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Two Free Microwave Engineering Software for Online REU-RET

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ABSTRACT: Two free microwave engineering software were used in an online REU-RET summer program recently.The first free software is AppCAD. This software was used to simulate a microstrip and a coplanar waveguide. The second free software is Sonnet Lite. It was used to simulate a microstrip, a coplanar waveguide, an open-stub bandstop filter and a coupled lines bandpass filter. This online REU-RET Summer Program was very successful in the pandemic season.

KEYWORDS: AppCAD, Sonnet Lite, Microstrip, Coplanar Waveguide, Bandstop Filter, Bandpass Filter.

I.INTRODUCTION

The Summer Program is called REU-RET Mega-Site: Research Experiences for Undergraduates and Teachers in Smart and Connected Cities. It was led by Morgan State University and was funded by NSF. Its purpose was to recruit and train a diverse population of underrepresented minority students and teachers who work in minority-serving K-12 schools. The project involves the development of a combined Research Experiences for Undergraduates and Research Experiences for Teachers (REU-RET) Mega-Site that is centered on the following research topics that are related to Smart and Connected Cities: IoT Security, Renewable Energy, Energy Storage, Smart Grid, Human Computer Interaction, Advanced Materials, and Microwave/RF Technology. Providing quality research experiences to an underserved group of undergraduate students and teachers will lay the foundation for positively impacting the retention and graduation of engineering students for years to come, while also increasing the number of minority students who will eventually pursue graduate degrees. In addition, the program will improve the quality of science and engineering education at local high schools, further stimulating the interest and imagination of underrepresented minority students who might not otherwise be inclined to pursue higher education in Science, Technology, Engineering, and Mathematics (STEM) fields.

For a microwave engineering group within such a REU-RET Summer Program, there were five undergraduates and one high school teacher. This group was supposed to work on microwave transmission lines and microwave filters. Due to the current wide spread of COVID-19, this group had to work online, and to get advised remotely using Zoom software. The fabrications of a bunch of microwave circuit boards became very difficult within an eight-week period. The testing of any microwave circuit board was impossible, since all the six group members did not have access to the expensive microwave network analyzer. Then this group had to switch to the simulation of microwave transmission lines and microwave filters. But they also lost accesses to all the software on campus computers, including the microwave engineering software. Routine electronic simulation software cannot be used at microwave frequencies [1, 2]. In such a tough situation, two free software, AppCAD and Sonnet Lite were proposed to be used for this group. In this paper, these two free microwave engineering software are introduced, and some simulation results from these two software are shown.

II.AppCAD SOFTWARE

HP/Agilent/Keysight/Avago AppCAD is an RF (radio frequency) and microwave design piece of software meant to help telecommunication engineers make a selection of RF products provided by Agilent that are appropriate for the wireless design applications they are working on [3]. This software is free, and no license is needed to use it. Six REU-RET participants downloaded and installed this software on their computers. Then they used this software to simulate a microstrip and a coplanar waveguide. They also did some parameter studies on these two transmission lines' characteristic impedances. The operation of this software is very simple and very straight forward.

