Balanced Amplifying Microstrip Patch Antenna at 2.4 GHz

*S.K. Behera, **R. K. Mishra and ***D. R. Poddar
* National Institute of Technology/ Dept. of ECE, Rourkela, Orissa,
** Berhampur University/Department of Electronic Science, Berhampur, India
***Jadavpur University/Department of Electronics and Telecommunication Engineering, Kolkata, India

Abstract— **In this paper a balanced amplifier embedded power amplifying antenna is proposed. The advantages of an ideal balanced configuration include good isolation with improved stability; good input and output external matching; cancellation in the load of products and harmonics are considered in designing a balanced configuration for the active antenna. The noise factor is slightly more than 2.21dB, where as the gain is more than 10dB without any distortion of radiation pattern at the design frequency of 2.4 GHz.**

I Introduction

Most high power amplifying antennas contain two independent devices without any internal transversal connection between them. Invariably these devices are connected in the push-pull [1] configuration. Usually the push-pull configuration is used for relatively narrow band commercial applications from UHF to S-band. Due to its popularity with the circuit designers, it has been implemented in active integrated antenna.

However, there are a variety of alternative configurations to combined external components such as 180-degree splitters/ combiner (baluns [2]), 3 dB quadrature couplers (like branch line or Lange couplers), in-phase couplers (like Wilkinson couplers), etc. In microwave circuits the balanced [3] configuration also finds wide application. This paper proposes the balanced configuration as an alternative to Push-Pull configuration.

II Balanced Configuration

The balanced amplifier employs two quadrature hybrids. Reflections of the input signals due to poor matching are channeled back to a matched load where they get absorbed. Same phenomenon occurs at the output port also. Therefore, theoretically, both at input and output ports one will see matched loads. A schematic of this configuration is depicted in Fig 1.

The real advantages of an ideal balanced configuration include good isolation with improved stability; good input and output external matching; cancellation in the load of products and harmonics like $2f_1+f_2$, $2f_2+f_1$, $3f_1$, $3f_2$, ... and attenuation by 3dB of products like $f_1 \pm f_2$, $2f_1$, $2f_2$... Further the balanced amplifier has clear edge over the push-pull counterpart in terms of the output impedance matching. It is also more stable due to good isolation between its input and output sides. These characteristics have inspired us to consider a balanced configuration for the active antenna instead of the conventional push pull configuration. This amplifier is simulated using AWR Microwave Office™ [6].

The disadvantages include matched load to dissipate power in the decoupled port; no virtual ground and hence less compact structural realization.

III Balanced Amplifying Antenna

Using the optimization feature of the EDA software AWR Microwave Office™, the amplifier was designed for optimized gain and noise figure. Normally, active integrated antenna amplifier design still follows the procedure of microwave transistor amplifiers. The only difference being that the radiating patch acts the load in transmitting case and as source impedance for the receiving antenna. If Z_s is the complex source impedance and Z_l is the input impedance of the patch antenna, then the transducer power gain G_T is defined as the ratio of power delivered to the load Z_l to the power available from the source [7]. The expression for G_T in terms of Γ_s and Γ_l is

$$G_T = \frac{1-|\Gamma_s|^2}{|1-\Gamma_{in}\Gamma_s|^2}|S_{21}|^2\frac{1-|\Gamma_l|^2}{|1-S_{22}\Gamma_l|^2} \tag{1}$$

$$G_T = \frac{1-|\Gamma_s|^2}{|1-S_{11}\Gamma_s|^2}|S_{21}|^2\frac{1-|\Gamma_l|^2}{|1-\Gamma_o\Gamma_l|^2} \tag{2}$$

In the above equations,

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_l}{1-S_{22}\Gamma_l} \tag{3}$$

$$\Gamma_o = S_{22} + \frac{S_{12}S_{21}\Gamma_s}{1-S_{11}\Gamma_s} \tag{4}$$

For unconditional stability of the transistor, the necessary and sufficient condition is expressed by the following two inequalities, in terms of Δ (= $S_{11}S_{22}$-$S_{21}S_{12}$).

