Design and Analysis of Class-E Power Amplifier for Wired & Wireless Systems

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Abstract

In this research article, an advanced class-E Power Amplifier (PA) working at center frequency 1842.5MHz with 75MHz bandwidth is proposed. The class E type power amplifier is premeditated and realized using 0.35μm CMOS technological file in ADS. The proposed class E power amplifier provides low return loss, Signal and Noise Ratio of 47.5dB, low noise figure of 1.434dB and PAE of 69.3%.
Keywords*: PA, Return loss, SNR, NF, PAE.*

I. Introduction

Power amplifiers are usually employed to translate radio frequency signal with low power into a high amplitude signal which is opted to drive the antennas in the receivers and transmitter. Modern day portable systems employs power amplifier as it act as the heart of these systems. Power amplifiers (PAs) also play a significant role in the transmitter leading to superior amplification of baseband and narrowband signals. Figure 1 depicts the block diagram of transmitter.

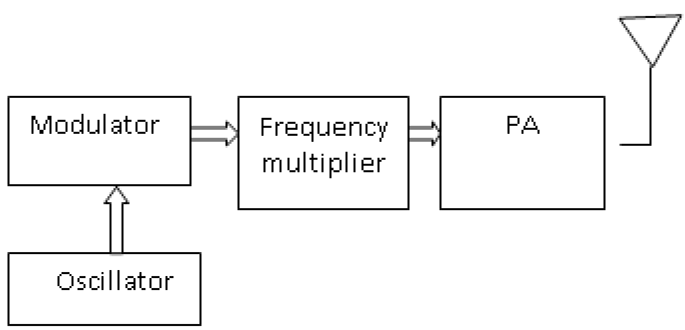

Fig 1. Sketch of a transmitter

Power amplifier selection depends on efficiency and linearity of the particular amplifier. The various classification of power amplifiers are given below:

- Efficient Class A PA
- Efficient Class B PA
- Efficient Class AB PA
- Efficient Class C PA
- Efficient Class D PA
- Efficient Class E PA
- Efficient Class F PA

All the above power amplifiers differs in conduction input angle, frequency variations, biasing and harmonics condition. The increase in linearity of the PA is inversely relative to its efficiency. In other words, increase in linearity drastically affects the efficiency of the PA. Class E-PA is preferred because linearity of the class E – PA is directly relative to its efficiency. Other reasons include: size parameter, easy design features and less weight.

II. Proposed Class-E Power Amplifier

All the power amplifiers uses active device for power amplification. Power amplifier's high efficiency is due to the presence of active devices comprising of various transistors. Initially Class-E power amplifiers included BJT as its switching device [1].
Due to power dissipation, output undergone major loss of power. Therefore, power dissipation is minimized in power amplifiers to work at high frequencies [2]-[3]. Nathan Sokal et al. (1970) were the first to explore the design concepts of class-E PA.
Nathan et al. (1970) also provided the design equations of class E PA that act as a benchmark for future research work in class E power amplifiers. They also identified matching networks play a vital role in reduction of power intake by amplifiers [4].
The matching network of class E amplifier has a sophisticated design with low loss. The efficiency of class E amplifier is relatively higher than class B and class C amplifiers [5]. The vital conditions to get better the competence of the amplifier is as follows:

1. The peak point of I & V waveforms during full scale operation must be greater than time. When switch is on, it should not lead to any voltage drop and the current flows through the circuit [6].
2. On contrast, a small amount of voltage is induced during switch off condition leading to blockage of any current flow.

The design equations used for finding the values of circuit elements of the class E-PA are shown below:

$$R_L = \frac{(V_{DD} - V_{DS(Sat)})^2}{P_a} \left(\frac{2}{\frac{\pi^2}{4} + 1} \right) = 0.577 \frac{(V_{DD} - V_{DS(Sat)})^2}{P_a} \quad (1)$$

$$L = \frac{Q_L R_L}{2\pi f} \quad (2)$$

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$$C_1 = \frac{1}{2\pi f R_L \left(\frac{\pi^2}{4}+1\right)\left(\frac{\pi}{2}\right)} \tag{3}$$

$$C_2 = C_1 \left(\frac{5.447}{Q_L}\right)\left(1+\frac{1.42}{Q_L - 2.08}\right) \tag{4}$$

The schematic sketch of Circuit of class-E PA is shown in figure 2.

