USING OF H-FIELD ANTENNAS IN SYSTEM FOR SEARCHING OF PEOPLE UNDER AVALANCHE

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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 mutual positioning of the coils by a method of a maximum is possible. With using of H-field antennas in system for searching of people under avalanches the positioning of objects of searching is possible.

Keywords: coal-mining industry, H-field antenna, searching system, beacon.

1. INTRODUCTION

The safety issue of workers is the most essential, especially, when it concerns a coal-mining industry. Danger of work in mines is related with probability of rockslide which, as a rule, can be caused by the gas explosion. Today there is no possibility to prevent explosions in mines as there is the spontaneous release of gas (methane) and there is explosion hazard of a coal dust. The main problem of rescue of human's life after the explosion in mine is the fast and accurate search of people behind and under the rockslide. As a rule, the reason of people’s loss was inefficacy of searching and also absence of equipment of search of victims. The equipment of localization of victims in blockages would promote to life rescue by much of them, and also would decrease the economic expenses related with liquidation of the consequences of underground accidents.

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 first [1] it can point out the problem of searching of coalmminer 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.

2. TASK STATEMENT

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 efficient antennas of this band are unsuitable for the purposes of victim's searching.

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
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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. Such approach will allow us to solve a problem of determination of position of 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.

![Fig. 1. Mutual positions of multi-turn loop antennas.](image)

### 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 [2].

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:

$$e = -L \frac{di_1(t)}{dt}, \quad (1)$$

where $i_1(t) = I_1 \cos(\omega t)$ — 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:

$$d\vec{B} = \frac{\mu_0 \mu_1 [d\vec{l} \times \hat{r}]}{4\pi r^3}, \quad (2)$$

where $d\vec{B}$ — induction of the magnetic field created by a segment of a current $d\vec{l}$; $\hat{r}$ — 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 $L$ of a conductor:

$$\vec{B} = \oint_{\text{coil}} d\vec{B}$$

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 coil, 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:

$$d\vec{B} = \frac{\mu_1 \mu_2 N_{H} S}{2\pi r^3} dl,$$  \quad (3)

where $R_1$ — radius of transmitting coil, $I_1$ — amplitude of current, $\mu_1$ — effective permeability of the ferrite rod.

We will consider a receiving coil of the searching devise. The induced voltage and the inductance can be represented as

$$E = F_{d\vec{l}} [d\vec{l} \times \hat{r}] S N_{H} S_{l_1} H,$$  \quad (4)

$$L = K\mu_0 \mu_2 \frac{N_{H} S}{l_1},$$

where $\mu_0 = 4\pi \cdot 10^{-7}$, $N$ is the number of turns, $\mu_2$ — effective permeability of the ferrite rod of the receiving coil, $\omega$ — frequency of signal, $S$ — the rod cross-section area, $l_1$ — the length of the ferrite rod. Both $K$
and $F_A$ are not very clearly described in the literature.

All non-ideal behavior of the ferrite-loaded rod seems to be united in these two factors.

From both expression for induced voltage and the inductance we will get

$$E = \frac{F_A}{K} \frac{\omega L H}{n},$$

where $n = \frac{N_2}{l_r}$ — the number of turns incoming in unit of length of the coil.

We substitute (3) in (4) and get

$$E = \frac{F_A}{K} \frac{\omega L I_1 N_1 R_1 \mu_1}{n} \left( \frac{1}{2r^3} \right).$$

This result shows dependence induced voltage or EMF in receiving coil from a distance to transmitting coil, and also dependence of this result from external parameters of coils.

4. PRACTICAL REALIZATION OF SYSTEM

The problem of searching of people is solved by use of the unit which is disposed on each mine-worker. 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 mine-worker.

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. It is possible due to the properties of an electromagnetic induction for an alternative magnetic field. The received signal can be regarded as result of action of forces of the variable magnetic field penetrating a contour of the reception coil. This signal is numerically equal to electromotive force of an induction. The magnetic field in a near zone has theoretically been calculated. It was established that the magnetic field decreases in inverse proportion to a distance cube.

In paper there are presented the results of experimental researches, that confirmed the correctness of approach (fig.2 and 3). So, by the measuring of the level of receiving signal we can determine the distance to the beacon.

Due to the possibility of a finding of distance to beacon, it is possible to define its co-ordinates. It must to determine the distance to beacon from another point of search. In paper the aspects of design of system are discussed.

Fig. 2. Appearance of model of searching device.

Fig. 3. Experimental dependence of level of receiving signal $i$ from distance $r$, m.

As the beacon forms alternative magnetic field, it will be possible to identify the beacon by the assigning the certain frequency to each beacon in a chosen band. It will allow rescuers to find precisely and in due time victims.

5. CONCLUSION

It was shown the possibility of creation of searching system, based on direct measurements of receiving signal level and determination of the distance up to beacon. Loop antennas do for solution this problem to the best advantage.

REFERENCES
