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L.V. Beylis[1], V.F. Zjukin[2], S.V. Kukobko[2]

[1] *Command of Air Force of Ukraine, Vinnytsia*
[2] *Ivan Kozhedub Kharkiv National Air Force University, Kharkiv*

RADAR RECONNAISSANCE CAPABILITIES ESTIMATION OF LOW-SIZED LOW-ALTITUDE AIRCRAFTS BY MEANS OF RADIOTECHNICAL TROOPS SURVEILLANCE RADARS

Estimation procedure of informational capabilities of surveillance radars in reconnaissance of low-contrast targets is observed. Variant of procedure use for mass surveillance radars П-37 type is considered. Quality ratings, obtained as a result of calculations, are analyzed.

Keywords: *unmanned air vehicle, radar detection zone, surveillance radar, low-contrast target.*

Introduction

Wide use of reconnaissance unmanned air vehicles (UAV), which provides all-weather enemy observation and fire control, is the one of foreground orientation during modern local wars. For tactical aerial reconnaissance mainly use easy-to-work low-sized (wing span about a few meters) of close- (until 10 km) and medium-range (until 100 km) unmanned air vehicles. Radar cross-section of such air targets is about σ~0,001…0,1 m^2, takeoff weight may be about several kilograms. Flight speeds usually are not exceeding 100…200 km/h (~30…60 m/s); combat altitudes h – until 1…3 km. UAV flight duration – is until 1…3 hours and more. It is possible to use reconnaissance UAV with hovering flight function. UAV with such characteristics (low-contrast targets) are the most complex for radio detection. Let's consider estimation procedures of the ability to detect suchlike UAV by S-band surveillance radars of the radiotechnical troops (П-35, П-37Р, 1РЛ139 types). These radars have: narrow beamwidth of radiation pattern at azimuthal plane (β_a~1°), several review space modes (the main antenna azimuth rotation speed is n=6 rpm), several low parcels probing pulse frequencies F with wobble within the bounds ±10%. Will round F to the 400 Hz (for definiteness), that providing unambiguous measurement of distance to targets within the limits of 0…375 km. Pulse packet of target echo amount M≈10. Radar intelligence capabilities of UAV can be characterized by the shape of the vertical section of the radar detection zone, to begin with - in the absence of clutter.

Basic calculation relations

1. Vertical section of П-37 type radar detection zone at the reconnaissance of UAV

Detection zone of radar П-37 is formed by combining zones of five independent channels, which antenna patterns rays in elevation plane are covered the range of 0.5 ~ 28°.

Ordinarily, the interference distortions have an influence only on low-altitude beam of radiation pattern at elevation plane. Therefore, in accordance with well-known radar equations, will suppose, that for upper beams changing of radar cross-section (RCS) at m times reduce for changing of detection range at m$^{1/4}$ times (at given elevation direction). Calculation of the lower edge of the beam pattern (within the limits of the lower beam) is an exception, when, with approach of elevation angle ε to zero, indicated functional dependence smoothly converge to m$^{1/8}$ [1].

Detection zone of radar П-37, which calibrated by fighter with RCS σ=1 m^2 (at conditional probability of proper detection D=0,5 and false alarm F=10^{-6}), is characterized by maximum detection range 180 km and unfailing ceiling 18 km. The shape of vertical section zone, which is evaluated for detection of UAV with RCS σ=1 m^2, is shown at fig. 1 (solid thick curve).

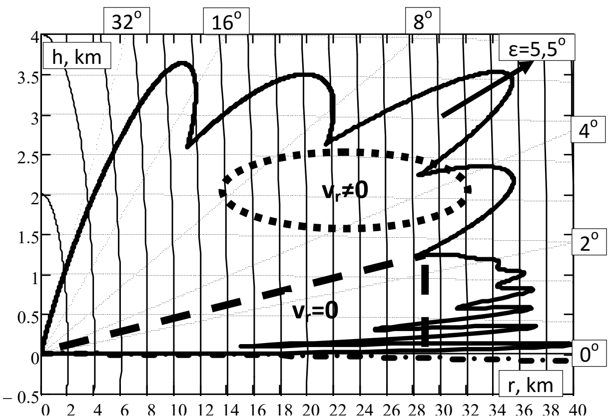

Fig. 1. Vertical section view of UAV detection zone

This zone have such parameters: maximum detection range (or distance for constant range edge, which approximately equal 30 km), unfailing ceiling (is equal 2,7 km), cone of silence radius (r_{cs}~(2…2,5)h). When target surveillance at altitudes of h<500 m significant interference distortion of the lower antenna beam radiation pattern reduce to reduction of detection range up to 15…25 km. Calculated detection zone include constant range and constant altitude (cosecant) sections, boundary of these sections passes through line $\varepsilon=5{,}5^o$, which marked at fig. 1 by arrow.

