



Cairo University

# **DESIGN AND IMPLEMENTATION OF A MULTI-BAND HIGH EFFICIENCY ENVELOPE ELIMINATION AND RESTORATION POLAR TRANSMITTER FRONT-END**

By

**Ahmed Mamdouh Metwally Mansour**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
in  
**Electronics and Communications Engineering**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
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**Title of Thesis:**

Design and Implementation of a Multi-Band High Efficiency Envelope  
Elimination and Restoration Polar Transmitter Front-End

**Key Words:**

Power amplifier; Multi-band; Polar transmitter; Envelope elimination and  
restoration; Supply modulator

**Summary:**

In this work, the design and implementation of a multi-band polar transmitter front-end has been introduced. The transmitter circuit is implemented using a 130nm standard CMOS technology. To the best of the author's knowledge, this is the first transmitter front-end design that can cover frequency range from 0.75 up to 2.2GHz and yet compatible with most of the modern communication standards.

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# List of Symbols and Abbreviations

$\eta_D$	Drain Efficiency
$\eta_{PAE}$	Power Added Efficiency
$\eta_{overall}$	Over All Efficiency
$P_{out}$	Output Power
$P_{in}$	Input Power
$P_{1dB}$	One dB compre
ACLR	Adjacent Channel Leakage Ratio
EA	Envelope Amplifier
EER	Envelope Elimination and Restoration
EVM	Error Vector Magnitude
GMSK	Gaussian Minimum Phase Shift Keying
HF	High Frequency
LTE	Long Term Evolution
MF	Medium Frequency
MMMB	Muti-Mode Multi-Band
MEMS	Microelectromechanical Systems
OFDM	Orthogonal Frequency Division Multiplexing
PA	Power Amplifier
PAPR	Peak to Average Power Ratio
RFPA	Radio Frequency Power Amplifier
SC-FDMA	Single Carrier Frequency Division Multiple Access
SDR	Software Defined Radio
SNR	Signal to Noise Ratio
SoC	System on Chip
WCDMA	Wideband Code Division Multiple Access
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access

# Abstract

Due to the continuous advance in modern communication systems, the need for developing new systems supporting multiple communication standards on one device becomes a crucial requirement. The challenge becomes severe when the required system is installed on a hand-held device which uses a battery with limited capacity as a power source. One of the most challenging blocks in the design of this system, is the power amplifier (PA) which contributes with the majority of power consumption of any transceiver system. According to this, the design of PA should be meeting all the required specification with maximum efficiency.

This work proposes a new design for a multi-standard high efficiency PA. In this design polar transmitter architecture is utilized using envelope elimination and restoration (EER) technique. In EER technique the modulated signal is divided into two signals. First signal is the amplitude or envelope signal, while the other signal is the phase signal. The phase signal is applied to a highly efficient nonlinear PA, and the amplitude signal is applied through a supply modulator which tracks the envelope signal.

In order to satisfy the wide coverage of multiple frequencies, the proposed PA uses a wide-band output matching network. In order to increase the bandwidth coverage, two power amplifiers have been integrated and combined using antenna switches for the band select capability. The proposed concept has been proven through design equations. Design has been implemented and simulation results have been reported. A prototype design has been fabricated and measurements have been performed to verify the functionality and performance of the proposed design.