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Innovative Design of a Miniaturized Wideband Port-Multiplexing Microstrip Circuit

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ABSTRACT: This paper presents a miniaturized broadband port-reuse microstrip circuit to address the challenges of bulky volume, excessive insertion loss, and parameter deviation superposition caused by discrete port design and discrete circuit design in the interconnection between active phased array antennas and T/R components. Based on an integrated design methodology, the circuit achieves band-pass filtering, bidirectional power coupling output, DC power supply port functionality, and RF/DC isolation through a single-port interconnection. Experimental results demonstrate that the implemented circuit in Ku-band exhibits 13.5–15.18 GHz band-pass filtering characteristics, bidirectional signal power monitoring capability, 0–12 V/2.5 A DC power supply functionality, and effective RF/DC signal isolation. The measured results align well with theoretical predictions. This architecture demonstrates exceptional adaptability and seamless integration capability, showing significant potential for large-scale deployment in various transceiver architectures such as satellite communication systems.

1. INTRODUCTION

In today's rapidly evolving information age, the functionality of communication and electronic devices is becoming increasingly sophisticated, and correspondingly, circuit design is growing more complex. Miniaturization has always been a crucial direction in the development of complex communication and electronic devices [1]. With the widespread adoption of emerging technologies such as phased arrays, the demand for device miniaturization has become even more pressing [2]. Traditional designs that rely on separate ports and discrete components often occupy a significant amount of space, making it difficult to meet the requirements for miniaturization and high performance. Achieving more functionality within limited space while maintaining high performance and reliability has thus become a major challenge for designers.

Active phased array antennas and T/R (Transmit/Receive) terminals in systems require interconnection through multiple ports and various cables to achieve signal filtering transmission, DC power supply for active antennas, and power monitoring of transmitted signals. However, due to space and size constraints of the platform, issues such as large wiring volume and inconvenient maintenance arise. The miniaturization of interconnections has always been one of the key focuses in the miniaturization of phased array devices [3]. In recent years, research on single-port multiplexing transmission of multiple signals has been continuously increasing. By integrating circuit functions through structural multiplexing and topological fusion, all signals can be transmitted through a single port. This allows for a single cable connection between active phased array antennas and T/R terminals in the system. This approach not only effectively saves space and improves performance indicators but also provides convenience for subsequent maintenance and upgrades.

This paper innovatively proposes a miniaturized wideband port-sharing microstrip circuit, which is integrated at the RF (Radio Frequency) port of the T/R terminal. It enables single-port and single-cable interconnection between phased array antennas and T/R components, while simultaneously achieving band-pass filtering, high current power supply at the antenna end, and real-time bidirectional power coupling detection of transmitted and received signals. This greatly simplifies the interconnection method and optimizes space occupation. This design not only significantly reduces the size and weight of the circuit while enhancing performance but also offers excellent scalability and compatibility, allowing for easy integration into existing communication systems.

2. SCHEME DESIGN

The miniaturized wideband port-sharing microstrip circuit designed in this paper achieves a single-port and single-cable connection between the antenna end and T/R component end of phased array devices through topological integration and structural fusion. Integrating this circuit at the signal port of the T/R component allows for signal filtering, high current power supply to active transmit and receive antennas, and real-time bidirectional power coupling monitoring of the transmission port. The traditional interconnection method is shown in Fig. 1. In this scheme, an active antenna port is connected to a T/R component port through power and RF cables, which transmit power and RF signals separately. Inside the T/R component, discrete filters and directional couplers are cascaded to achieve

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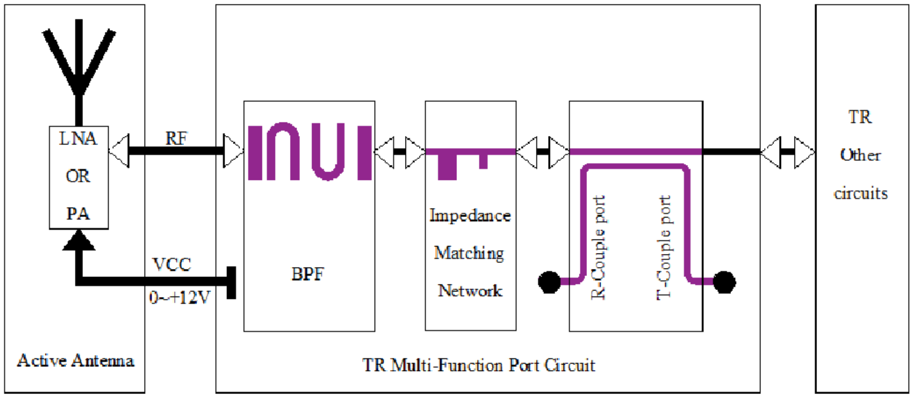

