UDK 621.371: 550.837.6

INTERACTION OF PULSED ELECTROMAGNETIC WAVES WITH ENVIRONMENTS OVER HYDROCARBON DEPOSITS

A. KOCHANOV, V. YANUSHKEVICH
Polotsk State University, Belarus

The article presents the results of the interaction of electromagnetic waves in the mode of pulsed signals with the environments over hydrocarbon deposits. The behavior of the components of the dielectric constant of an anisotropic environment over the reservoir in the mode of pulsed signals based on the quasi-hydrodynamic approach is investigated. An analysis of the constituent components of the dielectric constant of the medium over hydrocarbons for electromagnetic waves with right and left circular polarizations, depending on the pulse frequency.

Introduction. Methods for the search for hydrocarbon deposits are based on the analysis of electrophysical and electrochemical processes in anisotropic environment over hydrocarbon deposits [1 - 4]. Similar studies for plasma-like media make it possible to use existing solutions for studying the interaction of electromagnetic waves (EMW) with hydrocarbon deposits when studying plasma based on the quasi-hydrodynamic approach [5 - 8]. The propagation of radio-pulse signals in the environment above the reservoir can be the basis for many methods of hydrocarbon exploration [9 - 10]. The relevance of the tasks considered in this work is to improve the existing electromagnetic methods of geological exploration and to develop new methods for searching, identifying oil and gas (hydrocarbon) deposits, which are a strategic type of mineral resources. The characteristics of the environment above the reservoir during the propagation of electromagnetic waves with right and left circular polarizations are determined, which increases the information content of the methods of contouring and allocation of hydrocarbon deposits. It is shown that the research results can be used to identify the environment above the deposits by the nature and value of the total and difference components of the dielectric constant of the anisotropic layer.

The interaction of the medium over hydrocarbon deposits with pulsed signals. Consider the process of interaction of EMW with hydrocarbon deposits in the pulse mode of the form:

$$S(f)=\frac{U\cdot\tau_u}{2}\cdot\frac{\sin\frac{(\omega-\omega_0)\cdot\tau_u}{2}}{\frac{(\omega-\omega_0)\cdot\tau_u}{2}}+\frac{\sin\frac{(\omega+\omega_0)\cdot\tau_u}{2}}{\frac{(\omega+\omega_0)\cdot\tau_u}{2}}, \tag{1}$$

Where $\frac{U\cdot\tau_и}{2}$ =1 – amplitude ; $\omega=2\cdot\pi\cdot f$ – frequency ; ω_0 – carrier frequency ; $\tau_и$ – pulse width.

The process of interaction of electromagnetic waves with local switching on the propagation path of radio waves can be represented in the form of an oblique incidence of a plane wave with vertical polarization in a medium with parameters ε_0, μ_0, δ_0 on an infinite surface with anisotropic impedance. This EMW is excited using a portable transmitter that moves along the studied profile.

It is of interest to analyze the frequency characteristics of combinational components.

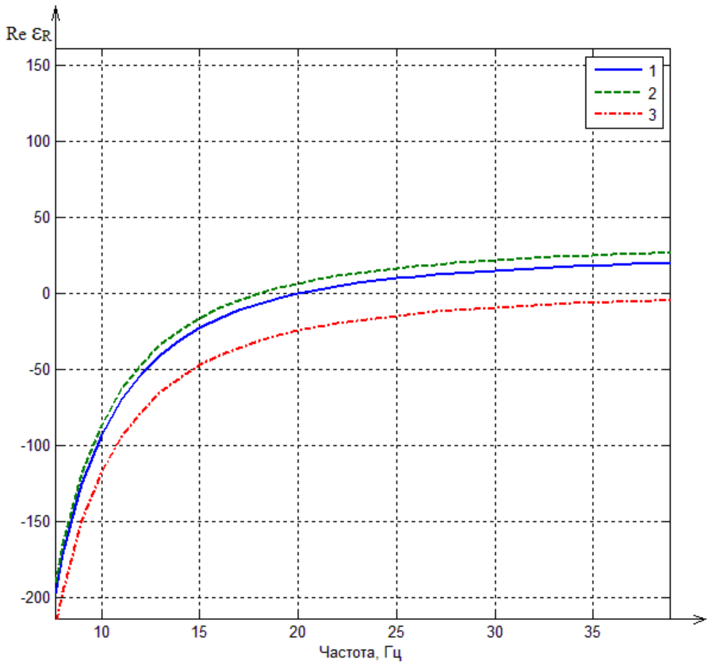
$$\begin{aligned}\dot{\varepsilon}_R(\omega)&=\dot{\varepsilon}_1+\dot{\varepsilon}_2=\operatorname{Re}\varepsilon_R+j\operatorname{Im}\varepsilon_R\\ \dot{\varepsilon}_L(\omega)&=\dot{\varepsilon}_1-\dot{\varepsilon}_2=\operatorname{Re}\varepsilon_L+j\operatorname{Im}\varepsilon_L\end{aligned} \tag{2}$$

