

DESIGN OF 2.4 GHZ MMIC FEED FORWARD AMPLIFIER FOR WIRELESS APPLICATIONS

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ABSTRACT

This paper proposes a design of 0.15 μ m Monolithic Microwave Integrated Circuit (MMIC) power amplifier using GaAs pHEMT technology at 2.4 GHz which employs feed forward linearization technique to improve linearity. The amplifier is designed to operate in personal communication systems (PCS) frequency range using WIN semiconductor GaAs pHEMT technology. Single stage power amplifier is designed in lumped and distributed components with its layout. Linearity of PA is improved by Feed forward Linearization technique. To evaluate the performance of proposed linearized amplifier, Advanced Design system (ADS) tool is used. The designed circuit results with 13.65dBm output power at 1dB compression point (P1dB), 6dB power gain and maximum Power added efficiency of 16.4%. Linearity achieved by feed forward linearizer circuit with third order intermodulation suppression of 30dBc for the output power level of 8.217dBm and 1dB compression point at an input power of 15 dBm whereas 6 dBm for the Power amplifier without feed forward linearizer circuit. The designed Power amplifier system with feed forward linearizer had IMD3 suppression of 30dBc which is in appreciable range with improvement in 1dB compression point.

KEYWORDS

Power amplifier, Feed forward, Intermodulation, Third order Intermodulation, Power added Efficiency

1. INTRODUCTION

The performance of a wireless system over which the communication takes place is decided based on transmitter; receiver and communication medium. The nonlinear elements used for a linear purpose will generate nonlinear distortion which leads to spectral regrowth. The design of PA linearizing and efficiency improvement schemes, and architectures is attracting much attention in recent years. The attempts to reduce the effective PA compression and phase variation effects to meet air interface specifications, while maximizing the PA efficiency is being carried on. Few Included among them are feed forward, envelope elimination and restoration (EER), Cartesian feedback, and Pre distortion techniques. A feed-forward mitigation algorithm with an adaptive filter implemented and applied real time measurements [1], To improve better efficiency and linearity, PA linearization technique is inevitable[2].

The paper [3] discussed a feed forward linearization technique implemented on a PA at 2 GHz which results with third order intermodulation suppression of 108dBm. A new technique explored with a combination of feed forward and predistortion method results with better linearity [4]. Linear and wide band characteristics by feed forward linearization technique achieved, where the circuitry is complex with an auxiliary error amplifier and passive control circuits [5]. The author discusses the Modified quasi memory less nonlinear Saleh model for implementation of power amplifier which is done using Simulink [6]. The paper [7] executed a feed forward amplifier with

adaptive network implemented using Advanced design systems for wireless communication applications. An ANN based controller is trained to handle all the mappings associated with the inputs and the corresponding outputs associated with all the controllers of the UPFC [8]. Simulations are performed in the MATLAB / SIMULINK environment. Feed forward Linearization techniques results in higher level of intermodulation cancellation of all products with wider bandwidths and stability over other linearization methods.

A methodology for precise balance of amplitude and Phase with the loops of feed forward amplifier is exhibited for perfect intermodulation cancellation. The implementation of digital control of feed forward amplifiers reduces the sensitivity to amplitude or phase shift [9].

2. FEED FORWARD SYSTEM

A typical feed forward system as in Figure1 involves two loops. The first loop is signal cancellation loop which samples input signal by a coupler which then amplified by the main amplifier with a time delay.

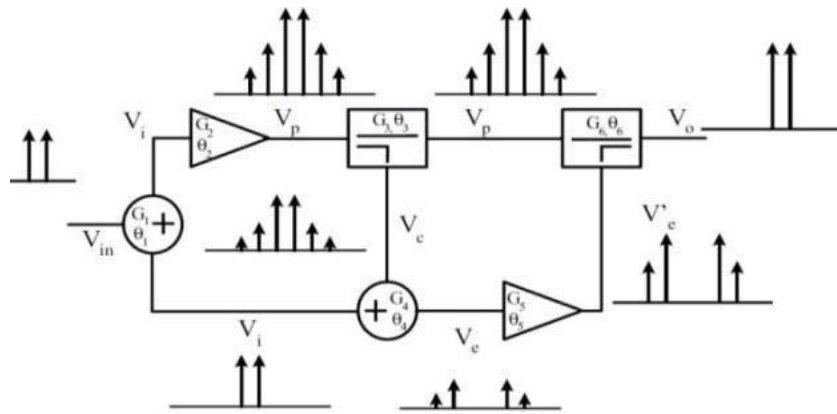


Figure1. Feed forward system

Feed forward was invented for distortion reduction in amplifiers by Black. The second loop called distortion cancellation loop comprises of an error amplifier, couplers and delay element.

