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RESEARCH ARTICLE

Zigbee Power Amplifier Linearization Using Cartesian Feedback.

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Abstract

This paper presents the design of a Power Amplifier (PA) operates in the 868MHz frequency range for Zigbee Wireless Sensor network (WSN) applications. The PA is designed for 11mW output power. The Cartesian Feedback (CFB) has been applied to the designed PA to improve linearity. The linearized PA designed is designed in UMC 130nm CMOS technology and has ACPR 22dB at 24.3 KHz from the carrier, total output power of 10.4 dBm and transducer power gain 7.6dB. The designed PA consumes 22mW at efficiency of 44.5%for power source 1.2Volt.

I-Introduction

Zigbee wireless technology is a short-range communication system for applications with relaxed throughput and latency requirements in wireless personal area networks. The key features of ZigBee wireless technology are low complexity, low cost, low power consumption, low data rate transmissions, Flexible and dynamic network topologies supported by cheap fixed or moving devices. The main field of application of this technology is the implementation of WSNs The IEEE 802.15.4 Working Group focuses on the standardization of the bottom two layers of the ISO/OSI protocol stack. The other layers are normally specified by industrial Consortia such as the Zigbee Alliance [2, 3, 4]

RF PA is the basic component for any wireless transceiver so its efficiency directly influences the complete communications system. PA consumes the lion's share of the power budget in most transceivers. On the other hand, it may be desirable to have high spectral efficiency increase the ability to transmit data at the highest possible rate for a given channel bandwidth.

This paper is organized as follows section II shows different architectures for low power PA for WSN Applications. section III presents the design of proposed PA and its performance. in section IV we demonstrate the CFB linearization applied to the proposed PA and its simulation output. Section V is the conclusions.

II-Literature Survey

Different architectures has used in the WSN applications a Class E is one of the most popular technique used for Zigbee design. Usually most of WSN communication systems require good efficiency for longer life time and often uses Class E or Class F power amplifier then we apply one of linearization techniques. Many linearization techniques can be used to adopt PA performance.
in [K n-Wai Li • Ka-Nang Leung] proposed a class E PA that operates for 433MHz the designed PA has 40.2 % drain efficiency while output power is 14.7 dBm at 433 MHz under 1.2-V supply.
Briffa et.al, [4] has designed a PA with CFB linearization; the proposed PA operates at 2GHz and ahs an eff of 22%.
This PA consumes 22.4mW power for 1.2V supply with 42.4% efficiency .To improves PA performance, CFB linearization has been applied to the designed circuit. Fig 2 and linearized using CFB technique to improve the linearity and ACPR.

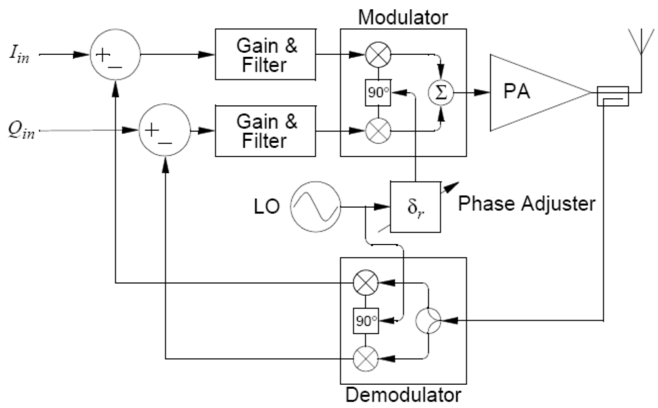


Fig. 1: Cartesian feedback transmitter.

