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A Capacitive-Gap Coupled Terahertz Planar-Goubau-Line Power Divider

Juan Cabello-Sánchez, *Member, IEEE,* Vladimir Drakinskiy, Jan Stake, *Senior Member, IEEE,* Helena Rodilla, *Senior Member, IEEE*

***Abstract*—The planar Goubau line is a single-conductor waveguide with a low attenuation constant at terahertz frequencies compared to other planar waveguides. However, its single-conductor nature complicates the design of circuit elements compared to multi-conductor waveguides, especially when impedance transformation is needed, like in the case of power dividers. In this paper, we present a power divider for a planar Goubau line based on capacitive-gap coupled lines, providing a matched input port. A 900-GHz equal power divider was fabricated on a suspended silicon membrane and was characterized with a Vector Network Analyzer and terahertz probes between 0.5 THz and 1.1 THz. Simulations and measurements are in good agreement, the measured input return loss is lower than 15dB at the design frequency, and the average coupler loss is estimated to be lower than 1 dB when de-embedding the feeding lines.**

***Index Terms*—On-wafer measurements, planar Goubau lines, power dividers, scattering parameters, silicon membrane, splitters, terahertz, vector network analyzers (VNA)**

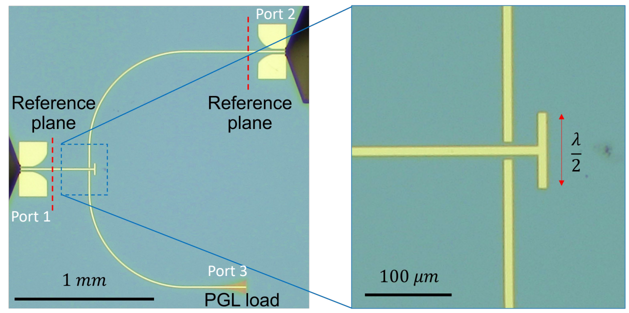

Fig. 1. Micrograph of the fabricated power divider taken while measured with ground-signal-ground probes. The reference planes for the calibration are shown in the red dashed lines. A PGL load terminates port three to avoid reflections back into the circuit and allows accurate S-parameter measurements. The inset shows the power divider's junction.

I. Introduction

The planar Goubau line (PGL) is a single-conductor planar waveguide that can propagate a surface wave with a quasi-TM mode (hybrid EH mode). The displacement currents surrounding its metal strip act as return currents [1], reducing ohmic losses compared to conventional multi-conductor planar waveguides. Moreover, radiation losses can also be minimized by the use of electrically-thin substrates, becoming a low-loss planar waveguide for terahertz frequencies, with a demonstrated attenuation coefficient of 0.32 Np/mm at 1 THz [2]. The disadvantage of having a single conductor is a mode that is less bound to the metal strip, and the associated challenges of designing circuit elements without a ground plane, like the limitations to modify the impedance. Despite the challenges, several components have been proposed for PGL like antennas [3], [4], resonators [5]–[7], filters [8], or impedance-matched loads [9]–[12].

Power dividers are widely used components in electronics to distribute and combine signals for various applications [13]. For PGL, some splitters have been proposed based on the Wilkinson [14] power divider design [9], [10] or on a split tee junction [11]. An ideal simple split-tee power divider is lossless and reciprocal, so it cannot be matched at all ports without impedance transformation. In the case of a PGL-based transformer, this is a major limitation, as controlling the characteristic impedance over a wide range is very limited. The same limitation applies to uneven power splits [15], or Gysel power dividers [16]. On the other hand, resistive splitters and Wilkinson dividers require lumped resistors, which are hard to realize at terahertz frequencies [17].

Here, we propose and demonstrate a THz PGL power divider centered at 0.9 THz based on capacitive-gap coupled lines [18] placed at an enhanced electric field produced by the standing wave generated by a short-circuit [19] located at the end of the input line, see Fig. 1. We describe the concept, design, fabrication, and measurements of the capacitive-gap coupled power divider.

