Contactless pin-flange adapter for high-frequency measurements

CONTACTLESS PIN-FLANGE ADAPTER FOR HIGH-FREQUENCY MEASUREMENTS

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***Abstract* — We present a first contactless pin-flange adapter for high-frequency measurements based on gap waveguide technology. Conventionally, standard (WR) flanges are used, these require good electrical contact and are sensitive to small gaps. The pin-flange adapter has been fabricated and demonstrated for the frequency range 220-325 GHz. It shows similar or better results than a standard flange or a choke flange without requiring electrical contact. The pin-flange adapter has a lower noise level compared to the other flanges, almost 10 dB lower.**

***Keywords:* GHz, High-frequency, MEMS, RF, Metamaterial, Gap Waveguide, Measurement adapters, Pin flange**

I – Introduction

Gap waveguide technology has over the course of a few years been develop from gap waveguides constructed for 10-20 GHz [1] to micromachined gap waveguides constructed for 220-320 GHz [2]. This technology is based on the realization of a metamaterial so called bed of nails [3]. The bed-of-nails structure is a surface with electrically conducting pins which from a macroscopic point of view creates an Artificial Magnetically Conducting (AMC) surface. By applying an electrically conducting lid above this surface, a stopband is created [4].

A challenge with measurements on the first micromachined gap-waveguide resonator, presented in [5], was to obtain a good electrical contact between the measured device and the measurement flange. Most high-frequency measurements are performed with standard rectangular waveguide (WR) flanges. These need to be in good electrical contact with the measured object to avoid losses. This is achieved by screwing the flanges tightly to the object. However, if the surface is uneven or if anything is in the way that can create a gap, losses will increase, e.g. with a 20 μm gap, return losses can exceed 20 dB [6]. To solve this, a flange was modified to have a $\lambda/4$ ring around the opening, a so-called choke to damp the leakage caused by the gap (see figure 1). The choke flange will work even with a small gap between the flange and the measurement object.

Inspired by this technology and with the idea of avoiding different sets of waveguides during measurement, a first contactless waveguide measurement pin-flange adapter has been fabricated. The adapter can be placed on any WR standard flange and does not require electrical contact. Simulations and theory of this pin-flange adapter were presented in [6]. In this paper, we present a prototype of the pin-flange adapter, the first measured results with a ridge-gap resonator and a proposed MEMS process.

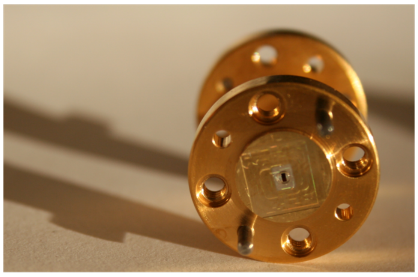

Figure 1: *WR03 standard flange modified with a choke ring close to the opening*

II – Design

The pin-flange adapter has a disc shape. There are four big holes for the flange screw and four smaller holes for the guiding pins on the flange. They are placed so as to match the WR03 waveguide standard such that the adapter can be slid onto any WR03 flange and provide the user the option of using the flange or not.

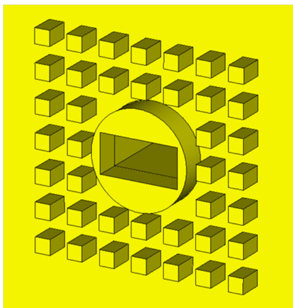

Figure 2: *A design of the pin-flange surface.*

Two rows of pins (fig. 2) around the rectangular waveguide opening create the AMC surface which is needed to create a parallel-plate cutoff region within the air gap in figure 3. No pin-flange adapter is required on the opposing side. The pin-flange adapter works provided the opposing surface is electrically conducting.

Around the rectangular waveguide opening, a round wall with the same height as the surrounding pins (figure 2) has the purpose of avoiding reflections that can occur between the waveguide and its object of measurement. To achieve this, the wall needs to be a quarter wavelength wide at its widest side to act as an impedance transformer which transforms an open circuit to a short circuit [6].

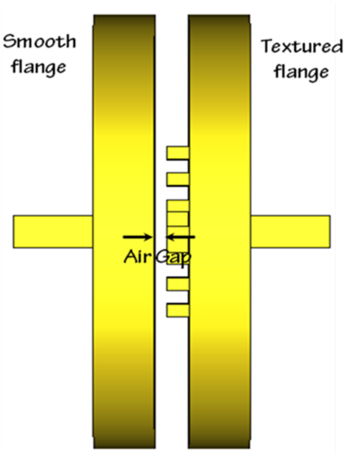

Figure 3: *To the right; a pin flange facing a regular flange with an air gap between them.*

Although the flange works for any gap which is smaller than quarter of a wavelength of the operation frequency range, the gap is fixed to facilitate comparison of the measured data with the simulated data. Therefore, four spacers were added to the pin-flange adapter to keep a fixed 56 μm air-gap between the pin-flange adapter and the device to be measured.

