



## Study And Analysis Of X Band Onboard Power Dividing And Combining Techniques

Mrs. Shafali Tandon<sup>1</sup> Mrs.A. Sujatha Reddy<sup>2</sup>, V. Venkata Lakshmi Kamakshi Likhitha<sup>3</sup>, R. Swathi<sup>4</sup>

<sup>1</sup>NRSC, ISRO, Hyderabad, Telangana

<sup>2</sup>G. Narayanamma Institute of Technology and Science, Hyderabad, Telangana, India

<sup>3</sup>G. Narayanamma Institute of Technology and Science, Hyderabad, Telangana India

<sup>4</sup>G. Narayanamma Institute of Technology and Science, Hyderabad, Telangana, India

### ABSTRACT

This study explores advanced power combining and dividing techniques essential for high-power satellite communication. Techniques like corporate, radial, spatial, and serial are examined, emphasizing the evolution of Solid State Power Amplifiers (SSPAs) using GaAs FETs and GaN technology. SSPA advancements have led to increased power, broad bandwidth, high linearity, efficiency, and reduced size. Challenges in high-power device design, including heat dissipation and limited chip space, are discussed. The paper compares SSPAs with Traveling Wave Tubes (TWTs), highlighting the former's preference for space applications due to lower costs and higher reliability. The need for low-cost, reliable, and efficient amplifiers drives the development of various power combining techniques. Microstrip couplers, integrated into RF circuits on a single substrate, are explored for their ease of integration. The study concludes by presenting a 3-dB wide-band branch line coupler design at 8.2 GHz in the X-band, focusing on bandwidth optimization and size minimization using Advanced Design Software (ADS).

### Keywords:

Branch Line Coupler, Power combining techniques, Power dividing techniques, Microstrip, Advanced Design System, 3-dB wide-band coupler

### 1. INTRODUCTION

There has been a steadily growing interest in developing high-frequency solid-state power combining systems for various wireless applications. Researchers have made significant strides in the design and implementation of these systems, aiming to improve efficiency, reliability, and performance across different frequency bands. This literature survey offers a thorough examination of key works in this area, noting significant contributions and progress.

Yazhou Dong et al. [1] presented a pioneering study on a solid-state power combining system showcasing the potential of millimeter-wave technology in wireless applications. Their research established the groundwork for investigations

following this line of inquiry, underscoring the critical value of efficient power combining techniques.

Fathy et al. [2] proposed a streamlined design technique for Radial Power Combiners offering insights into the optimization of power combining networks. This work contributed valuable methodologies for the design and implementation of compact and efficient power combiners, facilitating advancements in high-frequency circuitry.

Grebennikov [3] provided comprehensive insights into power combiners, impedance transformers, and directional couplers, offering a deeper understanding of fundamental principles and design considerations. This reference is an invaluable resource for researcher's active voice to delve into the theoretical underpinnings of power combining systems.

Kumar et al. [4] introduced a broadband branch-line hybrid with multi-section impedance transformation., addressing the need for broadband impedance matching in high-frequency circuits. Their work underscores the importance of impedance transformation techniques in achieving optimal performance across a wide frequency range.

Matthaei et al. [5] presented seminal work on components for Microwave systems offering foundational knowledge for the design and analysis of RF and microwave circuits. Their comprehensive treatment of fundamental concepts continues to inform research efforts in the field of high-frequency circuit design.

Lindmark [6] proposed a new dual-polarized patch antenna element featuring a single-layer feed network and achieving high isolation., demonstrating innovative approaches to antenna design and integration. This work plays a role in advancing the progress of compact and efficient antenna systems designed for a variety of wireless applications. Paul and Gardner [7] introduced a microwave quadrature active phase shifter using MESFETs, showcasing advancements in phase-shifting technologies for RF and microwave applications. Their work highlights the potential of active components in achieving precise phase control and modulation.

Luxey and Laheurte [8] presented an array of microstrip leaky-wave antennas producing dual beams., offering insights into the design and implementation of advanced antenna

arrays for beamforming applications. Their research plays a part in advancing the development of adaptive and reconfigurable antenna systems for next-generation wireless networks.

Pozar's "Microwave Engineering" [9] stands as a cornerstone text in the field, offering a comprehensive treatment of microwave circuit theory, analysis, and design. This authoritative resource has served as a fundamental reference for generations of researchers and engineers, providing a solid theoretical foundation for understanding microwave circuit phenomena.

