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IMPROVEMENT OF DIGITAL DEVICE FOR SUPPRESSION OF ERRONEOUS REQUEST BY LATERAL PETALS OF THE ANTENNA OF AIR TRAFFIC CONTROL SYSTEMS

This article considers the expansion of the capabilities of digital devices of three-pulse suppression of the request of aircraft responders with side petals in terms of increasing the accuracy of measuring the azimuth of flight of aircraft. In existing devices, the response of aircraft responders is carried out at the time of the boundary crossing by the aircraft of the frequency pattern of the antenna. The directional pattern of the radar systems of the main petal has an angle of 2o-4o in the horizontal plane depending on the type of radar system and the request period of terrestrial radar stations is 500 Hz, and the antenna rotation speed is 10 rpm and the distance between pulses P1 and P3 is 14 μs. The time the aircraft is within the directional pattern of the main petal will be requested 17 times and the same number of responses, which in turn leads to ambiguity in fixing the definition of the aircraft in azimuth, especially over long distances. The response of the aircraft respondent to the request will be answered when approaching the middle of the directional pattern of the antenna of the main lobe, where the highest power of the emitted signal, which will significantly reduce the error of determining the aircraft by azimuth.

Key words: *radar system, air traffic control, aircraft responder, aircraft, analog-to-digital converter, three-pulse suppression, «request-response» mode.*

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ВДОСКОНАЛЕННЯ ЦИФРОВОГО ПРИСТРОЮ ПРИДУШЕННЯ ПОМИЛКОВОГО ЗАПИТУ БОКОВИМИ ПЕЛЮСТКАМИ АНТЕНИ СИСТЕМ КЕРУВАННЯ ПОВІТРЯНИМ РУХОМ

В даній статті розглядається розширення можливостей цифрових пристроїв трьохімпульсного придушення запиту літакових відповідачів боковими пелюстками в плані збільшення точності виміру азимута польоту повітряних суден. В існуючих пристроях відповідь літакових відповідачів здійснюється в момент граничного перетину повітряним судном частотної діаграми направленості антени. Діаграма направленості радіолокаційних систем головної пелюстки має кут 2о-4о в горизонтальній площині в залежності від типу радіолокаційної системи і період запиту наземними радіолокаційними станціями складає 500 Гц, а також швидкість обертання антени складає 10 об/хв, а відстань між імпульсами Р1 і Р3 складає 14 мкс. Час знаходження повітряного судна в межах діаграми направленості основної пелюстки буде здійснено запит 17 разів і стільки ж відповідей, що в свою чергу приводить до неоднозначності фіксації визначення повітряного судна по азимуту, особливо на дальніх відстанях. Здійснення відповіді літаковим відповідачем при запиту буде відповідати при наближенні до середини діаграми направленості антени головної пелюстки, де найвища потужність випромінюваного сигналу, що значно зменшить похибку визначення повітряного судна по азимуту.

Ключові слова: *радіолокаційна система, керування повітряним рухом, літаковий відповідач, повітряне судно, аналого-цифровий перетворювач, трьохімпульсне придушення, режим «запит-відповідь».*

Introduction

Known devices for three-pulse suppression of erroneous request by side lobes of antennas of air traffic control systems built on analog elements (resistors, capacitors, bipolar transistors) [1, 2] give a fairly high probability of erroneous determination of azimuth of flight range defendants placed on board the aircraft in the "request-response" mode (active radar) [3-5]. Incorrect determination of the flight amplitude of the aircraft is possible when receiving a request by the lateral petals of the radar antenna, emitting a "response" signal by relatively simple analog devices of three-pulse suppression of the request by the lateral petals, they have a significant (-60°Ñ – +60°Ñ).

In order to reduce the probability of response of aircraft responders to the request by side lobes was developed digital device suppression of the request using small high-speed analog-to-digital converters [6, 7] which increased by 30% range at a given level of false response.

This article considers the expansion of the capabilities of digital devices of three-pulse suppression of the request of aircraft responders with side petals in terms of increasing the accuracy of azimuth measurement of the aircraft [8]. The essence is that in existing devices the response of the aircraft transponder is carried out at the time of the boundary crossing of the aircraft frequency diagram of the antenna.

