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Results of experimental studies of geologic profile over hydrocarbon deposits

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Abstract. The article presents the results of experimental studies of geologic profile over hydrocarbon deposits in the Republic of Belarus. Experimental studies were carried out at the Marmovichi and the Geologicheskoye fields of hydrocarbon deposits in the Gomel region. Measurement of the phase of the surface impedance of the geological profile over hydrocarbon deposits under the influence of electromagnetic waves with amplitude-frequency modulation was carried out. It has been found that the use of two modes for measuring the phase of surface impedance increases the accuracy of delineation of hydrocarbon deposits. A method at carrier frequencies of 0.1...2 GHz for amplitude-frequency modulated signals has been developed. The above studies can be applied to the development of methods for exploration of hydrocarbon deposits.

1 Introduction

The relevance of hydrocarbon deposits prospecting methods is caused by the increased needs of electrical exploration for the accuracy of hydrocarbon delineation [1]. At the same time, a great role is given to the interpretation of soil distribution, fault mapping and obtaining information on rock characteristics [2]. Studies have been carried out to determine the rate of surface uplift under the influence of steam-assisted gravity drainage (SAGD) at the Hangingstone oil sands deposits in Alberta (Canada) using interferograms of synthetic aperture radar (SAR) [3].

The modes of application of two-frequency electromagnetic waves increase the accuracy of hydrocarbon boundary identification to determine the reflecting characteristics of the geological profile over hydrocarbon deposits [4]. The results of the monotonous function method showed fairly high estimates of the probability of determining possible deposits at sufficiently low error probabilities [5]. The cases of reservoir studies by methods and methodology of SPFB detection are considered [6].

At present, marine electromagnetic methods are rapidly developing with the industrial introduction of equipment for the study of offshore hydrocarbon facilities [7]. The dynamics of displacement of crustal structures in the area of a large oil field under development is being studied [8]. Modern methods and algorithms for processing space,

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geological-geophysical and geochemical information are one example of improving the accuracy of hydrocarbon boundary delineation [9]. The opportunities and results of practical use of satellite radar imagery and interferometry in geological exploration for oil and gas are presented in the paper [10].

The analysis of the possibilities of using the radar interferometry method is given for quantitative assessment of the rates of modern relief-forming processes [11]. The complexity and high cost of obtaining geological and geophysical information by traditional methods in hard-to-reach areas where hydrocarbons are prospected and produced increases the importance of remote data acquisition technologies [12].

The purpose of this research is to develop a method for prospecting hydrocarbon deposits.

2 Materials and methods

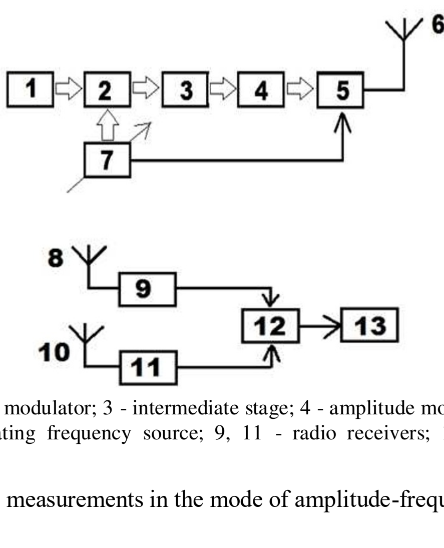
Experimental studies of the surface impedance of the medium above the hydrocarbon deposits in the mode of amplitude-frequency-modulated signals (AFM) [1] with the use of a system for the realization of phase measurements (Figure 1) were carried out. The use of this type of interaction of signals with hydrocarbon deposits will increase the informativeness of prospecting and identification methods.

With the help of device 12 and phasemeter 13 phase shifts are determined:

$$\Delta\varphi_1 = \varphi^1{}_{z11} - \varphi^2{}_{z11} \tag{1}$$

$$\Delta\varphi_2 = \varphi^1{}_{z12} - \varphi^2{}_{z12} \tag{2}$$

Where $\Delta\varphi_1$, $\Delta\varphi_2$ - phase differences of the surface impedance for 1 and 2 channels, respectively; $\varphi^1{}_{z11}$, $\varphi^2{}_{z11}$ – phases of the surface impedance for the components of the AFM signal along the x and y axes for the right circular polarization; $\varphi^1{}_{z12}$, $\varphi^2{}_{z12}$ – phases of the surface impedance for the components of the AFM signal along the x and y axes for the left circular polarization.



