Novel Technique Developed to Design and Simulate RF Amplifier Using GaAs MESFET In ADS Tool

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***Abstract*—This paper concern with the design and simulation of RF amplifier using MESFET [TIM 8596_4UL] at 8.1 GHz to 10 GHz within x-band frequency range. RF amplifier designs rely on the terminal characteristics of the transistor as represented by S-parameter. S-parameter of transistor provides the necessary values to perform the analysis such as stability, DC-biasing and available gain. Based on the S-parameter of the transistor and certain performance requirements a systematic approach for the designing of RF power amplifier is developed using ADS[Advanced Design System]. RF amplifier circuit designed and simulated in ADS which has better stability but low magnitude of S21. By optimizing the DC-biasing circuit and using proper values of passive components, dielectric constant weachieved better performance.**

***Keywords*-RadioFrequency,S-parameter, Gain,Gap CapacitorStability, x-band, etc.**

I. INTRODUCTION

Gallium Arsenide [GaAs] field effect transistors are vital devices for MICused in X-band frequencies because of low power requirements, high efficiency and better stability. The GaAs MESFET has increasingly been adopted in large-signal microwave applications such as power amplifiers and oscillators [1]. As is well known, an essential prerequisite for Advanced Design System (ADS) software to obtain a reliable design depends critically on an accurate DC bias class A amplifier model for GaAs MESFET, especially its linear behavior. Therefore, much work has been undertaken and varieties of analytical models have been developed to describe the operation characteristics of a GaAs MESFET. Among the field-effect transistor (FET)'s nonlinear characteristics, the most important ones are the drain–source performance and the linear gate charge with respect to drain–source and gate–source voltages. It is worth noting that the accuracy of the charge model affects the simulation results for frequency-dependent characteristics such as S-parameters, as well as linear properties includingstability, maximum gain.

II. LITERATURE REVIEW

This paper presentamplifiers for the first time.The author demonstrated the input power dependency of the flicker noise temperature and shown it to be significantly higher than the corresponding tovalue at the amplifier ambient temperature even for input powers which are well below the 1 dB gain compression point. The flicker noise demonstrates a dramatic increase as the amplifier physical temperature is reduced below 100 K, in direct contrast to the well understood temperature dependence of the small-signal noise temperature. It forces us to operate the GaAs MESFET amplifiers at 77 K or 300 K instead of in a liquid helium environment and to reduce the carrier powers to$< -60\ dBm$to achieve reasonable noise temperature close in to the carrier. [4] The aim of this work is to design and analyze power amplifiers that operate in the microwave band (9-11GHz) within the X-band and used in the terminal stage of solid-state transmitters. Design and analysis approach is entirely S-parameters dependent [5]. In this paper real frequency technique is modified to design a stability-guaranteed broadband microwave amplifier consisting of a potentially inconsistent transistor. The load and source terminations can be complicated impedances. The stability is maintained by the conductance resulted from transforming the source and load terminations through the input and output matching circuits. The input and output matching circuits are derived at the same time, instead of consecutive [3]. Retell the design of an example from a previous paper shows that the transducer gain obtained by using this method is better, with some other matching circuit elements, than by using Super compress optimizers. And, withthe equal quantity of matching circuit elements, the transducer gain is slanderly higher than that by using the dynamic CAD technique.

This paper, discussed the 168-hour burn-in and 1000-hour life tests for the hybrids that have been undergoing device screening and space qualification testing. Burn-in test shows the almost same 140 samples, negligible changes showed there were minor shifts in certain device parameters such as the 1 -dB compression and power gain, although the gate currents and DC drain. Such initial parameter shifts are distinctive of devices settling into their fix long-term useful-life behaviors. All preliminary indications point to sufficient device reliability for the MESSENGER space mission [9].

