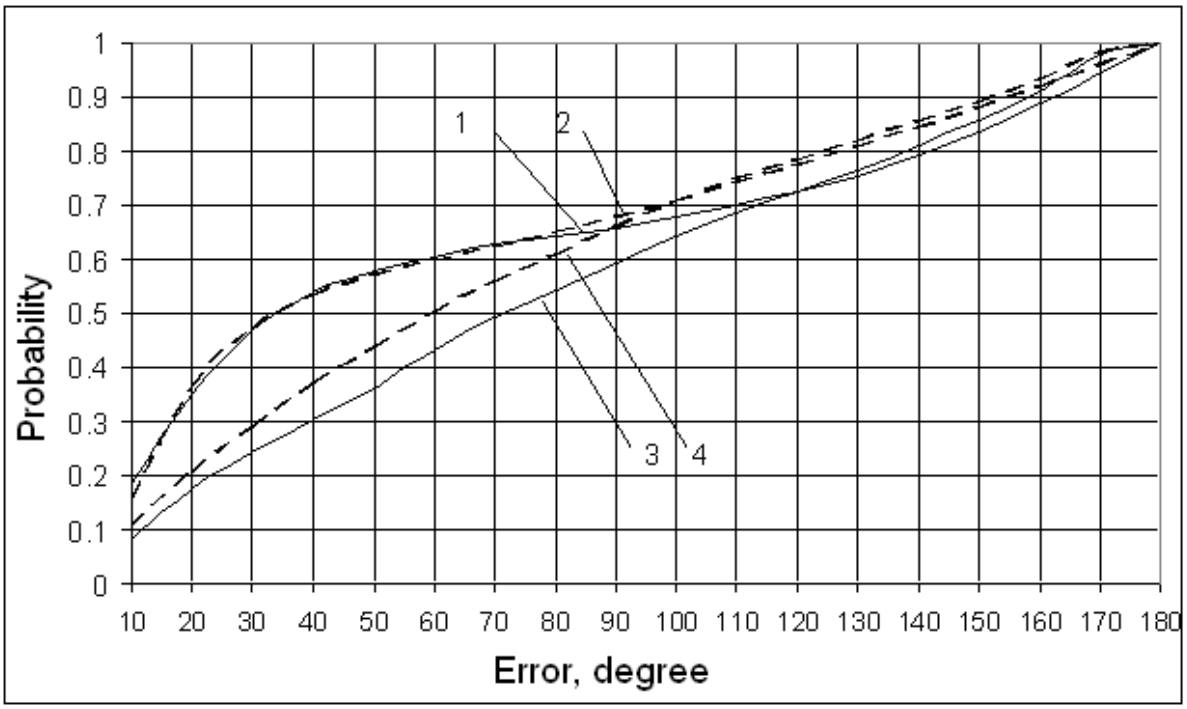
FIGURE 7

Estimation of bearing error probability



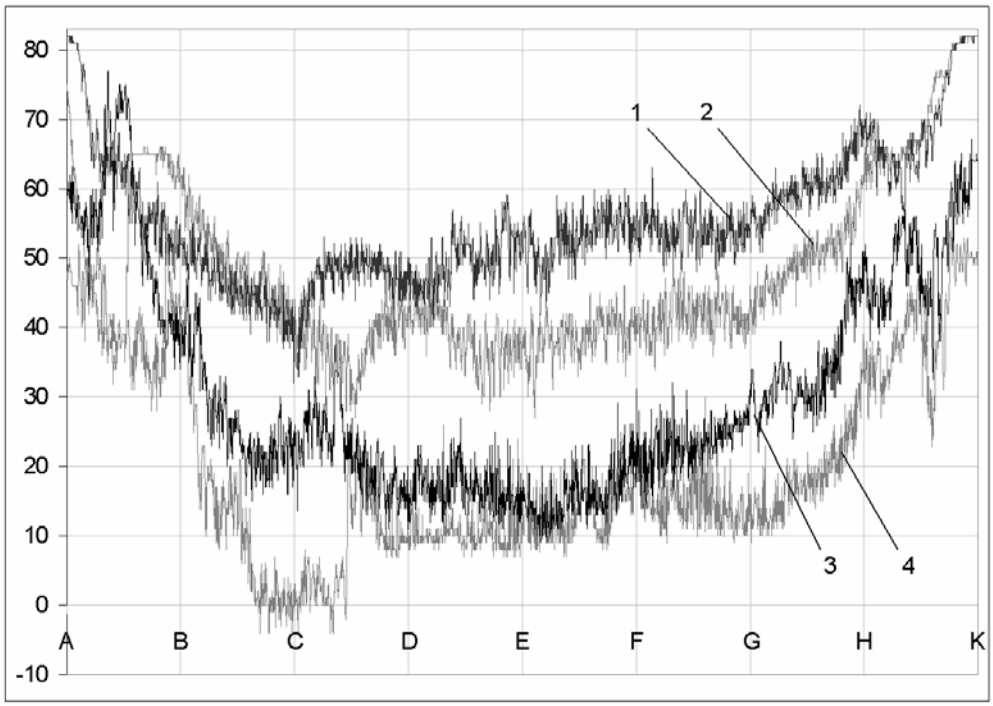
From Figure 7 it can be concluded that the probability of a bearing taking with an error smaller than 10 degree in the country zone is about 0.2 and in the city zone is about only 0.1. For errors smaller than 20 degree these probability figures are 0.4 and 0.2 accordingly. In the city zone deterioration of the bearing accuracy on higher frequency is observed. It can be assumed that the main influence on the bearing accuracy is due to radio wave interference caused by their multi-beam propagation that is more distinctive in the city conditions because in cities there are more various discontinuities. Therefore, in the country conditions error probabilities are considerable smaller that in the city conditions.

