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LNA Design for Airport Surveillance Radar Receiver System

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Abstract:**An airport surveillance RADAR is used to identify and display the presence and position of aircraft in the terminal area which is one of the major responsibility of air traffic control system. One of the major parameters which are to be considered in this RADAR is the receiver system which has to be sensitive enough to capture all the signals. But this will increase noise and reduce the signal strength and then RADAR operation becomes difficult. This problem is reduced due to the use of low noise amplifier at the receiver system which increases the strength of the signal and reduces the noise figure making RADAR operation smoother. In this paper low noise amplifiers with different stabilization techniques are designed to achieve a favorable gain and minimum noise figure with the help of ADS tool and obtained an efficient power gain of 17.613 dB and optimum noise figure of 0.746 dB at 2.8 GHz center frequency in the range of 2.7 GHz to 2.9 GHz.**

Keywords: LNA, RADAR, distributed components, power gain, noise figure

I. INTRODUCTION

In a RADAR communication, the receiver receives all available signals which are normally weak and also contain noise. This signal is passed to RF Amplifier which is a low noise amplifier which eliminates the noise content and improves the signal strength. An airport surveillance RADAR is used to identify and manifest the presence and position of aircraft in the terminal area. It plays a pivotal role in the air traffic control system. Due to the large size of airports, two surveillance RADARs are implemented viz. primary and secondary surveillance RADARs. The primary RADAR operates in S microwave band at 2.7 to 2.9 GHz frequency range which detects the position and range of aircraft. The secondary RADAR operates in L microwave band at 1.03 to 1.09 GHz which interrogates with the transponders of aircraft and gathers its information and send it to the RADAR screen display.The important parameters that determine the overall performance of LNA are gain, input and output impedance matching, noise figure, etc, [1]. Iman Farjamtalab, Seyed Mohsen, Mirhosseini designed low noise amplifiers using lumped elements for wideband wireless receivers operating in S-band and obtained the noise figure of 3.51 dB, 2.6 dB and 2.37 dB at 2 GHz, 3 GHz and 4 GHz respectively. They obtained 1.2 dB, 0.99 dB and 6.02 dB noise figures at 2 GHz, 3 GHz and 4 GHz respectively for LNA's designed using Microstrip transmission line components [2].

R. Ramya, T. Rama Rao and M.S. Vasanthi designed a con-current pent band low noise amplifier for frequencies between 1.2 GHz to 3.3 GHz and obtained power gain in range 15.09 dB at 1.2 GHz to 14.302 dB at 3.3 GHz, noise figure (NF) in range of 0.48 dB at 1.2 GHz to 0.572 dB at 3.3 GHz [3]. Bhushan R. Vidhale, Dipali C. Nitnaware, et al. designed a wideband low noise amplifier with negative feedback for stability improvement and obtained a power gain of 22 dB and noise figure of 2.3 dB at 3 GHz [4]. Firmansyah Teguh, Supriyanto, Herudin, et al designed a multiband low noise amplifier with multi-section impedance transformer for various frequencies and obtained a power gain of 3.81 dB, 2.59 dB, 1.69 dB and noise figure of 1.75 dB, 1.99 dB, 2.9 dB at 0.95 GHz, 1.85 GHz and 2.45 GHz respectively [5].

In this paper, we have managed to design a low noise amplifier for airport surveillance RADAR receiver system by balancing the trade-off parameters.

II. DESIGN DETAILS

The Low Noise Amplifier is designed using pseudomorphic HEMT ATF-35576 of Agilent technologies with different techniques for improving the stability of the device and conclude for a better design in aspects of noise figure, stability and gain of the amplifier. Advanced Design System (ADS) simulation tool is used for designing the low

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noise amplifier. There are two different types of device libraries available in the ADS software namely S – parameter library and RF Transistor library. S – Parameter library works on fixed bias i.e. these parameters of the device are fixed for a particular bias point of the device. In this work, the S – parameter library device is used.

In low noise amplifier, MAG (maximum available gain) and NFmin (minimum intrinsic noise) figure are the important parameters of active devices to be considered, which in turn depends on the S parameters of the device. The S parameters determine the stability criteria of the device at various biasing points. Theoretically, the stability of the device is checked using the K - |Δ| test where K said to be Rollet's Stability described in [6].