The input signal is splitted into two identical signals by power splitter, with one signal directed to main PA while the other signal enters a delay component. The upper path signal is amplified by the main amplifier whose inherent nonlinearity results in intermodulation components. This signal is sampled and attenuated by attenuator and then added with delayed input signal. The gain of error amplifier decides amplification factor which cancels out the distortion components present in main amplifier output. The directional coupler is fed with error amplifier output. This coupler is fed with another input which is the delayed main-path signal both in time and phase. The cancellation accuracy of the main signal in the first loop and error signal cancellation from the output of coupler-combiner determines the quality of operation of the linearizer system. Higher linearity is achieved when the insertion losses of power splitters and combiners total about 30% of output power of PA.

The equation that describes the output of Feed forward linearizer is,

$$V_{out}(t) = \frac{A_1}{2} V_{in}(t) e^{-j\omega(\tau_1 + \tau_2)} \quad (1)$$

Where A_1 is the main power amplifier gain, τ_1 and τ_2 is the delay associated with main power amplifier and error amplifier and V_{in} is the input signal.

A variable phase shifter is used to adjust the phase of PA output by taking the input reference. The delay line in error cancellation branch is used to achieve wider bandwidth and takes care for main amplifier group delay by time aligning the main power amplifier output and reference signal.

DESIGN OF POWER AMPLIFIER

The pHEMT technology provides excellent low-noise properties due to high transconductance and better electron mobility. Power amplifier is designed using 0.15 μ m GaAs pHEMT. Transconductance G_m is increased by proper choice of biasing point which improves gain of PA. The bias point is selected from transfer characteristics, at V_{ds} of 3V and V_{gs} of 0V, with drain current of 398mA. Figure 2 shows the schematic of single stage PA.

