JOURNAL OF MECHANICAL AND TRANSPORT ENGINEERING
Vol. 69, no. 4 2017
DOI 10.21008/j.2449-920X.2017.69.4.06

Rafał URBANIAK*
Wojciech JUDT*
Agnieszka WRÓBLEWSKA*
(Received 05 May 2017, Received in revised form 01 Nov 2017, Accepted 22 Jan 2018)

A DRAFT MODEL OF A TEST STAND FOR AUTOMATIC POSITIONING SYSTEMS OF ANTENNA REFLECTORS

The paper presents a draft model of a test stand for the measurement of the efficiency of automatic positioning systems of radar antenna reflectors. The described test stand was designed and constructed for the identification of the aircraft position during air show aerobatics.

The authors of the paper have presented and discussed in detail the test stand's individual components and measurement equipment.

Keywords: Antenna reflector, reflector positioning, antenna testing

1. INTRODUCTION

Antenna reflectors are frequently used in radiolocation because of good parameters and low costs of their production. They are composed of two components – a reflector being a fragment of a rotary parabola and the radi-ating element placed in the focus.

A parabola, owing to its properties, is a very good reflector and has be-come a fundamental component of radiolocation antennas. Two geometrical properties of a parabola allow concentration of the radiated energy. Firstly, a parabola is a geometrical set of points equally distant from point F referred to as the focus and from straight line y" – y" referred to as the directrix [Langer 2009]. Figure 1 presents the course of the beams of a parabolic antenna. We can see that the line is perpendicular to the symmetry axis of the parabola, otherwise known as the parabola axis. Second-

* Poznan University of Technology, Faculty of Machines and Transport.

ly, the tangents to the parabola, at any point, form equal angles φ with the straight line crossing this point and the focus and the straight line parallel to the parabola axis. From the second property it results that the beams going from the focus and reflected at any point of the parabola will be parallel to its axis after the reflection, according to the principle that the angle of incidence equals the angle of reflection. From the first property it results that the wave of a spherical wavefront, emitted in the focus, will turn into a wave of a flat wavefront because the total distance covered by the beam from the focus to the front of the flat wave y' – y' equals the distance between the directrix and the front of the wave i.e., it will always cover the same distance to the front of the flat wave irrespective of the point at which the beam reflects.

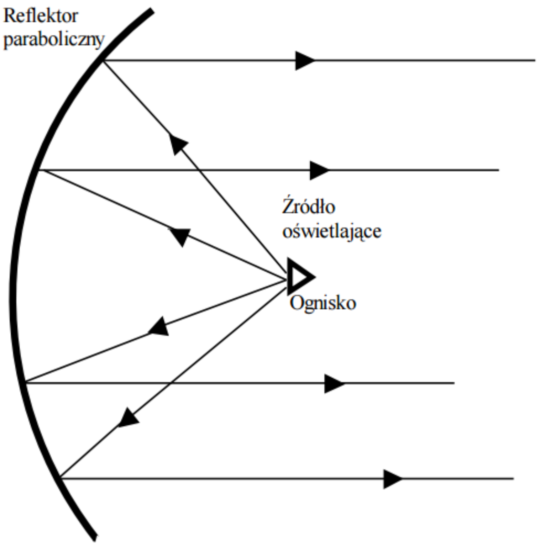

Fig. 1. Course of the beams parallel to the optical axis in the parabolic antenna [Instytut Łączności 2006]

A parabola is, obviously, a two dimensional curve and the antenna re-flector is a three dimensional surface referred to as rotary paraboloid. This surface forms as an effect of the 360-degree rotation of a parabola around the axis and has the above-described properties. If it is beamed by a source placed in the focus, the paraboloid will form a symmetrical cigar-shaped beam referred to as pencil beam. The width of the beam Θ in a vertical and horizontal plane is the same and amounts to approximately (in radians).

$$\theta = \frac{\lambda}{D} \tag{1}$$

where:
λ – wavelength,
D – diameter of the reflector.

The process of tracing the flight trajectory requires implementing con-trol algorithms of the antenna actuators and a digital processing of the sig-nals received from the transmitters. In order to ensure tracking of the receiv-ers in the azimuth and elevation, it is necessary to obtain return signals from the receivers, yet in terms of control of the antenna actuators, it is necessary to select proper alignment algorithms that will allow a quick determination of the required position irrespective of the current position of the antenna reflector.

