MODULATION OF THE MICROWAVE RADIATION BY INFLUENCE OF WEAK REFLECTED POWER

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In (1) it was shown that the weak frequency broad signal reflected from the plasma object affects and modulates the high power gyrotron radiation spectrum. In given report are presented the results of model experiments with modulation of reflected microwave radiation on sonic and ultrasonic frequency. It was obtained, that an oscillating metal membrane can efficiently be used to modulate of the microwave reflected radiation on the sonic and ultrasonic frequency interval from a few kHz up to 30 kHz. The phase of the modulation depth was no less, than (3-5)%.

Earlier the modulation of the gyrotron power and the change in its mean value under the action of reflected power of gyrotron radiation from plasma object in relatively broad frequency interval has been found experimentally at low values of the reflection coefficient (-0.001)[1]. The observed effect can be attributed to the resonant frequency locking of gyrotron oscillations by the waves that arise from the scattering of gyrotron radiation by plasma fluctuations, propagate backward, and arrive at the gyrotron output window.

These results permit to consider the possibility of gyrotron radiation modulation on the separated frequencies by using of the corresponding low power signal reflected from chosen object, for example, - the metallic membrane vibrating on sonic and ultrasonic frequencies.

In this report the results of model experiment on modulation of reflected low power are presented. The experimental scheme using an oscillating metal membrane based on the phase modulation of microwave radiation due to the interference (mixing) of two signals, one of which is reflected from the oscillating membrane described above and another one (the reference signal), from a fixed reflector with a variable reflection coefficient was proposed. In the regime of homogeneous reception, the low frequency (LF) modulation signal can be separated out from the mixed signal. Then, from the ratio between the amplitudes of the LF and microwave signals, the modulation depth can be determined. The modulation depth is determined by the phase difference $\Delta\varphi$ between the reference microwave signal and the signal reflected from the membrane. The value of $\Delta\varphi$, which depends on the amplitude of the membrane oscillations, can be estimated by the formula $\Delta\varphi = 2\pi\Delta z/\lambda_0$, where λ_0 is the wavelength of microwave radiation. For $\lambda_0 = 4$ mm ($f_0 = 75$ GHz) and $\Delta z = 60\ \mu$, we obtain $\Delta\varphi/2\pi = 3\times10^{-2}$. Hence, it can be expected that the modulation depth will be no less than 3%. This scheme was chosen by us as a basic one by carrying out experiments in the regime of "cold" measurements with the use of low-power microwave radiation. We marked that the experiment described in the present report should be considered, first of all, as a demonstration of the possibility of using a metal membrane oscillating at an ultrasonic frequency to modulate the reflected microwave signal.

Figure 1 presents the block-diagram of the experimental stand that was used to perform the above measurements. The stand consists of the following components:

(1) a microwave generator with an output power of $P_0 \approx 10$ mW, operating at a frequency in the range $f_0 = 60$–80 GHz (for the given series of experiments, the working frequency was chosen to be 75 GHz);

(2) a ferrite isolator;

(3) a rectangular waveguide with a horn antenna, a NO-4-30 directional coupler (3 db/30 db) for receiving the reflected signals, and an NO-4-05 directional coupler (4 db/5 db) for receiving the incident radiation signal;

(4) detectors;

(5) Teflon lens with a focal length of $L_f = 158.4$ mm and diameter of $D = 100$ mm;

(6) dielectric reflector with a variable reflection coefficient (two mica plates with a variable distance between them);

(7) magnetostriction antenna with a membrane oscillating at an ultrasonic frequency in the range $f_s = 21$–23 kHz with the maximum amplitude $\Delta z \approx 60$–70 μ;

(8) ultrasonic generator ($P_s \approx 600$ W at $f_s = 21$ kHz);

(9) unit for receiving and recording the microwave and LF signals in the regime of homogeneous reception. The unit consists of an amplifier (with an amplification factor of 100 and a bandwidth of 0–1.4 MHz), a low-frequency RC filter (with an upper boundary frequency of $f_{RC} \approx 3$ kHz), and an analog-to-digital converter (with a digitizing interval down to 40 ns).

