C-X Band 14W Power Amplifier Having Flat Gain and Power Response

Mitsuru Mochizuki, Yasushi Itoh, Masaki Kohno*,
Hiroyuki Masuno**, and Tadashi Takagi

Electro-Optics & Microwave Systems Laboratory
Mitsubishi Electric Corporation
5-1-1 Ofuna, Kamakura, Kanagawa, 247 Japan

Abstract

A 5 to 10GHz 14W high power amplifier has been developed. It utilizes a multisection maximally flat impedance transformer whose length is designed to become a quarter wavelength at the highest frequency of the design band to achieve flat gain and flat power response over a wide bandwidth. With the use of this transformer, the amplifier has achieved a linear gain of 7±1dB, a 1dB compressed power of 41.5±0.8dBm, and a power-added efficiency of greater than 25% over 5 to 10GHz.

Introduction

In microwave communication and measurement systems, traveling-wave tubes (TWTs) are being replaced by solid state power amplifiers (SSPAs) because SSPAs have several advantages over TWTs including small size, light weight, and high reliability. In the design of SSPAs, a quarter-wavelength impedance transformer[1] has been used as an impedance matching and transforming network. The conventional high power amplifiers have chosen the length of an impedance transformer to a quarter wavelength at the center frequency of the design band[2],[3]. However, this design method provides a serious problem when applied to the design of wideband high power amplifiers. The gain and power decease drastically at the highest frequency of the design band because a perfect match is obtained only at the center frequency of the design band. In addition, the gain and power of FETs decrease monotonously as the frequency increases. To overcome this problem, we employed a design method to utilize a multisection maximally flat impedance transformer whose length is chosen to a quarter wavelength at the highest frequency of the design band. The feature of this design is in that flat gain and flat power can be obtained by optimizing the number of sections of the input and output impedance transformers to compensate for the frequency-dependent gain and power slopes.

*Kita-Itami Works, Mitsubishi Electric Corporation, 4-1 Mizuhara, Itami, Hyogo, 664 Japan

**Communications Equipment Works, Mitsubishi Electric Corporation, 1-1, Tsukaguchi-Honmachi 8-Chome, Amagasaki, Hyogo, 661 Japan

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Circuit design

Fig.1 shows a schematic diagram of the 5 to 10GHz high power amplifier. In order to achieve a

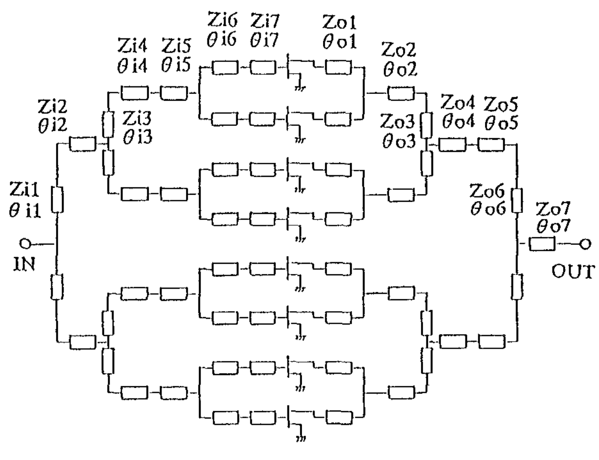

Fig.1. Schematic diagram of the C-X band amplifier.

linear gain of 8dB and a 1dB compressed power of greater than 40dBm over 5 to 10GHz, eight GaAs FETs with a gate periphery of 5.25mm were combined in parallel. The input and output matching networks employ a multisection impedance transformer whose length is chosen to a quarter wavelength at 10GHz to achieve flat gain and flat power of the amplifier. Fig.2 shows a simplified schematic diagram of the multisection quarter-wave impedance transformer where θ is the electrical length, Z_O and Z_L are the source and load impedance, and N is the number of sections.

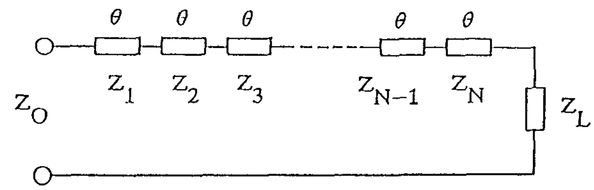

Fig.2. Schematic diagram of multisection impedance transformer.

