Power Divider Design in the Silicon Photonic Integrated Substrate (SPIC) Technology with Purpose of the Signal Transmission Coefficient in the 5G Band Frequency

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ABSTRACT:
In research, the signal Power Divider (PD) has been designed with a photonic integrated substrate with the silicon substrate and benefits from MEMS technology in its geometry configuration in the microwave high-frequency bandwidth of 120 to 260 GHz with coverage of signal exchange with telecommunication bulk data in the fifth-generation protocol been done. The proposed has been designed micrometer dimensions with wide microwave bandwidth coverage in the division of bulk data signals, which indicates the use of this model in optical telecommunication devices. Also, it has been used by BCPD, TL, WPD, and PNPTL techniques to create a configuration with a simple geometry in the form of a U-shape and a T-shape connection, each of the branches is isolated in very small dimensions, and impedance matching and creates frequency balance in signal exchange and division; So it has been results obtained from it includes the improvement of the dispersion parameter and also causes its time delay function to have a lower value of the time delay function than the time derivability function to the frequency bandwidth in the sigma function in the differential order, which has been being around 4.3 (ns) in the range of 170GHz has been obtained in the value of -3.1 (dB), and the value of its transmission coefficient is also in the range of -3.0 to -4.98 (dB). The design has been our technique for improving the numerical values of the dispersion parameters and creating a configuration in the simplicity of its geometry in dimensions T=10um, L=315um, and W=400um. The application of the proposed has been used in creating a photonic substrate in signal transmission for high bandwidth microwave in the 5G telecommunication protocol, which is simulated in the ADS software.

KEYWORDS: Power Divider, MEMS, PIC, 5G-Microwave, Silicon.

1. INTRODUCTION

With the design of new circuits and the use of signal dividers and collectors in telecommunication circuits, the increasing need of telecommunication systems for signal dividers and collectors is fulfilled. Due to this, by creating a signal divider and collector platform in the receiver and transmitter circuits, we can perform signal divider and collector in different circuits and to be able to send signals with a suitable platform for dividing and collecting signals so that the amount of delay and noise is low. By creating a suitable substrate, the noise of the substrate can be minimized. It is also possible to design the signal divider and collector as a circuit element with admittance and impedance structure; But in the majority of signal divider and collector circuits are designed in passive mode and transistor signal switching in active mode, which are designed in different microwave frequency bands.

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2. TECHNICAL WORK PREPARATION

The proposed design is in the design of the passive signal splitter and collector model in the frequency bandwidth of 5 GHz high band microwave protocols which is simulated in the material under the silicon layer by considering pic and RF MEMS technologies by having several signal ports in the ads software. One of the users of this research is the application between the antenna and the telecommunication transmitter board, which is used in portable and stationary devices. Another use of it is to use it in the communication between the internal structure of signal amplifiers hampon circuits, which are designed in several layers, which are designed in the input part of the amplifier circuit from the signal divider bed and at its output from the signal collector bed. In the transmission of the signal from an input port to several separate branches to divide the signal power equally, and in collecting the input signals, separate branch paths are used to the output port. Time delay function or signal switching circuit is used to determine the signal division and addition function. So that the substrate with two functions is placed between the antenna and the circuit or between two blocks of the circuit and by determining the signal exchange in the specified time function, the frequency signal transmission is done.

2.1. Designing a signal splitter substrate with silicon substrate material in the field of photonics

The research conducted is about electrophotonics, which is carried out in the field of microwave circuits. Many applications of photonic devices and technologies for circuits of arbitrary microwave waveforms, with high processing speeds, use microwave circuits in the field of optoelectronics. This class of photonic applications for microwave engineering is known as microwave photonics. Extensive capabilities have enabled the realization of key functions that are either very complex or simply not possible in the microwave domain alone. Recently, this growing field has adopted integrated photonics technologies to develop microwave photonic systems with greater robustness as well as significant reductions in size, cost, weight, and energy consumption. In particular, silicon photonics technology is of great interest for this purpose because it offers tremendous possibilities for the integration of highly complex active and passive photonic devices, allowing seamless integration of MWP with high-speed silicon electronics [1].

2.2. The design of the signal splitter substrate with the aim of improving the return loss in the WIFI, LTE frequency band

In this research, we present the first experimental demonstration of a microwave photonic integrated circuit for analog active interference cancellation. This circuit is unique in its ability to operate in any radio frequency band from 400 MHz to 6 GHz while requiring no optical input or output. First, we examine the amount of interference cancellation that can be achieved over a wide range of operating frequencies. We show that the circuit can achieve close to -30 dB of interference cancellation in all available frequency division duplex local thermal balance bands and WIFI bands. Second, we examine aspects of integrated circuit control and determine how much amplitude and phase adjustability can be built into the implementation [2].