Given that the radiation pattern of the radar system of the main petal has an angle of 2^o-4^o in the horizontal plane depending on the type of radar system and the request period of terrestrial radar stations is 500 Hz, and the antenna rotation speed is 10 rpm [6], and the distance between pulses P_1 and P_3 is 14 μs [7], then due to simple calculations it can be determined that during the stay of the aircraft within the directional pattern of the main petal will be requested 17 times and the same number of responses, which in turn leads to ambiguity fixing the definition aircraft in azimuth, especially over long distances [9-12].

The goal is to respond to the aircraft responder when asked when approaching the middle of the directional pattern of the antenna of the main lobe, where the highest power of the emitted signal, which will significantly reduce the error of determining the aircraft by azimuth.

Related Works

Device for suppressing erroneous request of aircraft responders of the air traffic control system includes an input bus which is connected to the first input of the second analog-to-digital converter and the first input of the synchronizer, outputs 1, 2, 3 are connected according to inputs 2 "Start" of the first, second and third digital converters, the output of the second analog-to-digital converter is connected to the first inputs of the first and second comparison circuits, the outputs of the first and second comparison circuits "YES" are connected to the first and second inputs of the coincidence circuit "AND", the outputs of the first and second to the first and second inputs of the circuit "OR", and its output is connected to inputs 3 of the first, second and third analog-to-digital converters and to the fourth input of the synchronizer Set "0", the output of the driver is connected to the output bus. Additionally, the first and second digital dividers "9 dB", the third matching circuit "AND", the counter first input is connected to the output of the matching circuit "AND", the first input of the third comparison circuit is connected to the output of the first analog-to-digital converter and the first input of the first digital divider "9 dB", the output is connected to the second input of the first comparison circuit, the output of the third analog-to-digital converter is connected to the first input of the second digital divider "9 dB" output is connected to the second input of the second comparison circuit, the second inputs "9 dB" are connected to the output of the circuit "OR", the first inputs of the first and third analog-to-digital converters are connected to the input bus, the output of the third comparison circuit is connected to the second input Set "0" counter and input shaper.

Figure 1 shows a functional diagram of a device for suppressing erroneous requests of aircraft responders of the air traffic control system.

