

## Unequal, Equi-phase, 1:N Power Divider Based on a Sectoral Waveguide

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**Abstract-** A high power 1:N divider for unequal output amplitudes with equal output phases, based on a H-plane sectoral horn, is presented. The divider has one input port in the rectangular part of the horn and five output ports in the sectoral part of the horn. The divider was simulated and measured. Good agreement between simulation and measurement was achieved, as well as good accuracy of the output amplitudes, phases and matching level for bandwidth of about 46% for SWR = 2.

**Index Terms-** Sectoral waveguide, unequal power divider.

### I. INTRODUCTION

Unequal power divider is a very important component in a low sidelobes antenna arrays. It is well known that one of the common ways to get a radiation plot with low sidelobes using antenna array is feeding the elements of the array with unequal amplitudes, equi-phase signal, where maximum of the amplitude is applied to the central element and it decreases in other elements [1]. Unequal power distribution with equal output phases using passive component was discussed for example by [2]. In this case a two way unequal Wilkinson power divider based on microstrip transmission line with defected ground structure was designed. This structure achieves a division ratio of -1dB and -7dB at its output ports in a frequency range of 1.2GHz to 1.8GHz. Two way, unequal power divider based on H-plane waveguide T-junction with two irises

(first for splitting the input power between output ports and the second for input port matching) was presented in [3]. Design data was present for different mechanical dimensions of the divider over normalized frequency range of  $0.57 < \lambda_0/\lambda_g < 0.84$ . A structure based on combination of unequal T-junction power dividers was presented in [4]. This structure allows unequal distribution of high power signals with amplitude error up to 0.23dB and phase mismatch up to  $1.5^\circ$  between output ports over a 10% frequency band. Unlike unequal structure of power dividers, interesting structure of equal, high power, power divider based on radial waveguide was presented in [5]. The advantages of this structure express in its radial symmetry, which for the central excitation leads to equi-phase power division, compactness and capability to work with high power signals. However, in this case one has to use attenuators at the output ports in order to have unequal output amplitudes.

In this paper we present an unequal, equi-phase 1:5 power divider based on a radial waveguide with H-plane sectoral horn geometry. The power divider was designed to have unequal power weights based on Kaiser-Bessel distribution [6]. Phase match in output ports is also guaranteed by the geometry of the divider, which is based on radial wave propagation.

The structure of the paper is as follows: in section II theoretical aspects of the power

divider's design are presented. In section III simulation results using CST Microwave Studio software are shown. Measured results are described in section IV, as well as a comparison between the design, simulation and measurement. Finally conclusions are presented in section V.

II. DESIGN

A. Geometry

The divider is composed of a rectangular waveguide in its input port, as shown in fig. 1, and a sectoral waveguide for the output ports, as shown in fig. 2

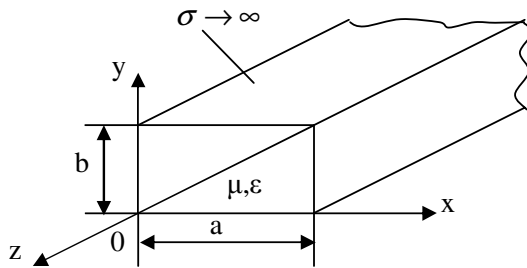


Fig.1. The input rectangular waveguide part.

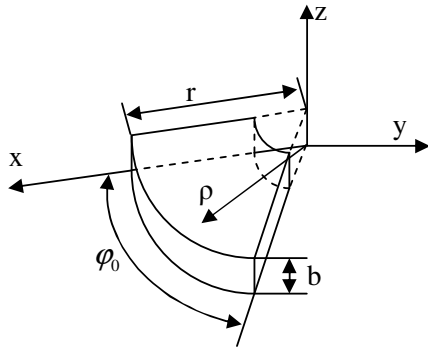


Fig.2. The output sectoral waveguide part.

The physical dimensions of the power divider are presented in Table 1, and were chosen for getting needed frequency range and power distribution as will be further described. Dimensions of internal

and external radii were optimized using CST Microwave simulation software.

Table 1: Physical dimensions of the rectangular waveguide and of the sectoral waveguide.

