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High efficiency dual-band filtering power amplifier

Yuanchun LI[1], Yuanbo WANG[1], Disi WU[1], Runze ZHAN[1], Shichang CHEN[2] & Quan XUE[1,3*]

[1]School of Electronics and Information Engineering, South China University of Technology, Guangzhou 510640, China;
[2]School of Electronics and Information Engineering, Hangzhou Dianzi University, Hangzhou 310018, China;
[3]Intelligent Sensing and Wireless Transmission Center, Pazhou Laboratory, Guangzhou 510330, China

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Dear editor,

In the past decades, filtering power amplifiers (PAs) have attracted much attention due to the integration of PA and filter and the potential for overall performance improvement. Nevertheless, all the reported filtering PAs only focus on single-band responses [1–4]. The dual-band filtering PA remains technically challenging because the output matching network (OMN) with fundamental mode and harmonic impedance transformations in two bands and simultaneous filtering characteristics is complicated and difficult to design.

In this study, a novel dual-band filtering PA is proposed. By using the proposed impedance transformation network (ITN), several transmission zeros (TZs) are provided to guarantee the filtering response. The automatic optimization method combining Levenberg-Marquardt (LM) with the Inpolygon algorithm is applied for converting fundamental modes and the second harmonic impedances to the optimum ones in the two bands. Benefiting from the proposed ITN and the optimization method based on it, the OMN parameters are easily obtained, and therefore a dual-band filtering PA working at 1.79 and 2.45 GHz is realized. In measurement, high power-added efficiencies (PAEs) in the two passbands and good filtering selectivity are observed. Thus, the proposed method is applicable for the sophisticated PA design with multiple design targets.

Dual-band filtering network. Figure 1(a) displays the proposed OMN, which is composed of a dual-band ITN, two tuning lines, and a short-circuited bias line. For the ITN, two uniform stubs are loaded symmetrically on the main transmission line and coupled with each other to generate transmission zeros pair (TZP) for the dual-band response. Moreover, a stub with its end open is loaded at the midpoint of the network.

Due to the symmetry of the ITN, the even- and odd-mode method is utilized for analysis. And the even- and odd-mode equivalent circuits are also depicted in Figure 1(a). Based on the lossless transmission line theory, the even-mode and odd-mode input impedances of the ITN, $Z_{\rm in3e}$, and $Z_{\rm in3o}$, could be obtained. Accordingly, the related S-parameters could be calculated and shown in Figure 1(b). As seen, two transmission zeros $f_{\rm TZ3}$ and $f_{\rm TZ4}$, i.e., TZP, are generated around 2 GHz. Then the two separated filtering passbands are obtained. Moreover, there are one and two TZs in the upper and lower stopbands, respectively.

Dual-band filtering network optimization method. Because the OMN should satisfy the optimum impedances of fundamental modes in the two bands and make impedances of the second harmonics located in high-efficiency regions (HERs), the parameters of the OMN are time-consuming to obtain. Here, HERs represent the ranges of the second harmonic impedances to ensure high PAE. Thus, an optimization method based on the ITN is utilized to speed the design up. According to the transmission line theory, the input impedances $Z_{\rm in}(f_i)$ $(i = 1, 2)$ at the package plane in Figure 1(a) could be obtained, where f_1 and f_2 are 1.8 and 2.4 GHz, respectively. To evaluate the matching results, the difference between the input impedances $Z_{\rm in}(f_i)$ and the optimum impedances $Z_{\rm opt}(f_i)$ is defined as the optimization criterion, which is described as

$$\Delta Z = \sum_{i=1}^{2} \left| \frac{Z_{\rm in}(f_i) - Z_{\rm opt}(f_i)}{Z_{\rm opt}(f_i)} \right|^2, \quad (1)$$

$Z_{\rm opt}(f_i)$ could be evaluated from load-pull simulations. After running the Levenberg-Marquardt algorithm in MATLAB, ΔZ is minimized to get the network parameters. Besides, the Inpolygon algorithm is utilized to ensure the second harmonic impedances $Z_{\rm in}(2f_i)$ in the HERs. Overall, the guideline is summarized as follows. (1) Build the ITN with TZP according to the dual-band filtering response. (2) Calculate $Z_{\rm in}(f_i)$ of the OMN. (3) Employ the LM algorithm for minimizing ΔZ based on Eq. (1) to obtain the structure parameters. (4) Estimate whether the second harmonic impedances are inside the HERs or not. If not, randomly reinitialize parameters. Then iterate steps (2)–(4) until the design goals are satisfied. (5) Derive the final parameters of the dual-band filtering OMN.