II. Method

The proposed power divider is based on two output lines capacitively coupled to an input line tuned with an inductive short-circuit stub to provide an input match at the center frequency, see Fig. 1. In the case of PGL, the short-circuit can be provided by two balanced open quarter-wave stubs, forming a T-shaped termination with a span of $\lambda/2$ at the center frequency [19]. A non-terminated PGL produces a non-perfect open, benefiting the short-circuit from a balance configuration. The short-circuit at the end of the input line produces a standing wave, and the energy is then capacitive-gap coupled

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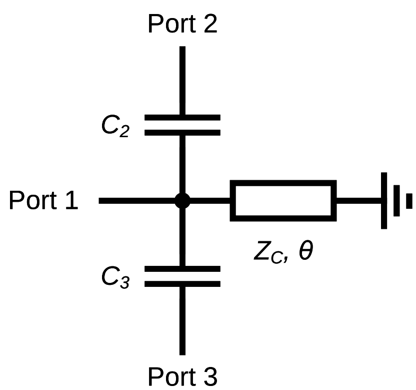


Fig. 2. Circuit topology of the proposed power divider.

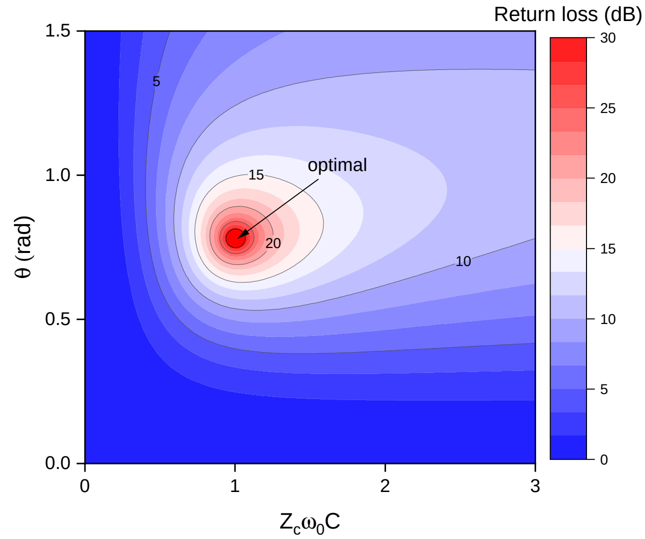


Fig. 3. Input return loss as a function of θ and $Z_c\omega_o C$ for an even 3-dB power spliter. The optimal point with 6-dB isolation and 6-dB output return loss is found at $\theta = 45°$ and $Z_c\omega_o C = 1$.

into the output lines at a distance where the field is maximum. In this section, the ideal properties of the capacitively-gap coupled power divider and the implementation of an equal two-way power splitter at 0.9 THz are described.

A. Circuit and Analysis of Performance

The proposed reciprocal three-port network can be analyzed using the simplified circuit topology shown in Fig. 2, where losses are neglected and the short-circuit produced by the balance stubs is replaced with a ground. A condition for a perfect input match, $S_{11} = 0$, can be derived by analyzing the input admittance of the shunt-connected output lines and the short-circuited stub. For arbitrary output power division ratios, the perfect input match conditions are:

$$Z_c\omega_o\sqrt{C_2C_3} = 1 \tag{1a}$$

$$\tan\theta = \frac{C_2 + C_3}{2\sqrt{C_2C_3}} \tag{1b}$$

where Z_c is the characteristic impedance of the transmission lines, ω_o is the center frequency, and C_2 and C_3 are the coupling capacitors. The power division between ports 2 and 3, K, is then:

$$K = \frac{P_2}{P_3} = \frac{C_2}{C_3}. \tag{2}$$

For an even 3-dB power split, it follows that $Z_c\omega_o C = 1$ and $\theta = 45°$ ($\lambda/8$-stub) at the center frequency, being $C = C_2 = C_3$, see Fig. 3. In this case, the complete S-matrix of the lossless, three-port, capacitive-gap coupled power divider is:

$$S = \frac{1}{2}\begin{pmatrix} 0 & 1+j & 1+j \\ 1+j & -j & j \\ 1+j & j & -j \end{pmatrix}. \tag{3}$$

Compared to the conventional split-tee power divider, the advantage is a perfect input match at the center frequency using lines with the same characteristic impedance. Theoretically, the proposed divider exhibits a 6-dB isolation and 6-dB output return loss.