Rectangular waveguide	Sectoral waveguide
Height (b) = 20mm	Height (b) = 20mm
Width (a) = 40mm	Aperture angle ( $\phi_0$ ) = 60°
Length = 37.5mm	r = 138.5mm

B. Operating Frequency Range

Using the rectangular waveguide described in fig. 1, we are planning to work, as usual, only with the dominant mode  $TE_{10}$  of the rectangular waveguide, which defines a theoretical operating frequency range as follows [7]:

$$a = 40mm \quad b = 20mm$$

$$3.75GHz < f_{w(Recl)} < 7.5GHz$$

Using the sectoral waveguide described on fig. 2, we find out that there is more than one mode in the frequency range calculated in section II.B. We want to work with only one propagating mode for preventing distortion in the output signal and this issue is obtained in the sectoral horn structure [8-10]. The throat of the horn structure serves as a filter device, allowing only a single mode to be propagated freely to the aperture [10]. As a conclusion we can say that the operating frequency range of the sectoral horn structure is defined by  $TE_{10}$  mode of the rectangular waveguide. The dominant propagating mode in the sectoral waveguide part of the horn is  $TM_{01}$  (Pay attention to differences in coordinate system definition in fig. 1 and fig. 2).

C. Power Distribution

The power distribution relationship between the output ports of the power divider can be obtained

from analysis of the sectoral waveguide assuming that there is no backward power from the aperture of the waveguide, from the circumference of the sectoral part, and no mutual coupling between output ports [8-10]. The power density in the aperture of the sectoral waveguide for  $TM_{01}$  mode is given by:

$$0 < \varphi < \varphi_0$$

$$H_{\pi/\varphi_0}^{(1)}(k_\rho \rho) = 0$$

$$S_\rho = \frac{1}{2} \text{Re}\{-E_y H_\varphi^*\} \sim \sin^2\left(\frac{\pi}{\varphi_0} \varphi\right)$$

(1)

Eq. (1) allows designing of unequal power distribution with any theoretically needed ratios between output ports, but careful must be taken while value of the angle  $\varphi_2$  is too small, in this case power distribution behavior is different than described in eq. (1). For getting the Kaiser-Bessel distribution, one needs the following weights:

$$C_{(2)} = 0 \text{ dB}, C_{(3)} = C_{(5)} = -1.91 \text{ dB}, \text{ and}$$

$$C_{(4)} = C_{(6)} = -8.32 \text{ dB}, \text{ for } \alpha = 1.4 [10].$$

Using eq. (1), it can be shown that the output port's angles are given as follows:  $\varphi_0 = 60^\circ$ ,  $\varphi_1 = 17.8^\circ$ ,  $\varphi_2 = 7.52^\circ$ , according to definition of their location on fig. 3.

#### D. Output Phase Tracking

Low phase mismatch between output ports is obtained by placing output ports on the same circle line, since in this case all output ports are located on the same wave surface.

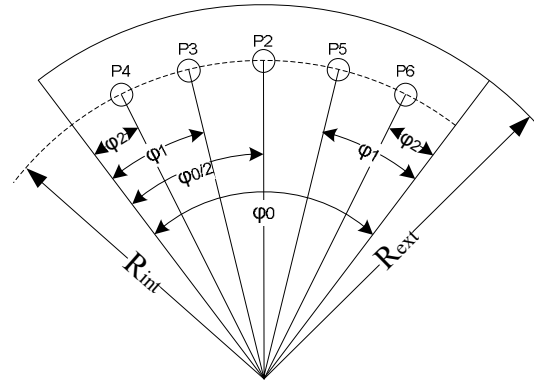


Fig.3. Angles definition of output ports.

### III. SIMULATION

Fig. 4 describes the geometry of the simulated divider. P1 is the input port and ports P2, P3, P4, P5, P6 are the output ports. The results for the scattering parameters of the divider are presented in fig. 5. It is seen that the divider is matched between 4.92 GHz to 7.2 GHz for  $SWR < 2$ .

