NEW DEVICES FOR PROCESSING OF POWERFUL SHORT– DURATION SINGLE MICROWAVE PULSES

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ABSTRACT

The problem of measuring of the single MW radiopulse parameters is actual. In this report new devices for processing of such signals based on the excitation and propagation surface or bulk acoustic waves (SAW and BAW) in nonlinear crystals are described.

INTRODUCTION

Presently, the problem of measuring of the electric and magnetic field intensities of high – power single microwave radiowave pulses which are generated by relativistic electronic devices [1]– [3], is extremely difficult. Available methods based on the use of magnetoresistive, semiconductor and other elements exhibit a number of shortcomings which are mainly due to a poor noise immunity and a strong distortion of the field structure being measured. The amplitude of an output signal must not be smaller than 200-300 V for good resolution on the background of low – frequency radio interference at a microwave power of 0.1–1.0 GW. The value of 200–300 V is unattainable for most familiar intensity meters. The only intensity meter exhibiting high output signal amplitude is the sensor on p–germanium using hot charge carriers. However, a substantially higher power is needed to operate this device which is ensured using a wide-flare-angle horn. Thus the measured characteristic is the integral over its area for this case.

The meters for measuring the electric and magnetic field of single microwave pulses having a new principle of operation is presented in this paper.

The measurement of the carrier frequency of described pulses is also an urgent problem.The available methods based on the use of a system of filters, heterodyne reception or dispersive delay lines have a number of shortcomings. The system of filters (a set of cutoff waveguides or of MW resonators and acoustooptical spectrum analyzers) permit one to assess only the amplitude spectrum of a signal. As for the phase spectrum, information about it is lost resulting in the characteristics of frequency – modulated radio – wave pulses to be not measurable. Furthermore, the resonators' system is incapable of measuring the frequency of a radio – wave pulse whose duration is comparable to or less than the time of oscillation transition to a steady state in a separate resonator. Finally, the above frequency meters offer poor noiseimmunity against the low – frequency impulse radiointerference that is attendant on a radio – wave pulse while operating with MW relativistic electron beam generators [1]– [3].

The exception is provided by the heterodyne method that employs a semiconductor hot – carrier – charge mixer. However, this method is in successful operation only at a high input power (> 1 GW).

As for dispersive delay lines, for example, those on magnetostatic waves (MSW) and surface acoustic waves (SAW), they are unsuitable for analyzing signals whose frequency modulation follows a law being not known beforehand. Moreover, the frequency range of these delay lines is restricted from above: it is 3–5 GHz and 1–2 GHz for the MSW and SAW, respectively.

A new meter for measuring the carrier frequency of single microwave pulses free above disadvantages is presented in this paper.

At last a high level radiofrequency radio interference propagating outside the waveguide prevents an analysis the pulse envelope by conventional detectors. The new electroacoustic detector for receipting of such

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pulses is also described in this paper.

MEASURING THE ELECTRIC FIELD STRENGTH

A meter for measuring the electric field of single microwave pulses having a new principle of operation is presented (Fig.1).

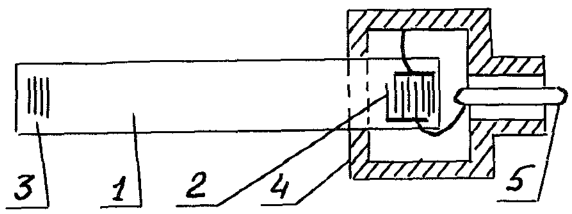

Fig. 1.

This meter presents a SAW delay line consisting of two transducers. The former transducer 3 is nonlinear in the field and can be implemented in two different ways. The first way is deposition of the metal strips system on the surface of electrostrictive or nonlinear piezoelectric substrate. Thus, the surface areas, which remain uncovered with the metal, form the regions of SAW excitation. In the second way, a film coating made of electrostrictive or nonlinear piezoelectric strips is deposited on the dielectric substrate. By affecting such a transducer with the microwave pulsed field, mechanical deformation takes place which varies as the square of the field strength. As a result, the mechanical deformation contains harmonic components of both the radiowave pulse envelope and the doubled carrier frequency radiowave pulse. The doubled carrier frequency radiowave pulses exhibit high attenuation and do not contribute practically into the operation of the device. The harmonic components of radiowave pulse envelope lie, usually, in a range to 200 MHz where the attenuation of elastic waves is small.

