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Simulation and Analysis of Symmetric Diplexer for 5G Applications

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Abstract: The current dominating communication system is 4G. However, with the increase in the data rate and in the number of users in the world, the 4G communication system has started to saturate and couldn’t manage to keep up with user demands and there is less room for progress at 4G systems. In search of finding a system that covers the future interests of users, a new communication scheme is being processed as 5G. The objective of this research is to explore, develop and characterize advanced substrates for 5G applications in the frequency range of 26-33 GHz.

Keywords: Diplexer, 5G, symmetric system.

I. Introduction

Wireless technologies and communication system had become mainstream for people a long time ago. They took a great place in every aspect of life such as high-quality data transfer, cloud operations, vehicle-to-vehicle or vehicle-to-infrastructure communication, virtual/augmented reality applications, automation of industrial devices, smart houses/cities, personal healthcare applications and the unlimited number of examples can be given for applications of the wireless systems. From the emerging point of telecommunication until now; there is a rapid improvement and development in the field of communication systems. During this period, communication systems completely evolved and changed not once but several times [1]. Today the most recent technology is the fourth-generation mobile phone standards (4G). For instance; today, with 4G’s high data transfer rate, it is providing high-quality video and audio streaming. However; even 4G structures can’t handle today’s user demand and there is only fractional room is left for development. The most important problem for 4G is the increase in both demand and device numbers. The demand for data is growing not linearly but exponentially with each year. From 2015 to 2016, mobile data transfer rate is increased by 63% from 4.4 exabytes to 7.2 exabytes. Also, the number of active devices raised from 7.6 billion to 8 billion in only one year. In 2021, the expected number of mobile devices is 11.6 billion [2]. The disadvantages of 4G can be explained as follows: Firstly, even though 4G has a large bandwidth, they are not used by all of the world. These bandwidths are specialized to different locations and mobile devices can’t operate in every single one of them due to the electronic component limitation. Secondly, the 4G communication system is not compatible with Wi-Fi structures. Being suitable with Wi-Fi technology could create great benefits for bandwidth and it would relax the bandwidth requirements. Also, with the introduction of more and more internet of things (IoT) devices to the market, wireless systems became more important. Finally, 4G will not be able to provide the sufficiently low latency values (~1ms) especially for IoT devices [3]. Until now 4G met the demands of the users; however, due to the reason that has been mentioned above, the technology needed a brand-new communication system called 5G. While thinking about the requirements of 5G structure, the inadequacies of the 4G system can be taken as references. First one is latency and the second one is cost and efficiency. The last and most important of the requirements is the high data rate. 5G is promising the data rate which thousand times of 4G. One of the key steps that make this available is increasing the operation frequencies of the communication systems. The frequency spectrum that is common today is almost full and communication requires new bandwidth. It is the most effective way to provide large bandwidth for the users. For this purpose, millimeter wave (mmWave) frequencies come into consideration. However, these frequencies were not thought of as suitable for communication systems. Basically, because, they are hard to propagate. Few of the reasons for this property can be given as path loss, low penetration to walls, atmospheric and rain absorption [4]. In recent years, several different ways to overcome these problems emerged. For example, keeping the antenna sizes which are used for smaller frequencies may be a solution for higher frequency applications. These large arrays can eliminate the frequency dependence of the propagation path loss. Another way can be smaller cells with narrower beams with their low interference behavior [5]. An additional challenge with working at higher frequency is how can the integrated circuit technology satisfy the high-frequency operation. As the size of the chips becomes smaller and smaller, and as the fT’s of the transistor becomes higher, the complexity of chip fabrication increases drastically and this leads to the higher prices for the production of circuits.