B. Design of a 0.9-THz equal power splitter

An equal power PGL splitter centered at 0.9 THz was designed. The PGL power divider was designed using a 350-nm thick gold strip on a 10 μm thick high-resistivity suspended silicon membrane ($\epsilon_r = 11.7$ and $\tan\delta = 1.7 \cdot 10^{-5}$ [20]). The electrically-thin suspended membrane minimizes radiation loss, as it lowers the phase constant of the PGL propagation mode compared to other modes in the substrate [21]. Full-wave electromagnetic simulations were run in CST Microwave Suite using the time-domain solver. The materials—gold and high-resistivity silicon—were modelled with both dielectric and ohmic losses. The frequency dependency [22] of the thin-metal conductivity was neglected [23], and a constant conductivity of $\sigma = 4.1 \times 10^7$ S/m was assumed. To excite the PGL, we used square ports with sides equal to a wavelength at the lowest frequency, 0.4 THz.

The PGL was designed with a width of 10 μm. The distance from the short to the output lines was optimized to 30μm, avoiding coupling between the output lines and the balanced stubs that create the virtual ground. The gap between the input and output PGLs was selected to maximize coupling in the output ports and had a value of 5μm. It must be noted that a too-short gap would short-circuit the lines. This design corresponds to an electrical length of around $\theta = 60°$ and an estimated $Z_c\omega_o C$ of 1.2 assuming $Z_c \simeq 70\Omega$ at 0.9 THz and $C \simeq 3$ fF, both from [8] and assuming a linear relationship between the capacitance and the PGL width.

Fig. 4 shows the simulated electric-field intensity of the proposed capacitive-gap coupled divider at the center frequency, 0.9 THz. The short circuit at the end of the input line produces a standing wave with a maximum at the output lines. At this maximum, the field is capacitive-gap coupled into the output lines.

The proposed design was compared to a conventional Tee splitter with 120° between the output lines. For the compari-

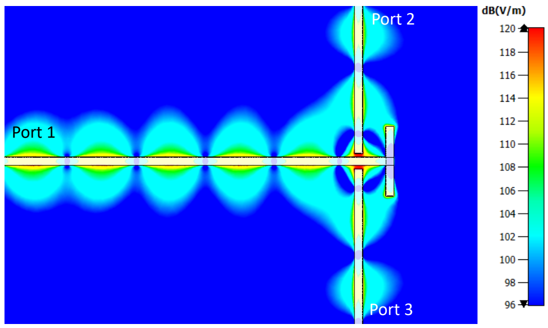


Fig. 4. Simulated electric-field intensity of the proposed design at the center frequency, 0.9 THz, where the short circuit at the end of the input line produces a standing wave with a maximum at the output lines.