-Digital modulation formats such QPSK and π/4 DQPSK is used. The digital application is referred to digital modulation such as Pi\4 DQPSK which has a peak to average power of 3 dB ratio. These modulations Types combines' phase and amplitude modulation. Amplifiers handling such signals must be carefully characterized and designed if adequate Amplitude and phase linearity are to be maintained. [6]

III-Zigbee PA Design procedure

In this section, the design of the proposed PA is presented A class E PA is designed to operate in the 868 MHz frequency range. The PA is shown in Fig.2 The following set of equations shows the design steps for the PA. [7]

$$P_{out} = \frac{\pi^2 + 4}{8} I_{DC}^2 R \quad (1)$$

$$R = \frac{8V_{DD}^2}{P_{out}(\pi^2 + 4)} \quad (2)$$

$$L = \frac{8V_{DD}^2 Q_L}{wP_{out}(\pi^2 + 4)} \quad (3)$$

$$C = \frac{P_{out}(\pi^2 + 4)}{w8V_{DD}^2 Q_L} \quad (4)$$

$$Cd = \frac{P_{out}}{\pi w V_{DD}^2} \quad (5)$$

Where Pout is the output power, R is the optimum load resistance, VDD is the supply voltage, Cd is the shunt capacitance at the drain-to-source ,L-C tuned circuits where Q is the loaded quality factor of the resonant circuit R_L_C, supply voltage ,operating (angular) frequency ω,

Table 1 design value

Variable	value
P	11mW
R	75.5 Ohm
L	96.9nH
C	346.9fF
Cd	445.8fF

For an output power 11mW (where Zigbee has an average power 1-100mW), R is calculated to be 75.5Ω, which is the optimum load resistance for maximum power transfer. this R is then matched to RL=50Ω which represents the antenna.

LB1 and LB2 are Dc feed coils Rm1 and Lm1 are input matching elements and Rm1 acting as stabilization resistance Cd is the external part of the total shunt capacitance L and C are the wave form shaping elements Cm2 and Lm2 are the output matching elements M5 is the switching transistor which include inside it apart of shunt capacitance .

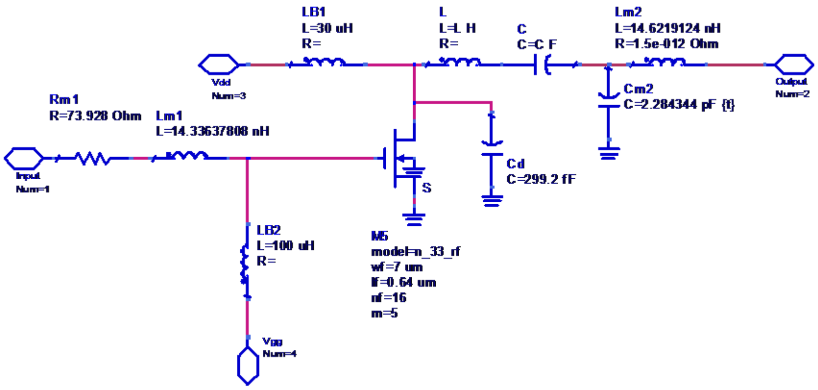


Fig. 2 Zigbee class E Power Amplifier

Fig.2 above illustrate proposed class E designed power amplifier with output power 11mW at center frequencies of 868MHz.

IV–I-Simulations Result

In this section, the complete set of simulations that shows the designed PA performance are demonstrated. Fig. 3 shows the S-parameter of the PA, with gain 7.5 at 868 MHz freq. the S parameters (S11, S22) are used to get the optimum i/P and o/P matching network for the designed PA,

