Improved Shape of an Input/Output - Wave Guide with Integrated Taper for W-Band Muffin-Tin WBAND-003

Rolf Merte
Technical University Berlin
Department of Electrical Engineering
Institute of Theory of Electricity
D-10587 Berlin
merte@tetibm1.ee.tu-berlin.de

This paper is part 2 of a group of papers for the first TU-Berlin structure WBAND-003

Abstract

This Paper presents a new design of a redirected or detoured wave guide with an integrated taper. Further, the comparison of numerically calculated S_{11} and S_{12} parameters of two different designs is also presented. An improved shape is suggested.

This presentation is one part of the complete design of the first TU-Berlin W-Band accelerating structure WBAND-003. It is split from the rest, because there is maybe no interest in W-Band structures, or generally in muffin tin's, but a design of a detoured wave guide or a taper, or both may be needed. In that case, this paper and some of the references could be helpful.

I. Introduction

If we look at [1], [3], [4] and [5], we see that it is necessary to detour the wave guide from the input and output coupling cells to the exterior boundary of the structure. The connected WR-10 flange is as large as half the structure, so it is not possible to use a transverse fiber for a bead-pull-measurement. The flange overlaps the pumping slots, or fiber pipe, which are needed for the fiber. Further the size of the first and last cells are smaller than the size of a WR-10 wave guide, that means tapering in this direction is also necessary. The depth of this part is chosen as the depth of a WR-10 wave guide, therefore no tapering in this direction is necessary.

The problem shown in figure 1 and how to solve it, is the subject of the following analysis. The zoomed area, so called critical area, contains a very tiny piece of copper. These noses will be mounted on two solid mechanical supports. The possibility of damage to this sensitive part during mounting is high. Therefore it is a further aim to minimize this critical area.

All numerical simulations are done with our improved code GdfidL [6], which is freely available and faster than MAFIA.

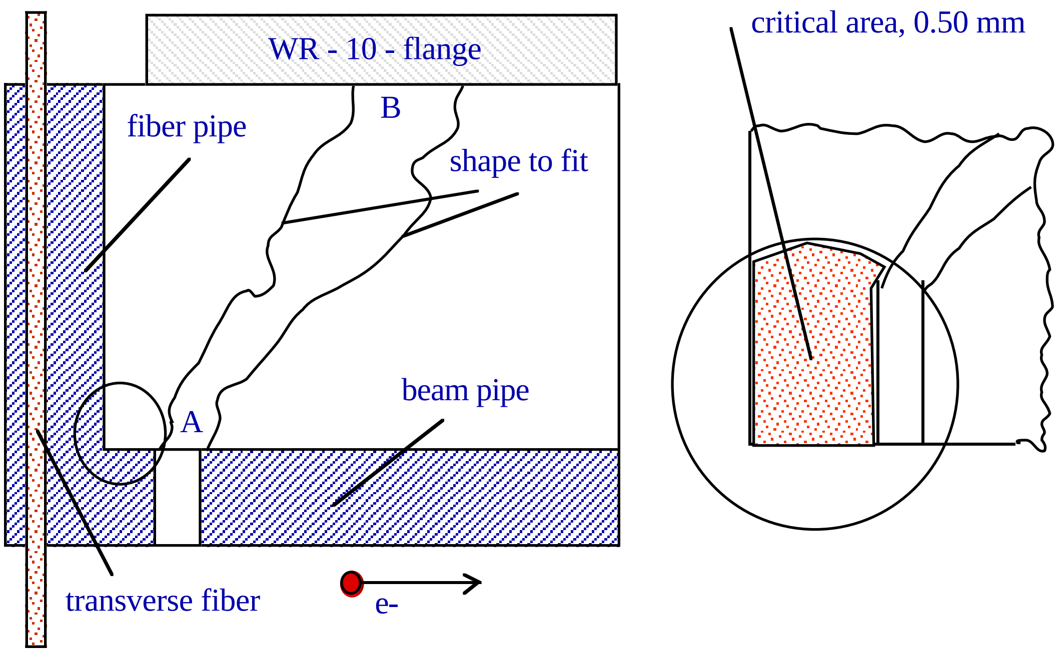

FIGURE 1. The problem: how to go from point A to point B.

