SINGLE STAGE RF AMPLIFIER AT 5.8GHZ ISM BAND WITH IEEE 802.11a STANDARD

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Abstarct - **This paper describes the circuit design and measurement of a single stage RF amplifier for 5.8 GHz-band with IEEE 802.11a standards for WLAN applications. The circuit was simulated using Ansoft Designer where a 14dB of gain; input and output return loss less than -10dB were observed. The GaAs Hetrojunction FET (HFET), capacitors and resistors are combined with the microstrip line pattern by silver epoxy. A 1dB output power compression point (P_{1dB}) of 17dBm and 14.56dB of gain when -1dBm power injected under 6V and ½ I_{dss} biasing are measured.**

Index Terms: RF Amplifier; Gain; Matching Circuit; Wireless LAN.

I. INTRODUCTION

Current solutions exploit the worldwide license-free 2.4 GHz frequency band. Unfortunately, many applications nearly overcrowd this band such as high-power microwave ovens, cordless phones, Bluetooth® and HomeRF applications, WLAN, game pads, etc. As a consequence, significant RF interference is present within the 2.4 GHz band [1]. Recently, wireless LAN system have been developed for the C-band (4~8 GHz) frequency. Proposals for wireless data system in the C-band range such as 5.8 GHz (Wireless LAN for U.S.A) and 5.2 GHz (Hiper LAN for Europe) have been submitted [2]. The license-free 5.8 GHz frequency band provides wider spectrum frequency. Furthermore, investigations showed that 5 GHz applications in narrow surroundings can provide better performance than 2.4 GHz applications as the shorter wave length propagates farther. In addition, 5.8 GHz system nearly always be operated at higher data rates than 2.4 GHz systems in form of bandwidth [3].

The power amplifier is the most important and expensive device in the RF block of Wireless LAN system [4]. Like all other amplifiers, stability is a major concern [5]. This paper is focused on the development of RF amplifier for point-to-point WLAN application. A single-stage RF amplifier is fabricated using GaAs HFET on microstrip substrate. The size of the circuit is reduced by utilizing high dielectric substrate. Figure 1 shows the block diagram of RF amplifier module.

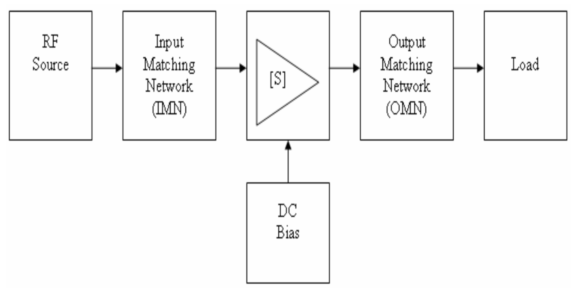

Fig. 1. Schematic diagram of RF amplifier module

The RF amplifier consists of input and output matching network as passive part and amplifier chip driven by DC bias circuit as an active part. The impedance of the circuit is relatively 50Ω.

II. CIRCUIT DESIGN

In short, basic concept of high frequency amplifier design is matching input/output of transistor for high frequency having [S] frequency characteristics at a specific DC-bias point with source impedance and load impedance. I/O matching circuit is essential to reduce unwanted reflection of signal and to

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improve efficiency of transmission from source to load [6].

The DC bias circuits are designed not to disturb the RF performance [4]. Bias circuit was set at 6V and ½ I_{dss} to operate a HFET EPA 018A-70 at Class A using voltage regulator. This method can achieve high linearity using optimal power back off from the power compression point while maintaining high efficiency [7]. One of the most important factors in high frequency amplifier design is to determine stability of the given bias frequency. Equations in Table I are used to determine the stability of the amplifier. RF amplifier need to be in unconditionally stable where Stability Factor, K higher than 1 with Delta Factor must be smaller than 1, otherwise the amplifier is considered potentially unstable.

TABLE I
STABILITY DETERMINATION BY FORMULA

Stability	*Criteria*
Unconditionally stable	$K > 1 \ \& \ \|\Delta\| < 1$
Potentially unstable	$K > 1 \ \& \ \|\Delta\| > 1$ or $K < 1 \ \& \ \|\Delta\| < 1$
Stability Factor $K = \dfrac{1 - \|S_{11}\|^2 - \|S_{22}\|^2 + \|\Delta\|^2}{2\|S_{12}S_{21}\|}$ Delta Factor $\Delta = S_{11}S_{22} - S_{12}S_{21}$	

The input and the output circuits should be matched each other to deliver maximum power to the load. After stability of active device is determined, input/output matching circuits should be designed so that reflection coefficient of each port can be correlated with conjugate complex number as given in equations (1) and (2).