The second transducer 2 (Fig.1) is a conventional interdigital system on a linear piezoelectric substrate 1. With the nonlinear transducer placed in the microwave electric field, a low-frequency acoustic pulse is excited which is received by the linear transducer. The output signal amplitude seems to be related to the peak electric field strength. A meter under study exhibits a better pulse low-frequency noise immunity since the output signal has a time delay which is defined by a spacing between the transducers.

Using a simple theoretical analysis of the meter's operation, we could optimize the geometry of the transducer to operate in a specified range of pulse durations.

The sensitive element of the sensor was made based on the Y-cut lithium niobate plate. To decrease feed through, the output interdigital transducer was placed in the metal screening box 4. The signal from the output coaxial line 5 was recorded by the storage oscillograph.

The measurements were carried out on a relativistic microwave generator of the ubitron type with the pulse parameters: power 4-5 MW, duration 500 ns, wave length 3.9 cm. The measuring element was placed into a microwave electric field and its output was connected with the storage oscillograph.

With a microwave radio pulse applied, a series of delayed acoustic signals are excited in the plate (Fig.2). The first pulse ($7\mu s$ delay time) corresponds to the BAW 1, the second ($13\mu s$) to the SAW 2; the following pulses are multiply reflected acoustic signals. The duration of these signals was $0.1 - 0.2\mu s$ at a carrier frequency of 100 MHz. The experiments which were carried out on a transducer placed into the rectangular waveguide showed that the transducer responds only to a tangential component of electric field (with respect to the surface of the transducer). Calibration of the sensor readings was performed with the help of the known gas method.

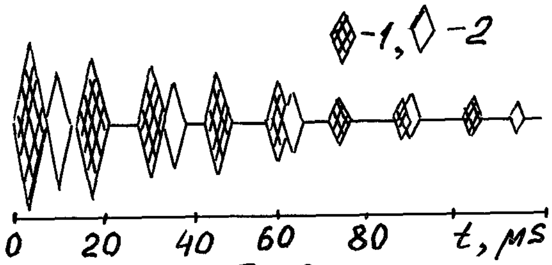

Fig. 2.

The calibrated curves for the sensor under study are depicted in Fig.3 (1-BAW, 2-SAW), i.e. the amplitude

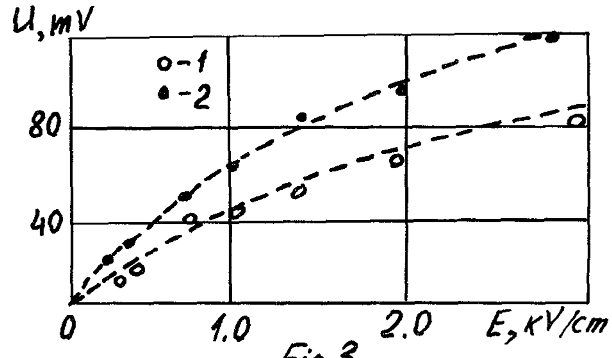

Fig. 3.

of the output electric signal versus the strength of MW electric field as the duration of input pulse is 500 ns. Using this dependence one may find the electric field strength by the measured output pulse amplitude and the duration of the input signal T. When $T \neq 500$ ns the scale in the ordinate is to be increased by the ratio $T/500$ ns.

MEASURING THE MAGNETIC FIELD STRENGTH

The schematic of the sensor and its principle of operation are similar to that of the electric field sensor (Fig.1).In this case the acoustic line was composed of a GGG plate 1. The SAW exciting transducer 3 was a system of YIG strips with a thickness of 10 mkm and a period of 10 mkm fabricated by photolithography. The receiving interdigital transducer 2 was placed in a metal shield and was connected to a coaxial output.

