# Design of Dual-Band Substrate Integrated Waveguide (SIW) High Efficiency Power Amplifier

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***Abstract* — In the modern communication systems, it is of key importance that transceivers are capable of operating with multiple communication standards in the same equipment. To this end, the design of multi-band and broadband power amplifier systems is a major challenge that may lead to cost-effective and compact devices. The proposed project addresses the design of a low-cost high efficiency dual-band power amplifier based on the Substrate Integrated Waveguide (SIW) technology.**

***Index Terms* — Composite Right/Left-Handed cells, GaN HEMT, Metamaterial, Multi-Band Power Amplifier, Substrate Integrated Waveguide**

## I. INTRODUCTION

NOWADAYS, power amplifiers are critical components in modern transceivers since they are responsible for most of the total power consumption in base stations and user equipment. Hence, the design of high efficiency power amplifiers is of key importance to boost the battery life of portable devices and increase the reliability of base stations.

Apart from the need for high efficiency amplification, the emergence of new communication standards requires transceivers capable of operating at multiple frequencies/ standards simultaneously. Multi-band and broadband devices can substantially reduce the number of circuit components needed in a transceiver resulting in low-cost and compact devices.

The design of multi-band and broadband power amplifiers is a challenging task as both the input and output matching network of the topology should be designed to meet the same behavior at an arbitrary set of frequencies. The selection of such impedance matching networks depends on the application scenario, the operating frequencies and the available technology.

Among the available technologies for the design of devices operating at the microwave and millimeter wave frequency bands stands the Substrate Integrated Waveguide (SIW) technology that combines the advantages of a bulky metallic waveguide (such as low-losses and high isolation) and microstrip technology (such as ease of fabrication and reduced fabrication cost) [1]. Additionally, SIW technology provides the possibility to integrate passive and active components and antennas in the same substrate. Despite the inherent advantages of the SIW technology, active SIW circuits have received less attention if compared to passive circuitry [1].

In this project, we address the design of a high output power dual-band power amplifier based on the SIW technology. The design of multi-band and broadband power amplifiers based on SIW technology opens a variety of new perspectives for modern communication systems, since it combines the advantages of the capability to operate with different standards with compact and ease to fabricate devices.

## II. PROJECT

Among the efforts for multi-band operation stands the implementation of impedance matching networks based on the metamaterial properties [2]. The proposed power amplifier topology is inspired from the metamaterial concept and is based on the properties of the Composite Right/Left-Handed (CRLH) unit cells, as described in detail in [2], [3].

The design of the dual-band impedance matching networks in substrate integrated waveguide technology arises from the equivalence between the CRLH unit cell of Fig. 1a and the SIW characteristics (intrinsic shunt inductance, shunt capacitance and series inductance). The necessary series capacitance of the CRLH unit cells, which is not met at the conventional SIW topology, can be added in the waveguide by etching meander slots on the top metal surface of the waveguide [3].

The design process of a multi-band power amplifier starts with selection of the active device and the definition of the systems specifications. The 10 W RF power GaN HEMT transistor from Cree is selected for the design of the high output power amplifier [4]. Stability considerations are also taken into account during the design phase of the power amplifier [5]. In particular, resistances are placed at the input matching network and at the gate bias of the power amplifier to ensure a stable operation under all the expected operating conditions.

Initially, the input and output matching networks of the power amplifier are represented as the equivalent LC structure of the CRLH unit cells (Fig. 1a). Then, the power amplifier is simulated using the Harmonic Balance (HB) analysis in the commercial software Agilent ADS. The lumped-element

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components are optimized in order to achieve the desired performance in terms of output power and power added efficiency at the selected operating frequencies (2.45 GHz and 5.8 GHz). The optimization of the lumped-element matching networks results in the information regarding the desired frequency response for each unit cell.

