Design of a Dielectric Waveguide Sensor for Pseudo-Transmission Measurements

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Abstract—This contribution discusses a novel, dielectric waveguide (DWG) based, permittivity sensor. A design concept, that realizes a pseudo-transmission measurement approach for attenuating disturbing feed-side reflections, is presented. Measurement results, which prove the high measurement accuracy and sensor applicability, are discussed in detail.

Permittivity Sensor, Dielectric Waveguide, Time Domain

I. INTRODUCTION

Microwave based, time domain (TD) sensors are a popular alternative for the measurement of material parameters such as the material's permittivity. Independently of the actual sensor design, TD sensors have in common that when stuck into a material under test (MUT) the propagation velocity of an electromagnetic wave is altered. Furthermore, all TD sensors must tackle the challenge of feed-side and multiple reflections as these can mask or disturb the actual signal of interest. In the past, this challenge has been mastered by designing transmissometry sensors for line-bound setups [1] or pseudo-transmission sensors for free-space applications [2]. In this work, a pseudo-transmission sensor is introduced that realizes a pseudo-transmission approach on a DWG.

II. SENSOR DESIGN

Quadratic DWGs provide a broad mono-mode operation area for their fundamental mode, which is ideal for a sensor design. By applying a transpolarizing reflector to the DWG's end, a pseudo-transmission structure is realized as the in- and outbound signals are decoupled in their polarization and are therefore orthogonal. However, when using DWGs as TD sensor, one need to consider that the DWG's group velocity increases with the surrounding permittivity. By applying Marcatili's approximation, the group velocity of a specified DWG can be calculated as shown in Fig. 1. The sensor setup is completed by adding an orthomode transducer, which discriminates the polarizations of the in- and outbound signal, a DWG feed as well as a transpolarizing reflector must be added to the DWG structure. Fig. 2 shows a photograph of final sensor

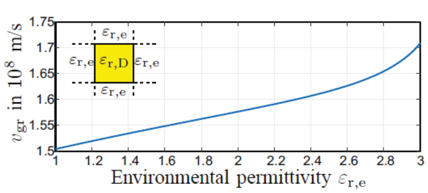

Figure 1: Group velocity of a quadratic DWG (w = 8.5 mm, $\varepsilon_{r,D}$ = 3, f =25 GHz) for different environmental permittivities $\varepsilon_{r,e}$.

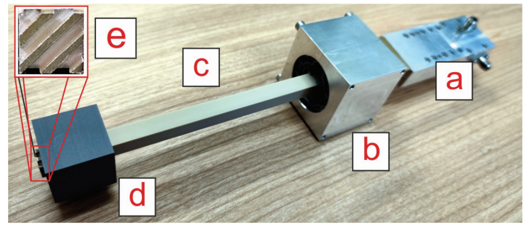

Figure 2: Photograph of the sensor setup indicating: a) OMT, b) corrugated DWG feed, c) rectangular DWG, d) MUT, and e) transpolarizing reflector.

setup. The transpolarizing reflector was realized by metallic, λ/4-deep gratings, orientated 45° to the propagation mode's electrical field direction.

III. RESULTS

The illustrated sensor operates in K-band and is capable to measure permittivities in the range of 1< $\varepsilon_{r,e}$ < 3. Test measurements were recorded by means of a calibrated VNA and 3D-printed test objects with different permittivities. Consequently, the S11-parameter illustrates

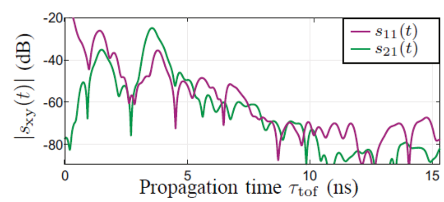

Figure 3: Measured co- and cross-polarized signals in time domain for an MUT permittivity of εr,e = 2.48.

the direct reflection signal, which contains all disturbing reflections, while the S21-parameter represents the pseudo-transmission signal. Fig. 3 shows that the pseudo-transmission design is successfully realized as feed-side reflections are attenuated by more than 15 dB compared to S11. Fig.4 reveals that the fundamental dependency between surrounding permittivity and increasing group velocity was proven. Moreover, the proposed setup is applicable for permittivity measurements as the obtained permittivities have an error of only 0.4%.

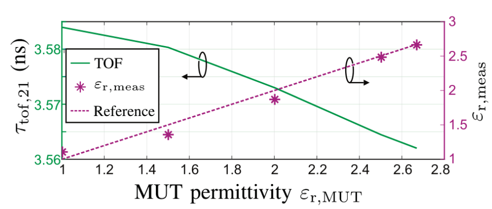

Figure 4: Measured propagation times and derived, MUT permittivities compared to the ideal MUT permittivities.

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