PLASTIC LANDMINE DETECTION BY THE SLOW WAVE STRUCTURE-BASED SENSOR

Pchelnikov Yu.N.[1], Yelizarov A.A.[2], Shaymardanov R.V.[2]
[1]SloWave Inc.
104, Drexelbrook Ct., Cary, 27519, NC USA
Ph.: (+1 919) 3036212, e-mail: yupchel@gmail.com
[2]Moscow Institute of Electronics and Mathematics, Higher School of Economics (MIEM HSE)
3, Bolshoi Trekhsvyatitelskyi lane, Moscow, 109028, Russian Federation
Ph.: (+7 495) 9168856, e-mail: a.yelizarov@hse.ru

Abstract — A sensor for detecting plastic explosives placed in the ground is presented in this paper. The detection effect is based on the intensive radiation from the section of a slow-wave structure at slowing down less than slowing of the light in the medium, i.e. in the soil at the place of possible laying of the mines. High effectiveness and small dimensions in comparison to the wavelength in free space and possibility of monitoring at a wide frequency band define its significant advantages in comparison to another devices for detecting explosives.

ОБНАРУЖЕНИЕ ПЛАСТИКОВЫХ МИН С ПОМОЩЬЮ ДАТЧИКА НА ЗАМЕДЛЯЮЩЕЙ СИСТЕМЕ

Пчельников Ю. Н.[1], Елизаров А. А.[2], Шаймарданов Р. В.[2]
[1]SloWave Inc.
104, Drexelbrook Ct., Cary, 27519, NC USA
тел.: (+1 919) 3036212, e-mail: yupchel@gmail.com
[2]Московский институт электроники и математики, Высшая школа экономики (МИЭМ ВШЭ)
3, Большой Трехсвятительский пер., Москва, 109028, Россия
тел: (+7 495) 9168856, e-mail: a.yelizarov@hse.ru

Аннотация — Представлен датчик для обнаружения пластиковой взрывчатки, установленной под слоем почвы. Эффект обнаружения основан на интенсивном излучении с поверхности отрезка замедляющей системы в контролируемую среду при замедлением волны меньшем, чем замедление скорости света в среде, т.е. почве на участке предполагаемого залегания мин. Высокая эффективность предлагаемого датчика, малые по сравнению с длиной волны в свободном пространстве размеры и возможность осуществления мониторинга в широкой полосе частот определяют его существенные преимущества по сравнению с известными приборами для обнаружения взрывчатки.

I. Introduction

"Landmines continue to threaten U.S. and allied forces. Conventional mine detection sensors, such as ground penetrating radar (GPR), can give many false alarms due to natural and manmade objects in the ground having mine-like characteristics to these sensors" [1]. This can result in a slow advance rate as the forces must deal with these false alarms. Nuclear Quadrupole Resonance (NQR) developed in Russia can be utilized to detect plastic explosives and drugs [2]. NQR technology developed by the U. S. Army for application to landmine detection can be used to verify the presence of landmines and eliminate false alarms from GPR. Based on the nuclear spectroscopy, this "…technology has the capability to detect and discriminate explosives from other items in the environment and it can discriminate among the different types of explosives found in landmines" [1]. In the same time, the devices for this technology realization are bulky and expensive. It is the objective of this project to demonstrate the possibility of developing for the USA Army novel, cheap, and portable RF (including microwave) method for detecting coverless (plastic) landmines hidden under a ground surface.

II. Main Part

The described in this paper detecting method was offered in the former USSR in the middle of 80's, but its practical realization was interrupted by "perestroika" and it was just patented [3].

The offered method is based on the property of a slow-wave structure (SWS) to radiate electromagnetic energy into electro-dynamically dense medium if the phase velocity v_p of the slowed electromagnetic wave in a SWS exceeds the light velocity in the surrounding medium [4]. The wave is radiated step by step, the radiation intensity and the radiation angle depending on the velocities ratio (figures 1, 2).

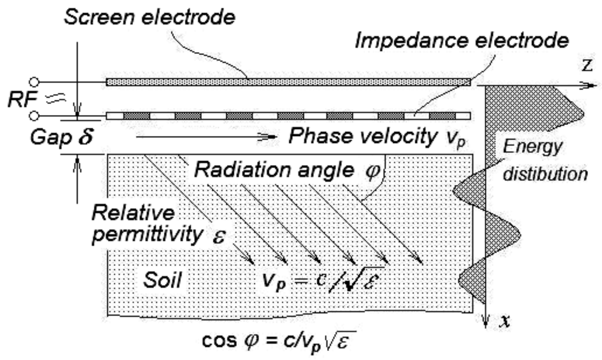

Fig. 1. Radiation in the soil.

Рис. 1. Излучение в почву

The radiation from SWSs differs from the conventional antennas radiation and provides much more operating possibilities.

In the most designs, SWS's are formed by two placed in parallel conductors, so called impedance and

2013 23rd Int. Crimean Conference "Microwave & Telecommunication Technology" (CriMiCo'2013). 9—13 September, Sevastopol, Crimea, Ukraine
 ISBN: 978-966-335-395-1. IEEE Catalog Number: CFP13788

screen conductors, the impedance conductor being formed by transverse conducting elements connected in series by longitudinal conducting elements at a given period or a given pitch. It is well known also that so called "smooth" SWS's (with the pitch or period much smaller than the slowed wave length) do not radiate energy in the surrounding medium with a relatively small density.

