SATELLITE COMMUNICATION SYSTEMS IN AVIATON

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The aim of the contribution is to analyze the principle of operation of satellite communication systems, their architecture and the services provided to users. It descrbes the individual satelite communication systems, which ensure reliable communication. Also introduced are the potentials of using satellite communication systems in aviation. It is followed by comparison of the systems in terms of data trasfer and ruggedness against interference.

Keywords: Satellite, frequency, orbit, segment, signal, system

1 INTRODUCTION

In the current era, satellite communication systems are highly perspective for the the development of the communication industry. Already since 1957, when the first satelite was launched from the Earth, the Sputnik, it caused a revolution in transfer information and collection of data. As it was impossible to ensure coverage on all parts of the world, there arsose the idea of developing satellite communication systems. With time, these systems had grown out into systems with multiple areas of utilization, well proven by the services they provide. Space vehicle of multiple use and rockets have facilitated launching of thousands of satellites during the past 40 years, thus enabling mediation of satelite broadcasting.

In civil aviation there arose the need for maintaining constant communication between the aircraft and the ground. This purpose is well served by satellite communication systems. Continuous improvement of aviation technology earmarking the progress in civil aviation is unthinkable without high-quality transfer of data and information. This brooadcasting is realized in air-to-ground or ground-to-air directions.

2 PRINCIPLE OF OPERATION OF THE SATELITE COMMUNICATION SYSTEMS

A satellite system is an antenna array orbiting the Earth. It maintains communication with one or more ground stations based on Earth. A typical satellite communication system can be divided into ground, space and user segments, where each of them is responsible for interlinking of the satellite communication with the rest of the communication network infrastructure. In the ground segment of the satelite communication system, the ground infrastructure is adjusted so as to enable data distribution for network ports, which in aviation communication systems are known as ground stations. The system on the Earth is set so as to be capable of controlling and handling space operations, receiveing and processing data from satellites and if necesssary to generate and transmit all the products. The space segment is made up of the satellite itself, or a satellite constellation and satellite uplink and downlink, which is established between the space and ground segments. The last utilizer segment, as its name implies, serves utilizers of satellite communication.

Satelite, uplink, downlink, spoace segment, ground segment, transmitting station, receiving station. [1]

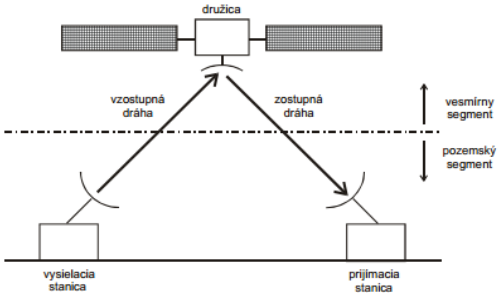

Fig. 1 Generating the transfer route in the satellite communication system

The basis of these satellite systems is made up of the satellite located on the orbit of the Earth, which is defined as a trajectory of the center of gravity with respect to the given referential system. So, the orbit representing the path of the satelite, which is moving around the Earth. The individual orbits such as the GEO, MEO, HEO, LEO provide advantages for a certain groups of satellite services, and positioning of the satellites on the orbits is realized arbitrarily as the Earth´s magnetic field catches inionized particles and the electrones rediated by the Sun generating high energy bands. [2]

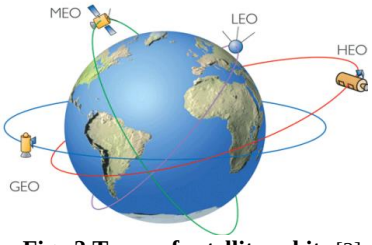

Fig. 2 Types of satellite orbits [2]

From the very beginnings till the present days, satellite communication technology has gone through many changes in their development and form inevitable part of communication systems. When compared to classical means of communication, such as those of ground communication, the satellite –based ones are typical

for lots of advantages of which the strongest are in the multiple signal coverage of areas, i.e. reaching higher portion of the Earth surface.

Currently, satellite communication technology is subjected to several limitations, which are experienced predominantly in remote areas of the world. In case of satelite communication systems, providing satellite services, one has to take into account various malfunctions of volatility of signal performances caused by several barriers located along the direct line of sight between the satellite and the receiving terminal, or those caused by interferences of reflected radio waves. In case when these statistical characteristics affecting propagation do not suffice, it can be concluded that the *S/N* ratio is overly big or too small.

