SATTELITES – A NEW ERA IN COMMUNICATIONS

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Abstract. The important advantages of the satellite systems, their applications in a very large technical and scientific domains lead to their unexpected and rapid development. In this paper firstly is presented a short history of satellite communications in the world and especially in Romania. There are described the different existing systems and satellites types, geostationary and non-geostationary and the satellite services: fixed-FSS, mobile-MSS, broadcasting-BSS, the applications in cellular domain, for data transmission-VSAT, for global positioning and navigation-GPS, GLONASS, broadcasting. There are presented some technical parameters regarding the multiple access methods and the frequency bands utilized. Tendencies in development of future generations of satellites resume as the increase of emission power for the satellite's transponders, increases of transponder's capacity, improving the techniques for digital signal processing, use of frequency band of over 30GHz, respective the bands 40-50 GHz, V 60-75 GHz and W 75-110 GHz, the use of laser systems and the coherent modulations of the light sources, diversifying the services and development of wideband services, etc.

Keywords: space communications, satellite, frequency band, multiple access, services.

1. SHORT HISTORY

The launching of the first artificial satellite, in 1957, inaugurated the spatial era, a new age of using of cosmic space by the human being. From the beginning the satellites occupied uncontested places in the development process of many domains of science and technology, starting with communications, cosmonautics, metrology, geodesy, astronomy, etc.

The satellite telecommunication technique makes possible the realization of communication connections between points that are located at very long distances on the earth surface and opened large perspectives for the international exchange in the fields of science, culture, education, sport domain, etc. contributing decisively at development of informatics society.

Until the launching of the first operational satellite INTELSAT I-Early Bird, 1965, were made many experiments with other satellites such SCORE-1958, COURIER-1960, TELESTAR I and II-1962, 1963, RELAY I and II-1962, 1964, SYNCOM I, II and III-1963, 1964, realizing experimental transmissions for telephony, telegraphy, TV programs broadcasting, photo-telegraphy [6].

The results of the experiments realized with each satellite in each research program lead to the improvement of the satellite system, culminating with the launching, in 1965, of the first commercial geostationary satellites INTELSAT I,

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Early Bird, and then MOLNIA non-geostationary satellites from the ORBITA system.

Initially, TV programs and telephonic channels were transmitted. This new communication satellite system between continents, replaced the existing long distance communications, realized through transoceanic cables or by short radio waves.

For the INTELSAT I system, were built in Europe three earth stations, in France at Pleumeur-Bodou, in Germany at Raisting and in England at Gunhilly. Through these stations it was ensured the transmission of 240 telephonic channels. Because of the technical conditions, small power transmitted by the satellites (minimum 40W), the low performances of the earth stations receivers, the connection between satellite and earth station were ensured successively, by one of the earth stations, each month another. The interconnections between earth stations were realized by terrestrial cables (Fig. 1).

