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An Overview of the Recent Developed MSDES Software used in Distributed Microstrip Circuit Design

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Abstract: **The aim of this paper is to present the author recent development Software program used in the design of distributed Microstrip Circuits. The designed circuits are analyzed using the recent ADS program. The paper demonstrates the design and analysis of Microstrip amplifiers and oscillators designed at frequency 2.4 GHz in addition with design and analysis of rectangular branch line couplers (one-section and two-section), Ring Couplers and Wilkinson couplers. The ADS layouts and the applications of the designed Microstrip Circuits are presented.**
Keywords**: Microwave Circuits and systems, Computational Microstrip Circuit Design, Microwave Circuits analysis.**

I. INTRODUCTION

Since the mid-1970s, a number of computer programs for microwave circuit design had become commercially available. Some well-known microwave computer-aided engineering software packages are SUPER COMPACT [1], TOUCHSTONE [2], and others. All of these programs have certain advantages and some disadvantages.

In this paper we introduce the recent version of our previous [3] computational programs, named HHSS4. In the comparison with the last versions, the additional features summarize as: 1) It covers a wide range of applications in the design of Microstrip passive/linear active microwave circuits, 2) It is an easy-to-use user-oriented program. 3)The output data are formatted and stored in the output files for each application. 4) The program results can be utilized in many programs analysis packages such as PSPICE, MCAP, modified MCAP, CNL2, Super Star... etc. 5) It does not need a high memory size and it can be used in XT, or AT PC computers. 6) The program can be modified for use in the design of nonlinear microwave circuits. This will be the subject of future work.

II. GENERAL DESIGN METHODOLOGY OF THE PROGRAM

The general design methodology of the program is [9-11]:

- Depending on the type of the circuit (active or passive) and the internal parameters of the specified circuit, the software displays all the required parameters that can be specified by the user.
- The substrate parameters of the Microstrip (H, ε_r , and T) are given as common parameters. If the user needs to change these parameters, the software can interact with him/her to enter the new substrate parameters.
- The software can interact with the user for some selections and assumptions inside the specified circuit such as the number of sections in Lowpass filter, or rectangular branch coupler, and the bandwidth of the Wilkinson hybrid.
- After the entry of all parameters required by the user for the specified circuit design, the software performs a complete analytical design with appropriate lengths and widths of the Microstrip lines of the designed circuit.
- The software introduces an optimum selection of circuit elements to fulfill some requirements. These requirements include: i) unconditional stability, ii) potential unstability, iii) simultaneous conjugate match, iv) changing the transistor stability, v) feedback circuit parameters to maximize S_{11}, vi) optimum termination for the output circuit to get the maximum output power, and vii) optimum selection of S-parameters (with the optimum feedback stubs at different frequencies or cascaded resistors) to achieve the transistor changes from unconditional stability to potential unstability and vice versa.

III. PROGRAM DESCRIPTION

It is a user-oriented CAD program used for a wide range of Microstrip applications [12-15,30]. It can be used for active and passive circuits design such as Microstrip amplifiers, oscillators, couplers, and mixers. The program entries are: 1) substrate parameters: relative permittivity (ε_r), substrate height (h), conductor thickness (t), and characteristic impedance of the

Microstrip line (Z_o), 2) equivalent circuit model of the diode chip, and 3) S-parameters of the used transistor. The program mainly has four selected subroutines shown in tables 1 through 4. Table 1 is the main selected subroutine (SELECT). According to the item selected from table 1, the program illustrates one of the other three selected subroutines (SELEC, SELM, and SELE) given in table 1.

Table 1: Subroutines Used in the Developed Program

Subroutine **SELECT** (Main selected subroutine)	Subroutine **SELEC** (Amplifier and oscillator circuit design)	Subroutine **SELM** (Diode/MESFET mixer circuit design)	Subroutine **SELE** (Hybrid coupler circuit design)
1) amplifier circuit design 2) oscillator circuit design 3) mixer circuit design. 4) low pass filter circuit design 5) directional coupler circuit. 6) transistor [S] parameters design with a series feedback stub 7) transistor [S] parameters with a cascaded resistor 8) analytical matching circuit design for a given Z 9) feedback circuit design. 10) conversion between Γ and Z 11) ε_{eff}, λ_g and width calculation for given Zo and f_o	1) stability circle, K, and Δ 2) unilateral figure of merit 3) simultaneous conjugate match 4) noise figure circles 5) power and available gain circles 6) input/ output reflection coefficients 7) Z_o and $\lambda_g/8(3\lambda_g/8)$ analytical matching circuit design	1) diode mixer circuit design using hyperbolic mean technique 2) diode mixer circuit design using diode equivalent circuit 3) Single and dual gates mixer circuit design	1) coupled-line couplers 2) branch-line couplers 3) ring couplers 4) Wilkinson couplers 5) Lange couplers