Effective design of mobile satellite services requires knowledge of the coefficients affecting signal propagation. It is about attenuation caused by ground clutter or sea clutter, or those caused by buildings, pillars, trees, terrain, the Doppler effect of moving terminal, precipitation, inonospheric effects. These characteristics of propagation are known for different statistical values for aviation. Therefore, in the future satellite communicationon systems are expected to be capable of overcoming these defficiencies, because their error-free quality will be of great use in the airspace with high density of traffic, and will remain complementary to ground systems and provide services related to air traffic safety. [2]

In accordance with the task fulfilled, satellites can be divided up into groups. This classification distinguishes satellites specialized in meteorology to provide weather forecasting or monito hurricanes, and those serving for atelecommunication, military and navigation, determining position and direction of aircraft. Satellite services as defined by The International Union of Telecommunication [2] :

- Fix satellite services (FSS)
- Broadcasting satellite services (BSS)
- Direct broadcasting services (DBS)
- Mobile satellite services (MSS)
- Rádiodetermination satellite services (RDSS)
- Rádionavigational satellite services (RNSS)
- Inter-Satellite Services (ISS)

According to the UCS Satellite Database, on the orbits there are as much as 59 % active satellites of communication of the total number of the currently known number of 1046 satellites. [3]

3 SATELLITE COMMUNICATION SYSTEMS

Concrete satellite communication systems ensure safe and reliable transfer of information fromany part of the Earth. In aviation, the advantage in using satellite systems is mostly in their capability of providing services such as communication or navigation over a wide area, depending on the altitude of their orbit. A geo-stationary satellite is capable of spreading its global lights roughly over one-third of the Earth surface. Among those satellite communication systems belong networks of already realized satellite communication, such as:

3.1 Globalstar

The system provides coverage making use of its 48 stationary communication satellites, as its satellite communication services can be operated from any part on the world. Similarly to all satellite communication sstems, this system is also made up of segments, where its terminals for their error-less operation, alike the GPS, are in need of a line-of-sight not obscured by by any of the other satellites. In case a satellite is off the line of sight, there arise problems at voice and data communication, which is subsequently decomposed. Reestablishment of communication link can occur only on the other satellite having flown away. [2][4]

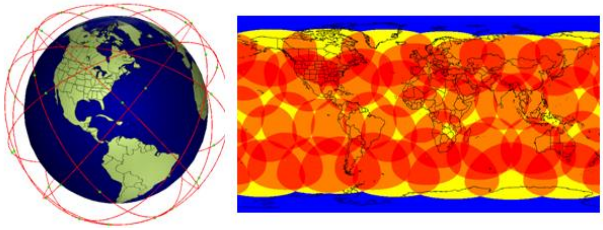

Fig. 3 Orbits and their coverage by Globalstar [2]

3.2 INMARSAT

Inmarsat its use appears to be more advantageous as the previous system, especially in case of the Inmarsat M and for its geo-stationary satellite, where the arranged and measured communication will not desintegrate. The coverage provided by the INMARSAT system is 98% of the Earth´s surface on grounds that on the GEO orbit use is made of 4 satellites located at an altitude of 36 000 km Earth ´s equator. Appart from the poles of the Earth, the system provides worldwide coverage and ensure voice and data transfer at a speed of 2,4 kb/s. Currently, its operation is focused on communication in aviation. For gaining a better overview of services, i.e. by which of the terminals of the INMARSAT system the are presented, their names are given in alphabetical order. For aviation satellite communication, the advantage of INMARSAT-A consists in that the service is focused on maintaining telephone links for passengers travelling aobard the aircraft, where the standard speed up to 4 800 b/s ensures voice, data and electronic mail transfer. Followers of the system are the INMARSAT-B featuring similar applications and the INMARSAT- C for military and private aviation limited only to providing data transfer at a maximum

speed of transfer 600 b/s. Next in the order of the INMARSAT systems is INMARSAT –D and D+, which ensure papingu service and in via of the D+ variant also the service of two-way paping, then they are the already mentioned INMARSAT M a INMARSAT P, which ensure two-way transfer of fax and text data. [2][4]

3.3 Iridium

The name of this satelite commucnication system is derived from the substance of Iridium, which has 77 electrones, the number of satellites planned originally. WHen compared to the Globalstar, the satellites of the Iridium system enure mutual communication with one another. The main purpose of Iridium is to set up an international wireless network of communication for mobile telephones and the search terminals. Based on this idea, it will be possible to realize communicate from any part of the Earth, all that with making use of the ground–based wireless communication system and 66 satellites on the LEO orbit. It is a matter of course for the system to ensure aviation users reception and transmission of voice-based data and messages regardless of their position, air-to-ground, ground-to-air or air-to-air. Services of this satellite system are highly practical in using it for aviation communication. The system provides coverage for almost the entire surface of the Earth and all that on condition that there exists a direct line-of-sight between the satellite and the mobile station. [2][4]

