RESONANT HIGH POWER COMBINERS

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Abstract

Particle accelerators need radio frequency sources. Above 300 MHz, the amplifiers mostly used high power klystrons developed for this sole purpose. As for military equipment, users are drawn to buy "off the shelf" components rather than dedicated devices. IOTs have replaced most klystrons in TV transmitters and find their way in particle accelerators. They are less bulky, easier to replace, more efficient at reduced power. They are also far less powerful. What is the benefit of very compact sources if huge 3 dB couplers are needed to combine the power? To alleviate this drawback, we investigated a resonant combiner, operating in TM010 mode, able to combine 3 to 5 IOTs. Our IOTs being able to deliver 80 kW CW apiece, combined power would reach 400 kW minus the minor insertion loss. Values for matching and insertion loss are given. The behavior of the system in case of IOT failure is analyzed.

INTRODUCTION

Combining *n* high power RF sources (eg. : 4*80kW to obtain 300 kW @ 500 MHz) with conventional 3dB couplers leads to bulky set-ups. Additional complexity is required if *n* is not a power of 2.

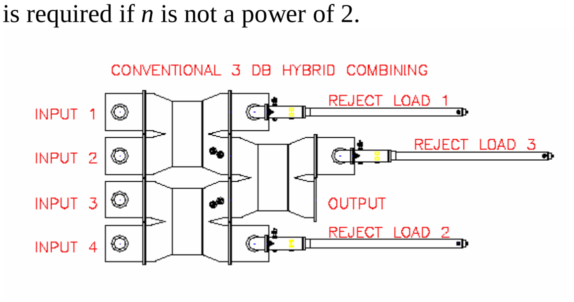

Figure 1: Conventional combiner (courtesy Thales broadcast and multimedia).

Table 1: Conventional combiner parameters

3 dB coupler volume	372 liters
Load volume	43 liters
Total volume	1247 liters

More compact devices may be used, such as resonant combiners.

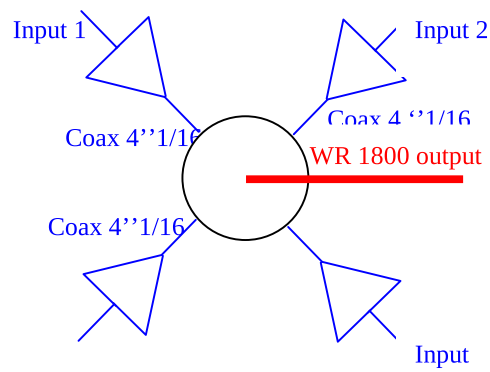

Figure 2: Resonant combiner.

Table 2: Resonant combiner parameters

Cavity volume	64 liters
Waveguide output volume	39 liters
Total volume	103 liters

This kind of device may receive an odd number of inputs without added difficulty. The cavity is roughly circular or polygonal and oscillates on the E010 mode at the desired frequency of operation. This frequency is slightly adjustable with a mobile part. The inputs are coupled through loops protruding inside the cavity. The output looks like a coax to waveguide transition coupled to the cavity by capacitance or iris.

EXAMPLE 1: 2 INPUT PORTS, 500 MHZ

A proposal was made to ALBA, a Spanish synchrotron, to design and manufacture such a resonant combiner to couple 2 TH 793 IOTs operating at 500 MHz. The maximum output power of each IOT is 80 kW CW. The 2 following figures show the electric and magnetic field patterns for such a combiner.

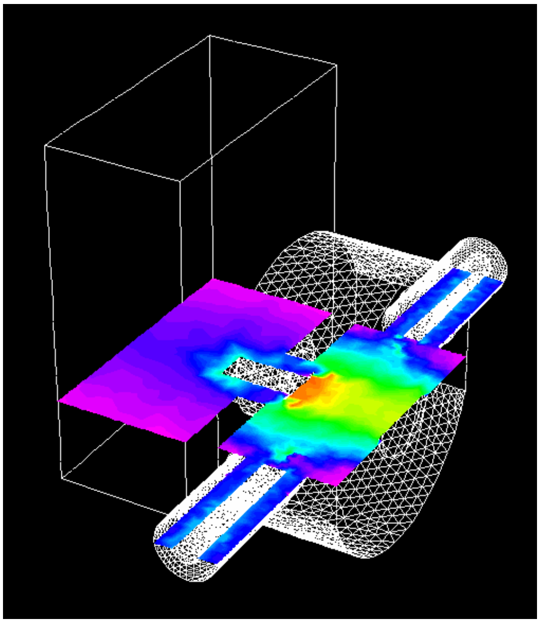

Figure 3: E field in the 3 ports resonant combiner.

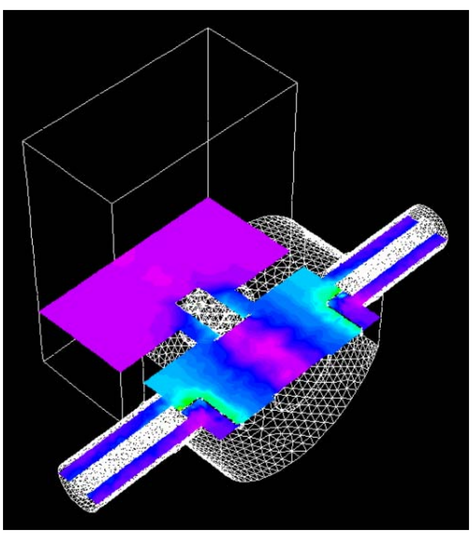

Figure 4: H field in the 3 ports resonant combiner.