To achieve flat gain and flat power of the amplifier, the reflection coefficient of impedance transformers is required not to show any ripples as the frequency changes. Thus a maximally flat impedance transformer is employed. The number of sections (N) of the input and output impedance transformers was determined by using the following approach. First, for a flat power of the amplifier, the number of sections of the output matching network is determined to compensate for the frequency-dependent power characteristics of FETs based on load-pull measurements. Second, for a flat gain of the amplifier, the number of sections of the input matching network is determined to compensate for the frequency-dependent gain characteristics of FETs based on small-signal S-parameter measurements. In this case, the output matching network is fixed. In the design of impedance transformers, Z_O is 50Ω and Z_L is assumed to be real and positive. For the input matching network, the value of Z_L was determined to the sum of the gate resistance (R_g), the gate-to-source resistance (R_i), and the source resistance (R_s) of eight GaAs FETs with a gate periphery of 5.25mm whose small-signal equivalent circuit is shown in Fig.3. For the output

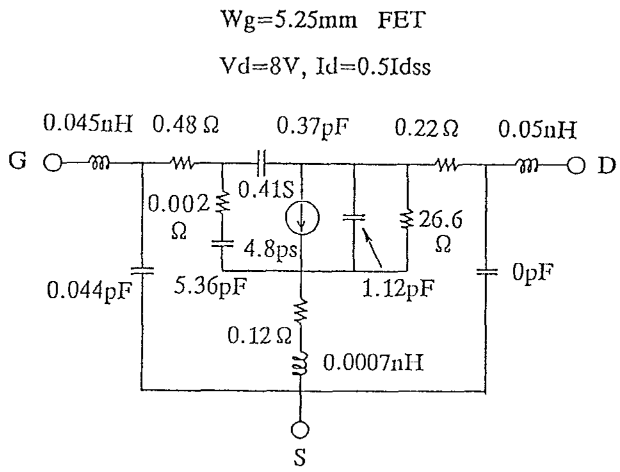

Fig.3. Small-signal equivalent circuit of the 5.25mm FET.

matching network, the value of Z_L has to be determined to the large-signal drain-to-source resistance (R_{ds}) of eight GaAs FETs with a gate periphery of 5.25mm to obtain high power. Fig.4 shows a set of load-pull contours of the 5.25mm FET measured at 6GHz. Fig.4 also shows a locus of the output impedance as a function of R_{ds} which

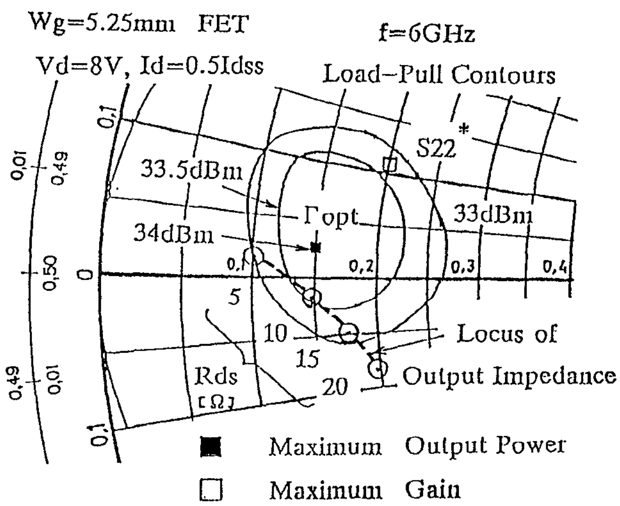

Fig.4. Load-pull contours of the 5.25mm FET.

is calculated from the small-signal equivalent circuit of the 5.25mm FET shown in Fig.3. In Fig.4, Γ_{opt} is the load impedance which provides the maximum output power. The value of R_{ds} which provides the output impedance corresponding to the conjugate of Γ_{opt} can be obtained from Fig.4 to be 10.5Ω. By scaling the gate periphery from 5.25mm to 42mm, R_{ds}= 1.32Ω was employed as the load resistance of Z_L. The number of sections of impedance transformers was determined to 7 for both input and output matching networks.

The circuit parameters shown in Fig.1 were optimized to show a linear gain of 8dB and a 1dB compressed power of greater than 40dBm over 5 to 10GHz by using the harmonic balance method[4]. The final length of each impedance transformer shown in Fig.1 was a quarter wavelength at around 15GHz. This is mainly attributed to the feedback effect through the large gate-to-drain capacitance of the 42mm FET. In addition, the input and output impedance of FETs does not show a pure resistance, as shown in Fig.3.

Fabrication and performance

A photograph of the amplifier appears in Fig.5. Both input and output impedance transformers were fabricated on high dielectric substrates by using thin film circuits. The circuits have several thin film resistors for restraining oscillation. The size of the amplifier is 14 x 17 mm^2. The measured and calculated linear gains, 1dB compressed power, and power-added efficiency of the amplifier are shown in Figs.6, 7, and 8, respectively. A measured linear gain of 7±1dB, a 1dB compressed output power of 41.5±0.8dBm, and a power-added efficiency of greater than 25% are obtained for 5 to 10GHz. Both measured and calculated linear gains and 1dB compressed output power are in good agreement. Some discrepancy between measured and calculated power-added efficiency appears in Fig.8. This is mainly due to errors in the modeling of FETs.