The condition for stability is that if K > 1, |Δ| < 1 and B = +ve, then the device is unconditionally stable and if K < 1 then device is potentially unstable. This condition will tend the device to oscillate and the maximum gain that will be obtained is the maximum stable gain (MSG) expressed,

$$MSG = \frac{|S_{21}|}{|S_{12}|} \quad (1)$$

If the device is unconditionally stable i.e. K > 1, then the gain obtained will be maximum available gain which is expressed as,

$$MAG = \frac{|S_{21}|}{|S_{12}|}(K \pm \sqrt{K^2 - 1}) \quad (2)$$

The matching networks help in transferring maximum power from the source to load and hence the circuit should be terminated properly to avoid reflections [7]. Here the circuit is designed using the distributed components i.e. transmission line equivalent of the lumped components because of the fact that at high frequencies in GHz range the lumped components possess parasitics which affect the system performance. The 50ohm terminations are provided for calculating the S parameters of the network

III. PROPOSED DESIGN

Since the device is potentially unstable the theoretical design procedure of LNA and its calculations are time-consuming. First using smith chart we have to plot the input and output stability circles using standard equations of radius and center of stability circles of load and source, and then designing the input and output matching networks which is a tedious activity. This task is much easier to simulate under ADS in minimum time.Different techniques are available to improve the stability of low noise amplifier [8]. Connecting a single passive element or combination of one or more components with the terminals of the active device (here pHEMT) improves the stability of the device. These techniques are:

- Connecting a feedback RLC components between the gate and the drain terminal of HEMT.
- Connecting a parallel RLC combination at the drain terminal of HEMT.
- Connecting a series RLC combination at the gate terminal of HEMT.

The first low noise amplifier designed for this application is shown in fig. 1 in which a resistor, inductor and a capacitor is connected in feedback [9] between the gate terminal and drain terminal of HEMT.

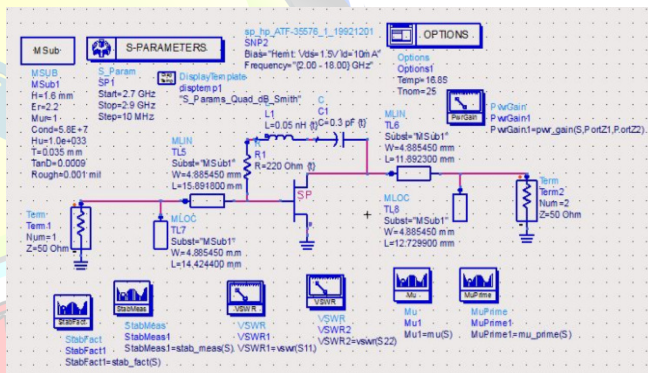

Fig.1.Feedback RLC LNA Design

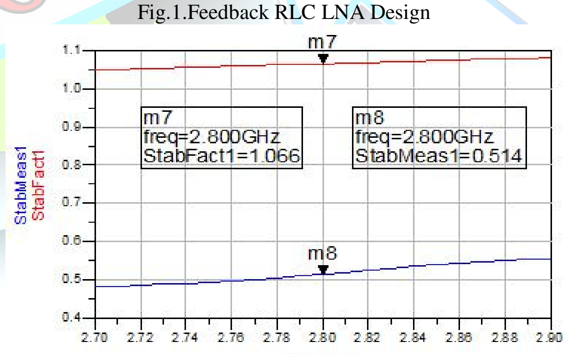

Fig.2.Stability Curve of feedback RLC

In ADS Rollet's stability factor k (m7) and |Δ| (m8) obtained is shown above in fig. 2 which is obtained as 1.066 and 0.514 respectively.

The second design deals with the resistor, inductor,and capacitor in parallel and this combined network connected to the drain terminal of the device as shown in fig. 3.

