The Approach to a Problem of Search of People under Avalanches

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Abstract

Some aspects of creation of system for searching of people under the rock's obstruction, avalanches, and construction's ruins are considered. Taking into account the impossibility of use of standard antenna's systems on working frequencies and on working distances the using of inductance coils for signal's reception and signal's transmitting was offered. In this case due to the mutual induction between the coils it is possible to establish the communication and it is possible to estimate the distance up to object of search. Owing to properties of a magnetic field the choice of a method of a maximum by the mutual positioning of the coils is possible.

1. Introduction

Various search services have a problem of victim's search as a result of extreme situations of both anthropogenic and natural character. At first [1] it can point out the problem of searching of coalminer after the accident. This problem consists in fast and exact definition of a placement of the victims under thicknesses of rock. As a rule, the reason of people's loss was inefficacy of searching and also absence of equipment of search of victims.

Therefore, there is necessity of design of search devices for implementation of the duly help to victim and for control over the moving of search service workers. At the design of searching system it must be taken into account the specificity of realization of equipment, namely the influence of environment on signal's propagation, working distances and the restriction on dimensions of equipment of receiver's and transmitter's units.

There is a precise dependence between penetrated capacity of an electromagnetic signal in the rock and its frequency. Therefore at a choice of a frequency band of search system it is necessary to be guided by following reasons. In the rock's avalanche on a long distance rather low-frequency waves are useful. However in this case it is impossible to achieve high resolution of search systems. The high resolution of search system can be achieved when high-frequency waves are used, but the working distance will be much less. Based on numerous references data it can assume, that optimal from the point of view of penetration of waves it is possible to consider the using of frequencies in 100 kHz band. Waves with higher frequencies are quickly damped in a rock. From the other hand, the electromagnetic field with lower frequencies is difficult for transmitting and receiving, since dimensions and weight of high efficiency antennas of this band are unsuitable for the purposes of victim's searching.

2. Task Statement

The problem of searching of suffered people is solved by use of the unit which is disposed on each man. This unit we will name it as beacon. The beacon forms the electromagnetic alarm signal in emergency. So, the second unit, we will name it as searching device, must receives the beacon's signal and must determines its parameters. Based on these parameters it can determine the position of beacon or man.

Being based on operating conditions and features of work of searching system, working distance should be up to hundred meters. However for reception of a signal the minimal range should be commensurable with wave-length of radiation. For frequency of a signal 100 kHz its wave-length will be 3 km. Therefore, normal work of any of antennas of such working frequencies and at such distances is impossible. We must consider the near-field zone in this case. The antenna's pattern in this zone is not formed and we cannot use, for example, loop antenna for solving classical task of navigation with the minimum of pattern. As it is well known, no of loop antenna cannot radiate the electromagnetic wave in a direction which is perpendicular to the plane of loop. The most of navigation systems use this advantage. But in our case it does not work. For example, it was carried out the natural experiment with determination of signal strength when one multi-turn loop antenna was the transmitting one, another — the receiving one. The distance was about 10 m, working frequency was 100 kHz. The position of one of antennas was changed and level of signal was fixed. It was established, that the level of received signal was maximal in both mutual positions of antennas, as shown on fig 1.

Obviously, the electromagnetic theory does not work in this case and we deal with ordinary alternating magnetic field of low frequency. Such approach will allow us to solve a problem of determination of position of

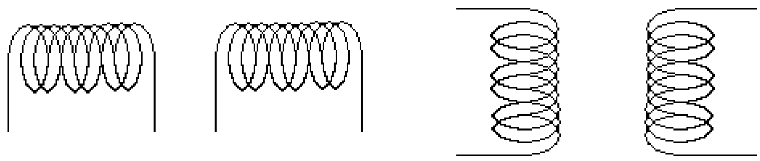

Fig.1 — Mutual positions of multi-turn loop antennas

beacon rather with signal strength method than the method of minimum of antenna's pattern. Such approach let us determine the distance between beacon and searching device. For the elimination of doubts, we must use two receiving antennas, the distance between these antennas must be known.

