Review on Wideband Power Amplifier with for Plasma Application

Palak A. Soni[1] Priyanka Shah[2] Ramesh B. Patel[3]
[1,3]Student [2]Assistant Professor
[1,2,3]Department of Electronics and Communication Engineering
[1,2]Parul Institute of Technology, Limda, Vadodara [3]R.F. Engineering, Manjalpur, Vadodara

Abstract— Radio Frequency power amplifiers (RF PA) are widely used for several applications e.g. wireless communication, wireless power transmission (WPT) and radio frequency heating. HF band (3~30MHz) has been widely used in many communication and other systems, in military and civil applications. Generally the circuit design in this band is not a challenge; however this is not the case in some circuits, especially in the case of power amplifier design. The RF devices play a key role in design of power amplifier. In addition, HF frequency is used in many Industrial, Scientific and Medical (ISM) applications. As an example, HF frequency is widely used in plasma generation and heating systems in various applications. LDMOS devices are widely used for power amplifier design and development. Plasma load need to be heated to get desire temperature from RF source. For proper heating of plasma power amplifier plays major role so for plasma application we need highly efficient power amplifier and class-c amplifier offers high efficiency with simple topology, leading to optimal costs of production and system operation therefore this paper gives review for implementation of a high efficiency with high output power of 1.5kw 3-30MHz wideband class-c power amplifier is done for plasma application.

Key words: Plasma Application, Wideband Power Amplifier

I. INTRODUCTION

Based on the International Telecommunication Union (ITU) standard, 3~30MHz band is denoted as High Frequency (HF) band. Despite of its limited span, HF band is used in numerous modern systems for many applications. Communication systems, radio location beacon and navigation systems, dedicated communication systems, HF radars and amateur radio and broadcasting systems are examples of these systems. In addition, HF frequency is used in many Industrial, Scientific and Medical (ISM) applications. As an example, HF frequency is widely used in plasma generation and heating systems in various applications, e.g. semiconductor fabrication systems. The RF power in conventional high power HF systems varies from few watts up to many hundreds of kilowatts. The power amplifiers in these systems are designed in different classes, such as Class-B or C, using solid state high power RF devices. Power transistor is one of the most expensive parts of power amplifier and is more prone to failure. Different types of MOSFETS are used for construction of power amplifier. LDMOS (Laterally Diffused MOSFET) transistors are suitable for HF power amplifiers and conventionally used in this band. These devices have higher power rating and are unmatched input and output designs allowing wide frequency range utilization.

In this paper we reviews Progress in RF power amplifier.A comparison was done in terms of operating frequency, efficiency and output power.

II. BASIC RF POWER AMPLIFIER

Basic RF Power amplifier is either transconductance amplifiers or switching-mode amplifiers. A switching type power amplifier. The basic circuit diagram is shown in Fig. 1.The basic Class-E power amplifier is an amplifier which has an interesting compromise between a linear Class AB power amplifier and a switched power amplifier (the main idea behind switch-mode Power Amplifier technology is to operate the transistor in saturation, so that either voltage or current, depending on amplifier class, is switched on and off) and has zero overlap between voltage and current over and through the transistor so giving 100% theoretical efficiency and potentially robust performance[3].

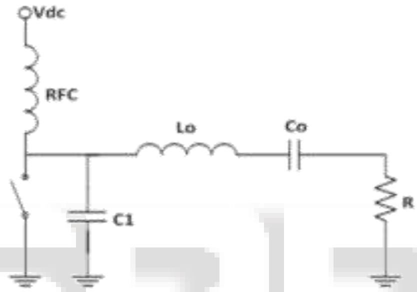

Fig. 1: Ideal circuit for class E power amplifier[4]

As shown in Fig. 1 Class E amplifier consists of an active device that works as a switch, a parallel capacitor that models parasitic capacitances, a resonant circuit and a load. The basic Class E amplifier assumes that the transistor is a perfect switch with zero-switching time, no output capacitance in OFF state, C_{off}, and zero resistance in ON-state, R_{on}. At microwave frequencies, all of these assumptions are violated and one cannot achieve 100% efficiency[2], but achieve less than 100% efficiency.