2.3. Designing a signal transmission substrate with the purpose of a low-pass filter in optical circuits

In this research, silicon-based photonic integration, there is a growing interest in the electronic circuit community to develop hybrid photonic electronic systems. However, photonic integrated circuit design tools using numerical methods are focused on solving Maxwell's equations. PIC system-level design tools recently use s-parameter modeling of optical components. However, detailed modeling of electronic driver and interface circuits is not supported on such platforms [3].

2.4. Design of wideband signal splitter on silicon substrate

A new method for near-hermetic packaging of integrated passive UWB devices based on multilayer liquid crystal polymer technology is presented in this research. The aim of this work is to develop an inexpensive and easy-to-fabricate method that can be used to encapsulate already designed devices without the need for redesign and operate up to 20 GHz. To achieve this goal, a coplanar waveguide-to-microstrip transmission is designed to connect the enclosed device with the external environment. This allows the device to be mounted to the PCB and also isolated [4].

2.5. Signal division substrate in creating integration with CMOS substrates

In this research, we are dealing with the design of the integration platform of photonics and electronics in the transceiver, the energy efficiency of broadband acceleration and a path for radical miniaturization has been facilitated. We present and implement a wafer-to-wafer integration method that combines electronic and photonic casting technologies. The motivation to integrate electronic and photonic systems into an aligned manufacturing process is long-standing, but it is now becoming a necessity with light-based detection and ranging subsystems envisioned for future data center technologies And high-density programmable neuromorphic photonics in the future of high-speed, high-density, low-energy electrical interconnects in transceivers also enable performance improvements through optical serialization advance equalization and drive voltage reduction. Photonic transmitters require accurate dc biasing and broadband impedance matching to ensure data integrity. Photonics and electronics chipsets, historically designed separately, have been implemented with biased tees and 50-ohm interfaces to facilitate interoperability and portable design, but with increasing speed in a limited energy envelope this is no longer attractive. Components must be placed closer together within the package towards a composite 3D assembly and ultimately on the same processed wafer.

3. APPENDIX

The proposed design is used in the integrated platform with the ability to use the passive signal splitter model in photonics and telecommunication circuits, which by using MEMS technology has caused the geometry of the proposed design to be designed in micrometer dimensions. The use of mems technology in the design of signal exchange platforms makes its configuration simple and its dimensions are very small. This causes the proposed model to be designed in a very small geometry and the efficiency of the circuit increases. In substrate models, the feature of integration is used to reduce signal transmission attenuation at the substrate level for dividing and exchanging telecommunication signals. By using OIC, MEMS technologies, this causes signal transmission to have the least delay and attenuation, and the results of its dispersion parameters are also improved. This is one of the important features in the design at high microwave frequencies. **Table 1** shows the values of the standard parameters in measuring the results of various signal splitter design technologies. Also, in **Table 2**, the specifications of the frequency bandwidth in the 5g protocol are shown.

Table 1. Values of standard parameters in measuring the results of various signal splitter design technologies.

Parameter	Value	Value of Range	Frequency Coverage	Device Passive/Active
S11 (dB)	Under (-0)	[-0 ~ -30]	All microwave frequency bands	ALL
S12 (dB)	Under (-30)	[-0 ~ -40]	All microwave frequency bands	ALL
S21 (dB)	-20 to 0	[-0 ~ -5]	All microwave frequency bands	ALL
S22 (dB)	Under (-0)	[-0 ~ -30]	All microwave frequency bands	ALL
Delay Time (ns)	[-,+]	1nS, [-60 ~ +60]	All microwave frequency bands	ALL
VSWR (s/v)	UP +0	[+0 ~ +80]	All microwave frequency bands	ALL
Isolation (dB)	Under (-5)	[-0 ~ -35]	All microwave frequency bands	ALL

Table 2. Specification of frequency bandwidth in 5g protocol.

