

# Linear CMOS Power Amplifier for WiMAX Application

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**Abstract**— CMOS power amplifier is field of interest of developers now a days due to high demand of mobility requirement with higher data transfer speed. Pas are the most power consuming part and main contributor in transceiver chain. Since we have limited power source of lithium battery for mobile communication more effort for more innovative ideas and better performance of designs are welcomed to improve its performance. CMOS is field of interest due to its cost and integration benefit. In this paper, linear CMOS power amplifier for WiMAX application is presented for 2.5 GHz frequency. For increasing linearity and efficiency, a parallel cascade class A&B power amplifier is used. The power stage of proposed power amplifier with 1 volt power supply provide maximum output power of 0.45mW and power added efficiency of 29% with 33.4dB gain at 2.5 GHz operating frequency

**Key Word** —CMOS power amplifier, parallel class A&B power amplifier, transformer, power combiner, WiMAX.

## I. Introduction

The rapid growth of wireless systems has created increasing demand of lower cost, smaller form factor systems with superior and complex functionalities. This demand has promoted the pursuit of single-chip transceivers realized in CMOS technology. Transmitter for the wireless systems requires amplification of signal with high efficiency and linearity in order to transmit signal efficiently.

Power amplifiers are main block for constructing wireless communication system. Also radio frequency power amplifiers are one of challenging block in designing RF transceiver.

PA is most power hungry component in RF front end side, a highly efficient power amplifier with high output power is necessary for longer battery life in wireless applications. CMOS technology is famous for low power driving however additional function is required to increase output power of PA, i.e. power combiner combines several power cells in order to achieve high output power.

Recently, the most successful attempt for creating a component that perform impedance matching and power combining simultaneously have been done. One of function that fulfill this work is transformer that according to the class of combining current or voltage is classified

into series-combining transformer (SCT) and parallel combining transformer

Transformer and power combining transformer (PCT), respectively.

The worldwide interoperability for microwave access (WiMAX) wireless communication system gradually becomes research topic due to the advantages of high data rate, long transmission distance, wide coverage, and good quality of service technology. In WiMAX front-end circuits, the power amplifier is an important component, which decides the transmission coverage and entire efficiency of the system. The most critical issues for power amplifier design are linearity and efficiency. High linearity is needed due to complex modulation technique where phase and amplitude modulation are applied to transmit data as much possible for the given bandwidth, while the high efficiency improve thermal management, reliability, cost and battery life.

In this work , a fully integrated power amplifier with high output power using parallel class AB for WiMAX application in standard 90 nm technology is presented..

## II. Transformer design as power combiner

In this transformer perform power combining operation as a method for increasing output power and convert differential to single ended signal in power amplifier circuit is used. In this output of amplifiers are added using transformer.

The schematic diagram of 2 × 1: 2 transformer is shown in fig. 1(a). This transformer is constructs from two primary windings which have magnetic coupling with the secondary winding. Fig 1(a) shows output of two power amplifiers which are connected to the primary winding of transformer and because of mutual inductance between primary and secondary winding the output current will be the ratio of input current at primary winding.

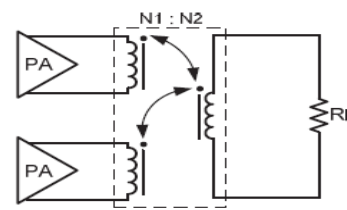


FIG 1 Schematic diagram of 2 × 1: 2 transformer

### III. Proposed High Power Amplifier

The whole schematic diagram of proposed power amplifier is shown in fig. The proposed power amplifier consist of input balun, driver stage, inter-stage impedance matching network, power stage and power combining transformer (PCT). Input balun shown in fig. is an electronic device which convert single ended to differential signal. Application of balun is to interface unbalanced signal to balanced transmission line for long distance communication.

A double stage is used to provide enough gain, the driver and power stages are designed in cascade topology. Also the driver stage is biased in class A to increase overall linearity of PA. Impedance matching network are placed between driver and power stage such that they maximize transferred power from driver to power stage. In power stage two Class-AB power amplifier combinations are used in cascade topology in which upper PA combination is similar to lower one.