FIGURE 1. Schematic diagram of the traditional implementation method.

filtering and coupling detection. The overall circuit volume and insertion loss are represented as follows:

$$V_{\text{total}} = V_{\text{filter}} + V_{\text{coupler}} + V_{\text{cable}} + \Delta V \tag{1}$$

$$\text{IL}_{\text{total}} = \text{IL}_{\text{filter}} + \text{IL}_{\text{coupler}} + \text{IL}_{\text{cable}} + \Delta\text{IL} \tag{2}$$

where ΔV is the additional volume introduced by the cascaded matching structure, and ΔIL denotes the additional insertion loss due to the matching network [4, 5]. While this discrete combination can achieve the required functions, it has two inherent drawbacks. First, the physical size and performance deviation exhibit a linear superposition effect. Second, impedance mismatch between cascaded structures may occur, leading to an increase in insertion loss due to the addition of impedance matching networks.

The wideband port-sharing microstrip circuit proposed in this paper is shown in Fig. 2. The innovative design is primarily reflected in three aspects: (1) The interconnection between active antennas and T/R terminals carries RF and DC signals simultaneously through a single cable, thereby reducing the space occupied by interconnection cables; (2) The integration of comb-line coupling filters and coupler structures not only effectively reduces the insertion loss of the circuit but also prevents DC power from entering the T/R signal chain; (3) By utilizing terminal open-circuit transmission line theory, the DC input node is cleverly designed to achieve power supply within the existing space without introducing additional circuit loss. Based on the relationship between the discrete design size and wavelength, the physical size of the new structure is reduced by approximately 50% compared to the traditional solution under the same operating frequency band [6, 7], while the insertion loss is reduced by approximately 30%.

This design significantly reduces the volume of the original interconnection method. When being used at the end of the transmitter output signal, it can improve the transmitter's efficiency, reduce heat generation, and lower power consumption. When being used at the front end of the receiver chain, it can directly improve the receiver's sensitivity and enhance its working performance [8, 9]. The reduction in size will bring considerable benefits to the miniaturization design of transmitters or receivers.

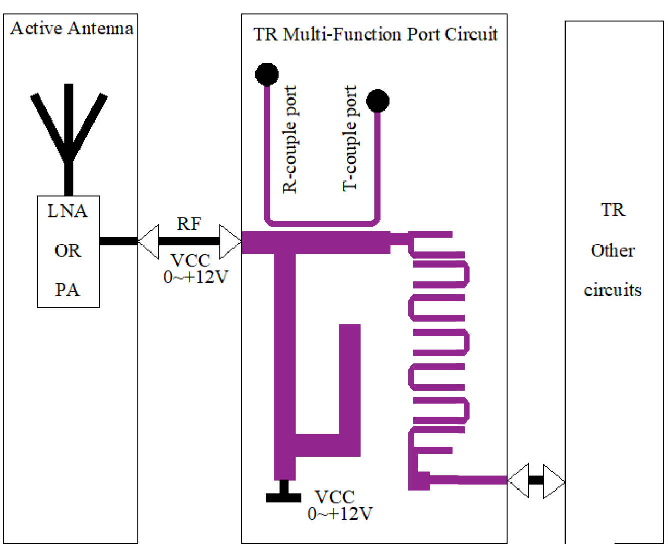

FIGURE 2. Schematic diagram of the novel integration method.

3. CIRCUIT DESIGN

3.1. Design of the Circuit Evolution Process

Traditional discrete port feeding designs, separate microstrip filter designs, and separate microstrip parallel coupler designs are numerous. Significant progress has been made in the research and methods of miniaturization in recent years. This paper does not elaborate on discrete design methods and parameter calculations but focuses on the research and design of port sharing and structural fusion.

