Design of Power Amplifier for High Intensity Focused Ultrasound Using State-of-Art Technology

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Abstract—The High Intensity Focused Ultrasound is finding its relevance in most of the tumor treatments and the associated research fields. This research paper is focused on introducing the design of power amplifier used in High Intensity Focused Ultrasound using active element AD846AN. The comparative analysis of the designed power amplifier with existing ones depicts its efficiency in terms of different parameters i.e. stability, impedance matching, unilateral figure of merit and other RF parameters.

Keywords*- High Intensity Focused Ultrasound, Power Amplifier, Active Element, RF Parameters*

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I. INTRODUCTION

The introduction of High Intensity Focused Ultrasound in the treatment of different types of deadly diseases like tumors in breast, brain, prostates etc. has set researchers across the globe to explore this technology and find the more efficient ways for its implementation. This HIFU has been very successful in treating diseases like Parkinson, Essential Tremors, Uterus Fibroids and Prostate Cancer. It is currently being explored further for treatment of many more deadly diseases like Depression, Bone Cancer, Neurological defects and many more [1-6]. This technology is being studied in terms of techniques for improvement in its success rate for treatment of above mentioned diseases as well as in terms of advancement of equipments being deployed for its implementation. The different types of equipments built for implementation of this technology are utilizing one of the basic analog component in it i.e. Power Amplifier. In this research paper, the different types of preexisting radio power amplifiers are discussed and compared with the newly designed power amplifier and it is depicted that the power amplifier designed with the state-of-art technology is more stable, efficient and reliable for this particular field of application [1 – 6, 9].

II. INTRODUCTION TO POWER AMPLIFIERS

The Power Amplifiers are finding their wide application in almost every field as they are the prominent components used at the final stage of any circuit for driving the load. This load can be defined in terms of any electric or mechanical component like power amplifiers are used to drive loud speakers in some applications and are also used to drive motors in most of the applications. Thus they find their utilization in almost every walk of automated sections of life. The general stages before any power amplifier use amplifiers which are used to increase the signal strength in terms of voltage or current which is in terms of micro or mili volts, micro or mili amperes, micro or mili watts respectively. However the power amplifier stages increase the signal strength in terms of watts or thousands of watts and further. The general classification of power amplifiers is done as linear power amplifiers and nonlinear power amplifiers. They are also classified as small signal power amplifiers and large signal power amplifiers.

III. DIFFERENT TYPES OF RADIO POWER AMPLIFIERS

The power amplifiers deal in different levels of frequencies paving way for their classification as mentioned below:

1. Audio-power amplifiers
2. Radio-power amplifiers

Audio-Power Amplifiers – This type of power amplifiers are also known as the small signal power amplifiers. They have the tendency to increase the power levels of signals whose frequency range is 20 Hz to 20 KHz which is more specifically the audio frequency range.

Radio-Power Amplifiers – This type of power amplifiers are also known as large signal power amplifiers. They have the tendency to increase the power levels of signals whose frequency range lies in radio frequency range. They reject all other frequencies and amplify a particular frequency or narrow band of frequencies.

The Radio Power Amplifiers are generally the final stage of any electronic circuit as they are supposed to drive the load. The Power Amplifiers are designed for a specific application e.g. LTE, HDTV, Radar, GSM, Point-to-Point Microwave etc. For this reason, they use a particular signal type, modulation scheme, and a set of specifications. In order to use an amplifier for a dedicated application, it becomes necessary to match the different attributes of the amplifier product with the application needs.

On similar background, it is necessary to consider the specific attributes while selecting the right Radio Power Amplifier. These attributes include a particular technology used for fabricating the radio power amplifier i.e. GaN or GaAs or InGaP or LDMOS, a particular frequency range used for designing the radio power amplifier, a particular Gain in (dB), Gain Flatness (dB), Supply Voltage (VDC), P1dB (dBm), and Package Type used for radio power amplifier designing [7].

Some of the Radio Power Amplifiers designed using traditional active elements have been depicted below:

Wideband RF Power Amplifier: The RF Power amplifier shown in Figure 1 is a wideband power amplifier employing four capacitors, two inductors, four resistors and one Motorala made NPN BJT i.e. MRF927T1 apart from dc power supply of 9V.