II. Waveguide - Taper Design E1

A quick and dirty solution for this, is shown in figure 2. There are also some defined variables, which we will use later. GG stands for groove guide, because it is as such in the original application, T for top, B for bottom, I for inside and O for outside. We simply take some straight sections and connect them in one way. The middle section which is the diagonal part of the wave guide, should contain the taper, as shown. The angle alpha of this part depends on the length of the values of GGBI, GGBO and GGTI, GGTO. This is shown in figure 3.

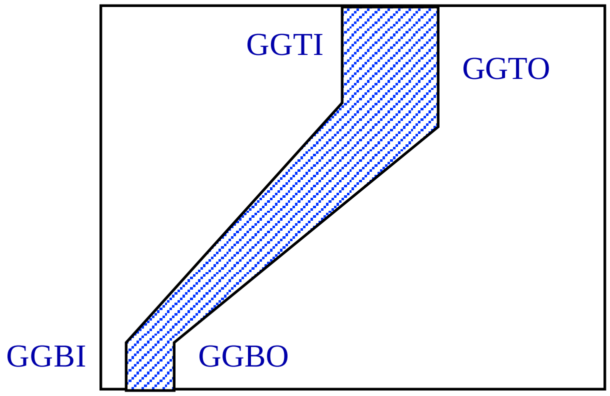

FIGURE 2. Simplest solution.

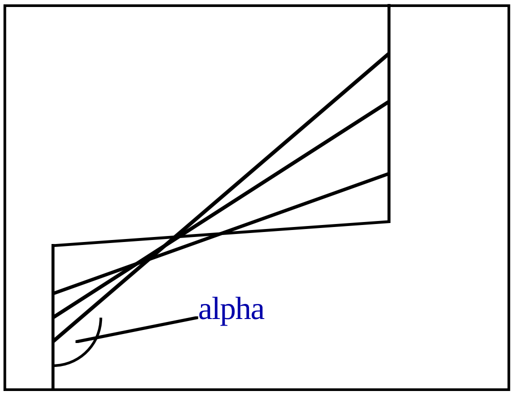

FIGURE 3. Definition of angle alpha.

It seems logical, that a larger angle of alpha is better than a smaller alpha. What do we want? We are looking for good S_{11} and S_{12} parameters. This means we want a maximum of transmission and a minimum of reflection. Further we want losses as small as possible. Losses are proportional to the length of the section. We can reach these aims by minimizing the whole surface in this way.
The outer dimensions are approximately 25 times 25 mm. The first bend should be a little bit more than a wavelength. Let us start with 3 mm.

GGBI = GGBO = GGTI = GGTO = 3.0 mm

The next thing to do, is to be clear about the relation of GGBI / GGBO and GGTI / GGTO. We can optimize the transmission by modifying these ratios. We define variables FAC and x:

FAC = x / 100% + 1.00, x = 1%, ... , 50%,

usage of FAC:

GGBI = GGBI * FAC, GGBO = GGBO / FAC,
GGTI = GGTI * FAC, GGTO = GGTO * FAC.

This means, we increase one side at x% and decrease the other side by the same amount. Now, let us calculate some different x-values and find a good geometry. Figure 4 shows the GdfidL model of the wave guide. Much calculation is done and figures 5-6 show the results for amplitudes of S_{11} and S_{12} for some different x. As we can see, we get the best results for a relation of x=7%. Further, we can see a relatively good transmission and an unacceptable high reflection. A further increase leads to much worse behavior. At the desired frequency of 91.392 GHz we get a S_{11} between 0.07 to 0.13. Expressed in terms of voltage standing wave ratio:

