Uniplanar Broadband Balun Design for Sub-THz Antenna On-Wafer Characterization

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***Abstract*—A uniplanar broadband balun is designed on** SiO_2/Si **substrate at sub-THz through this work. The structure is proposed for CPW to CPS transition establishing efficient on-wafer characterization environment for balanced antenna structures over the D-band. The balun is composed of a CPW linearly tapered into CPS and a broadband open termination of one side ground of CPW. The designed structure is analyzed and optimized through HFSS simulation. The designed model showed a bandwidth ratio of 55% at 140 GHz with insertion and return loss of 1 dB and 17 dB respectively. The results of the back-to-back structure are also presented.**

***Keywords*—THz antenna, broadband balun, radial stub, CPW-CPS.**

I. Introduction

Recently, the interest in terahertz (THz) band, defined as a couple of decades of spectrum centered at 1 THz, has exponentially increased in the research community. It has been of ultimate promise for ultra-high data rate throughput and wide bandwidth wireless communication systems as well as a wide range of high-resolution imaging potentially applied in various fields [1]. In exploring THz band, a wide range of antenna structures have been employed such as leaky wave, folded dipole and bow-tie antenna [2]–[4]. To establish new frontiers in the field of THz devices and systems, a very well THz antennas characterization environment is demanding. Wide bandwidth response of such environment is essential to sufficiently cover the band of interest. Since the most commonly used antennas are balanced structures, a broadband balun transition structure is required to enable efficient interfacing to the unbalanced measurement equipments and attain both impedance and field match. Besides, uniplanar design is required to avoid antenna performance degradation caused by intervention on the substrate at such band.

Different uniplanar transitions have been addressed in the literature at microwave band [5]–[7]. Among the various structures presented in the literature, the radial slot based balun has a broadband, less power loss and compact in size. Accordingly, broadband radial slot-line stub based balun with linearly tapered section is used for CPW-CPS transition through this work. The parameters of the designed structure as well as its performance analysis are carried out using the full-wave HFSS electromagnetic simulation tool. This paper will first describe the proposed structure in detail and list down its proper designed values. The performance of the balun will be then presented through the simulation's results. Finally, a short discussion will brief in a conclusion the advantages and limitations of the model.

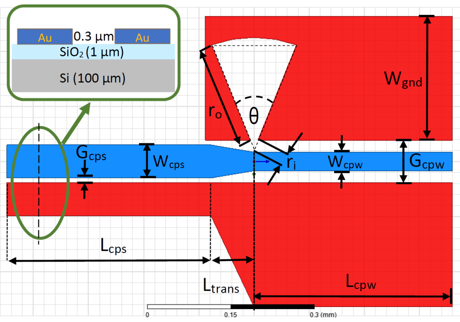

Fig. 1. Detailed illustration of the proposed balun with the set of design parameters and cross sectional view at the upper-left corner

II. Model Design

The proposed design through this work is defined through a 300-nm-thick Au layer on SiO_2/Si substrate for the operation over the D-band (110 to 170 GHz), as depicted in Fig. 1. The aspect ratio (slot/strip width) of the CPW as well as the CPS, are both designed to posses a characteristic impedance of 50 Ω. The length of both CPS and CPW sections are set to $\lambda/4$ through this work. The finite width of the ground plane of the CPW is set to be at least 2.5 times the width of the slot between grounds. A linearly tapered interface section of length L_{trans} is defined for a smooth transition between CPS and CPW. The gradual tapered transition serves to reduce the effect of discontinuity and attain the impedance match as well. The radial stub is slotted in the upper side ground plane of the CPW representing a wide-band open circuit termination of the slotted ground. Such termination of the upper ground serves to efficiently couple the EM field at the upper slot to the lower one. The radial slot is defined in terms of its inner and outer radii as well as its flare angle. The resonant radial frequency, ω_o, is given by:

$$\omega_o = \frac{c}{r_o\sqrt{\frac{\epsilon_{eff}}{2}\left[\ln\left(\frac{r_o}{r_i}\right) - 0.5\right]}} \quad (1)$$