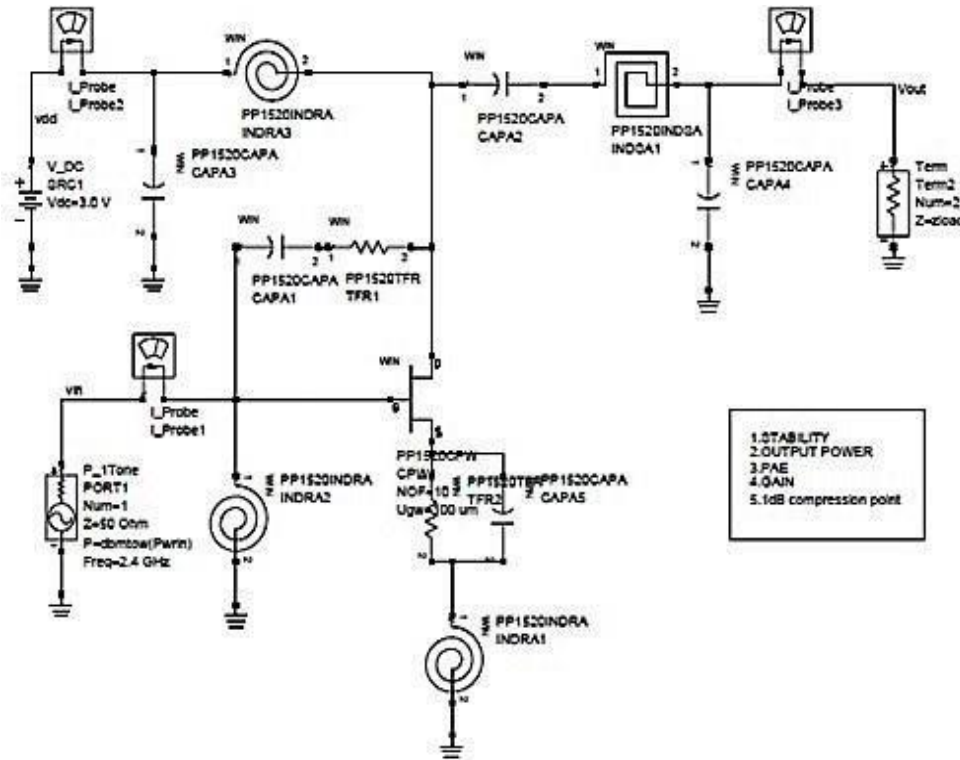


Figure 2. Schematic of single stage PA using WIN components

3. SIMULATION AND RESULTS

One tone simulation and two tone simulation is performed. The Rollet factor $K > 1$, makes the amplifier unconditionally stable. PA circuit with distributed components designed and simulated. At an input power of 13dBm and output power of 16.8dBm, Power added efficiency of 16.77% is obtained as in Figure 3.

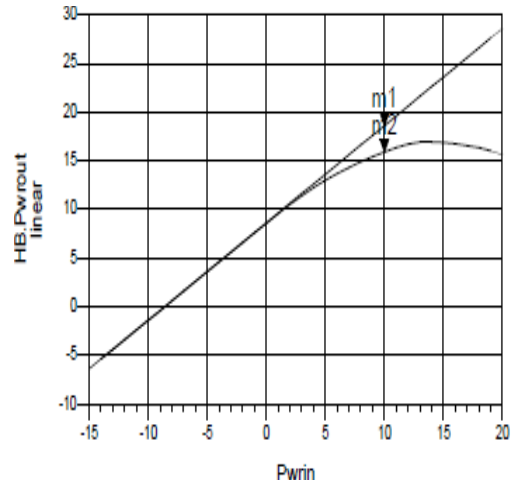
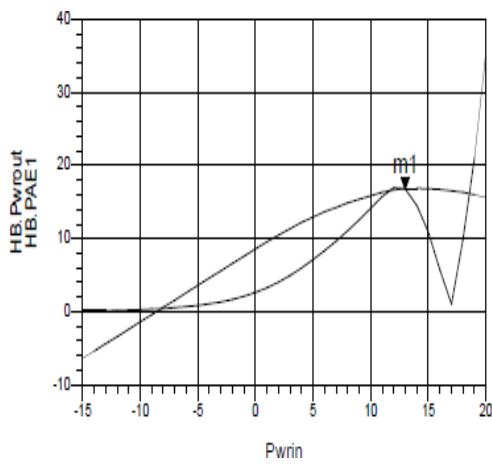


Figure 3.PAE and output power versus input power Figure 4. 1dB compression point

The output power of 14.5dBm at 1dB compression point (P1dB) at an input power of 9dB obtained as in Figure 5. The two-tone test is performed at frequencies of $f_1=2.404$ GHz and $f_2=2.414$ GHz. The layout is constructed with components from WIN foundry as in Figure 5.

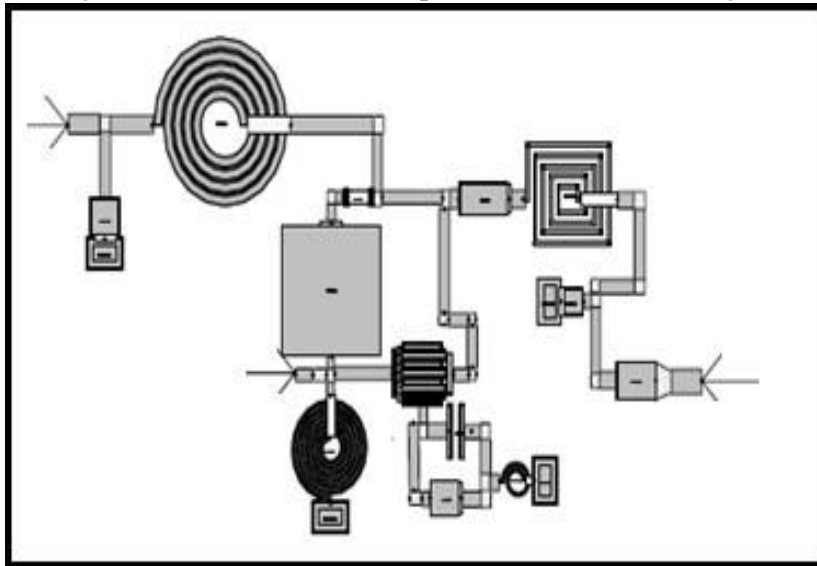


Figure.5. Complete layout of 2.4 GHz PA

4. DESIGN OF FEED FORWARD LINEARIZER

Feed forward linearizer circuit comprises of passive elements and Power amplifier as in shown in Figure 6. Feed forward system of proper design is proven to provide a better IMD3 suppression¹.

