Confinement and Losses of THz Planar Goubau Lines Fabricated on a Thin Silicon Substrate

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***Abstract*— Low loss broad band transmission lines are of great interest for terahertz applications. To overcome high losses, Planar Goubau Lines (PGL) have been designed and fabricated on high resistivity silicon substrate. The measured loss level is typically 1dB/mm around 250GHz. The transitions are also extremely efficient for CPW-to-PGL conversion. The loss level depends on certain parameters such as length and width of the rectangular cross section or the thickness of the silicon substrate. The confinement of the electromagnetic wave will be also discussed particularly for different values of the strip's width.**

I. Introduction And Background

Transmission of Terahertz (THz) waves is a growing area of research due to the increased availability of THz sources. Developing low loss broad band transmission lines is especially important for low power THz spectroscopy and imaging [1]. These applications require low-loss transmission lines to preserve the purity of the transmission mode. The losses in these lines occur due to ohmic and dielectric losses in the fundamental mode. Numbers of approaches have been served to design terahertz transmission lines with low loss levels. The most common approach is the use of waveguides, in which the guide radius is much larger than the wavelength. Such waveguides can be corrugated metallic waveguides, dielectric waveguides or metallic waveguides with dielectric coatings. One of these lines is the Planar Goubau Line (PGL) which offers the possibility of tailoring their phase and impedance, what makes them suitable for terahertz device design. We have demonstrated an original way to excite properly the Goubau mode and to combine it with resonators like Split Ring Resonators (SRR) [2]. In this paper, we report an investigation at the sub-terahertz domain of PGL fabricated with different length and width of the rectangular cross-section.

II. Planar Goubau Lines on Silicon substrate

The design of our PGL is shown in Fig 1(A). The PGL structure was previously discussed in detail elsewhere. We have designed our CPW in order to carry out the measurements in the sub-terahertz band. Herein, the aim of this work is to develop low loss band transmission lines at the sub terahertz frequencies. To this purpose, different simulation and experimental studies have been achieved to demonstrate the influence of the length and width of the PGL's response. An example of the field distribution around the PGL is given on Fig. 1 (B). The investigated PG-line is 1-mm-long with different width rectangular cross-section signal conductor made from Ti/Au (50/450 nm). The considered widths are 1, 5, 10 and 20 µm. We have also fabricated and characterized longer lines with other parameters as well. The PGLs are simulated using the software MWS-CST and they have been fabricated using E-beam lithography technique ensuring a very accurate fabrication.

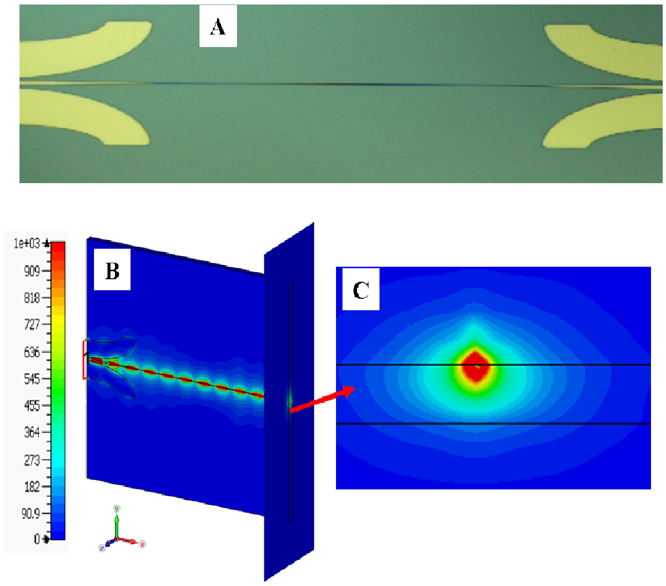

Figure 1 (A): PGL structure fabricated on Si-High Resistivity substrate with W_G=20 µm, (B) and (C): H-field views at f=250GHz obtained with MWS-CST.

These PGL were fabricated on high resistivity silicon with thickness of 380µm. Before any characterization, the sample has been thinned down to 70µm thickness to avoid substrate modes as identified in our earlier work. The experimental results are shown in Fig.1 (B). We can observe the difference in transmission between the different PGLs. The best insertion loss has been obtained for a PGL having a width w_G=20 µm. In that case, the total loss is -3 dB at 250GHz for a back-to-back topology. One can notice the insertion loss in the PGL increases dramatically with the decreasing in the width of line rectangular cross-section. Further improvements could be controlled in the PGL response by varying their rectangular cross section width, length or the thickness of the Si substrate.

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When we reduce the width of the strip, the confinement becomes higher but the losses are also increasing. The electromagnetic field distribution will be presented during the conference and we will also present intensive simulations and measurements on corrugated PGLs up to the highest frequencies with on probe measurements as demonstrated in [3-4] up to 750GHz and beyond.

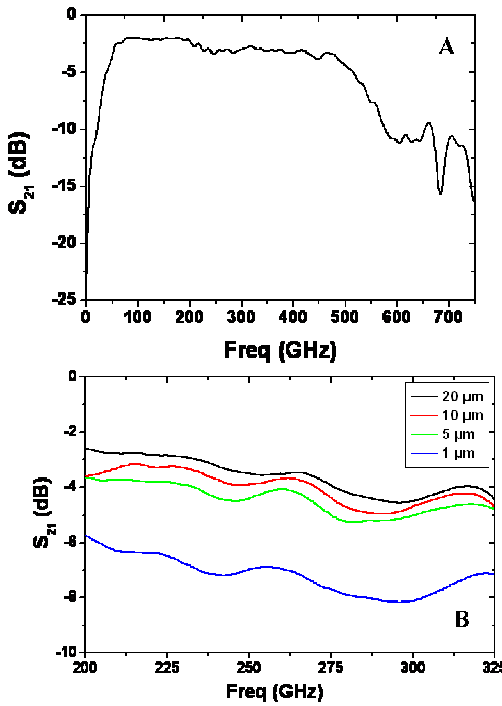

Figure 2 (A) Simulated spectra of PGL fabricated on Si-HR substrate with W_G=5 µm calculated using the software MWS-CST, (B): Measurements of the transmission parameter of PGL structures as function of its width.

On the figure 2, we have plotted the simulated transmission coefficient up to 750GHz and a zoom on the measurements performed in the J-band (220-325GHz). We can notice the appearance of parasitic substrate modes above 500GHz. This is explained by the high permittivity of Silicon which becomes quite fragile for thicknesses below 100µm. As the fields are highly confined around the central strip, we have also used PGL on this HR-Si substrate for microscopy applications. THz microscopy is one of the practical applications of these structures. In THz imaging techniques, a tip is also needed for reflectometry measurements in time domain as proposed by M. Nagel et al. [5]. A second interesting application is their use for different kind of filters: reject band [6] or pass-band filters with a good coupling between the PGL and resonators [7].

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