Protocol	Frequency Channels	Frequency Bands	Application
5G, multi-bands	5	5	Device, Radars
STD, Down-Band. 1	**STD, Down-Band. 2**	**STD, Down-Band. 3**	**IEEE Legal**
3.0-50.0 GHz	50.0-100.0 GHz	100.0-250.0 GHz	RF, microwave, millimeter-wave

4. RESULTS AND DISCUSSION

In this article, the analysis and dissemination of the design process of the proposed divider has been discussed in order to improve the parametric quantities measured in the simulation. Due to the fact that the splitter design model is capable of three ports to connect to the antenna and the telecommunication transmitter and receiver system and between circuits, in its technical design structure, the splitter is used in the high frequency bandwidth of the microwave in the high frequency volume data range of navigation. Because of this proposed design of the relevant devices in the side band, you can easily exchange signals in telecommunication radars and 5g frequency bandwidth. This improves the coefficient of dispersion parameters and related quantities of this parameter in radars set in the frequency band adjacent to the standard band. This research has been devoted to presenting a new model of the divider structure with PIC technology with the aim of application in the industry of telecommunication radars and optical devices. The design of the mems divider is done with the purpose of exchanging the signal transmission in the high frequency band. The geometry of the proposed design is U-shaped, and its connection is made in T-shape, which is spread in the dimensions of micrometers in the propagation of electromagnetic waves in E-plane and H-plane on the substrate surface of its silicon rough layer and it is shown in figures 1 to 7. From the proposed design with the aim of reducing the dimensions of the model and improving the coefficient of dispersion parameters and reducing the time delay coefficient for the applications of microwave high frequency band radars in the exchange of bulk data over long distances in the 5g telecommunication protocol and optical telecommunication devices.

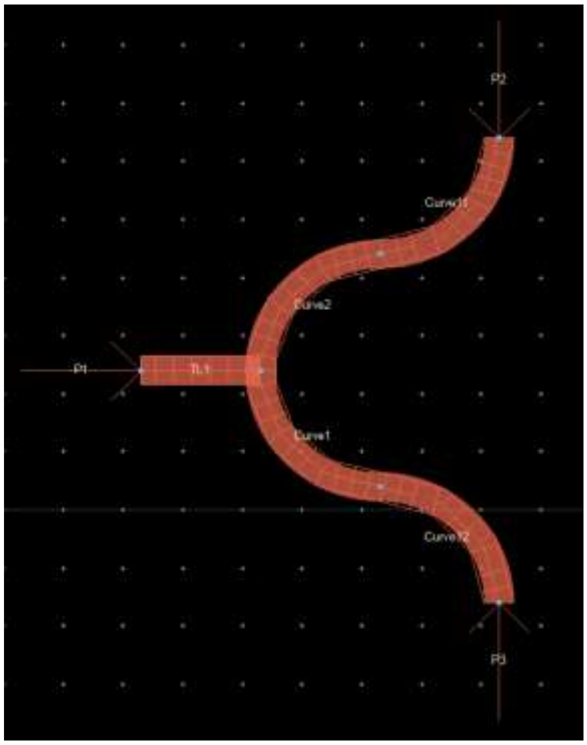


Fig. 1. Signal splitter schematic.

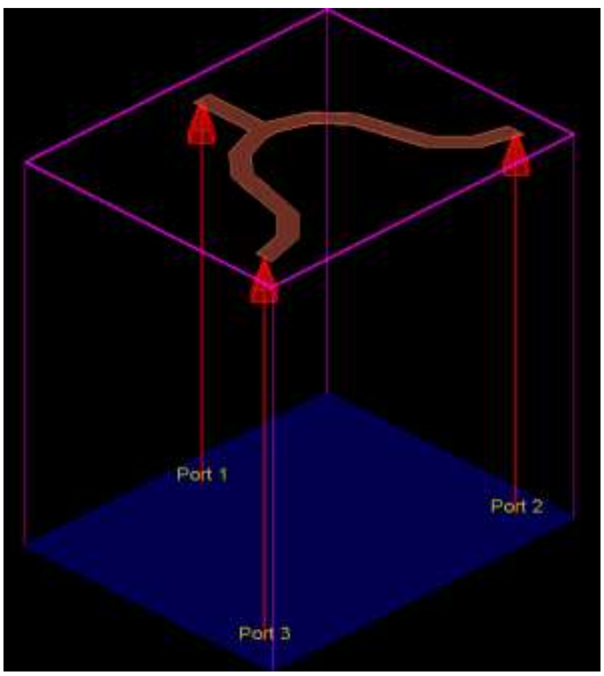
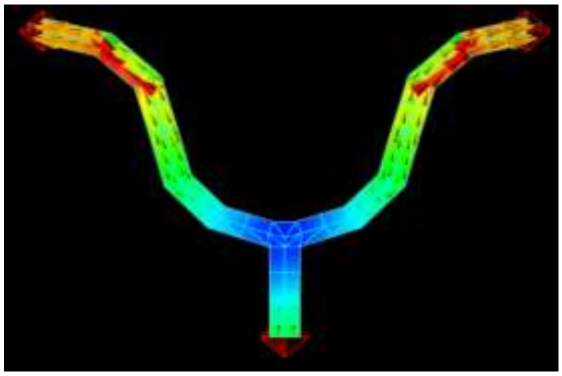
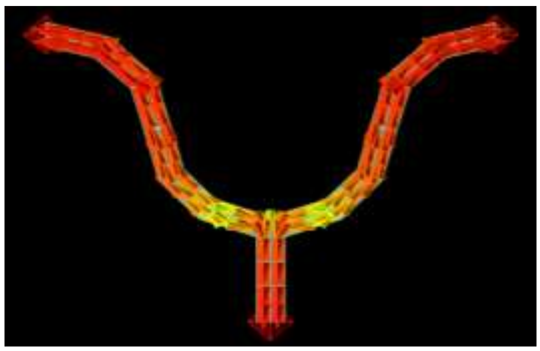