After choosing the optimal distances among the antenna horn, lens, reflector, and membrane; adjusting the system; and optimizing the ratio between the reference and reflected signals, we performed a series of measurements including

(i) the maximization of the ultrasonic generator power P_s and, accordingly, the amplitude of membrane oscillations Δz;

(ii) the recording of the LF modulation signal as a function of P_s in the continues-wave mode of microwave generation;

(iii) the determination of the modulation depth as a function of P_s in the pulse-periodic mode of microwave generation; and

(iv) the obtaining of the Fourier spectrum of the LF modulation signal as a function of P_s.

The results of the measurements are presented in Figs. 2–4. Figure 2 shows the LF modulation signals measured in the regime of homogeneous reception of microwave radiation for three values of the ultrasonic generator power P_s (the relative values of P_s are indicated in the figures). A comparison of Figs. 2a and 2c, shows that a twofold decrease in P_s leads to a decrease in the amplitude of the modulation signal by a factor of 1.5.

From the signal shown in Fig. 3, we can determine the modulation depth of the microwave signal. This depth amounts to 4–6% and can be varied by varying the amplitude of ultrasonic oscillations.

Figure 4 shows the Fourier spectra of the modulation signal for two values of the ultrasonic generator power P_s. It can be seen that the main line at the frequency 21-kHz is rather narrow (the full width at half-maximum is $\Delta f \approx 0.5$ kHz). Besides the line at the fundamental frequency, the spectrum contains the second-harmonic line, with the amplitude of one lower by a factor of about 20.

The obtained results have demonstrated that the proposed method for mechanically modulating the reflected microwave radiation with the help of a metal membrane oscillating at an ultrasonic frequency can be successfully implemented in practice. Thus, the method proposed can be used in experiments with high-power gyrotrons (with P_0 of up to several hundred kilowatts) and can be considered like alternative one to the electronic modulation using high voltage variation. A specific feature of experiments with high-power gyrotron radiation is that only a fraction of the main radiation is to be tapped for the modulation and, then, returned back to the gyrotron.

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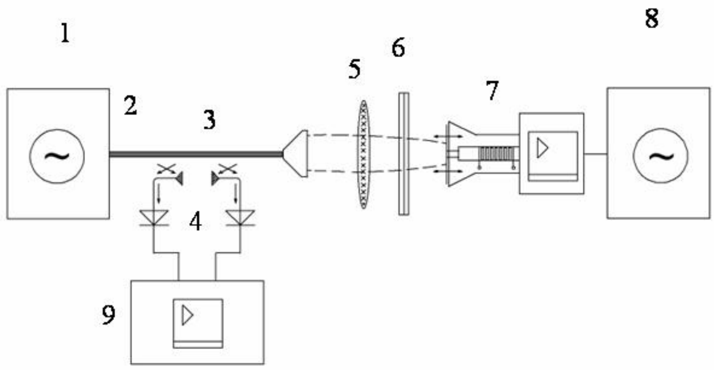

Fig.1. Block-diagram of the experimental stand.