The Power dividers with micro strip lines are constructed with MLIN, MCURVE and MTEE. The MSUB has been chosen to be as $H=10.0$ mil, $\epsilon_r=9.6$ which refer to the layout design. The Coupled line coupler with 10dB coupling loss is constructed with microstripline MCLIN which is simulated.

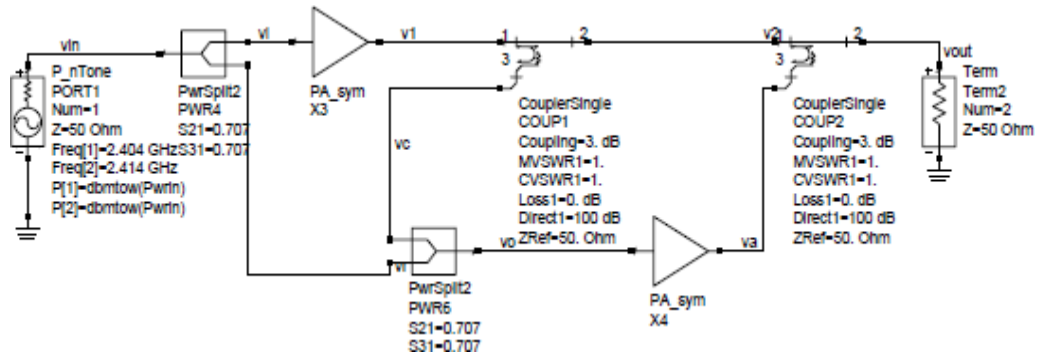


Figure 6. Feed forward amplifier circuit

Power amplifier without and with linearization are compared from the simulation results. The feed forward linearized amplifier resulted with third order intermodulation cancellation of 30dBc for an output power level of 8.217dBm as in Figure.7.

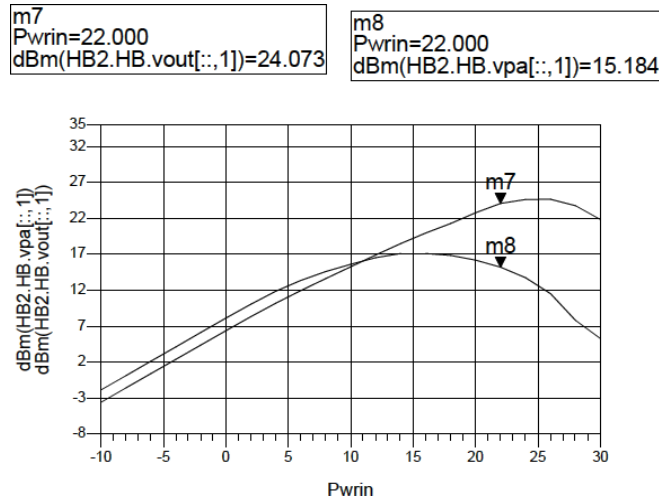


Figure. 7 Output power comparison of PA with Linearization (marker m7) and without linearization (marker m8)

The output power of linearized feed forward amplifier improved by 9dBm compared to 15dBm output power of PA without linearization. There is 6dBm improvement in input power for 1dB compression point for linearized circuit whereas it is 9dBm for PA without linearization. As shown in Table.1

Table.1: Comparison of results

Technology	Class-E power amplifier @2.4 GHz	Output power (dBm)	Input power @1dB compression point(dBm)
0.15 μ m pHEMT	Before Linearization	15	9
	After feed forward Linearization	24	15

5. CONCLUSIONS

A Feed forward linearized power amplifier is designed and presented. The layout is implemented using 0.15 μ m WIN GaAs pHEMT Technology. The simulated design resulted with a linear gain of 8.58dB, The O_{1dB} of 14.59dBm and PAE of 16.77%. Linearization helps to achieve 30dB improvement in carrier to interference ratio(C/I) and 1dB compression point achieved at an input power of 15 dBm rather than 6 dBm in PA without Feed forward Linearizer.

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