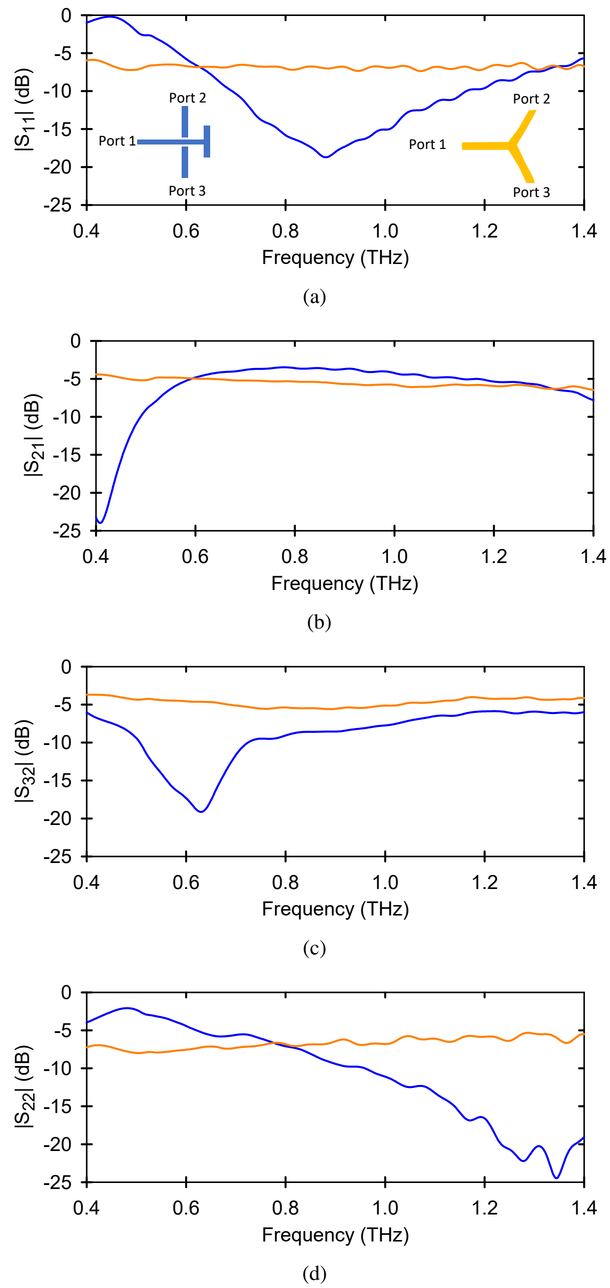


Fig. 5. Simulated S-parameters of the proposed power divider (blue continuous lines) compared to a 120° Tee splitter (orange continuous lines) both with 200μm length between input and output ports. Notice that the inset schematic representations for the legend are not in scale. Because of symmetry $S_{31} = S_{21}$, $S_{23} = S_{32}$ and $S_{33} = S_{22}$. The proposed power divider has lower input-port reflections, higher transmission, and higher isolation between output ports.

son, both the proposed capacitive-gap coupled power divider and the tee, had the same length between ports, 1mm, which was de-embedded [24] to a remaining length of 200 μm. Fig. 5 shows the simulated S-parameter results, showing that around the design frequency, the proposed divider has lower input-port reflections, higher transmission to output ports, and better isolation between ports than the tee power divider. The S_{11} and S_{21} of the proposed capacitive-gap coupled power divider deteriorate at frequencies far from the center frequency, as expected from a design based on electrical dimensions. As can be observed in Fig. 5c, in the proposed design, the isolation between ports has a minimum value below the design frequency, which according to simulations, is due to destructive interference caused between the output line and the opposite side of the short-circuit tee.

To provide lateral access for the probes to perform the measurements, the final power divider was designed with curved output lines, see Fig. 1. The total length between the input and output ports was 2.5 mm. The curved lines were designed with a sufficiently-large radius of curvature, 0.7 mm (around 2λ at 0.5 THz, which is the lowest measured frequency), to avoid leakage. The input port, and one of the output ports of the power divider, port 2, were terminated in a coplanar waveguide transition to be measured with Ground-Signal-Ground probes. The other output port, number 3, was terminated in a matched load, which provides a good match above 0.6 THz [12], to avoid reflections during S-parameter measurements.

C. Fabrication and measurement set-up

The power divider was fabricated on a 10-μm silicon suspended membrane. A 10/350-nm layer of Ti/Au was deposited and patterned using electron-beam lithography on a silicon-on-insulator wafer formed by an undoped high-resistivity (>10 kΩ cm) 10-μm device layer, 1-μm buried oxide layer and 400-μm thick silicon handle wafer. The suspended membrane was produced by etching the silicon from the backside of the chip under the area of the device using a Bosch process, leaving the rest of the substrate as mechanical support. More detailed information on the fabrication process can be found in [8].

