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Design of RF Power Amplifier for Military Applications

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***Abstract*— This paper discusses about the design of RF amplifier by considering linearity and efficiency as most important parameter. The amplifier must have unconditionally stable. This is to make sure that the device can work at the frequency desired conditions. In modern radio telecommunication system the design of linear and efficient radio frequency power amplifier present one of the most challenging design problems. The main purpose of RF power amplifier is to boost radio signal to a sufficient power level for transmission through transmission Medium from the transmitter to the receiver. In general, relatively high transmit power levels are needed and the power consumption of the power amplifier easily dominates over all other electronics and digital processing. In this paper, the calculations of the parameters are done with the low-power consumption (0 dBm max) and over specified frequency range of 1.7 – 2.1G Hz, thus RF power amplifier is simulated to deliver the output power of 10W. Hence it is used to meet the necessities of a secured communication in the military areas and variety of applications.**

***Index Terms*—RF power amplifier, dBm, pre-driver amplifier, driver amplifier, main amplifier, Efficiency, gain, frequency.**

I. INTRODUCTION

Radio Frequency (RF) Power Amplifiers (PA) are commonly used in wireless communication devices (such as cellular phones, radios, and wireless modem) to amplify and transmit radio frequency signals. Radio Frequency transmission of an electrical signal requires corresponding power amplification for the intended transmission range. RF signals typically have a broad frequency spectrum from several MHz to tens of GHz, and higher [1][2]. A power amplifier amplifies a radio frequency signal at the output of transmitter prior to transmission in a small size communication device. A typical radio transmitter uses a radio frequency power amplifier to amplify input RF signals for transmission by an antenna.

RF power amplifiers are generally designed to provide maximum efficiency at the maximal output power. Within the amplifier assemble a typical plural (the RF components are Mounted on a controlled dielectric printed circuit boards) on which components that process the RF signals are mounted. Typically a RF power amplifier consist of an integrated circuit chip having the transistors and the other circuitry associated with the amplifier and a number of Off-chip components that filter the signal or provide impedance matching at a particular operating frequency band. RF signals are transmitted between the various processing components.

Regardless of its physical realization, the task of a PA is to increase the power level of the signal at its input in a given frequency band, up to a predefined level at its output. As contrasted therefore to low-level (i.e. linear) amplifiers, often specified in term of small-signal gain, the absolute output power level, as well as the power gain, become the PA's primary performance. PA may be ultimately regarded as a component converting DC power from DC supplies (PDC) into microwave power (i.e. Pout).

Long-distance data communication is more effective through wireless networks but geographical obstacles and the curvature of the earth bring limitations to line-of-sight transmission. However, these issues can generally be mitigated through planning, calculations and the use of additional technologies.

For example, mobile phones use a modified line-of-sight transmission, which is made possible through a combination of effects like diffraction, multipath reflection, local repeaters and rapid handoff.

In this paper we introduced a RF power amplifier for the wireless network using frequency range of 1.7 to 2.1 GHz; by considering efficiency, gain, inter-modulation product and thermal effect.

II. PROPOSED DESIGN

The device is provided with input of RF power of 0 dBm (max) is being amplified through pre-driver amplifier and driver amplifier and main amplifier respectively to obtain the output power of 10W.

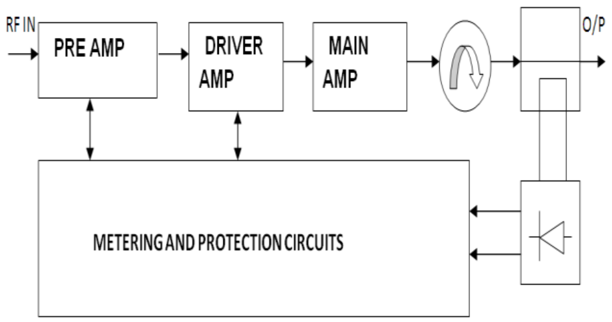

Fig. 1 Top level RF amplifier block diagram

A. Selection of device

LDMOS devices were surveyed and found that no device is available meeting the wide frequency range of 1.7GHz to 2.1GHz. LDMOS Devices available in the market are being

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used in WCDMA applications and they offer a limited band width of 60MHz only. All these devices are internally matched and difficult to optimize for our application.

