1:5 Way In-Phase Equal Power Divider/Combiner using Enclosed Cylindrical Rod lines for High Power VHF Applications

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Summary

Wind profiler radar system in 400 MHz band is used for real time wind measurements in clear air up to height of 8 kilometers or more (depending on atmospheric conditions) on continuous basis. Wind profiler system which has been built by SAMEER transmits 16 kilowatts peak power @ 10% duty at ~ 404 MHz. It requires high power in phase 1:5 way equal power divider/combiner in its chain of feed network. It has to handle same power as the transmit power and has to be placed in an open field. The design of this 1:5 way single section divider/combiner is based on the design given by Adel [1] for radial n-way power divide/combiner. The cross section view of transmission line used for the construction of power divider/combiner consists of hollow metallic cylindrical tube with metallic circular rods on the inner periphery. It is shown in Figure 1.

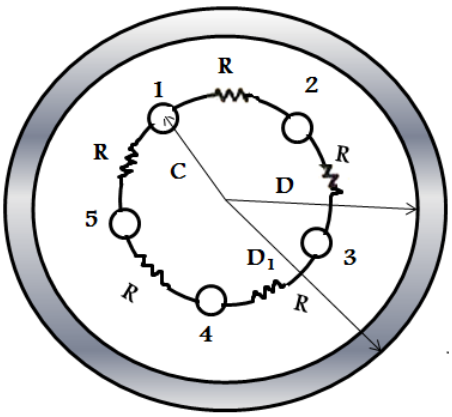

Figure 1. Cross section of 1:5 way Radial power divider/combiner with isolation resistor connected

A hollow metallic tube with one conducting cylindrical rod, as a first approximation, this structure of the transmission line can be considered as an eccentric co-axial line. The characteristic impedance of eccentric co-axial line can be found in [2] and is given in equation (1) for clarity.

$$Z_0 = 59.952\ ln\left[X + \sqrt{X^2 - 1}\right] \qquad (1)$$

$$Where\ X = \frac{1}{2}\left\{\frac{d}{D} + \frac{4H}{d}\left(1 - \frac{H}{D}\right)\right\}$$

'H' is the distance from the center of the rod to the inner wall of the hollow tube. 'd' is the diameter of inner rod and 'D' is inner diameter of the outer hollow pipe/tube.

The design of a single-section radial-type power divider/combiner is given in [1]. For a 1:N way in-phase radial power divider/combiner for 50 Ω input and output impedance, the characteristic impedance of each arm Z_d of the 'N' arms is given by equation (2).

$$Z_d = \sqrt{N}\ Z_0 \qquad (2)$$

For a 1:5 way power divider/combiner, the value of

$$Z_d = 111.8\ \Omega$$

The optimized isolation resistor from [1] is given by

$$R = \frac{50}{0.4471} = 111.8\ \Omega$$

The power divider/combiner is designed for 404 MHz. The gap between the surface of the inner rods and the inner surface of the outer hollow tube is kept at 6.0 mm for high power handling capability of 20 kW peak. Here D = 63.5 mm. From equation (1) for 111.8 Ω characteristic impedance, the inner conductor rod diameter comes out to be 6 mm. The structure simulated using HFSS is shown in figure 2. Dimensions were slightly optimized to get a good performance of power divider. Using these dimensions power divider/combiner was constructed.

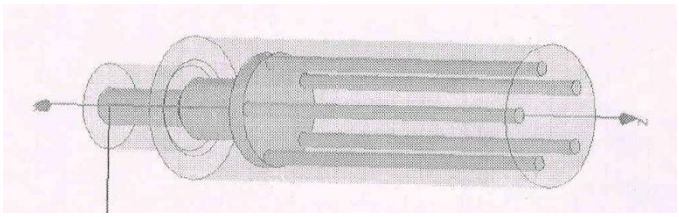

Figure 2 1:5 way power divider/combiner outline structure used in HFSS simulation

The different parts of the power divider/combiner are shown in Figure 3. It can be seen that high power resistors have been soldered to the output assembly unit in radial form. These resistors are important for the matching of the output ports and to achieve isolation between the output ports. Without these resistors, the output matching and isolation would be very poor. The resistors used are of Florida RF labs part no. 31-1075, 100 Ohms 150 Watt rating. The equivalent circuit of the resistor at RF would be a resistor with a capacitor in shunt. Moreover the leads of the resistor which is used for soldering and connection purposes would result in a series inductor. In order to get the proper response of the 1:5 way power divide/ combiner, one has to tune out these parasitics at the frequency of operation. It was found that two capacitors and one inductor had to be placed on each side of the resistor in shunt to tune out these parasitic. In this case we have placed 2.2 pF capacitors and inductors of 122 nH.

The power divider combiners were measured using R&S vector network analyzer ZVC. The measured input port return loss is nearly 20 dB over the 100 MHz band. All the five coupling is within 7.2 dB for all the five ports and is flat over the 100 MHz band. Variation in insertion phase among the five output ports are within 3 degrees. The measured isolation between adjacent ports which is better than17 dB and it is more than 20 dB for non adjacent ports. The output port return loss and isolation at the centre frequency is close to the theoretical value of 19.0 dB as stated by the design given by Adel [1]. It is found from the measured coupling values that the overall insertion loss of the unit is less than 0.1 dB which is very much essential in high power applications. These results show that the concept stated above for the realization of the 1:5 way power divider/combiner is feasible. Figure 4 shows the power divider/combiner connected to the wind profiler system in an open field. It is covered with a secondary cover for additional protection from rain. The unit has been placed in the field and connected to the system. It had been in operation for many months without any trace of high power breakdown.

Figure 3 Photograph showing different parts of the five way in- phase equal power divider/combiner

Figure 4. 1:5 way power divider/combiner placed in the field, five outputs can be seen clearly

REFERENCES

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2. S. D. Shamasundara and K. C. Gupta, Sensitivity analysis of coupled microstrip directional couplers, IEEE Trans. Microwave Theory Techniques 26 (1978), 788-794.