The expressions (2) contain matrix elements:

$$\dot{\hat{\varepsilon}}=\begin{bmatrix}\dot{\varepsilon}_1 & -j\dot{\varepsilon}_2 & 0\\ j\dot{\varepsilon}_2 & \dot{\varepsilon}_1 & 0\\ 0 & 0 & \dot{\varepsilon}_3\end{bmatrix}. \tag{3}$$

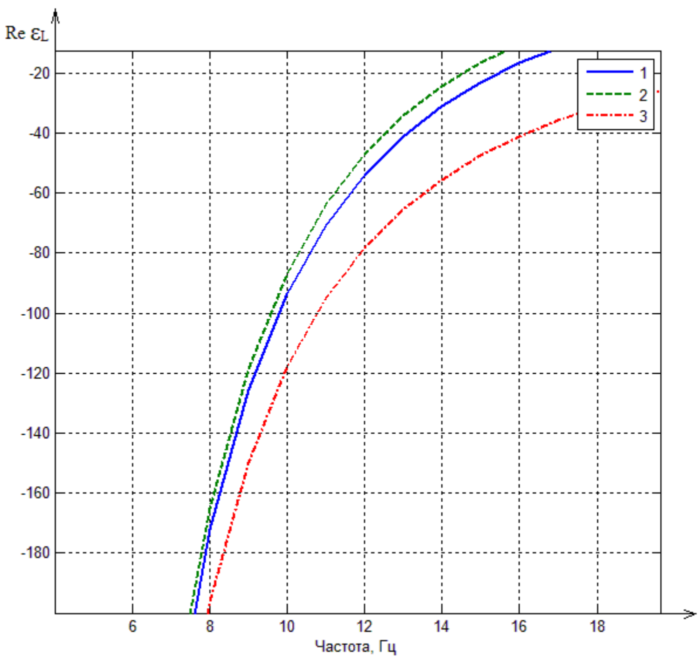
Information on the properties of the anisotropic medium is contained in the components of the tensor (3) $\dot{\varepsilon}_1,\dot{\varepsilon}_2,\dot{\varepsilon}_3$, that are studied in various modes of interaction of the environment with EMW. The calculation of the components of the dielectric constant tensors was carried out on the basis of experimentally obtained parameters of the environment over hydrocarbon deposits [3]: electrical conductivity δ_r =10^{-5} s/m; particle concentration $N_e = N_и$ = ($10^{15} – 10^{17}$) m^{-3}; particle collision frequency $\nu = 2 \cdot \pi \cdot 10^9$ rad / s. The dielectric constant of the environment was studied in the range from 1 to 25. The research technique involves irradiating the profile under investigation with an electromagnetic wave at a fixed frequency, receiving a reflected signal. The electric field strength of the reflected signal is measured at the measurement points of the studied profile, and the boundary of the hydrocarbon deposit is determined from the anomalous values of the electric field strength of the reflected signal.

A frequency analysis of expressions (2) for the combinational components has been carried out (Fig. 1, 2).