3. Solving of a Task

The decision of a problem of search of beacon consists of definition of qualitative dependence between the received signal level and the distance to beacon. This dependence is characterized by the design features of inductance coils, character of distribution of the magnetic field and the relative position of coils in an azimuthal plane.

So, the beacon consists of the inductance coil and oscillator which has been adjusted on certain frequency. The reception coil of the searching device is arranged similarly, only it has considerably large quantity of turns in comparison with transmitting one and therefore has the larger dimensions.

Alternating current in the transmitting coil $i_1(t) = I_1 \cos(\omega t)$ excites an alternating magnetic field intensity $H(t)$. Thus, the created magnetic field penetrates the reception coil, raising in it the e.m.f. as a self-induction which will be equal to:

$$e = -L\frac{di_2(t)}{dt}, \tag{1}$$

where $i_2(t) = I_2 \cos(\omega t)$ — the current, which is induced with the external magnetic field in the receiving coil, L — inductance of the receiving coil. Thus, the level of the received signal is defined as e.m.f., which is arising on the terminals of the coil. For the receiving of the maximum of induced current in a receiving contour it is necessary, that the axis of the receiving coil coincided with a direction of a vector of a magnetic induction of that magnetic stream which penetrates this coil. In this case the vertical component of vector $\vec{B}$ will be the greatest, and it creates the induced current in the coil.

Let's consider two special cases of positions of the coils. One when coils are in one plane and on one axis (fig. 1, a) and also when their axises are parallel each other (fig. 1, b). So, the problem consists in definition of the distance between receiving and transmitting coils, when the induced e.m.f. in the receiving coil is known. We will theoretically solve this problem for a case of coils without cores. For this purpose we will take advantage of law Biot-Savart-Laplace. According to this law the magnetic field of any current can be calculated as superposition of the fields created by separate elementary segments of current. We will write down analytical expression for a field finding in some point:

$$d\vec{B} = \frac{\mu_0 \mu I[d\vec{l} \times \vec{r}]}{4\pi r^3}, \tag{2}$$

where $d\vec{B}$ — induction of the magnetic field created by a segment of a current $Id\vec{l}$; $\vec{r}$ — radius-vector — distance from an element of a current to a considered point of space in which the magnetic field is searched. According to a principle of superposition, an induction $\vec{B}$ of sum field of a conductor with a current it is equal to the vector sum of contributions $d\vec{B}$ of segments $d\vec{l}$ of conductor. It can be found with the help of curvilinear integral on length L jf a conductor:

$$\vec{B} = \oint_L d\vec{B}$$

Let's find magnitude of the radius-vector for a case of the coaxial positioning of coils. For convenience of calculation we will replace in the transmitting coil the current which is equal to the current $i_1(t)N$, where N — number of turns in a coil.

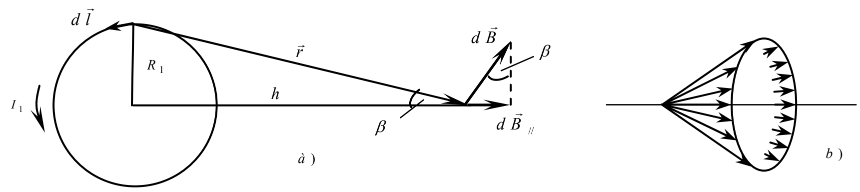

Рис. 2 — Diagram of the magnetic field on the axis of circular conductor with current

Let's find $\vec{B}$ on the axis of circular conductor with current on a distance h from the center (fig. 2). The vectors $d\vec{B}$ are perpendicular to a planes, which are passed through $d\vec{l}$ and the point in which we are finding the field. Hence, they form the symmetric conic fan. (fig. 2, b). According to a symmetry reasons, it is possible to assume the sum vector $\vec{B}$ is directed along a contour axis. Each of component vectors $d\vec{B}$ brings into the sum vector the contribution $d\vec{B}_{//}$, which is equal $dB\sin\beta = dB(R_1/r)$ in module. Angle α between $d\vec{l}$ and $\vec{r}$ is right, so $dB_{//} = dB\dfrac{R_1}{r} = \dfrac{\mu_0}{4\pi}\dfrac{I_1 dl}{r^2}\dfrac{R_1}{r} = \dfrac{\mu_0}{4\pi}\dfrac{I_1 R_1 dl}{r^3}$.