In a second step, a SIW section is designed for each CRLH unit cell in the commercial electromagnetic (EM) simulator Ansys HFSS and is adjusted in order to obtain the same frequency response as the lumped-element version of the CRLH unit cell. Meander slots are also designed for each SIW section that represents a CRLH unit cell in order to achieve a dual-band operation in two arbitrary bands.

The S-parameters resulting from the full-wave analysis of the SIW structure are then inserted in Agilent ADS and compared with the desired frequency response of the CRLH unit cells at the selected frequencies. An iterative process between the design of the lumped-element CRLH unit cell and the SIW section is followed, where the LC parameters of the CRLH unit cells and the dimensions of the SIW section are fine tuned to achieve the same frequency response at the selected frequencies. Fig. 1b shows the simulated input matching network based on the SIW technology and corresponds to a single CRLH unit cell. The same procedure applies for the design of the output matching network. Finally, the S-parameters of the input and output matching networks based on SIW technology are imported in Agilent ADS and a final analysis of the structure is carried on. Input and output 50 Ω microstrip lines are also added in the design for measurement purposes. Fig. 2a and Fig. 2b show the schematic of the proposed power amplifier and the fabricated prototype.

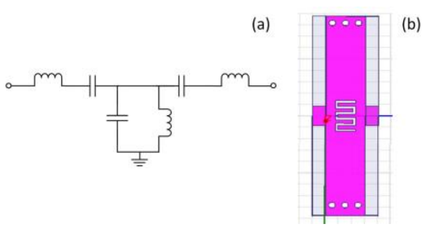


Fig. 1. a) Equivalent circuit model of a single CRLH unit cell, b) SIW implementation of the CRLH unit cell.

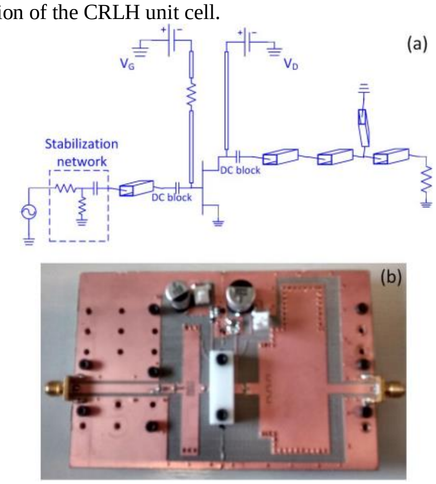


Fig. 2. a) Schematic of the proposed dual-band SIW power amplifier and b) fabricated prototype.

## III. Impact of the MTT Fellowship

### A. *IMPRESSIONS FROM THE ATTENDANCE OF THE 2014 IMS CONFERENCE*

The attendance of the 2014 IEEE MTT International Microwave Symposium (IMS) has been a great and valuable experience for me. During the conference, I had the opportunity to enhance my knowledge by attending the plenary talk, the technical sessions, the panel sessions and by visiting the industrial exhibit.

I also had the opportunity to make an oral presentation of my paper [6] practicing my communication skills. The feedback that I received from my presentation helped me to further continue and improve my work resulting in a journal publication [7]. During the conference, I (forming part of a team with international PhD students from Georgia Institute of Technology Atlanta, US) participated in the Student Design Competition on Wireless Energy Harvesting with the design and implementation of a wireless energy harvester (Fig. 3).

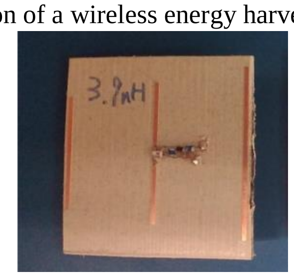


Fig. 3. Prototype of the fabricated 2.45 GHz rectenna.

### B. *NEXT CARRER PLANS*

An additional benefit from the attendance of the IMS conference is that I met scientists and researchers both from industry and academia. The interaction with experts in the field of microwaves has helped me to create a network of contacts that are expected to increase my career opportunities in the near future.

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