Fig. 2. 3D view of the proposed design

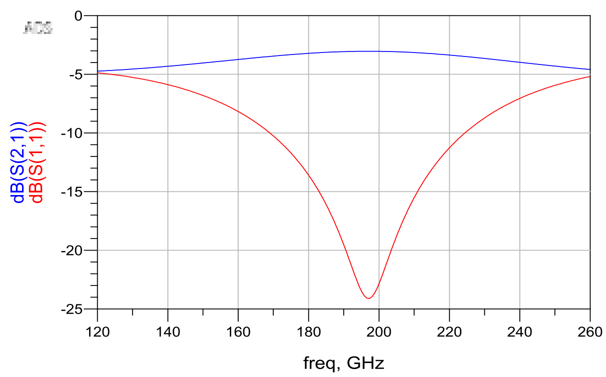


(a)



(b)

Fig. 3. (a) and (b) Signal transmission on the surface of the substrate in the form of convergence of electromagnetic waves.



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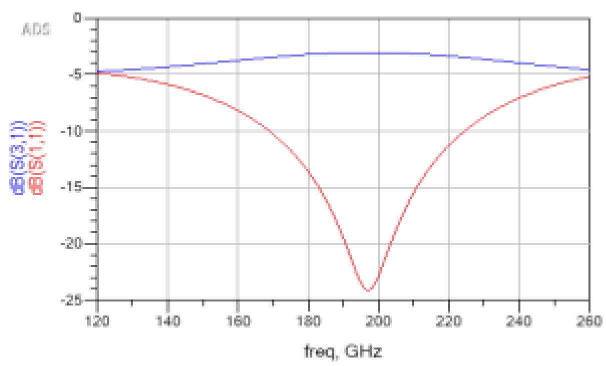

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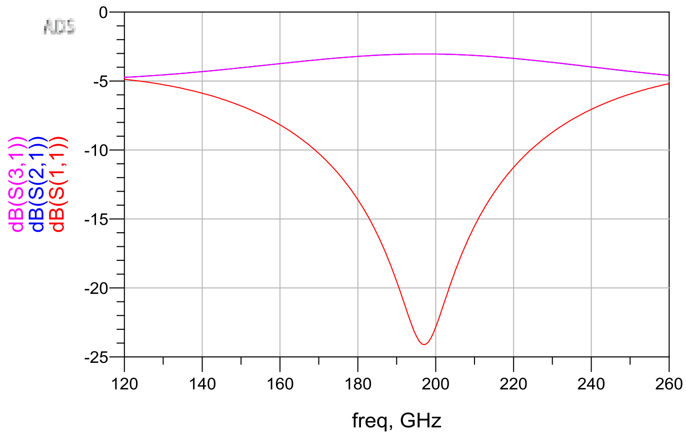
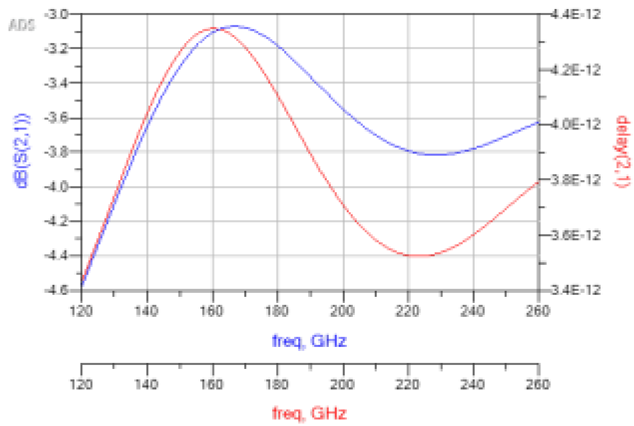
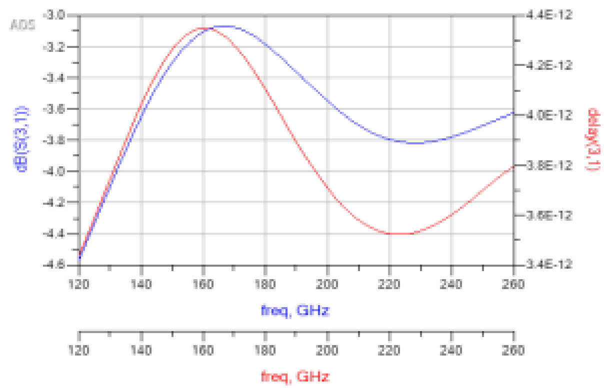