Information about spatial distribution of signal energy reflected by targets and clutters is necessary for estimation of the radar noise immunity level.

Energy noise-to-signal ratio within of the calculated detection zone can be estimated in the following way.

Conditional probabilities D and F, if at the interperiod processing unit exit (or at threshold device input) processed signals have Rayleigh distribution, are related by ratio [1]:

$$D = F^{\frac{1}{1+q^2}},$$

where q^2 is useful signal energy (of all M pulses in packet accumulated energy) to noise energy ratio.

Therefore, if for target which is located at boundary of detection zone D=0,5 and F=10^{-6}, threshold noise-to-signal ratio is equal to $q^2 = 13$ dB. When oncoming target (which has zero parameter), is at constant range section (target angle of elevation $\varepsilon<5{,}5^o$), q^2 value increment is proportionate to ratio $(r_1/r_2)^4$. For example, if $r_2 = 0{,}5\, r_1$ increase is approximately 12 dB. Within the limits of cosecant sections (before target entry to cone of silence zone) q^2 value is constant.

So, for UAV, which enter into detection zone (r=30 km) at cruising altitude h=3 km (UAV at once is in cosecant section) value $q^2 \approx 13$ dB will not change for range $r = 8$ km (cone of silence radius at altitude 3 km). That is, along the whole observation interval the detection probability of such blip is not exceed D=0,5.

For UAV, which approach at altitude h=2 km q^2 value will increase from 13 dB to 20 dB in the point r=20 km (blip detection probability D=0,87), whereupon, to range r=4 km, q^2 value will not change.

For h=1 km q^2 value will increase from 13 dB to 32 dB in the point r=10 km (at that D=0,99), whereupon, to range r=2 km, q^2 value will not change.

Relative power of signal strength at the input of interperiod processing unit P_s (before pulse packet accumulation), which is necessary for subsequent calculation, can be related with q^2 value by ratio: $P_s = q^2/M$. For example, if number of pulses in packet M=10, then value Ps is smaller than value q2 at 10 dB, therefore initial signal strength Ps will be changed from 3 dB at the boundary to 22 dB in the center of detection zone.

If the clutter is present, its level (which also normalized to noise floor) will be characterized at the input of interperiod processing unit by value P_c. Ratio P_c/P_s will be used at the estimation of radar immunity from clutter.

Shown calculation results (for $P_c = 0$) characterize radar potentiality to UAV reconnaissance. Configuration of clutters is necessary to detection zone shape correction when clutters exposed.

2. UAV detection zone characteristics correction taking into account clutters

Regular background returns (mean range rate $v_r \approx 0$, fluctuations bandwidth is small) with relative-signal level $P_c \approx 20\ldots50$ dB can present (for radar П-37) at lower elevation channel within the limits of distances $r < 30\ldots50$ km, and at adjacent elevation channel – at distances to $r \approx 5\ldots15$ km (that is determined by receiving interfering clutter signal at adjacent channel dipped beams). Value $P_c \approx 20$ dB ordinarily is corresponding to clutter zone boundary (let it's determined by range $r \approx 30$ km). Value P_c increase, in contrast to P_s, is proportional to ratio $(r_1/r_2)^3$ [1]. For example, if $r_2 = 0{,}5 r_1$ increase will be near 9 dB. Expected clutter impact zone is situated within the limits of elevation sector 0...2,5^o (it's delineated at Fig. 1. by thick cross-hatching line).

By thick dotted line is shown possible region of rain returns influence: with smaller power ($P_c \approx 10\ldots30$ dB), but with bigger fluctuations bandwidth. Range rate of clouds, which form such reflections, is in the range $|v_r| < 50$ m, and it's commensurable with speed range of UAV.

Detection zone characteristics can be corrected by threshold method: by comparison of ratio clutter/signal P_c/P_s at the input of interperiod processing unit with under clutter visibility factor K_{uv} [1; 2]. Calculation of this factor adds up to determination of such ratio P_c/P_s, which provides signal detection with established quality indexes. Detection region of target is that, where ratio $P_c/P_s < K_{uv}$.