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The new 5G mobile communication standard is defined to meet the increasingly pressing needs for bandwidth due to high data consumption and an increasingly lower latency in the network. This is obtained by moving much of the intelligence and algorithms necessary to the base stations themselves, moving them away from the core network. To accomplish the latter, installing networks with computing power equipment in these stations is needed, whereas to meet the other requirements of higher bandwidth is necessary to improve signal coding techniques or increase the frequency towards mm-Wave carriers. It is in the latter context where the current technology has several weaknesses, and to address them, the "gap waveguide" technology is being developed since its invention in 2009 [6]. In this technology, it is possible to propagate a quasi-TEM mode in the "Ridge" and "Inverted Microstrip" versions (a TE/TM in the "Groove" one) between parallel metal plates while periodic structures used as PMC prevent all other modes to propagate outside the propagation area. This technology allows to transmit high-frequency signals with low loss with a moderate cost, since generally dispenses dielectrics and uses air as the medium for propagation. In addition, this technology does not require electrical contact between the top and bottom parts existing in all its versions. There are many examples of designs of antennas and circuits made in gap waveguide technology in the literature, but not that many in the case of the inverted microstrip version. Some examples can be found in; also transitions to standard waveguides and transmission lines have been developped [6], the study of the optimal numeric port [7]; up to some of the various components that make up a RF front-end like antenna feeds [8]; beamforming Butler matrix or filters. Few studies on diplexers with this technology have been published apart from this one using the groove version. This version, like the ridge version, has less losses than the inverted microstrip because they do not use dielectrics, but at the cost of added manufacturing complexity and cost [9-10].

II. SIMULATION PROCESS FLOW

The research work is formulated to simulate diplexer model for 5G communication. A diplexer is a device that combines or splits signals into two different frequency bands, widely used in mobile communication systems. The model simulates splitting properties using a simplified 2D geometry. The computed S-parameters and electric fields at the lower and upper bands will show the diplexer characteristics in the Ka-band.

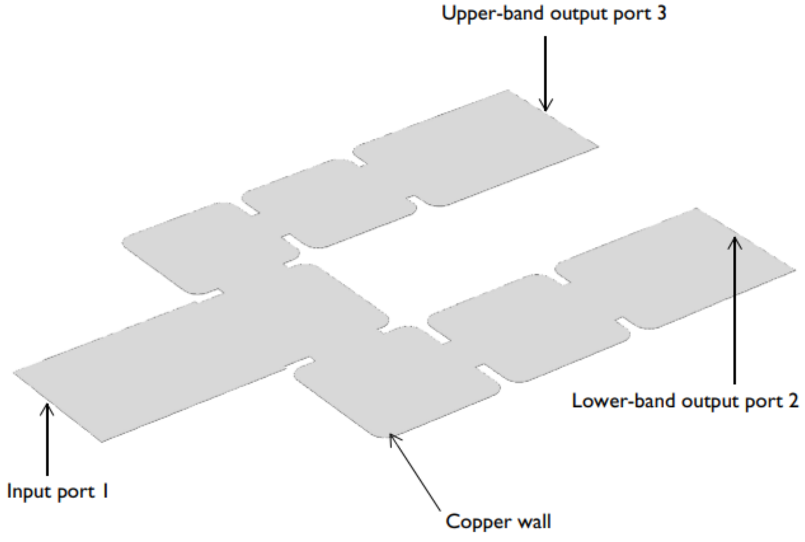

Fig. 1 Schematic of device.

The model is based on a WR-28 waveguide for Ka-band applications. The width of the 2D waveguide is 0.28 inches, which is the length of the longer side of a WR-28 waveguide aperture. The model considers only the dominant TE1 mode. The cutoff frequency of the dominant mode is 21.08 GHz. There are two cavities working as bandpass structures between the input and each output port that are connected with irises. The waveguides, cavities and irises are modeled as copper with finite conductivity using an Impedance Boundary condition to evaluate loss at a high frequency range and the inside of the waveguide is filled with air. On each end of the waveguide, a port boundary condition is applied with the predefined rectangular TE1 mode. Only one port is excited to observe the S-parameters in the model.