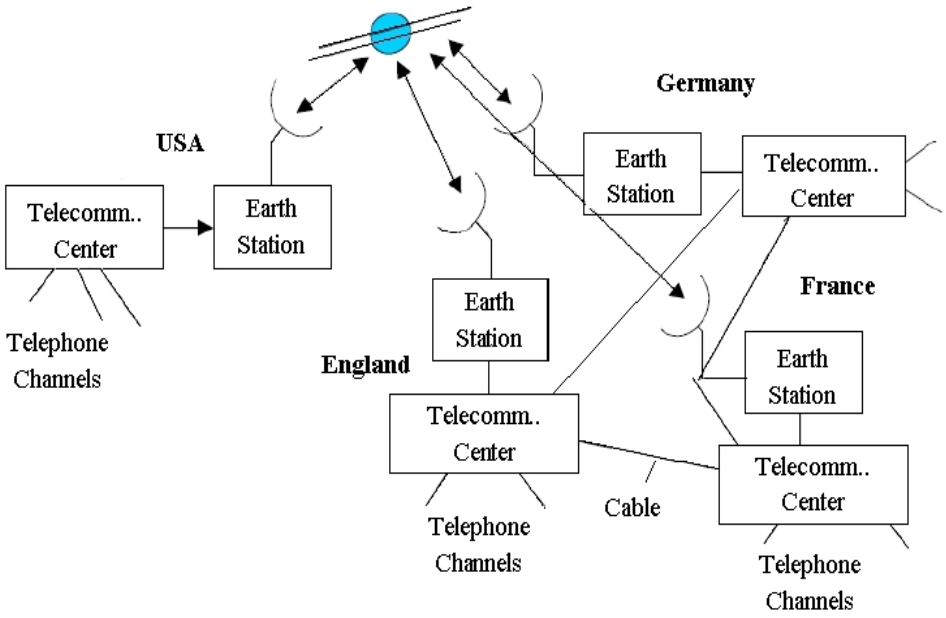

Fig. 1. First European telephonic connections with the INTELSAT satellite.

After reception and demultiplexing, the service coordination station distributed the traffic from the 240 telephonic channels to the other stations. This traffic represented a high capacity traffic in comparison with the capacity ensured by the transoceanic cables existent in that time period.

This generation of satellites, first commercial and operational generation, was in use until 1970 years. For the communications through satellites it was used the operating frequencies band C (4 GHz for down link and 6 GHz for up link).

For simultaneous access of all earth stations at the common resource represented by the satellite, it was necessary to use new methods for multiple access, more dynamical and capable to operate at long distances. Initially it was used the frequency division multiple access (FDMA) method, and frequency modulation of the signals. The use of relatively low frequencies of the microwaves domain and the low transmitted power from the satellites created the necessity to use at the ground stations the parabolic antennas with large dimensions of 32 m diameter.

Our country had a vanguard position in the field of communications by satellites, being the first and the only country from the socialist system that used the INTELSAT system and building the first earth station in Cheia (Prahova), that become operational in 1976 (Fig. 2).

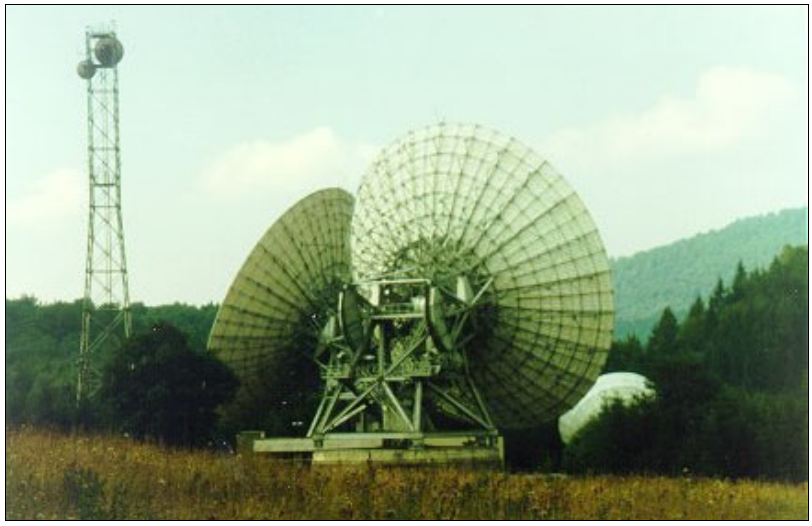

Fig. 2. Cheia Earth Station. The Antennas.

It was a courageous attitude of Romania, when already existed the Soviet satellite system ORBITA. The preparation for entering in use of satellite system and for the construction of earth station was started in 1970 years, by researcher studies realized at the Telecommunications Research Institute in Bucharest by a work group made of two researchers (Mariana Jurian and Cezar Boierescu). An important support came from professor dr. eng. Alexandru Spataru which initiated the realization of these studies. In 1974 was approved the construction of the earth station.

The site selection of the emplacement needs laborious work, including calculations for evaluating the protection against perturbations (especially the radio relays that operates in the same frequency band), calculations for coordination with neighboring countries, for ensuring the interconnection with national communications system, but also the analysis of the other criterions concerning the conditions

of supplying with electrical energy, the environmental conditions in the area, access roads, soil nature, seismicity, etc.