Grebennikov's monograph on "Power combiners, impedance transformers, and directional couplers" [10] offers a focused exploration of key components and techniques essential to the design of high-frequency circuits. By elucidating the principles and practical considerations behind power combining networks and related devices, this work provides invaluable guidance for engineers seeking to optimize performance and efficiency in their designs.

Mongia, Bahl, and Bhatia's "RF and Microwave Coupled Line Circuits" [11] delves into the intricacies of coupled-line structures, offering detailed analysis and design methodologies for a variety of RF and microwave applications. Their comprehensive treatment of coupled-line theory equips researchers and practitioners with the tools necessary to design innovative and efficient circuit architectures.

Collectively, these works represent made notable impacts in the field of high-frequency circuit design, providing valuable insights and methodologies for the development of efficient and reliable solid-state power combining systems.

## 2. DESIGN AND METHODOLOGY

Known for its capabilities in RF, microwave, high-speed digital, and power electronics, Keysight's PathWave Advanced Design System (ADS) is a prominent electronic design automation (EDA) software. Its widespread adoption within the industry is further bolstered by early access to support from leading manufacturers and foundries.

### 2.1 Software used: Advanced Design Software

Advanced Design System (ADS) empowers engineers with electronic design automation (EDA) capabilities for applications in RF, microwave, high-speed digital, and power electronics. The software balances a powerful interface with user-friendliness, while incorporating cutting-edge technologies like X-parameters and 3D electromagnetic simulation. This combination makes ADS a popular choice across various industries, including wireless communication, networking, aerospace and defence, automotive, and energy. From WiMAX™ and LTE to radar and satellite systems, ADS empowers engineers to design and validate a wide range of applications. This is accomplished through its extensive library of industry-standard design tools, application-specific components, and the ability to co-simulate electronic circuits, systems, and electromagnetic behaviour.

## 3. DESIGNING OF COUPLERS

### 3.1 Single- Section Branch Line Coupler

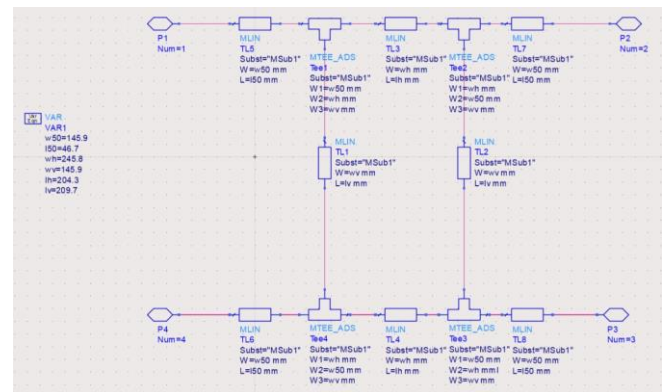


Figure 1: Single- Section Branch Line Coupler

Figure 1 depicts the configuration of the new single-section branch-line coupler. This design incorporates six microstrip lines coupled at quarter-wavelength intervals, accompanied by four sets of differential ports. The characteristic impedance is taken as  $Z_0/\sqrt{2}$ . The designated central frequency is set at 8.2 GHz. Microstrip Tapered-to-Edge (MTEE) structures are employed when crafting a design for single-section branch-line coupler to achieve impedance matching, precise control of coupling, reduced radiation losses, improved bandwidth, and enhanced power handling capabilities.

### 3.2 Multi-Section Branch Line Coupler

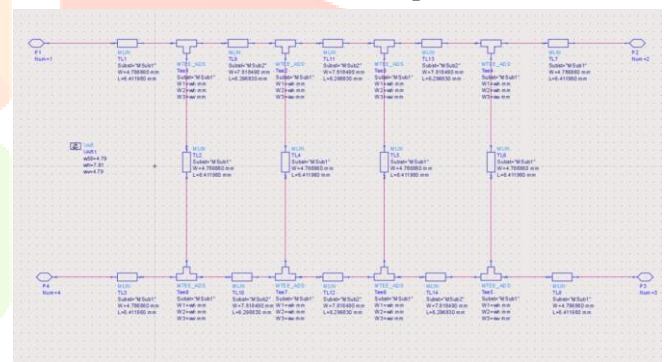


Figure 2: Multi- Section Branch Line Coupler

In the design of the multi-section branch line coupler, two branches were incorporated, featuring a total of 14 microstrip lines. The characteristic impedance was optimized to  $Z_0/\sqrt{2}$ , aligning with the desired impedance matching requirements. Set within the X-band spectrum, the central frequency for this configuration was established at 8.2 GHz. The intricate arrangement of microstrip lines and the consideration of characteristic impedance aim to enhance the coupler's performance in terms of power division and signal isolation within the designated frequency range.