A. Microstrip Amplifiers:

The design of Microstrip amplifier is performed with feedback or without feedback circuits. The program performs all the required calculations needed for transistor stability, simultaneously conjugate match and for available and operating power gain design. The program performs analytical and graphical matching circuit design for input and output of the amplifier. The design entries of the program are S parameters of the active element, the designed frequency, and the substrate parameters.

B. Microstrip Oscillator

The program performs all the required calculations needed for transistor stability [4,5]. The program performs analytical and graphical design approaches for the terminating and load matching circuits. The design entries of the program are S parameters of the active element, the designed frequency, and the substrate parameters.

C. Microstrip Antenna

The program is used for the design Microstrip rectangular patch antenna array with TL and coaxial feeding [31-35].

D. Microstrip Couplers:

The program is applicable for Microstrip coupler design, especially for rectangular branch and rate-race couplers design [5,6,9,18,19].

E. Microstrip Mixer

The program performs the design of singly balanced diode mixer [6,7,8]. The diode equivalent circuit and the substrate parameters are the entry of the mixer design. The program calculates the diode input impedance and performs a complete design of the diode matching circuits.

IV. PROGRAM APPLICATION IN THE DESIGN OF DISTRIBUTED MICROSTRIP CIRCUITS

The following section describes the use of the developed program in the design of Microstrip circuits [16-18]. The analysis and optimization of the designed circuits is introduced using ADS2017 Software [19].

A. Design And Analysis Of 2.4 Ghz Microstrip Amplifier

Input parameters: The substrate parameters with 50Ω normalized impedance are: ε_r = 4.3, h =1.58 mm, and t=0.035. HXTR 3101 BJT with [S] parameters at f_o = 2.4 GHz are: S_{11} = 0.602 ∠ 153, S_{21} =2.439∠ 39, S_{12} = 0.049 ∠ 46, and S_{22} = 0.406 ∠ -66 [22 - 29].

Output parameters: Δ = 0.1.57 ∠101.8, K = 1.03, (the transistor is unconditional stable), Complex Conjugate match at the input port: Γ_S (source reflection coefficient) = 0.9 ∠ -153.6 and Complex Conjugate match at the output port: Γ_L (load reflection coefficient) = 0.86∠ 62.64.

Input matching circuit: Width of Microstrip lines = 2.98 mm, length of series line = 34.5 mm, and length of single open stub = 14.82 mm

Output matching circuit: Width of Microstrip lines = 2.98 mm, length of series line = 13.78 mm, and length of single open stub = 14.21 mm.

ADS2017 simulation and optimization

Figure 1 shows the ADS-Schematic diagram of 2.4 GHz Microstrip amplifier. Figure 2 shows $|S_{21}|$,$|S_{11}|$ and $|S_{22}|$ in (dB) versus frequency for the 3 GHz amplifier. Figure 3 shows the input and output Voltages and different input powers.

