Project 2: 433 MHz Wilkinson Power Divider

Juan Ali Ruiz Guzman

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Introduction

The objective of this project was to design, simulate, implement and measure a Wilkinson power divider operating at 433 MHz within the ISM band. The divider was required to provide an equal power split of -3 dB at each output port while maintaining a system impedance of 50 Ω. Additional design goals included achieving good return loss (>10 dB), high isolation (>15 dB), and low insertion loss (<5 dB). The design was first simulated in ADS and then physically implemented using copper tape on a substrate.

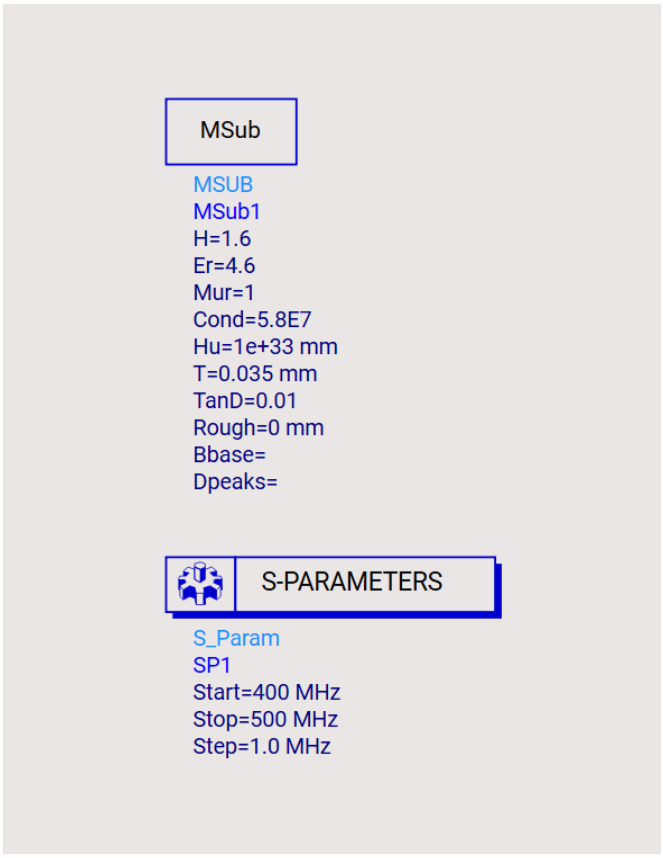
Design and Simulation

The Wilkinson power divider was designed using microstrip transmission line theory with quarter-wave sections at the center frequency of 433 MHz. The characteristic impedance of each branch was chosen as:

$$Z_{branch} = \sqrt{2}Z_0$$

which results in approximately 70.7 Ω for a 50 Ω system. A 100 Ω resistor was placed between the output ports to provide isolation.

The ADS simulation setup, including the substrate parameters and S-parameter sweep from 400 MHz to 500 MHz, is shown below.



