HIGH ALTITUDE PLATFORMS FOR COMMUNICATIONS AND OTHER WIRELESS SERVICES

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SUMMARY

High Altitude Platforms (HAPs) are quasi-stationary vehicles in stratosphere, i.e. between the operational space of the terrestrial and satellite communications equipments. The solar-powered airplanes, airships or balloons can serve in the role of HAPs. The HAPs and their applications offer potential benefits for the delivery of communications services, internet multimedia, remote sensing and navigation system support. The applications of HAPs have the best properties from both terrestrial and satellite broadcasting, such as a small delay and undisturbed line-of-sight link between the customer and base station. They have been the subject of civil and military interest and of international projects for the past few years.

In the following article the overview of the main aspects and some results of successive trials of this promising technology will be described.

Keywords: *HAP, wireless communications*

1. INDRODUCTION

There are several reasons for searching other possibilities how to exploit effectively the existing limited radio spectrum as well as to use advantages of both terrestrial and satellite propagations and to avoid their disadvantages. Broadband communications by means of high altitude platforms (HAPs) allows such possibility. HAPs, in US military development projects named Unmanned Air Vehicles (UAVs), are un-manned airplanes, airships, and balloons (like in fig.1), with radio communications payload, operating at stratosphere and providing wireless communications between terrestrial places. They can serve also as intermediary between satellites and terrestrial surface. HAP technology has been seriously developed since 1997 and there are several current worldwide projects on HAPs, including programs in US, Europe, Japan and Korea. Several successful trials have been already realized; some HAPs nowadays operate in Japan and America, and the other new ones are commercially tendered. Their main advantages are small delay, like in terrestrial telecommunications, and feasibility of line-of-sight coverage for all terrestrial places under considering, like in satellite communications.

The other interesting advantages in comparison with terrestrial and satellite communication will be described in third part of the following text. In the next parts of this article are listed the main technical propositions of HAPs, there are also briefly described the physical layer, expected utilization, some world HAPs projects and related successful trials.

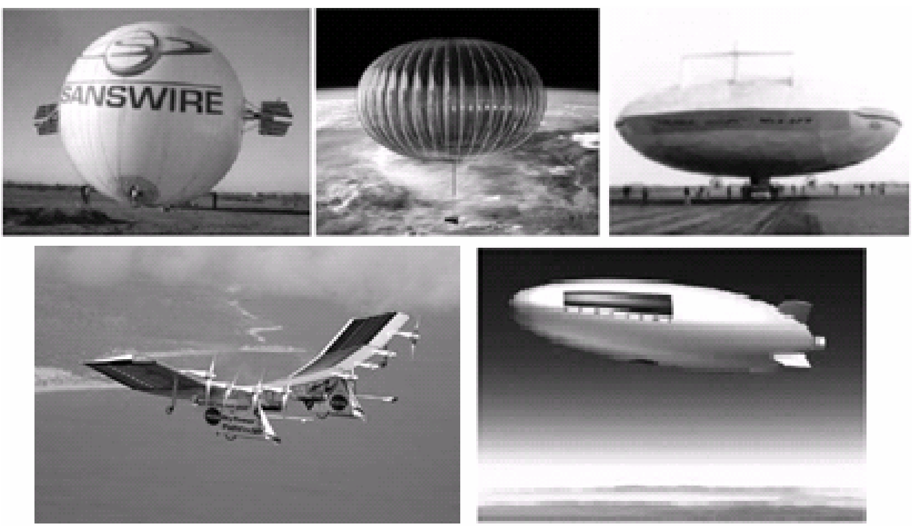

Fig. 1 Some successful HAP vehicle shapes [1], [2]