Integrating on all contour and substituting instead of r the $\sqrt{R_1^2 + h^2}$, we will obtain:

$$B = \int dB_{//} = \frac{\mu_0}{4\pi}\frac{IR_1}{r^3}\oint dl = \frac{\mu_0}{4\pi}\frac{IR_1}{r^3}2\pi R_1 = \frac{\mu_0}{2}\frac{IR_1^2}{(R_1^2 + h^2)^{3/2}}. \tag{3}$$

So, we have defined the magnetic field magnitude in the receiving point. Now we will consider a situation in which it is necessary to find a magnitude of a vector of a magnetic induction which would provide known (measured) e.m.f. on the terminals of the receiving coil. This magnitude of a magnetic induction will be numerically equal to magnitude B, which is defined by expression (3).

Let's consider now the receiving coil (fig. 3) and we will define the magnitude of a vector of a magnetic induction inside it. Owing to the bulkiness transformations we will write the end result

$$B = \mu_0 n I_2 \frac{1}{\sqrt{1 + \left(\dfrac{2R_2}{L}\right)^2}}, \tag{4}$$

where $n = \dfrac{N_2}{L}$, N_2 — number of turns in the receiving coil, L — the length of coil, R_2 — the radius.

From the equations (3) and (4) we will obtain the radius-vector r, equating of their right parts:

$$r = \sqrt[3]{\frac{I_1 N_1 R_1^2 \sqrt{1 + \left(\dfrac{2R_2}{L}\right)^2}}{2nI_2}} \tag{5}$$

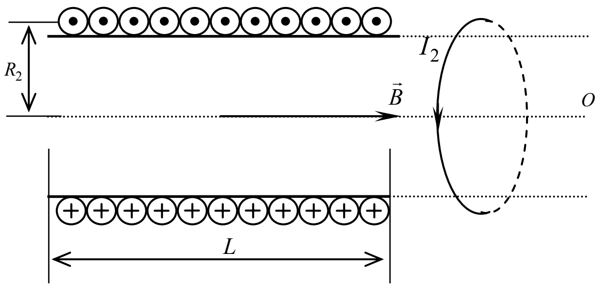

Fig. 3 — The diagram of magnetic field inside the receiving coil

Let's express I_2 through e.m.f. to a self-induction E and we will substitute this value in (5).

As the $I_2 = \dfrac{E}{L\omega}$, than $r = \sqrt[3]{\dfrac{I_1 N_1 R_1^2 L\omega\sqrt{1 + \left(\dfrac{2R_2}{L}\right)^2}}{2nE}}$.

The result of numerical calculations is presented on a fig.4.

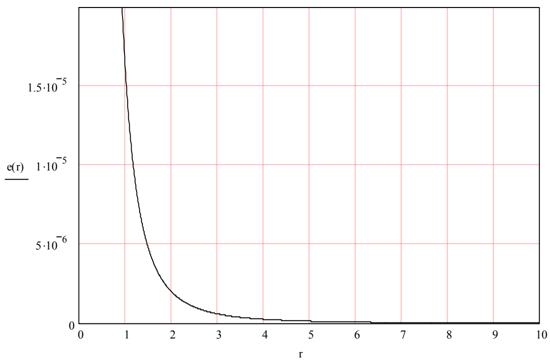

Fig. 4 — Dependence of e.m.f. from the distance between the coils (numerical calculations)