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{12}S_{21}|} > 1 \tag{5}$$

$$|\Delta|^2<1 \tag{6}$$

The following gives sample design of a balanced amplifier.

From Fig 2 (a) for the VSWR, the matching at the input and output ports over the desired frequency band is observed to be excellent. The performance of the amplifier is observed in Fig 2 (b) for the noise figure and the gain. Both these observations indicate a satisfactory design. It is also seen that the antenna is

978-1-4244-1864-0/07/$25.00 ©2007 IEEE

properly matched (S22 around -22dB) at the desired frequency of 2.4 GHz. The noise factor is slightly more than 2.21dB, where as the gain is more than 10dB. The radiation pattern at 2.4 GHz is undistorted, which suggests that the antenna is radiating in its dominant mode and the radiation is not contaminated by harmonic interferences.

IV Dual Feed Active Antenna

The inherent disadvantage with the balanced amplifier is the use of the matching load on the return path. This section examines the possibility of elimination of this load from the output port, using dual feed concept. It will also discuss the results obtained using this concept. As is well known, the output from the two amplifiers differs by 90 degree in phase. We propose to use the rectangular patch antenna with orthogonal inset feeds at two different points, as shown in Fig 3. The feeding microstrip lines at these places differ by quarter-wave length. Thus the feed will inherently introduce a phase difference of 90 degree. This throws a challenge in antenna design, because of the mutual impedance between the feed lines. Due to the existing mutual impedance, electrical isolation of the feed lines becomes a daunting task. The following procedure is adopted for this design.

First the amplifier is designed for a 50-ohm termination. Then the antenna is simulated. The starting point assumes no mutual coupling between the feeding lines. So to guess the feed points we calculate the position where the self-impedance shall be 50 ohms. Then a simulation is done and S-Parameters are found out. Then by trial and error method, the feed positions were continuously changed. The next step is the use of the antenna as an integral part of the balanced amplifier. For this the antenna is assumed to be a three-port device, with two input ports (to be connected to the amplifier output) and an imaginary output port matched to free space. Then S-parameters for a three-port circuit are generated, using the S-parameter information of the input ports and the imaginary output port. This S-parameter file is then used for simulation in the AWR Microwave Office™. This is used as a three-port sub-circuit. The two input ports are connected to the amplifier and the output port is terminated on a 376.6-ohm port. Fig. 4 (a) and (b) show the S-parameters at these three ports and between them respectively.

The simulation schematic is shown in the Fig. 5 below. The results of the simulation for the gain and noise figure between the port 1 and port 2 are shown in Fig. 6. The radiation pattern of the dual fed antenna is shown in Fig. 7. It is observed that the patterns of the mono-fed and dual fed antennas are identical. It suggests the same mode is being excited in both the cases and harmonics are not interfering. The reason for this can be that the antenna due to its symmetry has two distinct locations for excitation of the desired mode. By design optimization, these locations are being used for feeding. The 90-degree phase shift between the outputs from the two ends of the balanced amplifier is being cancelled out due to use of additional quarter-wave length on one of the feeding lines of the antenna.

V Conclusion

This paper suggested balanced amplifying antenna and found out its characteristics. For implementing the balanced amplifying antenna, first a balanced amplifier was designed. Its characteristics were observed for noise factor and gain. Then an inset fed rectangular antenna was used to replace the 50 Ohm matched termination in the output port of the hybrid coupler. Again the noise and gain characteristics were observed. Finally a dual fed patch antenna replaced the hybrid. In all the cases it was observed that it is not possible to obtain minimum noise figure and maximum gain simultaneously.

Reference

[1] K.Inoue, K.Ebihara, H.Haematsu, T.Igarashi, H.Takahashi and J.Fukaya, "A 240 W Push-Pull GaAs Power FET for W-CDMA Base Stations", 2000 IEEE MTT-S Digest, pp. 1719-1722.

