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Research Article

Dual-Band Matching Networks Using a Combination of Microstrip Lines and Active Switching Components

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Abstract

In this article, two novel dual-band matching networks (MNs) with adapted frequency are designed, constructed, and measured for a power amplifier (PA) module at the central frequencies of f1=2.4GHz and f2=5.8GHz. The proposed networks are to be utilized in a concurrent dual-band adaptive PA. In some high-frequency applications, active switching components are also employed in circuits to open and close connections or even change their branch-line parts. Besides, return and isolation losses (RLs and ILs) are regarded as the fundamental parameters to describe the performance of such components. Using a PIN diode, called the BAR50-02 (Infineon Technologies, Germany), two types of simultaneous MNs with the ability to change the frequency bands in a wide range are presented. Moreover, the equivalent circuit of the PIN diode, the integrated concurrent MNs, and the ideal circuit components are provided along with the relevant formulas. The dual-band MNs, characterized with frequency adaptation, are then designed, simulated, and built, and finally, the circuit characteristics are measured within both bands.

Keywords: Adaptive power amplifier, dual-band integrated matching network, switching components, stepped impedance amplifier.

Highlights

- Study Presentation of a compact dual-band matching network with frequency control over a wide bandwidth range.
- Presentation of a dual-band matching network using microstrip lines with frequency control over a wide bandwidth range.
- Integration of active switch components with compact elements for control and tuning of the center frequencies.
- Integration of active switch components with microstrip lines for control and tuning of the center frequencies.
- Proposing a novel combination of dual-band matching networks with controllable frequencies within the circuit's frequency response range.

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1. Introduction

The increasing demand for wireless communication systems requires transmitters with high efficiency, multi-band capability, adaptability, and proper linear operation. A cognitive radio system aims to operate over different frequency ranges in a way that does not interfere with other wireless communication systems and is not affected by interference from other systems [1]. Over the past two decades, numerous studies have focused on designing linear, simultaneous multi-band, and highly efficient power amplifiers [2–5].

Recently, attention has also been given to the design of flexible front-end components, which typically include three sections: a low-noise amplifier, a power amplifier, and a switching circuit. The power amplifier section is the most critical part of the front-end design. For a cognitive radio system, the power amplifier must be capable of adapting its frequency and power characteristics. Designing a power amplifier with adequate efficiency and adaptability is an important research task. Achieving high efficiency in power amplifiers for multi-band applications, such as Global System for Mobile Communications (GSM), worldwide internet access via microwave or WiMAX, code division multiple access (CDMA), and long-term evolution (LTE), remains a major challenge [6]. One approach for designing power amplifiers in mobile cognitive radio applications is the use of broadband power amplifiers, which cover the entire required bandwidth with a constant gain. However, broadband power amplifiers are often costly to design, and low power gain and efficiency reduce their overall performance [7].

Given these challenges, the design of various multi-band filters has become a current research topic. In this context, some designers have employed different microstrip geometries to achieve dual-band bandpass filters [2–6]. Reference [7] utilizes a stepped-impedance resonator for dual-band bandpass filter design, while reference [8] implements a two-state filter using a square-path resonator. In reference [9], MEMS structures are employed to generate a second frequency. By controlling switches (turning them on or off), optimal matching in two different frequency bands is achieved, as applied in references [10] and [11] to increase the number of bands and amplifier efficiency. Reference [12] presents a three-band bandpass filter at 5.6 GHz, 7.15 GHz, and 8 GHz using a multi-mode substrate integrated waveguide (SIW) with a rectangular cavity. In reference [13], varactor diodes are used as switches to achieve optimal matching across four frequency bands with a constant gain of 15 dB in each band. Other common methods include the use of PIN diodes and FET switches for realizing multi-band power amplifiers [14–16].

A cognitive radio system operates across different frequency ranges to avoid interference with other systems and to minimize the effects of external interference. Such a system requires adaptive power amplifiers whose operating frequencies can be tuned. For example, if at a certain frequency, such as 2.4 GHz, the cognitive radio system experiences interference from surrounding WiFi signals, the amplifier can immediately adjust its frequency slightly (e.g., to 2.42 GHz or 2.5 GHz) to minimize the impact of the interfering signal. The matching network proposed in this study provides this capability over a suitable frequency range. The main distinction of this design from other dual-band filters or matching networks is this important adaptive feature. To achieve a highly efficient and frequency-adaptive network, band-switching and PIN-diode-based matching networks have been utilized. The designed networks for two simultaneous frequencies have been designed, simulated, and implemented. By employing a PIN-diode switch (BAR50-02) and precise capacitor control, a wide frequency range can be obtained in both bands. The operating range of the proposed matching network is determined as 1.8 GHz < f_1 < 2.8 GHz for the first band and 4.9 GHz < f_2 < 6.9 GHz for the second band.