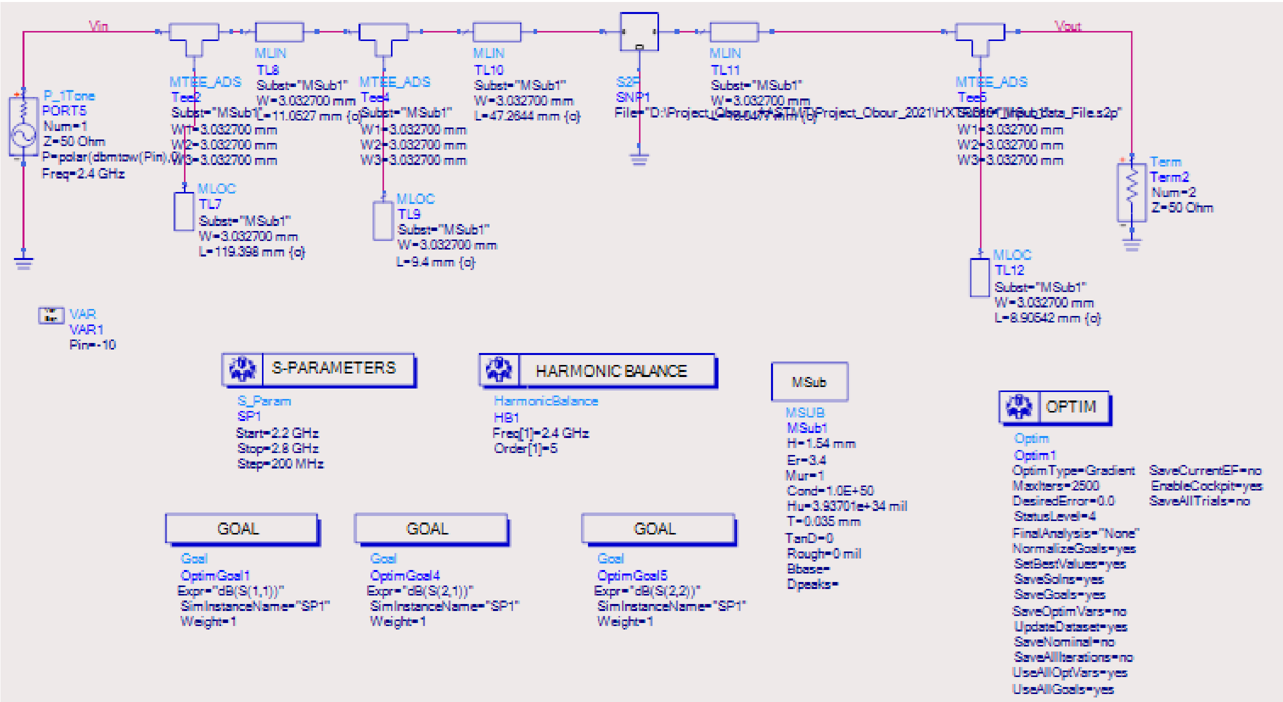

Fig. 1: ADS-Schematic diagram of 2.4 GHz Microstrip amplifier

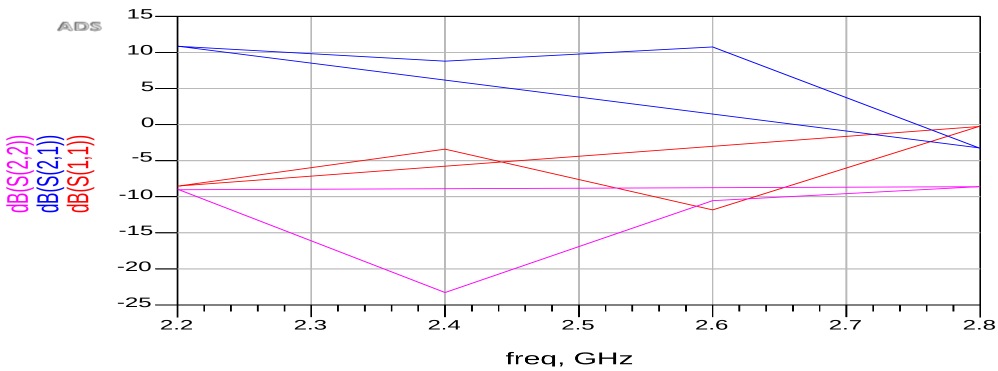

Fig.2: $|S_{21}|$, $|S_{11}|$ and $|S_{22}|$ in (dB) versus frequency for the 3 GHz amplifier.