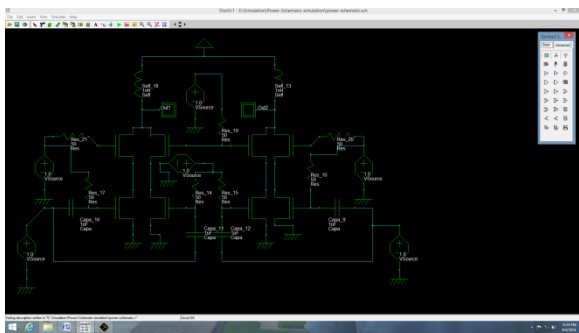


Fig 2. Power stage of power amplifier

Power combiner as a method for increasing output power, impedance matching and converting differential to signal ended signal n power amplifier circuit. In our circuit transformer is used as a power combiner which combines output of different amplifiers.

In this design of power amplifier, two amplifiers are used and their output current is added using off chip transformer. It is noticeable that upper power amplifier is similar to lower PA. Using parallel class A&B power amplifier can improve the dynamic range and PAE.

If we parallelize the class A and Class B power amplifier, the  $g_m$  of class A&B power amplifier will be linear in wide range. The parallel class A and class B power amplifier as follows:

$$g_{mA\&B} = g_{mA} + g_{mB}$$

Combining the class A and class B power amplifier can improve the linearity of the trans-conductance. When the input signal is low, class A power amplifier produce most of the output power, and when signal increase, the class B power amplifier is main amplifier for producing the output power.

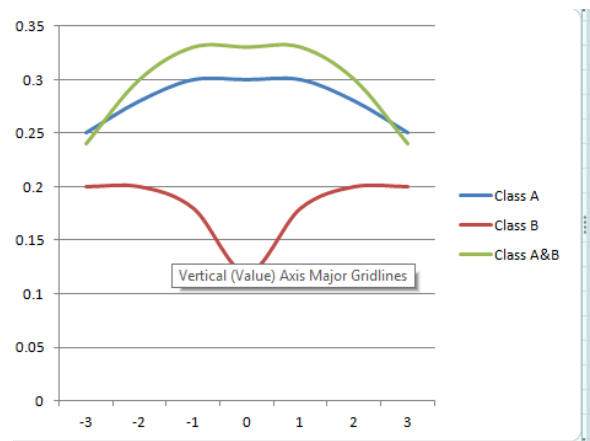


Fig3. gain of class A,B and AB amplifier

### Simulation result:

Simulation of power stage of proposed circuit gave given layout designs for transistor combinations and its analog representation is given below simultaneously.

With 1 V power supply in power stage simulation result gave 380μA drain current and output power of 0.45mW and transistor voltage of 1.2V.

PAE- Power-added efficiency (PAE) is a metric for rating the efficiency of a power amplifier that takes into account the effect of the gain of the amplifier. It is calculated (in percent) as:

$$PAE = 100 \times \frac{P_{out}^{RF} - P_{in}^{RF}}{P_{DC}^{Total}}$$

PAE will be very similar to efficiency when the gain of the amplifier is sufficiently high. But if the amplifier gain is relatively low the amount of power that is needed to drive the input of the amplifier should be considered in a metric that measures the efficiency of said amplifier. However the most common and accurate definition of efficiency, referred to as power added efficiency (PAE). So we achieved PAE of 29% for power stage by using data's and calculation.

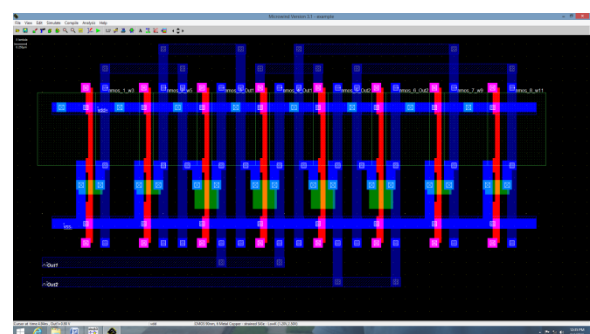


Fig 4 layout design of power stage simulation

**Gain -**

In electronics, gain is a measure of the ability of a two-port circuit (often an amplifier) to increase the power or amplitude of a signal from the input to the output port by adding energy converted from some power supply to the signal. It is usually defined as the mean ratio of the signal amplitude or power at the output port to the amplitude or power at the input port. It is often expressed using the logarithmic decibel (dB) units ("dB gain"). A gain greater than one (greater than zero dB), that is amplification, is the defining property of an active component or circuit, while a passive circuit will have a gain of less than one.