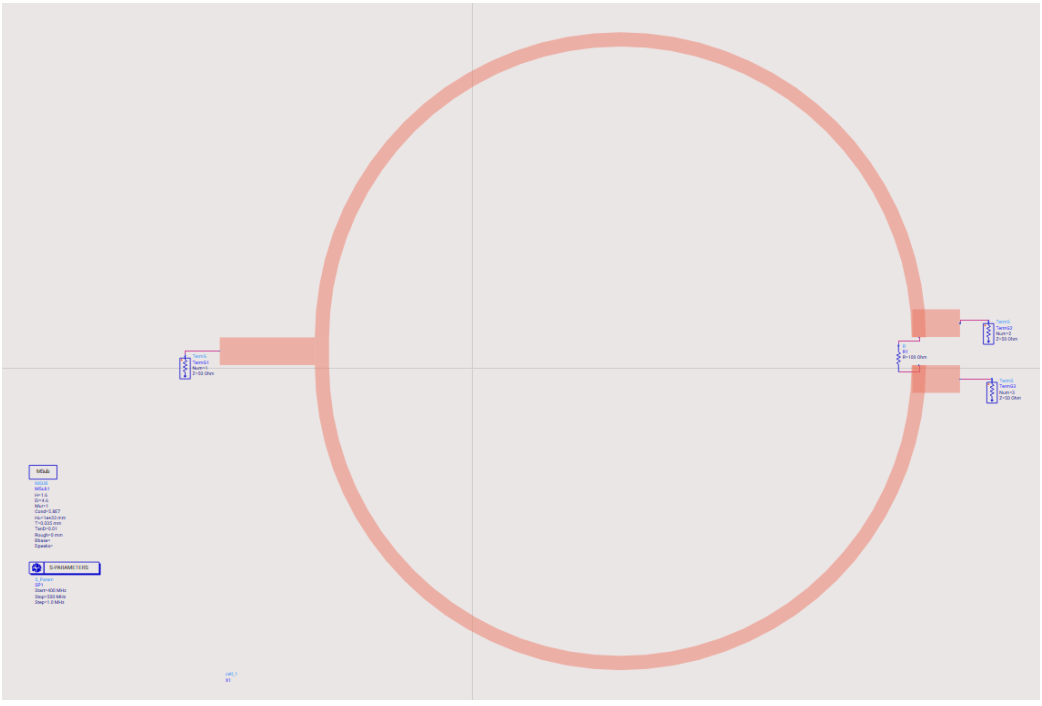


Figure 1. ADS simulation setup and substrate parameters

The layout of the divider was implemented using a circular microstrip structure to preserve the required quarter-wave electrical length while improving symmetry and compactness.