Waves excited in SWS's are characterized by concentration of energy near the impedance conductor surface. This means that the wave energy can be directed by this surface along SWS. We shall remind that all components of a slowed electromagnetic wave excited in a SWS are proportional to the "wave factor" $\exp(j\omega t - j\beta z)$, where ω is the angular frequency, t is time, β is the phase constant equal to ω / v_p.

In the case of a plane impedance conductor, the energy concentration in the transverse direction is characterized by the transverse constant γ, related to phase constant β and wave number k as

$$\gamma^2 = \beta^2 - k^2, \;\; k = \omega\sqrt{\varepsilon_0 \mu_0}, \qquad (1)$$

where ε_0 and μ_0 are the permittivity and permeability of free space. In the absence of an external screen, the field components are proportional to $\exp(-\gamma x)$, where x is the transverse coordinate.

It was shown that the angle φ between directions of the slow wave propagation and the radiated wave is defined by next formula [4]:

$$\cos\varphi = \beta / k\sqrt{\varepsilon} = c / v_p \sqrt{\varepsilon}, \qquad (2)$$

where c is the light velocity in free space, ε is the relative permittivity of the adjacent to the SWS medium (soil).

The described above physics of the radiation, which is offered for the military application, had been confirmed not only by the preliminary electro-dynamic analysis but also by its practical realization in microwave radiators for physiotherapy, which required multiple experiments and had been approved for application in medicine (Fig. 2) [6].

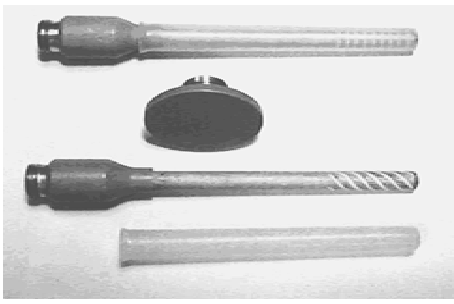

Fig. 2. Radiators for physiotherapy.

Рис. 2. Излучатели для физиотерапии

III. Discussion

According to the offered method, the SWS-based radiator is placed with a relatively small gap in parallel to the controlled object's boundary (surface) forming one, coupled, electro-dynamic structure (Fig. 1, 3). The described effect is caused by the equality of the phase constants in the longitudinal direction (direction of the SWS and the object, soil surface) in such coupled structure. To satisfy this requirement, the propagation constant in the electro-dynamically dense material changes its "imaginary sign" by the real one that leads to appearing of the wave, traveling outside at an angle to the object's boundary. The wave, reminding the "leakage wave" causing unwanted interference between elements of the schematic in the micro-strip lines technology [6]. Unlike it takes place in the mentioned example, the leakage from the SWS is very intensive and is over at a relatively small distance.

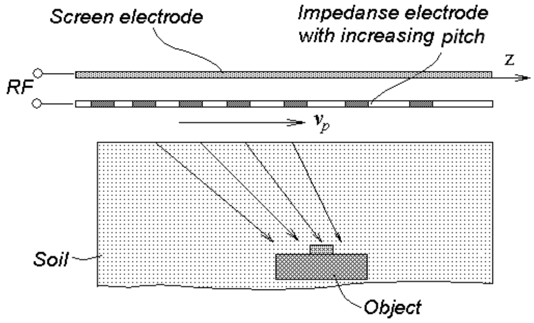

Fig. 3. Radiation from a SWS-radiator with the pitch increasing in the direction of the wave propagation.

Рис. 3. Излучение из датчика на замедляющей системе с увеличением шага в направлении распространения волны

The SWS-based sensor has in comparison to the conventional landmine detectors many advantages, such as much smaller dimensions and much larger sensitivity, absence of energy reflection from the object's surface, existence of a gap to the examined object, possibility to concentrate radiation in a given volume, and possibility to operate simultaneously at different frequencies, including operating with a sweep frequency signal as well as the white noise signal.

IV. Conclusion

The design simplicity, small dimensions, and small weight of the SWS-based radiators provide possibility to operate at relatively low frequencies at wide operating band. Cheapness and the listed above advantages make the development of the offered landmine sensor very promising.

The results used in this study were carried out within the research grant *(No.13-05-0017)* under 'The National Research University Higher School of Economics' Academic Fund Program support in 2013.

V. References

[1] Robert M. Deas*, Constantino Cervantes and Stephen F. Schaedel, Landmine Detection by Nuclear Quadrupole (NQR), US Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate Fort Belvoir, Virginia, 22060-5806. *UK MOD Exchange Scientist from the Defence Science and Technology Laboratory (Dstl).

[2] Grechishkin V. S. NQR Device for Detecting Plastic Explosives, Mines and Drugs. *Appl. Phys. A*, 1992, vol.55, pp.505-507.

[3] *Пчельников Ю. Н.* А.с. 7392265 (СССР). Способ обнаружения неоднородностей и дефектов в диэлектрических материалах. Опубл. в Б.И., 1989. № 21.

[4] Пчельников Ю. Н. Излучение замедленной электромагнитной волны в магнитодиэлектрик. *Радиотехника и электроника,* 1995, Т. 40, №5, с. 532-535.

[5] Oliner A.A. Leakage from higher modes on microstrip line with application to antennas. *International Symposium on Electromagnetic Theory*, Budapest, 1986, vol. 22, pp. 907-912.

[6] Pchelnikov Yu.N., Kholodnyi, V.A. Medical Application of Surface Electromagnetic Waves. *Bioelectrochemistry and Bioelectronics*, 1988, No 47, pp. 238-290.