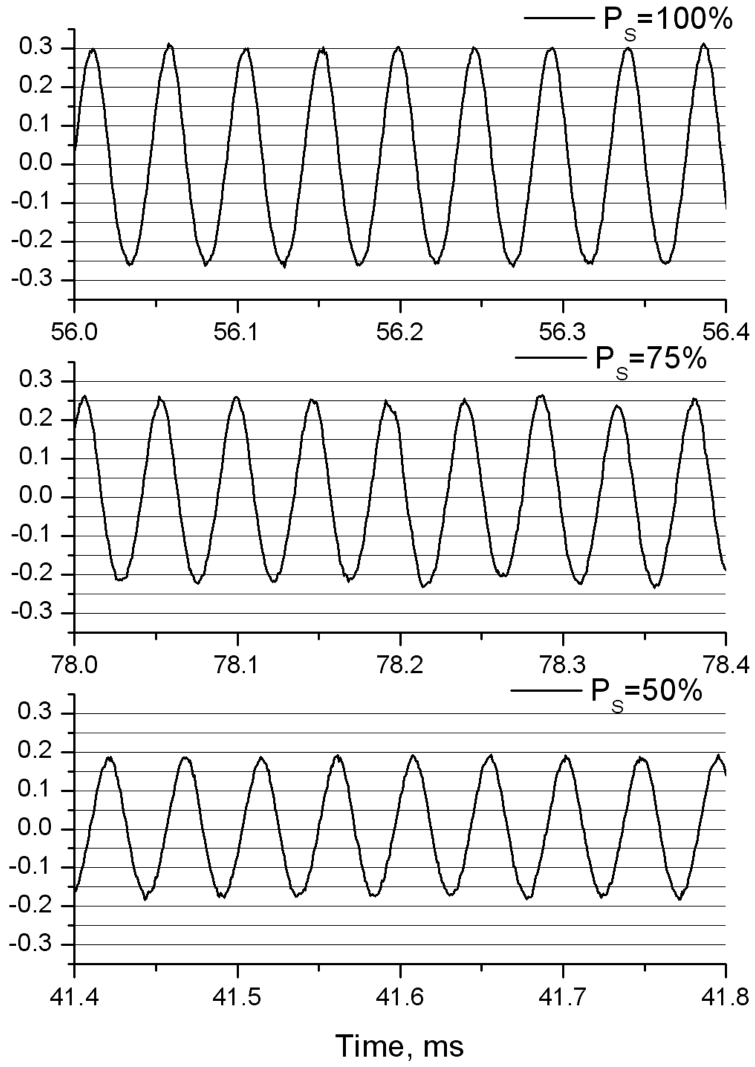

Fig.2. LF modulation signal at a frequency of f_s = 21 kHz for three values of the ultrasonic generator power P_s.

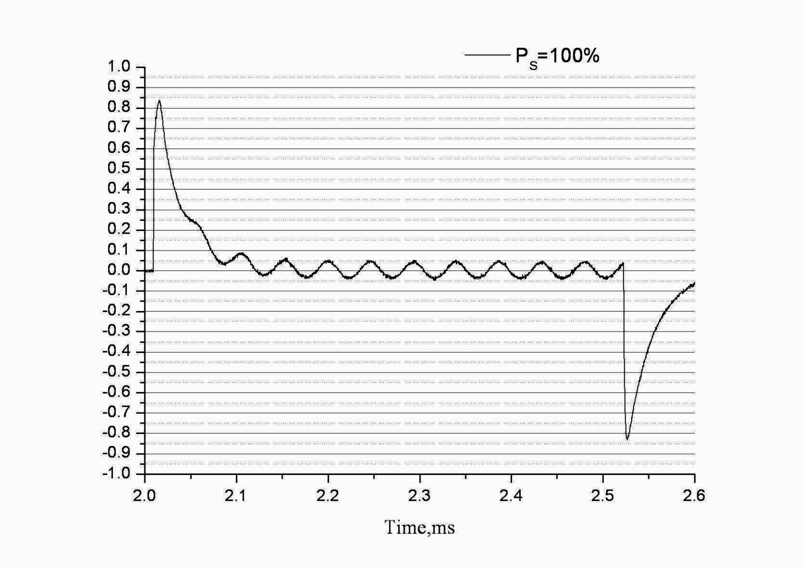

Fig.3. Microwave signal measured in the pulse-periodic mode of microwave generation (the LF filter is switched off).

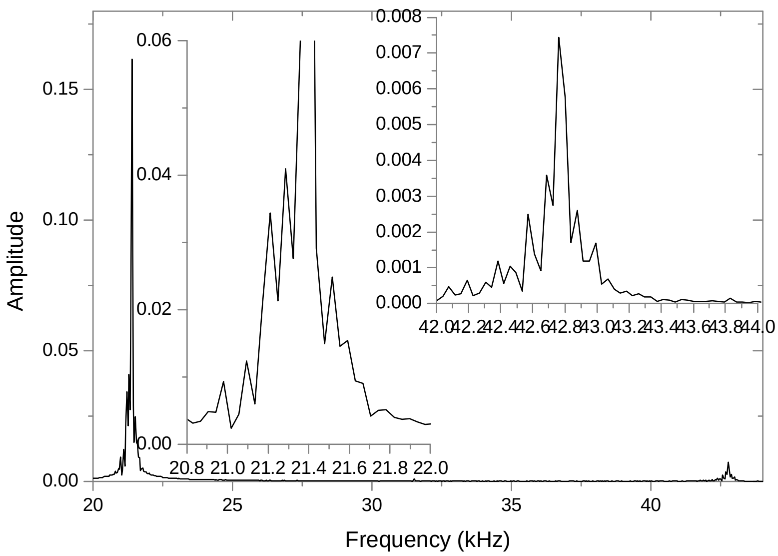

Fig.4. Fourier spectra of the LF modulation