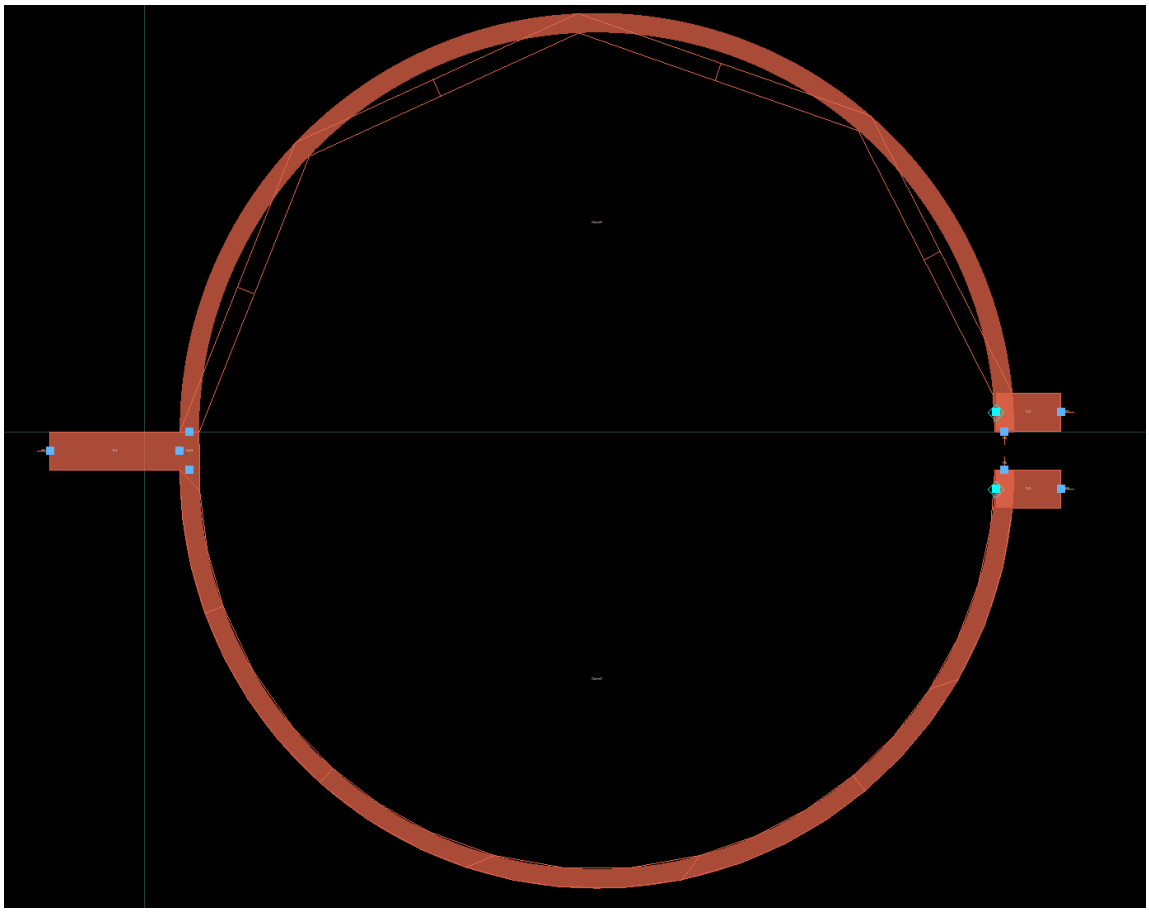


Figure 2. ADS layout of the Wilkinson power divider

The simulated S-parameter results are shown below. At 433 MHz, the simulation produced approximately −3 dB insertion loss for both output ports, along with strong return loss and isolation.

