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

[#]A. Mestezky [1], H. Matzner [2]
[1] Department of Communication, Holon Institute of Technology
52 Golomb St., Holon 58102, Israel, amestezkey@gmail.com
[2] Department of Communication, Holon Institute of Technology
52 Golomb St., Holon 58102, Israel, haim@hit.ac.il

## 1. 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 bandwith of about 46% for SWR = 2.

Index Terms- Sectoral horn, unequal power divider.

## 2. Introduction

Unequal power dividers are very important components, especially 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.

Unequal power distribution with equal output phases using passive component was discussed for example by [1]. 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 it's 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 [2]. 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 a combination of unequal T-junction power dividers was presented in [3]. This structure allows unequal distribution of high power signals with amplitude error up to 0.23dB and phase mismatch up to 1.5° 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 [4]. 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 horn with H-plane sectoral geometry. The power divider was designed to have unequal power weights based on Kaiser-Bessel distribution. 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 3 theoretical aspects of the power divider's design are presented. In section 4 simulation results using CST Microwave Studio software are shown. Measured results are described in section 5, as well as a comparison between the design, simulation and measurement. Finally conclusions are presented in section 6.

## 3. Geometry and Design

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

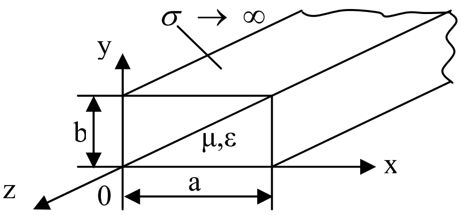


Fig.1. The input rectangular waveguide part.

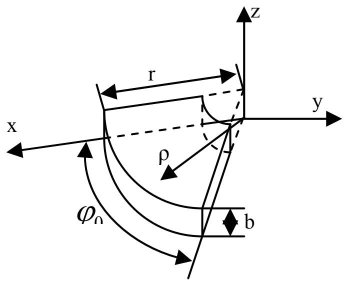


Fig.2. The output sectoral waveguide part.

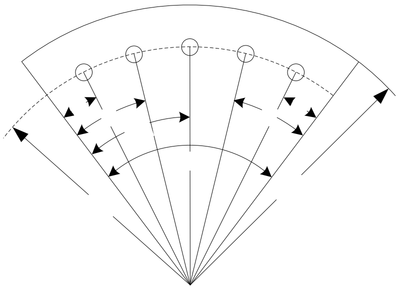
The physical dimensions of the power divider are presented in Table 1, and were chosen for getting needed frequency range and power distribution as will be further described. Dimensions of internal and external radii were optimized using CST Microwave simulation software.

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

| **Rectangular waveguide** | **Sectoral horn** |
|---|---|
| Height (b) = 20mm | Height (b) = 20mm |
| Width (a) = 40mm | Aperture angle ($\varphi_0$) = 60° |
| Length = 37.5mm | r = 138.5mm |

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: $3.75\text{GHz} < f_{w(Rect)} < 7.5\text{GHz}$.

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. The power density at the aperture of the sectoral waveguide can be approximated by $\sin^2(\pi\varphi/\varphi_0)$ and the needed power amplitudes at the output ports for getting the Kaiser-Bessel distribution: $C_{(2)}$= 0dB, $C_{(3)}$= $C_{(5)}$=(-1.91)dB, $C_{(4)}$= $C_{(6)}$=(-8.32)dB for $\alpha = 1.4$ will be optimized by the software. The relevant angles are $\varphi_0$=60°, $\varphi_1$=17.8°, $\varphi_2$=7.52° according to definition of their location on fig. 3.



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. Definition of angles of output ports.

## 4. 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's. 5, 6.

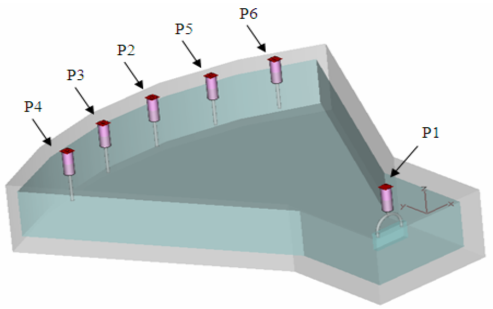


Fig.4. Structure of the 1:5 unequal power divider based on sectoral horn waveguide.