III. DESIGN PROCEDURE

GaAs MESFET is used to design a power amplifier.
Q-point is verified which lies in active region in voltage-current characteristics.
Using s-parameters of device we have analyzed amplifier stability at different stages as measured by the K factor.Simulation Parameters: DC bias, Stability, Gain

$$K = \left[[1 - |S11|^2 - |S22|^2] - |DELTA|^2\right] / 2|S12\,S21|] \quad (1)$$

$$DELTA = |S11 \times S22 - S12 \times S21| \quad 1 \quad (2)$$

Basic Circuit of Power Amplifier:

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Basic circuitry of power amplifier in this research work includes the GaAs MESFET due to its less power dissipation as compare to BJT, MOSFET, and JFET. MESFET TIM 8596_4UL of Toshiba is used for biasing of class Apower amplifier. Inductor is used as a RF chokes and capacitor is used as a block capacitor [DC block] and source capacitor Cs is used as a bypass capacitor. Simulation of MESFET TIM 8596_4UL required a pre-defined data sheet at 8.1 GHz to 10 GHz within x-band frequency range. RF amplifier designs rely on the terminal characteristics of the transistor as represented by S-parameters. S-parameter of transistor provides the necessary values to perform the analysis such as stability, maximum gain, RF frequency etc.
In the design of the power amplifier with the S-parameter method determines whether the transistor is stable or unstable.
This can be analytically proved by using equation of stability and gain easily estimated by using the stability factor [K] and delta [5]. The power amplifier will be stable if it is calculated and then design is verified in [Advanced Designed System] ADS tool

K>1 and meg (delta<1)

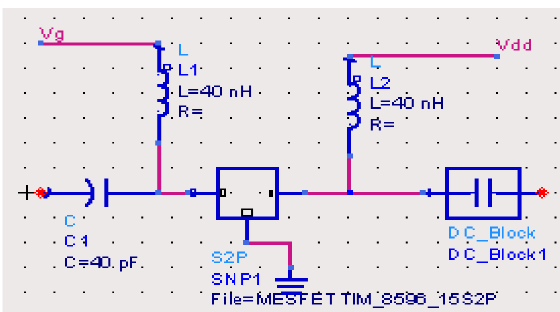


FIGURE 1: Basic circuitry of power amplifier

Design of RF-Power amplifier circuit using MESFET [TIM 8596_4UL\Toshiba]. In this paper we have to use the standard data sheet of the MESFET [TIM 8596_4UL\Toshiba] having slandered magnitude and angles i.e. S2P FILE_8596_15, in this research designing of power amplifier,Initially it is necessary that the system must be matched i.e. input and output ports must be matched with the 50 ohm termination resister. Bias the circuit with DC biasing. Then it is used to insert RF choke as inductor, and capacitors for dc-blocking. Matched RF-amplifier circuit with the terminating at input and output ports with 50 ohms, Having S-Parameters START=8.1GHz, STOP=8.9GHz, STEP=50MHz. This work is simulatedin ADS tool.

IV. MEASUREMENTS

The design and simulation of RF amplifier using MESFT [TIM 8596_4UL] at 8.1 GHz to 10 GHz within x-band frequency range According to Data sheet**.**

Calculation of Rs and Vgs

Drain to Source Current [I_{ds}=0.8 A]

Drain voltage [V_{dd}=12V]

$$Vdd = Vds + IdRs \quad (3)$$

$$Vgs + IdR = 0 \quad (4)$$

By using above equations we calculated the Source Resistance [Rs].

$$12 = 10 + 0.8Rs \quad (5)$$

$$Rs = 2.5\Omega \quad (6)$$

$$Vgs + IdRs = 0 \quad (7)$$

$$Vgs = -0.8 \times 2.5 \quad (8)$$

$$Vgs = -2V \quad (9)$$

Calculation ofInductor [L]

$$L = 5.08 \times 10^{\wedge} - 3 \times l \times \ln\left[\frac{l}{w+t} + 1.19 + 0.022 \times \frac{w+t}{l} nH \quad (10)$$

By using above formulae length and width of inductor [L] were calculated.