Conclusion

A C-X Band 14W amplifier has been developed by using a multisection maximally flat impedance transformer whose length is designed to become a quarter wavelength at the highest frequency of the design band to achieve flat gain and flat power over a wide bandwidth. With the use of this transformer, the amplifier has

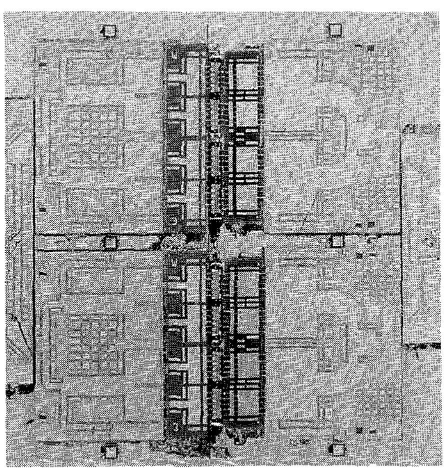

Fig.5. Photograph of the C-X band amplifier.

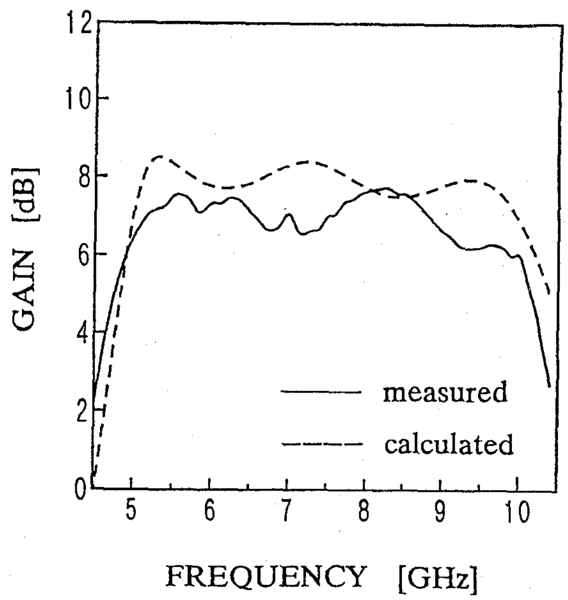

Fig.6. Linear gain.

achieved a linear gain of 7±1dB, a 1dB compressed power of 41.5±0.8dBm, and a power-added efficiency of greater than 25% across 5 to 10GHz.

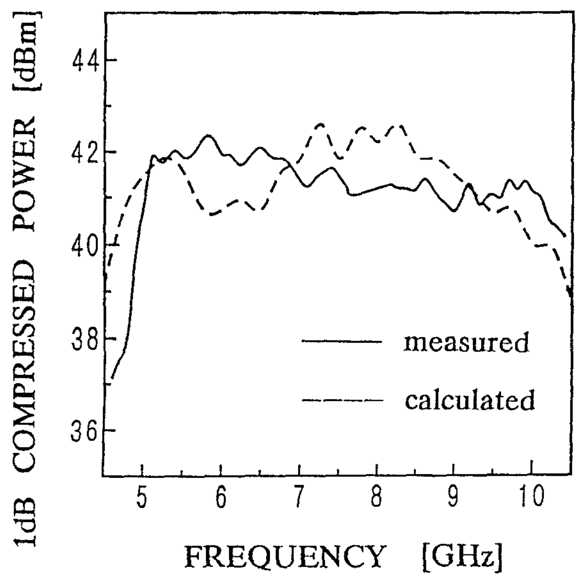

Fig.7. 1dB compressed power.

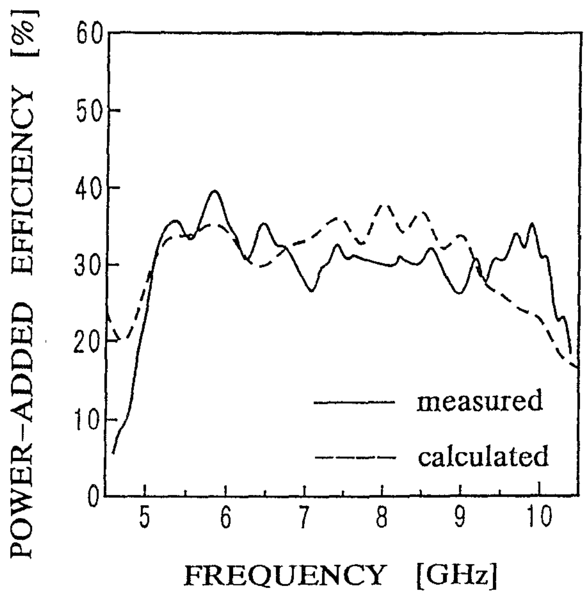

Fig.8. Power-added efficiency

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