A Novel Design of a Microstrip Microwave Power Amplifier for DCS Application using Collector-Feedback Bias

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ABSTRACT

This paper presents a 1.80GHz class-A Microwave power amplifier (PA). The proposed power amplifier is designed with single-stage architecture. This power amplifier consists of a bipolar transistor and improved by Collector-Feedback Biasing fed with a single power supply. The aim of this work is to improve the performance of this amplifier by using simple stubs with 50Ω microstrip transmissions lines. The proposed PA is investigated and optimized by utilizing Advanced Design System (ADS) software. The simulation results show that the amplifier achieves a high power gain of 13dB, output power rise up to 21dBm and good impedances matching ;For the input reflection coefficient (S11) is below than - 46.39dB. Regarding the output reflection coefficient (S22) is below than -29.898dB, with an overall size of about 93 x 59mm². By the end; we find that this power amplifier offers an excellent performance for DCS applications.

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1. INTRODUCTION

BiCMOS, GaAs (Gallium Arsenide) and CMOS are some of the dominant technologies used for radio frequency and microwave circuits. These technologies suggest excellent quality of monolithic capacitors and inductors, lower substrate loss and higher breakdown voltage compared with silicon bipolar technology. Nevertheless, they are more expensive. The realization of radio frequency and Microwave circuits using silicon bipolar technology can provide good solution, which substantially reduces the cost. Furthermore, the advance in silicon bipolar technology process has made it more possible to realize radio frequency and microwave circuits with performance comparable to that using BiCMOS, GaAs, and CMOS. Most of the basic building blocks of a transmitter, such as Switch, Oscillators and Mixers, have been realized by silicon bipolar technology processes [1]-[7]. However, not much work has been done or reported on microwave PA with silicon bipolar technology due to the area size and difficult matching network impedance (MN).

Matching impedances of the PA becomes one of the crucial parameters to be optimized for eliminate reflection wave that results in a decrease in energy consumption. However, matching impedances of the PA is degraded by growing output power. Matching impedance and output power are the main considerations when a class of PA is to be chosen. Different applications will result in different choices of PAs. Therefore, it has to understand the specifications of the PA in advance.

The PA are key element of a transceiver compared with other building blocks in full telecommunication system. Add to that, it is the main element remains responsible in terms of power consumption of the all transceiver system. Many circuit architectures commonly with the different technologies used for to design the power amplifiers have been proposed in literature [8]-[17]. Each of them presents a microwave power amplifier with BiCMOS, GaAs and CMOS topologies.

This paper presents, a novel design of microstrip microwave power amplifier is target for applications DCS at 1.80GHz. This power amplifier consists of a silicon bipolar technology and it is improved by Collector-Feedback Bias configuration with a single power supply to achieve good performances at desired frequency.

The result of the paper is organized as follows: Section 2 presents the biasing methods, the schematic of proposed PA in detail is presented in Section 3, Section 4 presents the simulation results including a discussion and lastly, Section 5 offers the conclusion.

2. BIASING METHODS

Biasing is needed in a RF/Microwave power amplifier circuit to work with good performance, the DC bias condition of the RF/Microwave transistors is usually established independently of the RF/Microwave design and ease to utilize are the principal concerns when choosing a bias configuration correctly.

There are several biasing techniques to feed an amplifier [18]. These are:

a. Fixed base bias
b. Collector-feedback bias
c. Dual feedback bias
d. Emitter-bias
e. Emitter feedback bias
f. Fixed bias with emitter resistor
g. Voltage divider bias

Among all Biasing Methods of microwave PAs, the Collector-feedback bias is the most attractive candidate in terms of high performance and circuit simplicity. The Collector-feedback bias configuration is used to design the proposed power amplifier at 1.80GHz. Typically, This kind of biasing can operate with a single power supply and power losses smaller compared with other Methods of biasing.