Calculation of Capacitor [C]

Capacitor used in our DC biasing circuit is Gap Capacitor and the values are taken from reference [9].

Calculation of Stability Factor [K]

$$K = \frac{[[1 - |S11|^2 - |S22|^2] - |DELTA|^2]}{2|S12\ S2|} \quad (11)$$

$$DELTA = |S11 \times S22 - S12 \times S21|\ less\ than\ 1 \quad (12)$$

V. DESIGN AND SIMULATED RESULT

I. Designof RF Power Amplifierwith source grounded

By using Advanced Design System [ADS] Tool we have to design and simulate the RF Power Amplifier with source grounded. By using the S-parameters S_param SP1, analysis of stability factor (K) is done. S-parameters having START at 8.1 GHz, STOP at 10GHz and STEP at 50MHz. For the stable system we have to use stability factor, Stab Fact1=stab_fact(S). For the system gain MaxGain1=max_gain(S) to obtained maximum gain by the circuit.

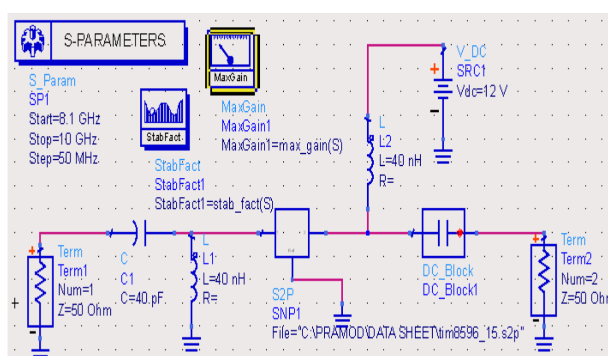


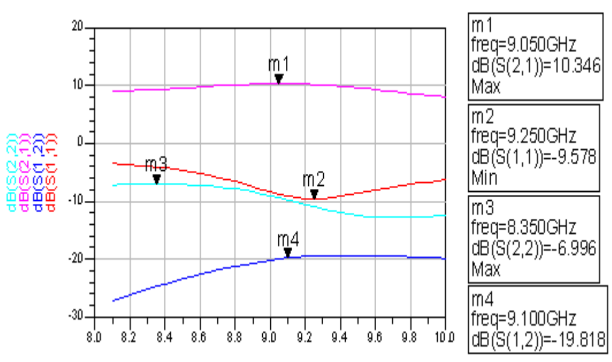
FIGURE I (a) Design of RF Power Amplifier with source grounded.

DATA ITEM S2P [TWO PORT] is used as a MESFET, Data Sheet of MESFET 8596 TIM_4UL is browse in it. Power supply V_DC, 12V is used.
Circuitry is terminated with Term1 and Term2of 50 ohms terminating resistances. Capacitor C1 of 40pF and DC_Block1 is used for blocking DC supply. Inductors L1and L2 of 40 nH. Circuit is perfectly grounded by simulating then we got the following results:

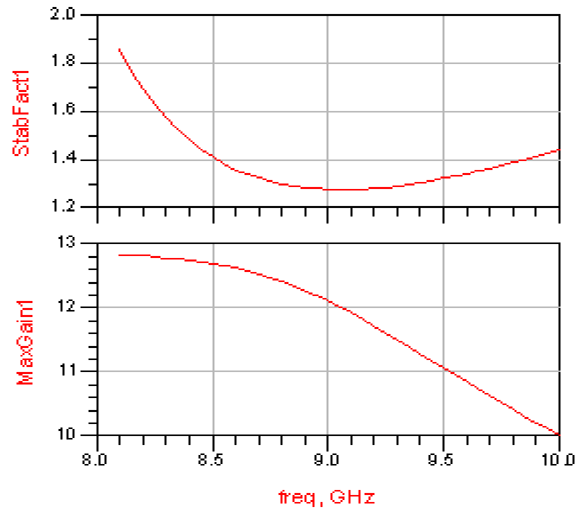
TABLE I (a): Relationship between Frequency, S21 (Transmission Coefficient), Maximum Gain, stability Factor [K]