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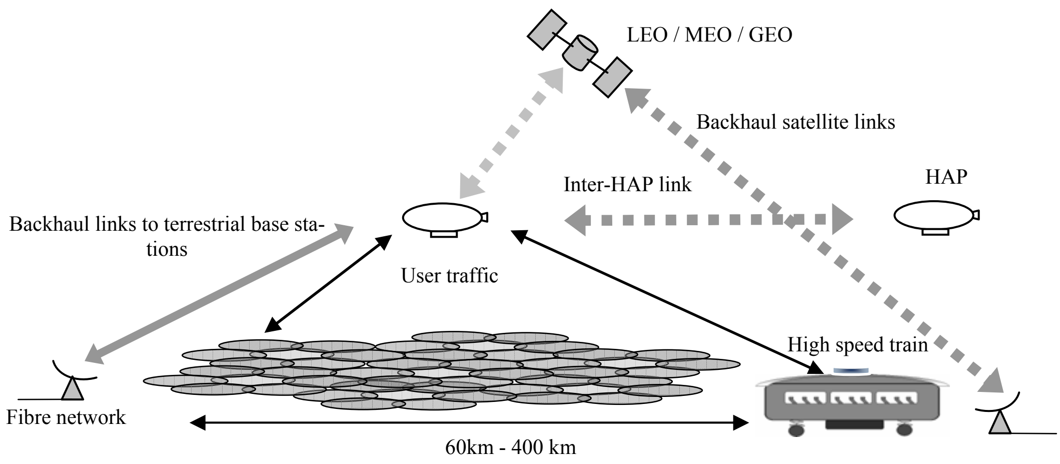

Fig. 2 Communication possibility conception and cellular frequency reuse covering [1], [3]

2. THE SPECIFICATIONS OF HAPS

In the following we can introduce some interesting specifications of HAP systems:

- "Floating" or quasi-stationed position in stratosphere at about 20 km altitude, well above both civil air routes and wind flowing (there is 5% of air density of atmosphere at sea-level). The aeroplanes and aircrafts can circle or move slowly in air space with radius of several kilometres.
- Solar powering.
- Remote controlling from the earth stations on the ground.
- In the case of airships - long endurance of station, e.g. several months or more. The ship can be brought down for retrofitting and maintenance, and can be returned back to its position.
- Line-of-sight up to 800 000 square kilometres area, according to operation altitude.
- Payload capacity allows uphold a lot of antennas for different services.
- Cellular covering by wireless signal, without deaf places on the earth surface with broken relief (fig. 2).
- Providing communications also for users in high speed moving terrestrial vehicles.
- WiFi technology and WiMax application for communications in bands 2 – 66 GHz. The work group ITU-R 9B have proposed more ITU-R recommendations for HAPS systems.

3. SUPPOSED UTILISATION OF HAPS

The scope of utilisation of HAP is great and very promising. There is intended many of civil and military HAPs benefits, which can be divided in three groups:

1. Broadband telecommunications services (cellular, a lot of new generation multimedia broadcasting and both-directions communications like as video-on-demand, video conferencing, Internet browsing, files downloading, interactive games, e-commerce, etc.). They will be allowed not only for static receivers, but also for slow walking users or for users travelling in high speed moving vehicles.

2. Environment monitoring (security and other commercial and military purposes).

3. Vehicles localisation.

These possibilities will be provided for much more users in high density urban environment and also for sparse populated rural regions. HAPs will be able to supplement the insufficient capacity of stationary terrestrial and satellite basic stations and can be fast allowed in the case of extraordinary or acute mass happenings, like as great sport matches and competitions, culture actions and catastrophes as well.

4. COMPARISION OF HAP WITH BOTH TERRESTRIAL AND SATELLITE COMMUNICATIONS

As it is described in introduction, HAP communications are fast as the terrestrial ones. Moreover, the signal attenuation and distortion on the score of rain and meteorological perturbations are less, because of less distance of their activity. The signal covering of terrain can be perfect, due to undistorted line-of-sight between transmitter and receiver antennas, which is not always possible in the case of terrestrial broadcasting. The HAP vehicles can be placed on the quasi-stationary position more fast and less difficulty than it is in the case of the placement of the radiocommunication masts. The change of HAP placement is possible and fast, as well, unlike of terrestrial base station.

The main advantage aspects of HAP exploitation in comparison with satellite communication are about a tenth of the cost, less demanding start and maintenance, the possibility of start repetition, and, at last but not at least, the larger capacity and smaller signal delay.

5. THE MAIN TASKS OF HAP DEVELOPMENT

The aeronautic constructors in area of HAP stations (HAPS) have a lot of interesting work. It deals with a research and development of suitable shapes of vehicles, coverage and construction materials, propulsion and movement of HAPS, power supply and exploitation of solar energy.