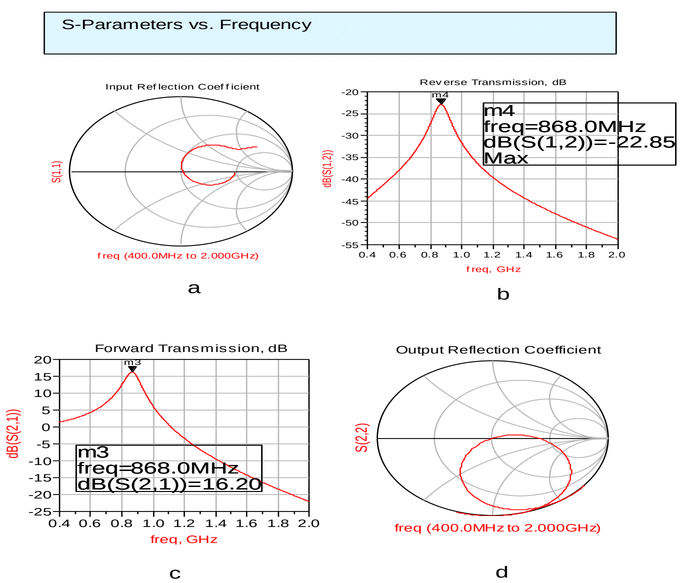


Fig.3.a S1,1 matching, Fig.3.b S 2, 2 output matching, Fig.3.c. reverse transmission, Fig.3.d Forward Transmission

The designed Amplifier Achieve input matching and output matching and peak gain at the desired frequency

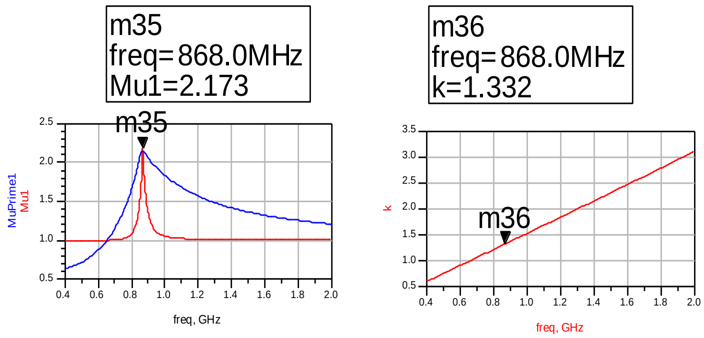


Fig. 3 (e) stability simulations

As illustrated above the designed class E is matched in both input and output ports as in Fig.3.a-3.b. While Fig.3.c measure the reverse and forward gain (S12, S21) and The following step will provide you with K (stability factor), mu (load stability) and mu_prime (source stability). To get these values, you will set up an S-parameter simulation and use Predefined equations in ADS

Fig.3.e showing that the circuit is stable at input and output with mu value and muprim value greater than unity and the overall circuit is stable since k factor is greater than unity.

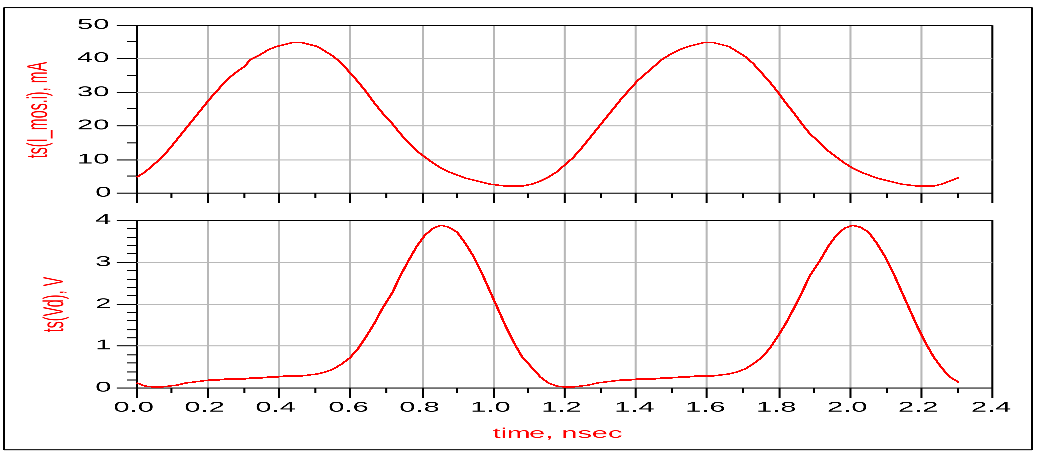


Fig.4 voltage and current waveform at the drain of the MOS Transistors

Fig.4 shows that there are little interaction between voltage and current waveform at the drain of the MOS Transistors

Which reduce the loss in MOS and posting the efficiency

Fig. 5 shows the PAE of the designed PA. At (a) the PA has an output power 11 mW with 42.4% PAE.

