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 2°-4° 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 direction of the aircraft in azimuth, especially over long distances. The response of the aircraft on 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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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 defenders 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 \(-60^\circ \text{N} - +60^\circ \text{N}\).

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°-4° 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 P1 and P3 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 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.

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 $9\,\text{dB}$ 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 $P_2$ of the interrogator code are emitted by a directional antenna, and pulse $P_3$ (suppression pulse) is emitted by a separate omnidirectional antenna (suppression antenna) which is much smaller than $P_1$ and $P_2$ and the difference is $9\,\text{dB}$ (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 $9\,\text{dB}$, 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 $P_2$ compared to $P_2$, the difference is less than $9\,\text{dB}$, these signals are erroneous and suppressed.
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 $N_{D2} \geq N_3$ is performed in the scheme comparing the value of the pulse amplitude $P_i$ in the first request $N_{1,0}$ amplitude of the pulse $P_i$ in the second request $N_{1,1}$ if condition $N_{1,0} \leq N_{1,1}$ is not met, the process the measurement is repeated, and the comparison of the amplitudes of the signals $P_i$ 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 $N_{D3} \geq N_3$ 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


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