$$VSWR = \frac{1+|R|}{1-|R|} = 1.15 \ldots 1.28 .$$

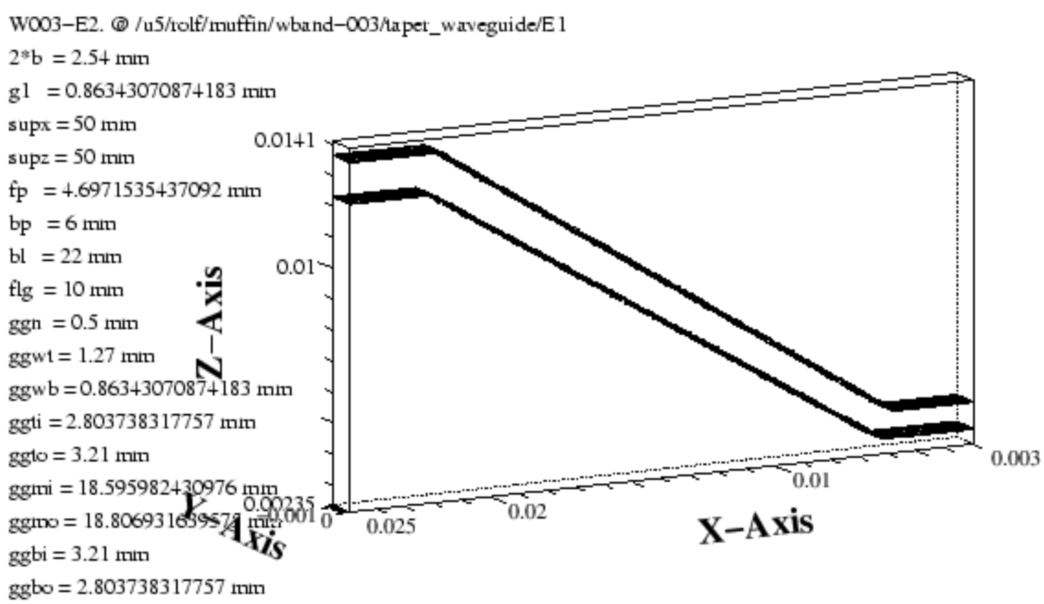

FIGURE 4. GdfidL model of Design E1.

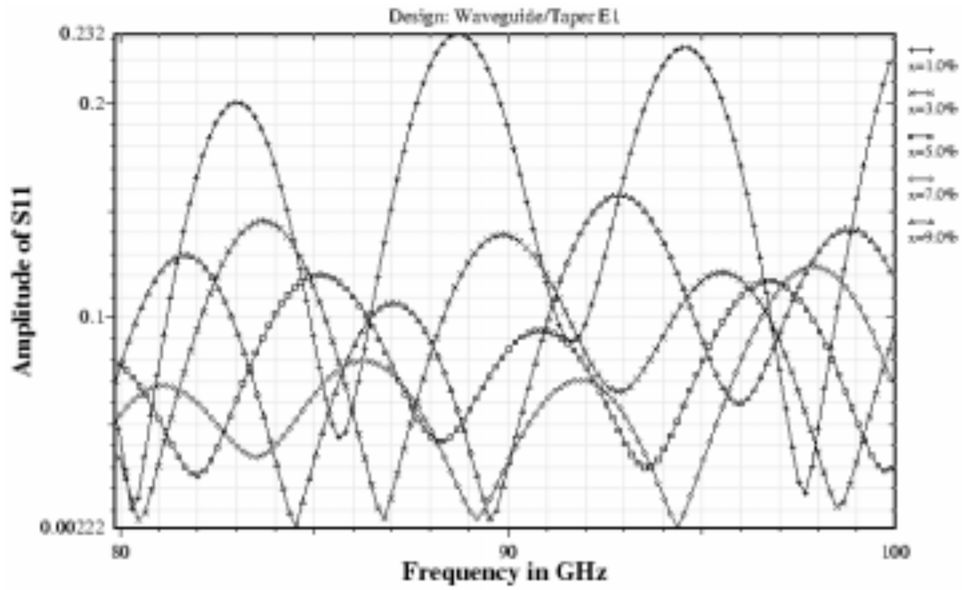

FIGURE 5. Amplitudes of S_{11} for Design E1 for different x.