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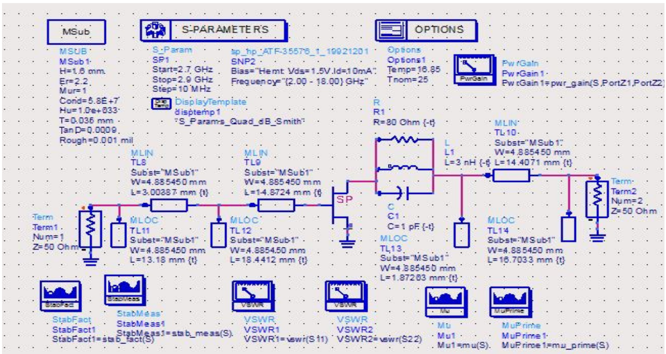

Fig.3.LNA Design with drain RLC network

The Rollet's stability factor k and |Δ| obtained is 1.038 and 0.425 respectively.

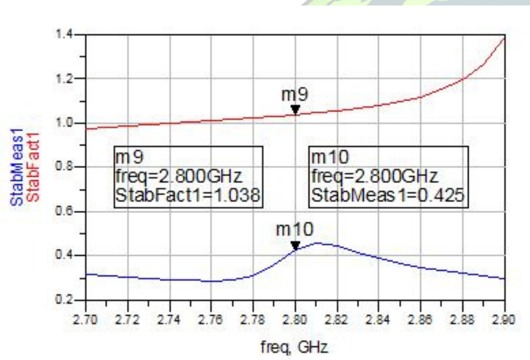

Fig.4. Stability of drain RLC

The third design deals with the RLC components connected in series and the combined network is connected to the gate terminal of the device as shown in fig. 5.

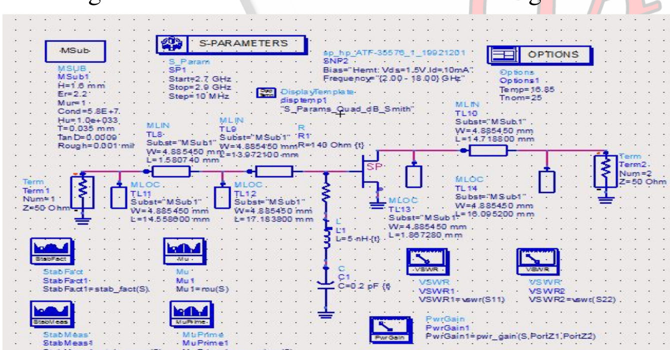

Fig.5. Gate RLC LNA Design

The Rollet's stability factor k and |Δ| denoted as stabfact and stabmeas is shown in fig. 6 which is obtained as 1.039 and 0.432 respectively.

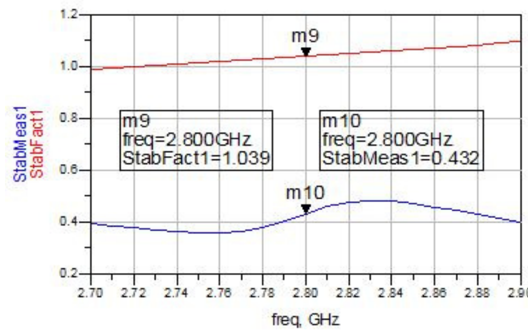

Fig.6. Stability of Gate Series RLC

IV.RESULTS AND DISCUSSION

The addition of matching circuit will vary the stability of overall design and hence the gain and noise figure. The power gain and noise figure obtained for the feedback RLC LNA are 10.019 dB and 2.608 dB as shown in fig. 7 and 8 respectively.

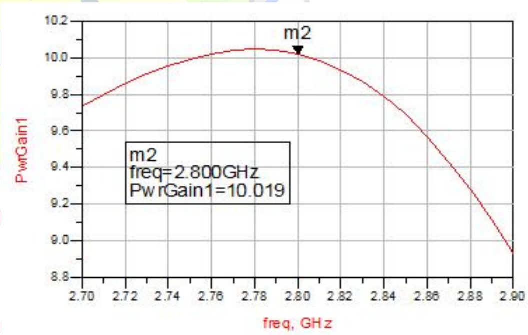

Fig. 7. Power Gain

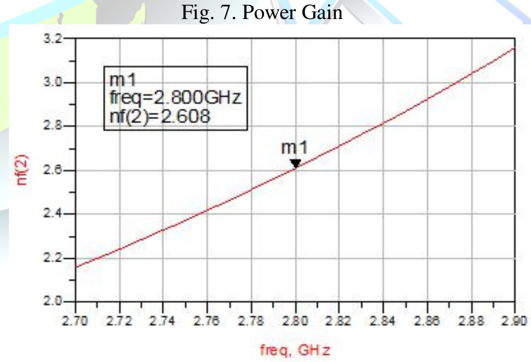

Fig. 8. Noise Figure

Standing wave ratio (VSWR) is another parameter which determines the amount of reflections that occurs in a microwave circuit due to improper impedance matching. It is represented in the form of reflection coefficient which is mathematically represented below. The range of VSWR

