Nikolas ŽÁČIK, Andrej NOVÁK

COMPARISON OF PASSIVE AND ACTIVE RADAR SYSTEMS

Abstract

This article presents the conclusion from my two theses, Comparison of tracking systems and Tracking systems. In the first part with title Comparison of tracking system, was my work focused to research of primary and secondary radar technology with very detailed description and principle of their use. This part of my research consists also from comparison of those two different types of technologies, their advantages and disadvantages. This research was the base stone for my second part of thesis with title: Tracking systems and conclusions, summarized in this article. The second part of thesis is more focused to civil and army passive radar and meteorological technology. The main topic is: how to build up the new radar network by using passive radar technology and what are the advantages and disadvantages of this concept, in comparison with actual primary and secondary radar network. I have chosen Slovak Republic for new network planning but this theory and research is applicable for all the other countries, with some minor changes. This topic is focused mainly to advantages of passive surveillance system and multilateration.

INTRODUCTION

The main problem in general aviation is still the rapid rising level of congestion in the airspace in the whole world. It may cause a problem with accommodation, controlling and tracking of all planes in the airspace with actually not upgraded land facilities. The main idea of this topic is to give solution for increasing of tracking capacity in the airspace for very long time, for very low price in the short time period and with sufficient precision for increasing of safety. For this task I have chosen passive surveillance technology, previously used just for army operations but nowadays still more consulted in the civil sector. Another task summarized in the topic is to approximate operation and principle of the radiolocation facilities and to describe them also from the historical point of view (development, invention and importance). The result of the thesis is a clearly described geographical position of the radar equipment in a territory of Slovakia and the map of future alternative solution of coverage in this territory by passive radar technique. This article provides you through information about advantages and disadvantages of using passive surveillance technology and multilatertion in Air traffic control network. Principle of work of PSS systems

PSS system is working without transmitter which is usually providing radars with ability of transmitting signal into the space and after detecting all objects by receiving of reflected signals. The Main part of PSS is the system of several receivers. PSS system is transmitting any electromagnetic signal into the space. Its principle is based just on receiving of electromagnetic energy from the space in coverage of radar. Precise position of targets is determined by comparison of all detected signals from all receiving stations of PSS system. This kind of radar is the most common and mostly used for the army application. On the other hand this technology is not fully used in civil air traffic. Potential of PSS technology is often underestimated by the civil air traffic sector. For air traffic control is the most common concept of radar network based on impulse and primary radar technology.

PSS is working on principle of cooperative, independent tracking. PSS system consists of several antennas located at different places and one central antenna which is used as reference point for all received signals at all antennas. After receiving of signals are all signals evaluated and compared by central antenna. Theoretically is PSS able to detect and track all possible sources of electromagnetic signals. In aviation is commonly used principle of transmitting and receiving message by using secondary radar technology used with cooperation with PSS. In case of this concept is assertion that PSS radar is transmitting any signal, false.

PSS is not transmitting signal, PSS just receives electromagnetic signals from the space by antennas system. Despite of passive principle of receiving signals, PSS receiving antennas still need some source of this signal (echo) for tracking of the target. For this purpose can be sufficient for example transmitter of radio, television or mobile network. The less common signal which is PSS able to detect are signals from home or foreign radars but also a jammer. All these kinds of signals are reflected from all objects in the sky and also on the ground. It creates natural signal which passive radar can processed. For data of higher quality are compulsory more antennas in the system for process of evaluating data relative to reference antenna. From differences in the signal of separated antennas is possible to precisely determine position, direction and speed of target in the time.

1. PRINCIPLE OF WORK OF ACTIVE RADARS

For safe air traffic in the air space is not important just localization of target in the space but also information about weather, mainly in case of appearance of significant weather phenomena. Two main types of active radars are meteorological and primary radar. The principle of work of both of this technology is very similar. The purpose of meteorological radar is tracking of cloudiness and precipitation. With this radar technology the Weather Service is able to send warnings for airplanes in case of poor meteorological conditions. Primary radar is able to detect other targets in the space and tracks their position.