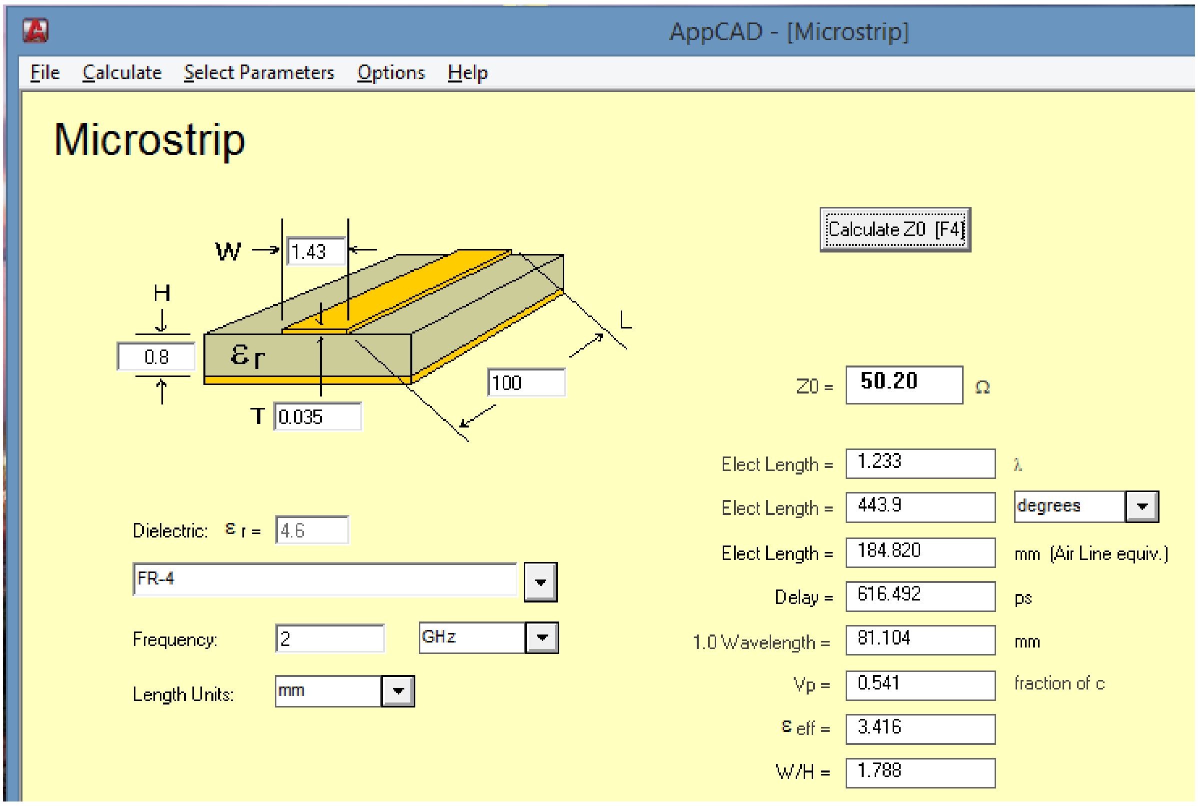

Fig. 1. A microstrip on AppCAD software.

Fig. 1 shows a microstrip on AppCAD software. The conducing strip is on the top of a dielectric substrate. This strip has a width of W and a thickness of T. The thickness or the height of the substrate is H. The dielectric constant of the dielectric is ε_r. The bottom of the substrate is the ground plane. On the left side of the AppCAD GUI, all the calculation conditions are listed. Length unit is mm. Frequency is at 2 GHz. The substrate material is chosen as Fr-4 with a relative dielectric constant of 4.6. This value may change from 4.2 to 4.8 for different Fr-4 products. The substrate height is 0.8 mm. The strip width is 1.43 mm, and the strip thickness is 0.035 mm (1 ounce copper in the industry). The substrate length is 100 mm. This value does not matter.

With these parameters are set, once the “Calculate Z0” button is clicked, all the simulation results come up on the right side of the AppCAD GUI. The most important result is the characteristic impedance Z0. It is 50.20 Ohms. Other calculated values are listed under this Z0. Another very important parameter among them is the wavelength. It is 81.104 mm. Some parameters studies were conducted for this microstrip. Its impedance decreases with line width W and substrate relative dielectric constant ε_r, and increases with substrate height H. This impedance also decreases very slightly with metal line thickness T.

REU-RET participants also used AppCAD to simulate a coplanar waveguide. Fig. 2 shows this coplanar waveguide on AppCAD software. Its structure is similar to that of a microstrip except that there are two ground planes beside the metal strip on top of the substrate. The strip has a width of W, and length L. The metal thickness is T. The substrate height is H. The relative dielectric constant of this substrate is ε_r. There is a new dimensional parameter gap G. It is the distance between the strip and the two metal grounds on the top layer. All the simulation conditions are on the left side of the GUI. All the calculated results are listed on the right side of the GUI. The characteristic impedance Z0 is 50.0 Ohms, and the wavelength is 85.616 mm. The simulation process for a coplanar waveguide is very similar to the microstrip simulation process. Parameter studies were also conducted for this coplanar waveguide. Its impedance decreases with line width W and substrate relative dielectric constant ε_r, and increases with substrate height H and gap G. This impedance also decreases very slightly with metal line thickness T.