freq	S(2,1)	MaxGain1	freq	StabFact1
8.100 GHz	2.844 / -49...	12.815	8.100 GHz	1.859
8.150 GHz	2.858 / -55...	12.815	8.150 GHz	1.767
8.200 GHz	2.876 / -60...	12.805	8.200 GHz	1.694
8.250 GHz	2.893 / -65...	12.783	8.250 GHz	1.631
8.300 GHz	2.914 / -71...	12.769	8.300 GHz	1.575
8.350 GHz	2.938 / -76...	12.757	8.350 GHz	1.524
8.400 GHz	2.963 / -81...	12.731	8.400 GHz	1.483
8.450 GHz	2.990 / -87...	12.708	8.450 GHz	1.443
8.500 GHz	3.020 / -92...	12.678	8.500 GHz	1.411
8.550 GHz	3.052 / -98...	12.651	8.550 GHz	1.383
8.600 GHz	3.086 / -10...	12.618	8.600 GHz	1.358
8.650 GHz	3.120 / -10...	12.573	8.650 GHz	1.339
8.700 GHz	3.151 / -11...	12.518	8.700 GHz	1.323
8.750 GHz	3.184 / -12...	12.465	8.750 GHz	1.310
8.800 GHz	3.213 / -12...	12.403	8.800 GHz	1.298
8.850 GHz	3.240 / -13...	12.342	8.850 GHz	1.288
8.900 GHz	3.260 / -13...	12.263	8.900 GHz	1.283
8.950 GHz	3.277 / -14...	12.183	8.950 GHz	1.279
9.000 GHz	3.287 / -15...	12.105	9.000 GHz	1.275
9.050 GHz	3.291 / -15...	12.012	9.050 GHz	1.276
9.100 GHz	3.289 / -16...	11.925	9.100 GHz	1.276
9.150 GHz	3.273 / -17...	11.815	9.150 GHz	1.278
9.200 GHz	3.256 / -17...	11.715	9.200 GHz	1.282
9.250 GHz	3.231 / 17...	11.613	9.250 GHz	1.285
9.300 GHz	3.197 / 16...	11.502	9.300 GHz	1.292
9.350 GHz	3.158 / 16...	11.397	9.350 GHz	1.297
9.400 GHz	3.117 / 15...	11.290	9.400 GHz	1.304
9.450 GHz	3.068 / 15...	11.168	9.450 GHz	1.314
9.500 GHz	3.018 / 14...	11.057	9.500 GHz	1.323

Table I (a):Simulation Results:S21 [Transmission coefficient], Maximum Gain, Stability Factor with Frequency.Shows k>1, Gain varies 11.057 dB to 12.815 dB, Transducer gain S21 not better. Stability of circuit is good but maximum gain is not as per required.



FIGUREI (b): S-Parameters (dB) versus frequency (GHz)



FIGUREI (c): Maximum Gain and Stability Factor[K] versus Frequency.

II. Design of RF Power Amplifier with source grounded by using micro strip.

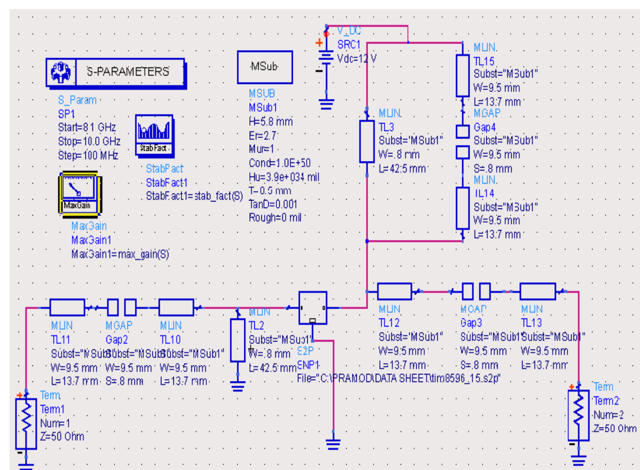


FIGURE II (a) Design of RF Power Amplifier with source grounded by using micro strip.