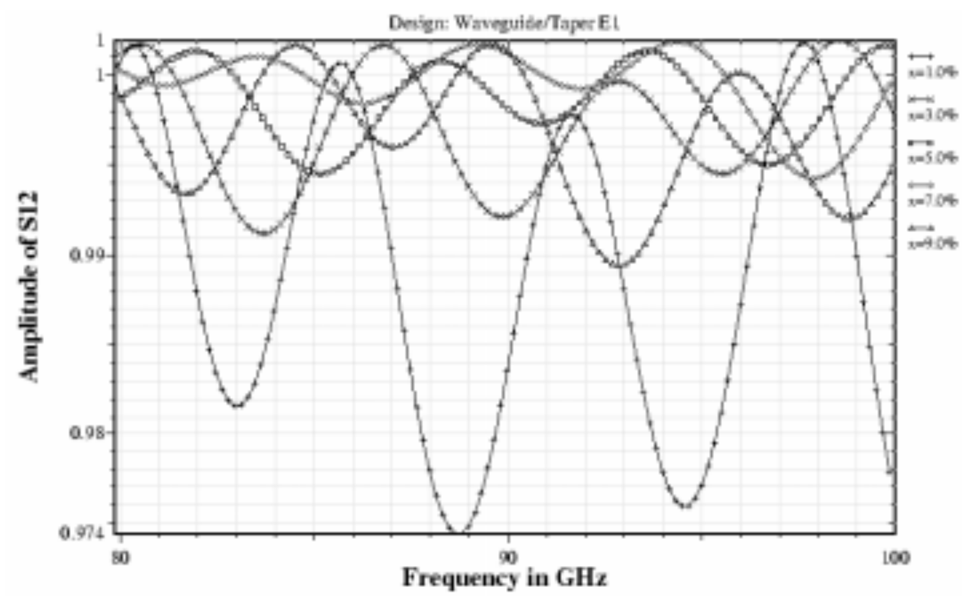

FIGURE 6. Amplitudes of S_{12} for Design E1 for different x.

III. Waveguide - Taper Design E2

An improved design is shown in figure 7. All corners are rounded by using different circles and in the middle we have a smooth adapted taper. This improved design was optimized and calculated numerically. A detailed explanation of the calculation procedure is proposed in [2]. All mentioned conditions are taken into account. Figure 8 shows the GdfidL model of the wave guide.

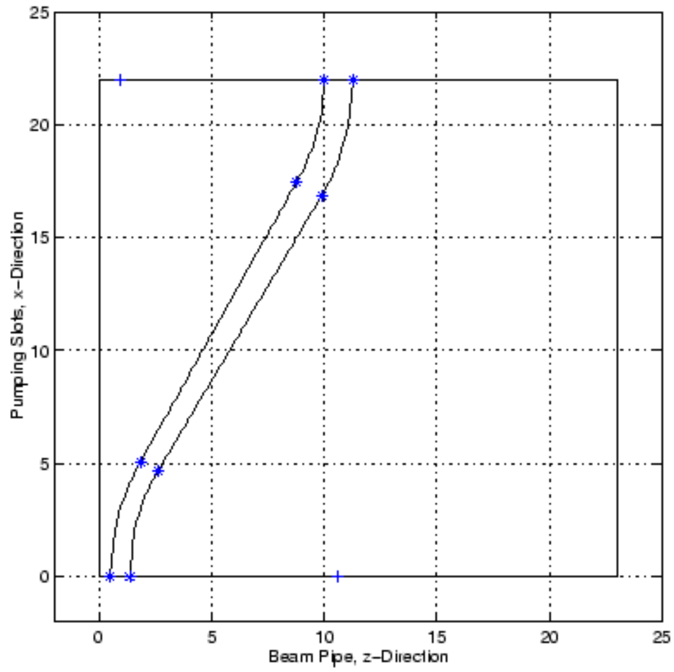

FIGURE 7. Improved Design E2.