III – Fabrication A prototype was milled into a

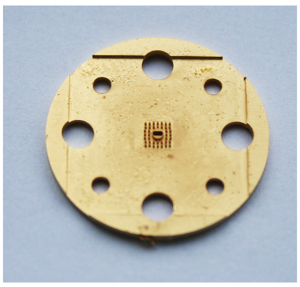

Figure 4: *The pin-flange-adapter prototype.*

1 mm thick brass disc and then electroplated with gold. The gold layer was 1.5 μm thick to assure conductivity at the frequencies 220-325 GHz. To be able to manufacture it by milling the design had to be adapted, this will be avoided if done by micromachining. The prototype is shown in figure 4.

Milling the pin-flange adapter is difficult and requires both skill and high-quality equipment to get the desired results. Therefore it is proposed that the pin-flange adapter can be manufactured with micromachining. Although this has not been done yet, the proposed process given here (figure 5) is based on previous work within our group with metamaterials and gap waveguides [5].

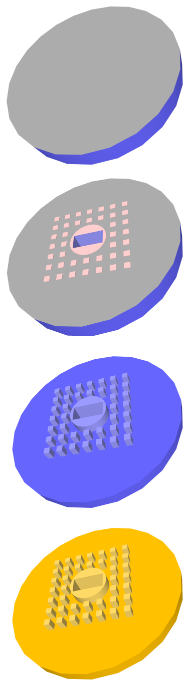

Figure 5: *Process diagram, blue: Si, grey: Al, pink: photoresist, yellow: gold.*

Figure 5 illustrates the process: a) starting with an aluminum layer deposited on a silicon wafer, b) pattern it with a photoresist, c) etch it down using deep reactive ion etching equipment (DRIE) and d) the wafers is diced, sputtered and electroplated it with gold.

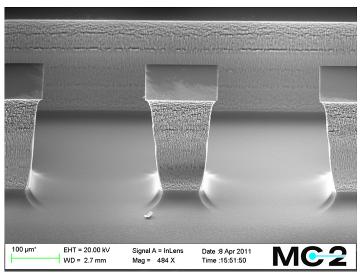

Figure 6: *SEM picture of micromachined pillars performed by the proposed process.*

By the following this process one have also the advantage of being able to fabricate pillars with a mushroom-like form as shown in figure 6. The inward slanted walls have the benefit of resulting in an increased bandwidth [7].

IV – Measurement Setup

To test and compare the pin-flange adapters with other flanges, three types of measurements were performed on a fabricated gap waveguide resonator [5]. In the first case, the resonator was measured with regular WR03 flanges. In the second case, the resonator was measured with choke flanges (figure 1) at both ends of the resonator. These choke flanges where also constructed within the group by milling. The last measurement type was with the pin-flange adapters at both ends, with the pin surface facing the resonator. All three measurements where performed on a single-pin-row ridge-gap-waveguide resonator as presented in [2, 5].

The measurement setup can be seen in figure 7, where (a) is a Network Analyzer (Agilent N5250C) connected to (b), a millimeter-wave controller (Agilent N5260A). The millimeter-wave controller goes out to the two OML extenders constructed for 220 GHz-325 GHz (c) where WR03 flanges (d) are connected to each side of the circuit under test. Between the WR03 flange and the support package (e) the pin-flange adapter is placed with the pin-side facing the chip inside the support package.

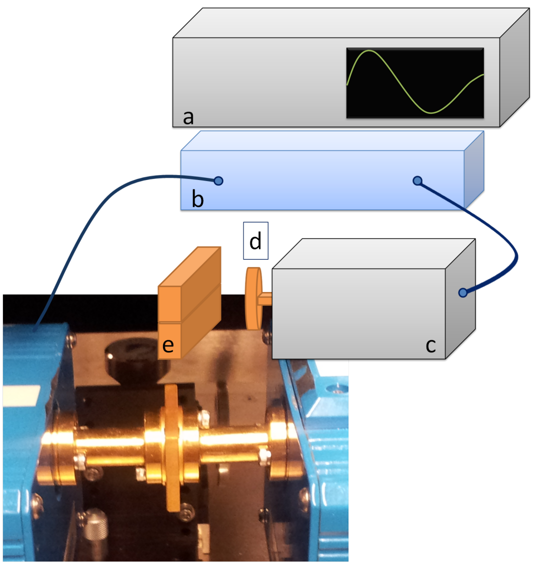

Figure 7: *Measurement setup*

V – Results and Discussion

A. Simulated data

Figure 8 shows the simulated S-parameters for the waveguide with the pin-flange adapter, connected to a standard waveguide flange, with an air gap of 56 μm between them. The reflection coefficient is below 20 dB from 200 to 310 GHz.

