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INCREASE OF EFFICIENCY OF ONBOARD RADIO LOCATION SYSTEM OF AIR TRAFFIC CONTROL

The paper considers the method for improvement of efficiency in interrogation signal suppression by sidelobes of air traffic control system, which implies the use of two stage level of suppression. There had been described two suppressing devices their comparative characteristics of stability of suppression level. There had been analyzed one of the main characteristics of aircraft responders, that is suppression the false interrogation signal from sidelobes with the ways for its improvement.

Key words: *sidelobes, two stage level of suppression.*

Introduction

Nowadays the issue of decrease in probability of false interrogation signal of air traffic controller (ATC) transponder becomes of great importance due to increase in density of air traffic, as well as use of air traffic automated control systems.

Modern ATC systems suppress the false demand signal by mutual operation of both, inland and airborne devices [5].

Main part

It is known that antenna directivity diagram of RCU in horizontal plane has sidelobes [1]. Despite they have lower emissive power, the air borne system is able to receive signal from sidelobes. As a result – produce response signal. Such a behavior of the system creates difficulties in identification of operation situation on the screen of RCU.

To suppress the interrogation signal fro sidelobes there has been used the difference in energy levels of radiation from the main and side lobes of inland RCU [5].

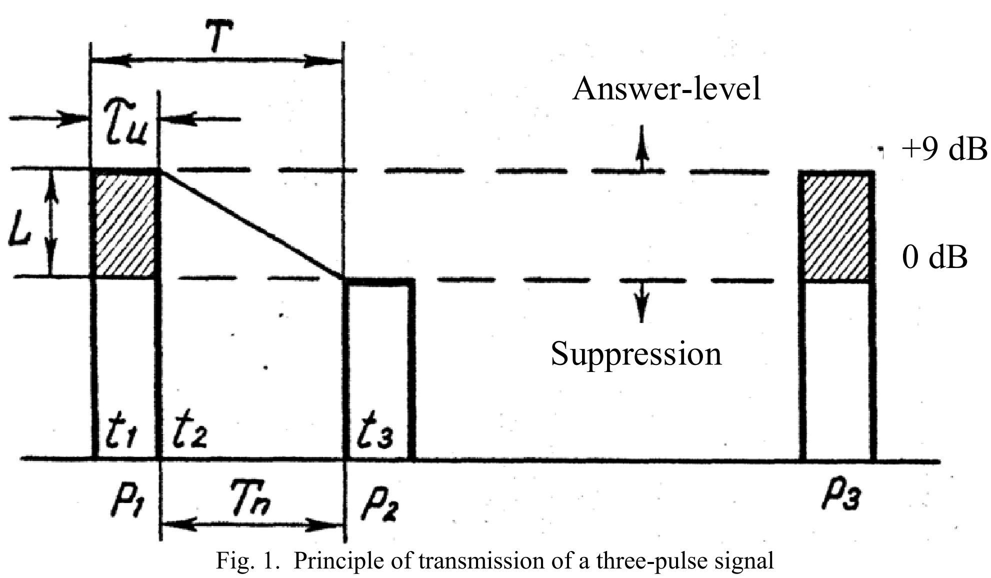

Fig. 1. Principle of transmission of a three-pulse signal

To two pulses of query coded designator P1 and P2 (see fig. 1), radiated by the directive antenna, the third pulse P2 (suppression pulse) radiated by the separate all-around directed antenna (suppression antenna) will be added. Thus there appears the following situation in the space. If flying object is directed to the main lobe, the third pulse P2 is considerably lower, which indicates the normal condition. During the receipt of the signal from the side lobe, the levels of P1 and P3 may be compared to P2 , consequently the signal is false and is subject to ignoring.

The suppression pulse lags behind by 2 + 0,15 mcs of the initial pulse of query coded designator. The airborne device compares amplitudes of code designator pulses P1 and P3 as well as suppression pulses P2. The answer arises only once, the level P1 and P3 exceeds P2 (level of suppression).