For example, for radar modification П-37Р (with moving-target indication digital system (double over-period subtraction), protection over rain returns influence by polarizing selection at three lower elevation channels), taking into account all conditions referred above, factor $K_{uv} = 15$ dB. Then, at boundary of clatters zone ($r = 30$ km), where values $P_c = 20$ dB and $P_s = 3$ dB, i.e. $P_c/P_s = 17\text{dB} > K_{uv}$, targets are not detected. However, when range r is decreases, ratio clutter/signal is decreases like (P_c/P_s) ($30/r$), therefore at $r < 15$ km ratio $P_c/P_s < K_{uv}$ and detection of targets is possible.

Thus, clutters influence lead to target detection range reduce within the limits of elevation sector 0…2,5° almost 2 times. If clutters level P_c increase on 10 dB, then UAV detection at this sector is impossible. Overall loss of detection zone dimension at the same time can amount to 30%.

Capabilities of target reconnaissance in the rain returns influence area is determined by ratio of relative-signal level of such interference P_i and suppression ratio of rain returns influence by polarizing selection K_p, which for radar П-37 is about 10…11,8 dB. If $K_p \approx P_i$, such clutters practically are not influence for target detection quality.

Polarizing selection is absent at two upper elevation channels, therefore, detection zone ceiling will decrease about 1,7 time, even if few clouds or mist are present ($P_c \sim 10$ dB). Analysis of calculation results shows [3], that when in radar П-37 used frequent start-up mode factor K_{uv} may rise at (3…5) dB, but there is a threat of ranging ambiguity which caused by superposition of clutters from remote zones. For successful multi-layer clutters equalizer (with "multihump" spectrum of fluctuation) it is necessary to optimize radiation modes and signal processing [1; 2].

Calculations results are averaged over according to all available radial velocities of target, when considered threshold method of detection zone characteristic correction is used. However, because of low airspeed of UAV, some part of targets will be lost in blind radial velocity zones. But more dangerous (attacking) targets can be observed at greater distance. More detailed estimations of informational capabilities and propositions for surveillance radars technical improvement can be obtained on basis of statistical analysis methods [1; 3], which proposed to consider in the following articles.

Conclusions

Analysis variant of one type of radiotechnical troops surveillance radar capability to reconnaissance low-contrast targets is considered. Offered method can be extended to another surveillance radars.

Obtained results argue that comparatively small dimensions of detection zone are diminishing by influence of clutters zone (for 30% and more). It is possible to assert that radiotechnical troops surveillance radars (taking into account their high price, inconvenience and low viability) are little avail to reconnaissance of UAV examined type.

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Рецензент: д-р техн. наук, ст. науков. співробітн. Г.С. Залевський, Харківський національний університет Повітряних Сил ім. І. Кожедуба, Харків.

ОЦІНКА МОЖЛИВОСТЕЙ РАДІОЛОКАЦІЙНОЇ РОЗВІДКИ МАЛОРОЗМІРНИХ МАЛОВИСОТНИХ ЛІТАЛЬНИХ АПАРАТІВ ЗА ДОПОМОГОЮ ОГЛЯДОВИХ РЛС РТВ

Л.В. Бейліс, В.Ф. Зюкін, С.В. Кукобко

Обговорюється методика оцінки інформаційних можливостей оглядових радіолокаційних станцій при розвідці малопомітних цілей. Розглядається варіант використання методики стосовно масових оглядових радіолокаційних станцій типу П-37. Аналізуються показники якості, які отримані в результаті проведених розрахунків.

Ключові слова: *безпілотний літальний апарат, зона виявлення радіолокаційної станції, оглядовий радіолокатор, малопомітна ціль.*

ОЦЕНКА ВОЗМОЖНОСТЕЙ РАДИОЛОКАЦИОННОЙ РАЗВЕДКИ МАЛОРАЗМЕРНЫХ МАЛОВЫСОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ С ПОМОЩЬЮ ОБЗОРНЫХ РЛС РТВ

Л.В. Бейлис, В.Ф. Зюкин, С.В. Кукобко

Обсуждается методика оценки информационных возможностей обзорных радиолокационных станций при разведке малозаметных целей. Рассматривается вариант использования методики применительно к массовым обзорным радиолокационным станциям типа П-37. Анализируются показатели качества, полученные в результате проведенных расчетов.

Ключевые слова: *беспилотный летательный аппарат, зона обнаружения радиолокационной станции, обзорный радиолокатор, малозаметная цель.*