The scattering parameters of the power divider were measured between 0.5 THz and 1.1 THz using a vector network analyzer (Keysight N5242A) with frequency extenders (VDI WR1.5VNAX and WR1.0VNAX) and DMPI T-Wave ground-signal-ground probes [25], [26]. Fig. 6 shows a photograph of the experimental setup. The intermediate-frequency bandwidth was set to 100 Hz. The measurements were calibrated using dedicated multi-line Thru-Reflect-Line standards for PGL [19] fabricated on the same chip. Calibrating allows setting the

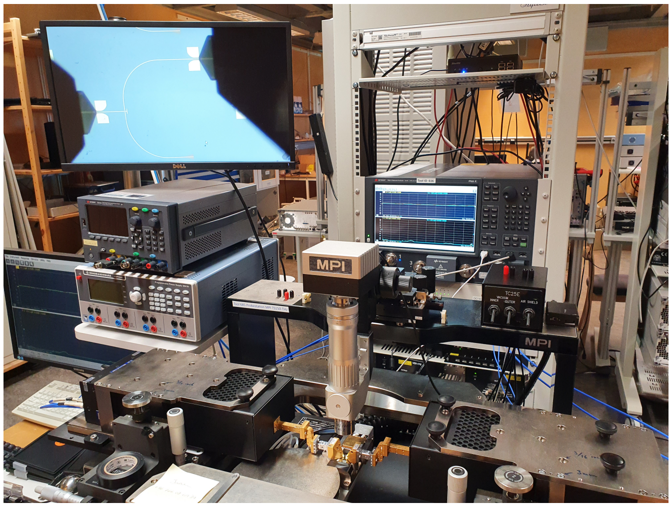


Fig. 6. Photograph of the measurement setup based on a probe station, a vector network analyzer, frequency extenders and T-Wave ground-signal-ground probes.

reference plane in the PGL (see Fig. 1) and to de-embed [24] the coplanar waveguide transition. The calibration plane was set 300μm inside the PGL, leaving a total length between the input and output calibration planes of 1.9 mm. The lines used for calibration have an electrical length of $\lambda/4$, $3\lambda/4$, and $11\lambda/4$ at 0.9 THz, with an effective refractive index of $n_e = 1.88$. The chip was placed on top of a ceramic chuck during measurements. The suspended 10-μm silicon membrane of the chip has enough mechanical strength to support the pressure from the measurement probes.

III. Results

A micrograph and a scanning-electron-microscope photograph of the splitter fabricated on a high-resistivity silicon membrane can be seen in Fig. 1 and Fig. 7, respectively.

Fig. 8 shows the measured coupling factor, S_{21}, input match, S_{11}, output match, S_{22}, and forward efficiency factor, $|S_{11}|^2 + 2|S_{21}|^2$, of the fabricated power divider compared to simulation results between 0.5 THz and 1.1 THz. The measurements

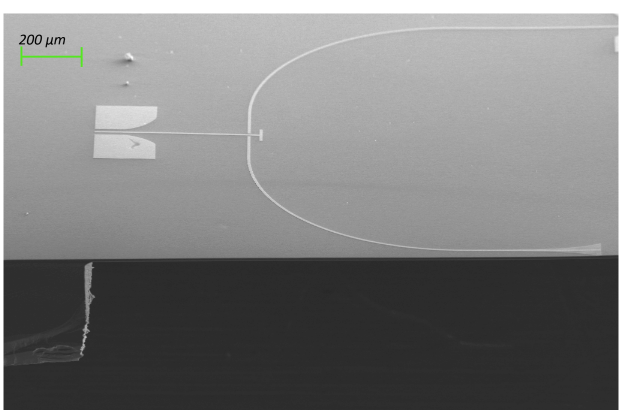
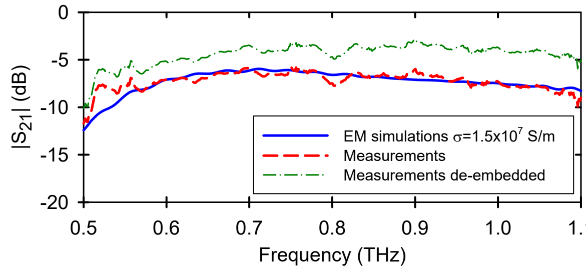
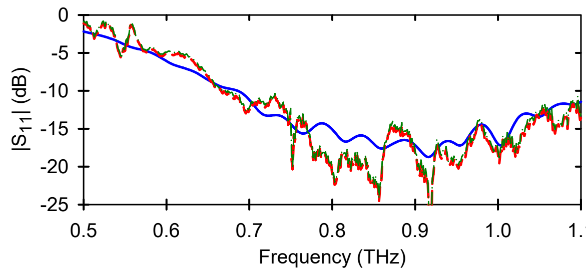


