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Development of an EMF Receiver for Protection of Archaeological Sites

CURCA Center for Undergraduate Research and Creative Activities

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Abstract

The goal of this research is to create an electromagnetic field (EMF) device capable of recognizing when a metal detector is being used on an archaeological site. The device could be developed to take photographs or alert authorities when triggered by an EMF. The initial research stage determined the feasibility of an EMF receiver for archaeological site protection, including which type of EMF receiver would work best, and calculated the relevant variables. The second stage of research will include the development of a prototype using the initial calculations. The prototype will monitor and record EMFs created by metal detectors used to loot archaeological sites.

UB's excavations at Idol Hill, near Hassloch, Germany, were damaged by looters with metal detectors on several occasions. The looters came at night, irreparably ruining some of the student excavators' hard work

Background

Archaeological Looting

A recent survey showed that 78.5% of 1,662 responding archaeologists reported that their sites had been looted (Bowman Proulx 2013).

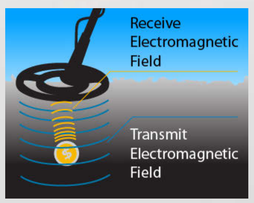
Metal detectors are the main tool used in the looting of archaeological sites. Detectors are used to locate underground metal artifacts. These artifacts are subsequently dug up and sold on the international art market. Illicit metal detecting destroys information about past societies and their cultural heritage.

Ancient coins, like these Greek silver coins depicting Alexander the Great, are a favorite target of looters. They are easy to locate with metal detectors and to sell. For archaeologists, coins are critical for dating stratigraphic layers.

Metal Detectors

The most popular type of metal detector is a very low frequency (VLF) detector.

Metal detectors' search coils are made of two parts; a transmitter and receiver coil. The transmitter coil's electromagnetic field causes an EMF in underground objects. The receiver coil acts as an antenna which senses and amplifies the frequency from the target object.



("Metal Detecting Terminology")

This diagram shows the electromagnetic field produced by the metal detector's transmitting coil. The receiving coil is displayed registering the EMF produced by the object.

Looters use metal detectors to find objects like this Bronze Age Arm Ring (1,600-1,200 B.C.) from UB's excavations at Idol Hill in Germany.

Methods

Constraints

The EMF receiver will be left at the archaeological site for the duration of one year. Data from the device will periodically be downloaded. A device which requires low voltage is necessary, as the power source of the device will not be able to be changed regularly. In addition, the device will be subjected to harsh weather conditions.

Decision Matrix

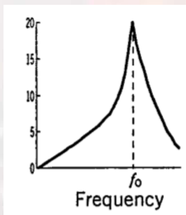
To determine what type of EMF receiver would be best for this project a decision matrix was used.

Below are some of the criterion used in the matrix:

EMF Receiver	Frequency (kHz)	Power Usage	Size of device	Outdoor use
Air Core Loop	0.1-10^6	None-low	Small-large	Feasible
Core Loop	0.01-200	None-low	Small-medium	Feasible
Fluxgate	Dc to several kHz	Medium	Small	Feasible
SQUID	100-500	None-Medium	Small	Not feasible

Decision: Voltage amplified air core loop antenna

Calculations



The graph above displays output voltage vs frequency of an induction loop, where f_o is the resonance frequency. (Macintrye,98)

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$R = \frac{\rho \cdot l}{d^4}\left(D - D_i\right)\cdot\left(D + D_i\right)$$

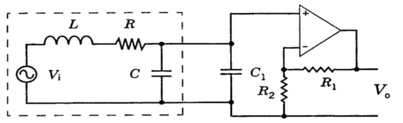
$$L = \frac{\mu_o n^2 A}{w}$$

$$C = \frac{\varepsilon_w \varepsilon_l}{\varepsilon_w t_l + \varepsilon_l t_w}(0.018544dw)$$

$$V = \frac{\pi^2 D^2 f n B}{2}$$

The equation for impedance and capacitance were substituted into the resonance frequency equation in order to determine diameter and turns (n). (Macintrye, 94 and Tumanski)

Calculations Cont.



This circuit will be used for the EMF detecting device. The circuit enclosed in the dash line represents the equivalent circuit for an induction loop. (Macintrye,98)

$$\frac{d^2 i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC}i = v'(t)\frac{1}{L}$$

The equation above was derived using Kirchhoff's' laws to find the induction loop's circuit.

The current of the loop was found by substituting the resistance, impedance, and capacitance found in the earlier equations and then solving the differential equation.

The amplifying circuits' resistance and capacitance were then calculated using Kirchhoff's' laws.

Conclusion

Through preliminary research it was determined that the employment of an electromagnetic field receiver for the protection of archeological sites is feasible.

The calculations suggest that an air core loop antenna receiver for the device should be 6 inches in diameter. A small sized receiver is required so that the receiver can be mounted in a tree. The calculated output voltage for this circuit at resonance frequency of the induction loop is 28 volts.

Future Research

The EMF prototype receiver is now being developed. Once testing of the prototype is finished, an outdoor model will be built. This outdoor model will include the appropriate insulation so that weather related damage will not occur. The device will then be installed in an archaeological site in Germany where it can monitor metal detector activity over a period of time. This testing will indicate how frequently a site is visited by looters, and whether a more complex version, capable of taking photos of the perpetrators, or calling the authorities is practicable.

Sources

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Acknowledgments

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