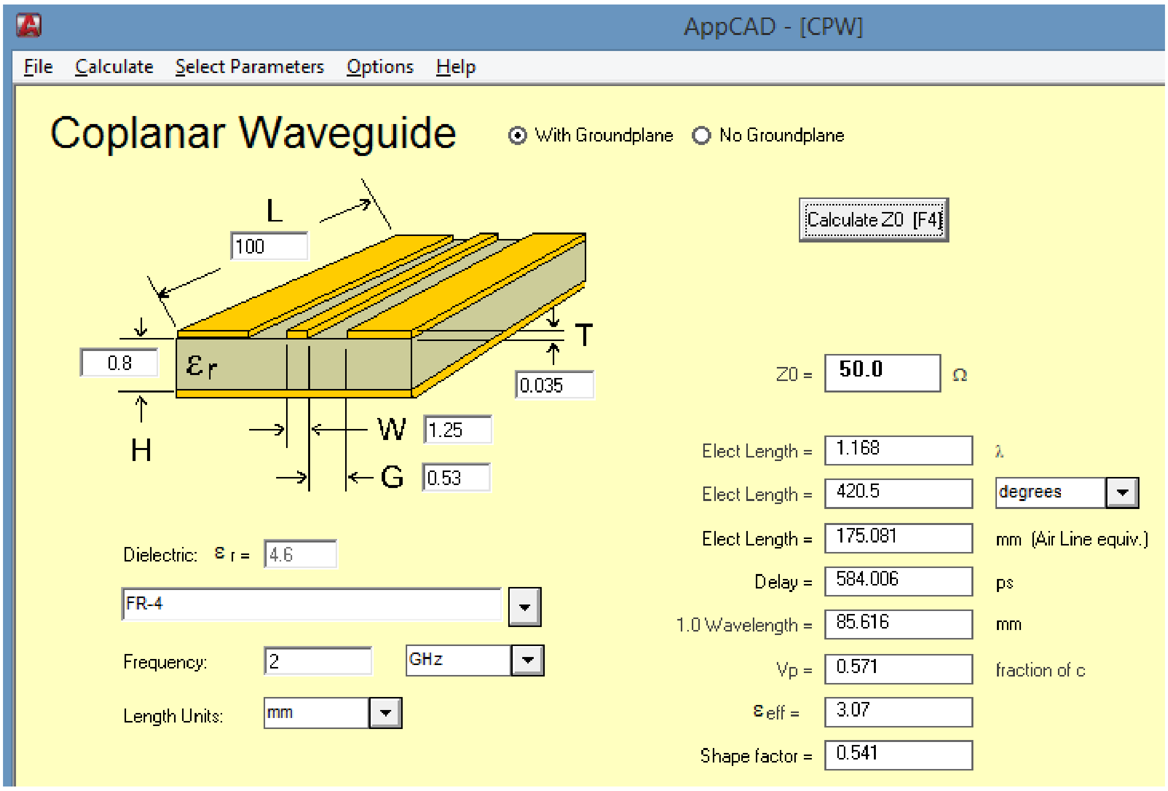

Fig. 2. A coplanar waveguide on AppCAD software.

III.SONNET LITE SOFTWARE

Sonnet Lite software is a free, feature-limited version of Sonnet's professional Sonnet Suite. Sonnet Suite provides EM analysis to thousands of companies across the globe [4, 5]. Many major manufacturers of high-frequency components and boards depend on Sonnet to analyse their predominantly planar high-frequency designs from 1 MHz through several THz [4, 5]. Sonnet Suite has been widely used by many researchers [6]. Sonnet Lite license is free. Each REU-RET participant registered for Sonnet Lite software and got a free license.

