DOI: 10.18721/JCSTCS.14305
УДК 621.396

INFLUENCE OF TRANSIENTS IN THE INFORMATION PROCESSING CHANNEL OF THE AIRPORT AUTOMATIC RADIO DIRECTION FINDER ON THE DIRECTION FINDING ACCURACY

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The article is devoted to the study of the transients influence in the information processing channel of an aerodrome automatic direction finder (ADF) on the accuracy of direction finding. This task is of great importance, since improving the accuracy of navigation equipment allows setting the separation standards higher and improving the aircraft flights safety. When the phase difference between the signals on the neighboring vibrators of the antenna system (AS) is equal to 180°, a signal loss is observed in the low-frequency filter of the ADF due to the amplitudes equality of the component signals from the k^{th} and $k + 1^{th}$ vibrators, that leads to failures (the appearance of abnormal errors) in the ADF operation. When using the radio direction finders operation to find speech-modulated signals (an amplitude-modulated signal), certain gaps emerge in the direction-finding signal due to the operation of automatic gain control in the ADF receiver, which leads to the accuracy deterioration of the direction-finding. We propose methods of reducing the transients influence on the accuracy of radio direction finding. To eliminate the influence of transients caused by the operation of the Automatic Gain Control, taking into account the fact that the processing of direction finding information in the ADF is carried out on a channel microprocessor, it is necessary to assign weight coefficients to the directions calculated for eight switching cycles of the AS elements and calculate the value of the weighted average finding.

Keywords: radio direction finder, antenna system, transients, finding accuracy, radio direction finder failures.

Citation: Aslanov G.K., Aslanov T.G., Kazibekov R.B., Musaibov R.R. Influence of transients in the information processing channel of the airport automatic radio direction finder on the direction finding accuracy. Computing, Telecommunications and Control, 2021, Vol. 14, No. 3, Pp. 56–63. DOI: 10.18721/JCST-CS.14305

ВЛИЯНИЕ ПЕРЕХОДНЫХ ПРОЦЕССОВ В КАНАЛЕ ОБРАБОТКИ ИНФОРМАЦИИ АЭРОДРОМНОГО АВТОМАТИЧЕСКОГО РАДИОПЕЛЕНГАТОРА НА ТОЧНОСТЬ ПЕЛЕНГОВАНИЯ

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Статья посвящена исследованию влияния переходных процессов в канале обработки информации аэродромного автоматического радиопеленгатора (АРП) на точность пеленгования. Эта задача большой важности, так как повышение точности навигационного оборудования позволяет ужесточить нормы эшелонирования и повысить безопасность полетов воздушных судов. При разности фаз между сигналами на соседних вибраторах АС, равной 180°, в низкочастотном фильтре АРП наблюдается пропадание сигнала из-за равенства амплитуд составляющих сигналов с пеленгования. Для устранения влияния переходных процессов, вызываемых работой АРУ (Автоматическая регулировка усиления), с учетом того, что обработка пеленгационной информации в АРП осуществляется на канальном микропроцессоре, необходимо к вычисленным за восемь циклов коммутации элементов АС пеленгам присвоить весовые коэффициенты и вычислить значение средневзвешенного пеленга.

Ключевые слова: радиопеленгатор, антенная система, переходные процессы, точность пеленгования, сбои в работе радиопеленгатора.

Ссылка при цитировании: Aslanov G.K., Aslanov T.G., Kazibekov R.B., Musaibov R.R. Influence of transients in the information processing channel of the airport automatic radio direction finder on the direction finding accuracy // Computing, Telecommunications and Control. 2021. Vol. 14. No. 3. Pp. 56–63. DOI: 10.18721/JCSTCS.14305

Introduction

Automatic direction finders (ADF) are widely used in navigation, radio monitoring, monitoring of rare animals movement, in seismic hazard assessment, etc., [1–6].

The growth of interregional and international traffic leads to the increase in the intensity of air traffic, which requires further improvement of radio equipment accuracy for flight support, in particular airfield automatic direction finders.