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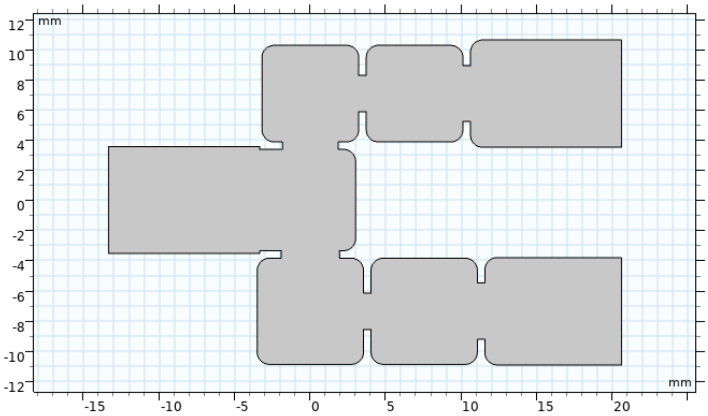

Fig.1 Designed model layout.

Figure 2 shows the assigned port to the structure. Single input and dual output port are used for the simulation process. Triangular meshing is taken for the geometry to solve the emwave equation on the geometry shown in Fig. 3.

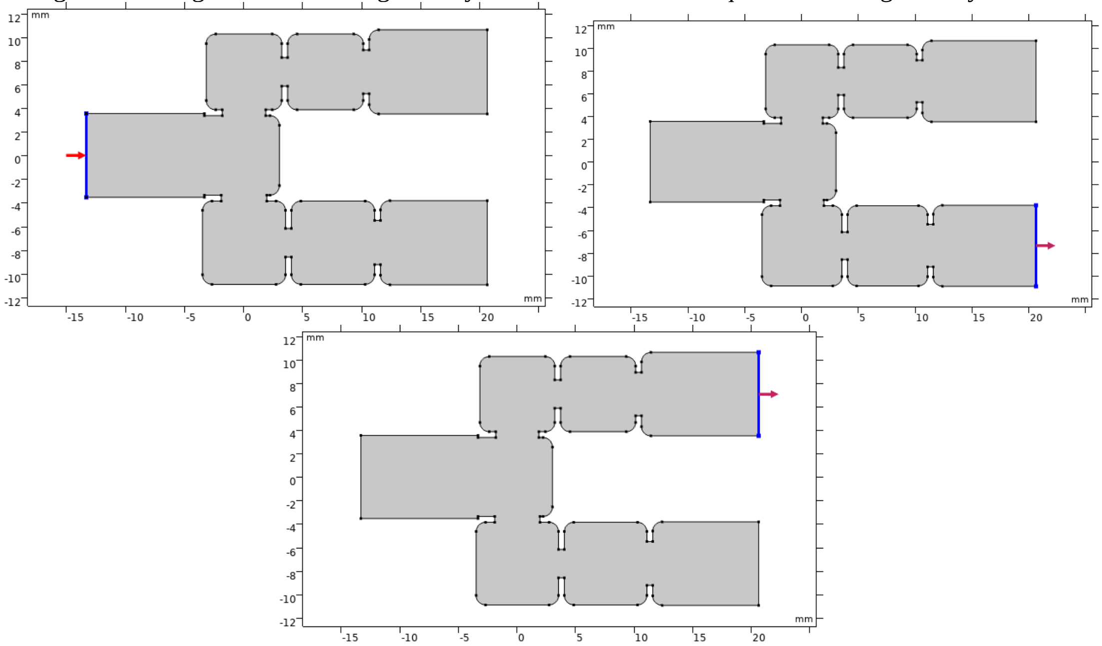

Fig. 2 Assigned input and output port to the structure.

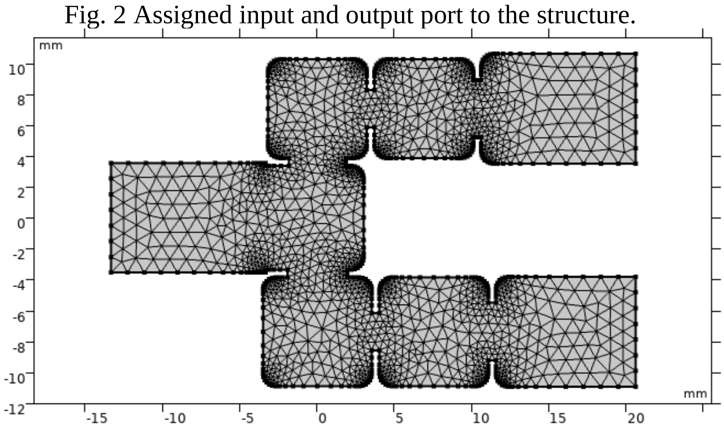

Fig. 3 Triangular meshing applied to the system.

