Design and RF test result of High Power Hybrid Combiner for Helicon Wave Current Drive in KSTAR Plasmas

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1. Introduction

Recently helicon wave current drive for efficient off-axis current drive has been proposed [1]. In 2015 KSTAR experiment, the mock-up traveling antenna was fabricated and installed to test coupling between antenna and plasmas. In 2016, we are preparing to inject high power rf for helicon current drive in KSTAR [2]. 200 kW RF power will be injected to plasmas through the traveling wave antenna after combining four klystrons output powers using three hybrid combiners. Each klystron produces 60 kW output at the frequency of 500 MHz. RF power combiners commonly used to divide or combine output powers for various rf and microwave applications. It is divided into several types according to the design type such as Wilkinson combiner, radial and quadrature hybrid combiner [3-5]. We designed high power hybrid combiners using 6-1/8 inch coaxial line. The power combiner has many advantages such as high isolation, low insertion loss and high power handling capability. In this paper design and rf test results of high power combiners will be described. High power combiners using three coaxial hybrid couplers will be utilized for effectively combining of 500 MHz, 200 kW output powers generated by four klystrons.

2. 6-1/8 inches High power coaxial hybrid combiners.

2.1 HFSS simulation results

We designed a 6-1/8 inch coaxial hybrid combiner for combining of RF outputs from 4 klystrons operating at 500 MHz for efficiently off-axis Helicon wave current drive in the KSTAR. High power hybrid combiner was designed using a three-dimensional electromagnetic simulation code HFSS [6]. Figure 1 shows a schematic diagram of the coaxial hybrid combiner. Coaxial hybrid combiner has length 3/4λ and 4/5λ with two Teflon to support inner and outer conductor of coaxial line as shown in Fig. 1. Figure 2 shows the simulation results of the coaxial hybrid combiner. HFSS simulations predicts that the hybrid combiner can obtain an exact 3 dB couplings at 500 MHz between ports 2 and 3. The simulated reflection and isolated coefficients of the hybrid coupler was obtained -18 dB at 500 MHz, respectively.

Figure 3 shows a schematic diagram of high power combiner to add the output powers from 4 klystrons using three hybrid combiners and inject total power to Helicon wave antenna for Helicon wave current drive in KSTAR plasmas. Three dummy loads need to match hybrid combiners and absorb reflected power from the antenna. Simulations predicts that three hybrid combiners operate with an excellent coupling flatness of –6.1 ± 0.1 dB at 500 MHz as shown in Fig. 4.

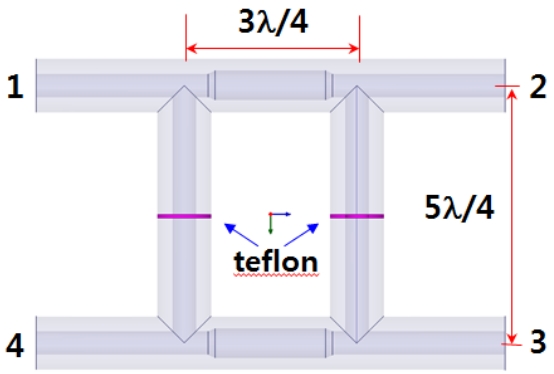

Fig. 1. Schematic diagram of a 6-1/8 inch coaxial hybrid combiner.

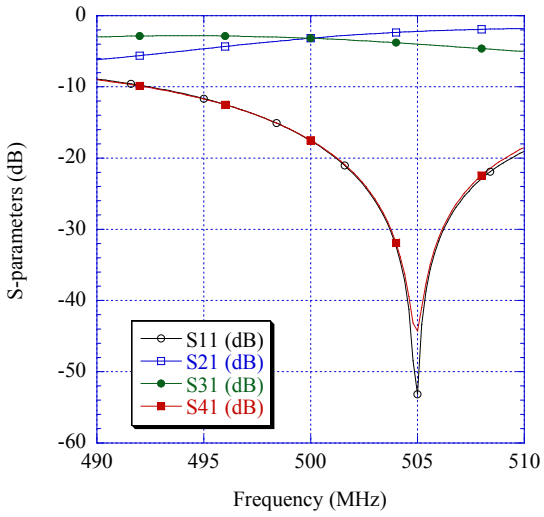

Fig. 2. S-Parameters obtained from HFSS simulation of a 6-1/8 inch coaxial hybrid combiner.