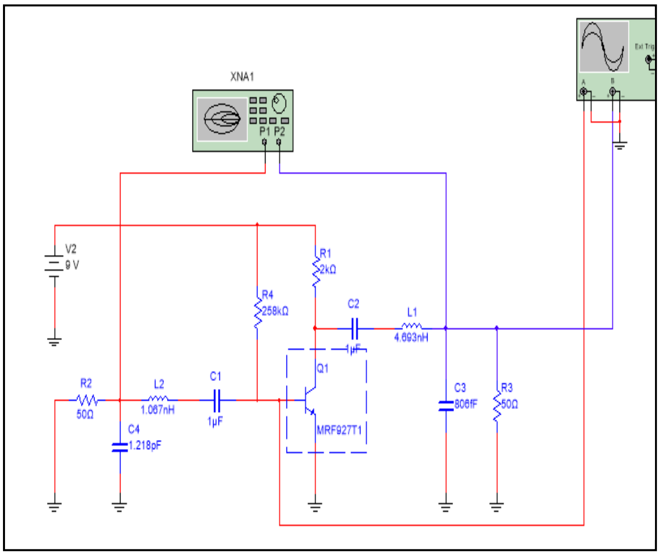

Figure 1. Wideband RF Power Amplifier

This power amplifier keeps on working in a frequency range of around 50KHz after which it loses its functional behaviour. The simuation output of this power amplifier is shown in Figure 2 below:

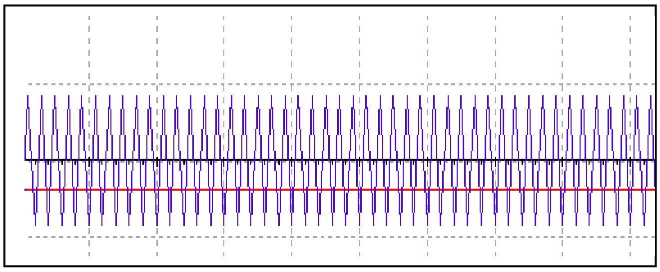

Figure 2. Simulation Output of Wideband RF Power Amplifier

RF Power Amplifier Using BJT BFR106: This power amplifier is better as compared to the previously discussed one as it uses less number of passive components than wideband RF power amplifier. It uses only two capacitors, three rsistors, one BJT trnasistor BFR106 and one power supply of 12V apart from input signal of 3MHz .

The circuit diagram of this power amplifier is shown in Figure 3 below:

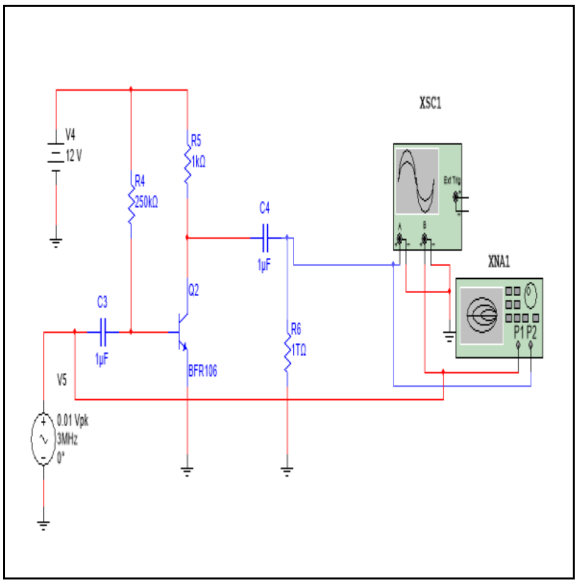

Figure 3. Radio Power Amplifier using BJT BFR106

The simulated output of this power amplifier is shown in Figure 4 below:

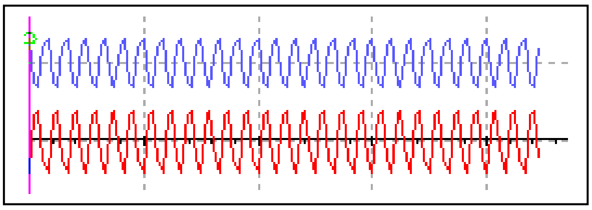

Figure 4. Simulated Output of Radio Power Amplifier Using BJT BFR106

The drawback of this Radio power amplifier is its more power utilisation as compared to the previously discussed power amplifier. It uses 12V power supply for maintaining the proper biasing of the transistor.