Figure 8 shows dependencies of received signal amplitudes at the measuring receiver input (in decibels according to microvolt) versus to the MMS positions on the route. Curves notations are the same as in Figure 7.

As it follows from the Figure 8, these dependences demonstrate fast fluctuations around rather slowly varying average values. Range of pulsations in separate points exceeds 10 dB. In the beginning of the route (point A), when the MMS was on the minimal distance from the transmitter, amplitudes of signals in the city and in the country zones were comparable, however further, in the process of the MMS movement along the route, stronger attenuation of the signal in the city zone was observed.

FIGURE 8

Dependences of radio signal amplitudes versus to the MMS position on the route



The curves presented in Figures 7 and 8 confirm that location of a transmitter by a stand-alone MMS station requires use of calculation algorithms.

Errors of transmitter location estimations by the considered statistical algorithms were compared. Methodology of the comparison is described in [6].

Table 1 shows calculated errors of transmitter location estimations expressed in meters and averaged for full routes ABCDEFGHK in the city and the country zones for each calculation algorithm indicated in the left column, and for frequencies of 146 MHz and 434 MHz. In the extreme right column of the Table overall average value of errors for each algorithm is given. All error values in the first four columns are averaged up to 10 m and in the fifth column up to 1 m.

Average value of an error, smaller than 50 m, shows the amplitude-goniometric algorithm, the greatest average value of an error equals to 100 m appears with the amplitude algorithm when a terrain relief is not taken into account. The account of a relief in the amplitude algorithm has led to reduction of a location error almost on one third. Average value of a location error in a city zone, calculated according to Table 1, is 78 m and in a country zone 65 m.

TABLE 1

Calculated averaged location error values

Coordinate calculation algorithm	Average location error, m				Overall average location error
	146 MHz		434 MHz		
	City	Country	City	Country	
Maximum likelihood algorithm	90	60	50	40	60
Amplitude algorithm without taking into account a terrain relief	140	50	90	120	100
Amplitude algorithm with taking into account a terrain relief	100	40	50	120	78
Amplitude-goniometric algorithm	30	30	70	60	48

The results presented in Table 1 confirm that all three algorithms have accuracy of the signal transmitter location comprehensible to practice. Therefore, for a choice of the preferable algorithm it is necessary to consider additional factors.

Recommendations on use of methods and algorithms of DF in actual operating conditions of MMS

The practice shows that if the MMS includes high-speed radio equipment, the navigating equipment and the corresponding software, the combined method of a signal transmitter search is more often used that combines homing and DF during the movement. At such combination there is a continuous reception of radio signals that is important for DF of periodic or short-term transmissions. In addition, it provides an opportunity to use a multi-channel DF for determination of coordinates of several signal transmitters simultaneously and to provide security of DF operations because in this case the MMS moves in a common city traffic stream.

The maximum likelihood algorithm in application to a stand-alone MMS cannot calculate a signal transmitter coordinates under using of homing; therefore it is expedient to use the amplitude-goniometric algorithm working simultaneously with bearing and field strength level data. The additional reason in favor of the amplitude-goniometric algorithm is the fact that its operation is accompanied by a vivid display at a map of a zone that corresponds to the most probable position of a signal transmitter.

If the MMS is equipped only by a measuring receiver it is possible to use only amplitude algorithm which provides comprehensible accuracy at presence of a digital map giving terrain relief and blocks of buildings. Limitation of the amplitude algorithm is its low sensitivity and impossibility of operation at low signal-to-noise ratios.

For the MMS equipped by the DF, the algorithms based on processing of obtained bearings are applied. In comparison with the amplitude algorithm they provide greater accuracy of a signal transmitter coordinate determination spending shorter time. They also provide possibility of calculation of a signal transmitter coordinates under low signal-to-noise ratios and in situations when the signal transmitter is working in a short-term regime.

Therefore, for the stand-alone MMS equipped by FD and field strengths measurement capabilities, it is preferable to use the amplitude-goniometric algorithm. If the MMS does not equipped by field strength measurement facilities, the maximum likelihood algorithm is suitable. And, at last, if the MMS is equipped by only a measuring receiver only the amplitude algorithm can be used for the signal transmitter localization.

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