ПОЛОЦКИЙ
ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ

CHARACTERISTICS OF ANISOTROPIC MEDIA OVER HYDROCARBONS IN THE MODE OF FREQUENCY-MODULATED SIGNALS

Viktar F Yanushkevich, Dzmitry A Dauhiala, Tatiana V Maladzechkina, Siarhei V Kalintsau and Vadim A Bogush

Polotsk State University, Belarusian State University of Informatics and Radioelecrtonics.

ПОЛОЦКИЙ
ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ

Abstract

The article considers the impact of frequency-modulated signals on an anisotropic medium over oil and gas deposits. Modeling of the components of the tensors of the dielectric constant of the medium over hydrocarbon deposits was carried out. The characteristics of the medium over accumulations of hydrocarbons for frequency-modulated signals from the frequency of the carrier oscillation, the frequency modulation index for the right and left polarizations of electromagnetic waves are studied. Methods of searching for hydrocarbons based on the variation in the characteristics of the applied signals are recommended. It is proposed to introduce new search modes to improve the accuracy of determining the boundaries of hydrocarbon deposits. The influence pattern of the dielectric constant of an anisotropic medium on the real and phase components of the tensor components are established. The research results can be applied in the electrical exploration of minerals.

We will analyze the effect of FM oscillations of the following type on an anisotropic medium

$$e(t) = E_2 \, cos(\omega_2 t + \beta \, sin \, \omega_1 \, t) \tag{1}$$

where E_2 and $\omega_2 = 2 \cdot \pi \cdot f_2$ - the amplitude and frequency of the carrier signal, respectively;

$\omega_1 = 2 \cdot \pi \cdot f_1$- modulating frequency; $\beta = \frac{\Delta\omega}{\omega_1}$ - modulation index; Δω - frequency deviation.

The dielectric permittivity tensor of the medium over the hydrocarbon deposits for such a mode has the form:

$$\begin{cases} \dot{\varepsilon}_1 = \varepsilon_r(1+\beta\cdot k_\omega \cos\omega_1 t) + \sum\limits_{i=1}^{2} \left\{ \begin{aligned} &\frac{\omega_{\Pi i}^2\widetilde{\omega}_3}{\omega_2}\frac{\omega_{\Gamma i}^2-\widetilde{\omega}_3^2-{\nu_i}^2}{({\nu_i}^2+\omega_{\Gamma i}^2-\widetilde{\omega}_3^2)^2+4\widetilde{\omega}_3^2{\nu_i}^2} - j\left[\frac{\sigma_r}{\omega_2\varepsilon_0}+\right. \\ &\left.+\frac{\omega_{\Pi i}^2\nu_i}{\omega_2}\frac{\widetilde{\omega}_3^2+{\nu_i}^2+\omega_{\Gamma i}^2}{({\nu_i}^2+\omega_{\Gamma i}^2-\widetilde{\omega}_3^2)^2+4\widetilde{\omega}_3^2{\nu_i}^2}\right] \end{aligned} \right\}, \\ \dot{\varepsilon}_2 = \sum\limits_{i=1}^{2} \left\{\frac{\omega_{\Pi i}^2\omega_{\Gamma i}}{\omega_2}\frac{\omega_{\Gamma i}^2-\widetilde{\omega}_3^2+{\nu_i}^2}{({\nu_i}^2+\omega_{\Gamma i}^2-\widetilde{\omega}_3^2)^2+4\widetilde{\omega}_3^2{\nu_i}^2} - \frac{2j\widetilde{\omega}_3\nu_i\omega_{\Pi i}^2\omega_{\Gamma i}}{\left[({\nu_i}^2+\omega_{\Gamma i}^2-\widetilde{\omega}_3^2)^2+4\widetilde{\omega}_3^2{\nu_i}^2\right]\omega_2}\right]\right\}, \\ \dot{\varepsilon}_3 = \varepsilon_r(1+\beta\cdot k_\omega \cos\omega_1 t) + \sum\limits_{i=1}^{2} \left\{\frac{\omega_{\Pi i}^2\widetilde{\omega}_3}{\omega_2}\frac{1}{{\nu_i}^2+\widetilde{\omega}_3^2} - j\left[\frac{\sigma_r}{\omega_2\varepsilon_0}+\frac{\omega_{\Pi i}^2\nu_i}{\omega_2}\frac{1}{\widetilde{\omega}_3^2+{\nu_i}^2}\right]\right\}. \end{cases} \tag{2}$$

$$\widetilde{\omega}_3 = \omega_2\ [1 + \beta \cdot k_\omega\, cos\, \omega_1\, t] \tag{3}$$

$$\dot{\varepsilon}_R = \dot{\varepsilon}_1 + \dot{\varepsilon}_2 = R\dot{e}\,\varepsilon_R + j\,I\dot{m}\,\varepsilon_R \tag{4}$$

$$\dot{\varepsilon}_L = \dot{\varepsilon}_1 - \dot{\varepsilon}_2 = R\dot{e}\,\varepsilon_L + j\,I\dot{m}\,\varepsilon_L.$$

$$\omega_{\Pi i} = q_i \left(\frac{N_i}{m_i \varepsilon_0}\right)^{\frac{1}{2}} \tag{5}$$