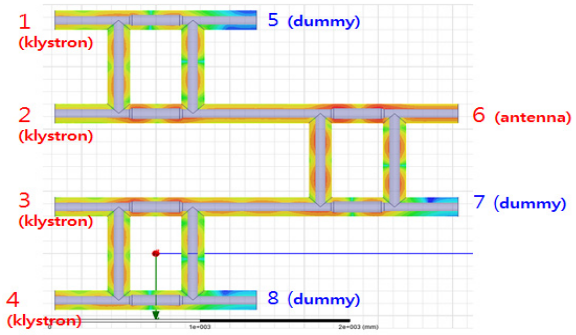

Fig. 3. Schematic diagram of three coaxial hybrid combiners to combine the output power of 4 klystrons.

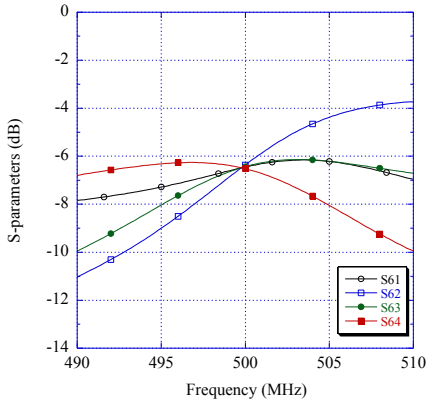

Fig. 4. S-parameters result of a 6-1/8 inches three coaxial hybrid combiners obtained from HFSS simulation.

2.2 Fabricated and RF test results

Figure 5 shows fabricated 6-1/8 inches coaxial hybrid combiner and set-up for RF test using Agilent vector network analyzer (VNA). Figure 6 shows the measured S-parameters of the coaxial hybrid combiner. The measured S_{21} and S_{31} at 499 MHz are about –3.1 ± 0.1 dB. The reflection and isolated coefficients are over -16.5 and -21 dB at 499 MHz, respectively. The measured RF performances of the hybrid combiner are in good agreement with the simulation result.

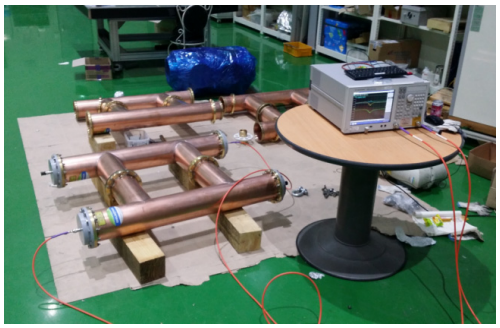

Fig. 5. Measurement of 6-1/8 inch coaxial hybrid combiners using a VNA.

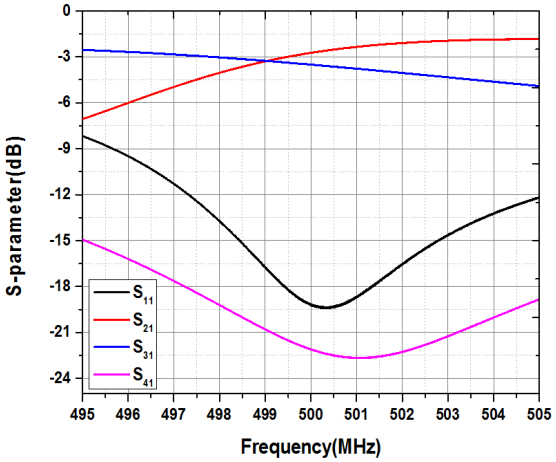

Fig. 6. Measured S-parameters of the coaxial hybrid combiner using VNA. 1 MHz frequency is down shifted.

3. Conclusions

We have designed, fabricated, and tested a 6-1/8 inch coaxial hybrid combiners at 500 MHz for efficiently off-axis Helicon wave current drive in KSTAR. Simulation and test results of high power coaxial hybrid combiners are good agreement. The proposed coaxial hybrid combiner will be applicable to combine high power for low power rf and microwave applications.

Acknowledgement

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