2. Innovation and contributions

In this paper, two novel dual-band matching networks are introduced, designed to operate at the two main frequencies of 1.84 GHz and 3.5 GHz for GSM and WiMAX standards.

The design method is as follows:

- Design using ideal components and lumped elements
- Design using microstrip lines

Both design methods are capable of being used in the final stage of a dual-band transmitter.

The mechanism applied in both designs allows the circuit to self-adjust in case the first frequency interferes with the second frequency, expanding or narrowing the frequency range as needed to minimize the resulting interference.

Reducing interference leads to an increase in the overall efficiency of the final power amplifier.

3. Materials and Methods

In this study, ADS software was used for the design and simulation. An 8 GHz spectrum analyzer was used to measure the S-parameters.

4. Results and Discussion

Figure 1 shows the characteristic responses of the scattering parameters (S11 return loss) for both single-band and simultaneous dual-band modes. In the simultaneous dual-band mode, a small frequency shift between the simulated and fabricated responses is observed in both bands, which is caused by losses from the circuit elements during fabrication. This shift can be corrected using the capacitor Cn. The first frequency, F1 = 2.4 GHz, and the second frequency, F2 = 5.8 GHz, have been selected, which are suitable for the operation of a power amplifier for WCDMA technology. Capacitor Cn is incorporated for use in cognitive radio systems. Figure 1(d) illustrates the limited variations of this capacitor. Table 1 shows the changes in the dual-band simultaneous frequency range corresponding to variations in Cn. It should be noted that in an integrated power amplifier, Cn can be controlled via software; therefore, in case of frequency interference in one band, the frequency range can be adjusted using Cn to eliminate the interference. This functionality is crucial in power amplifiers, leading to enhanced amplifier efficiency and, ultimately, improved transmitter performance.

5. Conclusion

This study presents the design and implementation of two dual-band matching networks for WCDMA applications, using active switch components in the 2.4 GHz and 5.8 GHz frequency bands. Because both bands have a broad range of frequency adjustment, if one of the bands becomes interfered with, it may be corrected using the regulator capacitor and switch to prevent the interference's negative consequences. These matching networks are used in adaptive power amplifiers for application in cognitive radio systems. In these systems, if the transmitter and receiver have interference or annoying noise in one of two frequencies, the system will be able to correct the frequency instantly. This feature is important in cognitive radio systems. The proposed dual-band filter with compact elements provides better responses than the proposed dual-band matching network with microstrip lines. But, choosing the second filter for the dual-band power amplifier is more suitable in terms of the uniform design of the microstrip circuit.

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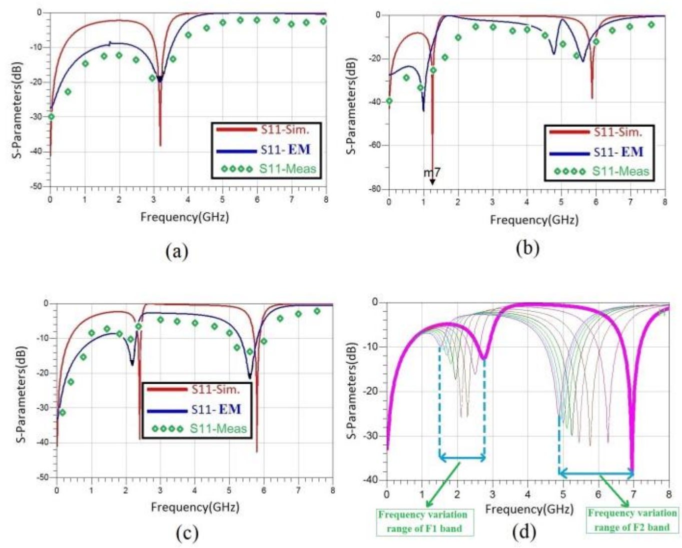

Figure 1. The characteristic response of the return loss S11, (a): the first band (SW1 = on) and (SW2 = off), (b): Second band (SW1 = off) and (SW2 = on), (c): simultaneous dual band mode (SW1= SW2=on), (d): Examining the changes of the capacitor (Cn) on the bandwidth.

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