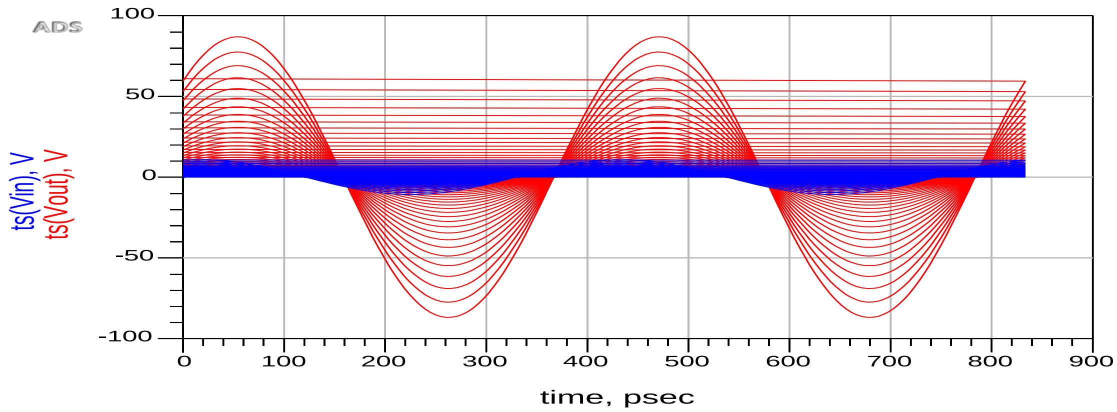

Fig.3: Input and output Voltages and different input powers

B. Design Of 2.4 Ghz Oscillator

Input parameters: The substrate parameters with 50Ω normalized impedance are: ε_r = 4.3, h =1.58 mm, and t=0.035. HXTR 4101 BJT with [S] parameters at f_o = 2.4 GHz are: S_{11} = 0.976 ∠ 136, S_{21} =1.966∠ -72, S_{12} = 0.057 ∠114.1, and S_{22} = 1.092∠ -56 [20-22].

Output parameters: Δ = 0.98 ∠83.8, K =0.825, (the transistor is potential unstable

Terminating circuit: length of open-circuit stub = 47.6 with width = 2.98 mm

Output matching circuit: Width of Microstrip lines = 2.98 mm length of series line = 10.7 mm, and length of single open stub = 9.6 mm.

ADS2017 simulation and optimization

Figure 4 shows the ADS- Schematic diagram of 2.4 GHz negative resistance Microstrip oscillator. Figure 5 shows $|S_{11}|$ in (dB) versus frequency for the 2.4 GHz negative resistance oscillator.