1 - signal source; 2 - frequency modulator; 3 - intermediate stage; 4 - amplitude modulator; 5 - power amplifier; 6, 8, 10 - antennas; 7 - modulating frequency source; 9, 11 - radio receivers; 12 - comparison device; 13 - phasemeter.

Fig. 1. Equipment for phase measurements in the mode of amplitude-frequency modulated signals.

3 Results and Discussion

The proposed method was tested at the Marmovichi and the Geologicheskoye fields of the hydrocarbon deposits in the Gomel region. When one point (Figure 2) of phase determination (mode 2) is located on the deposit boundary and the second one - behind the deposit (measurement point 250 for the Marmovichi field), the phase $\dot{Z}_{11}$ decreases from the value of 2.0 rad (carrier signal frequency f = 100 MHz) to the value of - 0.3 rad (carrier signal frequency f = 700 MHz) and changes to 0 rad (carrier signal frequency f = 1000 MHz). At carrier signal frequencies f = 1500 - 2000 MHz there is a decrease in the phase $\dot{Z}_{11}$ to a value of - 0.2 rad. According to the anomalous values of the phase $\dot{Z}_{11}$, the boundary of the hydrocarbon deposits was fixed. In the case of finding both determination points (mode 1) behind the deposit, the phases differ in two channels with a maximum of 0.3 rad (carrier signal frequency f = 100 MHz). In the case of both determination points (mode 3) above the hydrocarbon deposits, phase differences are observed in two channels with a maximum of 0.5 rad (carrier signal frequency f = 100 MHz).

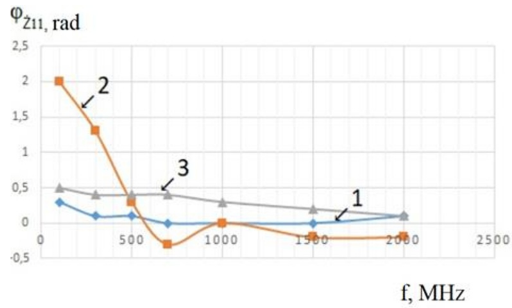


Fig. 2. Results of $\dot{Z}_{11}$ phase studies for the Marmovichi field: 1 - mode 1, 2 - mode 2, 3 - mode 3.

When one point (Figure 3) of phase determination (mode 2) is located on the deposit boundary and the second one - behind the deposit (measurement point 250 for the Marmovichi field), the phase $\dot{Z}_{12}$ decreases from 0.3 rad (carrier signal frequency f = 100 MHz) to 0.1 rad (carrier signal frequency f = 2000 MHz). According to the anomalous values of the $\dot{Z}_{12}$ phase, the boundary of the hydrocarbon deposits was fixed. In the case of finding both points of determination (mode 1) behind the deposit, the phases differ in two channels with a maximum of 0.3 rad (carrier signal frequency f = 500 MHz). When both determination points (mode 3) are located above the hydrocarbon deposits, phase differences are observed in two channels with the presence of both negative and positive phase differences.

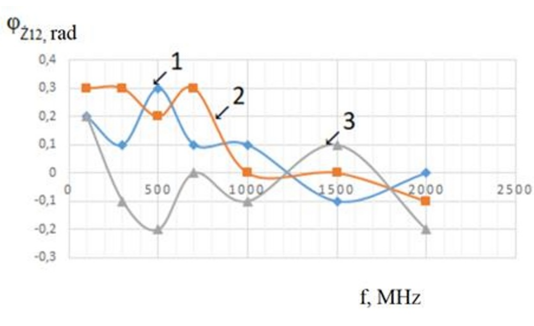


Fig. 3. Results of $\dot{Z}_{12}$ phase studies for the Marmovichi field: 1 - mode 1, 2 - mode 2, 3 - mode 3.