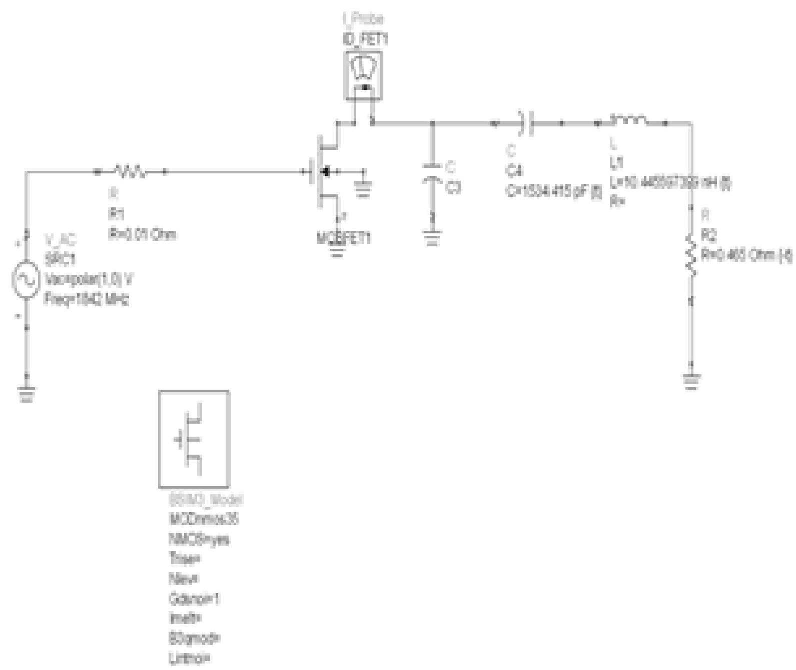

Fig 2.Schematic diagram of Class E PA

The design specifications for proposed class E PA include center frequency which tuned to 1842.5MHz. Bandwidth of the proposed circuit is limited to 75MHz. The design specifications of proposed class E PA with specified frequency in the specified band is given in table 1.

Table 1. Design Specifications of the Proposed Class E Pa

Parameters	**Power amplifier**
Center frequency	1842.5MHz
Bandwidth	75MHz
Technology	0.35µm CMOS

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The values of components used in the circuit of power amplifier is given in Table II.

Table 2. Values of Components in Class-E Power Amplifier

Components	**Values used in the circuit**
Length	0.68µm
Width	843µm
C3	0.466982pF
C4	1499.415pF
R1	0.0001Ω
R_L	100Ω

III. Simulation of the Proposed Class E Power Amplifier

Various PSPICE simulations are performed that includes transient analysis, S-matrix parameter analysis, and AC & DC analysis. Transient analysis predicts whether VI product is high or low. Transient response for the power amplifier operating at 1842.5MHz is shown in fig.3

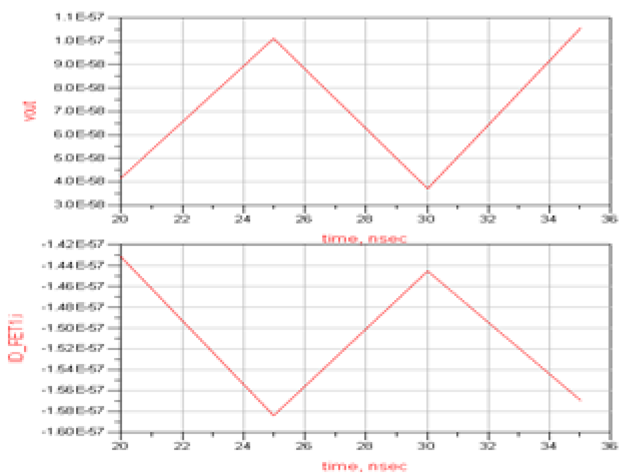
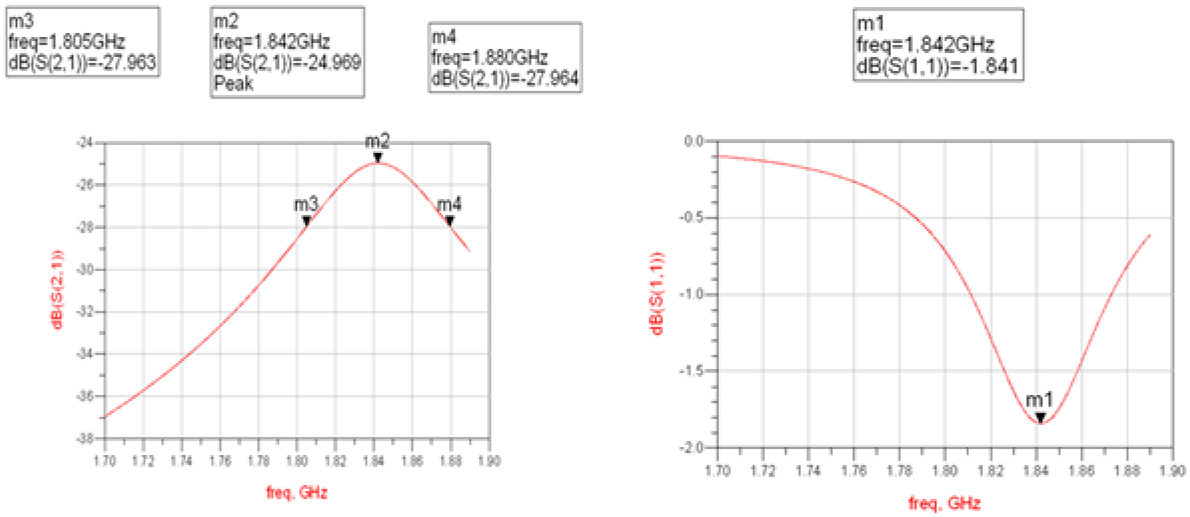