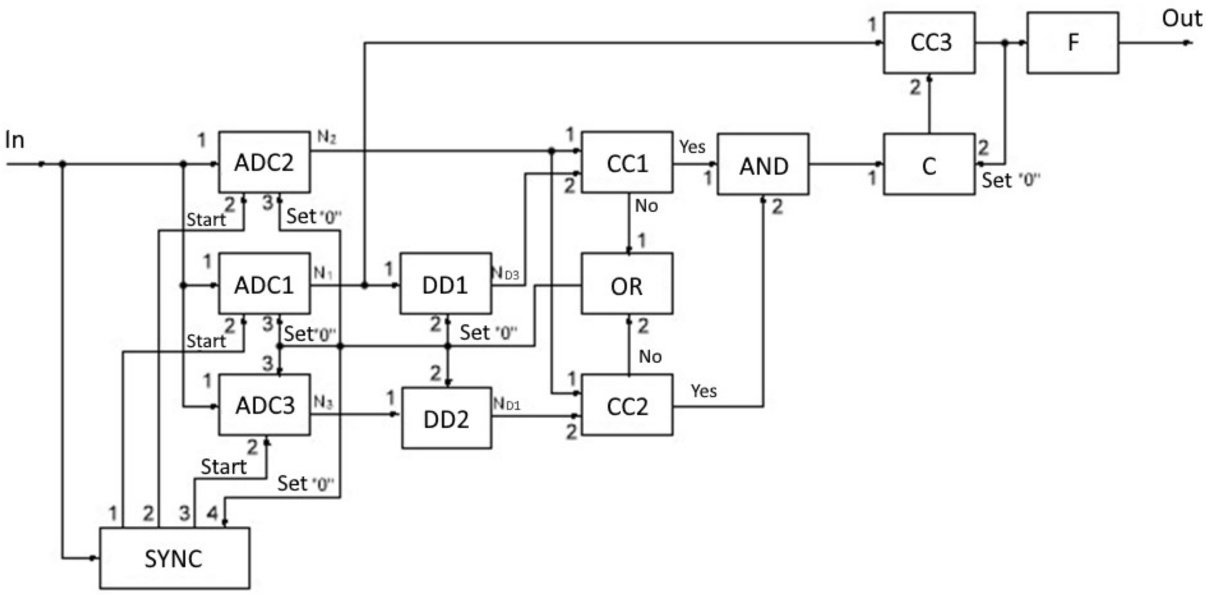

Fig. 1. Functional diagram of the device for suppressing erroneous request of aircraft responders of the air traffic control system: entrance bus - In; the second analog-to-digital converter - ADC2; the first analog-to-digital converter - ADC1; the third analog-to-digital converter - ADC3; synchronizer - SYNC; the first digital divider - DD1; the second digital divider - DD2; the first scheme of comparison - CC1; scheme "OR" - OR; the second comparison scheme - CC2; the scheme of coincidence "AND" - AND; counter - C; the third scheme of comparison - CC3; shaper - F; output bus - Out.

Figure 2 shows the radiation pattern of the antenna of the ground radar station that emits the request signals P_1, P_3, as well as the radiation of the omnidirectional antenna of the suppression signal P_3 which is 9 dB below the values of the request signals P_1, P_2 [13-15]. Figure 3 shows a timing diagram of the request and suppression signals.

The device works as follows. The input bus receives pulses P_1, P_2, P_3 from the amplifier with a logarithmic amplitude characteristic, which are emitted by a ground-based radar station (figure 2). Pulses P_1 and P_3 of the interrogator code are emitted by a directional antenna, and pulse P_2 (suppression pulse) is emitted by a separate omnidirectional antenna (suppression antenna) which is much smaller than P_1 and P_3 and the difference is 9 dB (figure 3).

If the aircraft is aimed at the main petal, then the pulse P_2 is much smaller than P_1 and P_3 by 9 dB, which indicates a normal condition and the aircraft responder emits a response signal.

When receiving a signal from the side petal, the levels of signals P_1 and P_3 compared to P_2, the difference is less than 9 dB, these signals are erroneous and suppressed.