Losses were computed and found to be less than 500 W. Water cooling may not be compulsory. The maximum value of the electric field was less than 500 V/mm. The risk of ionization is low. Possible resonance on harmonics were investigated. Figure 5 shows a possibility at 1.527 GHz, not so far from 3rd harmonic.

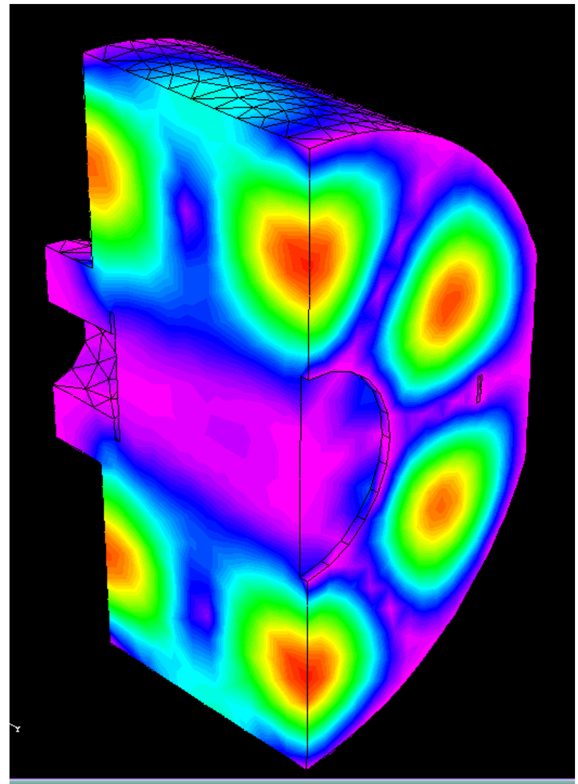

Figure 5: 1.527 GHz resonance.

EXAMPLE 2: 5 INPUT PORTS, 500 MHZ

In order to check the possibility of such a resonant combiner and to investigate its behaviour in case of a failure occurring on one of the inputs, a mock-up was designed and built. The shape is pentagonal, the 5 input ports are N-type and the output is 7/8''. Measurements were performed with a network analyser, hence with low level inputs.

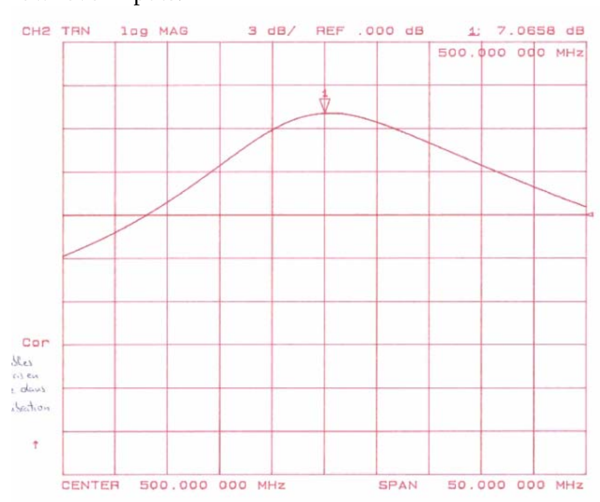

Figure 6: 5 inputs.

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Figure 6 shows the bandwidth of the pentagonal cavity. The output is 7 dB above the level of each input i.e. 5 times larger.

Figure 7: 4 active inputs.

Figure 7 shows the behaviour of the output when one of the 5 inputs is open. The ideal case would be 6 dB or 4 times the level of one input. Here, we have 4.8 dB (*3) instead. Figure 8 shows a schematic of the pentagonal resonant combiner.

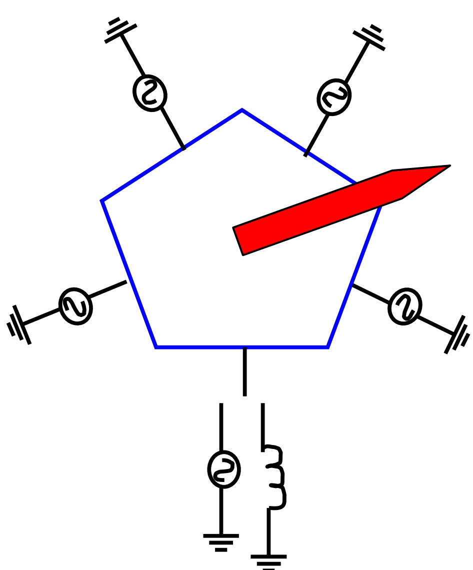

Figure 8: Pentagonal resonant combiner of which one input can be either active or connected to a reactance.

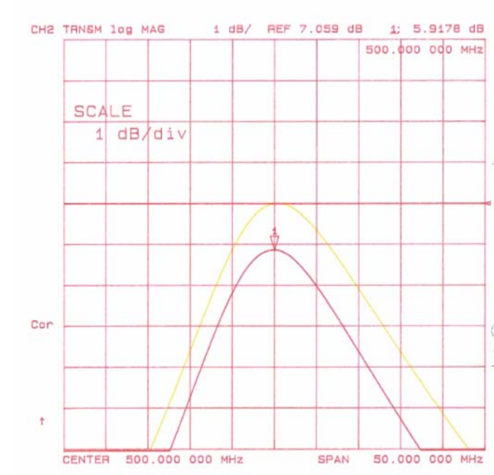

Figure 9: Resonant combiner with 4 active inputs and the 5th connected to chosen impedance.

Figure 9 shows the output when one of the inputs is terminated on the appropriate impedance, and the four others deliver 0 dBm each. This situation is met when the length of coax between the IOT output and the resonant combiner is properly adjusted.