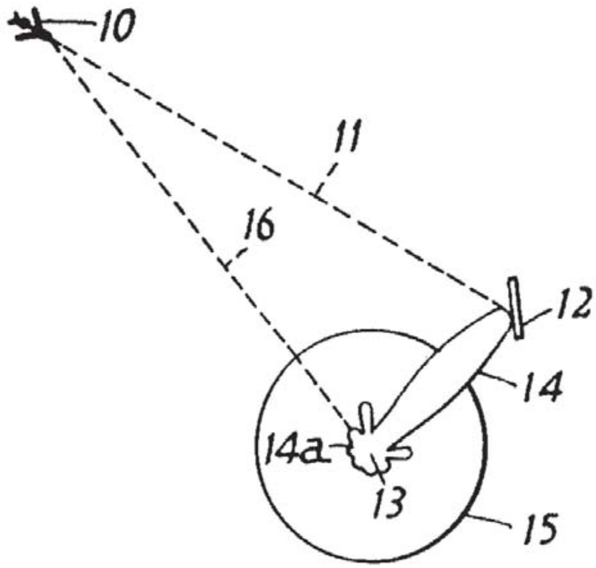

Fig. 2 Principle of interaction with three pulse system under the reflected signal conditions. Designations on the figure correspond with patent [5]: 10 – airplane, 11- reflected trajectory, 12 – reflecting surface, 13 – directed inland station, 14 – directional diagram, 15 – equidirectional diagram of control radiation, 16 – straight trajectory

It should be noted that area of ATC system coverage is divided by energetic level of suppression signal into the area of potential probability of false interrogation signal, that is the area in which false demand signal is possible, and area with absence of false demand signal – area of reliable interrogation signal. Since the energy level of a signal of suppression is selected so that it is higher then the level of signals radiated by side lobes, it is important to execute its exact selection, which is impossible without the analysis of the characteristics of accuracy of a suppressors transponders.

The devices for suppression of modern transponders use the schemes of amplitude comparison on transistors with accumulative capacitance in emitter circuits [0].

In such devices the level of suppression is formed by discharge with an identical current of accumulative capacitance prior to a pulse of suppression.

Fig. 3,a shows the scheme of amplitude comparison.

The instability of a level of suppression consists of a vacillation of a discharge current of accumulative capacitance δ_c and change of time frames of input signals δ_t .

The thermostabilisation of a discharge current of accumulative capacitance allows to restrict the first component – instability of a suppression level within the limits of some percents.

The main error of onboard suppressors is a dependence of suppression level on time intervals of input signals within the limits of 2±0,15 mcs and the duration of "PI" impulse in an interval 0,9±0,1 mcs (requirement of State Standard [**Ошибка! Источник ссылки не найден.**, **Ошибка! Источник ссылки не найден.**]), i.e. common change of time frames in range $(0{,}15+0{,}1)\cdot 2=0{,}5$ mcs.

Considering the requirements of State Standard to parameters of suppression systems of ATC, as well as the linearity of the logarithmic characteristic of the accepting channel of a transponder, instability of a suppression level ΔL equals:

$$\Delta L = L_n \cdot K \quad (1)$$

where K – relative factor of detuning of time intervals:

$$K = \frac{t_2 - t_1}{t_2};$$

t_1, t_2 – limiting values of time intervals: $t_1 = 0{,}95$, $t_2 = 1{,}45$ (see fig. 3); L_n – the set level of suppression 9 dB, so $\Delta L = 3{,}1$ DB.

So, the level of suppression signal, considering the destabilizing factors, has to be increased by 3,1 decibel, without the consideration of nonlinear character of suppression.