A number of over 100 sites, were analzyed and the Cheia location corresponded the best to all conditions that were imposed. From the view point of technology, the station corresponded to the standards specific to the first and second generation of INTELSAT satellites. For ensuring a noise figure as low as possible for the receiver amplifier (LNR-Low Noise Receiver) initially were used amplifiers cooled using liquid nitrogen. In conformity with to the visibility conditions of the satellites in Romania, were placed two antennas pointing towards the Atlantic and Indian satellites. The structure of the antennas was realized in Romania, in an enterprise from Piteşti specialized in manufacturing bridges structures.

The second generation of satellites that was developed along of few generations of technologies, starting with 1980, lead to an increase of the emission power of the equipments from the satellites, increasing the sensibility of the earth station receivers, the use of higher frequencies and of the smallest antennas.

There were applied new modulation and signal processing techniques, new modes for multiple access, time division multiple access (TDMA), digital techniques (first system been SPADE). For the coverage of large territories that had a rugged relief, were developed a regional satellite system (Africa) and domestic satellite systems (Brasilsat, Canadsat, Turksat, etc.).

The evolution of the technologies lead to the diversification and the development of a new service like the VSAT communications (Very Small Aperture Satellite), the use instead of fixed communications services of the mobile communications services with mobile stations placed on ships, planes or cars (MOBILSAT, MARISAT, INMARSAT).

In 1982, it was created the basis for the first world distress and safety system realized as a complex system using stationary satellites (INMARSAT) and non stationary satellites (COSPAS-SARSAT). Using these satellites was realized the GMDSS system (Global Mobile Distress and Safety System) that can locate any calamity on sea and launching the help actions in any season, in any environmental conditions, in any place on the earth and at any moment of time. This service extended also for aerial and terrestrial transports. The global system operates with geostationary satellites INMARSAT (INMARSAT 2 launched in 1990–1992 and INMARSAT 3- launched in 1996) situated in some areas from Atlantic, Pacific and Indian Oceans. For the coverage of the polar areas there are used the satellites on the polar orbits COSPAS-SARSAT.

Through this system beside the sensing and quick assistance in case of disasters, there are realized also the radio communications, the services for public correspondence, the ships management, the improvement of radio localization, etc. In the present, tens of thousands of ships, planes, or other mobile resources have this service, being equipped with satellite equipments.

The third generation of satellites belongs to the beginning of the XXIth century and develops in essence, besides the existent systems, the personal communications and mobile systems. These systems deliver radio communication services between very small portable terminals using one or many satellites. For establish of the communication connection, a personal terminal can access directly a satellite, without being necessary to be connected to a terrestrial station. In addition, the satellites can have sophisticated functions such: channel switch, navigation and signal processing. Through satellite, any person that uses a potable terminal can directly access the satellite for establishing a communication channel. It is desired the usage of frequency bands in domains above 30/20 GHz, 47/44 GHz and millimeter waves.

The European policies promoted by EU through its programs will facilitate the introduction of new satellite communication services, for covering the far regions, the regions with rugged relief and the rural zones for which the terrestrial communication services are difficult or impossible to be realized at affordable costs.

2. THE PRESENT SATELLITE COMMUNICATIONS SYSTEMS

Now the satellites that are used evolve on circular or elliptic orbits, and are geostationary or non stationary satellites. A mixed system based on many types of satellites, depending of the requests, of the type of services or of existent conditions, can be used [1,4].

The geostationary satellites (GEO satellites) are classifies as:

- MEGA GEO satellites used especially for business communication, they ensure data transmissions until 6Gb/s for multimedia applications and Direct-to-Office telecommunications;
- BIG GEO satellites, used in personal mobile communications;
- Little GEO satellites, that ensure communications with low speed data transmission (for example the transmission of short messages)

The non/geostationary satellites depending on the highness of the satellites orbits are classified as:

- LEO - Low Earth Orbit, satellites characterized by circular orbits with low altitude (500 Km –1,500 Km)
- MEO - Medium Earth Orbit, satellites characterized by circular orbits with medium altitude (5,000 Km – 12,000 Km). For complete covering the Earth surface are necessary of approximately 12–25 of such satellites.
- HEO - Highly Inclined Elliptical Orbit, satellites that evolves on elliptical orbits

In Table 1 are represented the main characteristics of the GEO, LEO and HEO systems.