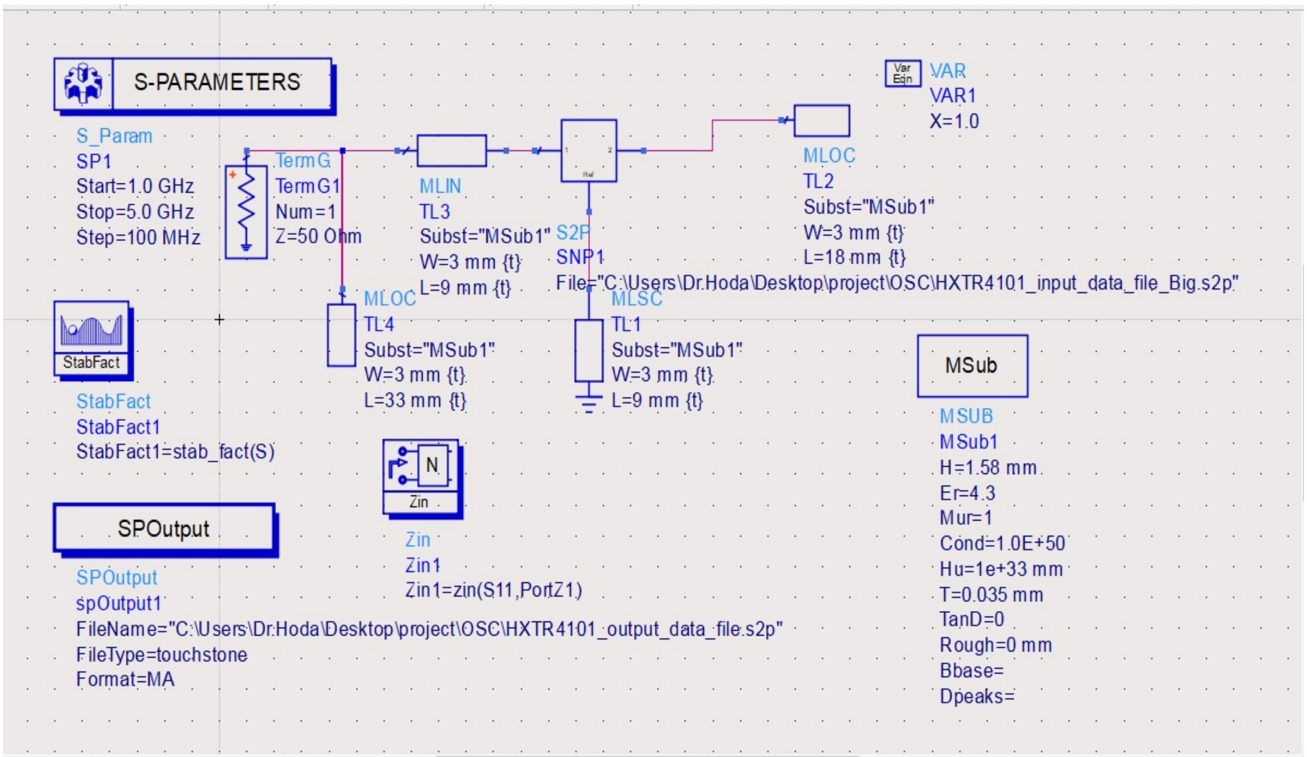

Fig. 4: ADS-Schematic diagram of 2.4 GHz negative resistance Microstrip oscillator

Fig. 5: $|S_{11}|$ in (dB) versus frequency for the 2.4 GHz negative resistance oscillator

C. Design Of A Ring Coupler

Input parameters: The substrate parameters with 50Ω normalized impedance are: ε_r = 4.3, h =1.58 mm, and t=0.035. The operating frequency f_o =2.4 GHz, and the coupling factor C = 3 dB.

Output parameters: Total length of circular line = 100 mm, λ_g for circular line = 71.25 mm, Width of circular line = 1.57 mm, Length of $\lambda_g/4$ circular line = 17.8 mm, Length of $3\lambda_g/4$ circular line = 53.44 mm, Impedance of circular line = 70.79 Ω, and Width of 50-Ω line = 1.578 mm.

ADS2017 simulation and optimization

Figure 6 shows the ADS-Schematic diagram of 2.4 GHz Ring Coupler. Figure 7 shows the ADS-layout of 2.4 GHz Ring Coupler. Figure 8 shows $|S_{11}|$,$|S_{21}|$ and $|S_{31}|$ and $|S_{41}|$,$|S_{11}|$ in (dB) versus frequency for the 2.4 GHz Ring Coupler. Figure 9 shows the Phase difference between port 3 and 3 versus frequency of the 2.4 GHz Ring Coupler. Figure 10 shows the Output power ration between port 3 and 3 versus frequency of the 2.4 GHz Ring Coupler.