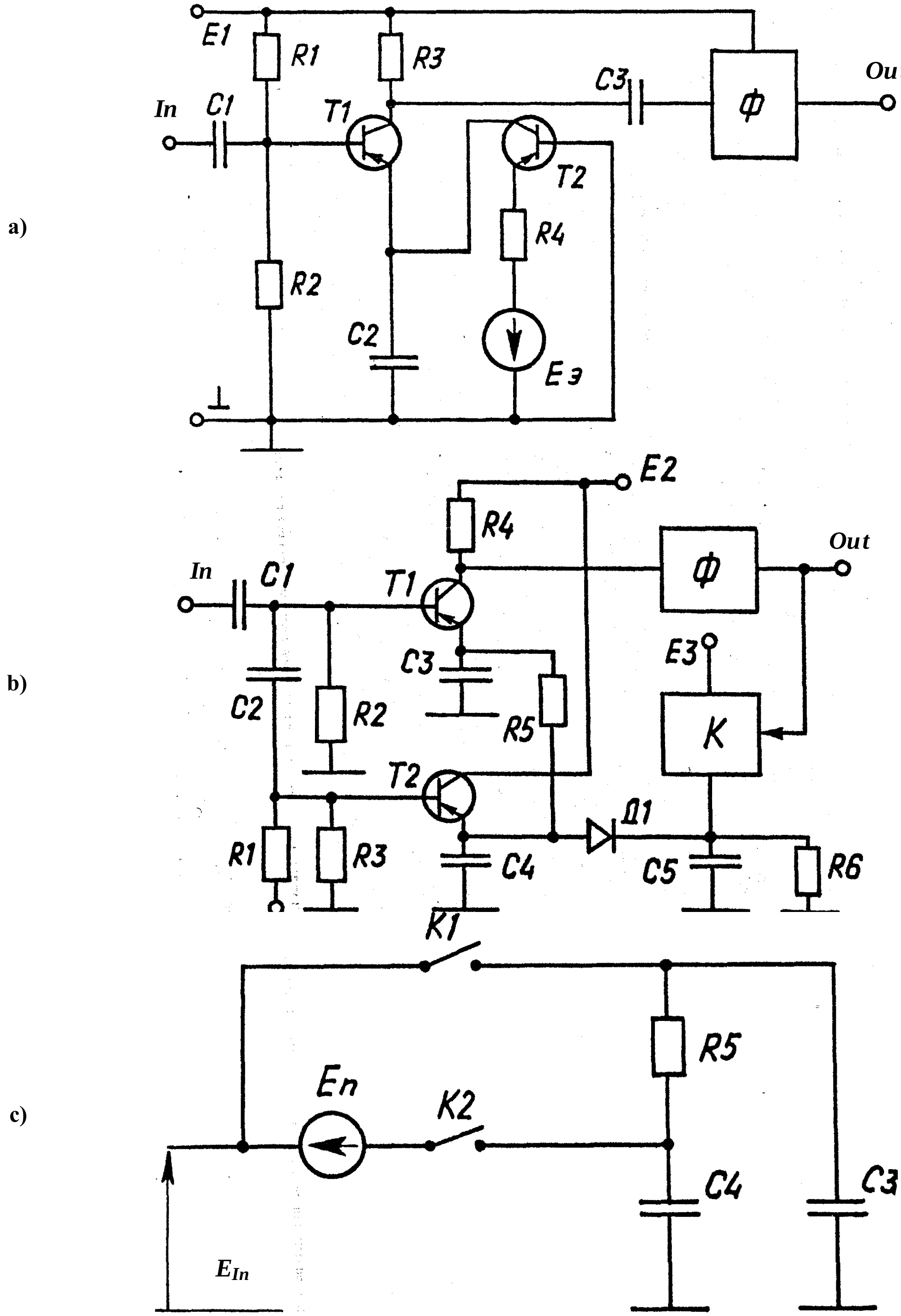

Fig. 3. Input circuits of suppressor's schemes of modern transponders:
a) Scheme of amplitude comparison; b) Scheme of three-pulse suppression;
c) Functional diagram of three-pulse suppression

It is known from the main equation of radiolocation [0], that during the active answer (signal from a transponder of radiolocation) the distance D to a transponder is determined by an expression:

$$D = \sqrt{\frac{P_{out} \cdot G_{out} \cdot G_{in} \cdot \lambda^2}{(4\pi)^2 \cdot P_{in}}}$$

Where P_{out} – capacity of inquiry transmitter; G_{out}, G_{in} – directivity indexes of antennas of the repeater and receiver of a channel of the inquiry; P_{in} – capacity in the receiving point, corresponding to the sensitivity of a transponder; λ – wavelength.

Then the relative change of a zone of efficient inquiry equals:

$$\frac{D_м}{D_н} = \frac{\sqrt{\dfrac{P_{out.м} \cdot G_{out} \cdot G_{in} \cdot \lambda^2}{(4\pi)^2 \cdot P_{in}}}}{\sqrt{\dfrac{P_{out.н} \cdot G_{out} \cdot G_{in} \cdot \lambda^2}{(4\pi)^2 \cdot P_{in}}}} = \frac{\sqrt{P_{out.м}}}{\sqrt{P_{out.н}}} \qquad (2)$$

where $D_н$, $P_{out.н}$ – rated value of inquiry transmitter capacity and receiving range of a signal of suppression; $D_м$, $P_{out.м}$ – maximum rating of a transmitted power inquiry and receiving range of a signal of suppression (in view of increase in a level of suppression of a transponder);

One of directions on increase in suppression efficiency of the inquiry by sidelobes of ATC systems is the application of two-stage level of suppression. The electrical circuit, explaining the principle of operation of the device of the three-pulse suppression using two-stage level, is shown in fig. 3б., 3в – conventional functioning scheme which explains the operational principles.

The circuit contains an input circuit with a divisor on R1, R3; element of comparison on VT1; an analogue memory on VT2, C4; a pulse shaper Ф; a key F with accumulative capacity C5 and discharge circuit VD1.