### 3.3 Wilkinson Power Divider

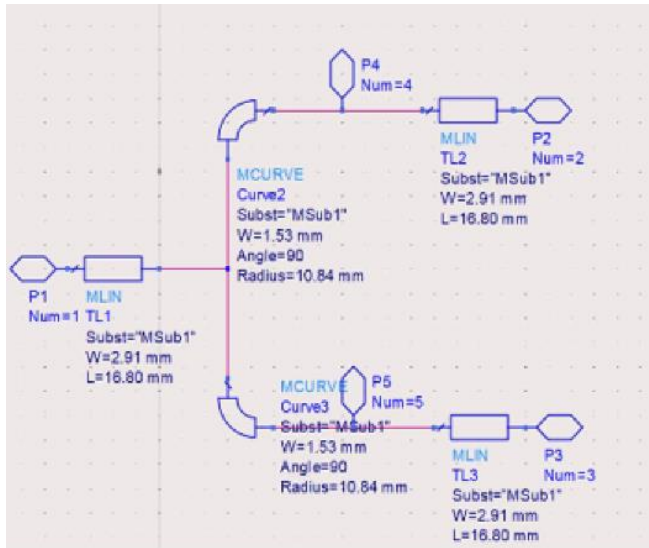


Figure 3: Wilkinson Power Divider Schematic Diagram

This passive device divides a signal from an input port (labeled in the figure) dividing evenly between two output ports.

Wilkinson power dividers often utilize microstrip lines with tailored characteristic impedances that correspond to a particular impedance ratio at the operating frequency. Within the diagram, there are two transmission lines depicted (labeled T1 and T2) are joined at a common point. A resistor (R) is connected between this junction and ground. The input signal is applied to one end of one of the transmission lines (labeled Port 1 in the figure).

#### Key Design Parameters:

- **Operating Frequency:** 8.2 GHz (X-band)
- **System Characteristic Impedance (Z<sub>0</sub>):** Typically, 50 Ω

The lines are designed with a characteristic impedance set at  $Z_0/\sqrt{2}$ , where  $Z_0$  is the system's characteristic impedance (typically 50 Ω).

### 3.4 Hybrid Rat Race Coupler

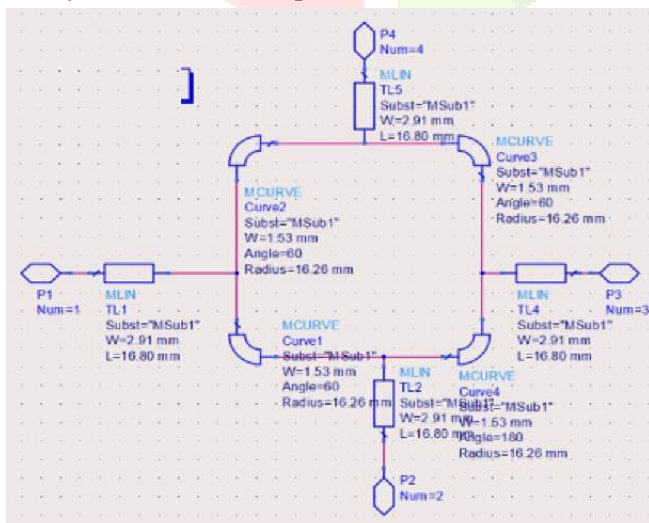


Figure 4: Hybrid Rat Race Coupler Schematic Diagram

This passive circuit functions by dividing an input signal from Port 1 and evenly distributing it to Ports 2 and 4, while also preserving a precise phase alignment between the output signals. The design utilizes four microstrip transmission lines (referred to as TL1, TL2, TL3, and TL4) with carefully selected electrical lengths. These lines are arranged in a

symmetrical ring configuration, incorporating specific angles between them to achieve the desired phase offset. The characteristic impedance of these lines plays a crucial role in achieving proper power division, impedance matching, and the intended phase shift

## 4. RESULTS AND DISCUSSIONS

The performance of the proposed design is assessed using ADS software to evaluate parameters such as return loss, insertion losses, and isolation. The electrical characteristics are given below:

#### Electrical characteristics:

Characteristic impedance  $Z_0 = 50\Omega$

Electrical length Design frequency  $f_0 = 8.2$  GHz

The widths of the lines are determined by calculating them based on the line impedances, along with their corresponding substrate and electrical characteristics, using the LINECALC feature within ADS software, specifically at a center frequency of 8.2 GHz.