The implementation forms of separate designs for microstrip filters, microstrip couplers, and microstrip port feeding technologies are diverse [10]. If an integrated design of the three is required, it should be achieved through topological integration and structural fusion, as shown in Fig. 3. Among them, Fig. 3(c) shows the integrated design of the port circuit. The transmission and reception RF signals are transmitted from port 1 to port 4, and the coupled monitoring signals are output from port 3 (transmit signal) and port 2 (receive signal). From the total port 1, according to the transmission line terminal open-circuit impedance transformation theory, λ is the

FIGURE 3. Minimization multiplexing superposition process, (a) coupler, (b) filter, (c) integrated design.

dielectric wavelength corresponding to the center frequency of the RF signal. When the length between node 1 and node 5 is $\lambda/4$ and the length between node 5 and node 6 is $\lambda/4$, the input impedance Z_{in} at node 1 of the main channel can be made equal to $+\infty$. Thus, the RF signal at this point in the branch can be regarded as an open-circuit signal with full reflection, avoiding power loss in the main signal channel of the port due to the absorption or reflection by other branches or inductive feeding circuits. Moreover, port 5 becomes an excellent DC input port [11].

3.2. Circuit Implementation and Simulation

The proposed circuit utilizes an RO4350B substrate with a thickness of 0.508 mm and a microstrip copper cladding thickness of 2 ounces [12]. Through topological integration and structural prototyping adjustments. The circuit integrates multiple functions, including high-current power supply (from P5 to P1), RF/DC isolation (from P1 to P4), bidirectional signal level monitoring for both transmission and reception (from P1 to P2 or from P4 to P3), and band-pass filtering for both transmission and reception signals (from P1 to P4). The relevant structures and dimensions are shown in Fig. 4 and Tab. 1.

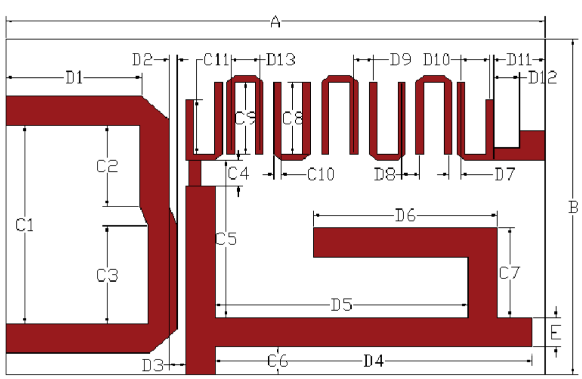

FIGURE 4. The proposed microstrip circuit structure.

TABLE 1. The dimension parameters of the proposed microstrip circuit.

A	21.00	C6	1.06	D2	1.14	D9	0.75
B	13.00	C7	3.50	D3	0.64	D10	1.11
C1	7.71	C8	2.80	D4	12.34	D11	2.15
C2	3.13	C9	2.80	D5	9.85	D12	0.81
C3	3.80	C10	0.30	D6	7.14	E	1.14
C4	1.00	C11	1.11	D7	0.50		
C5	5.10	D1	5.28	D8	0.70		

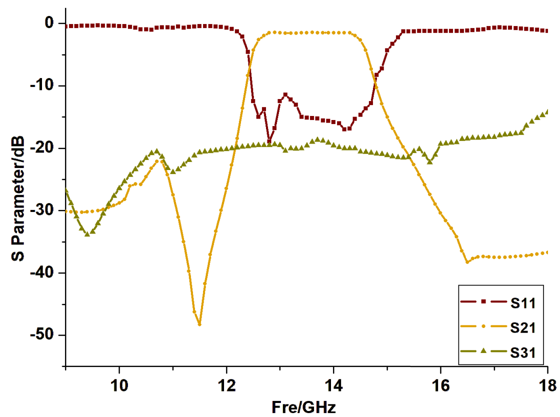

FIGURE 5. Simulated results.

After modeling, analysis, and optimization, the simulated results are presented in Fig. 5. With port 1 excited at 14 GHz and 1 W, Fig. 6 depicts the surface current distribution of the multiplexed microstrip circuit. The primary signal undergoes band-pass filtering along P1 to P4, while a secondary coupling route emerges from P1 to P2. The observed current patterns confirm the validity of the proposed design.

4. MEASUREMENT RESULTS AND ANALYSIS

The physical prototype is depicted in Figs. 7(a) and (b). As shown in Fig. 7(c), S-parameters of the prototype were measured using Keysight's vector network analyzer, which operated within a frequency range of 30 kHz to 26.5 GHz.

The response of the circuit's S-parameters was recorded, with the results presented in Fig. 8 and Tab. 2. The measured results are in good agreement with the theoretical simulations. However, there is a certain amount of drift in the filter passband

TABLE 2. The measured results of the proposed microstrip circuit.