$$\Gamma_{IN} = \Gamma_S^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \quad (1)$$

$$\Gamma_{OUT} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} \quad (2)$$

By combining the two formulas above, reflection coefficient of input/output matching circuits are determined by equations (3) and (4) and the substitution as in equation (5).

$$\Gamma_{SM} = \frac{B_1 - \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \quad (3)$$

$$\Gamma_{LM} = \frac{B_2 - \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} \quad (4)$$

Where

$$\begin{aligned} B_1 &= 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \\ B_2 &= 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2 \\ C_1 &= S_{11} - \nabla S_{22}^* \\ C_2 &= S_{22} - \nabla S_{11}^* \\ \nabla &= S_{11}S_{22} - S_{12}S_{21} \end{aligned} \quad (5)$$

The above formulas give power and load reflection coefficients to obtain maximum power gain. It can be seen that matching circuit is designed with scattering coefficient determined by the bias and frequency for the given active device.

III. SIMULATION

In the beginning of the simulation process, the RF amplifier is modeled in schematic using data sheet provided by manufacturer. With Ansoft Designer, the simulation result might not be accurate because the library has no data regarding the amplifier EPA 018A-70 chip. Furthermore, the data provided does not contain any information based on noise figure. So the simulation conducted is not based on the other important parameter, such as noise figure. However EPA 018A-70 was selected as its availability in market and good performance. Duroid 5880 is being used as the microstrip substrate and the characteristic of this substrate is shown in Table II. The advantages of microstrip technology include simple, small size, light weight and durable finish as compared to conventional design. These advantages are significant to smaller size RF components design, nowadays.

TABLE II
DUROID 5880 TLY-5A-0200-CH/CH SUBSTRATE PARAMETERS

Dielectric	*Metalization*			
H = 0.508mm $\varepsilon_r = 2.17$ TAND = 0.0018 (5.8GHz)	*Material*	*Resistivity*	*Thickness*	*Unit*
	Cooper	1.72414	0.0175	mm

The comparison between simulated result and original parameters from data sheet can be simplified as shown in Table III.

TABLE III
S-PARAMETER COMPARISON BETWEEN DATA SHEET AND SIMULATION AT 5.8GHZ

S-Parameter	*Data Sheet (at 5.8GHz)*	*Simulation (at 5.8GHz)*
S11	-2.24dB	-10.96dB
S12	-26.26dB	-23.78dB
S21	12.07dB	14.56dB
S22	-3.32dB	-4.86dB

From the simulated circuit, the stability, K of the circuit is 1.02. Usually, as long as the Stability Factor and Delta Factor are known as unconditionally stable, the stability circle is not necessary to be proved because the amplifier is stable at all area within the smith chart [8].

IV. FABRICATION AND MEASUREMENT

Fabrication was accomplished by a manufacturer because lack of instruments and tools for this purpose. The designed circuit was also tuned and optimized by the manufacturer in order to get an optimum layout. Somehow, the performances of the simulated circuit are remained.

During measurement process, losses affected the result; some of the losses are possible caused by conductor, dielectric and radiation mechanisms. So the designed amplifier has a small signal gain of 14.56dB better than two-stages PA reported with 6.5dB and 6.2dB [9][10]. The input and output return loss are -10.239dB and -10.937dB respectively at 5.8GHz frequency with operating bias of Vds=6V and Ids = $1/2I_{dss}$. Figure 2, 3, 4 and 5 are graph of S-Parameter of the RF amplifier measured using Network Analyzer. Table IV is comparison between measured and simulated S-Parameter at 5.8 GHz. This amplifier performed a 1dB compressed output power of 17dBm over 20dBm of EPA 018A-70 maximum output as shown in Figure 6. Figure 7 is the fabricated RF amplifier on Duroid 5880 microstrip substrate.