There is also a job for developers in the area of remote navigation, controlling and of operation without human operator on board.

In radio communications, the examination of well known communications modes, modulations, coding and net protocols will be pursued by searching of the new concepts in digital signal processing and communications. The communications feasibility of inter-platform links are investigated, likewise the backhaul links between HAPS and satellites. The new hardware including smart-patch antennas are developed for mm-waves and microwaves applications. Budget system design will be elaborated for all mentioned link types. Existing microwave ITU frequency bands utilization and searching of new bands must be reconsidered, investigated, discussed and negotiated.

6. THE SIGNAL TECHNICS PROBLEMS AND RADIOREGULATION STRATEGY

For each of the selected set of broadband telecommunications services a range of modulation/coding schemes are specified. The several linear and non-linear modulation schemes (including QPSK - Quadrature Phase-shift Keying, QAM - Quadrature Amplitude Modulation, M-APSK - M-ary Amplitude and Phase Shift Keying or StarQAM on the one hand, and CPM - Continuous Phase Modulation, GMSK - Gaussian Minimum-Shift Keying and MA-MSK - Multi-Amplitude Minimum Shift Keying on the other one) are the objective of evaluating process. Probably FEC coding will be required especially when channel conditions are poor to maintain link integrity. Appropriate codes will be selected for each service type, having regard to BER requirement (Bit Error Ratio), delay limitations, and computational load (especially for higher data rates). Codes considered will include (but not be limited to) convolutional codes, turbo-codes, product codes and RS (Reed-Solomon) codes.

The interference and synchronization problems must also be investigated and solved.

Regarding to equalisation it is expected that the platform - terminal link will be relatively benign in terms of dispersion, and hence that equalisation will not be required. However there may be circumstances where use of equalisation would allow access to a platform at low elevation angles, where ground reflection might occur.

Multiple Access methods are taken into account and may be based on a combination of Frequency / Time /Code Division Multiple Access. As well, TCP/IP, Wireless ATM, Wireless IP and HiPer Access protocols are investigated in context of HAP.

ITU-R Study Groups have extensively discussed the operational and technical characteristics of HAPS since the use of HAPS was agreed in WRC 97 (World Radiocommunication Conference in October-November 1997). There had been produce total 14 recommendations for HAPS in 47/48 GHz bands, 28/31 GHz bands and others for period of 2000-2005. It was a temporary solution, because the mentioned bands are reserved for Fixed Services and IMT-2000. In some works there are investigated the utilisation of IEEE 802.16a referred to WiMax and intended for terrestrial non-line of sight systems operating in the 2-11 GHz bands [4], [5].

As it was mentioned, there is cellular concept of covering considered. Recommendation ITU-R F.1500 indicates that a typical HAPS based network (HAPN) may offer up to 2100 cells, with a 7-times frequency reuse factor, within a service diameter of 468 km. In addition there may be up to 40 gateway stations within a diameter of 181 km. Dependent on the bandwidth assigned to an individual HAPN, there may be up to 330 000 simultaneous user terminals in operation from a subscriber base of more than 5 million. Each of these user terminals will have an antenna directed towards the HAPS. The 2 100 beams from the HAPS will extend across the whole of the coverage area, with frequency reuse.

6.1. HAP channel model problems

For perfect theoretical handling of many HAP communications problems it is necessary to have appropriate model of HAP channel.

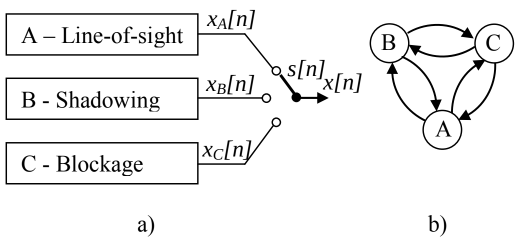

Fig. 3 Switching process $s[n]$ in generation of the observed sequence $x[n]$ (a), and semi-Markov state model of HAP communication channel (b) [6].

User link between HAP station and moving receiver in high speed train is critical in this sense, and hence it is an objective of intensive research and tests. The scenario of this channel can be modelled by analogy to statistical model for mixed propagation conditions described in ITU-recommendation [6], which was primarily intended for satellite links. This model exploits hidden Markov state chain approach. The chain comprises three type of states (A, B, C), i.e. three types of receive quality, and transitions between them, as it can be depicted by simple scheme in fig. 3.