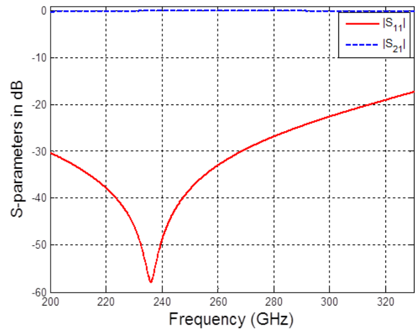

Figure 8: *Simulation of a standard connected waveguide and a pin-flange waveguide as in figure 3*

B. Measured data

Measurement results of the resonator connected to the pin-flange adapter at each side (blue line), together with simulated data for a standard flange connected to the resonator (red dashed line) are shown in figure 9. As it can be seen, the resonator shows clear resonances, even with an air gap of 56 μm present between the flanges and the chip.

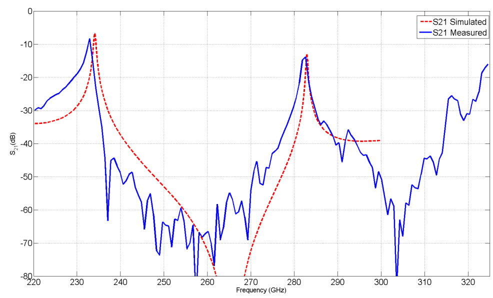

Figure 9: *Blue line: Measurement of a one pin-row resonator with the pin-flange adapter. Red dashed line: Simulated data with standard flanges connected to the resonator.*

C. Comparison with standard flange and choke flange

Figure 10 shows measurement results of the same chip measured with three kinds of flanges: pin flanges, choke flanges and standard flanges. The results agree quite well for the three cases.

The pin flange (i.e. a regular flange with a pin-flange adapter) performs as well as the regular flange in the whole intended frequency range even though there is a gap between the pin flange and the measured resonator which usually would be very detrimental to the system's performance. This shows the ability of

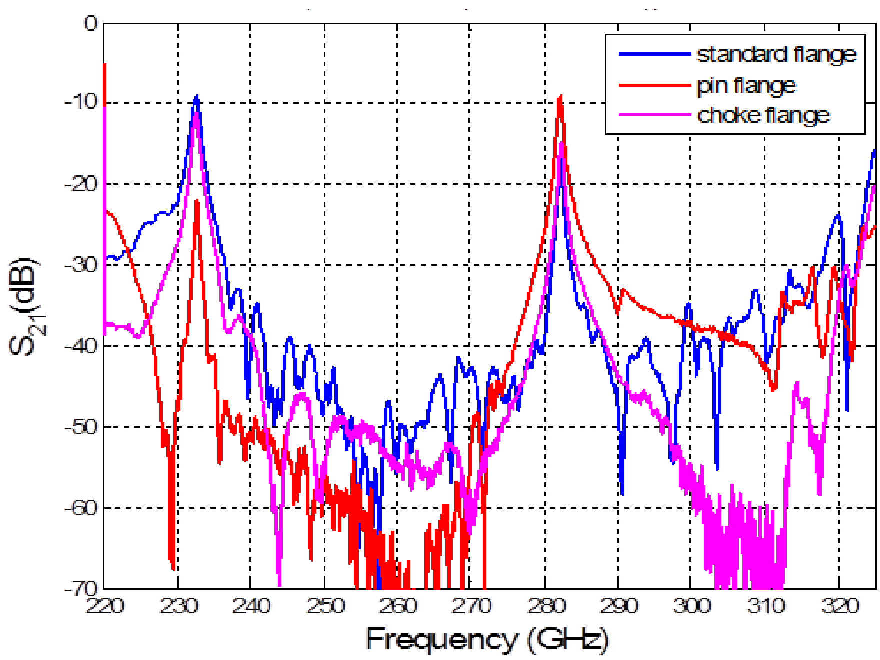

Figure 10: *Comparisons between the standard flanges (blue line), the choke flanges (pink line) and the pin flanges (red line).*

the pin flange to achieve more robust measurement setups. As for the choke flange, which also has a gap, the results are as good as the pin flange. However, the background noise was reduced by the order of 10 dB compared to the standard flange and the choke flange

VI – Conclusion

A first contactless pin-flange adapter has been demonstrated. The measurements shows that the pin-flange adapter shows similar performances compared to the choke flange and better performances than the standard flange considering the existing gap. It also has a lower noise level compared to both the choke and the standard flanges, almost 10 dB lower than the other flanges between the resonance peaks. The pin-flange adapter constructed in this paper also has the benefit of being easy to place on the existing measurement equipment and just as easy to remove. Therefore one can keep its existing measurement setup and just add the pin-flange adapter as an accessory.

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