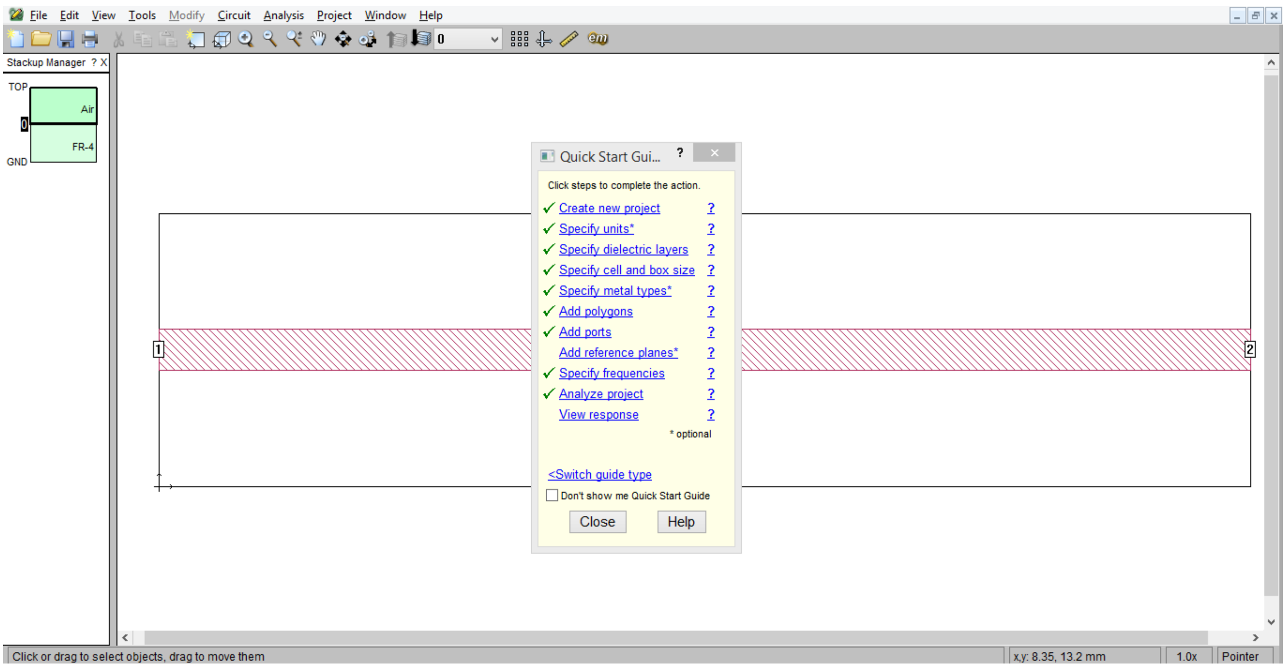

Fig. 3. A microstrip on Sonnet Lite.

The operation of Sonnet Lite software is not complicated. Fig. 3 shows a microstrip on Sonnet Lite. The operation steps are listed in the quick start guide menu. The circuit is built on a 0.80 mm thick Fr-4 substrate. This substrate material has a relative dielectric constant of 4.4 and a loss tangent of 0.02. The circuit board is 40 mm long and 10 mm wide. The linewidth is 1.53 mm. Port 1 is the input, and Port 2 is the output. The layout process of the circuit board is similar to that on a mechanical CAD software.

After the microstrip circuit board is drawn, it is meshed into 0.05 mm by 0.05 mm cells. The frequency range is from 1 to 10 GHz. The memory needed to analyse this circuit board is estimated to be about 5 MB. The circuit can be meshed into smaller cells for higher simulation precision. But it will take longer time to run the simulation, and the maximum memory that can be used for Sonnet Lite is 32 MB. Next, the circuit can be analyzed. During this process, a pop up window shows some data at selected frequencies, including S parameters, impedance, effective relative dielectric constant, and etc. The simulation results is shown in Fig. 4. The reflection coefficient is lower than -40 dB. The insertion loss is close to 0 dB, which means full pass.

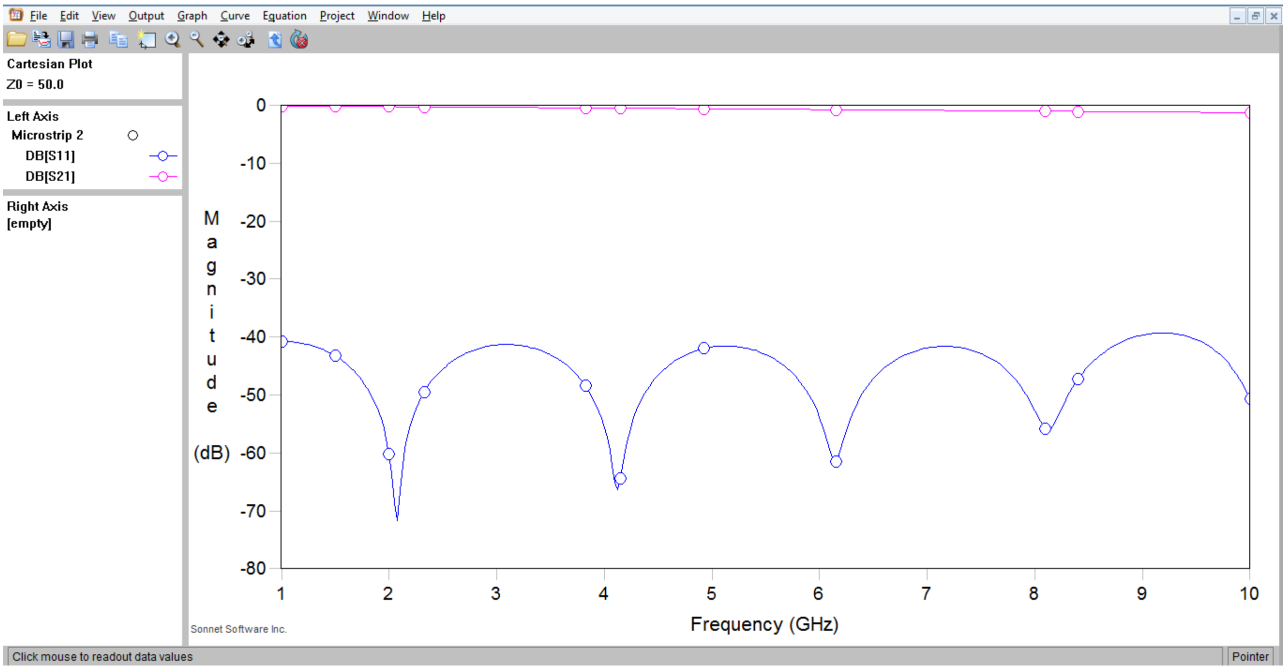

Fig. 4. The microstrip simulation results on Sonnet Lite.