Above circuit is same as fig: 3, all the lumped components are replaced by micro strip and substrate MSUB1 is used to define the substrate parameters.In the above circuit R, L and C are replaced by microstrip for the better stable circuit.

TABLE II (a):Simulation Results: S21 [Transmission coefficient], Maximum Gain, Stability Factor with Frequency.

freq	MaxGain1	StabFact1	S(2,1)
8.100 GHz	11.878	2.243	1.678 / -23.417
8.200 GHz	12.386	1.834	2.512 / -81.178
8.300 GHz	12.450	1.669	2.702 / -122.775
8.400 GHz	12.451	1.557	2.745 / -156.802
8.500 GHz	12.419	1.473	2.772 / 172.847
8.600 GHz	12.372	1.412	2.830 / 144.343
8.700 GHz	12.282	1.372	2.928 / 116.322
8.800 GHz	12.175	1.343	3.060 / 87.569
8.900 GHz	12.043	1.325	3.191 / 57.645
9.000 GHz	11.887	1.316	3.269 / 25.930
9.100 GHz	11.705	1.317	3.236 / -6.908
9.200 GHz	11.479	1.328	3.071 / -40.381
9.300 GHz	11.226	1.346	2.804 / -74.232
9.400 GHz	10.922	1.380	2.462 / -109.482
9.500 GHz	10.434	1.461	1.982 / -150.032
9.600 GHz	8.745	1.948	0.991 / 148.214
9.700 GHz	4.720	4.515	0.457 / -11.808
9.800 GHz	9.715	1.559	2.523 / -147.727
9.900 GHz	9.608	1.564	2.064 / 151.747
10.00 GHz	9.041	1.706	1.525 / 105.464

The above table II (a) shows stability is greater than 1 as per requirement varies between 1.328 dB to 4.515 dB. Gain varies from 9.041 dB to 12.450 dB as frequency increases Maximum Gain decreases. In this circuit we are getting better stability at 8.1GHz to 9GHz At 9.7 GHz.

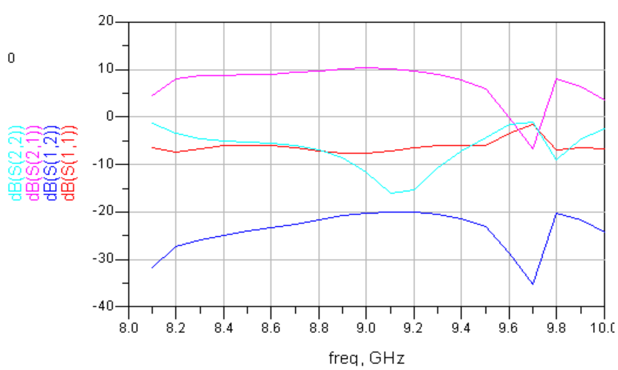


FIGURE II (b): S-Parameters (dB) versus frequency (GHz)

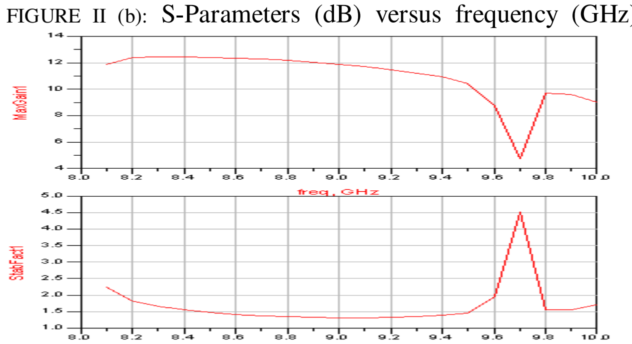


FIGURE II (c): Maximum Gain and Stability Factor [K] versus Frequency.