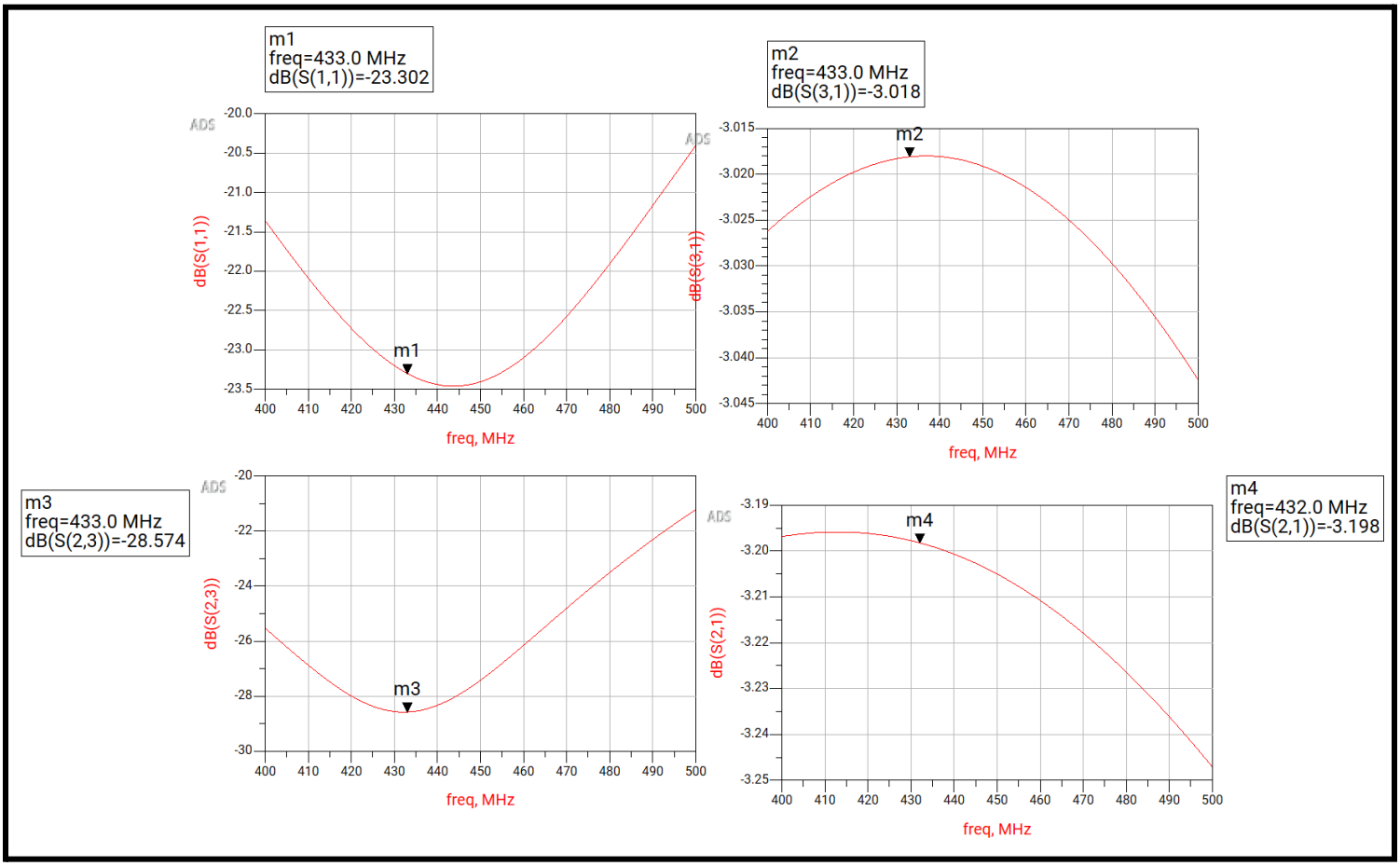


Figure 3. Simulated S-parameters of the Wilkinson divider

Implementation

The divider was fabricated using copper tape on an FR4 substrate, with three SMA connectors attached for measurement. A circular layout was used to maintain equal electrical path lengths to both output ports.

The physical characteristics of the fabricated divider are summarized in Table 1.

Table 1. Physical characteristics of the fabricated Wilkinson power divider

Physical Characteristic	**Value**
Substrate Material	FR4
Substrate Height	1.6 mm
Conductor Material	Copper Tape
Center Frequency	433 MHz
System Impedance	50 Ω
Isolation Resistor	100 Ω

Figure 4. Fabricated Wilkinson power divider using copper tape and SMA connectors

The 100 Ω resistor was soldered between the two output branches to provide isolation. Care was taken to maintain symmetry, although minor imperfections in the copper tape and solder joints were present.

Measurements

Measurements were performed using a Keysight FieldFox Network Analyzer over the frequency range of 400 MHz to 500 MHz.