P 1 – for εr = 25; 2 – for ε_r = 20; 3 - for ε_r = 2

Figure 1. – Dependencies Re ε_L = ψ (Fi)



1 – for εr = 25; 2 – for ε_r = 20; 3 - for ε_r = 2.

Figure 2. – Dependencies Re ε_L = ψ (Fi)

There was conducted an analysis of the interaction of the anisotropic layer over hydrocarbons with EMW in the mode of radio-pulse signals. The AC dielectric permittivity tensor is derived over hydrocarbon deposits in the mode of radio-pulse signals. The results of the study can be investigated in exploratory geophysics. In this connection, it should be noted:

- AC dielectric permittivity tensor over hydrocarbon deposits in the mode of radio-pulse signals can be used to determine the electrodynamic characteristics of the environment above the reservoir in a wide frequency range of the probed signals when the pulse frequency changes;

- studies can be used to determine the characteristics of the environment over the reservoir during the propagation of EMW with right and left circular polarizations, which increases the information content of the contouring and separation of hydrocarbon deposits.

REFERENCES

1. Гололобов, Д. В. Фазовые методы идентификации углеводородных залежей / Д.В. Гололобов, А.О.Рак, В.Ф.Янушкевич / Инженерный вестник. – Мн. –2001. – №1(20). – С. 16-18.
2. Гололобов, Д.В. Взаимодействие ЧМ-сигналов с анизотропной средой / Д. В. Гололобов, Н. В. Цывис, В. Ф. Янушкевич, С. В. Калинцев, Д. Л. Хадыко / Проблемы проектирования и производства радиоэлектронных средств. Сборник мат-ов 2 межд. научно-техн. конференции 15-17мая 2002г. – Новополоцк, 2002. – С.300-303.
3. Moskvichew, V.N. Interraction of electromagnetic waves (EMW) with anisotropic inclusion in communication line / V.N. Moskvichew // 9-th Microw. Conf. NICON – 91, Rydzyna, May 20-22, 1991. – Vol. 1. – P. 240-244.
4. Levashov, S.P. Electric-resonance sounding method and its application for, geological-geophysical and engineering-geological investigations / S. P. Levashov // 66nd EAGE Conference and Technical Exhibition, Paris, France, 7–10 June 2003 (CD-ROM Abstracts volume).
5. Adamovskiy, E. Simulation of electromagnetic waves interaction with hydrocarbon deposits / E. Adamovskiy, V. Yanushkevich // 8 Junior researchers conference European and national dimension in research. In 3 Parts. – Part 3. TECHNOLOGY. – PSU, Novopolotsk, 2016. – V. 179 – 183.
6. Янушкевич, В.Ф. Взаимодействие электромагнитных волн с анизотропными средами над углеводородными залежами в режиме радиоимпульсных сигналов. / . В.Ф. Янушкевич, К.И. Кременя, М.М. Иванов, Т.В. Молодечкина. Вестник ПГУ. Серия С. Фундаментальные науки. Физика. Новополоцк, 2016. – №12. – С. 45 – 50.
7. Иванова, К.И. Способ геоэлектроразведки углеводородной залежи с использованием радиоимпульсных сигналов. Фундаментальные и прикладные исследования в современном мир / К.И. Иванова, В.Ф. Янушкевич // Материалы XV Международной НТК . 4 октября 2016г.– Том 1. – Санкт – Петербург. – С.107 – 111.
8. Янушкевич, В.Ф. Электромагнитные методы поиска и идентификации углеводородных залежей / В.Ф.Янушкевич. – Новополоцк, ПГУ, 2017. – 232с.
9. Гололобов, Д.В. Электродинамические параметры подводных источников в поле поверхностной электромагнитной волны / Д.В.Гололобов, В.Н. Москвичев, Г.П.Турук, В.Ф.Янушкевич / Тез. докл. 35 Всероссийской Межвузовской НТК. – Владивосток. – 1992. –Т1,ч.1. – С.59 – 62.
10. Янушкевич, В.Ф. Моделирование двухчастотного взаимодействия электромагнитных волн с углеводородной залежью / В.Ф. Янушкевич. Приборы. Справочный журнал. –1999. – №10. – С.27 – 29.