The Collector-feedback bias as shown in Figure 1. In this circuit, the base resistor (R_B) is connected through the collector and the base terminals of the transistor. This signifies that the base voltage, V_B and the collector voltage, V_C are inter-dependent owing to the fact that (1):

$$V_B = V_c - I_B R_B \tag{1}$$

From these Equations (2), (3). The Q-point (operating point) stays fixed regardless of the fluctuation in the load current. As seen for this type of biasing network that an increase in I_C decreases V_C, which results in a reduced I_B, automatically reducing I_C.

$$V_{CC} = (I_B + I_C) R_C + V_C \tag{2}$$

$$V_C = V_{CC} - (I_B + I_C) R_C \tag{3}$$

Note that:

$$V_{CE} = V_C$$
$$V_{BE} = V_B$$
$$I_C = \beta I_B$$
$$I_E \approx I_C$$

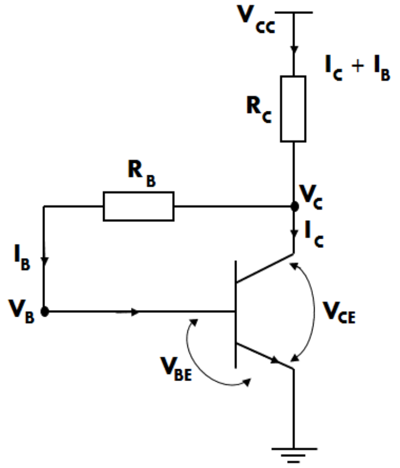

Figure 1. Collector-feedback bias circuit

3. CIRCUIT DESIGN

The proposed PA is designed with the Collector-feedback bias as illustrated in Figure 2. This amplifier is improved by microstrip transmission lines and with simple stubs to obtain a good performance in power gain with good matching impedances and high output power. A self-biased circuit (RF choke) is replaced by a high impedance quarter wavelength line (λ/4) with Radial stub connected in series for achieve proper isolation at desired RF frequency and Capacitors Cin and Cout at input and output stage is for DC blocking.

In this work, AT-41486 (Si BJT power transistor) die models from NPN with 4-terminal was chosen as the active device of the proposed PA. This transistor offers operating frequencies up to 10GHz, maximum output power of 500W, 12Vdc breakdown voltage. For low frequency of operation below than 10GHz, Si BJT is a more suitable device technology compared to BiCMOS, CMOS or GaAs due to lower cost for mass fabrication. For the circuit design and simulation on PC using Agilent's Advanced Design System (ADS) software.

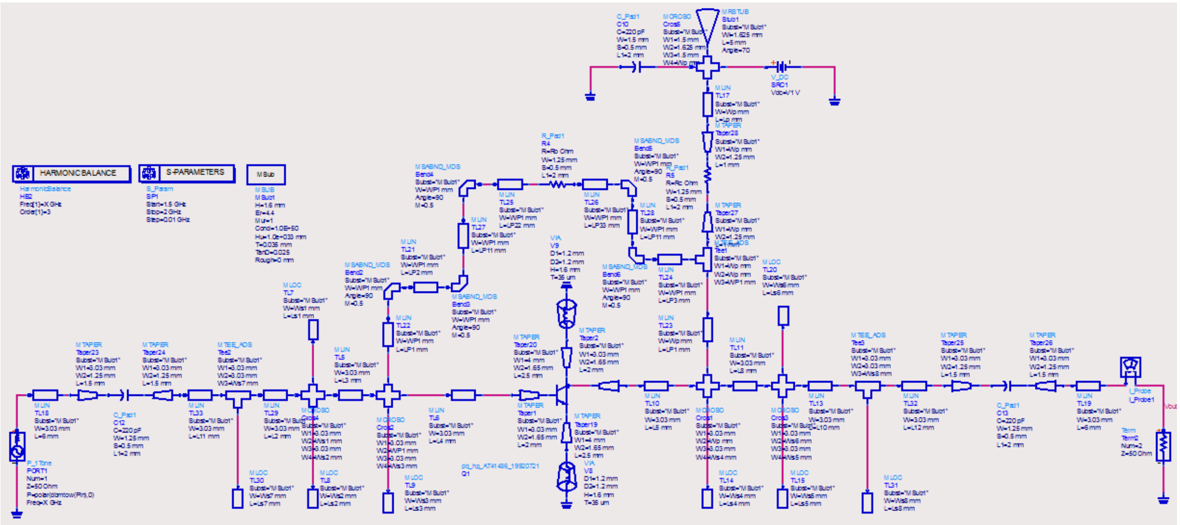

Figure 2. The Schematic of the proposed microwave amplifier

This power amplifier is printed on an FR4 substrate with a thickness of 1.6mm, a relative permittivity of 4.4, a tangential loss of 0.025 and a metallization thickness t=0.035mm. The proposed amplifier has an overall size of about 93mm (L) *x* 59mm (W). Figure 3 shows the Layout for the designed PA.