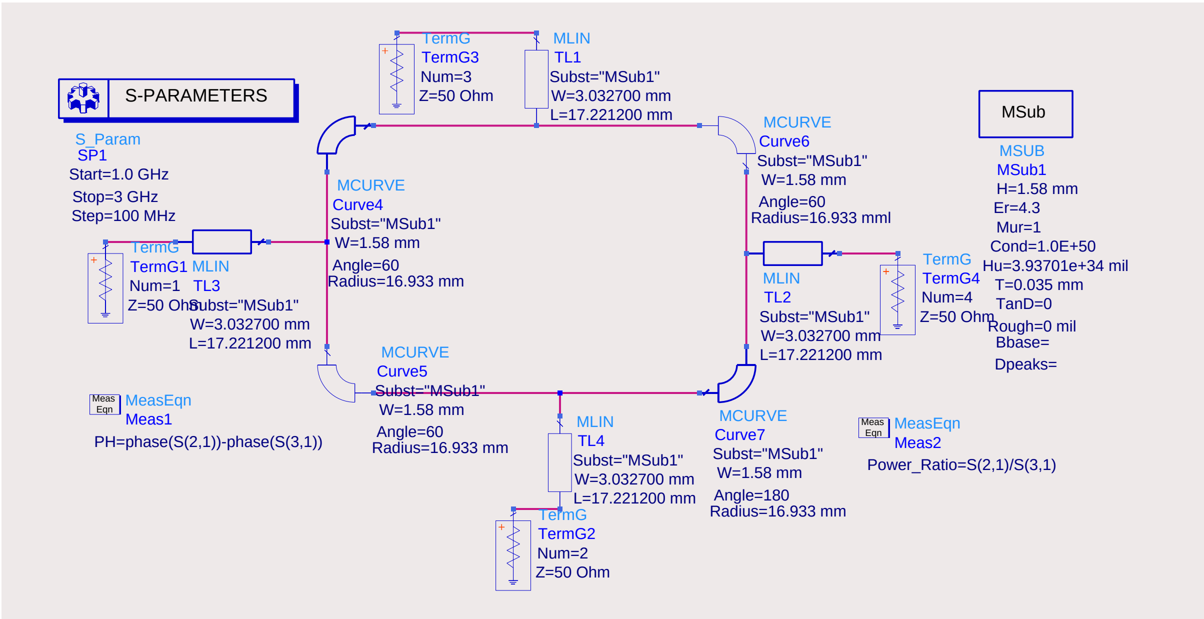

Fig. 6: ADS-Schematic diagram of 2.4 GHz Ring Coupler

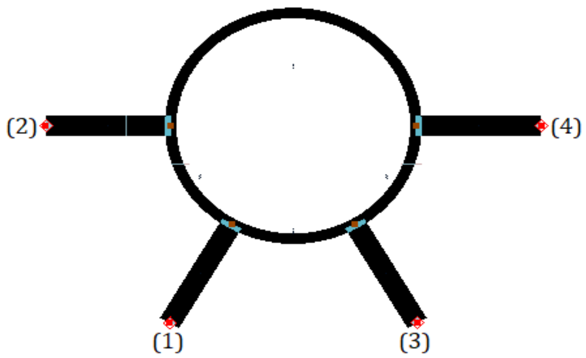

Fig. 7: ADS-layout of 2.4 GHz Ring Coupler

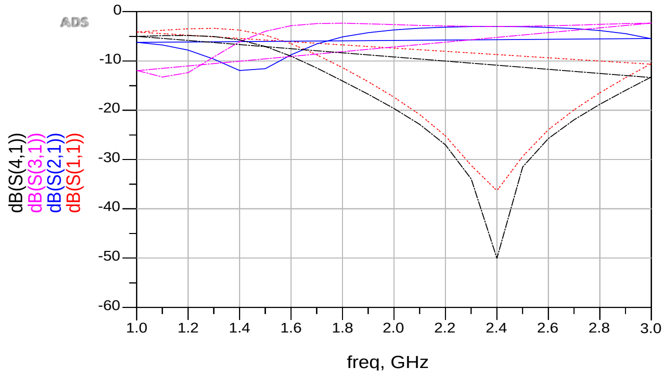

Fig.8 $|S_{11}|$, $|S_{21}|$ and $|S_{31}|$ and $|S_{41}|$, $|S_{11}|$ in (dB) versus frequency for the 2.4 GHz Ring Coupler

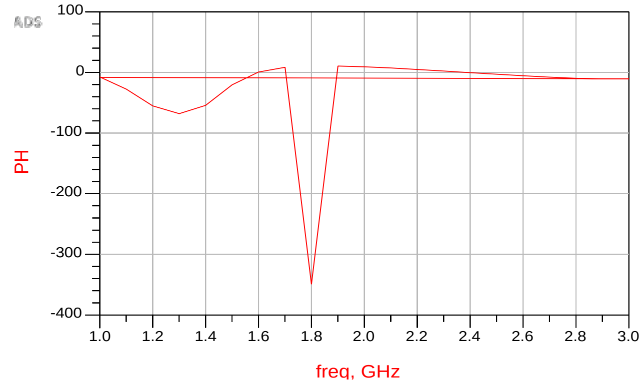

Fig. 9: Phase difference between port 3 and 3 versus frequency of the 2.4 GHz Ring Coupler

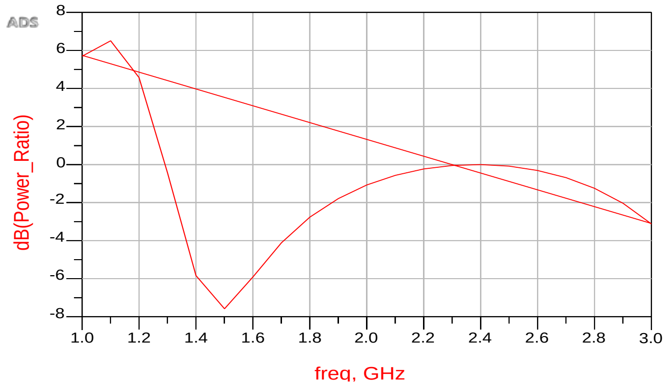

Fig. 10: Output power ration between port 3 and 3 versus frequency of the 2.4 GHz Ring Coupler

D. Design Of A Rectangular Branch-Line Coupler

Input parameters: The substrate parameters with 50Ω normalized impedance are: ε_r = 4.3, h =1.58 mm, and t=0.035. The operating frequency f_o =2.4 GHz, and the coupling factor C = 3 dB.