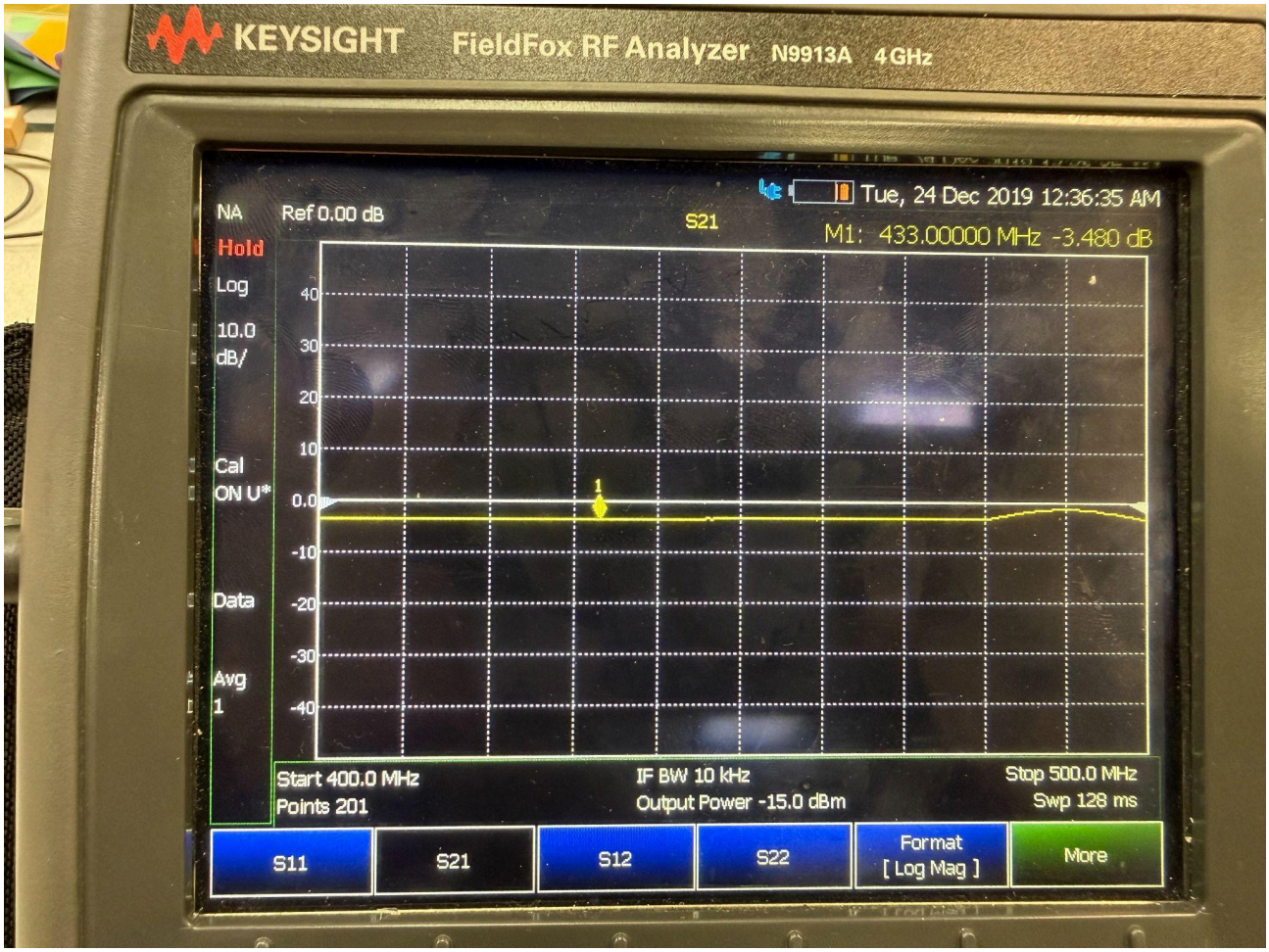


Figure 5. Measured S21 showing insertion loss of approximately −3.48 dB at 433 MHz

The second output port (S31) was measured by reconnecting the output port and using the S21 measurement on the analyzer. This result is shown below.