Test Parameters	Coupling Metric Results			
Frequency (GHz)	13.5	14	14.5	15
Insertion Loss (dB)	1.47	1.23	1.26	1.58
Coupling (dB)	27	26	25	26.5
Test Parameters	Filter Metric Results			
Pass Band (GHz)	13.5–15.18			
Out of Band Rejection (dBc)	$\geq$ 26 @10 GHz–13 GHz $\geq$ 28 @16.5 GHz–18 GHz			
VSWR (dB)	1.82			
Temperature (°C)	25			
Test Parameters	Power Supply Results			
Load Capacity	0–12 V@2.5 A			
DC Blocking	Blocked			

TABLE 3. Comparison with previous related works.

Num	Article	Frequency (GHz)	Size (unit: mm)	Integrated Function
1	Ref. [13]	2.7	about 50.0 × 16.5	Multi-Way Filtering Power Dividers
2	Ref. [14]	1.05, 1.40, 1.72, 2.05	about 5.7 × 2.8	Frequency Division, Frequency Selection, and Power Division
3	This work	14.0	about 13.0 × 21.0	DC power supply, RF DC isolation, bidirectional power monitoring, Frequency Selection

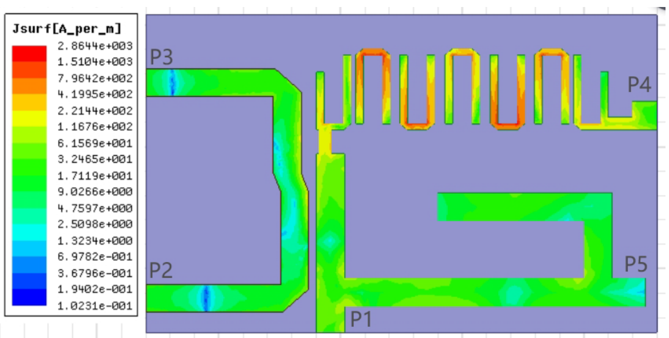

FIGURE 6. The surface-current distribution.

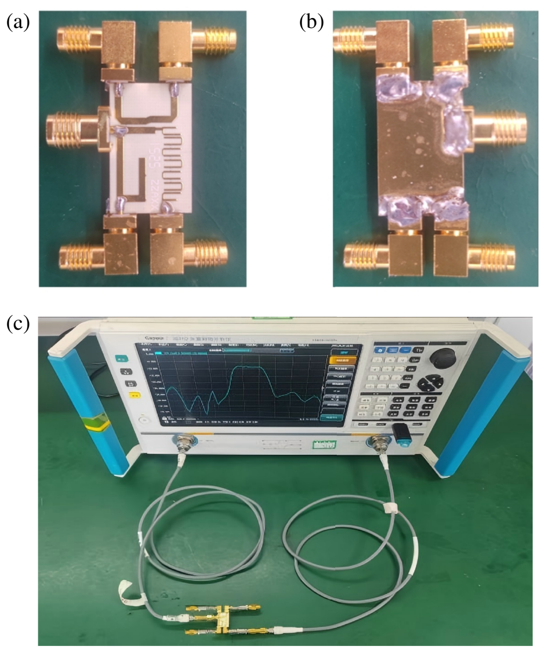

FIGURE 7. The prototype and measurement environment, (a) top view, (b) back view, (c) measurement setup.

and some deviation in the coupling compared to the simulated values. By improving the manufacturing process and strictly controlling the precision of the process, the performance errors can be controlled within the acceptable range.

Table 3 shows a comparison of the proposed work with previous related works, from which it can be seen that our new design has certain advantages.

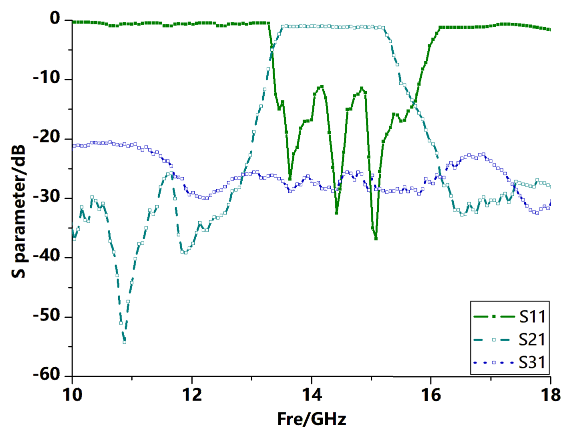

FIGURE 8. Measured results.

5. CONCLUSIONS

This study introduces a miniaturized wideband port-sharing microstrip circuit designed to address the issues of large size and compounded performance deviation in the interconnection between active phased array antennas and T/R components. Utilizing an integrated design approach, the developed circuit, when being integrated at the T/R component port, enables simultaneous signal filtering transmission, DC high current power supply, and bidirectional signal power monitoring through a single port and a single cable. This design not only significantly reduces volume, weight, and production cost but also markedly enhances performance metrics, thereby improving the working performance of phased array transceiver devices.

