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Class E Microwave Amplifier Built on a SiC Transistor with High On-State Resistance

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Abstract—Theoretical and experimental investigations of a wide-band microstrip-design class E amplifier on a SiC MESFET have been performed with due regard for the transistor on-state resistance. The efficiency versus passband relationships obtained by experiments are in good agreement with the results of theoretical calculation.

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The use of transistors based on wide-band-gap semiconductors (SiC and GaN) open up fresh opportunities in the semiconductor microwave electronics. Their high breakdown voltage and high heat dissipation capability make it possible to increase the output power. Low output capacitance and a high value of the load resistance enable us to build wide-band matching circuits and extend the frequency range of power amplifiers (PA). The first commercially available SiC transistors were CRF24010 and CRF24060 products developed by Cree Inc for the frequencies up to 2.5 GHz with the output power of 10 and 60 W, respectively. A two-stage linear PA for the frequency range of 0.01–2.4 GHz was implemented [1]. Its output power amounted to 5 W at the supply voltage of 40 V applied to the CRF24010 transistor of the output stage. Paper [2] presented the design of a wide-band linear one-stage PA built on the same transistor. In the frequency range 0.8–2.5 GHz its output power amounted to 8.5–12.5 W at the supply voltage of 48 V.

A CRF24060 SiC transistor was employed in the class E HF PA for the frequency of 145 MHz [3]. In class E amplifiers the efficiency tends toward 100% due to its operation in the switch mode and elimination of the switching losses [4]. The main source of losses is the transistor on-state resistance R_{on} and ohmic resistances of passive elements. The employed transistor CRF24060 has $R_{\text{on}} = 0.6\ \Omega$ (while according to paper [5] for transistor CRF24010 this value is up to 14.7 Ω). At the supply voltage of 30 V the output power amounted to 20.5 W, while the efficiency was 96.8%. However a significant output capacitance of transistor CRF24060 will not allow us to implement on its basis a class E power amplifier for frequency above 450 MHz due to the dependence of the class E cutoff frequency on the shunt capacitance [4].

The construction of class E power amplifier with an extended frequency range was examined in papers [6, 7], paper [7] describes a PA built on CRF24010 transistor for operation in the range 0.8–1.07 GHz. For the purpose of obtaining a higher efficiency in the class E microwave PA built on such transistors the present paper studied the effect of R_{on} on the efficiency by considering an example of the class E microwave amplifier for the frequency range of 520–620 MHz.

CLASS E MICROWAVE PA BUILT ON CRF24010 SiC TRANSISTOR

Dimensions of lumped elements operating in the microwave band become comparable with the wave-length that is why it is preferable to implement the load impedance required in class E amplifiers by using the output circuit built on striplines [4, 6]. A multiresonant matching circuit was applied using open loops for frequencies of three harmonics of the input signal [6, 8, 9]. In the operating band the impedance changes between the optimal values, while in the band of the second and third harmonics its value is much higher than in the operating band ensuring on these harmonics the capacitive impedance at the switch (transistor) commensurable with the load impedance. On the basic frequency the matching circuit produced the following impedances at the transistor drain (with due regard for parasitic components of the package and chip) at frequencies 500 MHz and 600 MHz: $Z_{500} = 44 + j54\ \Omega$ and $Z_{600} = 36 + j47\ \Omega$.