In this regard, priority attention is given to the issues of ensuring the accuracy characteristics of the ADF [7–14].

One of the reasons that reduce the ADF direction finding accuracy is the presence of transients in the information processing channel of the radio direction finder.

In the ADF, the direction-finding signal, in order to transfer to the phase relations stable frequency that occur in the antenna system (AS) in the radio direction finders (ADF-75, ADF-80K), is modulated at a frequency of 4200 Hz, and in the radio direction finders ADF AS (“Platan”, DF-2000, “Pikhta”) at a frequency of 5550 Hz [1].

Subsequently the signal is demodulated and filtered. The values of the phase differences between the filtered and reference signals determine the direction finding on the radiation source [16].

The narrowing of the filter bandwidth allows reducing the interference influence on the direction finding accuracy which simultaneously leads to the increase in the transients duration caused by switching the AS vibrators.

Fig. 1 explains the switching effect of the ADF AS vibrators on the accuracy of the direction finding. Fig. 1*a* shows the U_{in} signals induced on the k and $k+1$ ADF AS vibrators when they are switched sequentially (the moment of switching the vibrators on the time axis is marked with a dot). Fig. 1*b* shows the signal induced on the k vibrator after it passes through the bandpass filter. Fig. 1*c* shows the signal at the bandpass filter output when the $k+1$ vibrator is turned on.

After switching the vibrator, the filter output has a total signal U_{out} (Fig. 1*d*), equal to:

