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MICROWAVE RADIATION IN THE ELECTRICAL EXPLOSION OF CONDUCTORS

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The wide use of electrical explosions of conductors (EEC) in science and engineering [1, 2] is making it necessary to develop new experimental methods of diagnosing the accompanying physical processes (shock waves, pulses of electromagnetic radiation, etc.). The microwave (MW) method has recently been intensively studied in connection with this need, since the propagation of microwave radiation (MWR) in various media has been the subject of much research and since the method provides accurate and reliable information. Knowledge gained thus far from studies of the main mechanisms responsible for the generation of electromagnetic radiation in low-temperature plasmas makes it possible to solve inverse problems which establish the main parameters characterizing the formation of plasmas by unsteady sources from the characteristics of recorded electromagnetic radiation [3].

For example, data on the recording of electromagnetic radiation in EEC within the optical and infrared ranges was presented in [4].

Use of the MW method to diagnose impulsive plasma processes in EEC requires the use of low-inertia radiometers. In connection with this, we developed a compensation-type wide-band radiometer [5] for an 8-mm wavelength (working frequency 36 Hz, band width $\sim 2\%$ of the working frequency) to record 10^{-6}-10^{-3} sec pulses of MW radiation. Decay time ranges from 10^{-7} to 10^{-4} sec, which allows recording of the time dependence of the spectral intensity of the MWR.

Here, we report experimental data obtained on this dependence for MWR from the electrical explosion of wires and contacting metallic surfaces.

Copper wires 0.15 mm in diameter were electrically exploded with an initial supply voltage of 5 kV. The capacitance of the capacitor that discharged onto the wire was 2 μF. The distance from the edge of the waveguide of the radiometer to the wire was 3 cm. Figure 1 shows the experimental setup. The dashed lines outline components containing either (a) the wire 2 or (b) a hard-alloy electrode 3 and a steel plate 4. The MWR 1 from the electrical explosion of the conductor was recorded by a radiometer. The signal from the latter was then sent to a separate system for analysis. Figures 2 and 3 show signals recorded by the radiometer in the explosion of wires with lengths of 1 and 2 cm, respectively. Maximum MWR intensity in Figs. 2 and 3 corresponded to an antenna temperature ~ 180 kK.

Analysis of the resulting signals leads to the conclusion that they represent electromagnetic radiation from a discharge current, the maximum intensity of the MWR corresponding to the highest rate of current change. It is evident from Figs. 2 and 3 that the MWR from the explosion itself is separate from the MWR from the discharge associated with the radiation pause — which coincides roughly with the time of the current pause [1]. The earlier pulse is the MWR current flowing in the still-intact wire and starts the radiometer, which is operating in the slave mode. Figure 2 shows the amplitude of this pulse to be greater than the amplitude of the pulse in Fig. 3. The first pulse is larger because of the lower resistance and inductance of the wire in this case, the parameters of the leading edge of the discharge-current pulse being determined mainly by the electrical parameters of the wire. There is then a break in the current, since the resistance of the discharge gap increases sharply with vaporization of the wire. After the pause, the products of the exploded wire undergo electrical breakdown and a second MWR pulse is generated. It should be noted that shielding of the input to the waveguide channel of the radiometer caused a reduction in the signal by a factor of more than three, which indicates that the useful signal was stronger than the stray current by the same factor.

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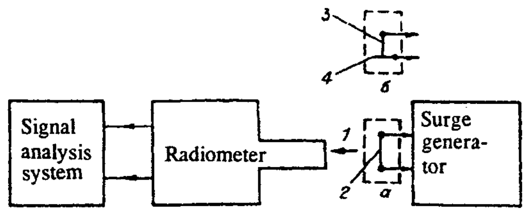

Fig. 1

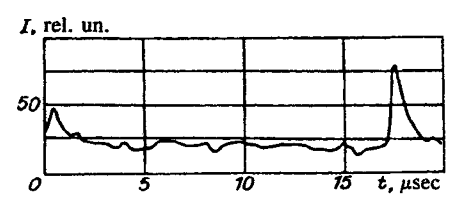

Fig. 2

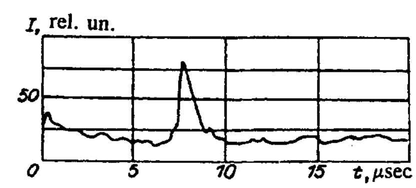

Fig. 3

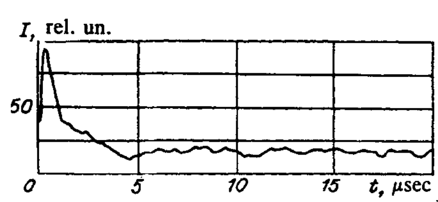

Fig. 4

The electrical explosion of contacting metallic surfaces was initiated by a high-voltage discharge between an electrode of a hard alloy based on tungsten carbide and a steel surface. The initial supply voltage was 1.5 kV, while the capacitance of the capacitor battery was 1800 μF. The distance from the edge of the waveguide of the radiometer to the electrode was ~20 cm.

Figure 4 shows the dependence of the spectral intensity I of the MWR on time for the conditions realized in the experiment. With shielding of the waveguide channel, the maximum signal decreased roughly threefold. This again indicates that useful signal was approximately three times stronger than the stray current. The maximum value of antenna temperature in Fig. 4 was 210 kK. We believe that, as in the first case, the recorded signal is the MWR from the discharge current. This conclusion is based on the fact that a MWR pulse formed in the discharge of a plasma should be longer and less intense. The amplitude–time characteristics of the spectral intensity of the MWR can be used to evaluate the parameters of the discharge current. In particular, the width of the MWR pulse characterizes the rise time of the current, while the MWR maximum coincides with the moment at which the rate of current increase is maximal. We should note here that a second MWR pulse is not generated in the electrical explosion of the contact — unlike the case of the exploding wire. This difference is probably connected with the fact that there is sufficient time for the explosion products that are formed to condense on the electrodes, which prevents a repeat breakdown from occcurring.

Thus, the results presented above show that relatively powerful electromagnetic radiation is generated within the microwave range as well in EEC. With an increase in the sensitivity of the radiometer, it would be possible to record the MWR of the plasma that is formed. This would in turn make it possible to determine the dependence of the temperature of the plasma on time.

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