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High Efficiency Waveguide-Planar Amplifier with Spatial Power Combining for Frequency Range 31-39 GHz

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Abstract—The article presents the development results of the hybrid-integrated waveguide-planar amplifier circuit for 8-mm wave range with spatial power combining. Affordable and inexpensive low-noise UMS CHA2494-QEC integrated amplifiers are used in the developed circuit. To improve the efficiency of power combining, new longitudinal probe transition designs from a rectangular waveguide to a coplanar strip line (CSL), and to a microstrip line (MSL), whose dimensions do not exceed $0.4\lambda_0$, are proposed. As a result of the amplifier electromagnetic system development, a high efficiency of power combining has been achieved up to $\eta \approx 85\%$. The paper presents the experimental results of phase-shift keyed signals transmission through the developed amplifier with a signal level that is slightly lower than the level of 1 dB gain compression. On the basis of the proposed model, the amplifier degradation was also theoretically investigated for various failure modes of one of its active elements.

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INTRODUCTION

Increasing the power of monolithic and hybrid-integrated circuits of the millimeter-wave amplifiers is an urgent problem and a lot of attention is paid to an appropriate solution. One of the effective ways to solve this problem is the spatial power combining, which eliminates losses for such systems with a tree structure [1–4].

Usually, it is necessary to solve the task of obtaining power of the order of tens to hundreds of watts. For this purpose, these devices include a significant number of active elements. However, spatial power combiners (SPC) can be useful as structural elements and in low-power circuits. For example, in the transceivers of the millimeter range communication systems, SPC can be used as a base oscillator amplifier for frequency converters or as a transmitter output amplifier, where the output power is of the order of 15–20 dBm.

In this case, the spatial power combiner must meet a number of special requirements, the main of which are completely planar structure, maximum efficiency of power combining, broadband and minimum cost.

The main purpose of this work is to create a hybrid-integrated waveguide-planar circuit (HIC) of the 8-mm wave range amplifier with spatial power combining that meets the stated earlier requirements.

1. ELECTROMAGNETIC SYSTEM OF AMPLIFIER HIC WITH SPC

A coplanar strip-line (CSL) with weak couplings is the electromagnetic basis of the amplifier proposed in this work. The coupling coefficient is determined as

$$k = \frac{2|\beta_e - \beta_o|}{\beta_e + \beta_o},$$

where β_e, β_o are phase constants of even and odd wave types. The value of k did not exceed the value of 0.03.

Unlike [3], where the active part of the amplifier's HIC is also a CSL, to excite CSL from a standard rectangular waveguide we did not use smooth transitions with intermediate fin-line sections. Instead we

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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