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Adaptive Kinetic Antenna

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Abstract – **The paper describes a method of kinetic antenna development that can be adapted to environmental conditions. The kinetic antenna is a variety of integrated into impulse generator active antenna that is used for kinetic energy accumulation. Such antennas are attractive for ground penetrating radars owing to its possibility to change radiation spectrum in according with ground properties. The adaptive kinetic antenna design has examined experimentally. It is shown that radiation spectrum can be change considerably for invariable antenna geometry.**

Keywords – **Impulse antenna, Kinetic antenna, Adaptive antenna, Ground Penetrating Radar, GPR, Adaptive GPR.**

I. INTRODUCTION

Adaptive antenna has ability to change his radiation features. Problem of the adaptive antenna realization is connected with presence dependence between antenna's geometrical dimensions and radiated spectrum. That is to change radiated spectrum the antenna's length should be changed. It can be made by placement electronically controlled switcher to gaps of the antenna's arms [1]. Unfortunately this way is considerably difficult in realization and has limitation of radiated power.

We propose to change radiated spectrum by tuning of pulse generator parameters. It is possible to realize if the antenna is a part of the generator. Here we describe adaptive antenna concept based on kinetic energy accumulated structures.

II. KINETIC ANTENNA

It is known that energy transfer from generator to antenna and its transformation to electromagnetic energy can be realized simultaneously and sequentially [2, 3]. Besides energy can be accumulated either primary power supply or antenna itself. A kinetic antenna (KA) – is an antenna with kinetic energy accumulation. The KA allows improving the energy use efficiency since energy accumulates close to antenna terminal.

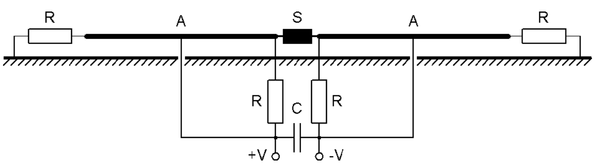

Figure 1. The kinetic antenna structure

The KA consists of radiation pattern forming elements (A), terminal switch (S) and damping circuits (R) (Fig. 1). The KA operation includes sequential processes of kinetic energy accumulation by antenna system, its transformation to electromagnetic energy with impulse radiation and residual energy recuperation to primary power supply.

The switch (S) is normally opened. When the switch closes the antenna current starts flow increasing. Meanwhile the current flows the antenna (A) accumulates kinetic energy. This is kinetic energy accumulation stage. Antenna, switch and energy supply parameters determine time constant of the energy accumulation (1).

$$\tau_a = \frac{L_{tf} + L_f}{R_{tf} + R_f + R_s}, \qquad (1)$$

where

τ_a – energy accumulation time constant;

L_{tf} – inductance of antenna segment between terminal and feeder point;

L_f – feeder inductance;

R_{tf} – resistance of antenna segment between terminal and feeder point;

R_f – feeder resistance;

R_s – switch resistance.

As soon as the antenna (A) accumulates required energy amount, the switch (S) interrupts the current flow. Kinetic energy transforms to potential energy that causes to opposite polarity impulses appearing on the antenna terminals. During kinetic to potential energy transformation an electromagnetic radiation is taken place. This is an impulse radiation stage. Rise time is determined by the antenna inductance and the switch and terminal capacitances (2).

$$\tau_r = \frac{\pi}{2}\sqrt{(L_{tf} + L_f)(C_s + C_t)},$$

(2)

where

τ_r – energy transformation time;

C_s – switch capacitance;

C_t – antenna terminal capacitance.

After the energy transformation completion reverse process begins. Main energy recovers to primary power supply. This is energy recuperation stage. Time constant of energy recuperation is determined by the switch capacitance and antenna inductance (3)

$$\tau_s = \frac{\pi}{2}\sqrt{L_a\,(C_s + C_t)}\,, \qquad (3)$$

where

τ_s – energy recuperation time;

L_a – antenna inductance.

Damping circuits eliminates after-oscillations. Their values are depended by the antenna design.

Point of feeder connection to the KA determines radiated impulse duration. To accumulate kinetic energy high voltage power supply is not necessary. Owing to low active resistance of the circuit strength current can be reached with comparatively low voltage powering. Therefore powerful impulse radiator doesn't require additional power transformation stages. Accumulated energy $\boldsymbol{E}$ is proportional to inductance of antenna segment between terminal and feeder point L_{tf} and current flow through the antenna (4, 5).

$$\mathrm{E} = \frac{1}{2}(L_{tf} + L_f)\,I_{\max}{}^2\,, \qquad (4)$$

$$I_{\max} = \frac{V}{R_{tf} + R_f + R_s}\left[1 - \exp\left(-\frac{\tau}{\tau_a}\right)\right], \qquad (5)$$

where

V – voltage of power supply;

τ – energy accumulation time.

Peak power $\boldsymbol{P}$ in the antenna terminals is proportional to accumulated energy $\boldsymbol{E}$ and energy transformation time τ_r (6).

$$P \approx \frac{E}{\tau_r}\,. \qquad (6)$$

Since energy accumulation duration is lengthy than energy transformation time the antenna to power supply matching requirement is simple enough and feeder line has not special frequency requirements.

One of the possible designs of KA is shown in Fig. 2. Antennas arms form exponentially expanded constant impedance TEM horn. Then arms modify to asymmetrical constant impedance TEM horns that terminates to ground plate. Thus edge effects transfer to another direction. Damping resistors shunt antenna's arms and suppress after-oscillations. Such geometry is able to radiate more low-frequency electromagnetic energy than the antenna aperture designates it.

