A FULLY-INTEGRATED BROADBAND AMPLIFIER MMIC EMPLOYING A NOVEL CHIP SIZE PACKAGE

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Abstract **In this work, using a novel RF-CSP, a broadband amplifier MMIC including all the matching and biasing components was developed for Ku and K band applications. To integrate DC biasing components on the MMIC, STO ($SrTiO_3$) capacitor was employed. By employing an ACF for RF-CSP, fabrication process of the packaged amplifier MMIC became very simple and cost effective. The packaged amplifier MMIC exhibited good RF performances in a wide frequency range. This work is the first report for fully-integrated Ku or K band MMIC which has all the biasing and matching components.**

I. INTRODUCTION

Recently, demands for fully-integrated RF devices with broadband operation range are increasing in the market of Ku/K band multimedia satellite communication systems [1,2]. Until now, a number of articles concerning broadband amplifier ICs have been reported for Ku/K band applications [1], but most of them are hybrid ICs which require biasing and matching components on boards. It has resulted in a high manufacturing cost due to a large module size and a high assembly cost.

In this work, using a novel RF-CSP (chip size package), a fully-integrated broadband amplifier MMIC including all the matching and biasing components was developed for Ku and K band applications.

II. RF-CSP

Figure 1 shows the structure of the developed RF-CSP. A flip-chip GaAs MMIC is mounted on the Al_2O_3 substrate of 200 μm thick. The electrode of the MMIC was electrically connected to the electrode of the substrate via Au bump and conductive particles. The electrodes of the substrate (port 1 and 2 of Fig. 1) are connected to

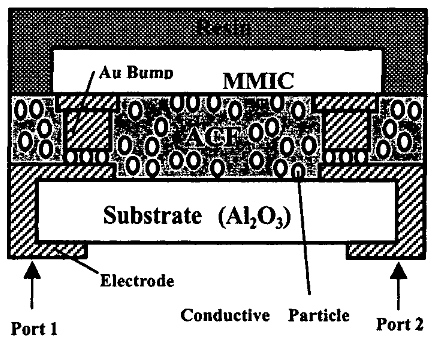

Figure 1. The structure of the developed RF-CSP.

backside of the GaAs MMIC was covered with the resin film. We adopted the anisotropic conductive film (ACF) for the underfilling material between the MMIC and substrate, which make the fabrication process of RF-CSP very simple and cost effective. The ACF plays important roles for the RF-CSP: bonding and underfilled insulator. The ACF has conductive particles of 5 μm in diameter which are dispersed in an insulating adhesive film of 30 μm thick. By heating and pressure, the conductive particles become an electrical and mechanical bond between the bump and electrode. On the other hand, the ACF exhibits conductivity less than 100 mΩ in the vertical direction, and serves as an underfilled insulator between MMIC and substrate. Due to the above functions of the ACF, the process of the RF-CSP becomes very simple and cost-effective via removal of bonding and underfilling process. In addition, in this work, gold bumps were formed by electroplating technology after fabrication of MMIC. Compared with conventional Stud Bump Bonding (SBB) [3], formation of multiple bump and adjustment of height of bump are possible by this method. A

CSP was employed for the development of broadband amplifier. The input impedance of the RF-CSP was optimized to 50 Ω in broadband. Table 1 shows the measured return loss of the RF-CSP at port 1 of Fig.1. To measure the return loss, a GaAs flip-chip having 50 Ω microstrip line was assembled in the package as shown in Fig. 1.

III. CIRCUIT DESIGN

A photograph and schematic circuit of the amplifier are shown in Fig. 3 and Fig. 4, respectively.

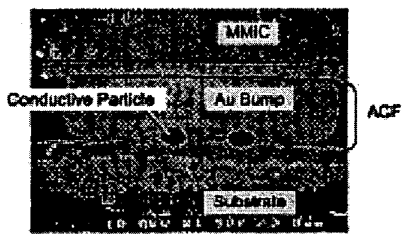

Figure 2. A microphotograph of the interconnection between MMIC and substrate.

Freq. (GHz)	Return Loss (dB)
0	-50
5	-29
10	-20
15	-8
20	-8
25	-16
30	-15

Table 1. The measured return loss of the RF-CSP.

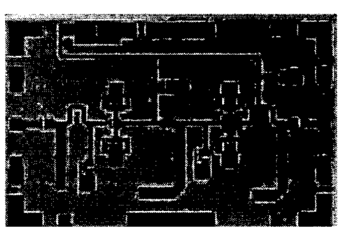

Figure 3. A photograph of the broadband amplifier MMIC.

For the broadband amplifier design, we employed prematching technique as shown in Fig. 4. Generally, the input and output impedances of FETs exhibit the frequency dependency due to their parasitic elements. In this work, using prematching circuit, the input and output of the FETs were matched to only real part impedances in wide frequency range. From 15 to 30 GHz, the input and output impedances of prematching circuits exhibited only the real values as shown in Fig. 4. By above means, the frequency dependencies of the impedances for the FETs were suppressed. Open stub transformers were used for the real part impedance matching of the input, output and interstage. For the broadband amplifier design, parallel RC gate stub were also employed as shown in Fig. 4. The resistor of the parallel RC gate stub reduces gain and increases stability in low frequency range, which contributes to the extension of bandwidth.

As is well known, a high capacitance value is required for the bypass of biasing circuit, and therefore, additional biasing components are necessary on a board for the operation of conventional MMICs. In this work, biasing components as well as matching components were integrated on the MMIC using small size STO ($SrTiO_3$) capacitor as shown in Fig. 4. Therefore, the packaged MMIC doesn't require additional matching and biasing components on a board. The STO film on GaAs epitaxial substrate was deposited by low temperature RF sputtering technique without degradation of the electrical performances of the GaAs substrate [4]. The relative dielectric constant of the STO film is 20 times higher than that of conventional SiN film (ε_r• 6.5). The EM simulation was used for the analysis of the passive components such as STO capacitor.