The measurements were performed on a relativistic MW generator of 3 – cm band. The sensor was fit along the narrow wall of a rectangular waveguide of size 23 $\times$ 10 mm^2 with a receiving horn and a short – circuit plunger connected at its one and another side, respectively. As the MW power was applied two series of delayed radiowave pulses arised at the sensor output which exhibited a carrying frequency of 40 MHz. One series was for BAWs and the other for SAWs.

The position of an active part of the sensor with respect to the waveguide testifies that the normal components of MW magnetic field were a source of acoustic waves. For lack of the methods for calibrating the MW magnetic sensors the sensitivity was estimated as follows. First, the peak value of the electric field strength was measured. Then reasoning from the condition of electric and magnetic energies being equal $\varepsilon E = \mu H$ the strength of magnetic field was determined. The sensitivity of the sensor was assessed by a measured amplitude of the output signal. It proved to be 1.2 $\times$ 10^{-2} V/Oe.

MEASURING THE CARRIER FREQUENCY

The approach was realized for the microwave band by using, as a transversal filter, a wide – band ($\Delta f/f \sim$ 30%) acoustic delay line (ADL) on BAW that operates under the conditions of multiple reflection. The ADL waveguides were acoustically uniform neither in attenuation nor in velocity; their reflecting edges were slightly fringe – counted and near – parallel (the edges are parallel only to within 15"). Such delay line can be represented as in – parallel – connected acoustic channels with different weight coefficients and delay times, i.e., as a transversal filter. The function of an oscillation divider and a summer was performed by a piezoelectric transducer for the ADL operating in the "reflection" mode or two transducers for the "transit" mode. The multiple acoustic signal reflections by imperfectly flat reflecting edges of the wave – guide, its static inhomogeneity and diffraction divergence resulted in a strong distortion of the original flat phase front (at the BAW length as long as 1-2 mkm) and a greater echo – pulse amplitude dependence on frequency. Fig.4 presents the typical echo – pulse oscillograms at the output of an ADL operating in the 3 cm wavelength band for various carrier frequencies. One may conclude the envelope of the first 4-6 echo – pulses to be an exact and unique frequency portrait of the input signal. This is confirmed in Fig.5 where two echo-pulse series are indicated which are superimposed and differ in frequency by 0.5%. The amplitudes of echo – pulses are seen to substantially differ.

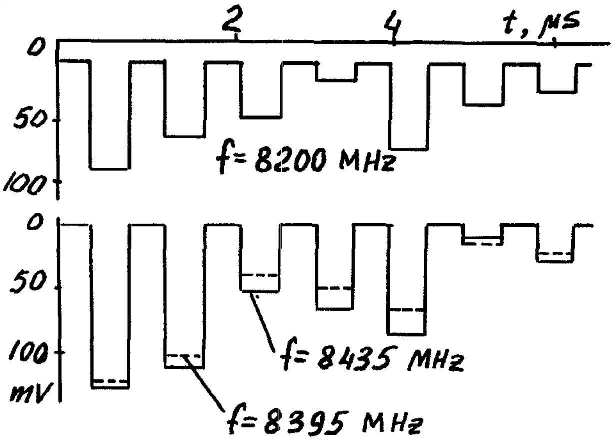

Fig. 4.

Relying on investigation performed in the recurring mode, a measuring complex have been developed and fabricated to determine the carrier frequency of single short – duration MW radio – wave pulses under the conditions of strong impulse radiointerference. The complex consists of wide – band BAW ADLs, transistor amplifiers and detectors operating in different subbands and, as combined, covering an operating frequency band as wide as 2.5-10.5 GHz. The errors of frequency measurement within the 2.5-7.5 GHz and 7.5-10.5 GHz bands were smaller than ±1% and ±0.25%, respectively.

By application of this complex, various operating conditions were examined for relativistic electron beam MW generators including carsinotron, magnetron, vircator and others. In Fig.5, the measurement results are displayed which are most representative of the potentials of the frequency meter developed. Fig.5a shows the echo – pulse oscillogram for a typical two – peak envelope of the instantaneous power of a MW radio – wave pulse with the 30-35 ns duration. The shape of the echo – pulse seems to be independent of its number. This means the absence of frequency modulation, i.e., the carrier frequency is constant along the pulse in spite of its two – peak behavior.