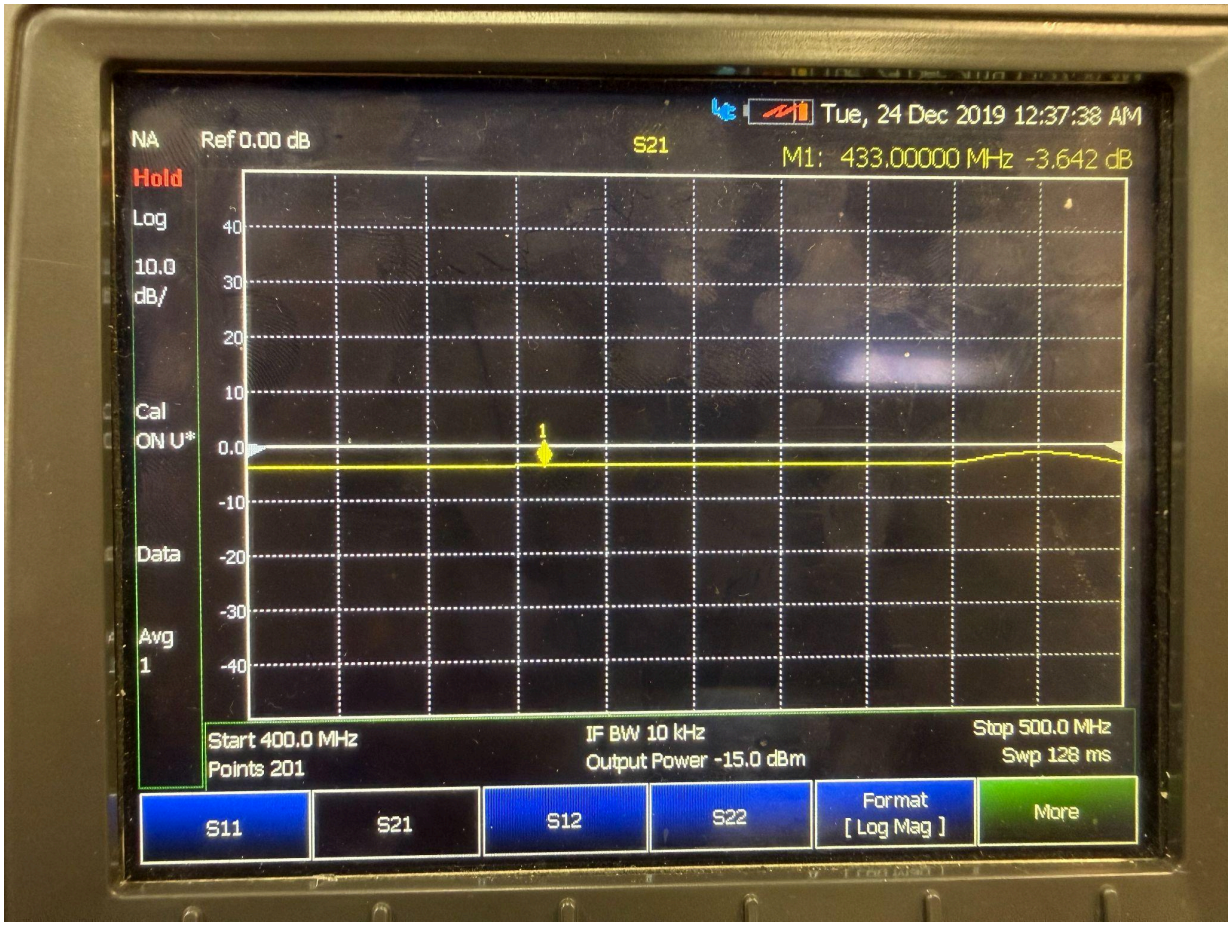


Figure 6. Measured S31 (taken using S21 configuration) showing approximately −3.64 dB at 433 MHz

Both measurements are close to the expected −3 dB split, confirming proper power division.

Return Loss (S11)