III. PREVIOUS IMPLEMENTED CIRCUIT DESIGNS AND RESULTS

Fig. 2 shows ADS (Advanced Design System) simulation of class E power amplifier with shunt capacitance at 0.5 GHz[6].

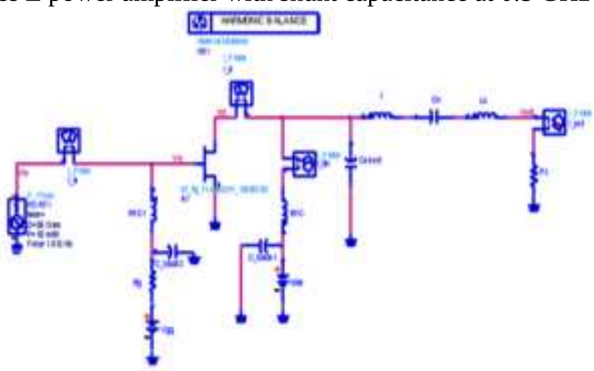

Fig. 2: ADS class E PA circuit with shunt capacitance configuration[6]

The drain voltage and current waveforms at 0.5 GHz of class E power amplifier with shunt capacitance is shown in Fig 3 [6].

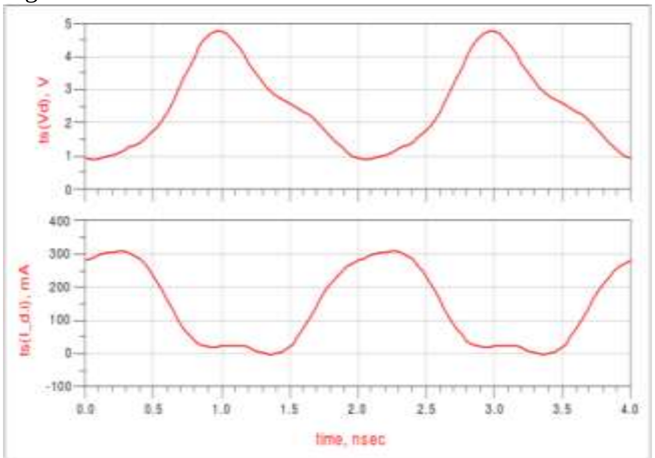

Fig. 3 Drain voltage and current for class E PA with shunt capacitance configuration at 0.5 GHz[6]

The comparisons of the performances of the different configurations (shunt capacitance, paralles circuit and shunt inductance) are shown in Figs. (4-7).

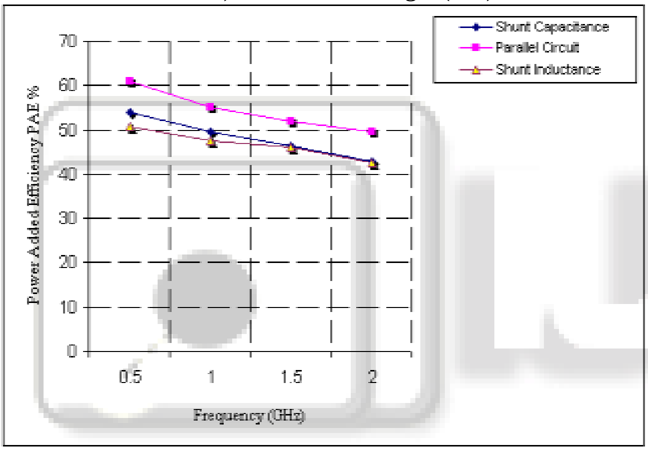

Fig. 4: Power added efficiency PAE of class E PA with shunt capacitance, parallel circuit and shunt inductance configurations at frequencies from 0.5GHz to 2 GHz in steps of 0.5 GHz[6]