Secondly, six RET-RET participants used Sonnet Lite software to simulate a coplanar waveguide. Fig. 5 is the top view of this coplanar waveguide. The dimensional unit is mm. The input is at port 1 on the left, and the output is at port 2 on the right side. This circuit board size is also 40 mm by 10 mm. The substrate is also a 0.8 mm thick Fr-4 material, which has a relative dielectric constant of 4.4 and a loss tangent of 0.02.

Then the coplanar waveguide was simulated on Sonnet Lite. The simulation results are shown in Fig. 6. The frequency range is from 1 to 10 GHz. The blue trace is the reflection coefficient S11, and purple line is the transmittance S21. The reflection coefficient is lower than -35 dB. The transmittance is close to 0 dB, which is 100% pass. The simulation results shows that the impedance of the coplanar waveguide should be close to 50 Ohms.

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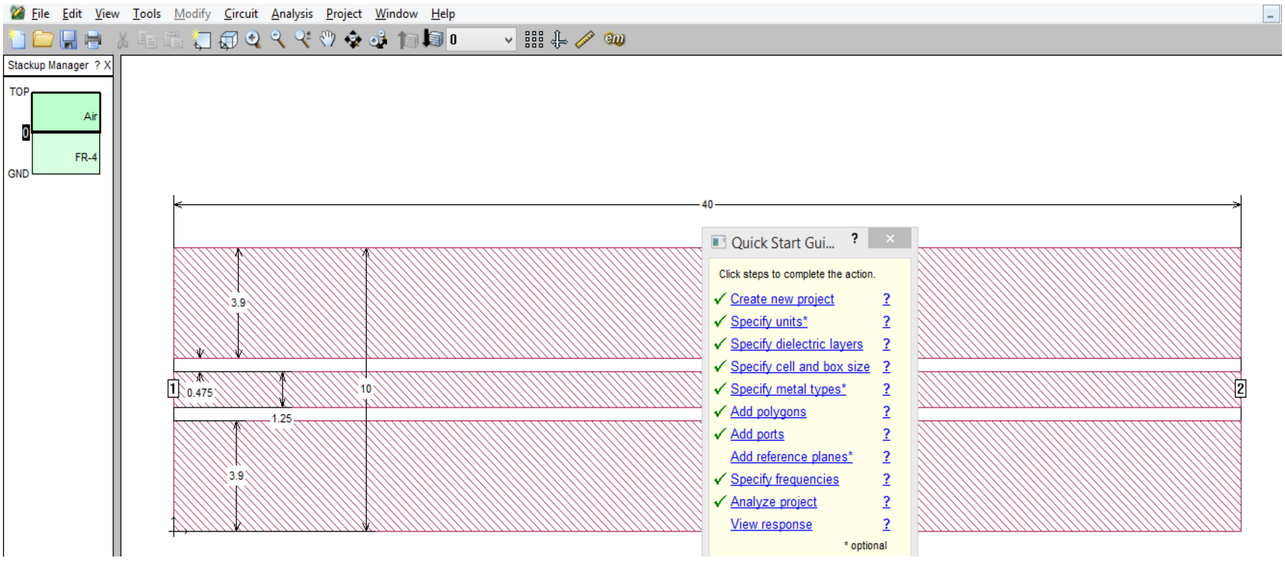

Fig. 5. A coplanar waveguide on Sonnet Lite.