Fig. 7. Scanning-electron-microscope image of the capacitive-gap coupled power divider fabricated on a high-resistivity silicon membrane.



(a)



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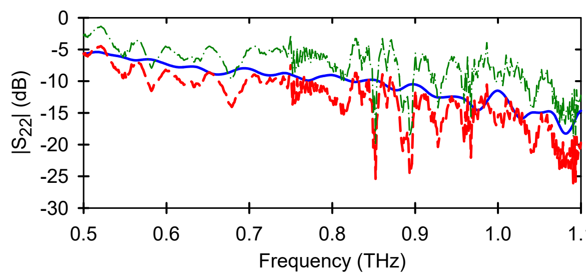
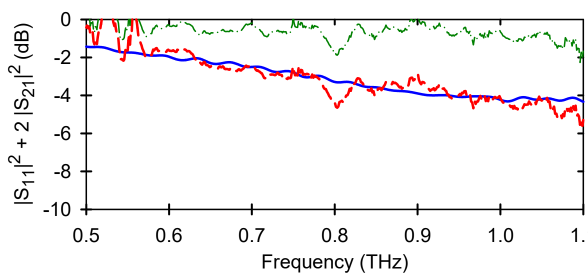


(c)



(d)

Fig. 8. Scattering parameters of the PGL power divider. Measured (red dashed line), simulated (blue continuous line) and de-embeded experimental results to a total length of 200 μm (green discontinuous line). a) Coupling factor, S_{21}, b) input match, S_{11}, (c) output match, S_{22}, and d) forward efficiency factor, $|S_{11}|^2 + 2|S_{21}|^2$.

and simulations show a good agreement when the conductor loss was increased by reducing the metal conductivity to $\sigma = 1.5 \times 10^7$ S/m in the simulations. A lower effective metal conductivity is likely attributed to surface and edge roughness. It must be noticed that the performance of the load deteriorates under 0.6 THz [12], affecting the measurements between 500 - 580 GHz. The input reflections are lower than 14 dB around the design frequency, 900 GHz. The measured transmission, $|S_{21}|$, around the design frequency, is around -7 dB, including the feeding-line losses. However, if we de-embed the PGL losses to a total length of 200 μm, the loss of the power divider is approximately 1 dB between 0.7 THz and 1.1 THz (see the green discontinuous line in Fig. 8a). The loss of a simulated PGL obtained using the reduced metal strip conductivity of 1.5×10^7 S/m (0.9 dB/mm at 0.5 THz and 2.2 dB/mm at 1.1 THz) was used for de-embedding the experimental results.

IV. Conclusion

One of the design challenges of the PGL is the limited freedom for impedance modification, needed, for example, to design power dividers. To overcome this challenge, we presented a PGL power divider centered at 0.9 THz based on output lines capacitive-gap coupled to the input line through the standing wave produced by a short-circuit at the end of the input line. The power divider was fabricated on a suspended silicon membrane and was characterized from 0.5 THz to 1.1 THz. The measured coupling was around 7 dB. However, if de-embedding the attenuation of the PGL feeds, the estimated loss of the power divider was around 1 dB between 0.7 THz and 1 THz. The presented topology, while demonstrated for PGL, could also be implemented in other types of transmission lines for input-match ac-coupled ports.

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References

[1] B. Vaughn and D. Peroulis, "An updated applied formulation for the Goubau transmission line," *Journal of Applied Physics*, vol. 126, no. 19, 2019, doi: 10.1063/1.5125141.