Active radars use principle of independent tracking of reflected electromagnetic signal from non cooperative target, similarly as primary surveillance radar (PSR) technology or meteorological radar. In case of tracking by meteorological radar is the target cloudiness or different meteorological objects. Despite of similarities in the principle of tracking with PSR, meteorological radar still has some differences. The most of them are described in the scheme and different parts of meteorological radar in my diploma thesis: Tracking systems. The basic principle of working active radars is the same as for classical PSR, transmitting of short impulses with high

energy level and waiting for echo from the target which is lately processed. All active radars have the same main condition that tracked target must have the ability of reflecting electromagnetic radio signal.

2. ACTUAL SITUATION OF USING MULTILATERATION EQUIPMENT IN THE SLOVAK REPUBLIC

2.1. Process of implementation of multilateration system

In the Slovak Republic is implemented any multilateration system nowadays. Also any PSS is used for civil operations and air traffic control in Slovakia. On the other hand in Czech Republic you can find three these systems used by Air traffic control now. The precise name of this system of PSS radars is Wide Area Multilateration (WAM) system. In Czech Republic is the system located in the area of cities Brno, Ostrava and Prague. Those three systems are able to cover the whole air space of Czech Republic and also the west part of Slovakia. In the Czech Republic is also in use one Airport Multilateration (AMLAT) system as part A-SMGCS in Prague.

My thesis is based on assumption that Slovak and Czech Republic are very similar areas with similar ground segmentation. If you take in account this assumption, ideal predicted number of stations is three central stations also for Slovakia. In case of cooperation with Czech Air traffic control organ (ŘLP) there is possibility to achieve in the air space of Slovakia, tracking information with higher precision or less used central stations in the network for lowering costs.

Number of stations for coverage of Slovak air space is dependant mainly on three parameters:

1. Area which has to be covered.
2. Ground segmentations and mountains in the country.
3. The lowest flying level which has to be covered.

Those factors are crucial and restrictive in term of principle of work of PSS radar technology. The principle is based on method of multilateraion. For this purpose is compulsory for PSS for detecting signals and targets direct visibility between the object and the radar. The condition of direct visibility between four antennas and the target in time must be always fulfilled. In area of Slovakia is compulsory to take in account also the mountains. The most significant obstacles during planning are in this case the Tatra Mountains. In case of request to cover lower flight level above ground level, you need to use more central stations and antennas.

2.2. Design of WAM system for area of Slovak Republic

This concept of design of WAM system for Slovakia is based on collected information about principles of work of this system in cooperation with company ERA. They supported my project with materials which contains manual and basic information for design of WAM networks, the same like was used for building up the radar network in the Czech Republic. My concept for Slovakia is designed in the area of cities as follows:

Bratislava

I have chosen this area for better coverage in proximity of international airport M. R. Štefánika in the capital of Slovakia- Bratislava from lower flight level. The main purpose is that there are expected aircraft operations in low altitudes, mainly during takeoff and landing. This position will also ensure very precise coverage of whole Danubian Plain and sufficient coverage of whole west part of Slovakia. The west part of Slovakia situated behind mountain Little Carpathians is perfectly covered by Czech WAM network. In the case of sharing of radar data between Czech and Slovak republic will be this part behind obstacle also under control of ATC. The condition of sharing data is not necessary, because there are not expected flights in so low altitude.WAM system designed for this area will partly cover also the area of middle part of Slovakia. My concept of architecture for this area is total of eight stations. Five of them will be situated near to the airport with direct visibility to lower altitude above area of Danubian Plain. Stations near around the airport guarantee higher precision mainly in critical area of the airport. Other three antennas will be situated farther from the airport for coverage and better precision of system in other parts outside of the airport.

Liptovský Mikuláš

This area was design to improve quality of coverage of whole WAM system mainly for mountain area, where the signal can be often shielded by obstacles for stations and antennas from Bratislava and Kosice systems. This central has to ensure the coverage of north Slovakia, mainly in area of the High and Low Tatras. This system also provides coverage for area of the third biggest international airport in Slovakia, airport Poprad – Tatry. My concept of architecture for this area is total of seven stations. Four of them will be situated near to the airport for the same reason as it is mentioned for WAM system Bratislava in article above. Other three antennas will be situated at the mountain comb of Low Tatras for better coverage and higher precision of system. The result will be better coverage of whole airspace above airspace of Slovakia, mainly in problematical mountain part. The Designed concept will ensure coverage also in area between hills, but in this altitude is not expected some air traffic, just in case of emergency.

