DESIGN AND ANALYSIS OF RF POWER COMBINERS/SPLITTERS AT 350MHZ

J.K. Mishra, B.V. Ramarao, Manjiri M Pande, V.K. Handu
Technical Physics Division, Bhabha Atomic Research Centre, Mumbai, India

Abstract

Radio Frequency (RF) power combiner enables the use of the solid state power amplifier modules for high power applications. One single solid state power amplifier cannot deliver RF power beyond 1 KW in the UHF band frequency; hence the need for combiner/splitter becomes very important. These combiners/splitters that have been developed were based on Wilkinson technique [2] without internal resistors (since amplifiers were protected against reflected power using circulators). These combiners/splitters had been designed for different power ratings at 350 MHz (up-to 2.4 KW of power) using coaxial technology. Number of ports to be combined/splitted had been 4 and 8 (two different combiner/splitter). Matching achieved at combining port was better than 20 dB at 350 MHz and matching at dividing ports was better than 12 dB. Isolation achieved was better than 25 dB with all other ports were terminated properly. The magnitude of transmission imbalance is < 0.2 dB and angle is < 3 degree. These combiners/splitters has been designed, fabricated and tested. The paper presents the designed details and measured results.

INTRODUCTION

It has been planned to develop high power RF amplifiers based on solid-state devices. Individual Solid-state devices can give RF power in the range of 300-1000 W max. in UHF band. To achieve higher power, these low power modules have to be combined using RF power combiners/splitters. This paper will discuss design, simulation and testing of RF power combiners/splitters designed and fabricated in our lab.

DESIGN AND SIMULATION

The design work has been started based on Wilkinson technique. The design goal was to make 8-way and 4 way combiners/splitters for 2.2 KW & 1.2 KW of RF power respectively using 300 W SSPA at 350 MHz. Coaxial line geometry was chosen for our work because it is compact, rugged and can handle the high power. The design was started with a coaxial line with characteristic impedance of $Z_0/(\sqrt{N})$ Ohms [1] (for Z0=50 Ohms) (where N is number of ports to be combined). Dimensions are chosen such that it can handle desired power levels. Then centre conductor has been split into N parts in the axial direction to make N transmission lines with outer conductor and each line having impedance of $Z_0*(\sqrt{8})$ Ohms [2]. These line lengths should be $\lambda/4$. At combining port, a constant impedance taper was used for smooth transition of the impedance without degrading the matching. This design has been simulated using CST microwave studio 2006[4] for both types of combiners/splitters. Return loss of better than 25 dB has been achieved at combining port with -9.1 dB transmission. At dividing ports, the return loss was better than 25 dB for even mode signal but only 12 dB for odd mode powers with internal resisters. This mismatch can be attributed to the odd mode impedance and phase velocity mismatch with even mode [3]. Very good return loss for odd mode power has been achieved by using compensating capacitors. These capacitors can be connected between adjacent dividing ports. From simulation, this value comes out to be 7.8 pF for 8:1 way combiner (with internal resistors). This improves the dividing port match to better than 25 dB for all modes.

FABRICATION AND TESTING

The designs have been converted into drawings and then they were fabricated. 8:1 way combiner was fabricated using copper material and 4:1 way combiner in aluminium (Fig. 1). High power port in 8:1 way combiner has been chosen to be 7/16” connector, which can handle power in excess of 2 KW at 350 MHz. For lower power ports, N type connectors have been used. For 4:1 way combiner, only N type connectors were used at all ports.

Figure 1: Picture of 1:8 and 1:4 Combiner

RESULTS AND DISCUSSIONS

Measurements results on fabricated combiners

The Vector Network Analyzer (VNA) measurement results are shown below in the Fig 2 and Fig 3.

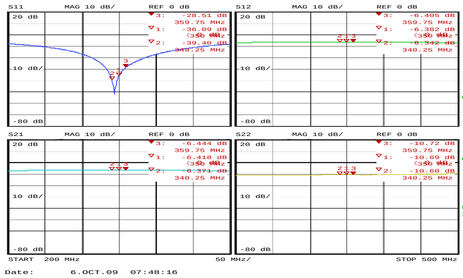

Figure 2: VNA measurements on 4 to 1 way combiner

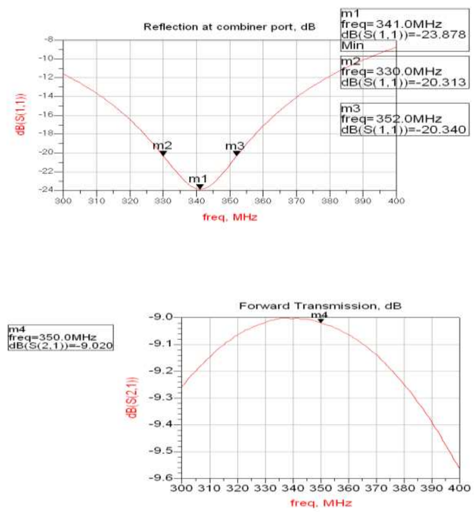

Figure 3: VNA (S2P) data plot for 8 to 1 way combiner

The table 1 (as shown below) describe the important parameters of the combiners as measured with VNA. There are some differences in the simulated and actual measured results on the fabricated part. The reason for this is due to error in the dimensions of the fabricated unit i.e. length of the $\lambda/4$ transformer. Since the length of transformer has increased by few mm, it has shifted centre frequency to 341 MHz for 8:1 way combiner. At designed frequency (350 MHz), return loss of 20.3 dB was observed for 8:1 way combiner. For 4:1 way combiner the centre frequency was at 345 MHz.

These combiners have been tested with VNA (low power) as well as with high power. For high power tests, two similar combiners were connected back to back, and power was fed through one of the two high power ports. These tests have been performed on both types of combiners. During high power testing of these combiners, the reflected power measured at the combining ports were 2.7 W and 12 W at 1 KW, 350 MHz input RF power for 8:1 way combiner and 4:1 way combiner respectively. The power loss in transmitting the power from one port to other port in high power test was just 7% (total) for 8:1way combiners and 10% (total) for 4:1 way combiner.

Table 1: Specifications of 8:1and 4:1 way combiners (as measured on VNA)

Specification		Design specs.	Specs. achieved	Remark
Centre frequency (MHz)	For 8:1	350	341	Shift in the centre frequency is due to increase in the length.
	For 4:1	350	345	
Return loss at combined port (dB)	For 8:1	25	24	Data at 341 MHz
	For 4:1	18	35	Data at 350 MHz
Return loss at dividing port (dB)	For 8:1	13	12	Data at 350 MHz
	For 4:1	14	10.7	Data at 350 MHz
Isolation (dB) for both		>30	>25	Data at 350 MHz
Insertion loss (dB)	For 8:1	0.02dB	0.15	Data at 350 MHz
	For 4:1	0.08	0.3	Data at 350 MHz

CONCLUSION

The results have been very much in line with theoretical and designed values. The deviations in the designed and measured parameters are due to fabrication inaccuracies which have been calculated. After these results we are planning to design an 8 KW RF power combiner using coaxial technology and 1:2 way combiner at 1.5 KW using micro-strip technologies.

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REFERENCES

[1] Ernest J Wilkinson, “An N way Hybrid power divider”, IRE Transactions on microwave theory and techniques, Vol. MTT-8 No 1 Jan 1960 pp. 116-118.
[2] David M Pozar, “Microwave Engineering 3rd Edition” John Wiley and Sons Inc.
[3] R E Collin, “Field Theory of Guided Waves”, McGraw-Hill Book Company Inc,
[4] CST Microwave studio, EM simulation tool from Computer Simulation Technology Inc,