Frequency stability instantly decreases and Maximum Gain increases rapidly. For the further improvement we use another circuit parallel of R and C with source. This provides better results. For the simulation we used the MSUB [M Substrate] with specific height [H], permittivity [ε] according to di-electric material.

III Design & Simulation of RF Amplifier with R and C in parallel

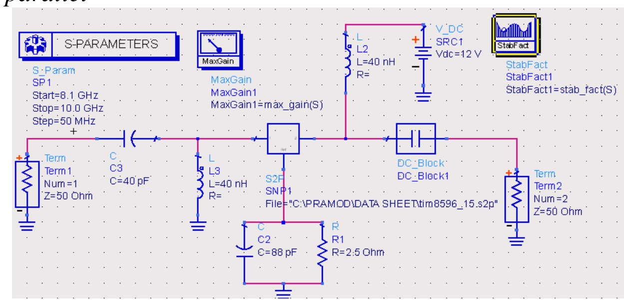


FIGURE III (a): Design & Simulation of RF Amplifier with R and C in parallel

Circuitry is terminated with Term1 and Term2 of 50 ohms terminating resistances. Rs [for negative feedback] and Cs [as a bypass] is used at the source. Circuit is perfectly grounded by simulation we got the following results:

When swept over a range of frequencies, it can be clearly seen where the device will be unconditionally stable (above 8.1 GHz).

G_T [Transducer Gain] is used to also calculate and plot MSG and the transducer gain, G_T, the transducer gain when both Γ^S and $\Gamma^L = 0$, $G_{T=}|S21|^2$

In the regions where K < 1, the maximum gain function plots MSG obtained.

These factors are easily calculated using Measurement Equations in the ADS schematic panel. K derived by S-parameter.

TABLE III (a): Simulation Results: S21 [Transmission coefficient], Maxi Gain, Stability Factor with Frequency.

freq	MaxGain1	StabFact1	S(2,1)
8.100 GHz	12.784	1.722	2.835 / -49.756
8.150 GHz	12.782	1.652	2.849 / -55.073
8.200 GHz	12.769	1.597	2.866 / -60.393
8.250 GHz	12.745	1.550	2.882 / -65.732
8.300 GHz	12.728	1.508	2.903 / -71.049
8.350 GHz	12.713	1.469	2.926 / -76.378
8.400 GHz	12.685	1.437	2.951 / -81.742
8.450 GHz	12.660	1.406	2.978 / -87.173
8.500 GHz	12.628	1.382	3.007 / -92.651
8.550 GHz	12.600	1.360	3.039 / -98.159
8.600 GHz	12.566	1.341	3.072 / -103.756
8.650 GHz	12.521	1.327	3.106 / -109.455
8.700 GHz	12.466	1.316	3.137 / -115.185
8.750 GHz	12.415	1.306	3.170 / -121.097
8.800 GHz	12.354	1.298	3.200 / -127.123
8.850 GHz	12.297	1.290	3.228 / -133.134
8.900 GHz	12.222	1.287	3.248 / -139.252
8.950 GHz	12.146	1.285	3.266 / -145.506
9.000 GHz	12.073	1.283	3.278 / -151.868
9.050 GHz	11.986	1.284	3.283 / -158.141
9.100 GHz	11.906	1.285	3.283 / -164.563
9.150 GHz	11.803	1.289	3.269 / -171.015
9.200 GHz	11.710	1.293	3.253 / -177.386
9.250 GHz	11.616	1.296	3.230 / 176.208
9.300 GHz	11.512	1.302	3.197 / 169.835
9.350 GHz	11.415	1.307	3.160 / 163.531
9.400 GHz	11.315	1.314	3.120 / 157.292
9.450 GHz	11.200	1.324	3.072 / 151.110
9.500 GHz	11.096	1.331	3.023 / 145.061
9.550 GHz	11.004	1.338	2.976 / 138.991