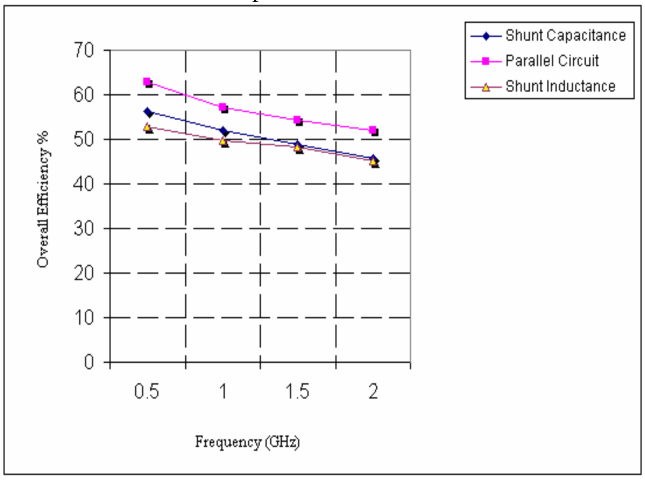

Fig. 5: Overall efficiency ηall of class E PA with shunt capacitance, parallel circuit and shunt inductance configurations at frequencies from 0.5GHz to 2 GHz in steps of 0.5 GHz[6]

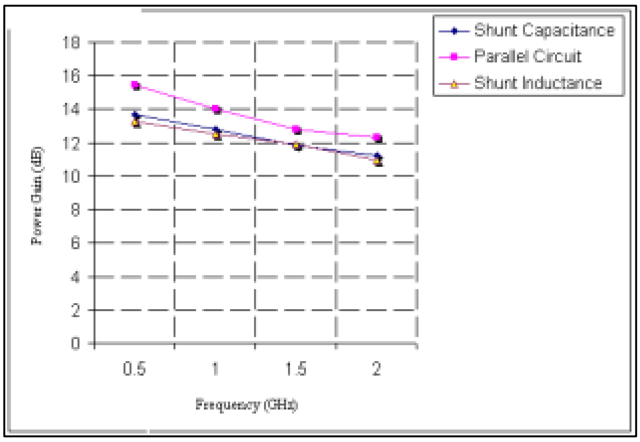

Fig. 6: Power gain of class E PA with shunt capacitance, parallel circuit and shunt inductance configurations at frequencies from 0.5GHz to 2 GHz in steps of 0.5 GHz[6]

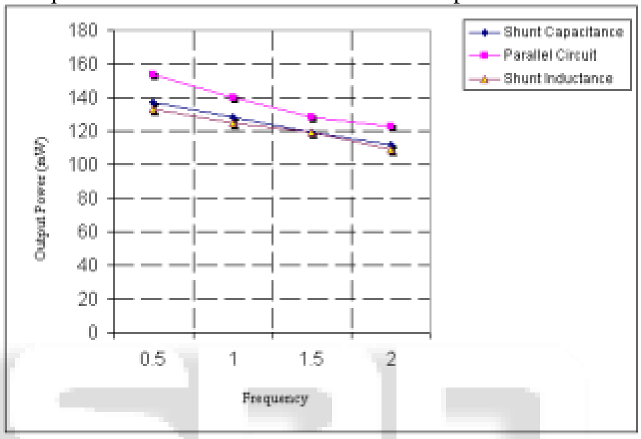

Fig. 7: Output power (P_{out}) in mW of class E PA with shunt capacitance, parallel circuit and shunt inductance configurations at frequencies from 0.5GHz to 2 GHz in steps of 0.5 GHz[6]

From this conclude that Class E power amplifier with parallel circuit gives better performance (PAE, drain efficiency, output power, power gain) than the other two at all the chosen frequencies of operation (0.5GHz., 1GHz, 1.5 GHz and 2 GHz) and the performance of all three configuration is the best at 0.5 GHz [6].