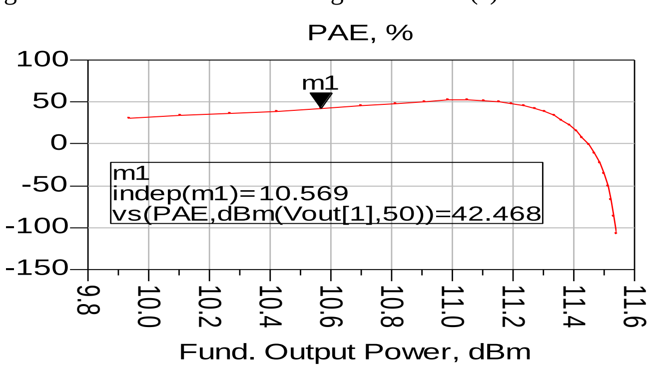


Fig. 5: PAE of the designed PA

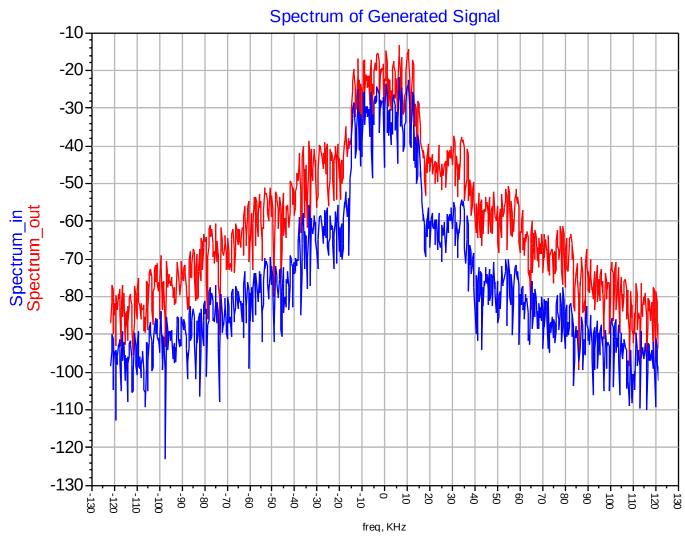


Fig.6 P.A. Frequency spectrum

Fig.6 shows that the frequency spectrum of the designed PA at 24.3 KHz symbol rate add spectrum spreading in the applied signal due to non linearity behavior of class E power amplifier

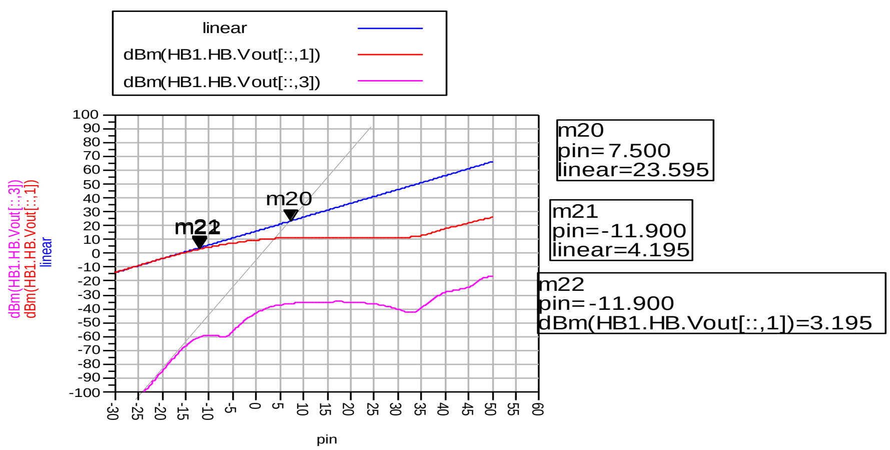


Fig.7 AM-AM response

Fig.7shows the AM-Am response of the PA, this relation is linear up to the compression point then non linearity is destroying linear relations fig shows that IIP1 happened at -11.9 dBm and IIP3 happened at 7.5 dBm