$$U_{out} = U_k + U_{k+1}. \tag{1}$$

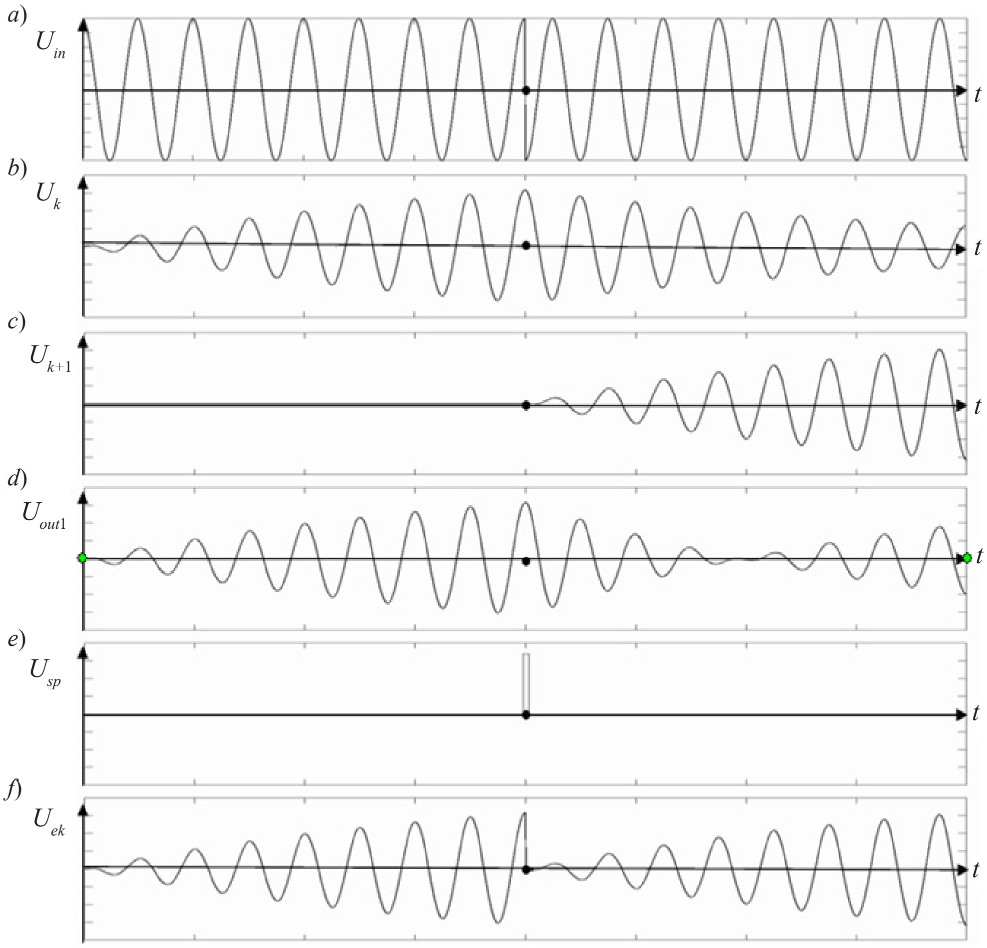

Fig. 1. The effect of radio direction finder vibrators switching on its accuracy

The Fig. 1*f* shows the case when the phase difference between the signals from the k and $k + 1$ vibrators is 180°, and if the signals are equal their sum is zero.

The phase difference $\varphi_{k+1} - \varphi_k$ is determined by the expression:

$$\varphi_{k+1} - \varphi_k = \frac{2\pi R}{\lambda}\cos\beta\left[\cos\left(\theta - \frac{2\pi k}{N}\right) - \cos\left(\theta - \frac{2\pi(k-1)}{N}\right)\right], \; k = 1, ..., N, \quad (2)$$

where R – AS radius; β – angle of the position on the radiation source relative to the ADF AS; λ – direction-finding signal wavelength; θ – azimuth (direction finding) on the radiation source; N – AS elements number.

In accordance with expression (2), for example, between 4 and 5 vibrators at a frequency of 300 MHz, a phase difference of 180° occurs at a direction finding of 0° and a position angle of 48°.

In addition, due to the vibrators switching the phase of the direction-finding signal is distorted, since its initial phase at the filter output will always be zero regardless of the input signal initial phase, which is confirmed by Fig. 1*c*,*d*. The use of such phases in direction finding calculation leads to significant errors and even to failures.

The accuracy of the bearing is also affected by the transients caused by the automatic gain control (AGC) operation of the ADF receiver.

The AGC leads to the gaps in the direction-finding high-frequency signal.

Fig. 2 shows the output signal waveform of radio station "Baklan" receiving channel, which explains the effect of the AGC on the transition process [15].

The figure shows that at the moment of the signal appearance, amplitude jumps appear at the input of the receiving device, and therefore the signal phases, which is explained by the sharp change in the AGC gain.

Reducing the influence of transients in the ADF information processing channel on the direction finding accuracy

Failures caused by switching of the AS vibrators can be eliminated by discharging the bandpass filter reactive elements at the moment of the ADF antenna system vibrators switching [17].

Fig. 3 shows the operating principle of such a filter.

Here, when switching the vibrators, a short pulse of U_{sp} is generated from the switching signal (Fig. 1*e*), which is fed to the electronic key. When a short pulse is received the electronic key discharges the capacitors.

Thanks to this, the filter is damped and the parasitic component of the signal from the previous vibrator quickly fades out.

After damping, the output signal of the U_{ek} filter has no interference component from the previous vibrator signal.

During the switching time of one AS vibrator pass through the filter eight periods allocated by the filter of the low-frequency signal, the phase of which is restored by the end of the vibrator switching time, so in the processing of direction finding information, it is necessary to use the averaged values of the phase differences of the seventh and eighth period signals [18].

In the ADF in operation since 2000, the direction finding information is processed in a channel microcomputer.

This allows reducing the direction finding error caused by the AGC operation by pre-processing the array of phase differences of the ARP AS vibrators signals.

It is experimentally established (Fig. 2) that the duration of the transient process in the receiving device can reach 0.2–0.3 sec. with the required ADF speed of 0.5 sec.