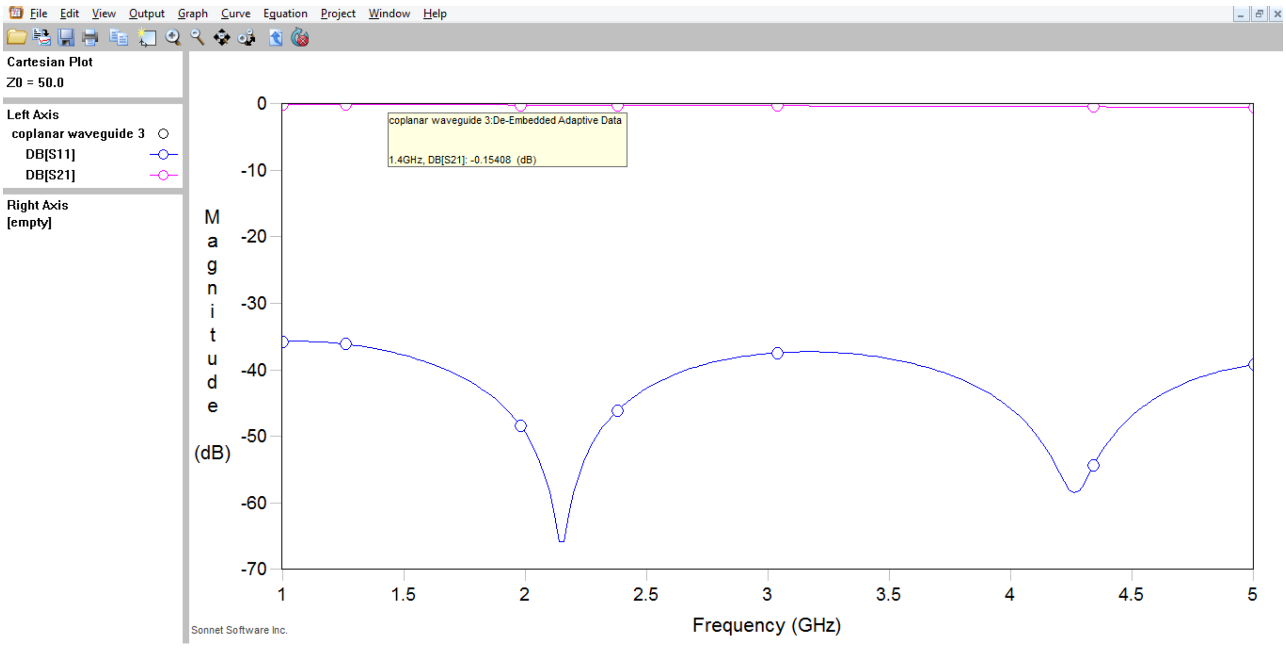

Fig. 6. The coplanar waveguide simulation results on Sonnet Lite.

Thirdly, six participants used Sonnet Lite to simulate a BSF. Thissecond order open-stub BSF having a center frequency of 2.0 GHz was designed (Fig. 7). The substrate is the 0.8 mm thick Fr-4 material mentioned earlier. Two open-stubs are attached to the main input and output transmission line. The main input and output microstrip is in the horizontal direction at the bottom. The two open-stubs in vertical direction have the length of a quarter of the wavelength, and the separation between the two open stubs is also a quarter of the wavelength at 2.0 GHz [6]. All the linewidth was calculated as 1.52 mm, and open-stub length was calculated as 20.55 mm.

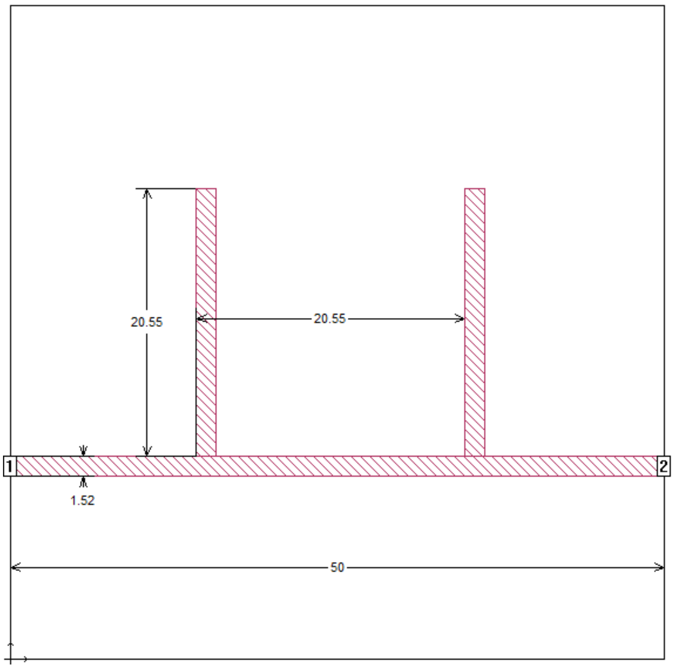

Fig. 7. Layout of a second order open-stub BSF on Sonnet Lite.