Algorithms of antenna alignment will be selected taking into account such parameters as: type of applied motors, return signal accuracy and signal rate informing about the current position of the antenna and the assumed number of tracked objects.

2. THE TEST STAND DESIGN

For research purposes, a test stand was built for investigations and alignment of the automatic ground antenna systems, allowing reproduction of the main components of the assumed construction of the actual antenna system. The objective of the research team of Poznań University of Tech-nology was validating the behavior of the model of the test stand in terms of application of the algorithms of alignment through individual actuator com-ponents.

Figure 2 presents the view of the designed test stand.

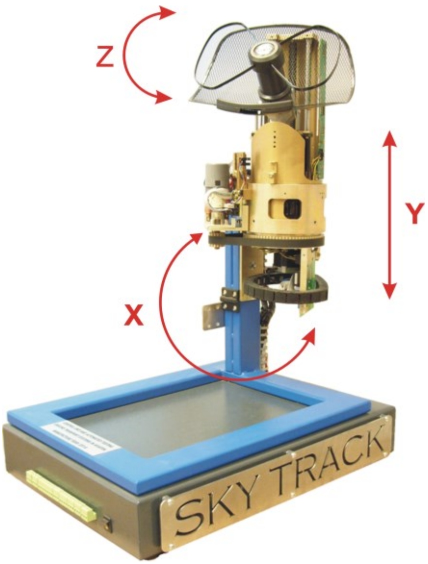

Fig. 2. View of the test stand of the automatic antenna systems [Judt 2015, Urbaniak 2015]

The test stand is equipped with three drive systems: two bipolar stepper motors working in the Z and Y axes and a direct current motor working in the X axis.

Owing to the need of testing of the accuracy of individual components, the applied motors differed in the method of positioning of individual actuators. The stepper motors were not fitted with external positioning systems that would generate feedback. In their case, it was the counter of signals clocking the engine operation that provided information on their position.

For the direct current motor, a system of external encoders was applied that provided information to the control systems related to the position of the aligned axis.

Because different types of actuators were applied, they needed different control signals. In the controller, two modes are available - with and without a generator. If the system works with a generator to actuate the arm motion it is sufficient to send a signal of a given value to individual inputs to move the axis with a constant speed. Operation with a generator pertains to inputs: STEP1, STEP2, DC90%, DC80%, DC70% and DC60%. Inputs KIER1, KIER2 and DIR serve to change the direction of a given axis.

The other operating mode provides full control over the device, ena-bling a smooth adjustment of the axis motion velocity. The velocity of the axis depends on the frequency of the impulses in the case of STEP1 and STEP2 inputs and the PWM duty cycle in the case of input DC100%. Ex-ample input courses have been presented below. Figures 3 and 4 present the basic principles of control of the direct current motors with PWM adjust-ment. Very often, the Matlab development environment is used to simulate the operation of stepping motors [Rusu 2008, Biorou 2008, Szoke 2008].

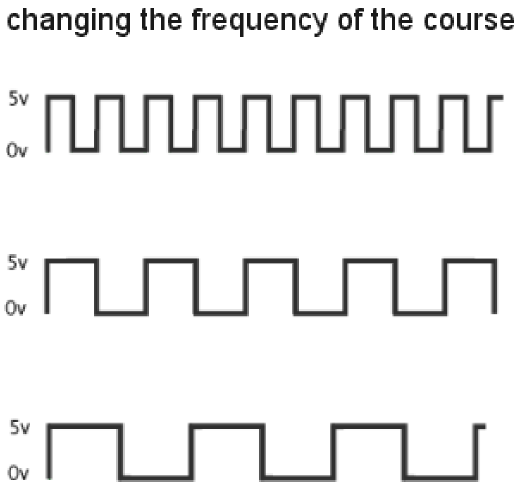

Fig. 3. Example control of the PWM signal for different values of the output voltage [Motorservice 2015]