During operation, ADF switches 8 cycles of the antenna system elements in 0.5 sec., i.e., the direction finding on the radio source is calculated eight times. Due to the AGC operation at the starting moment of

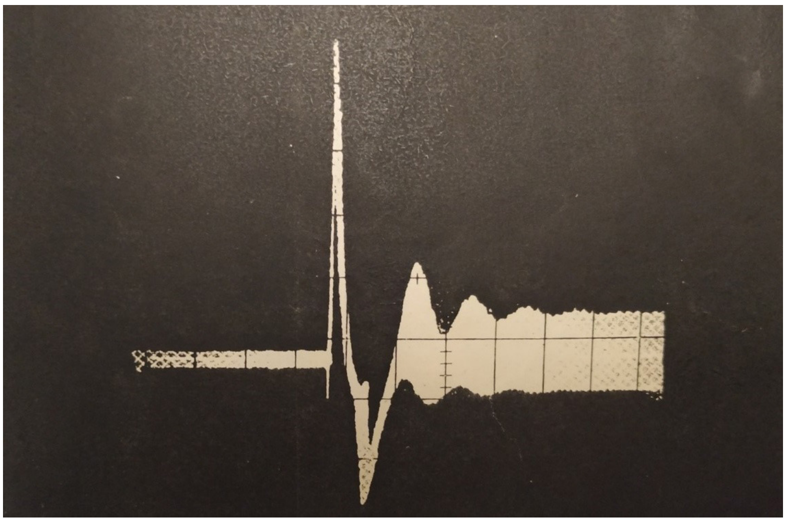

Fig. 2. Waveform of the output signal of radio station "Baklan" receiving channel

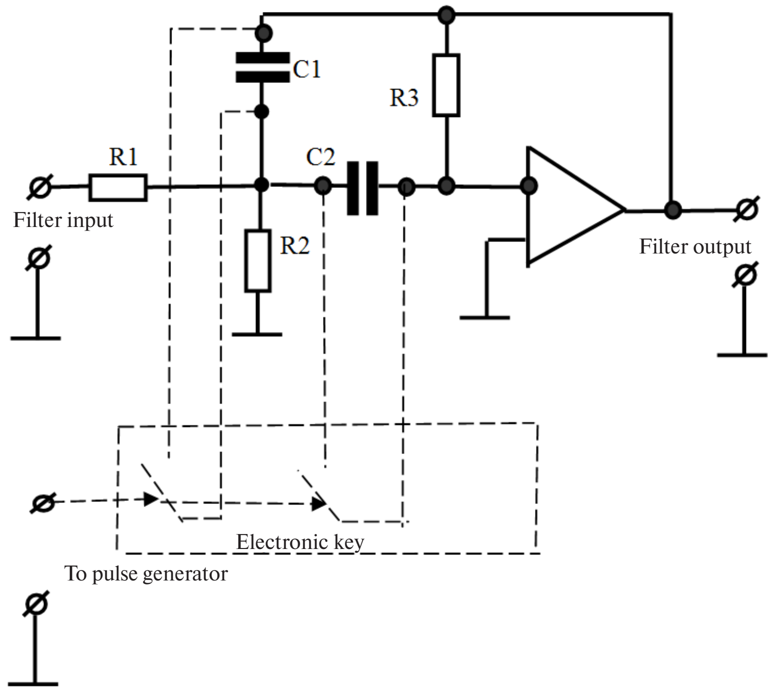

Fig. 3. Electronic key filter

the direction-finding onboard radio station operation, the signals phases from the AS vibrators have large jumps, hence the direction findings are calculated with large errors [19]. Therefore, it is necessary to assign weight coefficients to the calculated direction findings and calculate the value of the weighted average direction finding. At the same time the first direction findings should have minimum coefficients and the last ones should have maximum coefficients.

Conclusion

Transients that occur in the automatic radio direction finder when the direction-finding signal passes through the information processing path are one of the reasons for the occurrence of abnormal errors in the radio direction finder operation.

ADF failures caused by AS vibrators switching can be eliminated by discharging the reactive elements of the bandpass filter at the moments of ARP antenna system vibrators switching.

Processing of direction finding information in the ADF is carried out on a channel microprocessor which allows using software tools that significantly reduce errors caused by transients in the radio direction finder.

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Received 25.04.2021.

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Статья поступила в редакцию 25.04.2021.

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