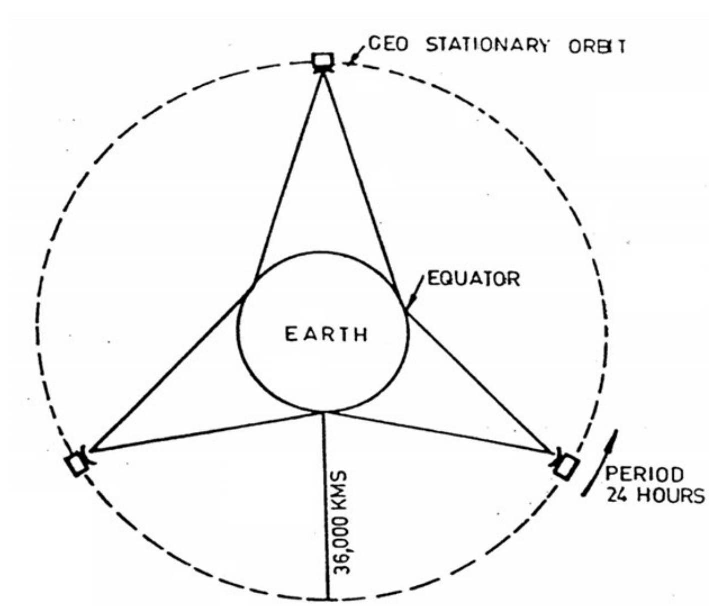

Fig 8 Arthur C. Clark's Postulation

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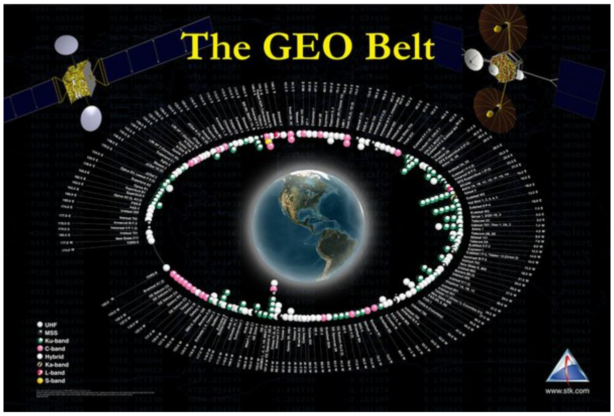


Fig 9 The Geo Belt in the 21st Century

Despite the above raising demands and operational constraints, Geostationary Satellite Communication has several advantages. Among the various advantages, the following aspects stand out very prominently.

1. Distance independent communication links that can be provided immediately once the satellite is declared operational; while the Terrestrial links needs to be extended in phases to cover the entire area of interest which will take a relatively longer time schedule. Further Satellite links provide easiness in reconfiguring or expanding a given Network.

2. Large area coverage is made possible irrespective of the terrain conditions, like water bodies, hilly areas, deserts etc.

3. Subject to Regulatory clearances, Coverage over lands that are not our own can be achieved. For example Intelsat provides coverage over continents. Our own INSAT system covers SAARC countries (for international cooperation), areas from Middle East to Australia (for commercial reasons). Hence Satellite Communication is Cost Effective over the terrestrial / submarine links.

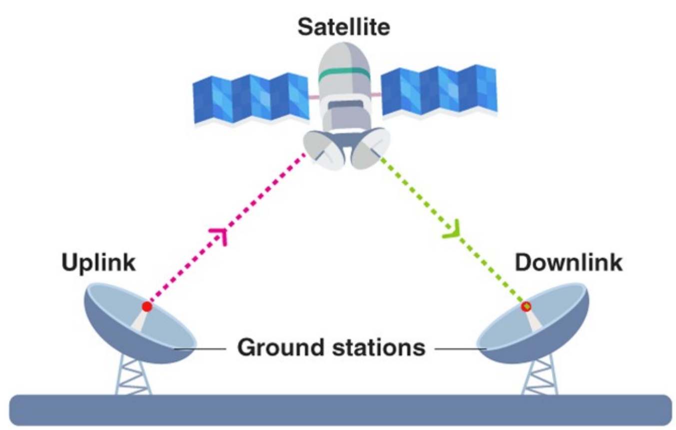
4. One striking advantage of Satellite communication has been demonstrated by the current Russia-Ukraine conflict (as an example). Satellite Communication came to the rescue of Ukraine, when the terrestrial links got severely hampered. It adequately demonstrated the resilience, ubiquity and security that the communication through satellite can offer.