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values is 1 < VSWR < ∞ for the corresponding reflection coefficient of $0 < \Gamma < 1$. The VSWR obtained for the source (VSWR1) and load (VSWR2) matching is shown in fig. 9 which are 1.012 and 1.022 at input and output side respectively. The less values of VSWR i.e. nearby 1 signifies that the amount of reflections is very less i.e. negligible.

$$VSWR = \frac{V\max}{V\min} \quad (3)$$

OR

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \text{ Where } \Gamma = \frac{Vr}{Vi} \quad (4)$$

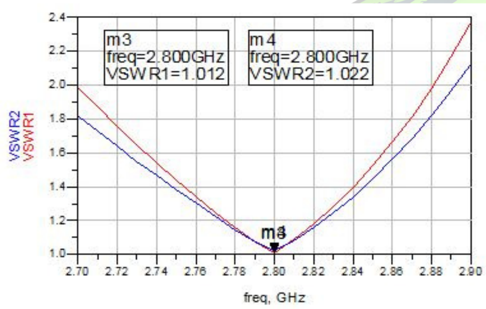

Fig. 9. VSWR

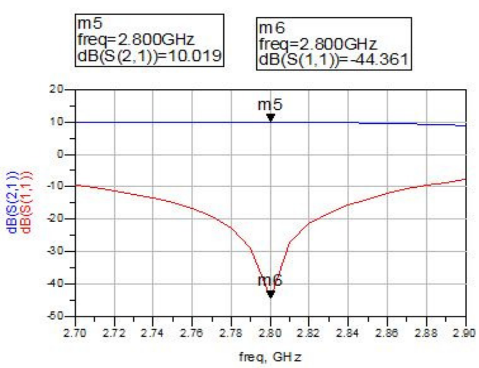

Fig. 10. S_{11} and S_{21} parameters

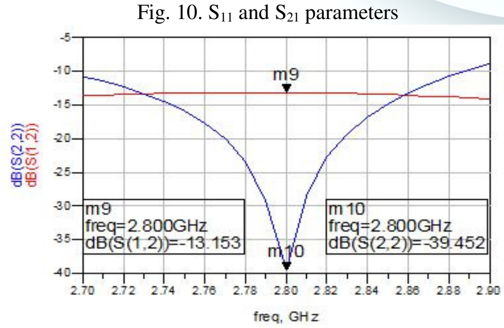

Fig. 11. S_{12} and S_{22} parameters

The S parameters of the designed LNA obtained are shown in fig. 10 and 11 respectively. The S_{11} is -44.361 dB, S_{21} is 10.019 dB, S_{12} is -13.153 dB and S_{22} is -39.452 dB.

The second design with parallel RLC in drain terminal provide a power gain of 17.613 dB and noise figure of 0.746 dB as shown in fig. 12 and 13 respectively.

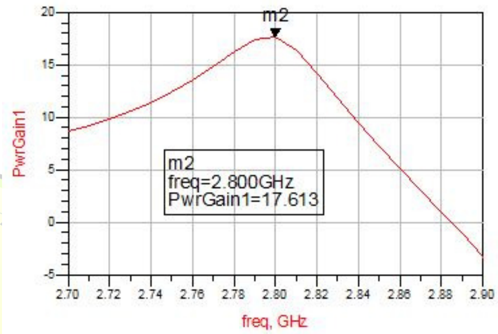

Fig. 12. Power Gain

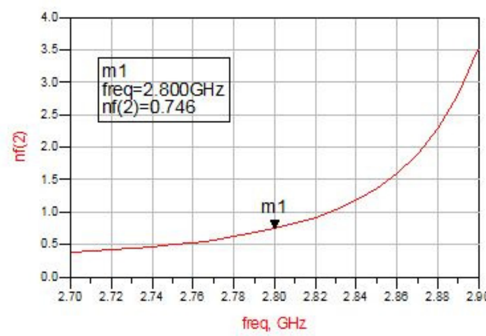

Fig. 13. Noise Figure

The VSWR obtained for the source (VSWR1) and load (VSWR2) matching is shown in fig. 14 which are 1.306 and 1.792 at input and output side respectively.

