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IDENTIFICATION OF TROPOSPHERE PROPAGATED RADAR SIGNALS BY THE COHERENCE PARAMETER FOR THE ALGORITHMIC ADAPTATION OF THE PASSIVE LOCATING RADARS

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1. Introduction

There are different methods of passive illuminating objects' location. These methods can use the same antennas and receivers but the methods' characteristics variously depend on the wave propagation conditions.

Synthesis of the optimal methods for the radar signals treatment can be called algorithmic adaptation. If conditions of wave propagation change randomly the adaptation should work permanently and automatically. In this case terms automized design, synthesis and algorithmic adaptation are equivalent.

The wider is the charge of wave propagation conditions the better is effectiveness of the signals' treatment adaptation. This effectiveness greatly depends on the choice of the adaptation parameter-measurable or calculated variable, which is used for correction of the signal's treatment algorithm.

There are great many radioelectronic systems using VHF signals propagated beyond-the-horizon. These systems need permanently improving accuracy of performance and reliability of tropospheric communication, radionavigation and location. Sensitivity of receivers and their immunity, the quality of antennas and of automized signals' treatment have been greatly improved lately and therefore the characteristics of the systems are defined by the wave propagation conditions - by distortions of the electromagnetic field propagated beyond-the-horizon.

Table 1

Change of signal parameters (confidence interval at probability 80%)

Parameter	*Meaning in ranges, cm*			
	3	10	35-50	150-200
A. Attenuation factor in dB:				
- season variations of monthaverages	15	20	25	30
- synopsis day variations	7-15	10-20	15-25	15-30
- day variations of houraverages		10-20	10-20	10-20
- hour variations of minuteaverages		7-12	5-12	5-20
- fast fluctuations on minute intervals	5-10	5-10	5-10	5-10
B. Coherence parameter (relation of regular and random components):				
- range, Summer		1-5	1-5	1-5
- range, Winter		0.5-3	1-3	1-4
C. Interval of fast fluctuations cross correlation (limits) related to the wave length:		15-60		40-150
D. Interval of the fast fluctuations time correlation on minute intervals (limits), sec:	0.08-0.3	0.2-0.7	1-5	3-10

The idea of algorithmic adaptation can be put into life designing passive radars meant to locate illuminating objects beyond-the-horizon. In the paper there are described some results of investigation in this field: choice of adaptation parameter, practical means of fast measuring of this parameter in the real time. There are given examples of such measurments over sea paths up to 500 km long.

All parameters of signals change greatly while-short radio-waves propagate in troposphere beyond-the-horizon. As a rule, there is no opportunity of the theoretical definition of these parameters using physical conditions of atmosphere. Table I shows what kind of change can be observed along paths 200-500 km long. These data were received in the north-western and western paths of the Pacific Ocean [1-4].

If signal changes so much the error of the object location can be large (error of range is about 300 km and more). Some methods of the object's location (Phase finders, for instance, in 20-30% of time) can become useless if the coherence parameter is less that 1-2. Better results can give methods based on estimation of indicatrix width of dissipative tropospheric volume. Therefore an effective system of location can be designed if its structure and signal's treatment algorithm are adopted to the changing conditions of wave propagation.

2. Parameter of adaptation

Parameter of adaptation should answer several demands:

- the error of the object's location should obviously depend on it;
- there should be the opportunity to measure it in real time;
- it should characterise the electromagnetic field at the receiving site, but shouldn't depend on the type of the receiving antenna and system;
- it is desirable that the parameter of adaptation has clear physical meaning and limited range.

These demands are answered by the so called coherence parameter, which is one of the most important characteristics of the Gaussian model of the electromagnetic field. This model supposes that the electromagnetic field is a combination of regular and random components and the random component has Gaussian distribution with the zero average. Coherence parameter g is the ratio of regular and random component's power. Coherence parameter at the receiving site depends on the structure and condition of atmosphere in the dissipation volume. Still, changing of the atmosphere conditions is of such a type that measuring it at one or several points don't allow to estimate the coherence parameter with necessary accuracy even if the mechanism of wave propagation is known. So the thickness of the layer with high gradient of the reflection index necessary for noticeble coherent reflection, can be about one or dozens meters, its horizontal size (Fresnel zone) about 4-6 km and the ranges where coherent signals are observed depend on the hight and the angle of observation of layer. Sounding of the dissipating volume of such size is not really possible.