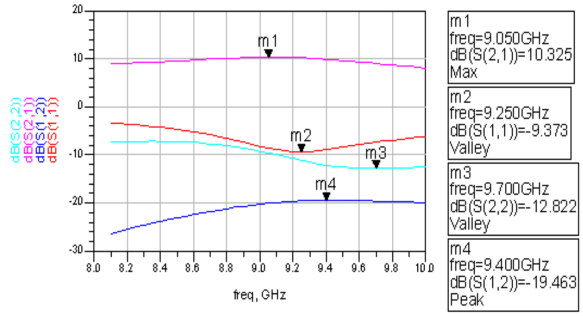


FIGURE III (b): S-Parameters (dB) versus frequency (GHz)

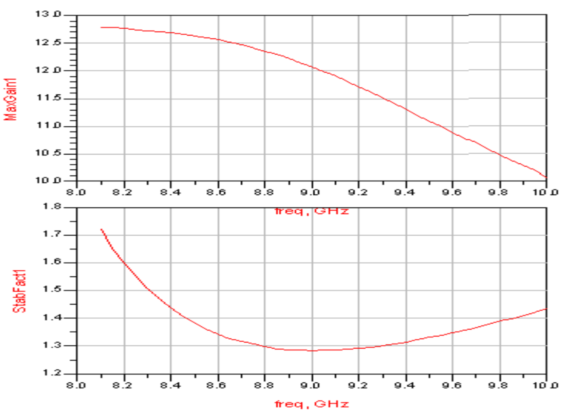


FIGURE III (c): Maximum Gain and Stability Factor [K] versus Frequency.

IV. Design & Simulation of RF Amplifier with R and C in parallel with microstrip.

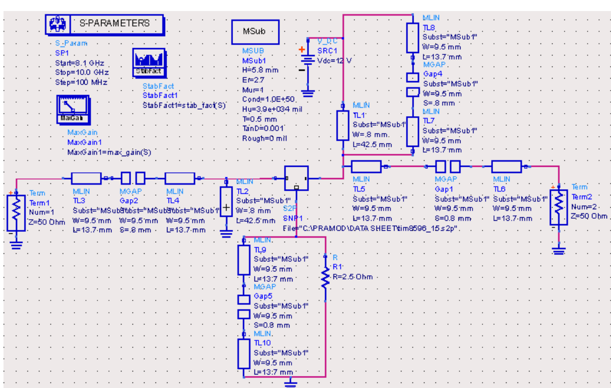


FIGURE IV (a) Design & Simulation of RF Amplifier with R and C in parallel with microstrip

Same circuitry as above figure II (a) all the lumped components are replaced by micro strip and substrate MSUB1 with specific height [H], permittivity [ε] according to di-electric material, is used to define the substrate parameters

TABLEIV (a):Simulation Results: S21[Transmission coefficient], Maxi Gain, Stability Factor with Frequency.

freq	MaxGain1	StabFact1	S(2,1)
8.100 GHz	15.981	1.028	1.763 / -33.550
8.200 GHz	16.106	1.006	2.354 / -88.164
8.300 GHz	14.819	1.080	2.491 / -127.211
8.400 GHz	14.017	1.176	2.523 / -160.043
8.500 GHz	13.362	1.283	2.542 / 170.266
8.600 GHz	12.816	1.386	2.589 / 142.153
8.700 GHz	12.313	1.477	2.671 / 114.340
8.800 GHz	11.874	1.539	2.782 / 85.666
8.900 GHz	11.479	1.572	2.887 / 55.726
9.000 GHz	11.123	1.580	2.936 / 23.988
9.100 GHz	10.799	1.573	2.882 / -8.840
9.200 GHz	10.484	1.558	2.708 / -42.229
9.300 GHz	10.188	1.540	2.446 / -75.949
9.400 GHz	9.880	1.533	2.117 / -111.033
9.500 GHz	9.410	1.576	1.661 / -151.302
9.600 GHz	7.642	2.097	0.777 / 149.262
9.700 GHz	3.425	4.981	0.381 / -0.773
9.800 GHz	9.023	1.489	2.402 / -141.047
9.900 GHz	9.075	1.436	1.962 / 156.736
10.00 GHz	8.638	1.515	1.464 / 110.343