5. Satellite communication seems to be on course to play a crucial role in the future of the Broad Band / Internet for the entire world, about which we will touch upon in the future prospects and challenges.

III THE SAT COM TECHNOLOGY

Satellite communication is the process of transmitting and receiving data or signals using satellites in orbit around the Earth. Data or signals are sent from a ground station on the Earth to the satellite in orbit, which then relays the information to another ground station on Earth. The process involves three main components: The ground transmitter, The Satellite, and the ground Receiver.

The transmitter sends the data or signal to the satellite using a radio frequency (RF) carrier wave. The satellite transponder then receives, amplifies and re-transmits the signal back to Earth. The receiver on the ground station receives the signal and decodes it to extract the original data or information.



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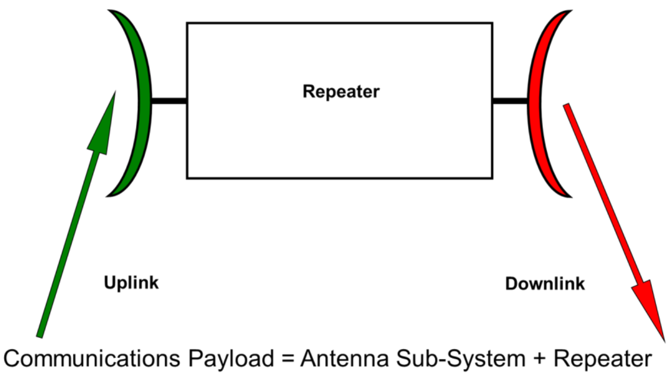

Fig 10 The Repeater comprises of Receivers, Filters, Power Amplifiers and Switches

In the early stages, the RF carrier wave used to be in C-Band, with 500 MHz wide at 6 GHz for the Up-link to the satellite and a corresponding bandwidth signal at 4 GHz downlink. The 6/4 GHz was chosen for the satellite link because the signal experienced the lowest combined losses due to atmospheric absorption and rain. However, as the time passed, demand for more bandwidth arose making the technology to deliver Payload and Ground system hardware at higher frequency bands such as Ku (14/11 GHz) and Ka Bands (18/30 GHz) and even beyond.

The Signal modulation over the carrier wave shifted from the analog modulation to digital techniques. Digitization of signals before transmitting to the satellite, made the link more reliable due to the use of data coding, error detection & correction techniques. Data Compression techniques enabled increased data transmission possibilities. For example DVB-S2 (Digital Video Broadcasting) and MPEG-3 or 4 technologies allow upto 24 TV channels to be transmitted through a 40 MHz Payload transponder, which used to be just one TV channel per transponder in the bygone era.

In the Payload Technology, single surface unshaped reflectors are no more in vogue. Instead use of polarization sensitive Dual Gridded, shaped beam reflectors has become a common place. Depending on the transmit power, Patch antennas or Phased Array Antennas are also employed. The Receivers have become very compact with the use of System on Chip (SOC) technology. The power amplifiers can be either SSPAs or TWTAs depending on the transmit power needs. However SSPAs are available for transmit power upto 50 Watts, while TWTAs can deliver power in the range of 200-250 W. Subject to frequency and power requirements, more and more Dielectrically loaded Filters are being used, which give mass and volume advantage over the conventional cavity filters. Use of Hybrid Micro Circuits for the supply of regulated DC power to the active units, using high voltage (70 to 140 V) power bus for high power devices, enable a mass efficient and performance guaranteed Payload Systems. Redundancies are employed for active payload subsystems to enhance the overall system reliability and availability over an extended on-orbit mission life (in excess of 15 years).

As for the transmission technology, newer approaches like

1. Demand assigned transmission, in which the Bandwidth capacity is allotted after assessing the traffic needs of a specific carrier,
2. Demand assigned power management, in which the Transponder RF power is assigned to a particular user carrier based on the need,
3. On-Board processing for a better signal transmission quality (Carrier to Noise density ratio)
4. Multiple Beam Transponders for higher signal strengths in the down-link paths (EIRP Values in excess of 55 DBw)
5. Switching signals between Beams (based on traffic needs)
6. Precision Beam pointing techniques like referencing to a Ground Beacon etc
7. RF Beam steering (either Mechanically or Electronically) from one coverage area to another

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are becoming reality in the modern days. Thus one sees a quantum jump in technologies from the days of Early Bird to the present day Satellite Communication.