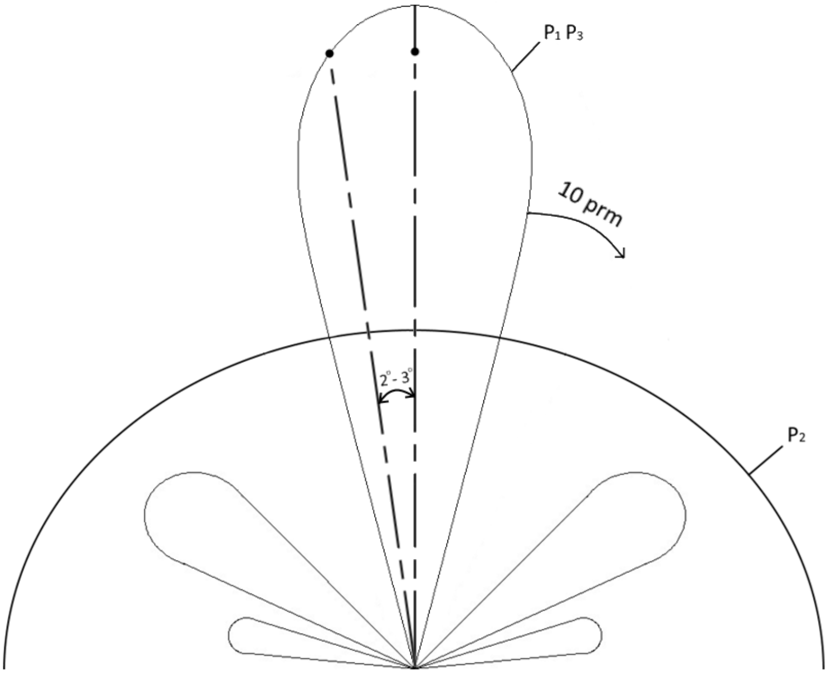

Fig. 2. Directional chart of the ground radar station

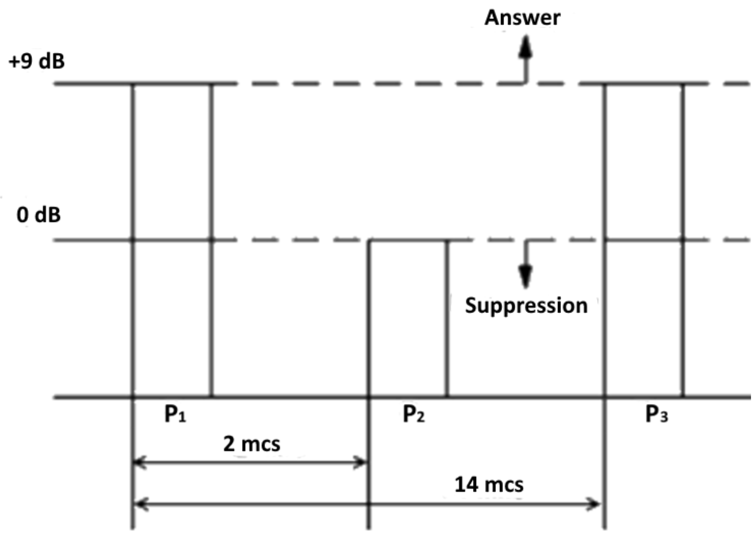

Fig. 3. Time diagram of request and suppression signals

When pulse P_1 appears on input bus 1, it is fed to the first inputs 1 of SYNC and ADC3, while from the first output 1 of SYNC 1 signal "Start" to 2 input ADC3, which fixes the digital value of the amplitude of the input signal P_1 as the number N_1, which is fed to the first digital divider DD1 in which the value of the number N_1 is reduced by 9 dB (N_{D1}).

At the time of occurrence on the bus input 1 of the pulse P_2 coming to the first inputs 1 of the synchronizer SYNC and ADC2 from the output 2 of the synchronizer SYNC receives the signal "Start" to the 2 input ADC2 at the output of which is fixed digital value N_2 amplitude.

At the time of the appearance on the bus input 1 of the pulse P_3, it is fed to the input 1 of the SYNC from the output 3 which receives the signal "Start" to the 2 input ADC4, 1 input which receives the signal P_3. At the output of ADC4 we obtain a digital value of the amplitude of the signal P_3, which is fed to 1 input of the second digital divider DD2 (9 dB) at the output of which we obtain a digital value N_3 of the amplitude of the signal P_3 reduced by 9 dB (N_{D3}).

The outputs of the second ADC2 and the first digital divider DD1 receive digital values N_2 of the amplitude of the suppression signal P_2 and the digital value of the signal P_1 reduced by 9 dB N_{D1} by 1 and 2 inputs of the first comparison circuit CC1 where the condition $N_{D1} \geq N_2$ 1 input of the coincidence circuit "AND", this corresponds to the condition that the amplitude of the pulse P_1 is greater than +9 dB from the pulse suppression P_2.

Similarly, the analysis of the condition of comparison of determining the amplitude of the signal P_2 and signal P_3 using the second comparison circuit CC2.

When the condition $N_{D3} \geq N_2$ from the output "Yes" of the second comparison circuit CC2 receives a signal to the 2 input of the matching circuit "AND".

In the presence of 1 and 2 inputs of the coincidence scheme "AND" signal "Yes" from the output of the coincidence circuit "AND" receives a signal to the 1 input of counter C from the output of which the signal to the 2 input of the third comparison circuit CC3.

In the second request and fulfillment of the condition $N_{D1} \geq N_2$ and $N_{D3} \geq N_2$ is performed in the scheme comparing the value of the pulse amplitude P_1 in the first request $N_{1,0}$ amplitude of the pulse P_1 in the second request $N_{1,I}$ if condition $N_{1,0} \leq N_{1,I}$ is not met, the process the measurement is repeated, and the comparison of the amplitudes of the signals P_1 of each previous request with the valid one takes place as long as the condition $N_{1(n-1)} \leq N_{1(n)}$.

This condition is possible when the center of the pattern of the request antenna with the main petal will be directed to the aircraft. In this case, the comparison circuit outputs a signal to the driver which issues a request signal on the output bus to the aircraft transponder to generate a response signal, while the output signal of the driver is fed to the 2nd input of counter C to set it to "zero" position.

If the condition $N_{D1} \geq N_2$ or $N_{Dn} \geq N_3$ is not met, the first or second comparison circuit sends a signal "No" to 1 or 2 input of the circuit "OR", which indicates an erroneous request on the side lobes of the antenna and the device stops determining the request signal. In this case, the output signal of the circuit "OR" Set "0" is fed to 2 inputs ADC2,3,4 digital splitters DD1,2 input synchronizer SYNC, the device accepts the initial state.