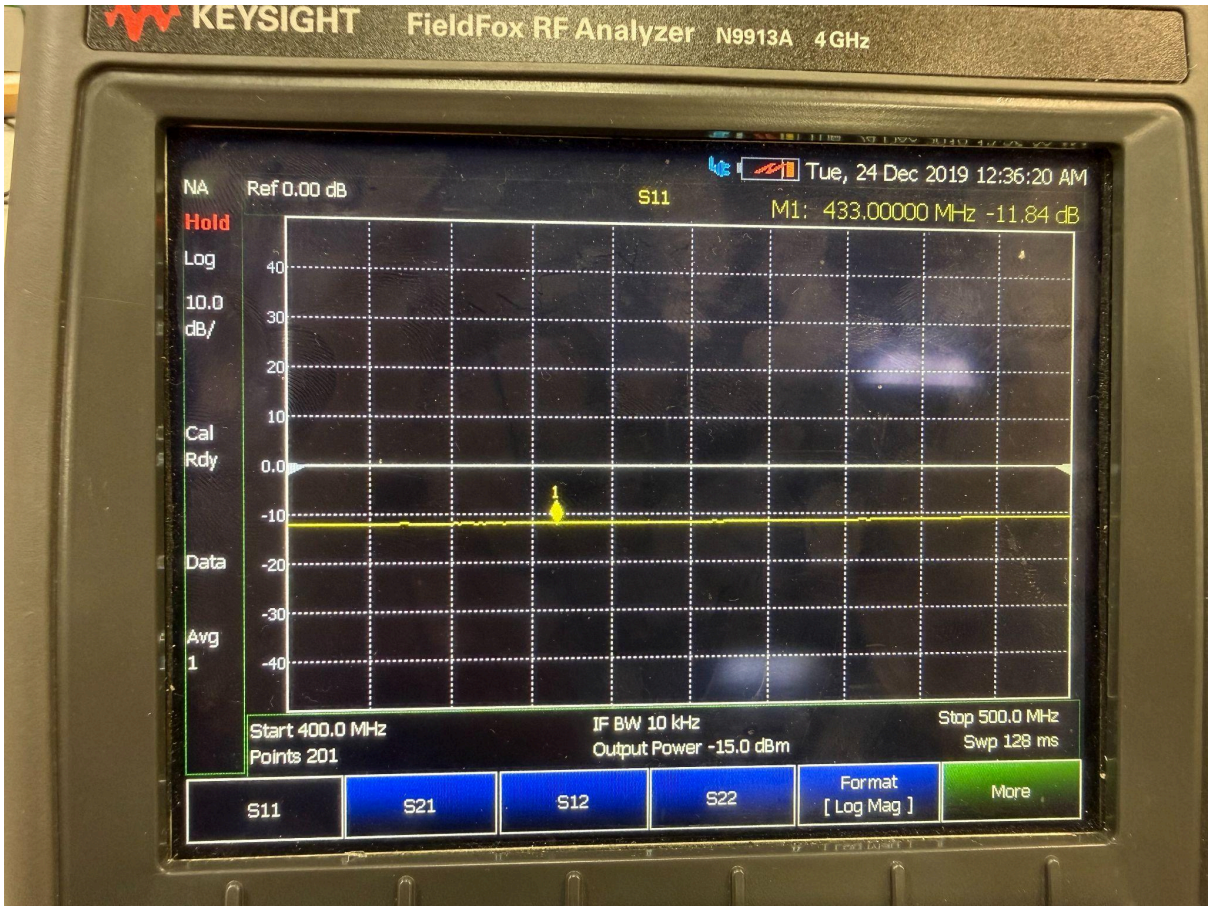


Figure 7. Measured S11 showing return loss of approximately −11.84 dB at 433 MHz

This meets the design requirement of greater than 10 dB return loss.

Isolation (S23)

The isolation between the output ports was measured and is shown below.