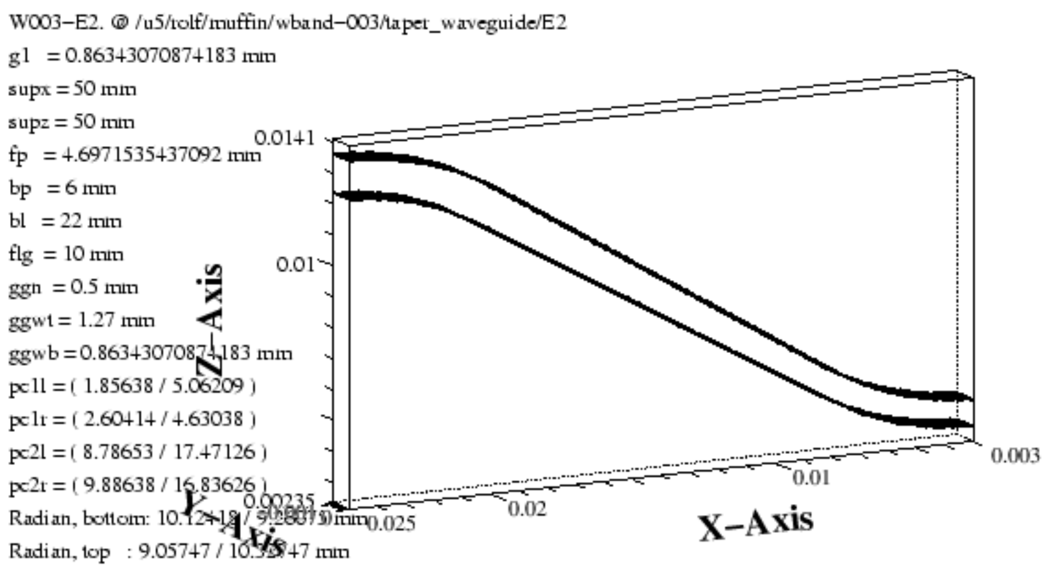

FIGURE 8. GdfidL model of Design E2.

IV. Comparison of Design E1 and E2

Let us finally compare the S_{11} and S_{12} calculations of the best results of design E1 at x=7%, with results of design E2. In figures 9-10 the amplitudes of S_{11} and S_{12} are shown and compared. Figures 11-12 show the phases of S_{11} and S_{12} of both designs. We can clearly see the improved transmission and decreased reflection of design E2. At the desired frequency of 91.392 GHz we get for design E2 a S_{11} of 0.01. Expressed in terms of voltage standing wave ratio:

$$VSWR = \frac{1+|R|}{1-|R|} = 1.02\,.$$

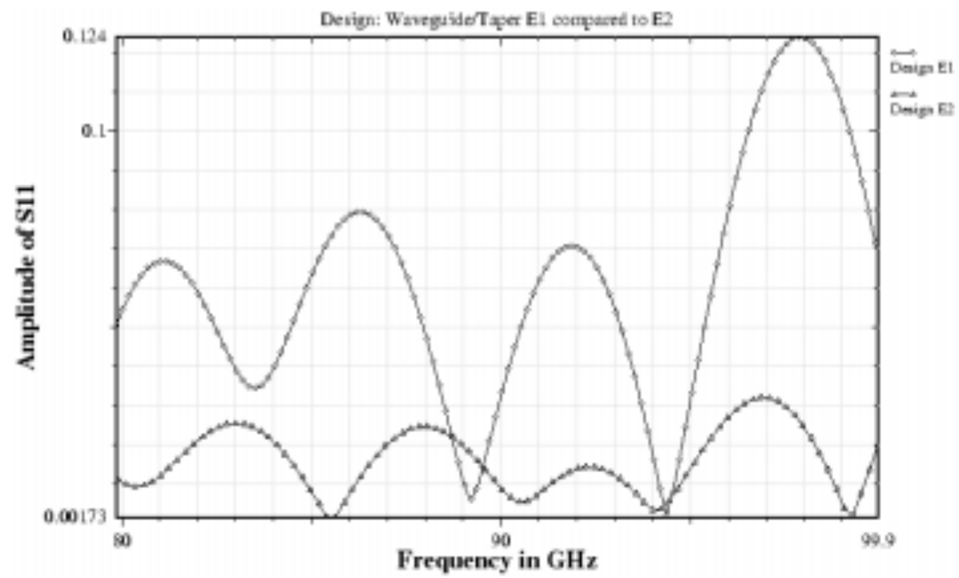

FIGURE 9. Amplitudes of S_{11} compared of both designs.