Table 1

Main characteristics of the GEO, LEO and HEO systems

	GEO	LEO	HEO
System			
Frequency	Ka band, millimeter waves	800 MHz, L band, S band	800 MHz, L band, S band
Coverage	Regional or global, excepting polar zones	Global, including Polar zones	Global, including Polar zones
Type of orbit	Circular	Circular	Circular
Number of orbits	1	Multiple	Multiple
Number of satellites	Small	Big	Big
Switching between satellites	No	Yes	Yes
Delay	270 milliseconds	5-15 milliseconds	20-80 milliseconds
Satellite			
Altitude	35,800 Km	500-1,500 Km	5,000-12,000 Km
Weight	>1,500 Kg	<800 Kg	<1,000 Kg
Antenna	10-30 meters	<5 meters	<10 meters
EIRP	High	Small	Medium
Board processing	Necessary	Sophisticated	Sophisticated
Revolution period	24 hours	Hours	Hours
Visibility period	24 hours	Tens of minutes	Tens of minutes - hours
Life period	12-15 years	5-8 years	Until 12 years

A satellite communication network must use more than one satellite to ensure an improved coverage area and a high quality of services.

As distinction between LEO and MEO satellites which must be numerous in order to be capable to offer a continuous service on the entire surface of the Earth, in the case of GEO satellites it is necessary only one satellite for covering with signal an entire big region or country.

The satellite based communications found these days applications in many domains. FCC (Federal Communications Comity) defines the classification of communication satellites after realized services as follows:

- Fixed satellite service (FSS);
- Mobile satellite service (MSS).
- Broadcast satellite service (BSS).

The satellite communications, initially were used for intercontinental connections and for television, but in time, they gain new valences in cellular applications. Many variants of realization for cellular networks by satellites exists now: MTSO-MTSO (Mobile Telephone Switching Office), MTSO-distant cells and MTSO – an intermediary switching center [4,5].

The European Community launched in 1988 the development RACE program (advanced technologies in telecommunications), followed in 1995 by the program ACTS (Advanced Communications Technologies and Services).

In the frame of this program the purpose is to define the concept of "Universal Communication System" and to elaborate the standards for the third generation of wireless systems, named **IMT, UMTS** (Universal Mobile Telecommunications System) and MBS/WCPN (Mobile Broadband Systems/Wireless Customer Premises Networks) [2,3].

These standards offer a basis for unifying in a single communication interface all the communication technologies existent in our days: satellites, cellular, cordless, country areas, local loop, paging, trunking, multimedia, computer networks (wireless/cable), digital telephony, classic radio networks, intelligent networks, etc. The reason that led to the use of satellites in cellular network are:

– The existence of areas with difficult access that make very difficult the installation of the cellular repeaters or radio modems (and other wireless equipments);

– High costs asked by the local operators for coverage through classical methods of such difficult zones;

– The quick installation and repositioning of the VAST terminals (Very Small Aperture Terminals);

The term VSAT refers to a fixed terrestrial station having antennas with small dimensions and which deliver the essential communication links necessary for establish a satellite based communication network.

VSAT is a satellite based communication system that ensures safe solutions, which is efficient from the economic point of view on a single channel dedicated for users that can be companies or private persons. A VSAT system can realize different types of communication: voice, data transfers and teleconferences, in conditions of high security.

VSAT represents a particular application of satellite data transmissions. Through VSAT the institutions that have many centers (buildings) placed at high distances can create a high speed Internet, a private network which ensures the links between headquarter and the other centers. The VSAT networks have specific applications in banking networks, real time transactions, data transfers, credit card checking, reserve systems, video conference, e-mail, facsimile, telephony, etc. They were rapidly accepted as communication method by the banks, governmental organizations, stocks, ensuring companies, oil and energetic companies, store networks, etc.

Another important satellite service is that for localization. The European Community and specialty organizations have decided to contribute to the development of the global satellite positioning and navigation system, known as GNSS (Global Navigation Satellite System). This system must be a unitary global navigation system, capable to answer to the all requests of the civilian community, in an efficient way and at competitive costs.