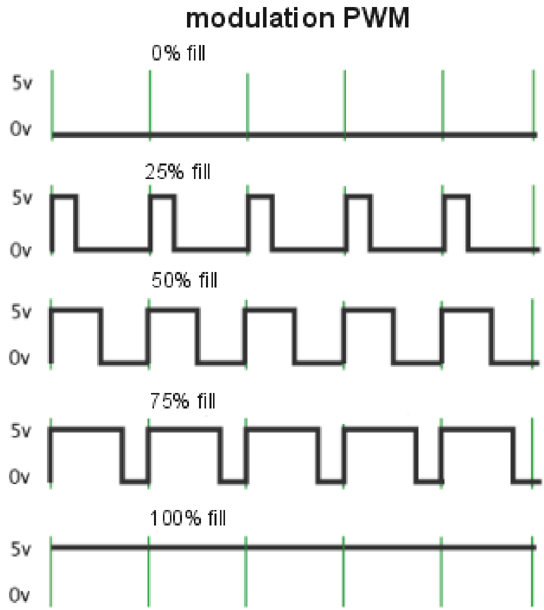

Fig. 4. Example of control with the PWM signal for different duty cycles [Motorservice 2015]

Due to the need of an accurate measurement of all data related to the opera-tion and accuracy of the antenna system positioning, a modern system (CompactRIO-cRIO-9024 by National Instruments) was applied for ad-justment and recording of the measurement data. The equipment can collect measurement data in its memory, record them and send the recorded file to the computer. This tool, due to the properties of its processor and highly expanded systems of operating memory, allows performing accurate meas-urements and control of the automatics (depending on the applied cards supported by the equipment). The system is fully compatible with the graph-ic programming language LabVIEW. For the realization of the research proprietary software was developed in the graphic LabVIEW environment.

3. CONCLUSIONS

An important component of aviation infrastructure are antenna sys-tems that ensure air traffic safety. They constitute indispensable equipment of the air traffic control systems. Their efficient and quick operation de-pends on the used positioning systems.

The authors of the paper have presented a model of the system for the testing of automatic systems of antenna reflector positioning used for identification of the aircraft position in aerobatics. Due to high costs and hazard resulting from the construction of such systems in real life, the pre-sented test stand is a basic tool for the development of modern positioning algorithms. Literature examples clearly indicate that the LabView environment is very often used in the latest scientific research to analyze modern control algorithms [Lisowski 2017, Sokołowski 2017].

The applied solutions and used equipment allow testing of the latest antenna reflector positioning algorithms under laboratory conditions. The obtained results will enable developing algorithms of alignment that will be used in the infrastructure of airports and air traffic control.

REFERENCES

Instytut Łączności, Państwowy Instytut Badawczy, 2006, Nowe rozwiązania anten satelitarnych, Warszawa.

Judt W., 2015, Badanie czasu reakcji silnika odpowiedzialnego za sterowanie obrotem głównej osi stanowiska symulującego ruch anteny, Politechnika Poznańska [raport z badań].

Langer M., 2009, Wprowadzenie do telekomunikacji, Instytut Elektroniki, Politechnika Łódzka.

Motorservice, 2015, Sygnały w pojeździe mechanicznym, rosnące znaczenie oscyloskopu.

Rusu C., Biorou I., Szoke E., 2008, Model Based Design Controller for a Stepper Motor, Automation, Quality and Testing, Robotics, IEEE International Conference, Romania.

Urbaniak R., 2015, Badanie nowoczesnych algorytmów pozycjonowania, dynamicznych układów antenowych z wykorzystaniem stanowiska regulacji i badania automatycznych naziemnych systemów transportu w lotnictwie, Politechnika Poznańska [raport z badań].

Lisowski J., Sokołowski Ł, 2017, Methods of Intelligent Control in LabView Programiming, Scientfic Journal of Gdynia Maritime Univeristy, nr 98, s. 131–138.

PROJEKT STANOWISKA DO BADANIA AUTOMATYCZNYCH SYSTEMÓW POZYCJONOWANIA ANTEN REFLEKTOROWYCH

Streszczenie

W artykule przedstawiono projekt stanowiska badawczego do pomiaru sprawności automtycznych systemów pozycjonowania radarowych anten reflektorowych. Opisywane stanowisko zostało zaprojektowane i skonstruowane na potrzeby systemu identyfikacji położenia statków powietrznych w trakcie prowadzenia zawodów akrobacji lotniczych.

Autorzy artykułu w sposób szczegółowy przedstawili i omówili poszczególne elementy składowe oraz niezbędną aparaturę pomiarową.

Słowa kluczowe: antena reflektorowa, pozycjonowanie anten, badania anten