After that from 2000-2012, analyzed over 200 papers in [2], both wide bandgap and narrow bandgap devices are considered [2]. A comparison is done in terms of maximum output power, efficiency and operating frequency achieved which is shown in Table 1[2].

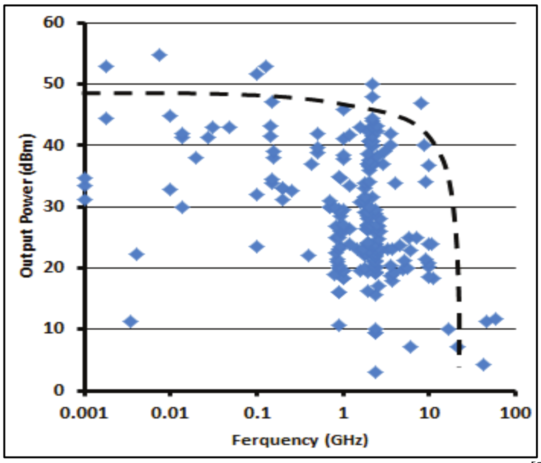

Fig. 8: Output Power Versus Operating Frequency[2]

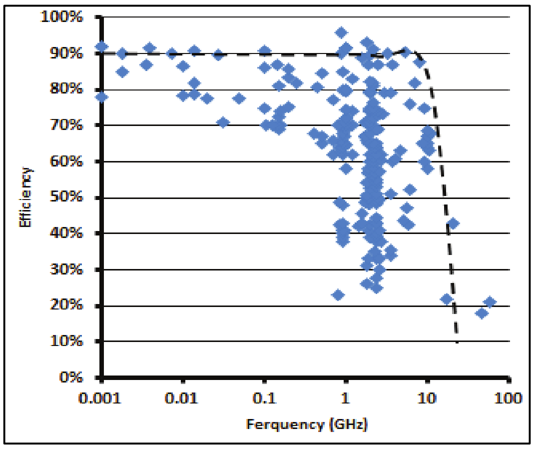

Fig. 9: Efficiency versus operating frequency [2]

Efficiency (%)	Output power (dBm)	Frequency (GHz)
91.00	41.27	0.014
90.10	54.77	0.0073
90.00	53	0.0018
89.60	41.4	0.027
87.80	46.9	8.00
83.00	33.4	1.20
82.00	40.4	2.10
82.00	30	0.014
81.00	34.4	0.150
79.70	41.03	1.00
79.20	40	3.50
77.75	38	0.020
76.50	44	2.14
75.00	50	2.14
75.00	34	9.20
75.00	34	2.00
74.10	43.1	2.14
74.00	40.6	2.00
74.00	40.7	2.14
74.00	41.8	1.19
74.00	38.3	2.50
73.10	37	2.85
72.50	33.9	0.150
72.30	43	2.14
72.00	19.68	1.00

Table 1: Class E amplifier [2]

These results can provide benchmarks against which new designs can be compared and gives progress in class E power amplifier through the last decade [2].

After that design and implementation of a high power and high efficiency 13.56 MHz class E power amplifier with parallel load circuit.

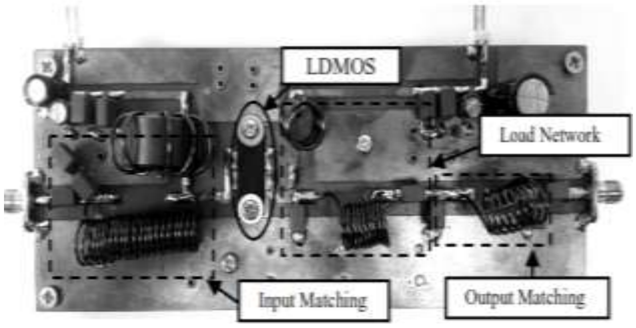

Fig. 10: 13.56 MHz class E power amplifier with parallel load circuit[5]

As a power device, LDMOS was chosen. The fabricated class E PA provides Power-Added Efficiency (PAE) of 94.6% with 21.92 power gain when maximum output power of 44.92 dBm (31 W) is delivered to the load [1], shown in Fig. 10 and regarding this circuit, the result is shown in Fig 11 [5].