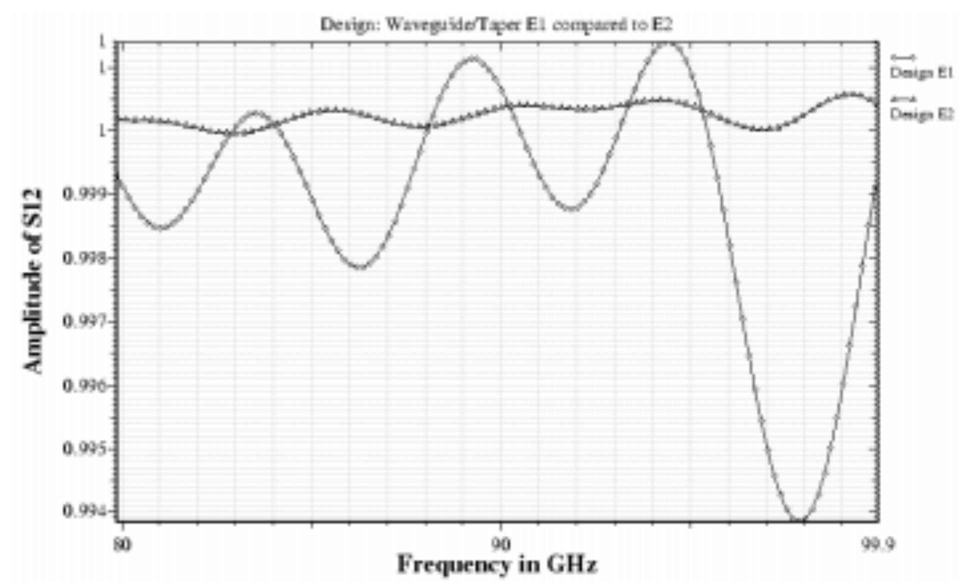

FIGURE 10. Amplitudes of S_{12} compared of both designs.

Do not be concerned with $S_{12} > 1$. The error is less than 0.3%. It looks bad, because this picture is a large magnification of a small range (too small for the postprocessing program PLOTMTV), but it is fine. For this reason, a program parameter called NDZ describes the quality of the absorbing boundary condition. The larger NDZ is, the smaller the error becomes. In this case NDZ is 4000, which is 10 times larger than usually necessary.