The second order BSF was meshed into 0.05 mm by 0.05 mm cells. The simulation frequency range was set as 1.0 GHz to 4.0 GHz. Then this second order BSF was also simulated on Sonnet Lite, and memory used was 21 MB. The simulation results are shown in Fig. 8. A wide and deep stop band is generated around 2.0 GHz. The attenuation depth at 2.0 GHz is -53.8dB.

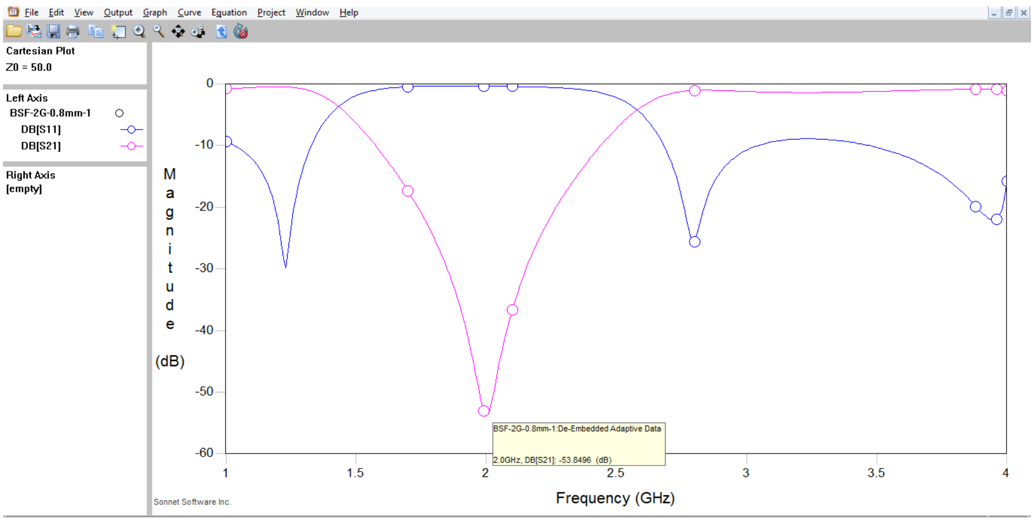

Fig. 8. Simulation results of the second order open-stub BSF on Sonnet Lite.

Fourthly, the six REU-RET participants also simulated a coupled lines BPF on Sonnet Lite. A parallel-coupled half-wavelength resonator bandpass filter gives high coupling for adjacent resonators and potential low insertion loss for the whole filter. A parallel-coupled microstrip bandpass filter can be designed through the calculation of even-mode and odd-mode characteristic impedances of coupled line pairs and the computation of physical dimensions of these coupled lines [7].

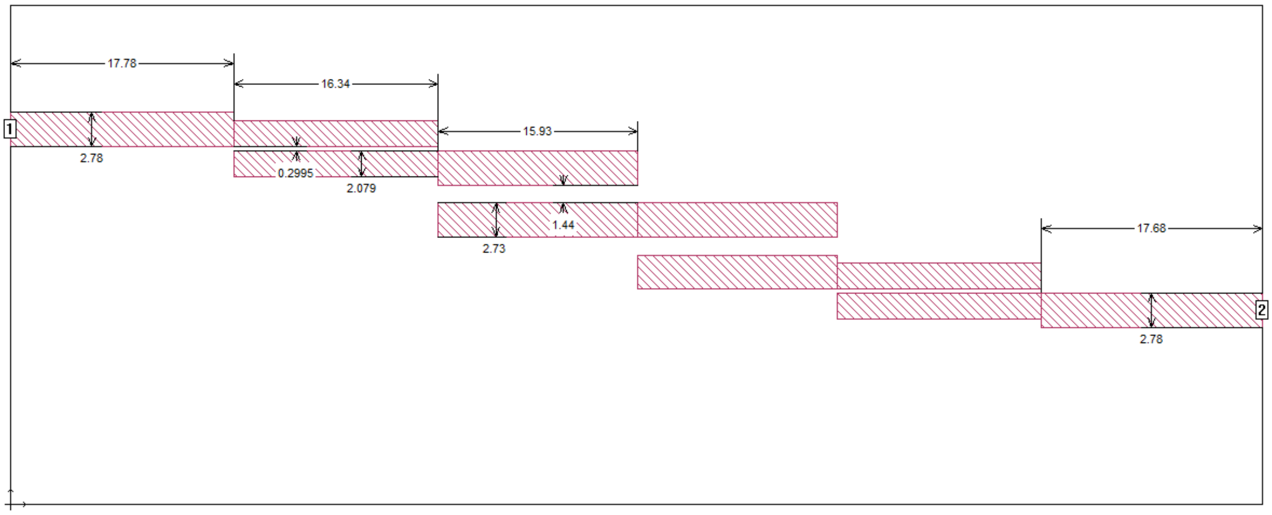

Fig. 9. A coupled lines BPF layout on Sonnet Lite.