III. Results And Discussion

The research work is carried out to estimate the em wave propagation for 5G communication system with dual split resonators. In Figure 4 (a-h) shows the E-field norm is visualized for each passband, showing that the input power at each passband is not split into two output ports, but separately distributed without being coupled to the other port. At

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frequency 26 GHz the right portion of the system allows the propagation of em waves and at frequency of 30 GHz it switch towards left portion of the system. Thus the system can be used to collect data from dual operating frequencies.

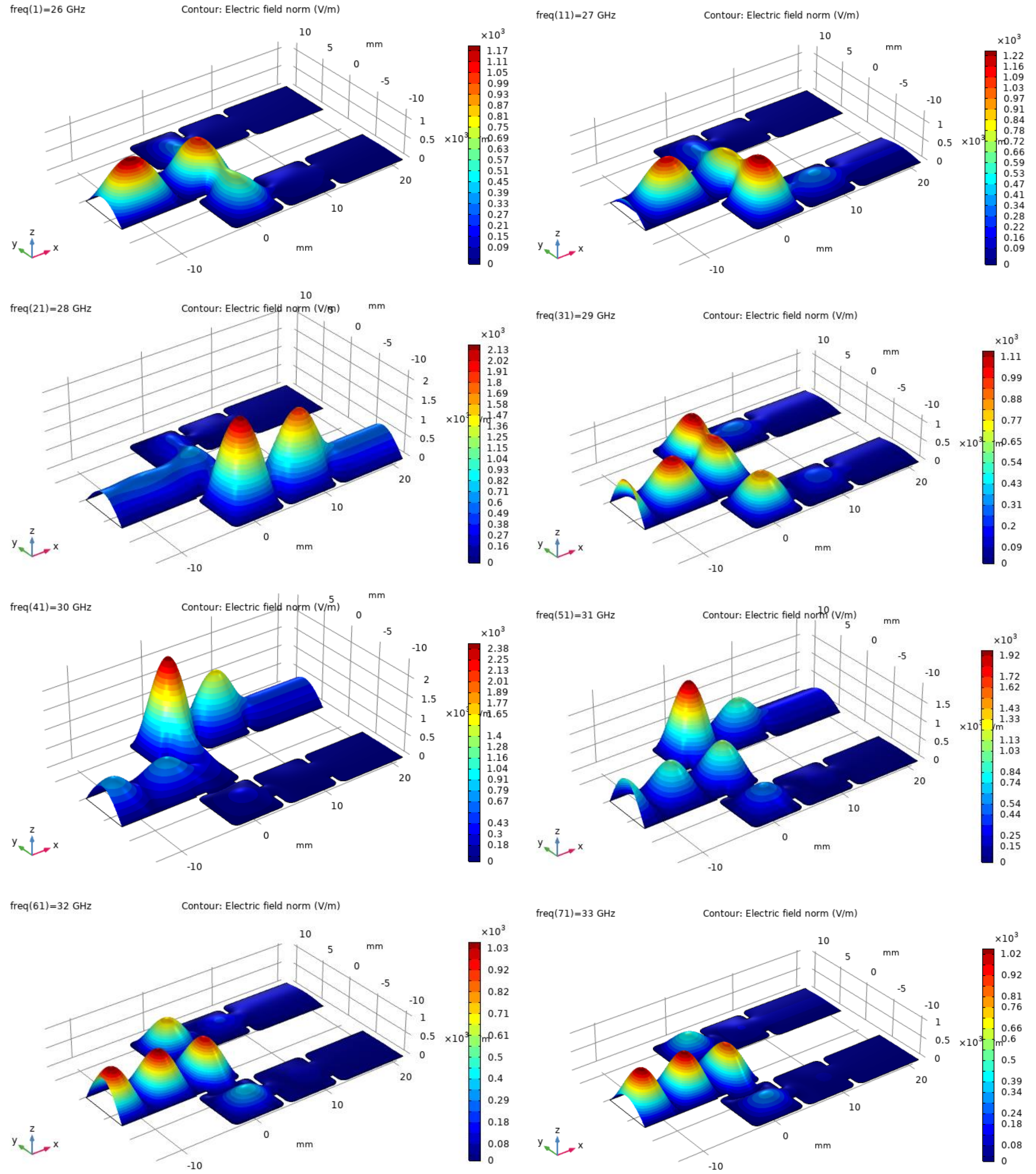

Fig. 4 (a-h) EM wave propagation at various frequencies.

S-parameters are plotted in Figure 5. The lower passband is around 28 GHz and the upper passband is around 30.4 GHz. The insertion loss in each passband