Abstract—In this paper an active antenna, including a compact high-efficient class E amplifier and a microstrip antenna working at 2.45 GHz is investigated for microwave front-end transmitter applications. At first, a probe fed microstrip antenna with an arc shaped slot is used to suppress the second harmonic. The probe position is aligned to obtain a 50 Ω matched load, and hence the matching network is eliminated. In Second design the probe position is found to give optimum impedance at fundamental frequency so size reduction of the transmitter is obtain by connecting the antenna directly to drain terminal of active device. A high efficient class E amplifier is also designed and investigated. Both structures are placed on a same PC-board of Rogers RT Duroid 5870. They are numerically investigated using Advance Design System (ADS). The results show that the Power Added Efficiency (PAE) is at least 71% at the frequency of 2.4 GHz. Also, the second and third harmonics of the amplifier are significantly suppressed at the output of the antenna.

Index Terms—active antenna, high efficient amplifier, harmonic rejection, slot antenna.

I. INTRODUCTION

In recent years, the concept of the active antenna has been employed in an effort to design high-efficiency microwave power amplifiers. In this approach, the antenna element is used not only for radiation to form a desired beam, but also as a part of the tuning circuit to appropriately terminate the harmonics at the output port of the amplifier. Many antennas with ability to eliminate harmonics are designed [1-3]. In this paper, arc slot antenna [1] is used for designing active antenna.

On other hand, Power amplifiers (PAs) consume the majority of power in cellular phone and other portable applications. Therefore high-efficiency power amplifier is required. Due to its high-efficiency capability and simple circuit topology, the class-E PA is very promising choice for radio transmitters, So in this paper class-E PA with Power Add efficiency (PAE) above 74% is designed.

Both antenna and amplifier are placed on a same PC-board of Rogers RT Duroid 5870(h=0.79 mm, εr=3.3, tanδ=0.0012). At first active antenna probe feed position on the antenna is located to give an input impedance of 50 Ω at fundamental frequency. In second design a size reduction of the transmitter is obtain by connecting the antenna directly to drain terminal of active device. In this design the drain bias network and the probe feed position are employed to obtain the required optimum load impedance in fundamental frequency.

II. DESIGN CLASS-EAMPLIFIER AT 2.45 GHz

For large-signal PA design, as it is necessary to account for nonlinear of active device, the load/source method is normally used to obtain the optimum load and source impedance. In this article ADS software is used to obtain load and source impedance.

In table 1 result from load/source simulation is shown. For finding component's value, simulation is carried out to sweep load impedance on the smith chart to optimum load is obtain. Using this optimum load the simulation is performed again to obtain optimum value for source impedance. And so on simulation is performed for three harmonics to obtain maximum PAE.

A medium power packaged pHEMT (ATF34143) is used in the amplifier. For application in mobile handset low voltages base and drain bias, V_gs = −0.5 v, V_dd = 3 v are used.

<table>
<thead>
<tr>
<th>Harmonic</th>
<th>Source</th>
<th>Load</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>19-j20</td>
<td>26+j1.4</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>25-j50</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>3-j188</td>
</tr>
</tbody>
</table>

After determined values of source impedance and load impedance, by using ADS software, impedance matching is designed (Figure 1).The simulated intrinsic gate voltage and drain current/voltage waveforms in the time domain are shown in figure 2 and 3 respectively. Also PAE performance versus frequency is shown in figure 4. PAE above 74% with Pout above 23 dB are achieved.
III. DESING APROACH OF ACTIVE ANTENNA USING THE ANTENNA AS A 50 OHM MATCHED LOAD

In this active antenna design a new class-E PA circuit in part II was used. so that arc slot antenna [1] replace 50 ohm load, as shown in Figure 5.

The arc slot microstrip antenna acts as a radiator, harmonic rejection and PA load.

Figure 6 shows that good harmonic suppression at the second and third harmonics has been obtain. active and passive antenna's return loss is compared in figure 7.

Figure 1 the class E amplifier designed in 2.45 GHz

Figure 2 Simulation intrinsic drain voltage/current wave

Figure 3 Simulation intrinsic gate voltage waveform

Figure 4 Simulation PAE as a function of frequency

Figure 5 circuit diagram of the active antenna

Figure 6 simulated Pout spectrum in Pin= 11 dBm
Figure 7 compare return loss in active and passive antenna

Compare bandwidth in active and passive antenna, shown that antenna's bandwidth is increased when active device is joined to it. Figure 7 show that active antenna's bandwidth is 0.55% however passive antenna bandwidth is 0.31%.

Active antenna's PAE is shown in figure 8. PAE has been above 71% when Pin was equal 11 dBm.

Figure 8 Simulated PAE as function of frequency with Pin=11 dBm

IV. DESIGN APPROACH OF ACTIVE ANTENNA USING THE ANTENNA AS THE OPTIMUM LOAD

A more compact form of active antenna is obtained, by eliminating the load matching network (TL5, TL6 and TL7) in figure 1. The dimension of arc slot antenna was same as in the first design but new probe feed location was found to obtain the required optimum impedance at the fundamental frequency. The active antenna circuit is shown in figure 9.

Figure 9 circuit diagram of new active antenna circuit

Figure 10 shows good harmonic rejection at the second and third harmonic. Also the figure shows gain of active antenna is above 11 dBm.

Figure 10 simulated Pout spectrum in Pin= 11 dBm

One of advantage of new active antenna is increase bandwidth antenna. The antenna bandwidth increased about 0.45% in compare with old active antenna bandwidth. (Figure 11)

Figure 11 compare return loss in active and passive antenna

The new active antenna has PAE above 71% at 2.45 GHz when Pin is equal to11 dBm. (Figure 12)
V. CONCLUSION

In this paper a class-E amplifier in 2.45 GHz with PAE above 74% is investigated. Also two amplifier type active antenna circuits have been design for operation frequency of 2.4 GHz. Both active antenna used Arc slot patch antenna for suppress harmonics. At first design load matching network eliminated because 50 Ω passive load power amplifier could be replaced by antenna. So PAE of 71% and a very good harmonic suppression at the second and third harmonics was obtained. In the second active antenna design, to further minimize the size, a new probe feed location was found to obtain the required optimum impedance at the fundamental frequency. An increased in bandwidth to 1% was obtained that was 0.45 % higher than obtained in the first active antenna design.

REFERENCES