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ScienceDirect

Procedia Manufacturing 22 (2018) 591–597

Procedia MANUFACTURING

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11th International Conference Interdisciplinarity in Engineering, INTER-ENG 2017, 5-6 October 2017, Tirgu-Mures, Romania

A DC-2.5 GHz high linearity CMOS attenuator in a 0.18µm technology

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Abstract

A CMOS attenuator with high linearity has been designed and measured in a 0.18-µm CMOS process, to be used for a variable gain amplifier of RF wireless transceiver. The design is based on four cascaded Bridge-T attenuator stages that are consecutively activated to adjust the attenuation level and improve linearity. The design operates in the frequency band of DC-2.5 GHz with 2 - 3.5 dB insertion loss and 14 dB maximum attenuation in the entire frequency range. Measured and simulated results are in good agreement over the frequency band of interest. Measured worst case S11 and S22 are –10 and -8.8 dB, respectively, across the frequency band. The measured 1-dB compression point is +22 dBm at maximum-attenuation.

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Peer-review under responsibility of the scientific committee of the 11th International Conference Interdisciplinarity in Engineering.

Keywords: attenuator; digital attenuator; CMOS; linear-in-dB; linearity; wide bandwidth.

1. Introduction

The modern communication systems have the ability to control signal strength consistently in the signal path. The received power between the receiver and base station depending on the distance may vary by orders of magnitude. Hence, precise gain control circuitry is needed to limit the incident power to the receiver chain. Likewise, in the transmitter chain modern communication standards require stringent power control in the transmitting circuitry. For

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Peer-review under responsibility of the scientific committee of the 11th International Conference Interdisciplinarity in Engineering.
10.1016/j.promfg.2018.03.086

example, a CDMA phone needs adequate control of its output power in order to maintain an efficient link between the user and the base station [1].

The variable gain amplifiers (VGAs) have been the traditional choice in implementing variable gain elements. VGAs are not optimal for multi-band applications since they have narrow band performance. They also exhibit high power consumption and poor linearity such as, cable modem receivers where the incident power can be as high as 0 dBm in 75 Ω, the linearity and power handling requirements for the variable gain element can be extremely difficult to meet with active elements. Power dissipation in such amplifiers may be hundreds of milliwatts to meet the system specifications [2]- [4].

Passive resistor network and FET devices as switches can be used as digital-controlled variable attenuators with modest dynamic range and righteous matching. The low cost and availability of CMOS process make it an attractive choice of technology to integrate systems on a single chip. Furthermore, the downscaling of the CMOS technology continues to provide devices with higher f_T, which are suitable for broadband RF circuits. The purpose of this paper is to use the CMOS technology to implement a broadband multi-purpose attenuator, which can be integrated on chip in a system design. With the passive-type construction, the attenuator core has a wide bandwidth without penalties in power consumption [1], [2].

In this paper, a 4-bit CMOS digital step Bridge-T attenuator networks are demonstrated. Analysis of the proposed 4-bit attenuator is also studied. In section II, we discuss the circuit architecture of the attenuator. In section III, the design concept of the proposed topology and the analysis of the 4-bit attenuator are also explained. In section IV, the measured and simulated results of the attenuator circuit are presented; Conclusions are reported in section V.

2. Circuit Architecture

Several topologies of digital step attenuators, shown in Fig. 1, have been demonstrated in the literature [5] - [10] for switched Π/T attenuators. These attenuators mainly achieve relative attenuations from insertion loss differences by on/off control of R_F switches. The switched Π/T attenuators have series and shunt FET switches merged with a resistive network for attenuation. These topologies have a single series switch in a signal path. The parasitic difference of the switch on/off state, however, causes the transmission phase change.

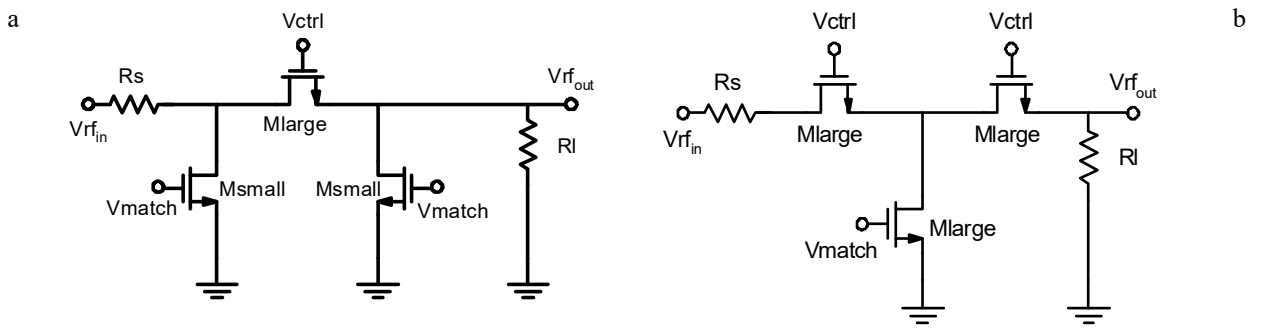

Fig. 1. Topologies of digital step attenuators Switched (a) Π and (b) T attenuators.

The Π-attenuator and T-attenuator shown in Fig. 1 are widely used as gain control elements. For linear-in-dB controllability, the series and shunt transistors are used as switches. A lot of efforts have been devoted to improve the linearity and matching of the discrete-step attenuator [4].

3. Circuit Design Approach

The schematic of the proposed differential attenuator is shown in Fig. 2-a. The proposed attenuator circuit consists of four cascaded bridge-T attenuators and utilizes different attenuation states controlled by 4-bit control

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