The scheme operates as follows. With incoming of pulse P1 the capacity C3 of element of comparison charges to its peak value, the capacity C5 of an analogue memory – to a level of suppression. The accumulative capacity C5 charges to voltage of the source E3 through a key K, which is closed during the operation of the output impulse of the former F.

After passing pulse P1 of interrogation code, the voltage on capacity C3 decreases to a level of suppression on capacity C5 and remains invariable to incoming a impulse of suppression P2.

After amplitude comparison of suppression impulse P2 the voltage on accumulative capacity C5 is reduced to a level of suppression, the diode VD1 opens and the voltage on capacity C3, C4, C5 is reduced exponentially to zero point.

Thus, the application of the two-stage suppression circuit allows to eliminate the dependence of level of suppression on measurement of time intervals of input signals.

Apparently, proceeding from conditions of expression (1) we obtain:

$$10\lg\frac{P_{out.м}}{P_{out.н}} = \Delta L = 3{,}1 \text{ dB, and } P_{out.м} = 2{,}04 \cdot P_{out.н} \qquad (3)$$

Consequently, an increase in a zone of the clear inquiry due to elimination of instability of a transponder suppression level and changing the time intervals of an inquiry signal taking into account the expressions (2) and (3) make up:

$$\Delta D = D_м - D_н = D_н \cdot \frac{\sqrt{P_{out.м}} - \sqrt{P_{out.н}}}{\sqrt{P_{out.н}}} = 0{,}43 \cdot D_н .$$

The improvement of a zone in a theoretical case of a horizontal level of signal suppression from the sidelobes will make up 43% from the nominal value. Since the analogue devices have considerable deviations of parameters during the influence of temperature, which results in significant deviations in operation [4] and makes up to 1,5 dB on voltage, which results in improvement of a zone for no more than 20 % of the nominal value.

The peculiarity of the three-impulse system is a difference of levels of signals P1 and P2 for 9 dB. According to this requirement, it is necessary to compare the received signals in decibel system.

Fig. 4. shows the classic scheme of a log-amplifier on the basis of a non-linear element with the logarithmic characteristic – semiconductor diode.

The simplicity of the scheme does not allow to achieve relevant parameter – recurrence of a design, which in turn requires more precise tuning and constant control during manufacturing and operation of the device. The accuracy of logarithmic conversion also depends on the state of a converting element.

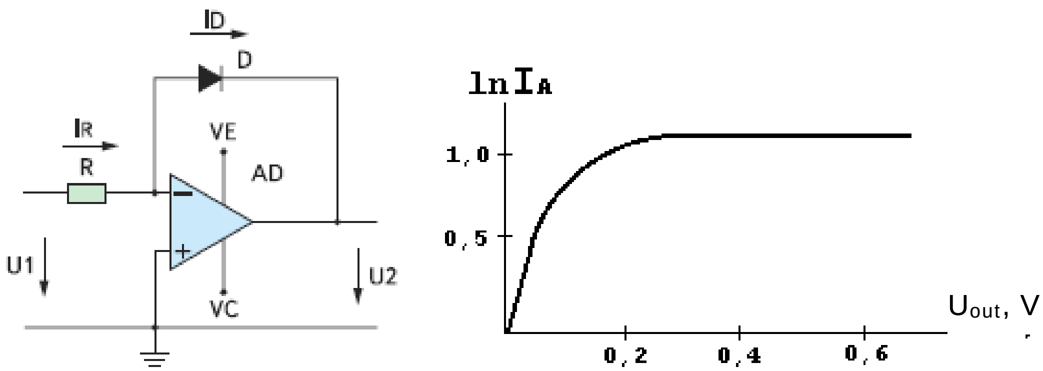

Fig. 4. A log amplifier on the basis of a non-linear element – diode

One of probable ways for solution of such a problem lies in use of modern ADC [7] together with microprocessor processing of the obtained result.

The digital high-velocity element base is capable to work in the range -40... + 60 º Celsius and allows to solve the set task with lower costs in achievement of recurrence of parameters of receiving equipment with simultaneous achievement of high reliability in indispensable range of operation temperatures.

Conclusions

1. Despite the fact that three-pulse system has been designed and used for a long time, it remains one of the actual systems, allowing to solve problem of detecting the false radar inquiries in the on-line mode.

2. Using the log-amplifier allows to simplify the system's operation and to proceed to a problem of measurement of a relative level of change between narrow directed and circular radiation in three-impulse system.

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