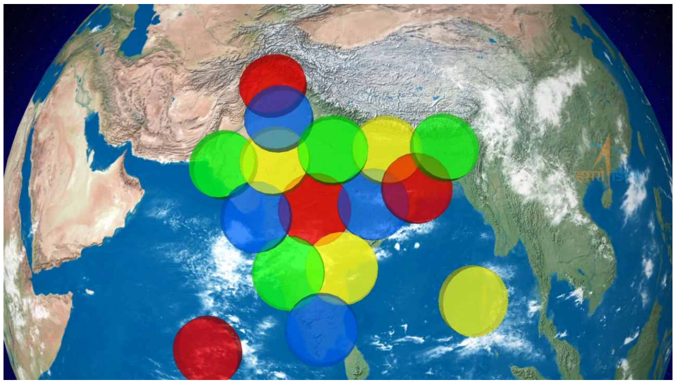

Fig 11 Multi Beam from an Indian Satellite

Fig 12 Mechanically steerable antenna

IV APPLICATIONS OF SATELLITE COMMUNICATION

As mentioned in the Historic Background, India's first SatCom Application were SITE STEP. It won't be out of place to mention a few lines about them. The SITE Scheme is shown below.

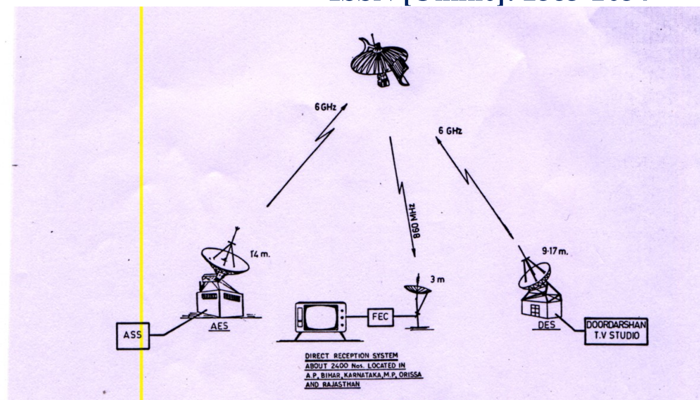

Fig 13 SITE DRS Configuration

Similarly, the STEP had the following Satellite Communication demonstrations: Links working in TDMA mode, Narrow Band Single Channel Per Carrier (SCPC) satellite links, Establishing communication links from remote locations using (1) Road transportable and (2) Compact, air lift able, suitcase type emergency communication terminals, demonstration of functioning of end to end telephone links, integrating satellite links with Telephone exchange switching circuits and many more novel experiments of those days.

Fig 14 Transportable Communication Terminal

From the operational INSAT System days, the scope of Satellite communication had expanded to include a wide range of Applications. Apart from the conventional Telecommunications and TV Broadcasting, its use covers

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1. Business Communications using VSAT terminals.
2. Captive Networks for corporates, Public Sector and Services Industry.
3. Providing Mobile Back hauls.
4. Proliferation of Direct To Home TV Broadcast.
5. Radio Networking.
6. Meteorological Data Collection from country wide spread unattended Data Collection Platforms (DCPs), which is received at a central place for processing and disseminating the weather data.
7. Meteorological Data transmission links from Weather monitoring Payloads.
8. Satellite Aided Search & Rescue using Emergency Beacon, location determination and providing Rescue services.
9. Satellite based Mobile communication with voice, data and messaging links.
10. Tele-Educational services for distantly located class rooms.
11. Tele-Medicine services to remote villages.
12. Village Resource Centers for better knowledge on agriculture, weather information, vocational training & skill development etc.
13. Cyclone warning along the coastal regions, including DTH based warning.
14. Mobile phone based communication link to Fishermen to warn them of their location with respect to international water boundaries, weather and sea conditions like high tides etc
15. Satellite based Navigation applications include tracking and fleet management, be it buses, trucks, trains, boats etc
16. Navigation aid for Aviation Industry using the Augmented NAVIC system.
17. Standard time dissemination.
18. High Data Throughput links
19. And the list is growing by the year.