In the first stage EGNOS (The European Geo-stationary Navigation Overlay Service) and GALILEO in the second stage, realize special performances in the satellite based navigation. EGNOS is completing the GPS (Global Positioning System) and GLONASS (Globalnaia Navigationnaia Sputnicovaia Sistema) systems and overcome the major limitations of them.

After applying the EGNOS program, the GALIELO system was developed as a completely independent alternative to the GPS and GLONASS, realizing high performances for all categories of users. Besides the global positioning systems exists also other regional systems such that for China, Japan, India.

GPS is the only global system completely operational, implemented initially only for military applications and opened later also for civilian applications. For military applications the system allows positioning of a mobile in three directions in any point on the terrestrial surface or in atmosphere. Can be determined also, the speed and the acceleration of the mobile for that zones where are visible more than three satellites. The error in position determination is smaller than 10 cm for military applications and smaller than 30 m for civilian applications [4,5].

The BSS-Broadcast Satellite Services has also important applications. The BSS deliver TV or/and radio directly to the consumer by using small antennas (under 2 m diameter). Through convention, if the service uses the BSS frequencies it is known as DBS (Direct Broadcasting by Satellite) and if it uses FSS frequencies then the service is named DTH (Direct To Home). The DTH includes a package of musical channels that can be received with a television set.

The radio service through satellites (S-DARS – Satellite Digital Audio Radio Service) allows delivering the audio programs transmitted directly to the mobile receiver (car, portable radio, home audio system, etc.) using frequencies allocated in S or L frequency bands.

Such radiobroadcast service allows coverage of an entire continent and allows an audio quality closed to that of a CD or an MP-3. Also, the digital multiplexing allows that narrowband services as radiophone talk shows or sport broadcasts to be combined with high-band services offering to listeners the high quality musical programs.

In SUA, in 1992 to implement the national radio system by satellites were allocated channels in S frequency band. Few years later, in 1997, two American companies – CD Radio (SIRIUS) and American Mobile Radio (XM) – have realized the development of the system. It is estimated that in the present in SUA exists approximately 11.5 million of subscribers of these services. The WorldSpace system was implemented in 1990 and represents the starting point for this global service. In the present WorldSpace, has extended the service in Asia, Africa and partially in Europe. The emission is realized in 12 languages and the channels can be divided in seven categories: music, news, debates, sport, education, life and spiritual life. In the future, this satellite radio system will cover the whole Europe. This project is developing at Ondas Media company with the headquarter in Madrid. However, the WorldSpace system is less suitable for mobile radio reception in comparison with Sirius and XM. The developed digital audio service, DARS (Satellite Digital Audio Radio System), uses low frequency band, L and S, for ensuring a signal having more resistance to the fading.

For video services, the most recent standard that was developed for DVB-S (Digital Video Broadcasting-Satellite) system is DVB-RCS (Return Channel by

Satellite). This system regulates the methods to realize bidirectional and asymmetrical connections by satellite transceiver equipment.

For Internet access, e-mail, virtual private network (VPN), etc. the efficient economical solutions are provided. Starting with year 2005, in the frame of this service are also available advanced multimedia services. On the basis of some service packages adapted to the necessities specific to each beneficiary frequency bandwidth is flexible. The DVB-RCS service allows a multitude of applications: distance learning, electronic commerce, telemedicine, communications in rural environment, commercial transaction, etc. The DVB-RCS service provides a wide spectrum of applications and interactive multimedia services based on IP. Another important advantage of DVB-RCS is the efficient implementation with the low cost for broadcast services and for multicast transmissions. Also, can be realized the point-to-point services, as VoIP for example, IP videoconferences, real time video transmissions, web- based television.

Other services by satellites include:

– The inter-satellite services (ISS-Inter Satellite Service) for links between satellites placed on orbit;

– Radio-determination through satellite system (RDSS-Radiodetermination Satellite Service) used for localizing the position, the radio-navigation through satellite system satelit (RNSS-Radionavigation Satellite Service).