One can expect better results if not instant meaning of coherence parameter but the average one is estimated. Necessary power of averaging minimizes the advantages of adaptation because change of parameter on the time scale is rather large. Therefore the only way to get the <<instant>> adaptation parameter is to estimate it on real-time scale using signal parameters.

The straight way of the coherence parameter estimation is analysis of amplitude fluctuations' variance or signal phase. Dependence of the coherence parameter with variance or phase in case of Gaussian model of the stationary field is unambiguous and shown in fig. 1 [5]. But in reality sometimes in order to estimate variance it is necessary to use longer periods that interval of stationary. More than that, this method is useless when the time of receiving is short or the signal is transmitted with scanning antenna.

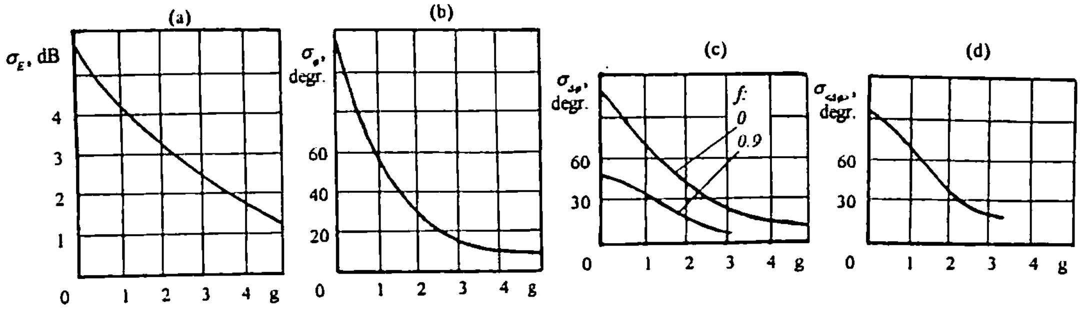

Fig. 1. Coherence parameter and standard deviations of fluctuations of:
a - amplitude, dB; **b** - phase; **c**- phase shift while spectrum is symmetrical (*f* - modulus of the field correlation factor at the receiving points); **d** - average phase shift.

The other method of algorithmic adaptation is using dependence coherence parameter, phase of the field space correlation function (the average signals' phase shift at cross diversion of receiving antennas) and the grazing angle of the transmitting antenna. Fig. 2,a shows the example of experimentally measured phase shift (with antennas' diversion 2.5 m, wave length 10 cm over the sea path 495 km long) against the transmitting antenna's lobe. Fig. 2,b shows calculated dependence parameter g from the phase shift angle gradient, which can be measured.

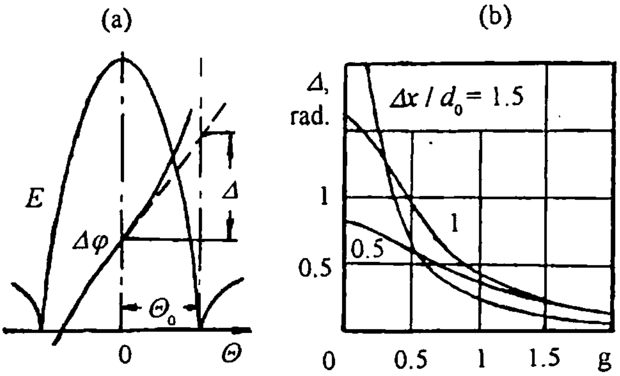

Fig. 2. Estimation of the coherence parameter g by the phase methods:
a - method, b - curves for calculation.