[2] J. Cabello-Sánchez, H. Rodilla, V. Drakinskiy, and J. Stake, "Transmission Loss in Coplanar Waveguide and Planar Goubau Line between 0.75 THz and 1.1 THz," in *2018 43rd International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz)*, Nagoya, 2018, pp. 1–2, doi: 10.1109/IRMMW-THz.2018.8510326.

[3] D. Sanchez-Escuderos, M. Ferrando-Bataller, J. I. Herranz, and M. Cabedo-Fabres, "Periodic Leaky-wave Antenna on Planar Goubau Line at Millimeter-wave Frequencies," *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 1006–1009, 2013, doi: 10.1109/LAWP.2013.2278035.

[4] Q. Le Zhang, X. G. Shi, B. J. Chen, K. F. Chan, K. M. Shum, and C. H. Chan, "325 GHz to 500 GHz Single-Layer Planar Goubau-Line Antenna with Endfire Radiation Based on Substrate Mode," *IEEE Transactions on Antennas and Propagation*, no. c, pp. 1–1, 2022, doi: 10.1109/tap.2022.3164180.

[5] W. C. Chen, J. J. Mock, D. R. Smith, D. R. Akalin, and W. J. Padilla, "Controlling Gigahertz and Terahertz Surface ElectromagneticWaves with Metamaterial Resonators," *Physical Review X*, vol. 1, no. 2, p. 021016, 12 2011, doi: 10.1103/PhysRevX.1.021016.

[6] A. K. Horestani, W. Withayachumnankul, A. Chahadih, A. Ghaddar, M. Zehar, D. Abbott, C. Fumeaux, and T. Akalin, "Metamaterial-Inspired Bandpass Filters for Terahertz Surface Waves on Goubau Lines," *IEEE Transactions on Terahertz Science and Technology*, vol. 3, no. 6, pp. 851–858, 2013, doi: 10.1109/TTHZ.2013.2285556.

[7] S. J. Park, R. Tucker, E. Pickwell-macpherson, and J. E. Cunningham, "Design of a Split Ring Resonator Integrated with On-Chip Terahertz Waveguides for Colon Cancer Detection," *Advanced Theory and Simulations*, p. 2200313, 2022, doi: 10.1002/adts.202200313.

[8] J. Cabello-Sanchez, V. Drakinskiy, J. Stake, and H. Rodilla, "Capacitively-Coupled Resonators for Terahertz Planar-Goubau-Line Filters," *IEEE Transactions on Terahertz Science and Technology*, vol. 13, no. 1, pp. 58–66, 2023, doi: 10.1109/tthz.2022.3220599.

[9] Y. Xu, C. Nerguizian, and R. Bosisio, "Wideband planar Goubau line integrated circuit components at millimetre waves," *IET Microwaves, Antennas & Propagation*, vol. 5, no. 8, pp. 882–885, 2011, doi: 10.1049/iet-map.2010.0025.

[10] A. Treizebre, S. Laurette, Y. Xu, R. B. P. I. …, and U. 2012, "THz power divider circuits on planar Goubau lines (PGLs)," *Progress In Electromagnetics Research*, vol. 26, no. November 2011, pp. 219–228, 2012, doi: 10.2528/PIERC11112409.

[11] Q. Le Zhang, B. J. Chen, K. M. Shum, and C. H. Chan, "Miniaturized Spoof Surface Plasmon Polaritons Load for Planar Terahertz Circuit Application on Thick Substrate," *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 69, no. 3, pp. 1049–1053, 2022, doi: 10.1109/TCSII.2021.3121068.

[12] J. Cabello-Sanchez, V. Drakinskiy, J. Stake, and H. Rodilla, "A Corrugated Planar-Goubau-Line Termination for Terahertz Waves," *IEEE Microwave and Wireless Technology Letters*, vol. 33, no. 6, pp. 643–646, 2023, doi: 10.1109/LMWT.2023.3239984.

[13] Y. Wu, L. Jiao, Z. Zhuang, and Y. Liu, "The art of power dividing: A review for state-of-the-art planar power dividers," *China Communications*, vol. 14, no. 5, pp. 1–16, 2017, doi: 10.1109/CC.2017.7942190.

