X-Band Nanosecond Microwave Gunn Generator

A.I. Klimov, V.P. Gubanov, O.B. Kovalchuk, V.Yu. Konev, and V.V. Rostov

Institute of High Current Electronics SB RAS, 2/3, Academicichesky ave., Tomsk, 634055, Russia
Phone: +7 (3822) 491-991, Fax: +7 (3822) 491-991, E-mail: klimov@fe.hcei.tsc.ru

Abstract – A solid-state oscillator capable of producing nanosecond X-band microwave pulses of 40-W peak power is described. The oscillator can be used for calibration of microwave detectors, for measuring characteristics of microwave units of various devices, and as a transmitter in nanosecond radar investigations.

1. Introduction

The sources of nanosecond X-band microwave pulses with peak powers of tens of watts [1] allow one to measure characteristics of the waveguide and antenna units of high power microwave generators [2] and calibrate detectors of nanosecond pulsed microwaves [3]. These devices can also be used in short-range radar systems allowing high space resolution [4].

2. Design of the oscillator

The oscillator uses a type 3A762 Gunn diode for the oscillating diode. The design of the oscillator microwave unit is shown schematically in Figure 1. Oscillating diode (7) is mounted in the end part of screw (2) inside resonator chamber (4) of cross-section 23 × 10 mm. A pulsed voltage is applied to the diode through microwave filter (10). The carrier frequency is finely tuned with screw (6) of waveguide resonator (3). Coarse tuning is provided by displacing the oscillating diode normally to the wide wall of the waveguide with screw 2, which is fixed with female screw (3). The oscillator microwave unit as a whole is similar in design to that used in our previous work [1]. However, the design of the oscillating diode mounting unit and that of the diode displacement unit were modified to provide finer and more precise tuning of the carrier frequency. A decoupling circulator is connected to the oscillator output, which is designed to be connected to the standard waveguide of 23 × 10 mm cross-section.

A pulser whose design and performance are better compared to those of its predecessor [1] is used for the pulse power supply of the oscillating diode. The pulser produces electrical pulses of amplitude ~ 100 V and duration ~ 10 ns. The function diagram of the pulser is shown in Figure 2 and its basic circuit is described in detail elsewhere [5].

The basic circuit includes a sync pulse former, the modulator, and the power supply of the modulator. These units are mounted in a common case together with the oscillator microwave unit. The basic unit of the sync pulse former is an EPM7064ATC44-10 complex programmable logic device that makes the pulser capable to operate either in the auto or in the ext triggering mode at a pulse repetition rate of 5 kHz.

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high-frequency transistor connects the strip line to the Gunn diode via limiting resistors of total resistance 28 Ohm. The amplitude and waveform of the oscillating diode voltage are matched for each diode specimen by fitting the diode circuit resistors and capacitors. The microwave pulse carrier frequency is set by using a 3A762 Gunn diode of suitable type (A, B, …) and tuning the diode resonator chamber and the waveguide resonator.

3. Characteristics of the oscillator

Figure 3 shows the detected microwave pulse waveform obtained with a 3A762D diode. It was measured with a TDS5104B oscilloscope and a waveguide detector based on a 6D16D vacuum thermionic tube diode [6] operated in the square-low detection mode.

The peak power of the microwave pulse (40 W) was determined from the average power measured by an M3-22A power meter taking into account the pulse length (9.6 ns) and shape and the pulse repetition rate. The pulse amplitude and length were stable to within 0.6 and 1%, respectively.

The spectral characteristics of the oscillator radiation were measured with the use of the heterodyne circuit described elsewhere [6]. The circuit included a standard G4-83 oscillator used as a heterodyne, a waveguide directional coupler with a coupling coefficient of 30.6 dB, waveguide directors and attenuators, and an X-band waveguide detector from the U3-29 amplifier kit that was used as a diode mixer. The heterodyne frequency was tuned to 9.5 GHz. The fast Fourier transform option of the above-mentioned digital oscilloscope was used to process the intermediate frequency (IF) signal and to determine the microwave signal spectrum. Figure 4 shows the IF signal and its spectrum plotted on a linear scale.

The frequency that corresponded to the maximum of the measured spectral curve was 10 GHz. The 0.707-level width of the main lobe of the spectrum was found to be 110 MHz. In view of the above-mentioned microwave pulse width, this points to high coherency of the microwave oscillation.

A set of 30 IF signal waveforms was used to estimate the microwave oscillation period deviation during a pulse. Six oscillation periods in a pulse were considered, and each period was averaged over all 30 waveforms. The root-mean-square error of the estimation was 0.6 to 3.2%. The estimated average period deviation during the main part of the pulse duration was not above 0.6% and, probably, was determined by the measurement error. A reliable increase of the estimates was observed only for the first and for the last period (near the pulse front and near the tail, respectively). The respective values were 3.5 and 5.5%.

Additional measurements of the spectral characteristics were fulfilled with the use of the above-mentioned detector and a waveguide band pass tunable filter [7] whose pass band width was 40 MHz. The detected signal amplitude was measured as a function of the central frequency $f$ of the filter pass band to estimate the pulse-to-pulse jitter $\delta f$ of the oscillator carrier frequency. The filter was tuned from...
the maximum microwave frequency to the frequency that corresponded to the maximum slope \((dU/df)\) of the spectral curve. The carrier frequency jitter was estimated by the formula \(\delta f = \delta U/(dU/df)\), where \(\delta U\) is the amplitude jitter of the detected signal corresponding to the filter detuning. The standard deviation of the central frequency of the oscillator microwave spectrum estimated from the measurements was no more than 0.5 MHz (0.005%).

The appearance of the oscillator is shown in Fig. 5.

References