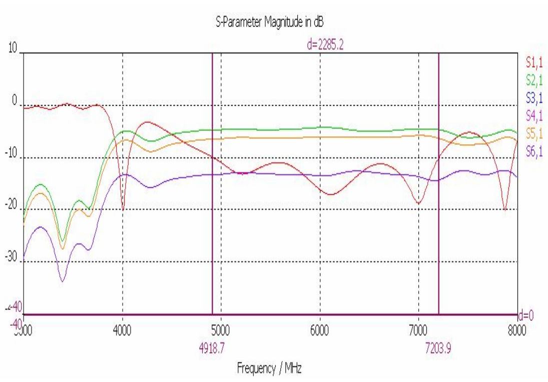


Fig.5. Simulated S-parameters amplitudes

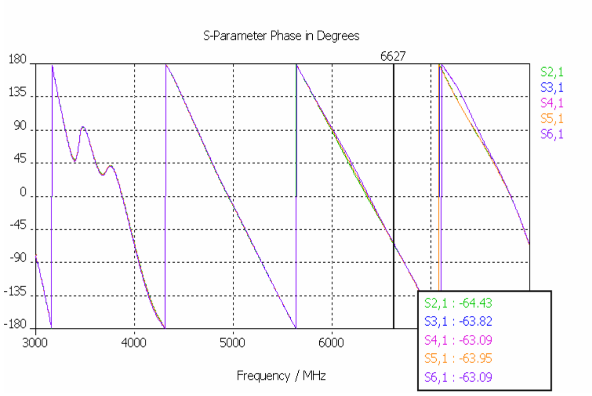


Fig. 6 Simulated S-parameters phases

It is seen that the frequency range for SWR < 2 is 4.92GHz < $f_w$ < 7.2GHz. 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 shows that the phase match is lower than 1.8° between the various output ports in the operating frequency range.

## 5. Construction and Measurements

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

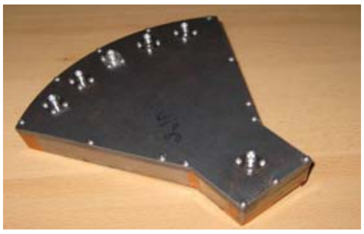


Fig.7. A picture of the closed power divider.

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

The measured scattering parameters of the divider are shown in fig's. 9 and 10. Measurement results show in fig. 9 an operating frequency range of 4.89GHz < $f_w$ < 7.49GHz for SWR< 2 ,that is 2.6GHz (46%). An accuracy of the Kaiser-Bessel weights is better than 0.2dB and Kaiser-Bessel weights ripple is up to 1.2dB. Fig. 10 shows a phase matching lower than 5.1° 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:

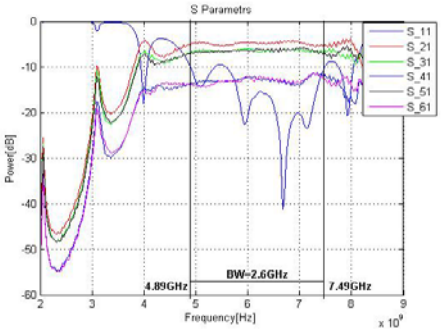


Fig.9. S-parameters amplitudes

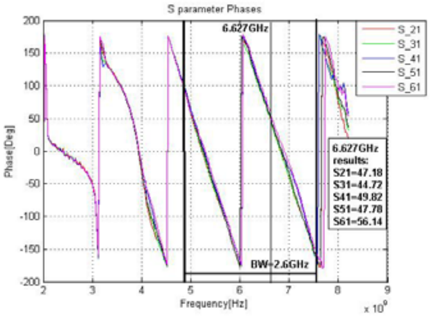


Fig. 10. S- parameters phases

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<br>C2-C0= -8.32dB | C1-C0= -1.82±0.3dB<br>C2-C0= -8.33±1.1dB | C1-C0= -1.8±0.4dB<br>C2-C0= -8.5±1.2dB |
| Output phase mismatch | 0° | 1.7°±0.4° | 6.1°±1.1° |

## 6. 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 need 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 system. 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 $\sin^2(\pi\varphi/\varphi_0)$ won't be valid. Accuracy in manufacturing process has directly influence on phase and amplitude parameters of the power divider.

## References

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