(c)

Fig. 4. Signal transmission coefficient diagram for each port.



(a)



(b)

Fig. 5. Time delay function diagram in signal transmission for each port.

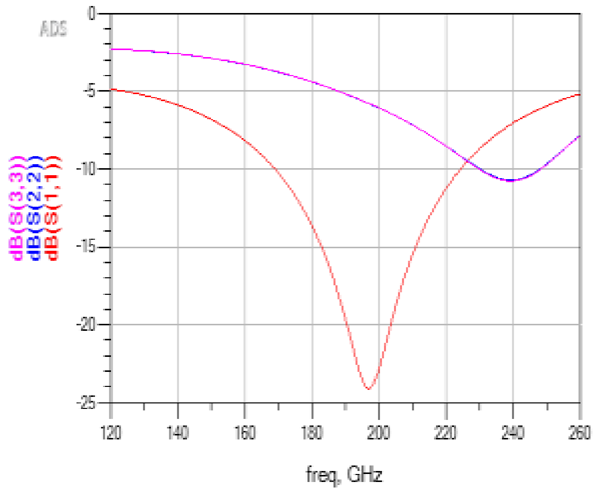


Fig. 6. Return loss diagram and output coefficient reflection.

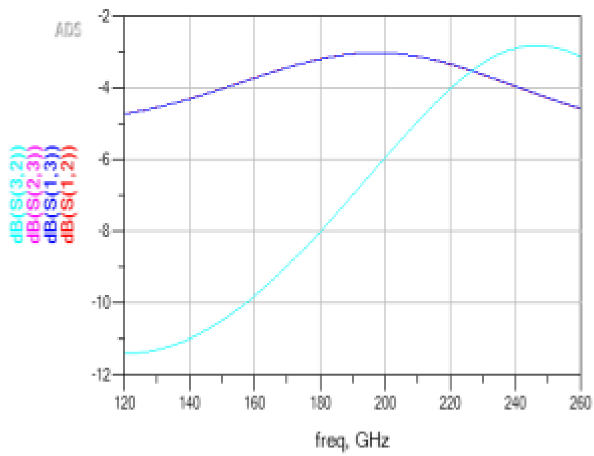


Fig. 7. Diagram of input to output isolation coefficient - output to output.

5. ACKNOWLEDGMENT

The research that has been done in the field of RF electronics is for the integrated and integrated design of the passive model of the signal power divider and the passive model of the signal collector. According to the base models, electronic resistors are designed in several ways in different technologies and for use in the system.

REFERENCES

[1] H. -Y. Liu, J. Xie and K. -K. M. Cheng, "Impact of Nonideal Auxiliary Current Profile on Linearity of Microwave Doherty Amplifiers: Theory and Experiments," in IEEE Transactions on Circuits and Systems I: Regular Papers, DOI: 10.1109/TCSI.2022.3152589.

[2] A. Jarndal and K. H. Hamza, "GaN Power Amplifiers Design Using Efficient GA-ANN Dynamic Nonlinear Model," 2021 14th International Conference on Developments in eSystems Engineering (DeSE), 2021, pp. 413-417, DOI: 10.1109/DeSE54285.2021.9719341.

[3] G. Bosi, A. Raffo, R. Giofrè, V. Vadalà, G. Vannini and E. Limiti, "Empowering GaN-Si HEMT Nonlinear Modelling for Doherty Power Amplifier Design," 2020 15th European Microwave Integrated Circuits Conference (EuMIC), 2021, pp. 249-252, DOI: 10.1109/EuMIC48047.2021.00074.

[4] M. Fares, D. Y. Wu, S. Boumaiza and J. Wood, "Inward nonlinear characterization of Doherty Power Amplifiers," 2009 IEEE MTT-S International Microwave Symposium Digest, 2009, pp. 1545-1548, DOI: 10.1109/MWSYM.2009.5166004.