Experimental results indicate that the circuit can achieve band-pass filtering in the Ku band, provide a 0–12 V/2.5 A DC power supply, and monitor bidirectional signal power transmission. The measured results align with theoretical estimates, thereby validating the circuit's effectiveness and reliability. The design concept presented in this paper is universal and transferable. Future work will continue to explore the application potential of this design approach in the multiplexing of other microwave devices.

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REFERENCES

[1] Lu, J., J. Bian, and B. Zhou, "Miniaturized lumped-element LTCC quadrature hybrid with LC stacked structure," *Progress In Electromagnetics Research Letters*, Vol. 106, 75–80, 2022.

[2] Yu, Z. J., Z. Xu, Y.-K. Deng, and Z.-G. Zhang, "An overall LTCC package solution for X-band tile T/R module," *Progress In Electromagnetics Research Letters*, Vol. 38, 181–192, 2013.

[3] Ali, A., M. N. Awan, W. A. Malik, S. Y. Chaudhry, Hidayatullah, and J. Haider, "A compact and high gain X/Ku band shared aperture antenna array with enhanced inter-band and cross-band isolation," *IEEE Access*, Vol. 12, 146 137–146 146, 2024.

[4] Bai, M. and H. Liang, "The analysis of impedance matching problem in RF circuit design," in *2010 International Forum on Information Technology and Applications*, Vol. 1, 350–353, Kunming, China, 2010.

[5] Wang, H., C. Chen, L. Ha, S. Xie, G. Ning, M. Su, and X. Huang, "Design method of impedance matching network for high power cascaded class-E inverter," *IEEE Journal of Emerging and Selected Topics in Industrial Electronics*, Vol. 6, No. 1, 327–337, 2025.

[6] Cheng, S. M. and D. Psychogiou, "Compact multi-band filter/diplexer LNAs using split-type multi-resonant stages," *IEEE Transactions on Circuits and Systems I: Regular Papers*, Vol. 71, No. 10, 4512–4523, 2024.

[7] Tang, T., R. Zhang, M. A. Aldhaeebi, and T. S. Almoneef, "Self-packaged compact filter array: Innovations based on modified substrate integrated suspension line technology," *IEEE Transactions on Components, Packaging and Manufacturing Technology*, Vol. 15, No. 5, 1025–1031, 2025.

[8] Zhang, Y., F. Huang, X. Tang, J. Li, Z. Wei, and Y. Cao, "A 4×4 fully integrated RF transceiver in 6 GHz frequency band with single-channel bandwidth of 400 MHz and PHY data-rate of 8.8 Gbps," *IEEE Transactions on Circuits and Systems II: Express Briefs*, Vol. 72, No. 5, 723–727, 2025.

[9] Bai, H., L. Hao, D. Wang, N. Zhang, K. Gao, J. He, J. Zhou, J. Liu, and H. Liao, "A sub-6 GHz wideband transceiver chipset with calibration-friendly harmonic rejection RF front-ends," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 73, No. 4, 2084–2096, 2025.

[10] Timmins, I. and K.-L. Wu, "An efficient systematic approach to model extraction for passive microwave circuits," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 48, No. 9, 1565–1573, 2000.

[11] Priyansha, , K. R. Samatha, and S. Sivasundarapandian, "A novel input output impedance matching network for LNA," in *2016 International Conference on Communication and Signal Processing (ICCSP)*, 2089–2093, Melmaruvathur, India, 2016.

[12] Drumea, A. and C. I. Marghescu, "Study on techniques for the increase of the current carrying capability of the PCB tracks," in *2021 IEEE 27th International Symposium for Design and Technology in Electronic Packaging (SIITME)*, 374–377, Timisoara, Romania, 2021.

[13] Zhang, G., Z. Qian, X. Zhang, and J. Yang, "A general and effective design method of multi-way filtering power dividers on a new multi-port topology for industrial application," *IEEE Transactions on Industrial Electronics*, Vol. 68, No. 6, 5436–5447, 2021.

[14] Chen, C.-F., K.-W. Zhou, R.-Y. Chen, H.-Y. Tseng, Y.-H. He, W.-J. Li, and J.-H. Weng, "Design of microstrip multifunction integrated diplexers with frequency division, frequency selection, and power division functions," *IEEE Access*, Vol. 9, 53 232–53 242, 2021.