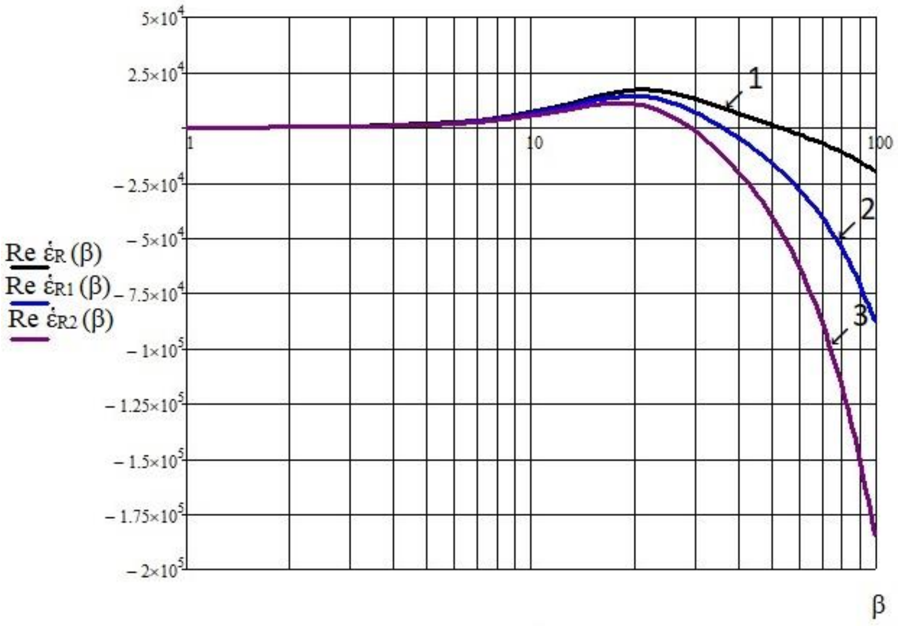

Figure 1 - Dependences of the real component of the permittivity on the modulation index for the right polarization of the EMW at $f_2 = 10^4$ Hz:
1 – Re $\dot{\varepsilon}_R(\beta)$, $\varepsilon_r = 3$; 2 – Re $\dot{\varepsilon}_{R1}(\beta)$, $\varepsilon_r = 10$; 3 – Re $\dot{\varepsilon}_{R2}(\beta)$, $\varepsilon_r = 20$

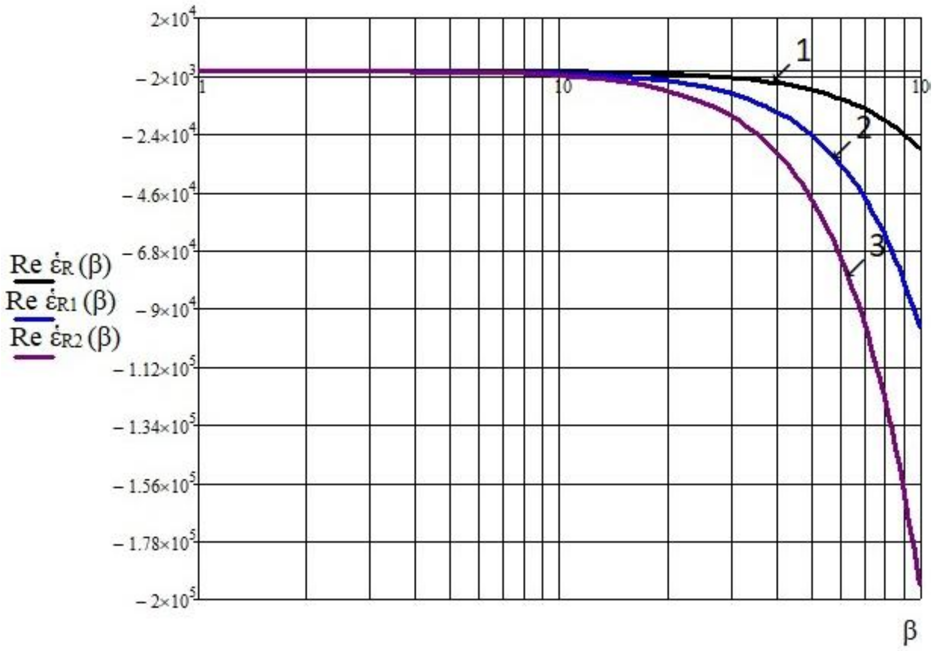

Figure 2 - Dependences of the real component of the permittivity on the modulation index for the right polarization of EMW at $f_2 = 10^7$ Hz:
1 – Re $\dot{\varepsilon}_R(\beta)$, $\varepsilon_r = 3$; 2 – Re $\dot{\varepsilon}_{R1}(\beta)$, $\varepsilon_r = 10$; 3 – Re $\dot{\varepsilon}_{R2}(\beta)$, $\varepsilon_r = 20$

Conclusion

The analysis of the interaction of FM signals with anisotropic media above hydrocarbons deposits showed:

- the range of modulation indices β = 10 - 100 is characterized by a sharp change in the material components of the permittivity for the right and left polarizations of the EMV with a transition point through zero at β = 30 - 50;

– the patterns of change in the phase components of the dielectric permittivity tensor of the medium over hydrocarbons are the same as for real components.