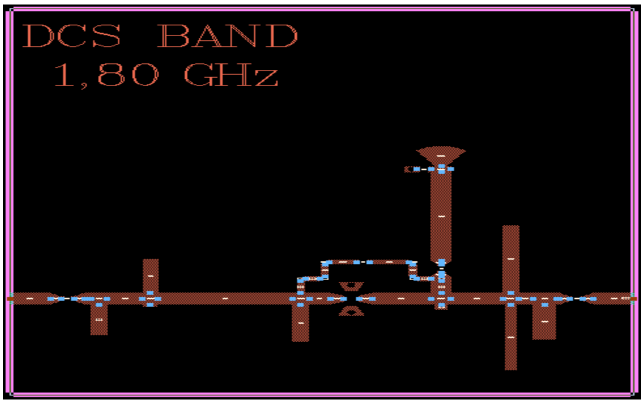

Figure 3. Layout of the validated power amplifier

4. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

This section presents the simulated results of proposed microwave power amplifier operating at DCS band. It was implemented based on Agilent's Advanced Design System (ADS) software. From the simulation S-parameter. As can be observed, the proposed amplifier has -46.39dB input return loss (S11) and -29.898dB output return loss (S22) at 1.80GHz. Figure 4 shows the simulated input/output return loss. While, the power gain (S21) has a maximum value of 13dB with a unilateral transmission coefficient (S12) less than -19.5dB in the operating frequency band.

The unilateral transmission (S12) is important to quantify in PA performance analysis as practically some signal transmitted back to the input from the output (Ideally should be no back reflection). This unwanted reverse signal interferes with fundamental signal flowing in forward direction from input to the output. In our proposed amplifier design, the input/output matching stage does not easily allow signals to propagate from the output to the input. Figure 5 shows the small-signal gain (S21) and the unilateral transmission (S12).

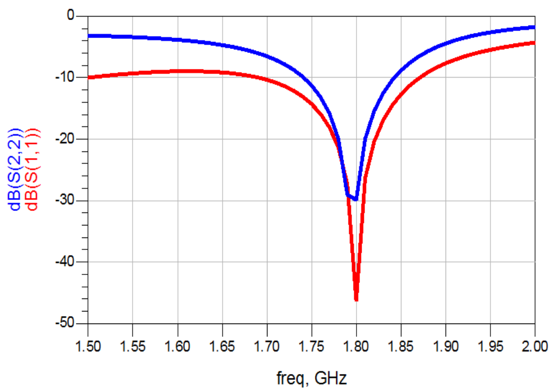

Figure 4. S11 & S22 versus frequency of power amplifier

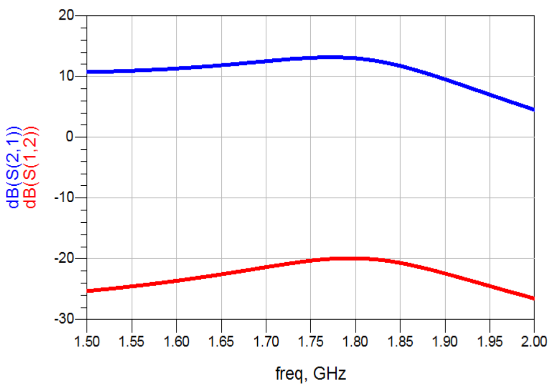

Figure 5. S21 & S12 versus frequency of the proposed power amplifier

Stability test is very important in RF/Microwave power amplifier analysis as circuit might oscillate because of voltage variations at unexpectedly low or high frequencies. Specially, when there is a feedback path from output to input, the circuit might become unstable for certain combinations of source (Z_S) and load impedances (Z_L). According to Rolett Criteria as expressed by Equations (4) and (5) where K > 1 and B1 > 0 [18]-[20]. The circuit is unconditionally stable. To ensure stability over a wide range of frequencies, the stability was tested from 1.50GHz up to 2GHz. Figure 6 and Figure 7 shows Stability Factor (K) is 1.33 and Stability measure (B1) is 0.795 Therefore, it can be said that amplifier is very much stable around 1.80GHz frequency range.