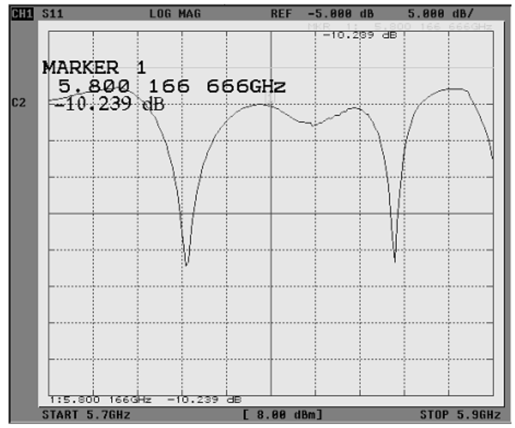

Fig. 2. S11 parameter at 5.8 GHz

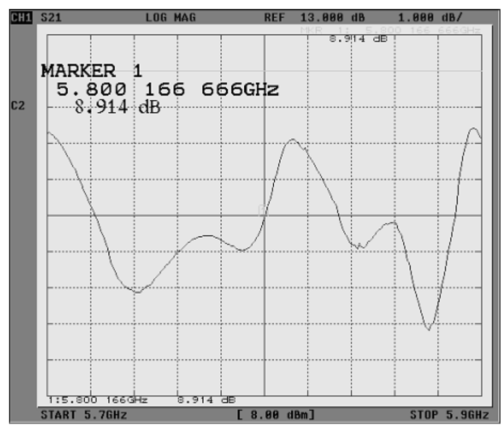

Fig. 3. S21 parameter at 5.8 GHz

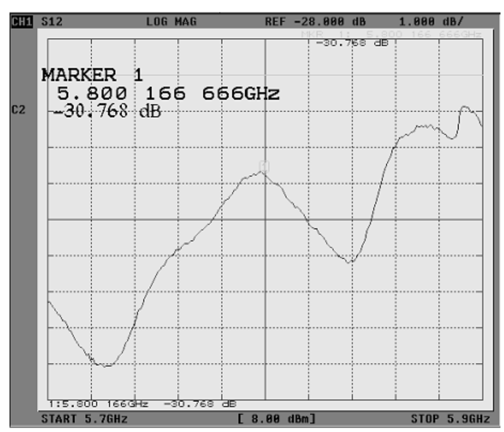

Fig. 4. S12 parameter at 5.8 GHz

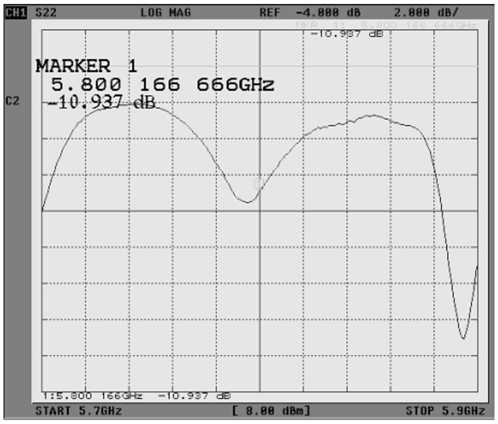

Fig. 5. S22 parameter at 5.8 GHz

TABLE IV
S-PARAMETER COMPARISON BETWEEN SIMULATION AND MEASUREMENT AT 5.8GHZ

S-Parameter	*Simulation (at 5.8GHz)*	*Measurement (at 5.8GHz)*
S11	-10.96dB	-10.239dB
S12	-23.78dB	-30.678dB
S21	14.56dB	8.914dB
S22	-4.86dB	-10.937dB

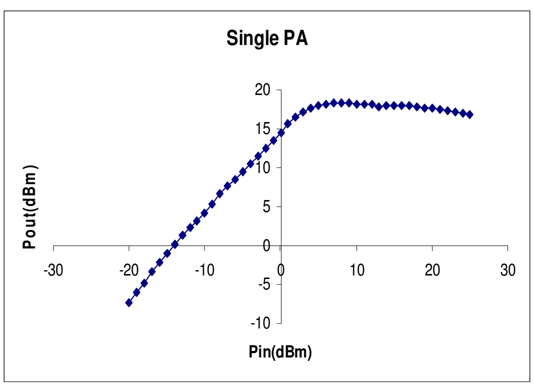

Fig. 6. P_{1dB} Compression at 5.8 GHz

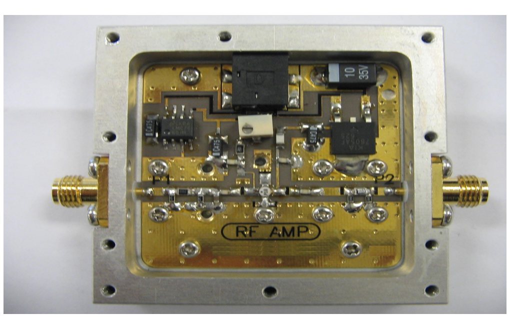

Fig. 7. Fabricated RF amplifier

V. CONCLUSION

A single stage RF amplifier for point-to-point WLAN has been designed and fabricated on GaAs substrate. At 6V collector bias, the amplifier has achieved gain of 14.56dB with input and output return loss of -10.239dB and -10.937dB respectively in the frequency range of 5.725 GHz to 5.825 GHz.

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