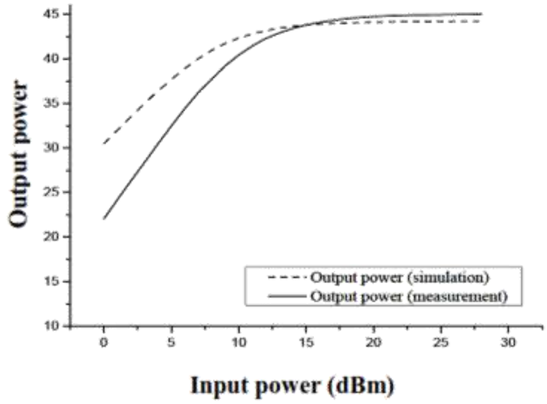

Fig. 11 Simulation and measurement results of output power versus input power at 13.56 MHz[5]

This work presents design and implementation of high efficiency 13.56 MHz, class E Power amplifier with parallel load circuit for wireless power transmission and heating applications[5].

IV. Class E Power Amplifier Design Comparison

Power-Added Efficiency (%)	Output power (dBm)	Frequency (MHz)
94.6	44.92	13.56
91	44.08	13.56
90	54.77	18
89.6	53	27.1
85.5	48	1 4
83	57	27.12
82	30	13.56

Table 2: Class E Power Amplifier Design Comparison[5]

V. Conclusion

Class E amplifier has been widely used in new applications due to its very high efficiency and relatively high power with straight forward design. A review was done to report the Progress in Class E power amplifier through the last decades. A comparision was carried out in terms of operating frequency, efficiency and output power.

VI. Future Expansion

By improving circuitry and changing components like MOSFET, Transformer, Thermistor and Zener Diode etc as per requirements, try to achieve high output level of classE radio frequency power amplifier above 100 watt at 13.56MHz frequency band for plasma application.

References

[1] Abdullah Eroglu (2013), "Phase Controlled Class E Amplifier Characteristics for Pulsing Applications" Indiana University-Purdue University Fort Wayne, USA, IEEE

[2] Ahmed Rajeja, Ahmed khorshid and Ali Darwish (2012), “Recent Implementation of Class-E Power Amplifier” American University Cario, Egypt, IEEE
[3] Bo Berglund, Jan Johansson and Thomas Lejon (2006), “High efficiency power amplifiers” Ericsson Review No. 3
[4] Christopher J. Cottee and Stephen R. Duncan (2003), “Design of Matching Circuit Controllers for Radio-Frequency Heating” IEEE Transactions On Control Systems Technology, Vol. 11, No. 1
[5] PattrawutSrimuang, Nutdechatorn Puangngernmak and Suramate Chalermwisutkul (2014), “13.56 MHz Class E Power Amplifier with 94.6% Efficiency and 31 Watts Output Power for RF Heating Applications” Civil Aviation Training Center, Thailand, IEEE
[6] Prof. KhairiaBelghet Prof. Amer ZraigNserAzroug (2011), “Performance Comparison of CLASS E RF Power Amplifier with differentload network configuration” Niagara Falls, Canada, IEEE
[7] Raul Andres Chinga, StudentMember, Jenshan Lin, Fellowand Subrata Roy (2014), “Self-Tuning High-Voltage High-Frequency Switching Power Amplifier for Atmospheric-Based Plasma Sterilization” IEEE Transactions On Plasma Science, Vol. 42, No. 7
[8] W. Chen, R. A. Chinga, S. Yoshida, J. Lin, C. Chen and W. Lo (2012), “A 25.6 W 13.56 MHz Wireless Power Transfer System with a 94% Efficiency GaNClass-E Power Amplifier” Industrial Technology Research Institute, Taiwan, University, Florida, U.S.A., NEC Corporation, Tsukuba, Ibaraki, Japan, IEEE