$$k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} > 1 \quad (4)$$

$$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 > 0 \quad (5)$$

$$|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| \quad (6)$$

Where

k is the Rolett factor
B1 is the Stability measure

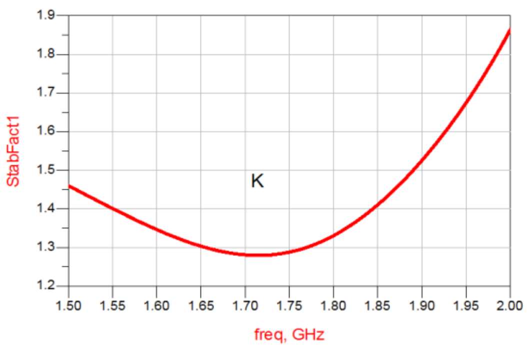

Figure 6. Stability factor versus frequency characteristics

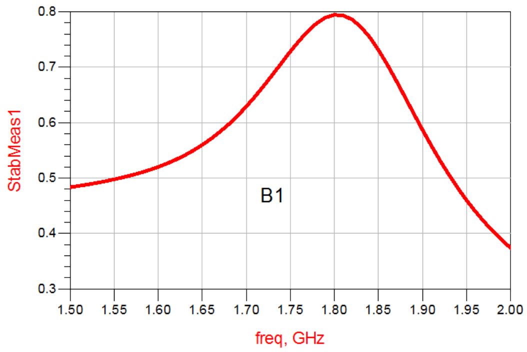

Figure 7. Stability measure versus frequency characteristics

Among all parameters indicated above as stability, power gain.

Output power is very important parameter for design the microwave power amplifier, generally to calculate the output power, the fundamental components of the load current and load voltage are take in consideration. Pout can be expressed by Equation (7) [18] and [19]:

$$P_{out} = \frac{1}{2} real(V_{out} * i_{out}^{*})_{|f=f_0} \quad (7)$$

As depicted in Figure below, this study was conducted for DCS applications at 1.80GHz. For power input range from -30 to 30dBm, the power amplifier exhibits a saturated output power of 21dBm and a P1dB of 19dBm. Figure 8 show output power versus input power for 1.80GHz.

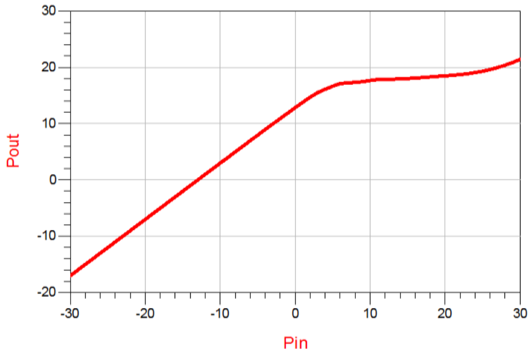

Figure 8. Output power versus input power for1.80GHz

Most of the reported design used different topologies and presented the results at different frequency band depending on intended applications. A comparison between the recently published works on state-of-the-art of microwave amplifiers and the one proposed here is made. Table 1 summarizes the performance of the presented PA in comparison with other reported PAs. It can be observed that the proposed PA has highly Power Gain and good Reflection coefficients at the operating frequency band than other amplifiers, which verifies the results exhibit excellent performance of our design approach compared to the reported works.

Table 1. Performance Comparison with Recent Power Amplifiers

Parameter	[21]	[22]	The Proposed PA
Process	GaAs PHEMT	0.25μm CMOS	BJTs
Frequency (GHz)	2.45	1.65-2	1.80
Power Gain (dB)	7.51	5.1 ± 0:5	13
Input Return Loss	-7.497	-14	-46.39
output Return Loss	-10.950	-19	-29.89
P1dB (dBm)	14.01	18:5	19

5. CONCLUSION

In conclusion, the design and analysis of a microwave power amplifier with a technology Microstrip has been presented. The simulation results show that the proposed amplifier offers an excellent performance for DCS applications at 1.80GHz. The proposed design exhibits a power gain of 13dB with reverse isolation less than-19dB under a 10V supply. The proposed power amplifier has successfully achieved and improved with good performance in terms of stability and matching impedance.This amplifier it is capable of delivering output power up to 21dBm.

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