Output parameters: Width of series line = 5.15 mm, Length of series line = 16.92 mm, impedance of series line = 35.3 Ω,Width of branch line = 2.99 mm, Length of branch line = 17.32 mm, and impedance of series line = 50 Ω.

ADS2017 simulation and optimization

Figure 11 shows the ADS-Schematic diagram of 2.4 GHz rectangular branch-line Coupler. Figure 12 shows the ADS-layout of 2.4 GHz rectangular branch-line Coupler. Figure 13 shows $|S_{11}|$, $|S_{21}|$ and $|S_{31}|$ and $|S_{41}|$, $|S_{11}|$ in (dB) versus frequency for the 2.4 GHz Rectangular branch-line Coupler. Figure 14 shows the phase difference between port 2 and 3 versus frequency of the 2.4 GHz rectangular branch Coupler. Figure 15 shows the output power ration between port 2 and 3 versus frequency of the 2.4 GHz Rectangular branch-line coupler

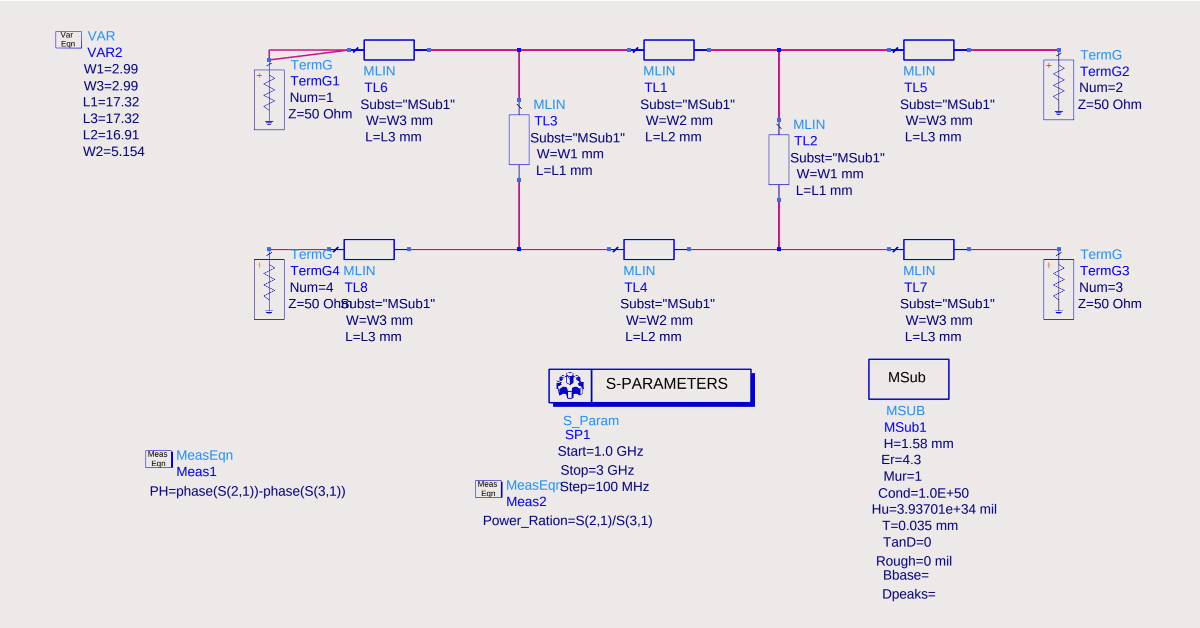

Fig. 11: ADS-Schematic diagram of 2.4 GHz rectangular branch-line Coupler

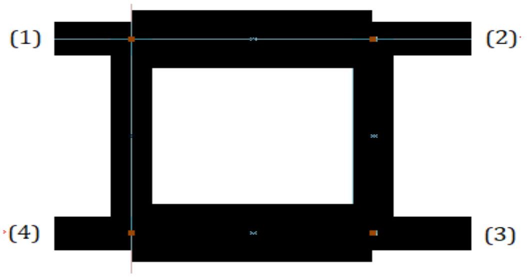

Fig. 12: ADS-layout of 2.4 GHz rectangular branch-line Coupler

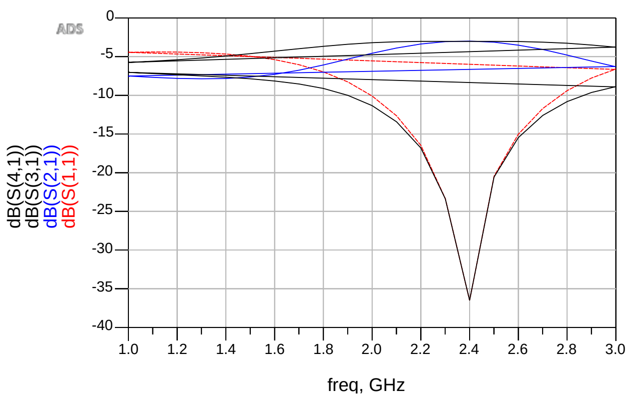

Fig.13 $|S_{11}|$, $|S_{21}|$ and $|S_{31}|$ and $|S_{41}|$, $|S_{11}|$ in (dB) versus frequency for the 2.4 GHz Rectangular branch-line Coupler

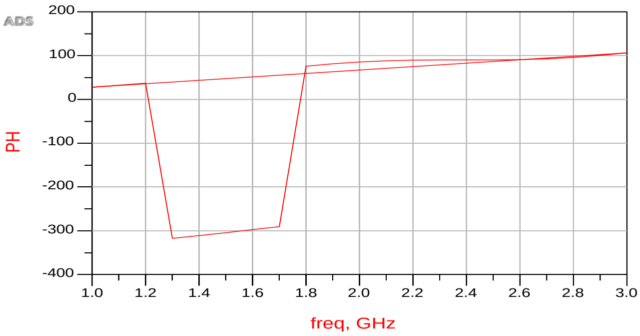

Fig. 14: Phase difference between port 2 and 3 versus frequency of the 2.4 GHz rectangular branch Coupler

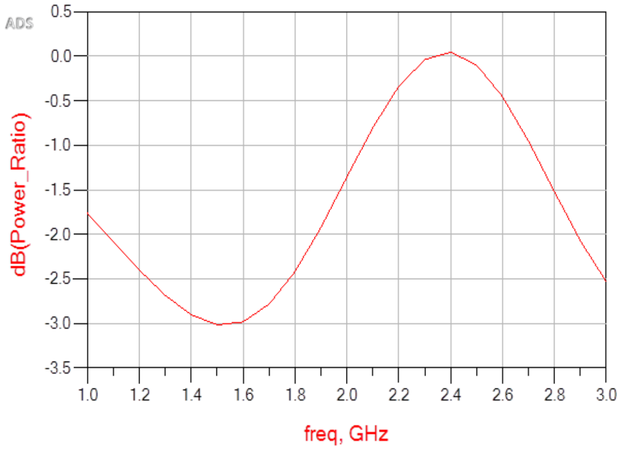

Fig. 15: Output power ration between port 2 and 3 versus frequency of the 2.4 GHz Rectangular branch-line coupler

V. CONCLUSION

This paper illustrates the general description of a user-oriented program called **HHSS4** for Microstrip circuit design performed by the author. The developed program is a full-scale comprehensive design program used for passive microwave circuit design such as directional couplers (especially circular/rectangular branch-line couplers, ring couplers, Wilkinson couplers, Lange couplers, and coupled-line couplers) and maximally flat or Chebyshev lowpass filters. The program is used also for the design of linear microwave active circuits such as amplifiers, oscillators, and mixers. The program can also be used for stability change from unconditional stability to potential unstability and vice versa by connecting a series feedback stub with a certain length or connecting a cascaded resistor to the transistor terminals. The matching circuit obtained by the program is accurately calculated without using Smith chart either by using stub lines of given Z_0 with different lengths or $\lambda g/8$ ($3\lambda g/8$) stub lines with different characteristic impedance. The results of the analysis of the Microstrip amplifiers, oscillators and couplers using ADS2017 proved the accuracy of the designed circuits using HHSS4 program

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