is about 0.1 dB, mainly caused by the finite conductivity of the copper walls. Figure 6 shows the energy propagation in the structure. The lower frequencies have higher energies with two maxima and higher frequencies have lower energy with dual maxima.

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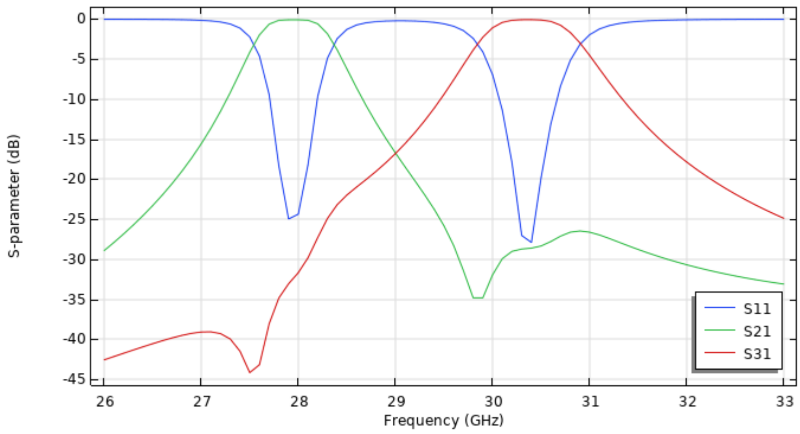

Fig. 5 S-parameters on input and output sides.

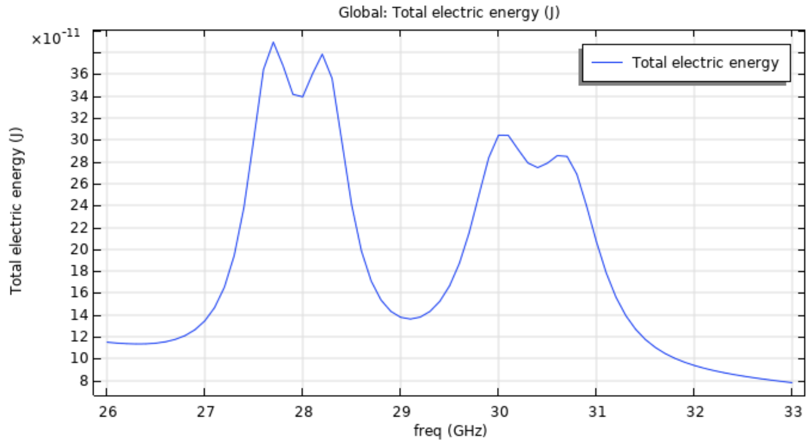

Fig. 6 Total energy at different frequencies.

IV. CONCLUSION

In this research work is focused on design and simulation of 5G diplexer. A symmetric structure is designed in finite element method based platform. The dimensions of designed geometry are 20 mm x 34 mm. single input and dual outputs are assigned to geometry to work as diplexer. The system operates in 26 GHz and 30 GHz domain to provide duplexing phenomenon.

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