Košice

The main reason for choice of this location is the second biggest international airport in Slovakia, Kosice airport. Other reasons are similar as above mentioned for area of Bratislava. This central of WAM system will cover the whole east part of Slovakia. My concept of architecture for this area is total of six stations. Three of them will be situated near to the airport for the same reason as it is mentioned for WAM system Bratislava in article above. Other three antennas will be situated at the mountain Slovak Rudohorie for better coverage and higher precision of system in the east part of Slovakia. Position of antennas at the elevated position will ensure direct visibility for whole this east area. The result will be the better coverage of whole airspace above the airspace of Slovakia, mainly in problematical mountainous part.

The best possible technology for purpose of build up new WAM network is actually the most modern Czech system: P3D-WS at all chosen positions of central stations. This technology removed bugs occurred in the previous versions and also meets all traffic safety requirements of ICAO. Previous version P3D-40 was just beta testing version with lower maximal range. All radar centrals in my concept where chosen for the best possible coverage of whole required airspace of Slovak Republic. The concept of three centrals will not ensure the coverage of whole area of Slovakia, but will ensure the coverage around all international airports in the country as well as the coverage of airspace in the mountain from altitude where the air traffic can be expected. All separated antennas must be placed in the range of 100 km from central stations. All antennas are communicating between each other and share information about the position of target. Chosen architecture of WAM network and distance between separated antennas can in ideal terrain condition ensure tracking targets in range of 350 km. Restrictive factor in maximal possible range is just range of the transponder station , which can effectively work just in range of 100 km. By company ERA is, recommended minimal number of antennas for one central

station, five. The price of this project designed for Slovakia, built up by company ERA is around 3 – 4 million euro. Whole this research was supervised by ERA during regular consultations about each point of my thesis. The concept was developed from theoretical knowledge, based on simulations of ERA company simulator, developed for this purpose. For better economical overview and advantages of this solution see graph at Pict. 2.

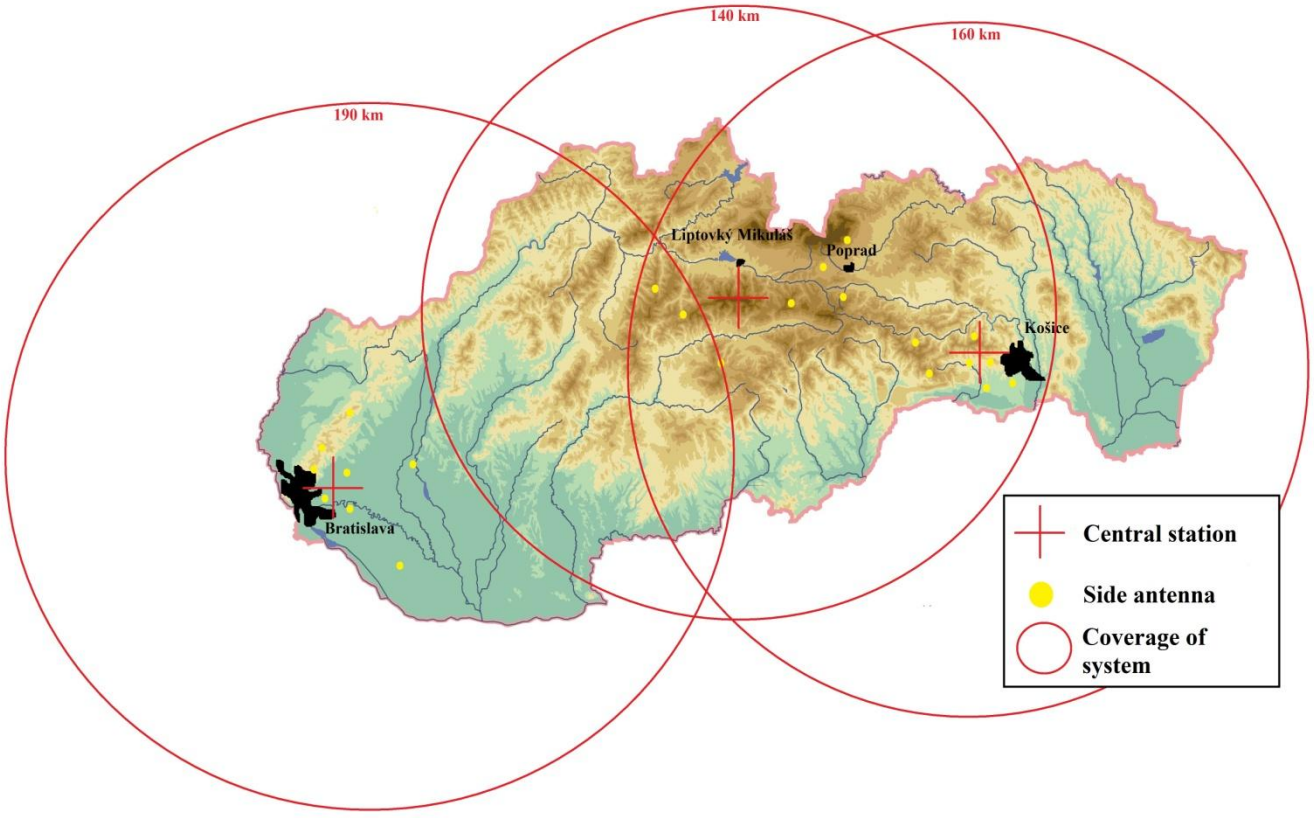
	Purchase	Yearly	15 years
Radar	€ 2,500,000	€ 270,757	€ 6,561,355
MLAT	€ 1,250,000	€ 50,000	€ 2,000,000