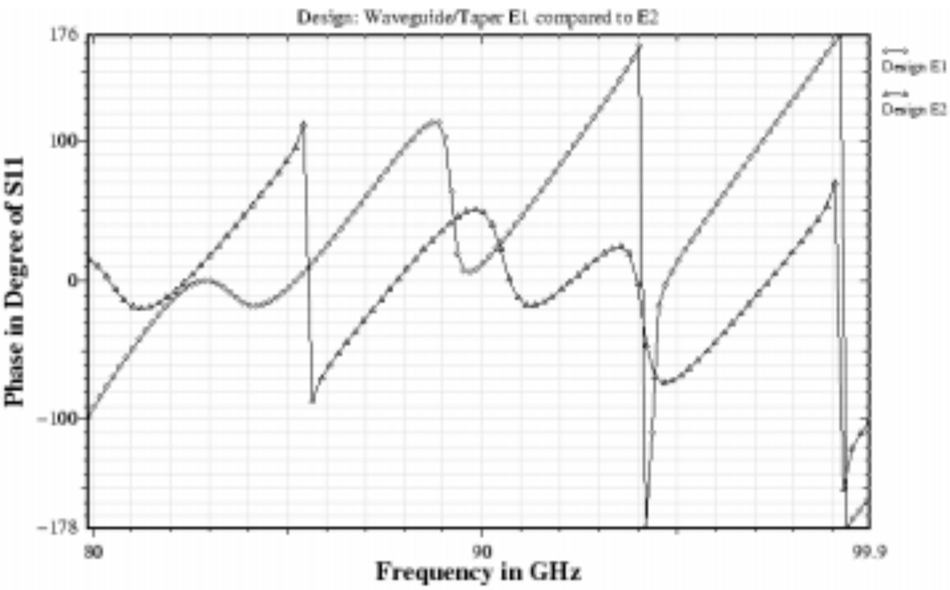

FIGURE 11. Phases of S_{11} compared of both designs.

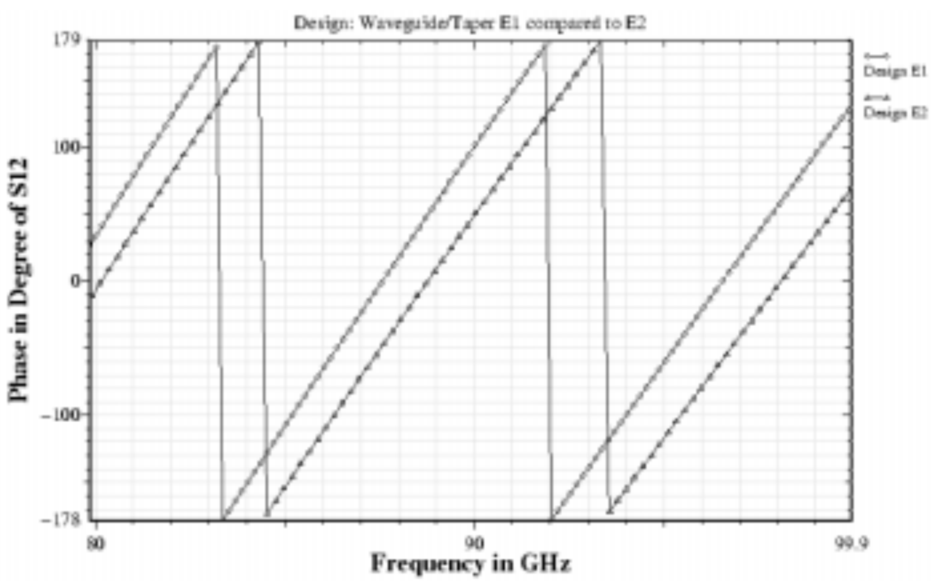

FIGURE 12. Phases of S_{12} compared of both designs.

V. Conclusion

It is shown that due to rounding corners and tapering smoothly, we increased the transmission and decreased the reflection. The improved design E2 leads to a VSWR of 1.02, which is tolerable and represents a not so high input loss to the structure. This presented design will be integrated in the complete design of the W-Band muffin tin WBAND-003 E2.

VI. References

[1] R. Merte, “First Design of a W-Band Muffin Tin, Cold Test Model, WBAND-003”, TET Note 15/97, Inst. f. Theoretische Elektrotechnik, TU-Berlin.

[2] R. Merte, “Detouring and Tapering a Wave Guide - A small mathematical Problem”, Tech. Note 141, ARDB, SLAC, Stanford.

[3] R. Merte, “Matched Input/Output Cavities of W-Band Muffin Tin WBAND-003”, Tech. Note 142, ARDB, SLAC, Stanford.

[4] R. Merte, “Technical Realization of W-Band Muffin Tin WBAND-003”, Tech. Note 143, ARDB, SLAC, Stanford.

[5] R. Merte, “Improved Design of W-Band Muffin Tin WBAND-003”, Tech. Note 144, ARDB, SLAC, Stanford.

[6] W. Bruns, “GdfidL: A finite difference program for arbitrarily small perturbations in rectangular geometries”, IEEE Trans. Magn. Vol. 32, No. 3 May 1996.