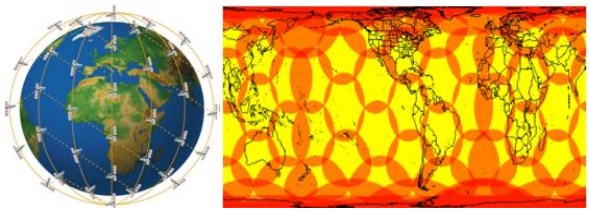

Fig. 4 Orbits and overlapping of the Iridium cells [2]

3.4 AeroPhone

AeroPhone - non the basis of the Iridium network, this satellite communication system is also available for civil aviation. Data communication, mediated via the AeroPhone communication system comprises first of all the relay of reports on position and textual messages. Its services can be used in the area of wheeled truck fleet for manual or semi-automatic reporting of poitions. To ensure the requirement for mobile phone use for passengers travelling aboard the aircraft when in flight, the system of AeroPhone makes best use of the available technology attached to the trasmitter. The system provides support for all wave band and causes no undesired effects, which could be affected by the electronic equipment of aircraft. [5]

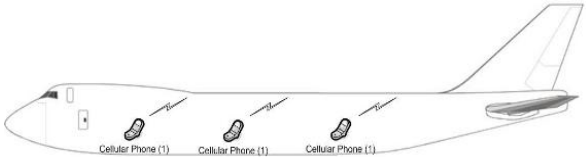

Fig.5 Transfer of data during flight
Zdroj: [5]

3.5 SkyBridge

SkyBridge – vat every place, where, it impossible to provide coverage by classical infrasturcture fro economic reasons, even for areas in the outback or remote parts of cities, the satellite-based wide-band system of Skybridge is a suitable solution, and is also specialized in services of providing video-conferences for participants worldwide and the fastest - possible access to the Internet. It is made up of an array of 64 LEO satellites, which ensure interconnection of the participants to ground-based switchboards. Some 200 switchboards are capable of ensuring a 90% coverage of the potential market for the Skybridge system. The interlinking realized by a switchboard relay making use of the double hop is realized in case of terminal-to-terminal communication. With the help of the cosmic segment, the separate switchboards are accumulating signals from terminals from a cell at a diameter of 350 km shaped as a circle. Permanent radiation of the Skybrdige cell at least by a one bunch of satellites. At our geographic location, a basic precondition to it is a cell having a minimum of two satellites constantly within reach. Based on the fact that the satellites are constantly moving, it is necessary for the switchboards to ensure continuous switching-over of the links for further or other satellites. Currently the systems is assisting as much as 15-20 mil. users throughout the world. [2]

3.6 Teledesic

The Teledesic networks uses 288 mutually interconnected satellites to provide access to voice-, data- or video-communication services. This satellite system ensures change-over digital link (via a switchboard) among users of various networks. The Teledesic network is made up of a ground-based network switchboard, network control and operation systems and terminals as well as the cosmic segment, containing the network of satellites enusring communication among the terminals based on the schitching over function. Te end-points of the Teledesic networks are the terminals, which provide interface between the end-users in the ground network and the satellite network and other networks. [2]

3.7 Orbcomm

Orbcomm – low-speed exchange of messages is the domain of the next system known as Orbcomm, which is the first small-size system of LEO in operation. It provides data communication services

based on two-way satellite systems. The design of such systems is realized so as to provide ,,store-and-forward“ and ,,near-real-time“ two-way communication of mobile and fixed-base eqipments. The utilization of this satellite communication system is oriented rather on the equipments employed to control transport of TIR trucks, railway carriages, heavy transport vehicles and other remote mobile equipment. [6]

3.8 Thuraya

The Thuraya system and its dual Mode is integrating satellite and ground services. As a result of the widening forntiers of providers, customers are enabled to be on the move without errors and limitations in the services over vast areas. And where there is incsufficient coverage of telephone operators, mobile services of the Thuraya are ideal solution for telephone services. On the basis of the GNMPRS service, the system further provides continuous connectivity to the Internet network all over the world and also provides the possibility of high-speed data link in via the ThurayaDSL. It is a solution suitable mostly for companies, government agencies and individual customers posing high demands on high-speed connectivity. The cosmic segment consists of towo satellites which are positioned on Geo-synchronous orbit with inclination of 6,3°. The antenna with the service of ,,on-board processing“ is located on the satellite is 12,25 m in diameter. [7]

In the time horizon till 2020 and further, a development of new satellite communication systems is expected to take place. Examples of systems having the potential for providing their services for the next time, have already been defined and studied. Design of the new generation of satellite communication system constellations has been initiated by the already mention Iridium, drafting up a new system sof far know only as as the Iridium NEXT. It is about a brave vision for the future of global communication. The Iridium NEXT is representing the capability of satifying the rapidly growing demand on true global mobile communicationon on the ground, see and in the sky. The initial draft consists in a problem-less replacement of satellites within the present constellation by a new system, which will also be compatible with the current applications and equipment. The idea is aimed to provide new, improved potentials that willbe made available for the aviation. [8]