Pict. 1. *The comparison of whole operation costs, in case of using of primary radar (PSR), in comparison with MLAT system (PSS).*

CONCLUSION

The theoretical part of my diploma thesis about tracking systems, in the territory of Slovak Republic adds to whole my 5 years research, chapters about principle of work of PSS and meteorological radar technology with meteorological channel included. This part of work also offers simple and straight explanation, how is radar technology working the above mentioned. Knowledge included in theoretical part, consist of four chapters, which are necessary for understanding of the whole concept of this topic. The most important part is the chapter about PSS radar technology.(for understanding all the differences of this technology, in comparison with the other types of radars.) You can find in my publication also a very detailed scheme of work of all parts of each type of radar for better understanding of their principles.

The final conclusion of my whole project is the offer of alternative solution, how to build up the radar network and the radar coverage for the whole air space of Slovak Republic's territory. My concept consists of PSS radar technology, is provided by Czech company ERA. This technology is characterized by high level of precision, reliability and low operating expenses. During designing of WAM system in Slovakia, there are two concepts of solution of positioning all stations and antennas. The first of them is to build up the network with three independent central stations with several antennas (in this case: receivers) for each of them. For this concept important is the cooperation between all three stations and also between all the antennas. The second possible solution is: to build up just one central station with more antennas in the space, like it is planned in the first solution, but the cost of this concept can be lower. The Disadvantage of this concept is: lower tracking capacity. After consultation and recommendations of specialists from company ERA, is my recommended solution of new WAM concept for Slovakia the first solution: to build up network with 3 separated central stations. The best location for this three stations regarding to terrain in the country are cities: Bratislava, Liptovký Mikuláš and Košice with total number of 21 antennas. The biggest challenge during design of WAM network in Slovakia, were mountains specially mountains in the area of High Tatras. PSS for his work need direct visibility of detected target for correct and smooth operation.



Pict. 1. *Design of WAM system for Slovak republic.*

In my chosen concept I have achieved the coverage of whole airspace of Slovak Republic with the wanted range and additionally this system covers the parts of the air space of surrounding countries. The range of one system of antennas with central station can be around 350 km (it depends on terrain). The price of the whole concept of designed WAM system is around 3 – 4 millions euro. The precise price is dependent on precise number of used antennas and stations. For better overview, one PSR applied for the same purpose, has the price around 3 million euro and his operating costs are 5 or 6 times higher than cooperating costs of PSS radar. The main advantage of WAM system is the increased level of safety in aviation.