IV-II-PA CFB Linearization

PAs are inherently non-linear due to their technology limitations. Non-linearity increases excessive distortion of the transmitted signal which can result in symbol recovery errors at the receiving end. since the nonlinearities, induced by the PA cause amplitude and phase distortion which reduce spectral efficiency.

while a spectrally efficient modulation technique produces Non-constant envelope signals, If it is applied to a nonlinear amplifier, the signal will suffer spectral growth, which will lead to adjacent channel interference. One of the solutions would be to use an efficient nonlinear PA and apply a suitable linearization technique to compensate for these nonlinear distortions, many linearization techniques have been proposed.

there is no ‘best’ linearisation technique.

linearisation technique Can be states as (Feed forward linearization, Feedback, adaptive digital mapping predistortion (table look-up technique), Envelope Elimination and Restoration, Linear Amplification With non Linear Component (LINC)) [10]

Our work focuses on Cartesian feedback systems for two main reasons. First, because they employ analog feedback and the Requirement for a detailed nonlinear model of the PA is greatly relaxed.

Second, Cartesian feedback systems automatically and elegantly compensate for process variations, temperature fluctuations. [11]

Cartesian feedback is a narrow band modulation feedback scheme .is an effective means of linearizing an efficient yet non-linear power amplifier. This reduces amplifier distortion to acceptable levels and enables the transmission of RF signals utilizing spectrally efficient linear modulation schemes with a lower consumption of DC power.

This work presents modulation analysis using π/4 DQPSK in a 868MHz power amplifier. This amplifier is designed using Advanced Design System (ADS) to demonstrate the Adjacent Channel Power Ratio (ACPR).

When using CFB The simulation block diagram of the closed loop Cartesian feedback P.A. is shown in Fig.(8) And The simulation result at frequency (868 MHz)

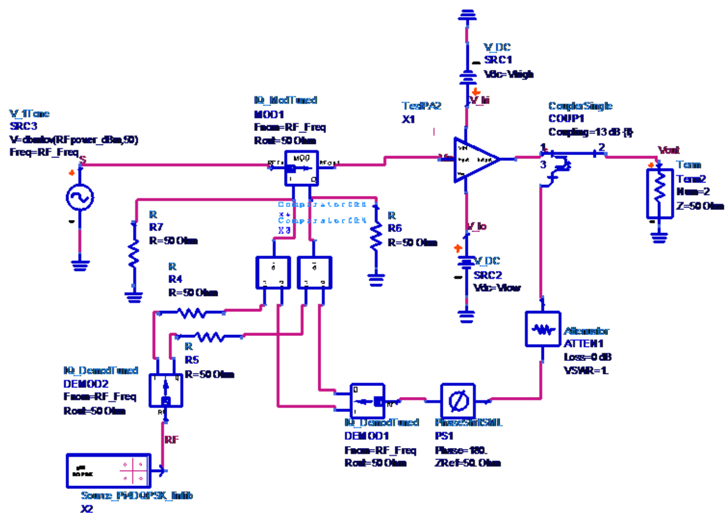
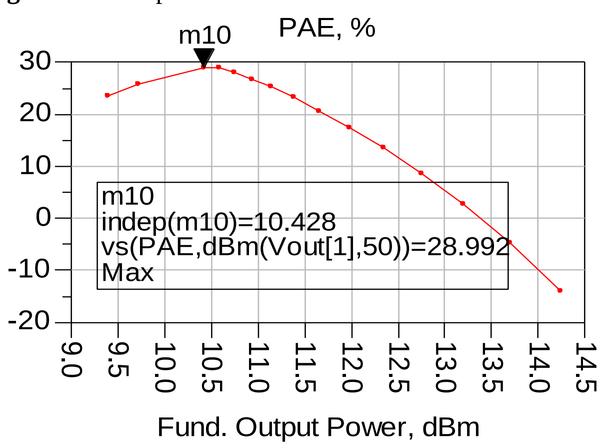
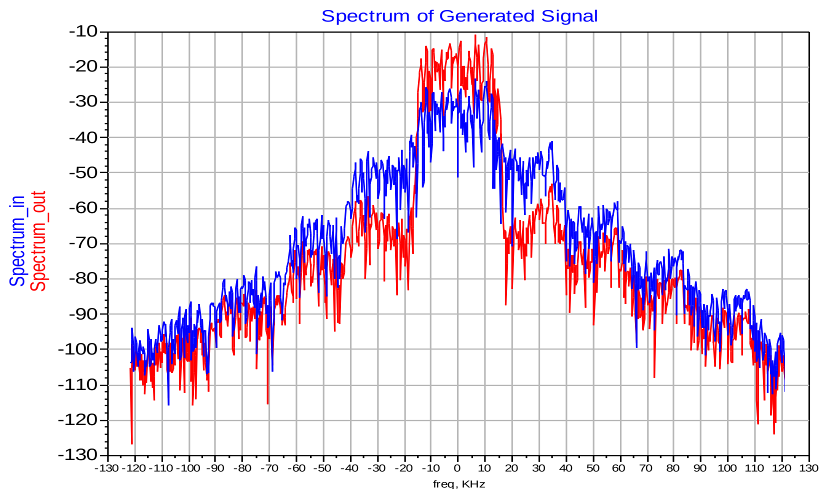