RF Power Amplifier Using BJT BF517: This radio power amplifier is shown in Figure 5 below:

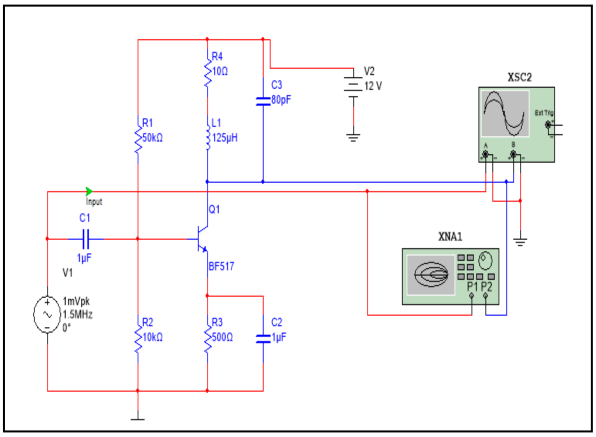

Figure 5. Radio Power Amplifier Using BJT BF517

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This radio power amplifier uses one active element i.e. BJT BFR517, four resistors, three capacitors, one inductor and one power supply of 12V apart from input signal of around 1.5MHz frequency. Though in this power amplifier the frequency output obtained is of 1.5 MHz approximately but it also uses inductor because of which it also becomes a poor choice for getiing it fabricated completely over single silicon chip [8].

The simulated output of this circuit is shown below in Figure 6:

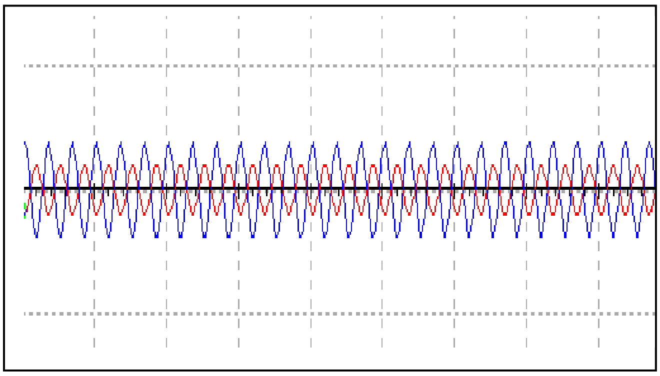

Figure 6. Simulated Output of Radio Power Amplifier Using BJT BF517

As can be visualised in the above figure, the input output waveform is 180^0 phase shifted with respect to each other and the quality of waveform is much better at frequency of 1.5 MHz.

IV. Proposed Radio – Power Amplifier

In order to overcome the drawbacks of the current based power amplifiers as has been mentioned in earlier times, the proposed radio power amplifier has been designed using the active element AD846AN which is a current feedback operational amplifier.

The AD846AN is a monolithic, high speed current feedback or transimpedance operational amplifier. It can achieve “12-bit” (0.01%) precision on critical ac and dc parameters. The limitations of traditional high speed operational amplifier is overcome using AD846AN as it supports in maintaining a nearly constant bandwidth and settling time to 0.01% over a wide range of closed-loop gains. The AD846 consumes only 5mA of supply current while achieving settling times of 110 ns to 0.01% for gains of –1 to –10, with a 450 V/µs slew rate. It uses supply voltage range of 5V to 18V [10].

The proposed radio power amplifier is shown in figure 7 below:

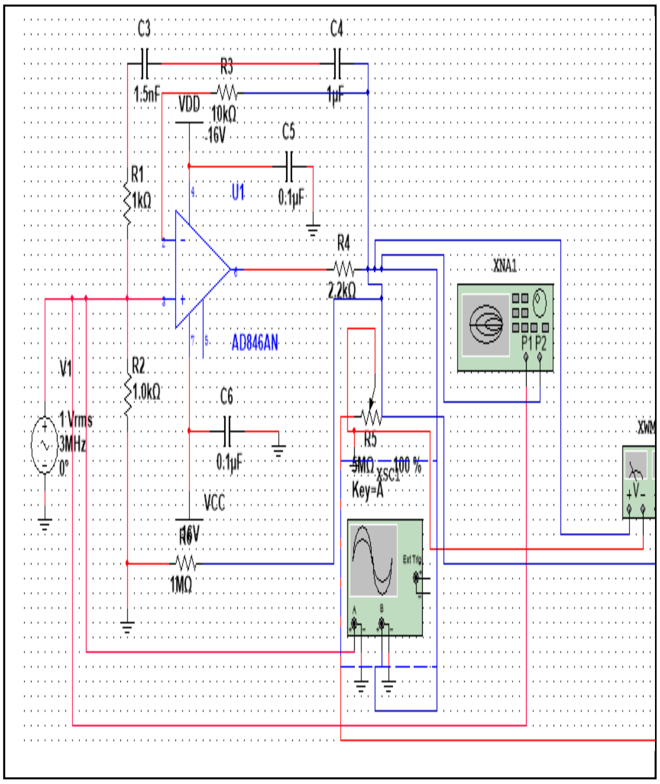

Figure 7: Proposed Radio Power Amplifier Using AD846AN

The proposed design is simulated using Multisim 12.0 software. This radio power amplifier utilizes five fixed resistors
of values 1KΩ, 1KΩ, 2.2KΩ, 10KΩ, 1MΩ and one variable resistor of 5MΩ. It also uses four capacitors of 1.5nF, 1µF, 0.1µF and 0.1µF. It uses power supply of ±16V and an input signal of 1V RMS with frequency of 3 MHz. The important point to note here is that this active element AD846 uses current as the main processing signal because of which the power dissipation in this circuit remains at minimal level as compared to all above discussed power amplifiers.