The first state (A) represents clear line-of-sight (LOS) condition. This state can occur with probability P_A and the signal level in this state can be described by the Nakagami-Rice cumulative distribution. The Loo distribution can be exploit to express the signal level in second type of state (state B with probability P_B), which represents slightly shadowed condition (by trees and/or small obstacles). Third state (C with probability P_C) is fully blocked receive (by large obstacles, such as mountains and buildings), and signal level has Rayleigh distribution.

The state transitions between states can be modelled by the switching process *s[n]* (fig.3). The all state durations can be described by probability functions as follows: power-law distribution for state A duration, log-normal distribution for duration of states B and C. The mathematical expressions of mentioned distributions and the choice or setting of their parameters can be found in [6], [7].

7. SOME WORLD HAP PROJECTS AND SUCCESSFUL TRIALS

The research program of HeliNet Consortium (2000-2003) funded by European Union Framework 5 Programme developed the small solar powered airplanes and focused also on traffic monitoring, environmental surveillance and broadband telecommunications [8]. The project participants were Politecnico di Torino, University of York, Josef Stefan Institute, Technical University of Budapest, CASA Technical University of Catalonia and Ecole Polytechnique Federale de Lausanne.

The European CAPANINA research consortium started its work at November 2003 and is led by University of York. It involves 14 partners from Europe and Japan and was partially funded by the European Union – Framework 6 Programme. The main objective of project is to deliver low cost broadband communications services to small office and home users. There was realized CAPANINA high altitude trial in northern Sweden, in October 2005. 12,000 m^3 balloon, carried radio and optical communications equipment, flying at altitude of around 24 kilometres and provided communications in mm-wave band (28/29 GHz) using WiFi (IEEE 802.11) at distances ranging up to 60 km. There was also performed the first known optical 1.25 Gbit/s downlink from stratosphere to an optical receiver on the ground over a link at distance of up to 64 km [1].

Currently the European COST 297 – HAPCOS is realized with participation of 16 countries. It's main objective is to increase knowledge and understanding of the use of High Altitude Platforms for delivery of communications and other services, by exploring, researching and developing new methods, analyses, techniques and strategies for developers, service providers, system integrators and regulators [9].

The USA already commercially offer Stratellites – HAP aircrafts, products of Sanswire Network, LLC., loaded by a lot of communications antennas for different purposes [2].

US also develop the military unmanned communications aircrafts equivalent to HAPs and named UAVs. (Unmanned Aerial Vehicles). They are remotely piloted or self-piloted and can carry cameras, sensors, communications equipment or other payloads. They have been used in a reconnaissance and intelligence-gathering role since the 1950s [10].

Japan and Republik of Korea have operated their own HAPs, and participate in international Asia Pacific Telecommunications HAP projects and in ITU-R Study Groups, Work Groups and Expert Groups in area of HAP communications. They joined European HAP projects, as well.

8. CONCLUSION

The aim of this article is to offer the knowledges about developing new communications technology. High altitude platforms (HAPs) can fill the gap between the communications feasibilities of both terrestrial and satellite base stations. This technology is an objective of interest of many universities and civil research centres, as well as of military research groups. It is an interesting call for constructors in area of aeronautic materials, vehicles shapes and propulsion. There are also the research tasks in area of wireless communications technologies, as well as of exploiting the existing WiMax and WiFi technologies.

In this paper, the brief overview of the technical specifications of HAPs, the aspects of communications research and development tasks, the utilization feasibility of HAP technology and state of art of this research problems in the world was described.

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BIOGRAPHIES

Ľudmila Maceková was born in Košice, Slovakia. She graduated (MSc. equiv. degree) in radioelectronics from the Technical University of Košice in 1983. She received PhD. degree in telecommunications in 2005 from the same university. Since 1991 she had been as assistant professor with Department of Electronics and Multimedia Communications of the Faculty of Electrical Engineering and Informatics of this university and since 1997 she has been working there as research assistant. She is working in projects in areas of image processing, teleeducation and telecommunications.

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