TABLE I
DESIGNED STRUCTURE'S PARAMETERS FOR THE PROPOSED BALUN

Item	Parameter	Symbol	Value
Substrate	Permittivity Height	$\epsilon_{SiO_2}/\epsilon_{Si}$ t_{ox}/t_{sub}	4.0/11.7 1/100 µm
CPW	Slot/Conductor GND Width Section Length	G_{cpw}/W_{cpw} W_{gnd} L_{cpw}	77/34 µm 225 µm 450 µm
CPS	Slot/Conductor Section Length	G_{cps}/W_{cps} L_{cps}	5.2/66 µm 450 µm
Radial Stub	Radii Angle	r_o/r_i θ	189/36 µm 40 Deg
Taper	Length	L_{trans}	88.1 µm

where ϵ_{eff} is the effective dielectric constant, c is the velocity of light in free-space, r_o and r_i are the outer and inner radii of the stub respectively. r_o and r_i are initially set to be less than $\lambda/8$ and $r_o/10$ respectively.

III. Results and Discussion

The proposed balun design is simulated and optimized in HFSS for the operation at the D-band. The best optimized values of the design parameters are listed in table I. The results showing the simulated performance for a single-stage balun as well as its back-to-back configuration are both presented in Fig. 2 and 3. It worth to note that the back-to-back configuration includes a single CPS section (450 µm) at the middle. The designed balun exhibits a 3-dB passband of 78 GHz, corresponding to a bandwidth ratio of 55%, which sufficiently covers the full range of the D-band as shown in Fig. 2. An insertion loss of 1 dB is obtained at 140 GHz (the center frequency of the D-band). As depicted in Fig. 3, the balun is showing return loss levels exceeding 13 dB in the full range of the D-band, and having a return loss level of 16.5 dB at the center frequency. Through the presented figures, it is obvious that the back-to-back model follows the same behavior of the single-stage balun, while the added losses is anticipated due to the duplicated CPW and tapered sections.

IV. Conclusion

A uniplanar compact wide-band sub-THz balun is designed through this work. The designed balun has shown a broadband performance that sufficiently covers the full range of the D-band. The design unlocks the potential for on-wafer characterization and development of balanced THz antennas. Along with antenna measurements, the balun can also be used for the development of other balanced elements over this band. It worth to note that the results presented here have not considered the dispersion effect in materials at this band.

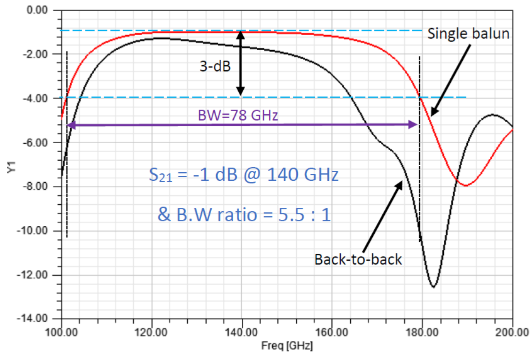

Fig. 2. Frequency response of the insertion loss for the designed balun only (red) and the back-to-back model (black)

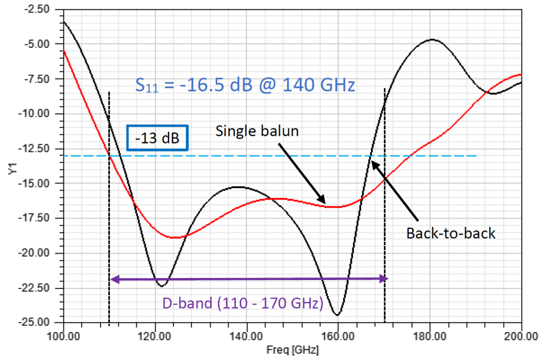

Fig. 3. Frequency response of the return loss for the designed balun only (red) and the back-to-back model (black)

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