[2] R. Basset, "Three Balun Designs For Push-Pull Amplifier", Microwave July 1980, pp. 47-53.

[3] S.Song and R.Basset, "S-Band Amplifier Modeled for Wireless Data", Microwave & RF, November 2000, pp. 53-160.

[4] S. Cripps, RF Power Amplifiers for Wireless Communications, Artech House Boston London, pp. 294-302.

[5] L.Max, "Balanced Transistors: A New Option for RF Design", Microwaves, June 1977, pp. 40-46.

[6] "AWR Design Environment", Applied Wave Research Inc.

[7] G. Gonzales, Microwave Transistor Amplifiers: Analysis and Design, 2nd ed., Prentice Hall, Upper Saddle River, NJ, 1997.

[8] "Low Current, High Performance NPN Silicon Bipolar Transistor", Agilent (HP) Technical Data 5965 – 8919E.

Online Resources

[1]www.educatorscorner.com/experiments/pdfs/exp98/exp98tech.pdf

[2] http://literature.agilent.com/litweb/pdf/5967-5486E.pdf

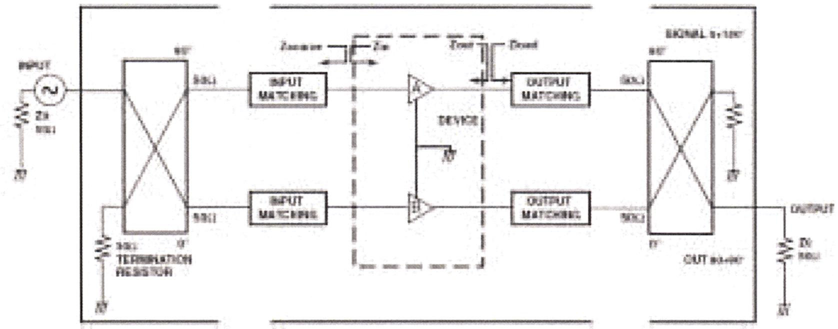

Figure 1 Schematic of Balanced Amplifier

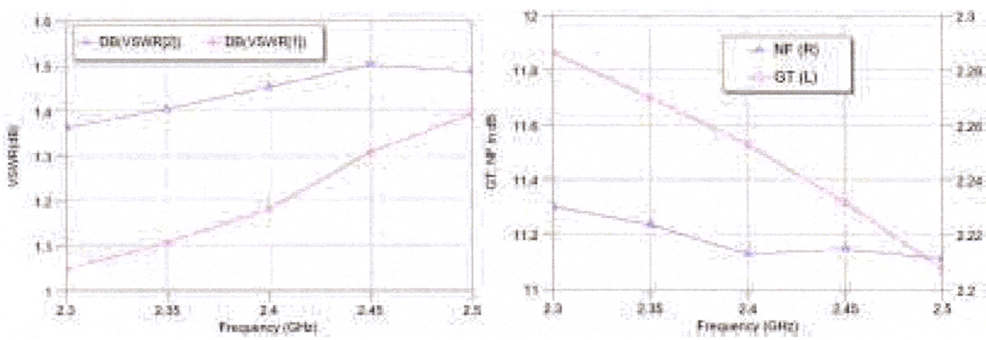

Figure 2 (a) VSWR at the input (#1) and output (#2) ports. (b) Response of Balanced Amplifier