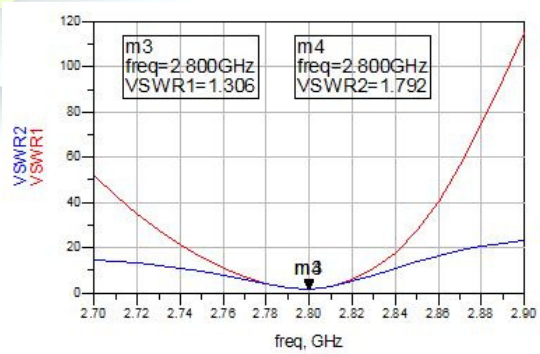

Fig. 14. VSWR

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The S parameters of the designed LNA obtained are shown in fig. 15 and 16 respectively. The S_{11} is -17.534 dB, S_{21} is 17.613 dB, S_{12} is -20.952 dB and S_{22} is -10.942 dB.

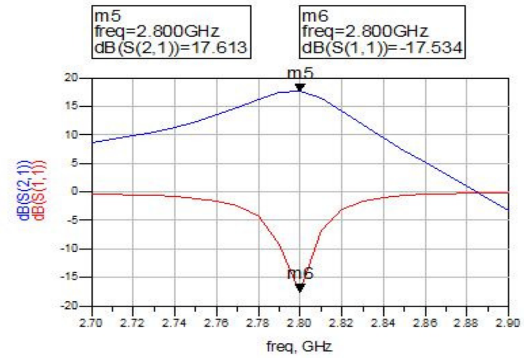

Fig. 15. S_{11} and S_{21} parameters

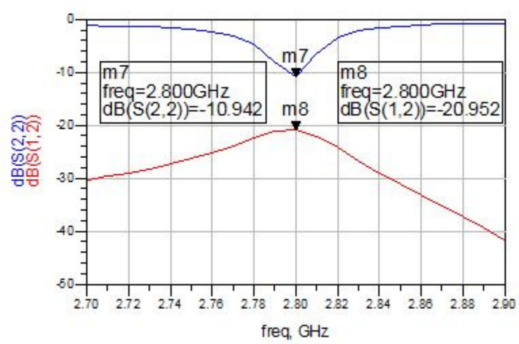

Fig. 16. S_{12} and S_{22} parameters

The third design with series RLC in gate terminal provide a power gain of 18.059 dB and noise figure of 6.476 dB as shown in fig. 17 and 18 respectively.The VSWR obtained for the source (VSWR1) and load (VSWR2) matching is shown in fig. 19 which are 1.084 and 1.020 at input and output side respectively.