Fig.3 momentary analysis of power amplifier

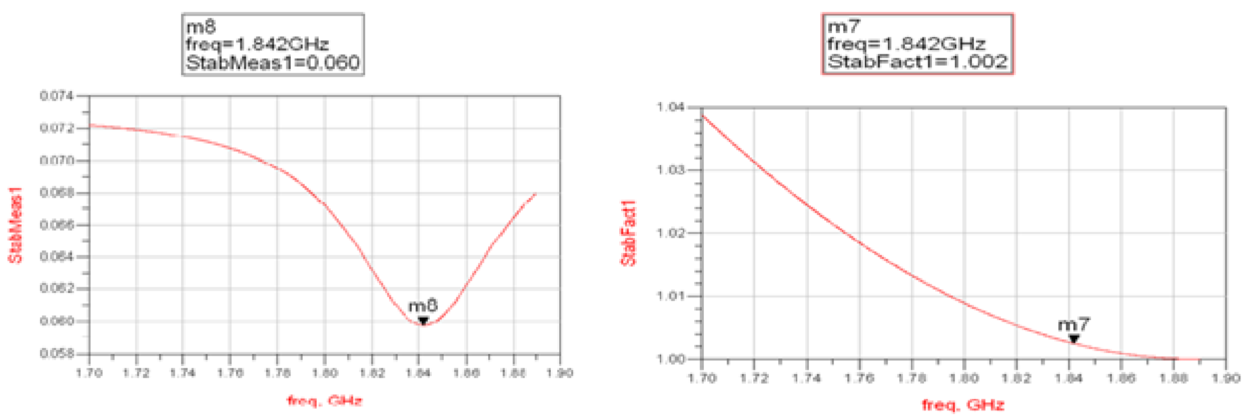
Figure 3 shows that product V x I is minimum in the proposed power amplifier. S-parameter simulation comprising of forward voltage gain curve (S_{21}), return loss (S_{11}). The S-parameter simulation results of proposed class-E PA is shown in fig.4.



S_{21} S_{11}

Fig.4 S-Parameter simulation of Class-E PA at 1842.5MHz

Rollette stability factor k>1 and stability measure Δ<1 indicates the system is unconditionally stable. Simulation analysis comprising of Stability measure Δ and Stability factor k are shown in figure 5.



(a) Stability measure Δ (b)Stability factor k

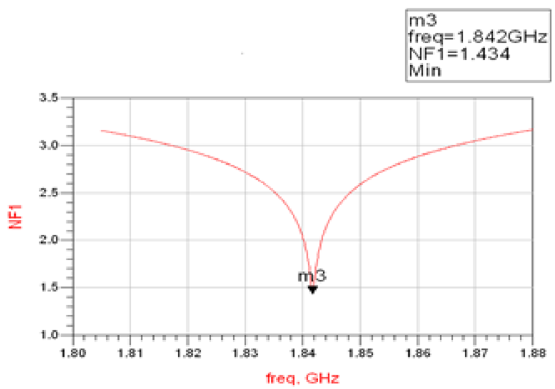
Fig.5 Rollette stability factors

AC Simulation is carried out to discover the NF & SNR. Noise figure is calculated using Eq.6 as:

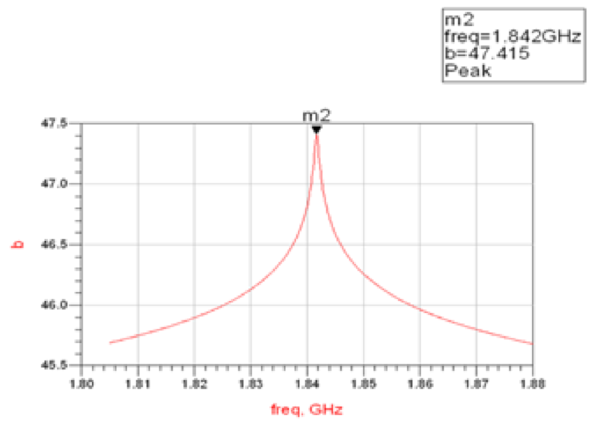
$$Noise\ factor\,(F) = \frac{SNR_i}{SNR_o} \qquad (5)$$

$$NOISE\ FIGURE\,(NF) = 10 * \log(F) \qquad (6)$$

Simulation analysis comprising of noise figure (NF) and signal / noise ratio (SNR) are shown in figure 6.



(a)NF



(b)SNR

Fig.6. Noise figure and SNR of power amplifier

Table 3. Iiummary of Results

PARAMETERS	RESULTS
Stability factor	Δ=0.060<1, k=1.002>1
Noise figure	1.434dB
SNR	47.415dB
PAE	69.30%

IV. Conclusion

Class-E Power amplifier for center frequency 1842.5MHz is designed and various performance parameters are analyzed. The proposed class E power amplifier gives a PAE of 69.30% which is higher than the power amplifiers in literature with PAE 64%. The NF of proposed amplifier at 1.434dB for 1842.5MHz is obtained. The output of Class-E PA is non-linear. As future work the linearity has to be improved by appropriate linearization techniques.

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