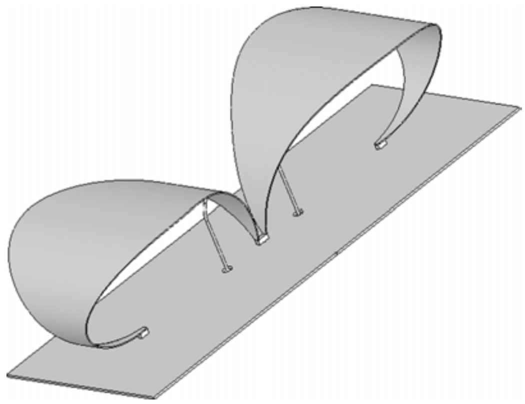

Figure 2. Kinetic antenna design

Proposed method of adaptive antenna design doesn't require special ultra wideband switch circuits. The KA allows separating excitation and generation (radiation) circuits because their spectrums are considerably differ. Besides these processes are separated in time and connect with different parts of the antennas. Excitation current of the KA is relatively low frequency that simplifies switching schematics and reduces influence of spurious parameters.

III. ADAPTIVE KINETIC ANTENNA

Adaptive kinetic antenna (AKA) can be created to adding of several feeder pairs to the KA. Schematic of three-band AKA is shown on Fig. 3.

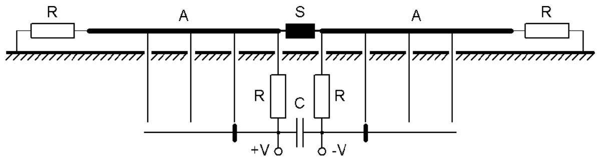

Figure 3. Adaptive kinetic antenna

In according with (1) inductance of antenna segment between terminal and feeder point designates the energy accumulation time constant. Thus controlling the switch open time the same energy for different feeder pairs can be accumulated. In according with (2) changing the antenna inductance influences on a rise time of electromagnetic impulse and radiation bandwidth. Transformation of the KA to AKA is shown in Fig. 4.

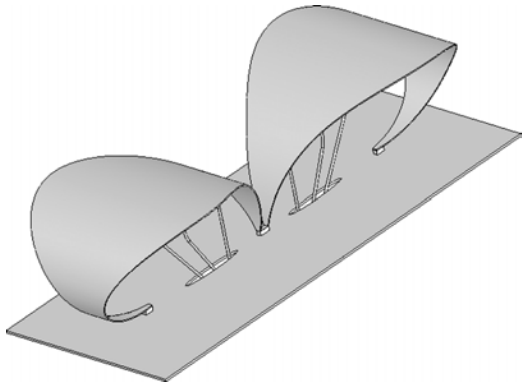

Figure 4. Adaptive kinetic antenna design

IV. AKA-BASED GPR

Media properties determine depth of sounding and achievable accuracy. In order to acquire complete information about survey area several antennas with different central frequency should be used. There are problems connected with topographic tie-in of several GPR data. At the same time AKA-based GPR can acquire some matched radar profiles with different accuracy. Required depth of sounding and accuracy are provided simultaneously.

Besides the AKA-based GPR allows solving of various problems without necessity of antenna replacement. This increase the GPR

V. EXPERIMENTAL RESULTS

To examine the AKA concept we designed and manufactured experimental setup including transmitting and receiving modules, computer and software package. Some of the setup's components are also applied in the VIY-2 ground penetrating radar. However antennas have unique design.

Transmitting module (Fig. 5) includes exponentially expanded constant impedance TEM horn antenna with 2 pairs of feeder contacts, nanosecond pulse generator and power supply. The pairs of feeder contacts are switched manually.

Figure 5. Transmitting module

Receiving module (Fig. 6) includes exponentially expanded constant impedance TEM horn antenna, differential strobe receiver, synchronizer and power supply.

Coaxial cable RG-58 connects receiving module and transmitting modules, and RS-232 communication cable connects synchronizer with computer. Sealed rechargeable lead-acid battery (12V, 7Ah) is used as primary power supply.

Figure 6. Receiving module

The experimental setup is still under examination now.

VI. CONCLUSIONS

The paper describes a method of kinetic antenna development that can be adapted to environmental conditions. The kinetic antenna is a variety of integrated into impulse generator active antenna that is used for kinetic energy accumulation. Such antennas are attractive for ground penetrating radars owing to its possibility to change radiation spectrum in according with ground properties. The adaptive kinetic antenna design has examined experimentally. It is shown that radiation spectrum can be change considerably for invariable antenna geometry.

REFERENCES

[1] A.Yarovoy, "Adaptive Bow-Tie Antenna for Ground Penetrating Radar", Proceedings of 10th International Conference on Ground Penetrating Radar, June 21-24, Delft, The Netherlands, pp. 121-126.

[2] V.P.Prokhorenko, V.E.Ivashchuk and S.V.Korsun, "Ground Penetrating Radar VIY-2", IEEE A&E Systems Magazine, vol. 20, No. 7, July 2005, pp. 16-18.

[3] V.Prokhorenko, V.Ivashchuk and S.Korsun, “Drift Step Recovery Devices Utilization for Electromagnetic Pulse Radiation”, Proceedings of 10th International Conference on Ground Penetrating Radar, June 21-24, Delft, The Netherlands, pp. 195-198.

[4] V.Prokhorenko, V.Ivashchuk and S.Korsun, “Improvement of Electromagnetic Pulse Radiation Efficiency”, Subsurface Sensing and Technology Applications, April 2004.