4 CONCEPT OF THE ATM/CNS

The ATM/CNS system is a compilation of digital Technologies, which provide services for air traffic control at geographical locations including large parts of airspace. To ensure services of global air traffic control, communication, navigation and survellillance systems based on digital technology also involving satellite systems and various levels of automation. are used. The development of the ATM/CNS concept was also joined by the ICAO, when in October 1991 on the occasion of the 10th Aviation CoOnference it was confirmed by 85 members states of the ICAO. When developing the ATM/CNS Concept, the ICAO made use of the equipment and systems already existing in the evolutionary process, and the concept enables civil aviation to overcome the deficits of the past and present systems and make use of the latest technology of the aviation transport. [9]

CNS - is the basic part of the concept and is forming the tecnical basis of the concept. Elements of the CNS system control the develoment and itroduction of the new systems they are used to date. In order to achieve safe control of the air traffic, the latest technologies are introduced which are expected to eliminate the current deficiencies so as to meet the various expectations of operators. It is important to understand that the elements of the system found in the ICAO concept of CNS can be viewed as the offer of element , which will be introduced in case a specific requirement is raised from a certain. [9][10]

ATM – the CNS systems help in realizing the contributions of ATM, which subsequently increase safety, capacity, flexibility of the system thereby reducing operational costs and delays. By definition of the ICAO, the ATM is a system made up of on-board and ground-based parts, and the are in permanent interaction.

The process of introducing of the ATM/CNS conscept is difering based on the different areas of the airspace typical for the nature of operation and for the given operational environment I tis therefore necessary to chose for scertain types of airspaces a suitable configuration of the ground equipment. It is important mostly for the user, who is tasked depending on it the area of assignment. Part of the infrastructure of the entire ATM/CNS concept is made up of the following subsystems [9]:

4.1 Communication

This ATM/CNS Communication element enables Exchange of aviation data and messages between users and the automated systems. Air-to-ground communication is ensured by a communication block.:

- **Data communication**, which assumes that

The majority of standard communication in AIr-to-ground direction on the en-route phase of the flight will be realized via digital Exchange of data. This exhcange of date will substantially reduce the volume of voice communication and thereby the workload of pilots and air traffic controllers.

- **Voice communication** using voice

communication in the area of air-to-ground communication will remain the priority and primary means of communication particularly for emergency and non-standard situations. [9]

4.2 Navigation

Navigation element of navigation aimed at at roviding precise, reliable and problemless location all over the world in via the introduction of satellite air navigation or the Global Satellite Navigation System, the GNSS. It is a service that enables autonomous area location with worldwide coverage, making use of satellites. Its clients make use of small electronic receivers, which, by way of the signals transmitted from satellites ensure the possibility of calculating their position with the accuracy measured in meters.

4.3 Surveillance

Actual surveliance is performed either by voice reporting of the positional data or on the basis of radar signal (primary surveillance radar- PSR, or the secondary surveillance radar- SSR), which measures asimuth of aircraft from the ground station. Voice reporting of the position is used mostly in the ocean ic airspace or in areas lacking radar coverage. Pilots report their positions in via VHF or HF radios.

In via ATM/CNS systems, it is possible to achieve improvement in handover and exhange of information, in transmission of navigation and extending surveillance, which is the way towards reducing separations between aircraft, thus increasing airspace capacity. Communication will be further ensured via digital data links and trough existing channels of communication. Regular use of data transfer for the purposes of ATM, as a form of air-to-ground communication will offer lots of new opportunities. [11]

5 CONCLUSION

By way of the analysing the requirements establsihed for the separate satellite communication systems, a relatively comprehensive picture on their usein civil aviation was generated. The results of the work done it follows that the currently used satellite communication systems are known for their high quality of fdata transmission and sufficient coverage of the area by communication signals. Therefore, on the basis of the services provided, they are capable of meeting user requirements. By way of continuous imporvments and modernization they are substantial equivalents to serve civil aviation purposes.

Every year, new possibilities for using satellite technology aire found supporting communication in aviation, thereby overcoming current limitations. Till 2020 the global world o fair transportation is assumed to double, which causes general overcrowding of the airspace. Therefore, there arises the need for a new, indipendent air-to-ground communication In order for the future users to profit from the data exchange in via satellite communication, it is necessary to supplement the already existing systems. This is the aim of all the autorities interested in and responsible for the European airspace, with Eurocontol or the European Space Agency included.

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