Part of the conclusion of my research is the sum of all the information which I have achieved during my work about geographical position of actual, future planned and by my designed radar network in Slovakia. Overview of summarization of actual and future radar situation in Slovakia, you can find in the map with legend, in my thesis: Tracking systems page 76, picture 20. and exact types of used radars in the table 19. at page 77. All results are based on the research of my bachelor and diploma thesis.

BIBLIOGRAFIA

1. ŽÁČIK N. 2013. Bachelor thesis: Porovnanie sledovacích systémov. 1. issue. Žilina: University of Žilina., 2013. 83 p.
2. Bc. ŽÁČIK N. 2015. Diplom thesis: Sledovacie systémy. 1. issue. Žilina: University of Žilina., 2013. 81 p.
3. HAVEL K. a kol. 2005. Základný kurz pre personál technického zabezpečenia prevádzkových služieb. Bratislava: LPS SR, 2005. 451 p.
4. OCHODNICKÝ J. – MATOUŠEK Z. 2013. Analýza rádiolokačných systémov. 1. issue. Liptovský Mikuláš: Akadémia ozbrojených síl generála M. R. Štefánika, 2013. 196 p. ISBN 978-80-8040-470-3
5. SVOBODA P. 2013. Skvelé pasívne radary Ramona, Tamara, Věra , vidia neviditeľné? [online]. [quoted 2015-04-08] Available at internet: <http://simon22.blog.pravda.sk/2013/09/10/skvele-pasivne-radary-ramonatamara-vera-vidia-neviditelne/>.
6. OPERA 1999 – 2003. Final Report [online]. [quoted 2015-04-08] Available at internet: <http://www.knmi.nl/opera/opera1/Final_Report.pdf>
7. STEVÁK M. 2013. PRENOSNÝ METEOROLOGICKÝ RADAR [online]. [quoted 2015-04-09] Available at internet: <http://www.meteoradar.eu/onas.html>
8. ERA. 2015.Web page [online]. [quoted 2015-04-11] Available at internet: <http://era.aero/>
9. UJCOVÁ M., employed of company ERA. Komerčné materiály, dokument: Wide Area Multilateration.docx [e-mail]. [quoted 2015-04-14].
10. JURASEK M. a kol. 2014. Close Future of Slovak Weather Radar Network [online]. Bratislava: SHI. 2014. 2 p. [quoted 2015-04-18] Available at internet: <http://www.pa.op.dlr.de/erad2014/programme/ExtendedAbstracts/368_Jurasek.pdf>

COMPARISON OF PASSIVE AND ACTIVE RADAR SYSTEMS

Abstract

This article presents the conclusion from my two theses, Comparison of tracking systems and Tracking systems. In the first part with title Comparison of tracking system, was my work focused to research of primary and secondary radar technology with very detailed description and principle of their use. This part of my research consists also from comparison of those two different types of technologies, their advantages and disadvantages. This research was the base stone for my second part of thesis with title: Tracking systems and conclusions, summarized in this article. The second part of thesis is more focused to civil and army passive radar and meteorological technology. The main topic is: how to build up the new radar network by using passive radar technology and what are the advantages and disadvantages of this concept, in comparison with actual primary and secondary radar network. I have chosen Slovak Republic for new network planning but this theory and research is applicable for all the other countries, with some minor changes. This topic is focused mainly to advantages of passive surveillance system and multilateration.

Authors:
Ing. **Nikolas Žáčik** – University professor in Žilinská univerzita v Žiline, Faculty: PEDAS, Department of Air traffic, nikolas.zac@gmail.com
prof. Ing. **Andrej Novák**, PhD.– University profesor in Žilinská univerzita v Žiline, Faculty: PEDAS, Department of Air traffic

Acknowledgement
This paper is published as one of the scientific outputs of the project: VEGA 1/0838/13- THE BASIC RESEARCH OF CHARGES POLICY AT THE SPECIFIC MARKET OF AIRPORT SERVICES and paper is published as one of the scientific outputs of the project: „Centre of Excellence for Air Transport ITMS 26220120065".