Circuit implementation and measurement. Following the

* Corresponding author (email: eeqxue@scut.edu.cn)

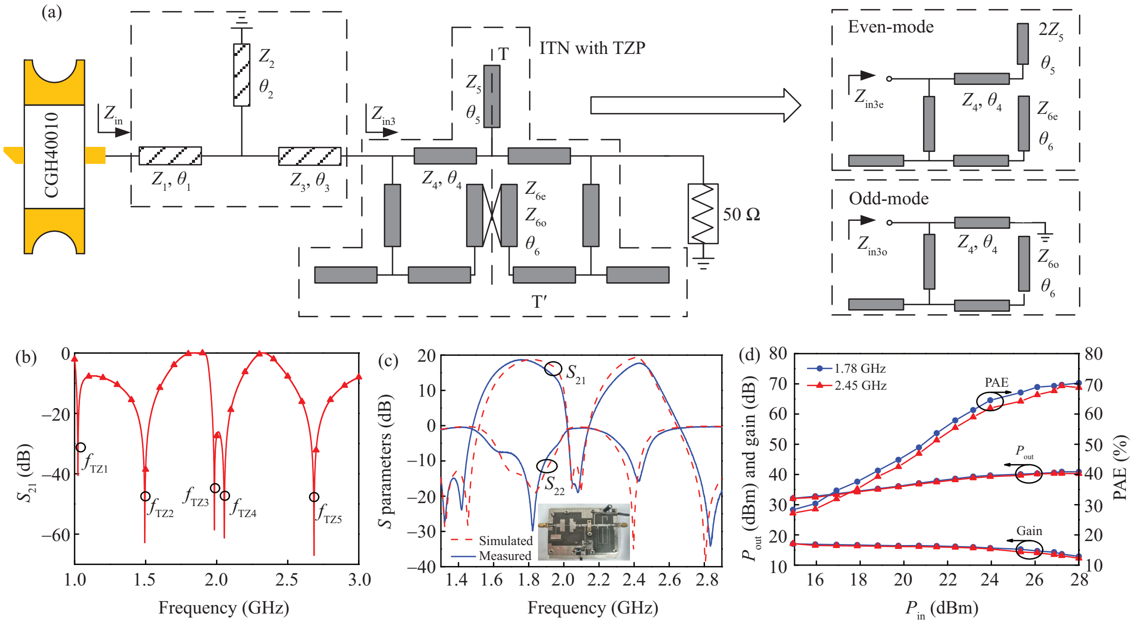

Figure 1 (Color online) (a) Dual-band filtering ITN of the PA; (b) calculated S_{21} of ITN; (c) simulated and measured S-parameters of the PA; (d) measured gain, P_{out} and PAE.

analysis above, a filtering PA with dual-band response is fabricated and measured. Figure 1(c) shows the measured small signal response. As observed, the two filtering passbands are located at 1.79 and 2.45 GHz with their gains of 18.6 and 17.4 dB. Five TZs are generated, enhancing the selectivity of the two passbands. Thus, the effectiveness of the proposed method in designing the dual-band filtering response is verified. From Figure 1(d), the saturation output power and the highest PAE at 1.79 GHz are 40.9 dBm and 70.2% at 28 dBm input power. They are 40.4 dBm and 69.2% at 2.45 GHz, respectively. With a constant input power of 28 dBm, the output power is around 40 dBm within the lower passband from 1.7 to 1.82 GHz. And the bandwidth with PAE of more than 60% is over 110 MHz. As for the upper passband, the output power is around 40 dBm from 2.4 to 2.6 GHz and more than 60% PAE is maintained from 2.43 to 2.48 GHz. The measured results demonstrates that the proposed dual-band PA owns good dual-band filtering performance and high PAEs simultaneously.

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