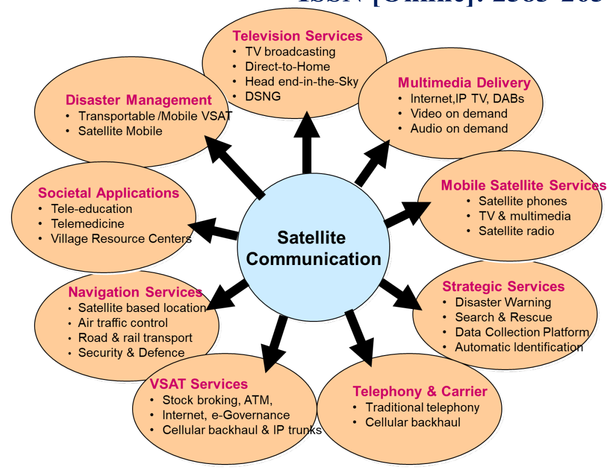

Fig 15

V FUTURE DEVELOPMENTS IN SATELLITE COMMUNICATION AND CHALLENGES

Satellite communication technology is constantly evolving, with new developments and innovations emerging all the time. While the tradition had been to place Communication Satellites in the geostationary orbits, the modern disruptive technology of satellite clusters being operated from MEOs (Medium Earth Orbiting satellites, in the range of 10,000 to 20,000 Kms) are already providing Broad Band services to the World community. This is a most exciting development in recent years. Constellations of small satellites, such as Starlink or OneWeb aim to provide global high-speed internet connectivity.

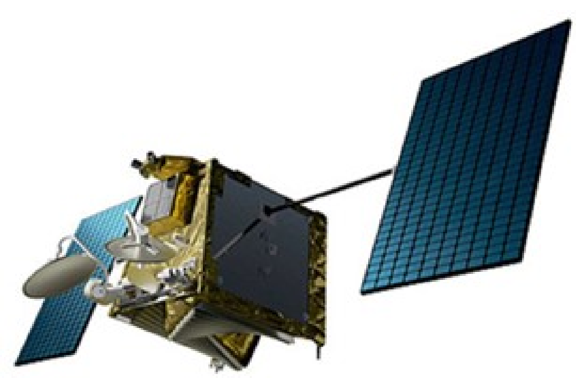

Fig 16

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Fig 17

Fig 18

The far left is 150 Kg One Web satellite being operated at an altitude of 1200 Kms in Polar Orbit and 650 satellites forms a cluster, providing Internet services in Ku-Band. On the right is the picture of the Star Link satellite each weighing around 250 Kgs. 4500 satellites is planned in different orbital planes, providing Internet links in Ku, Ka and E-Bands. Similar LEO and MEO Satellite Communications are also in the pipeline like the Amazon Kupier etc.

There is enough scope to enhance the Satellite based Mobile Applications to each human being on his hand held smart phone, while the present scheme is through a Cellular Network. Two Technology challenges are optimization of Bandwidth and overall Mass & Volume of the Mobile. Recent technology trends (LiFi Technology) report the development of light weight IR link based mobile antenna.

In India, the hardware technology has to improve substantially further to enable 150 to 200 Kgs of satellites to be realized and yet provide the state of the art communication services such as Broad Band Multi Media services.

May be one day AI will be used for On-Board signal processing and routing as well as to dynamically allot the resources of Power and Bandwidth. AI may also be used to identify interference to switch signals from interfering band to a reserve band.

There is need to enhance the security in the Communication Links. Electronics Intelligence, Communication Intelligence has to undergo an upward swing. In this regard, in recent days Quantum Communication (using Quantum Keys) is being experimented both in India and abroad. But it is yet to achieve the Range capability to enable its use for Satellite Communication.

VI CONCLUSION

Despite the proliferation of Fiber Optics links, OTT services, Mobile 5G services or its future evolution, the use of Satellite Communication will not fade any bit in its importance. At best, it will co-exist with the newer advents as it has its own advantages and Niche areas of applications. It will surely supplement and compliment the other modes of Communication services.

In conclusion, satellite communication has transformed the way we communicate and connect globally. It has made it possible to communicate with people in remote and inaccessible areas, and it has enabled us to access information and services from anywhere in the world. With the continued advancements in technology, satellite communication is likely to play an even greater role in the coming years.

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[11] Figure of GSAT-11 Coverage area – Open Internet Domain information from First Post

[12] Picture of INSAT/GSAT satellite from ISRO Website.

[13] All other figures are from Open Internet Domain information

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