Fig.8 closed loop Cartesian feedback



a

Fig.9-a PAE VS output power a: designed PA b: linearized PA



b

Fig.9-b linearized P.A. spectrum

At Fig.9-a and after linearization PAE drop to 29% which is the cost of linearization Process
As seen in Fig.9-b When CFB used the output spectrum is become more efficient and the overall output spectrum are improved by 22 dBm

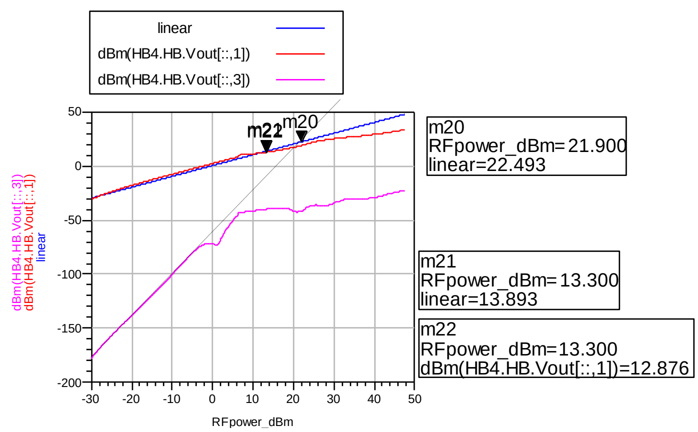


Fig.10 AM-AM plot
And the I/O relation in Fig.10 become more linear than non linearized E PA in Fig.7
And the IIP happened at 13.3 dBm insisted of -11.9 dBm and IIP3 happened at 21.9 dBm insisted of 7.5 dBm

V -CONCLUSIONS

A class E PA has been designed to operate in the Zigbee 868MHz frequency range the designed PA has been using CFB
The simulation analysis gives a good start to achieve our goal in Cartesian Feedback power amplifier design.
Cartesian feedback (CFB) is also a classic solution, in which continuous analog feedback makes the PA output linearly follow the input. Despite the excellent energy efficiency of CFB for PA linearization, and the natural robustness to variations in the PA model [8]

Simulation analysis can make predication of the actual PA performance. This paper makes a good agreement for linearity and efficiency of the E power amplifier. As the output spectrum of the PA has been compressed 22dB after close loop Cartesian feedback has been implemented, we can say that a good linearity is achieved. Or in other words, we can say that linearization performances 22dB ACPR improvement at 24.3 KHz offset. ACPR Global System for WSN which operates at 868MHz.

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