A revolutionary technology of satellite system for high speed mobile Internet, on two ways, is the **iNetVu** technology that allows for moving persons to have a continuous communication for high speed Internet access. With the **iNetVu** technological solution, the users have the possibility to manage the business from remote locations. The mobile technology **iNetVu** allows the high-speed Internet access using personal computers or notebooks, anywhere the used mobile moves.

3. ACCESS METHODS AND FREQUENCY BANDS USED IN SATELLITE COMMUNICATION SYSTEMS

Many methods of multiple accesses (MA – Multiple Access) are used in satellite systems:

- **FDMA** – Frecquency Division Multiple Access
- **TDMA** – Time Division Multiple Access
- **CDMA** – Code Division Multiple Access
- **SDMA** – Space Division Multiple Access
- **PRMA** – Packet Reservation Multiple Access
- **WDMA –** Wavelength Division Multiple Access

Nowadays most used multiple access method is CDMA with spectrum spreading techniques: DS (Direct Sequence), FH (Frequency Hopping), TH (Time Hopping) and hybrids techniques.

The majority of initially developed satellite systems had operated in C band. Later were developed technologies for higher frequencies, at the beginning in Ku band and then in Ka band [4,5].

For actual satellites communications, are available the following frequency bands:

- L band (1–2 GHz) – mobile communications,
- S band (2–4 GHz) – communications through satellite, telemetry, pursuit and command of spaceships,
- C band (4–8 GHz) – first band used for fixed satellites communications, commercial,
- X band (8–12 GHz) – reserved mostly for military communications but also for commercial communications,
- Ku band (12–18 GHz) – the second bad developed for fixed commercial communications,
- K band (18–27 GHz) – various communications,
- Ka band (27–40 GHz) – fixed communications, developed especially for wideband/multimedia applications.

In the Table 2 are presented the frequency bands used in satellite communication systems applications.

Table 2

The satellite system's specific services and frequency bands used
(according to the Radio-communications Regulation)

Services according to RR	**Frequency bands**						
	9÷300 kHz	0,3÷3 MHz	3÷30 MHz	30÷300 MHz	0,3÷3 GHz	3÷30 GHz	30÷300 GHz
	VLF, LF	MF	HF	VHF	UHF	SHF	EHF
Amateur through satellite				x	x	x	x
Meteorology through satellite				x	x	x	
Mobile communications through satellite				x	x	x	x
Radio navigation through satellite				x	x	x	x
Earth exploration through satellite					x	x	x
Radiobroadcast through satellite					x	x	x
Fixed telephony through satellite						x	x
Terrestrial mobile through satellite						x	
Inter-satellite						x	x

4. TENDENCIES IN DEVELOPMENT OF SATELLITE SYSTEMS AND SERVICES

The important problems for the development of the future generation of satellites is resumed as follow: the increase of transmission power for the satellite's transponders, increases of transponder's capacity, improving the techniques for digital signal processing, use of frequency band of over 30 GHz, respective the bands 40–50 GHz, V 60–75 GHz and W 75–110 GHz, the use of laser systems and the coherent modulations of the light sources, diversifying the services and development of wideband services, etc. The laser transmissions are used in this moment only for intersatellites communications.

The technological developments in access methods, modulation and coding techniques, the use of higher and higher frequencies lead to the increase of satellites capacity and the frequency bands, diversifying the mobile and fixed telephony services. Also these leads to high-definition video and audio radiobroadcast transmissions, development of the systems with small antennas as VSAT for wideband interactive applications, of transmissions through IN networks (VoIP), the covering of rural areas with diversified services (starting with the Integrated Project named Rural Wings).

The actual systems will be improved and developed with applications in the most diverse domains such as: meteorology, oceanography, hydrometeorology, agriculture, geodesy, astronomy, navigation and localization, etc.

A special attention is given to the personal satellites communication systems that allows the individual access, directly to the satellite's services, of persons that have a suitable portable equipment, (S-PCN- Satellite Personal Communication Network), of technologies iDirect, of high-speed mobile Internet – iNetVu, etc. Because of the diversity of the services and due to the quality and the global coverage of the Earth's surface, the satellite systems have a great future as much as for the commercial applications but also for military applications.

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