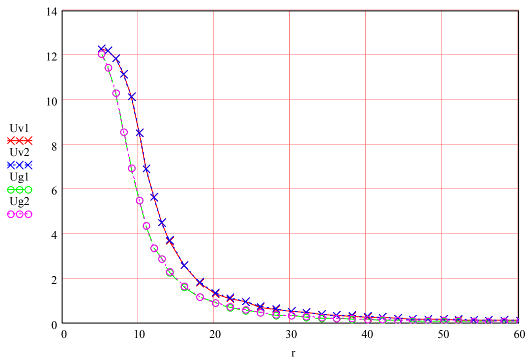

Fig. 5 — Experimental dependence of the level of receiving signal from the distance up to the beacon

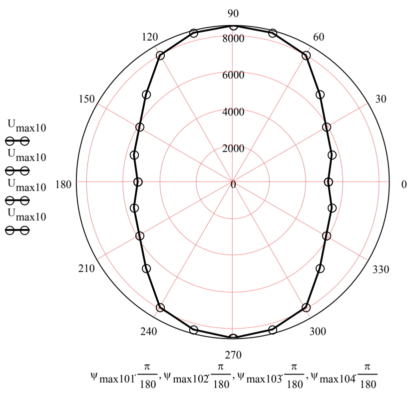

Fig. 6 — Experimental dependence of the level of receiving signal from the mutual positioning of the coils (maximum magnitude)

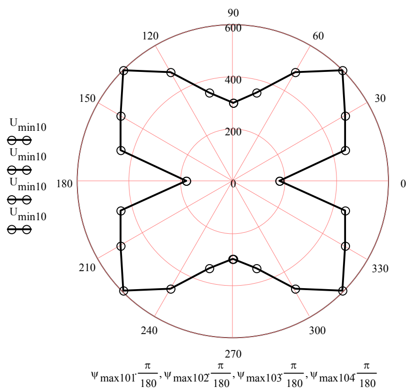

Fig. 7 — Experimental dependence of the level of receiving signal from the mutual positioning of the coils (minimum magnitude)

Along with the calculation there was carried out the experiment in which there were defined the dependences of level of receiving signal on the receiving part from the value of distance to beacon. Experimental curves are represented on fig. 5 for dependence from distance. It is very difficult to adequately represent the real value of excitation current in a coil of beacon, since it was used the resonant system of coils. We can only affirm that the power consumption of beacon was near 1 W and efficiency about 80%. Furthermore, we supplied both coils with ferromagnetic cores. The ferromagnetic core allows to increase the magnetic field many times over. The external magnetic field operates on ring currents in atoms of ferromagnetic substance in such a manner that these microscopic domains turn in one direction and start to create own magnetic field which can appear many times more strongly than external one, which is created by a current in the coil. Really, such approach let us increase the working distance. Using mentioned above power, we obtain the level of receiving signal about 10 μV on distance near 80 m. This is more than enough for functioning of searching system. As we can see the laws of curves for theory and experiment are very similar. The deviation of experimental curve from the ordinary law on small distances is stipulated with saturation of input cascades of receiver. Obviously, it must increase the dynamic range of receiver.

Further, there were obtained experimental dependences of the level of receiving signal from mutual angular positioning of coils on the fixed distance. Experimental curves are represented on fig. 5 for dependence from distance and on fig. 6 and fig. 7 from the mutual positioning of the coils. Measurements were made for two cases of a relative positioning of coils (which were discussed above).

3. Conclusion

It was shown the possibility of creation of searching system, based on direct measurements of receiving signal and determination of the distance up to beacon. Theoretical and experimental results are well agreed.

References

1. I.B. Shirokov, A.N. Demerza, “The Method of Search of Natural Disaster Victim”, IEEE Proc. of Int. Conf. Crimean Microwave Conference CriMiCo’04, September, 2004, Sevastopol, Ukraine.