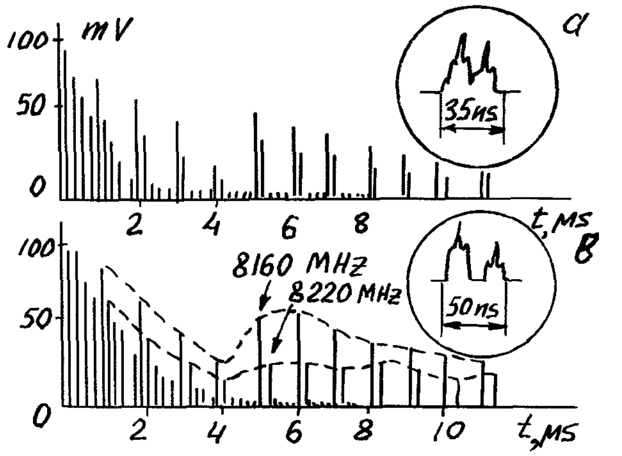

Fig. 5.

One of the most interesting operating conditions for relativistic electron beam devices is generation of single series of two or three and more closely spaced short – duration MW radio – wave pulses. Unlike the known methods, our method allows us to measure the carrier frequency inside a radio – wave pulse. Fig.5b is a typical oscillogram of echo – pulses corresponding to a double radio – wave pulse from the output of the relativistic magnetron. It is seen that the amplitude envelopes for two echo – pulse series diverge due to different frequencies. These frequencies proved to be 8160 and 8220 MHz, i.e., the difference constitutes 60 MHz for a measurement error of ±25 MHz. A low – frequency impulse radiointerference of 1.5 ms duration is also visible at the scan origin of Fig.5 that hindered the reception of useful signal. Hence, the measurements were carried out on the echo-pulses with the numbers > 4.

Any series fraction consisting of 4-6 echo – pulses can, obviously, be adopted for measurements. For example, under the conditions of impulse interference arising at the scan origin, one is able to carry out the measurements on the third or fourth echo – pulse that exhibits a great delay. In this situation, more convenient is to normalize the calibration curves to the power of the 3 -d or 4 -th echo – pulse, respectively. To lessen the BAW attenuation loss in the waveguide, the ADL may be allowed to cool to the boiling point of liquid nitrogen.

ACOUSTIC DETECTOR FOR HIGH – POWER MW RADIOWAVE PULSES

As mentioned, a great interest is the development of a unit that enables the information about the radiowave pulse envelope to be extracted and simultaneously be retarded for a time required to substantially low the interference level. This unit is an acoustical detector for high – power single or rarely recurring MW radiowave pulses (Fig.6). The MW electric field of a radiowave pulse propagating through the rectangular waveguide 1 transmits through the electrostrictive film (plate) 2 and excites an acoustic signal proportional to D^2 in the acoustic line 3. This signal, due to square – law detection, should comprise a videopulse corresponding to the envelope of the input signal and a MW radiowave pulse with a doubled carrier frequency. The last – named signal due to a great attenuation takes practically no part in the unit's operation. The acoustic pulse with the spectral components, lying conventionally in a band to 200 MHz, can be delayed for few 10 μsec and transduced to an electric videosignal by the broadband transducer 4.

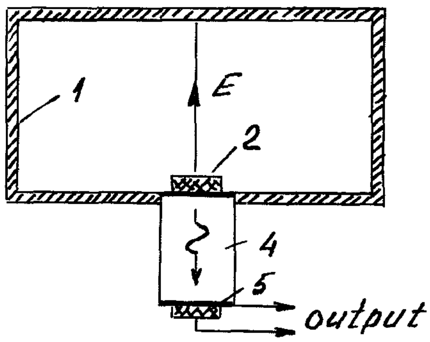

Fig. 6.

We considered the influence of transmission band on the deformation of the input signal. The required relative transmission band must be equal $(1-50)/T$ where T is the pulse duration. In the acoustic line there no distortions since there is no dispersion and attenuation is small.

References

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