Direct metal laser sintering printed millimeter and submillimeter waveguides

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I. INTRODUCTION

Passive millimetre-wave and THz components are traditionally fabricated by computer numerical control (CNC), micromachining, electrical discharge machining (EDM), or injection molding. 3D-printing is a fairly new fabrication technique and involves technologies, such as fused deposition modelling (FDM), stereolithography apparatus (SLA), ceramic stereolithography apparatus (CSLA), microstereolithography apparatus (μSLA), binder jetting (BJ), polymer jetting (PJ), selective laser melting (SLM), selective laser sintering (SLS), and electron beam melting (EBM).

In this paper we describe fabrication of stainless steel waveguides using DMLS process for the WR10 and WR3 band, examine the losses experimentally and compare with analytical calculations and HFSS simulations. There are many possibilities to reduce the losses which will be discussed in the presentation.

II. RESULTS

Theory:

The Huray Model [1] which has been proven to model the attenuation due to surface roughness accurately up to 50 GHz and predicted to work accurately up to 100 GHz was used in the theoretical calculations. The SR-value used in the Huray model is estimated to be about 1.1 using Scanning Electron Microscope (SEM) and Veeco optical interferometry. This value is used in the theoretical calculations of the losses in the waveguides.

Another approach to simulating the surface roughness in the waveguide is to place particles directly in the 3D-modell of the waveguide in Ansoft HFSS. Cubic particles of size 20x20x20 μm and spacing corresponding to an SR of 1.1 was simulated for the WR3-waveguide. The chamfered corners of the waveguide due to process is also taken into account.

Measurements:

The transmission coefficient in the waveguides was measured and a mean value with regards to the waveguide lengths was calculated. In Fig. 1 the transmission coefficients of the WR10 gold plated reference and 3D-printed waveguide are shown. The transmission coefficient of the reference waveguide is around 0.005 dB/mm and the 3D-printed waveguide is about 0.06 dB/mm. For the WR3 waveguides, as can be seen in Fig. 2 the measured reference waveguide (gold plated) is about 0.05 dB/mm and the 3D-printed steel waveguide is about 0.3 dB/mm. The results after implementing the Huray-model and HFSS will be shown in the presentation.

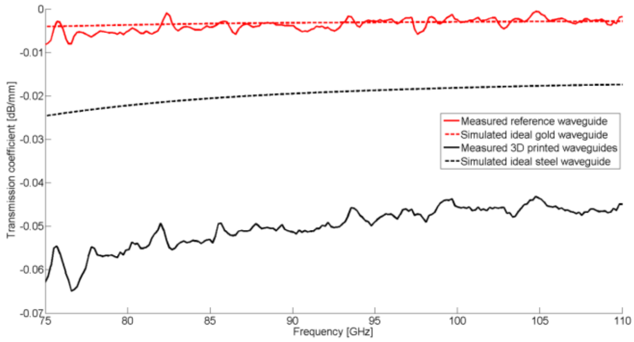

Fig. 1: Transmission coefficient as a function of frequency for the WR10 waveguide. Comparison of reference and 3D-printed waveguide. Solid red line: Measured reference gold waveguide. Dashed red line: Simulated ideal gold waveguide. Solid black line: Measured 3D printed waveguide. Dashed black line: Simulated ideal steel waveguide.

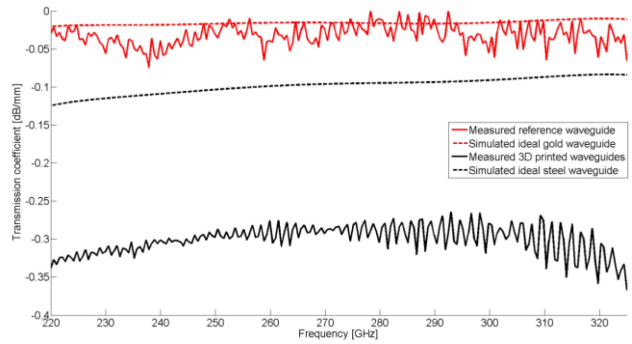

Fig. 2: Transmission coefficient as a function of frequency for the WR3 waveguide. Comparison of reference and 3D-printed waveguide. Solid red line: Measured reference gold waveguide. Dashed red line: Simulated ideal gold waveguide. Solid black line: Measured 3D printed waveguide. Dashed black line: Simulated ideal steel waveguide

III. CONCLUSIONS

Different lengths of WR10 and WR3 waveguides in steel are manufactured with DMLS 3D metal printing. The losses of 0.3 dB/mm for WR3 and 0.05 dB/mm for WR10 are of course higher than for a gold-plated CNC-manufactured waveguide but can still be acceptable for some applications where complicated 3D waveguide structures are used.

IV. ACKNOWLEDGEMENT

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V. REFERENCES

[1] P.G. Huray, O. Oluwafemi, J. Loyer, E. Bogatin and X. Ye, "Impact of Copper Surface Texture on Loss: A Model that Works," DesignCon 2010 Proceedings, Santa Clara, CA, 2010