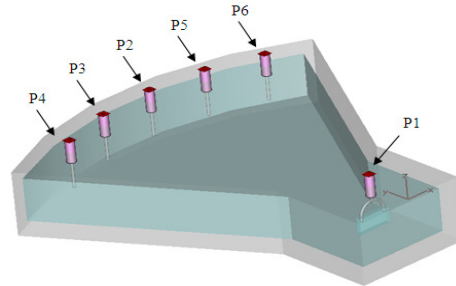


Fig.4. Structure of the 1:5 unequal power divider based on sectoral horn waveguide.

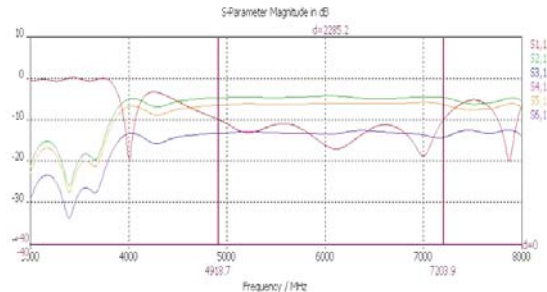


Fig.5. Simulated S-parameters of the power divider described on fig. 4. It is seen that the frequency range for  $SWR < 2$  is  $4.92 \text{ GHz} < f_w < 7.2 \text{ GHz}$ .

Hence we got a 2.3GHz frequency range (40.5%). The accuracy of the Kaiser-Bessel weights is better than 0.1dB and Kaiser-Bessel weights ripple up to 1.1dB

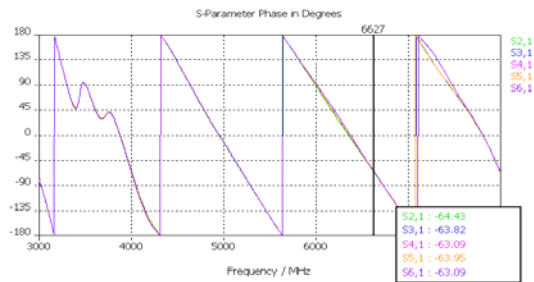


Fig.6. Simulated S-parameter phase of the power divider described on fig. 4.

Fig. 6 shows that the phase match is lower than  $1.8^\circ$  between the various output ports in the operating frequency range as defined on fig. 6.

#### IV. CONSTRUCTION AND MEASUREMENTS

Pictures of the power divider are shown in fig. 7 and fig. 8

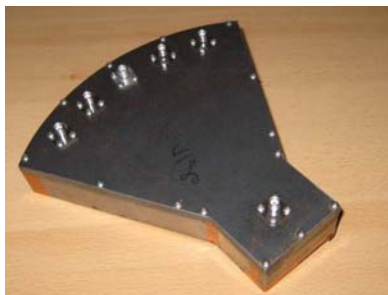


Fig.7. A picture of the power divider.



Fig.8. A picture of the opened power divider.

The measured scattering parameters of the divider are shown in fig. 9

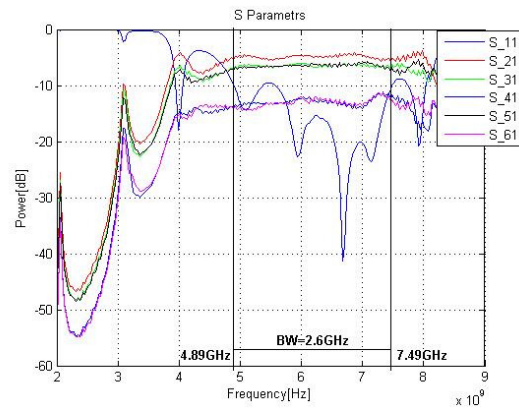


Fig.9. Measured S-parameters of the power divider showing a frequency range of  $4.89\text{GHz} < f_w < 7.49\text{GHz}$  for  $\text{SWR} < 2$ .

From measurement results shown in fig. 9 we get operating frequency range of 2.6GHz (46%). The accuracy of the Kaiser-Bessel weights is better than 0.2dB and Kaiser-Bessel weights ripple is up to 1.2dB.