Power gain in decibels (dB), is defined by the 10 log rule as follows:

$$gain(db) = 10 \log \left( \frac{P_{out}}{P_{in}} \right) dB$$

Where  $P_{in}$  is the power applied to the input and  $P_{out}$  is the power from the output.

By using above data's we get the db gain of 33.4dB values for power stage of proposed circuit.

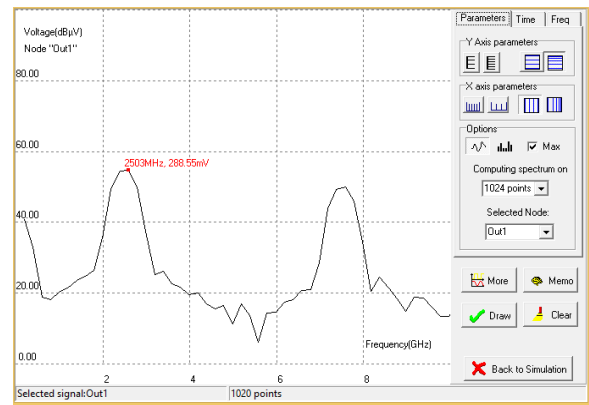


Fig.7 Output spectrum of power amplifier

With the power supply, the proposed power amplifier produce maximum output power of 0.45mW and PAE of 29% is achieved at the maximum output power. The power amplifier gives the gain of 33.4dB. The power amplifier is proposed for WiMAX (802.16e) signal which provide good linearity required for WiMAX.

**Conclusion**

In this paper, linear CMOS power amplifier in standard 90nm technology is presented. A modified parallel power amplifier is proposed for increasing the efficiency and linearity. The output of this power amplifiers are connected together by off chip power combining transformer. The power stage of proposed power amplifier gives output power of 0.45mW and PAE of 29% with 33.4dB gain for 2.5 GHz frequency range with 1V power supply for WiMAX application.

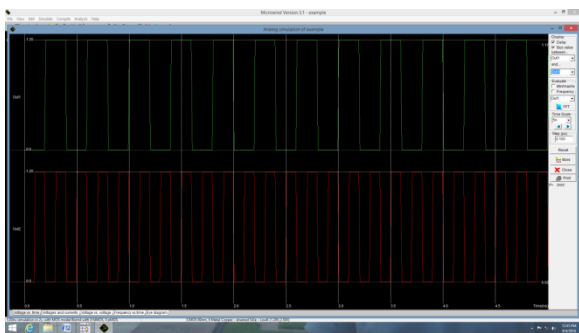


Fig 5 analog simulation of proposed power stage

**Output power-**

As we know the output power is major factor for WiMAX application because the range of coverage depends on output power. As we know it is power in watt produced by circuit at its loads given by mathematical expression :

$$Power = Voltage \times Current$$

So we get average output power of 0.45mW with 1.2 V drain voltage and 380μA of drain current at output of power stage.

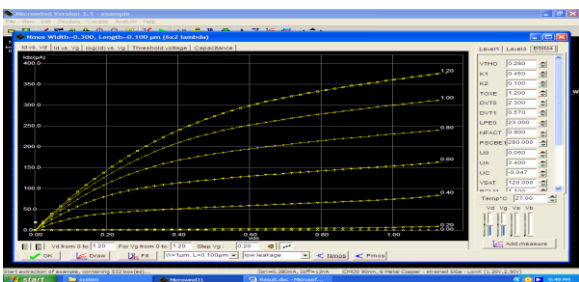


Fig 6 Current graph of simulation result

Table- Comparison among papers

Papers with Specifications	Ref.1	Ref. 2	Ref. 3	Ref. 4	This work
Power amplifier	Class AB	Class AB	Class AB	Class C+AB	Class AB
Process	180 nm	180nm	90nm	180nm	90nm
Operating Frequency	-	2.5 GHz	2.4 GHz	2.6GHz	2.5GHz
V <sub>dd</sub> (V)	-	3.3	3.3	3.3	1.2
PAE %	44	34.8	33	26.6	29
Gain(dB)	12	31.3	28	12.3	33.4

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