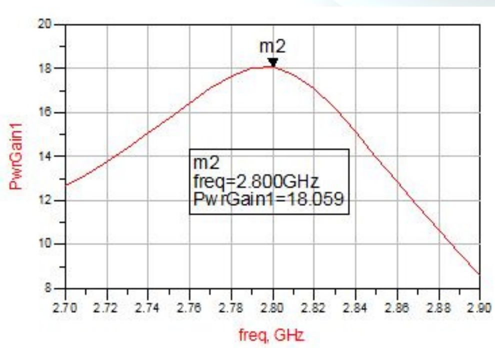

Fig. 17. Power Gain

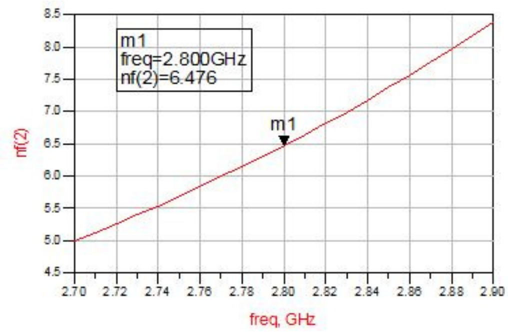

Fig. 18. Noise Figure

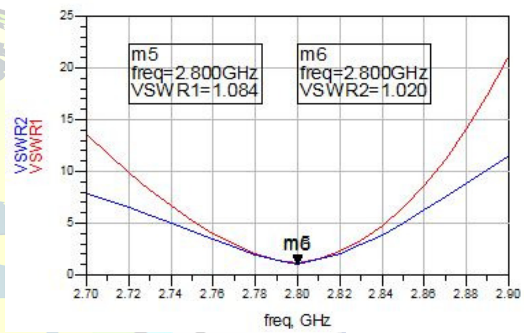

Fig. 19. VSWR

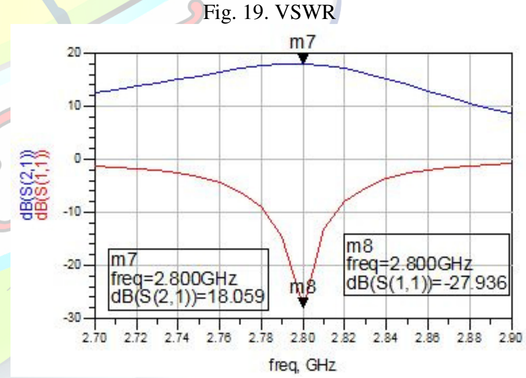

Fig. 20. S_{11} and S_{21} parameters

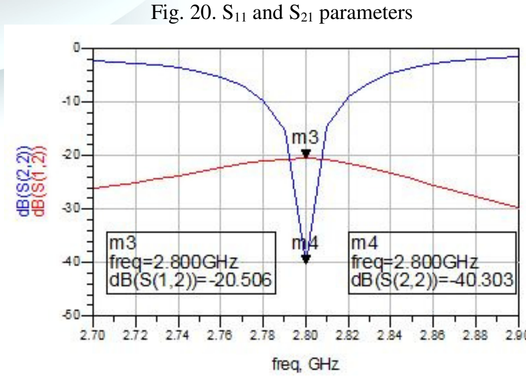

Fig. 21. S_{12} and S_{22} parameters

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The S parameters of the designed LNA obtained are shown in fig. 20 and 21 respectively. The S_{11} is -27.936 dB, S_{21} is 18.059 dB, S_{12} is -20.506 dB and S_{22} is -40.303 dB.

TABLE. 1. SIMULATION RESULTS OF PROPOSED DESIGNS

Parameters	Feedback RLC	Drain RLC	Gate RLC
K	1.066	1.038	1.039
$\|\Delta\|$	0.514	0.425	0.432
S_{11}(dB)	-44.361	-17.534	-27.936
S_{12} (dB)	-13.153	-20.952	-20.506
S_{21}(dB)	10.019	17.613	18.059
S_{22}(dB)	-39.452	-10.942	-40.303
G* (dB)	10.019	17.613	18.059
NF# (dB)	2.608	0.746	6.476
VSWR	1.012 (I) 1.022 (O)	1.306 (I) 1.792 (O)	1.084 (I) 1.020 (O)

G*-Power Gain, NF#- Noise Figure

V. CONCLUSION

Different techniques to improve the stability of the amplifier is discussed and analyzed to determine the suitable LNA for the Airport Surveillance RADAR application. The results of implementation in ADS is presented in this paper. The overall results are proving satisfactory. The amplifier with parallel RLC at drain terminal proves to be efficient and optimum since the power gain of that LNA obtained is 17.613 dB. The S_{11} obtained is -17.534 dB and S_{12} is -20.952 dB. The VSWR obtained is 1.306 onthe input side and 1.792 at output side which shows that the amount of reflections are more but can be improved. Also, the noise figure obtained is 0.746 dB which is very low compared to other LNA designs. Further to improve the gain of the amplifier and to reduce the noise figure inductive degeneration method can be used and also CMOS based cascade and cascode techniques can be implemented.

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BIOGRAPHY

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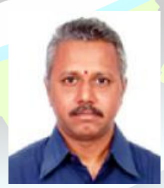

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