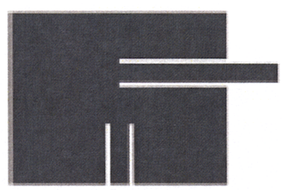

Figure 3 Orthogonal Dual Fed Patch Antennas

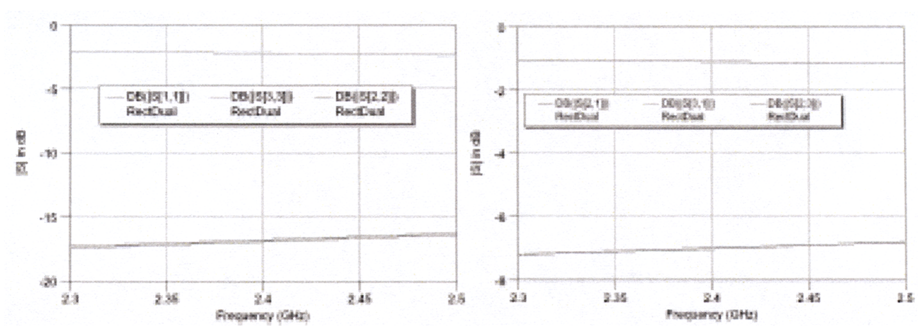

Figure 4 (a) S-Parameters of the Equivalent Three Port for Antenna at each port **(b)** Equivalent Three S-Parameters of Port for Antenna between ports

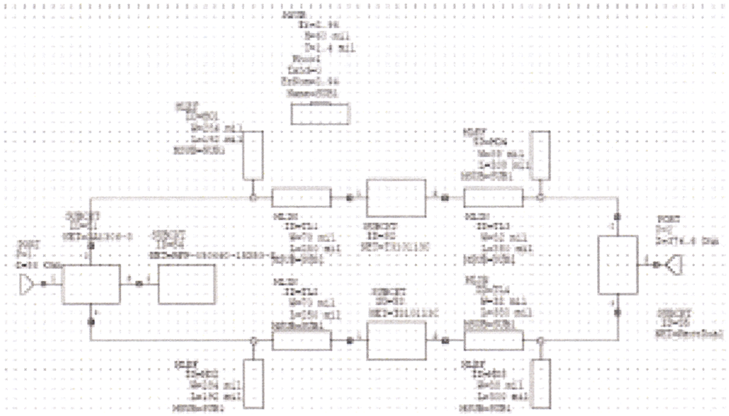

Figure 5 Simulation Schematics of the Dual Fed Balanced Amplifying Antenna

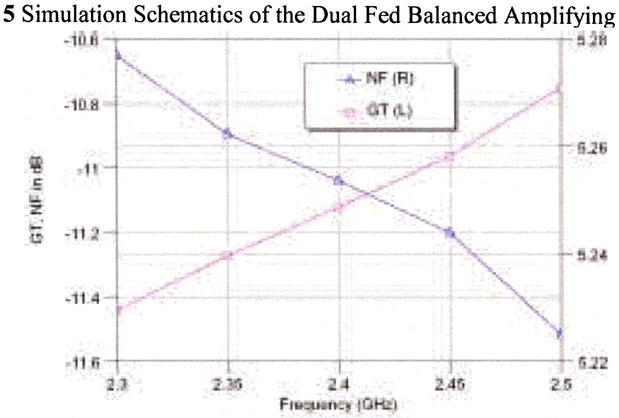

Figure 6 Gain and Noise Figure of the Dual Fed Balanced Amplifying Antenna

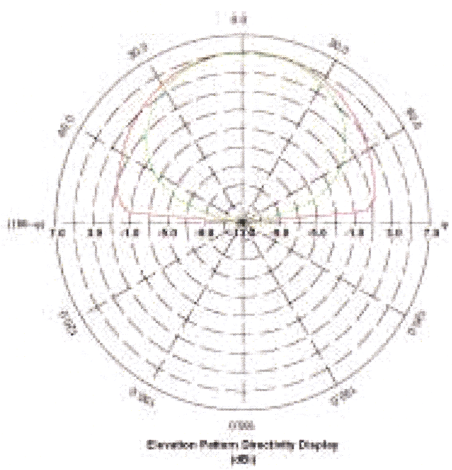

Figure 7 Radiation pattern of dual-fed Balanced Amplifying Antenna (Red line E_θ and green line E_ϕ)