Conclusions

The use of digital three-pulse method to suppress the erroneous request by the side lobes of the antenna in aircraft transponders of air traffic control systems will significantly improve the tactical and technical characteristics of the radar system: increase the accuracy of determining the position of the aircraft by the controller; increasing the stability of the suppression threshold through the use of digital signal processing methods, especially when exposed to temperature devices of aircraft transponders, which significantly increases the efficiency of air traffic control systems.

In the next work it is planned to carry out computer simulation using the MATLAB Simulink software environment, which will allow to investigate the exact characteristics of digital three-pulse suppression with changing their amplitude from changing the position of the radar antenna in real time.

References

1. N.I. Gigan, A. K. Yanovitskiy, N. A. Kharkevych. Author's certificate ¹682015. Device for suppressing requests by side lobes of ATC systems. BI, USSR, 1979.
2. V. Hovstein, A. Saegrov, T. Johansen. Experiences with coastal and maritime UAS BLOS operation with phased-array antenna digital payload data link. International Conference on Unmanned Aircraft Systems. 2014. Pp. 261-266.
3. F. Yanovsky. Radar systems of aircraft: textbook. 2012. 688 p.
4. G. Jiang, Y. Fan, H. Yuan. Assessing the Capacity of Air Traffic Control Secondary Surveillance Radar System. 2019 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference. 2019.
5. H. Wang, J. Johnson, C. Baker, L. Ye, C. Zhang. On Spectrum Sharing between Communications and Air Traffic Control Radar Systems. IEEE Radar Conference. 2015. Pp. 1545-1550.
6. V. Lyubchyk, O. Yanovitsky, O. Yanovitsky. Patent of Ukraine for the utility model ¹135866 "Device for damping the request by the side lobes of the antenna of air traffic control systems" from 25.07.2019. Khmelnytsky National University.
7. V. Lyubchik, Î. Yanovitsky, O. Yanovytsky. Development and research of digital method of suppression of request signal by lateral petals of radar air traffic control systems. Bulletin of KhNU. 2019. Vol. 4. Pp. 147-153.
8. O. Yanovitsky, V. Lyubchik, O. Yanovitsky. Patent of Ukraine for utility model ¹145085 "Device for suppressing erroneous request by the side lobes of the antenna of air traffic control systems" from 26.11.2020. Khmelnytsky National University.
9. A. Bamburkin, I. Kudryasov, G. Oliferenko. Radiotechnical means of flight support and communication organization in civil aviation. Transport. 2009.
10. T. Chen, Y. Ding, R. Pang, C. Gong, D. Xu, B. Chen, H. Zhang. Code Acquisition of a DS-CDMA Receiver with Antenna Arrays And Blind Adaptation for Air Traffic Control. IEEE-AIAA Digital Avionics Systems Conference. 2016.
11. T. Micskei, L. Dudas, R. Seller, J. Orban. Implementation of a Radar Tester for Air Traffic Control Applications. IEEE Mediterranean Electrotechnical Conference-MELECON. 2010. Pp. 274-279.
12. V. Verba, A. Bogachev, V. Merkulov. Multicriteria Collision Risk Ranking of Aircraft by Data from an Onboard Radar Station. JOURNAL OF COMMUNICATIONS TECHNOLOGY AND ELECTRONICS. 2021. Vol. 66. Issue 12. Pp. 1354-1362.
13. ÑÎ-69 Technical description 1234183 ÒÎ 1974. Part II. Description of the blocks and devices that are part of the defendant, a description of the nodes. Pp. 125-132.
14. B. Gumusel, C. Camci. Aerodynamic drag characteristics and shape design of a radar antenna used for airport ground traffic control. PROGRESS IN COMPUTATIONAL FLUID DYNAMICS. 2010. Vol. 10. Issue 1. Pp. 32-39.
15. G. Gottardi, L. Turrina, N. Anselmi, G. Oliveri, P. Rocca. Sparse Conformal Array Design for Multiple Patterns Generation through Multi-task Bayesian Compressive Sensing. IEEE Antennas and Propagation Society International Symposium. 2017. Pp. 429-430.

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