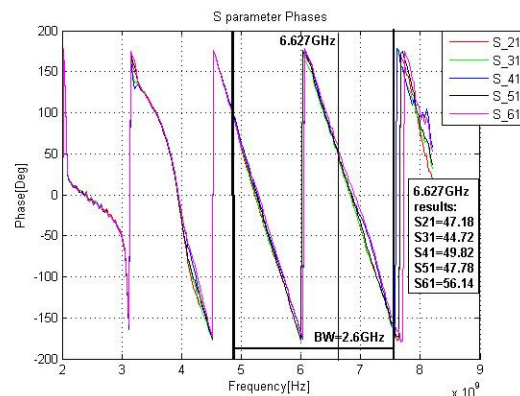


Fig.10. Measured S-parameter phase of the power divider.

Fig. 10 shows a phase matching lower than  $5.1^\circ$  between the various output ports in the operating frequency range as defined on fig. 9. As can be seen from fig. 6 and fig. 10 there is a little difference between simulated and measured results, the reason for this difference comes from small inaccuracies in the manufacturing process.

Table 2 summarizes design, simulation and measurement results:

Table 2: Comparison between design, simulation, and measurement results

Parameter	Design	Simulation	Measurement
Freq. range	3.75÷7.5 [GHz]	4.92÷7.2 [GHz]	4.89÷7.49 [GHz]
Power weights	C1-C0= -1.91dB	C1-C0= -1.82±0.3dB	C1-C0= -1.8±0.4dB
	C2-C0= -8.32dB	C2-C0= -8.33±1.1dB	C2-C0= -8.5±1.2dB
Output phase mismatch	0°	1.7°±0.4°	6.1°±1.1°

### V. CONCLUSIONS

We presented a 1:5 unequal, equi-phase power divider with Kaiser-Bessel weights based on sectoral waveguide. Using CST-Microwave simulation software the theoretical idea of radial wave propagation in the power divider was proven. Measured results are very close to the simulated results. The radial wave propagation and power divider's structure guarantee low phase mismatch between output ports and allow working with high power signals, which can be useful in antenna arrays that needs supply radiation plot with low sidelobe level. Achieved operating frequency range of 46% allows using this kind of power divider in a wide spectrum of microwave systems. Other power distributions can be achieved simply by changing the angles of the output ports. Care must be taken into account that the distance of outer output probes from the sector's side border walls will not be too small, otherwise the approximation of eq. (1) won't be valid. Accuracy in manufacturing process has directly influence on phase and amplitude parameters of the power divider.

### REFERENCES

[1] F. Gross, *Smart Antennas for Wireless Communication*, McGraw-Hill Companies, Inc, 2005, Ch. 4.  
 [2] Jong-Sik Lim, Sung-Won Lee, Chul-Soo Kim,

Jun-Seok Park, Dal Ahn, and Sangwook Nam, "A 4 : 1 Unequal Wilkinson Power Divider", *IEEE Microwave and Wireless Components Letters*, Vol. 11, No. 3, March 2001.  
 [3] J. Joubert and S. R. Rengarajan, "Design of Unequal H-plane Waveguide Power Dividers for Array Applications", *Antennas and Propagation Society International Symposium, Vol.3, pp. 1636-1639, 1996 IEEE*.  
 [4] S. Christopher, V. A. Abid Hussain, M. S. Easwaran and V. N. Dabade, "Design Aspects of Compact High Power Multiport Unequal Power Dividers", *Phased Array Systems and Technology, IEEE International Symposium, pp. 63-67, 1996., IEEE*.  
 [5] M. E. Bialkowski, V.P. Waris and P. W. Davis "Modelling and Testing of Radial Divider/Combiner", *Singapore ICCS apos 94, Conference Proceedings, Vol.1, pp.-234-240, 1994 IEEE*.  
 [6] F. Gross, *Smart Antennas for Wireless Communication*, McGraw-Hill Companies, Inc, pp. 85, 2005.  
 [7] M.D. Pozar, *Microwave Engineering*, Second Edition, John Wiley and Sons, Inc., Ch. 3.3, 1998.  
 [8] N. Marcuvitz. *Waveguide Handbook*, 1986 Edition, IET, Ch. 2.7, 1986.  
 [9] R. F. Harrington, *Time-Harmonic Electromagnetic fields*, John Wiley and Sons, Inc., 2001, Ch. 5.3.  
 [10] S. Silver, *Microwave Antenna Theory and Design*, 1-st edition, McGraw-Hill Companies, Inc, pp. 349÷357, 1949.