The simulated output of this power amplifier is depicted in Figure 8 below:

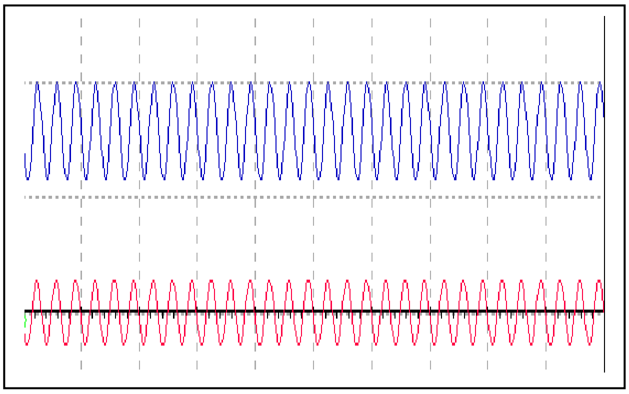

Figure 8: Simulated Output of Proposed Radio Power Amplifier Using AD846AN

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The comparative analysis of the discussed and proposed power amplifier is shown in figures below:

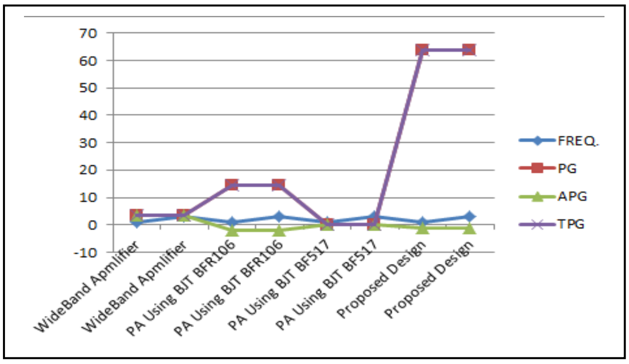

Figure 9: Power Gain Comparative Chart of Power Amplifiers

As is clear in the above figure, the power gain in terms of total power gain is found maximum in the proposed design. This parameter is very crucial which is considered at utmost priority while designing the power amplifiers.

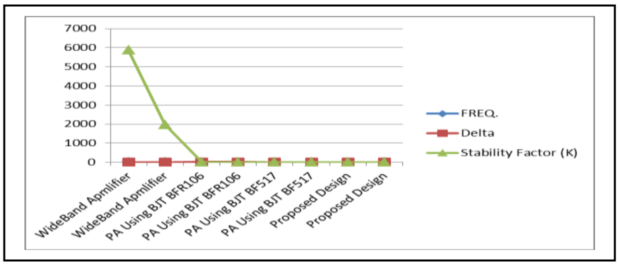

Figure 10: Stability Factor Comparative Chart of Power Amplifiers

The table shown below shows the comparative analysis of different radio power amplifiers discussed in this research paper:

Table 1 – Comparative Analysis of Different Radio Power Amplifiers

Design	FREQ.	PG	APG	TPG	Delta	Stability Factor (K)
Wide Band Amp.	1.00	3.50	3.50	3.50	0.00	5873.00
	3.02	3.50	3.50	3.50	0.00	1965.54
PA Using BJT BFR106	1.00	14.35	-2.11	14.35	7.99	0.90
	3.02	14.35	-2.11	14.35	7.99	0.90
PA Using BJT BF517	1.00	0.01	0.04	0.01	3.79	1.00
	3.02	0.00	0.02	0.00	3.79	1.00
Proposed Design	1.00	63.89	-1.29	63.89	0.08	1.06
	3.02	63.89	-1.29	63.89	0.06	1.37

V. CONCLUSION

The Radio power amplifier designed using active element - current feedback operational amplifier, AD846AN has been better in terms of good stability over a range of radio frequencies which is essentially going to play a vital role in HIFU (high intensity focused ultrasound) where a number of frequency components are used for diagnostic purpose with a suitable phase shift among them. The power amplifiers used in HIFU can be implemented using state of art technology as discussed in this research paper which can lead to more accurate results for such systems.

VI. ACKNOWLEDGEMENT

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