[14] E. J. Wilkinson, "An N-Way Hybrid Power Divider," *IEEE Transactions on Microwave Theory and Techniques*, vol. 8, no. 1, pp. 116–118, 1960, doi: 10.1109/TMTT.1960.1124668.

[15] L. I. Parad and R. L. Moynihak, "Split-Tee Power Divider," *IEEE Transactions on Microwave Theory and Techniques*, vol. 13, no. 1, pp. 91–95, 1965, doi: 10.1109/TMTT.1965.1125934.

[16] U. Gysel, "A New N-Way Power Divider/Combiner Suitable for High-Power Applications," in *1975 IEEE-MTT-S International Microwave Symposium*, 1975, pp. 116–118, doi: 10.1109/mwsym.1975.1123301.

[17] P. Siegel, "Terahertz Technology," *IEEE Transactions on Microwave Theory and Techniques*, vol. 50, no. 3, pp. 910–928, 2002, doi: 10.1109/22.989974.

[18] J. Cabello-Sánchez, V. Drakinskiy, J. Stake, and H. Rodilla, "Terahertz Planar Goubau Line Components on Thin Suspended Silicon Substrate," in *2022 47th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz)*, Delft, 2022, pp. 1–2, doi: 10.1109/IRMMW-THz50927.2022.9896069.

[19] J. Cabello-Sánchez, H. Rodilla, V. Drakinskiy, and J. Stake, "Multiline TRL Calibration Standards for S-parameter Measurement of Planar Goubau Lines from 0.75 THz to 1.1 THz," in *2018 IEEE/MTT-S International Microwave Symposium - IMS*, Philadelphia, PA, USA, 2018, pp. 879–882, doi: 10.1109/MWSYM.2018.8439138.

[20] J. Dai, J. Zhang, W. Zhang, and D. Grischkowsky, "Terahertz time-domain spectroscopy characterization of the far-infrared absorption and index of refraction of high-resistivity, float-zone silicon," *Journal of the Optical Society of America B*, vol. 21, no. 7, p. 1379, 2004, doi: 10.1364/JOSAB.21.001379.

[21] D. B. Rutledge, S. E. Schwarz, and A. T. Adams, "Infrared and submillimetre antennas," *Infrared Physics*, vol. 18, no. 5-6, pp. 713–729, 1978, doi: 10.1016/0020-0891(78)90094-5.

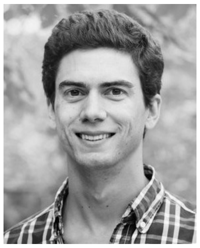
[22] M. Dressel and M. Scheffler, "Verifying the Drude response," *Annalen der Physik*, vol. 518, no. 7-8, pp. 535–544, 2006, doi: 10.1002/andp.200651807-810.

[23] N. Laman and D. Grischkowsky, "Terahertz conductivity of thin metal films," *Applied Physics Letters*, vol. 93, no. 5, p. 51105, 2008, doi: 10.1063/1.2968308.

[24] R. Bauer and P. Penfield, "De-embedding and unterminating," *IEEE Transactions on Microwave Theory and Techniques*, vol. 22, no. 3, pp. 282–288, 1974, doi: 10.1109/TMTT.1974.1128212.

[25] T. J. Reck, L. Chen, C. Zhang, A. Arsenovic, C. Groppi, A. Lichtenberger, R. M. Weikle, and N. S. Barker, "Micromachined Probes for Submillimeter-wave On-wafer Measurements - Part II: RF Design and Characterization," *IEEE Transactions on Terahertz Science and Technology*, vol. 1, no. 2, pp. 357–363, 2011, doi: 10.1109/TTHZ.2011.2165020.

[26] M. F. Bauwens, N. Alijabbari, A. W. Lichtenberger, N. S. Barker, and R. M. Weikle, "A 1.1 THz micromachined on-wafer probe," in *2014 IEEE MTT-S International Microwave Symposium (IMS2014)*, Tampa, FL, 2014, pp. 1–4, doi: 10.1109/MWSYM.2014.6848607.



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