When one point (Figure 4) of phase determination (mode 2) is located at the deposit boundary and the second one - behind the deposit (measurement point 200 for the Geological Field), the phase $\dot{Z}_{11}$ decreases from the value of 1.7 rad (carrier signal frequency f = 100 MHz) to the value of 0 rad (carrier signal frequency f = 1000 MHz) and with an increase to 0.1 rad (carrier signal frequency f = 1500 MHz). At the carrier signal frequency f = 2000 MHz there is a decrease in the phase component $\dot{Z}_{11}$ from a value of -0.1 rad. By the anomalous values of the phase $\dot{Z}_{11}$, the boundary of the hydrocarbon deposits was fixed. In the case of finding both determination points (mode 1) behind the deposit, the phases differ in two channels with maxima of 0.3 rad (carrier signal frequencies f = 100, 300 MHz). In the case of finding both points of determination (mode 3) above the hydrocarbon deposits, phase differences are observed in two channels with a maximum of 0.5 rad (carrier signal frequencies f = 100, 300 MHz).

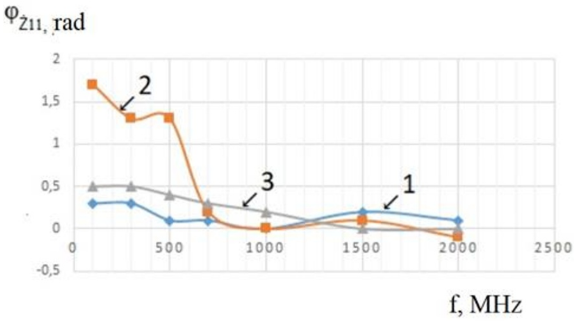


Fig. 4. Results of $\dot{Z}_{11}$ phase studies for the Geological Field: 1 - mode 1, 2 - mode 2, 3 - mode 3.

When one point (Figure 5) of phase determination (mode 2) is located at the deposit boundary and the second one - behind the deposit (measurement point 200 for the Geological Field), the phase Ż12 decreases from the value of 0.3 rad (carrier signal frequencies f = 100, 300 MHz) to the value of 0 rad (carrier signal frequencies f = 1000 - 2000 MHz). According to the anomalous values of the $\dot{Z}_{12}$ phase, the boundary of the hydrocarbon deposits was fixed. In case of finding both determination points (mode 1) behind the deposit, the phases differ in two channels with maxima of 0.2 rad (carrier signal frequencies f = 100, 300, 2000 MHz). In the case of both determination points (mode 3) above the hydrocarbons, the phase differences are observed in two channels with maxima of 0.3 rad (carrier signal frequencies f = 100, 300 MHz).

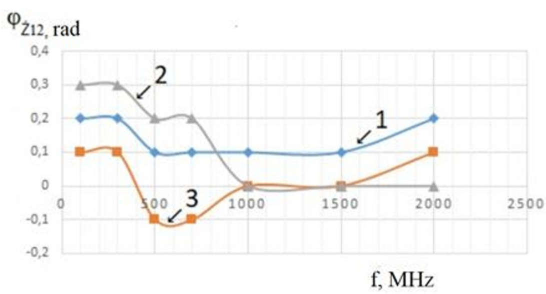


Fig. 5. Results of $\dot{Z}_{12}$ phase studies for the Geological Field: 1 - mode 1, 2 - mode 2, 3 - mode 3.

The measurement data of $\dot{Z}_{11}$ and $\dot{Z}_{12}$ phases of the surface impedance are given at modulation frequency F = 10 MHz, amplitude modulation factor k_m = 0.5 and frequency modulation index β = 20.

4 Conclusion

As a result of the conducted research it should be noted:

- The equipment for realization of phase measurements in the mode of amplitude-frequency modulated signals at carrier frequencies of 0.1...2 GHz has been developed.
- Application of two modes of surface impedance phase measurement increases the accuracy of delineation of hydrocarbon deposits.
- The results of the research can be applied in the electrical prospecting of hydrocarbon deposits.

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