The next method of the coherence parameter fast estimation uses amplitude sensor - several receiving antennas with divergent by angle narrow lobes. Let one of these lobes looks at the illuminator and another be divergent by angle $\Delta\alpha$. Dependence of the signal level from the transmitter antenna's direction angel Θ is different at every receiving channel: the signal maximum is shifted along Θ axis and the magnitude of this maximum is smaller that at output of the first antenna (see fig.3,a). It is obvious because the power of the divergent signal at the output of the receiving antenna is proportional to the integral of the product of the receiving and transmitting antennas gain and so called scattering factor $\sigma_p(\Theta_p, \nu)$ (where Θ_p - scattering angle, ν - angle between electromagnetic field's vector in the scattering point and of scattering) along the scattering volume. Scattering factor is the ratio of scattered power in unity space angle to the power stream falling at the unity volume. This factor depends on correlation function of the atmosphere reflection index. Correlation functions can be different, but they are successfully approximated by the generalised function [3] with index p, value of which changes from the Karman function (p=1/2) to nearly Gaussian functions (p=1...3).

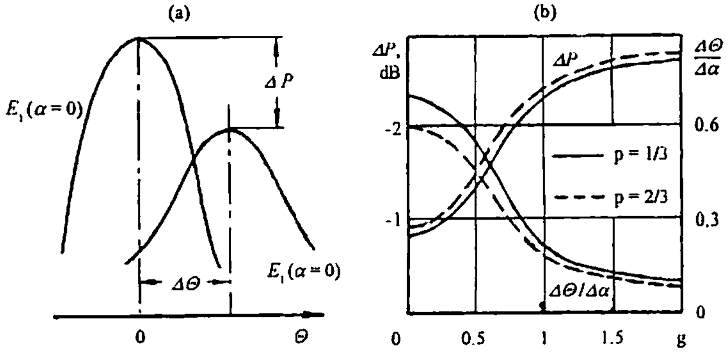

Fig. 3. Estimation of the coherence parameter g by the amplitude method:
a - method,
b - curves for calculation for λ=10 cm, transmitting antenna 10x2 m, receiving antenna 5x1.3 m, angle diverge is equal to the lobe width.

In order to find the dependence of the summerized level of the received signal from the transmitting antenna orientation scattering component with the propriate weight should be added to the coherent component found as the product of transmitting and receiving antennas' gains.

Relationship, calculated by A.V. Lopatin, between coherence parameter and angle relay of scanning transmitting antenna's maximum at the output of the receiving antenna's is shown in fig. 3,b. One of the receiving antennas looks at the illuminator, the second one is diverged by the angle equal to the lobe's width. Lobes' diagrams are approximated by Gaussian curves scaled by ratio of the wave length to the lobe width in corresponding plane.

Two last methods allow to estimate instantly the coherence parameter along with the range to the illuminator estimate, using the same equipment. The drawback of the methods is low accuracy in the case of single measurement.

Fig. 4 shows samples of signals used for estimation of coherence parameter over sea paths beyond-the-horizon in 10 cm band at both cross and angle diverge of receiving antennas.

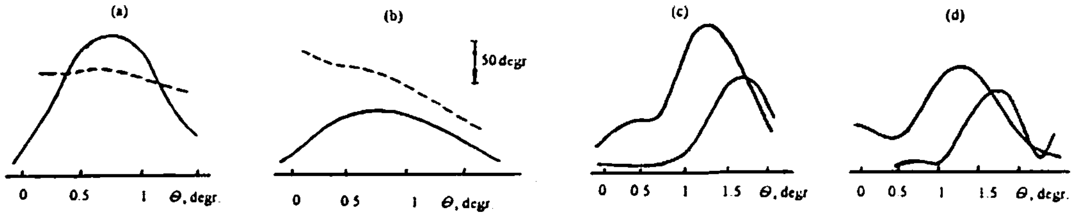

Fig. 4. Examples of receiving signals of scanning transmitting antenna

a - diverge of receiving antennas across path 222 km long, estimation $g^*=1...1.5$,

b - the same thing, $g^*=0.5$,

c - angle diverge of receiving antennas, path 180 km long, $g^*=0.7...0.8$,

d - the same thing, $g^*=0.4$.

3. Conclusion

Coherence parameter of the electromagnetic field is the universal and easily measurable variable, which can be used for algorithmic adaptation of locating radars using either one method or combination of methods with forming average estimate.

4. References

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