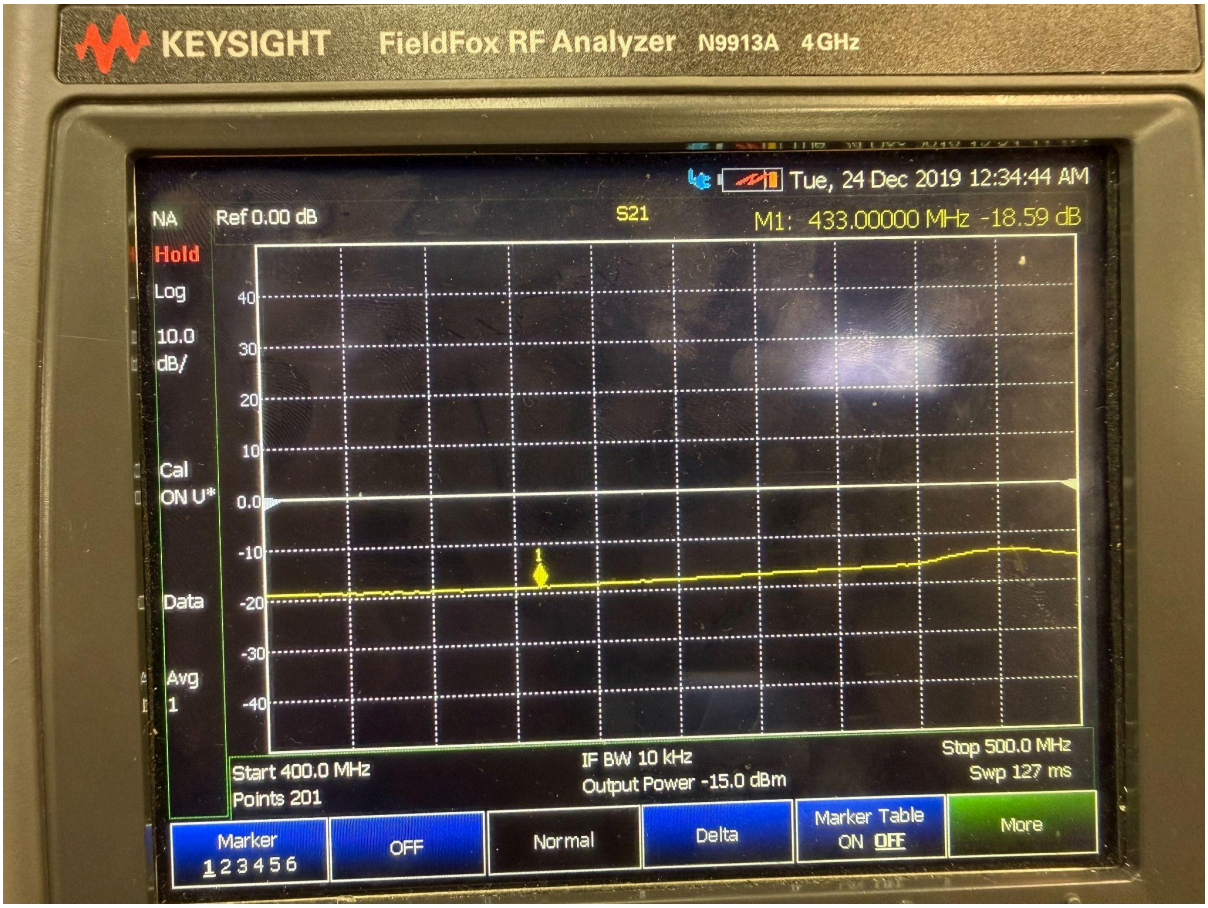


Figure 8. Measured S23 showing isolation of approximately −18.6 dB at 433 MHz

This exceeds the required dB isolation.

Table 2 compares the simulated ADS results with the measured performance of the fabricated Wilkinson power divider at the center frequency of 433 MHz.

Table 2. Comparison of simulated and measured Wilkinson power divider performance at 433 MHz

Parameter	ADS Simulation	Measured Result	Design Requirement
Center Frequency	433 MHz	433 MHz	433 MHz
S21	−3.02 dB	−3.48 dB	≈ −3 dB
S31	−3.02 dB	−3.64 dB	≈ −3 dB
S11 (Return Loss)	−23.3 dB	−11.84 dB	> 10 dB
S23 (Isolation)	−28.6 dB	−18.59 dB	> 15 dB
Substrate Height	1.6 mm	1.6 mm	—
Dielectric Constant	4.6	4.6	—
Isolation Resistor	100 Ω	100 Ω	100 Ω

The measured results generally agree with the ADS simulation results, although additional losses and reduced return loss were observed in the fabricated design. These differences are mainly due to fabrication tolerances, connector losses, and imperfections in the copper tape implementation.

Discussion

The measured results closely match the expected behavior of a Wilkinson power divider. Both output ports achieved near −3 dB insertion loss, indicating an approximately equal power split. The slight difference between S21 and S31 is likely due to small asymmetries in fabrication, including variations in copper tape width and soldering.

The return loss of approximately −11.84 dB meets the design requirement, although it is lower than the simulated value. This difference can be attributed to impedance mismatches introduced during fabrication and connector transitions.

Isolation between the output ports exceeded 15 dB, confirming that the 100 Ω resistor effectively isolates the two branches. Additional insertion loss beyond −3 dB is due to conductor losses, dielectric losses, and imperfect connections.

Conclusion

A 433 MHz Wilkinson power divider was successfully designed, simulated, and implemented. The measured results demonstrate proper operation, with an approximately equal power split, acceptable return loss, and strong isolation between output ports.

Although some deviation from simulation was observed, the overall performance met the design requirements. This project highlights both the effectiveness of the Wilkinson divider and the impact of practical fabrication limitations on RF performance.