Figure 5 shows the graphical representation of S-parameters in the research paper reveals the performance characteristics of the single-section branch-line coupler, illustrating its frequency response and power division capabilities with respect to different ports.

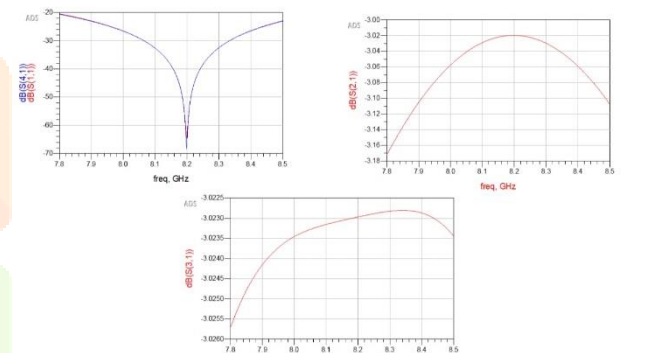


Figure 5: Single Section Branchline Coupler Results

The S parameters indicates,

- $S_{11}$  - RETURN LOSS
- $S_{21}$  - INSERTION LOSS
- $S_{31}$  - COUPLING LOSS
- $S_{41}$  - ISOLATION LOSS

Figure 6 shows the graphical representation of the performance characteristics of the multi sectional branch line coupler.

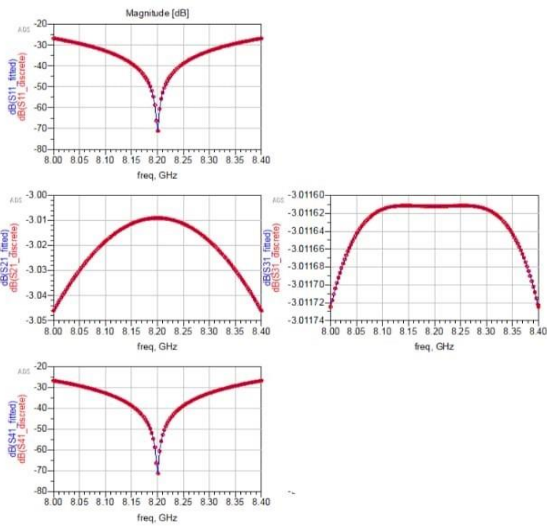


Figure 6: Multi Section Branchline Coupler Results

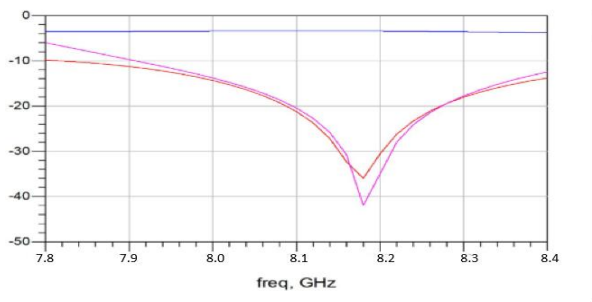


Figure 7: Wilkinson Power Divider Results

Figure 7 displays the outcomes and graphical representation of the designed circuit's performance.

Figure 8 shows the graphical representation of the performance characteristics

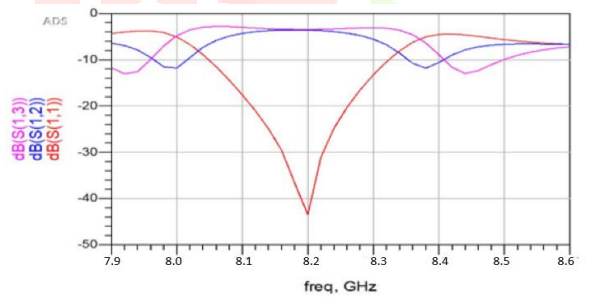


Figure 8: Hybrid Rat Race Coupler Results

### 5. CONCLUSION

In conclusion, power combining and dividing techniques serve as essential building blocks for RF communication systems. By strategically merging or distributing signals, these methods enable functionalities like phased-array antennas, distributed antenna systems, and efficient cellular networks. Selecting the most appropriate technique hinges on application-specific factors like power levels, frequency bands, and desired efficiency. As the future of wireless technology unfolds, advancements in power combining and dividing will be instrumental in achieving ever-increasing demands for data rate, coverage area, and spectral efficiency.

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