For the FET, a GaAs MODFET was employed. The length of the gate is 0.2 μm. The 0.2 μm gate finger was fabricated by PEL (Phaseshifter-Edge-Line) phase-shift lithography employing a conventional i-line stepper, which is more cost effective than an electron-beam lithograhy technique. The delta-doped epitaxial layer was grown on GaAs substrate by MOCVD. The threshold voltage (Vth) was –0.6 V, and the obtained maximum transconductance (gmmax) was 625 mS/mm. The current gain cutoff frequency (ft) and maximum frequency of oscillation (fmax) were 75 GHz and 135 GHz, respectively. For the bias of the FET, a self bias circuit was employed, which requires only a

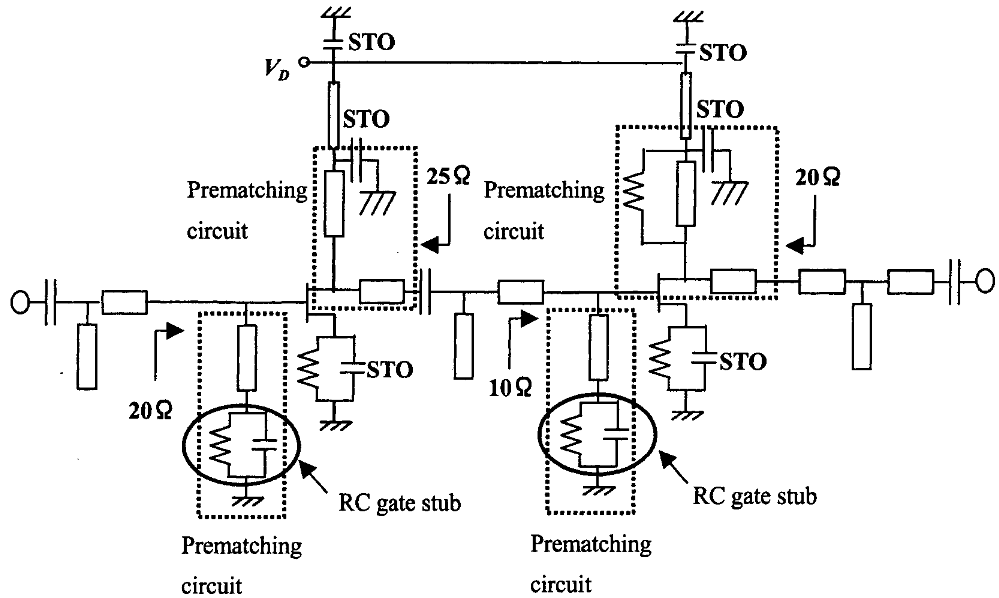

Figure 4. A schematic circuit of the broadband amplifier.

single supply voltage. Figure 5 shows a photograph of a bottom view of the MMIC packaged by RF-CSP. The size of the RF-CSP is 2X3 mm^2.

IV. RF PERFORMANCES

The measured gain and return loss of the packaged amplifier MMIC are shown in Fig. 6.

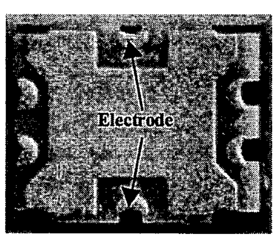

Figure 5. A photograph of the MMIC packaged by RF-CSP.

The solid line corresponds to the measured gains, and circles and solid triangles correspond to the measured input and output return losses, respectively.

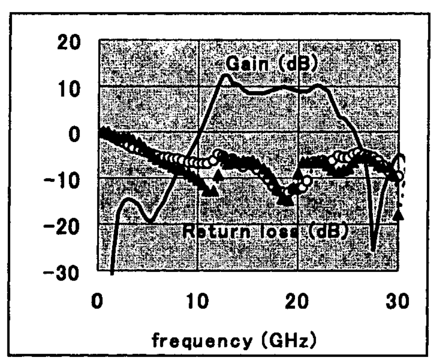

Figure 6. The measured gain and return loss of the packaged amplifier MMIC.

The measured gain exhibits a good flatness in a wide frequency range. It shows the maximum value of 12 dB with 3.5 dB ripple from 12 to 23 GHz. The input and output return losses show lower values than −6 dB in the frequency range. The measured P_{1dB} exhibited the maximum value of 19 dBm with 3 dB ripple from 12 to 23 GHz. The P_{out}-P_{in} characteristics of the packaged MMIC at 20 GHz is shown in Fig.7. The measured P_{1dB} at 20 GHz is 17 dBm.

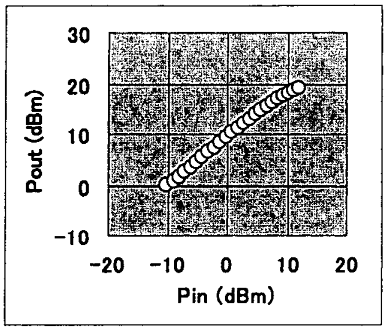

Figure 7. The P_{out}-P_{in} characteristics of the packaged MMIC at 20 GHz.

V. CONCLUSION

In this work, using a novel RF-CSP, the fully-integrated broadband amplifier MMIC was developed for Ku and K band applications. For an integration of the DC biasing component on the MMIC, STO capacitor was employed. Using the ACF for RF-CSP, fabrication process of the packaged amplifier MMIC became very simple and cost effective. The packaged amplifier MMIC showed good RF performances in a wide frequency range. This work is the first report for fully-integrated Ku or K band MMIC which has all the biasing and matching components.

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