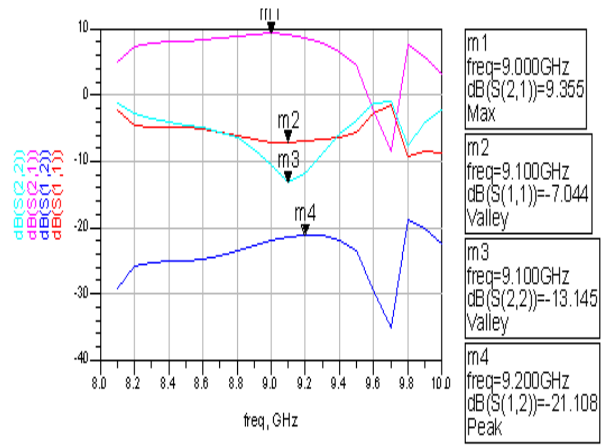


FIGURE IV (b): S-Parameters (dB) versus frequency (GHz)

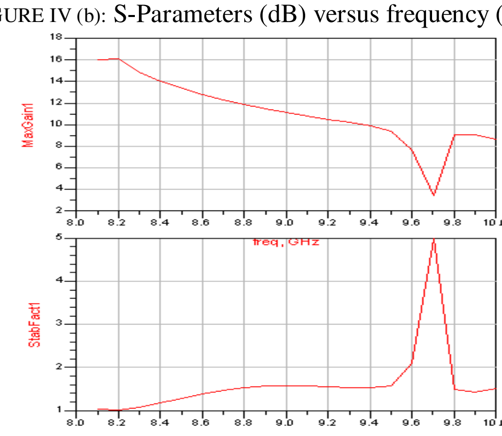


FIGURE IV (c): Maximum Gain and Stability Factor [K] versus Frequency.

In the above circuit R, L and C replaced by micro strip which improves the stability factor and maximum gain as compared to above circuits. We got better stable circuit varies from 1.006 dB to 2.097 dB, at 9.7 dB stability increases rapidly according to frequency of the circuit while gain decreases simultaneously. We achieve better stable system at 8.1 GHz to 9.4 GHz and 9.8 GHz to 10 GHz frequency. Better gain at the same frequency range.

VI. CONCLUSION

Various research worksis going on in the field of RF-Power Amplifier, LNA Designing, and Mixer Designing after studying various research papers we decided to doDESIGN AND SIMULATION OF RF-POWER AMPLIFIER USING Ga-As MESFET**.** We studied about design and simulation of different techniques RF-amplifier. We used X-band frequency range which is used in microwave laboratoriesto perform various experiments that are very compatible to exchange the damaged elements or components in the circuit.By optimizing the DC-biasing circuit and using proper values of passive components better performance achieved, it can be further improved by using chip resister optimum value of di-electric constant. Regarding to this technique adopted in realizing the design of power amplifier. By use of suitable substrate material as it offers low loss, the translation from lumped element matching network to microstrip maximum power is delivered to load are used in microwave frequencies, because ease of construction and reproducibility finalized by using ADS 2009. The tuning and optimization of the theoretical design verify the validity of layouts of final power amplifiers, and then verified using the ADS Tool. The DC biasing and class A network must be designedas to confirm, the Q-point of transistor is held at a suggested value, against variations in temperature and other transistor parameters. RF Power amplifier is used in the final stage of Rader Communication system provides increase in gain and better stability.

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