The layout of a coupled lines BPF is shown in Fig. 9. The dimensional unit is mm. Between the input port 1 and the output port 2, there are four coupled lines pairs. The circuit is built on a 1.52 mm thick Fr-4 substrate with a dielectric constant of 4.6. The circuit board area is 100 mm by 40 mm. The third coupled lines pairis the same as the second coupled lines pair. The fourth coupled lines pairis the same as the first coupled lines pair. The circuit board was meshed into 0.2 mm by 0.2 mm cells. The simulation frequency was from 1.0 GHz to 4.0 GHz. The memory used was 16 MB. This BPF was also simulated on Sonnet Lite. The simulation results are shown in Fig. 10. A passband is generated around 2.5 GHz.

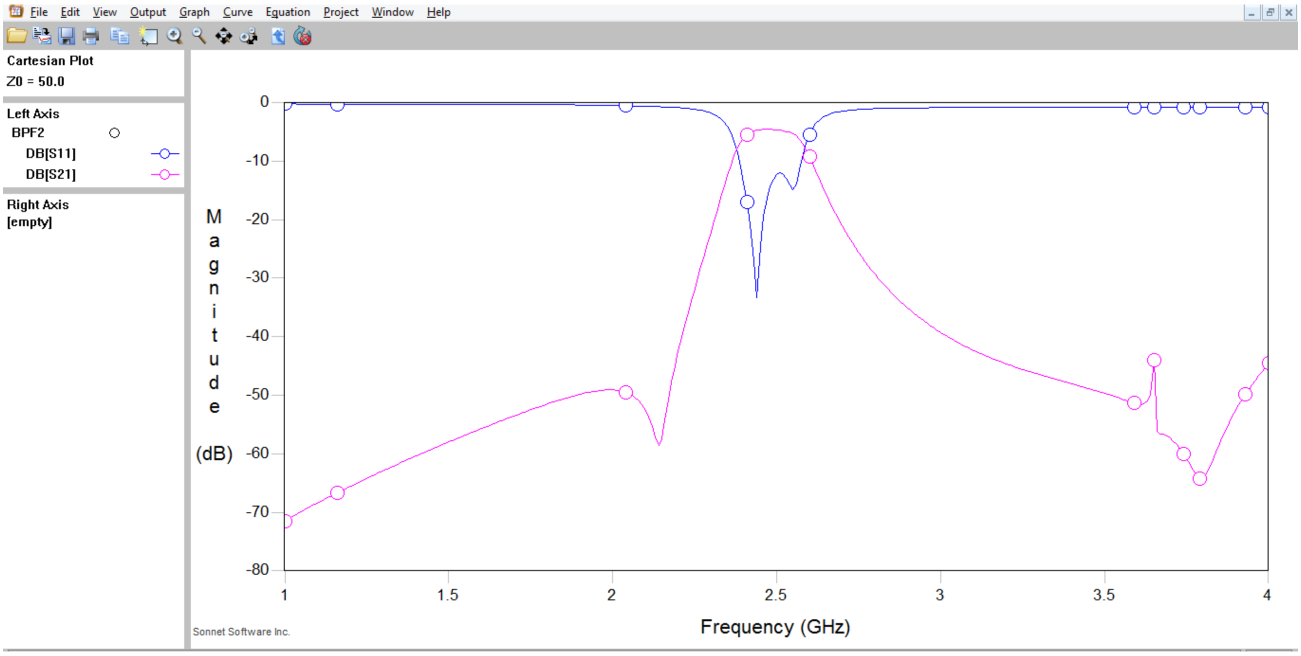

Fig. 10. The coupled lines BPF simulation results on Sonnet Lite.

IV.CONCLUSION

In this COVID-19 pandemic season,an REU-RET summer project was online. Six participants used two free microwave engineering software, AppCAD software and Sonnet Lite software, to study two microwave transmission lines, an open-stub BSF and a coupled lines BPF. AppCAD software was used to study a microstrip and a coplanar waveguide. Sonnet Lite software was used to simulate a microstrip, a coplanar waveguide, an open-stubBSF and a coupled lines BPF.This online REU-RET Summer Program was very successful in the pandemic season.It can be

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concluded that AppCAD and Sonnet Lite are the two right free software for this online REU-RET Summer program, and they should have potential applications in online undergraduate microwave engineering education.

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