NXP and CREE make GaN HEMT devices were surveyed and found that NXP Make CLF1G0035-50 suits the required application which is unmatched device.

The ADL5602 as a pre-driver amplifier is a broadband 18 dB gain linear amplifier that operates at frequencies up to 4 GHz. The device can be used in a wide variety of cellular, CATV, military, and instrumentation equipment.

The HMC457Q as a driver amplifier is a high dynamic range GaAs. In GaP Heterojunction Bipolar Transistor (HBT) 1 watt MMIC power amplifier operating between 1.7-2.2 GHz. Packaged in a miniature 16 lead QSOP plastic package, the amplifier gain is typically 27 dB from 1.7 to 2.0 GHz and 25 dB from 2.0 to 2.2 GHz. The power control (Vpd) can be used for full power down or RF output power/ current control. The power amplifier offered 28dBm output over a band width of 400MHz (1.7-2.1GHz).

The non linear model of CLF1G0035-50 as a main amplifier was obtained from NXP and design was optimized using simulation software such as AWR over frequency band of (1.7GHz – 2.1 GHz). This RF transistor is the unmatched device.

III. DESIGN METHODOLOGY

The amplifier is provided with input RF power supply of 0dBm (max), which is being amplified through pre-driver amplifier and driver amplifier and main amplifier to obtain the output power of 10W.

The Power Amplifier is controlled for: high input power, high output power, high VSWR and high temperature .The status of the amplifier are displayed by the status display PCB. The amplifier stages are being cooled by the DC fan which is mounted very close to the heat sink of the amplifier. A temperature sensor LM35 is used to monitor and control the temperature of the Amplifier.

A. Pre-amplifier

The pre-driver amplifier stage consists of two amplifier stage, which is built around ADL5602, one voltage variable attenuator and one RF switch and a RF Splitter. The RF input signal -15dBm (typ.) is amplified using the first stage of ADL5602. The amplified signal is divided using the RF splitter. One RF signal is passed to the Voltage variable attenuator and the other RF signal is routed for RF sensing purpose. The voltage variable attenuator is used to adjust the RF level of the amplifier manually or using the microcontroller to maintain the desired output power. The RF switch is used to cut-off the RF signal when amplifier is OFF or when any fault occurs. The output of the RF switch is amplified using ADL5602 to obtain the desired RF drive for the next stage i:e Driver amplifier. The output of the Pre-driver amplifier is +7dBm (typ.).

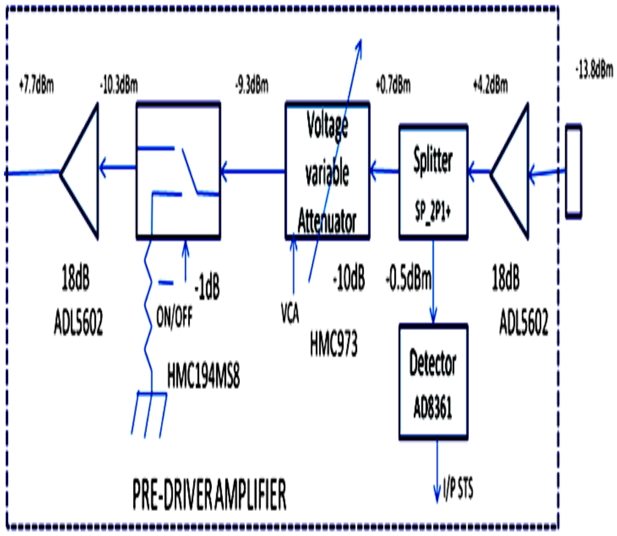

Fig. 2 Pre-driver RF amplifier block

B. Driver Amplifier

The driver amplifier is the intermediate amplifier stage that drives Main Amplifier. The 10W amplifier requires 27dBm input, but to cater the requirement of reserve power to compensate temperature and gain variations a 1Watt amplifier was planned.

The driver amplifiers requires +9dBm of output from the pre-driver. The input to Pre-driver will be passed through Voltage Controlled attenuator to compensate for gain reduction due to temperature.

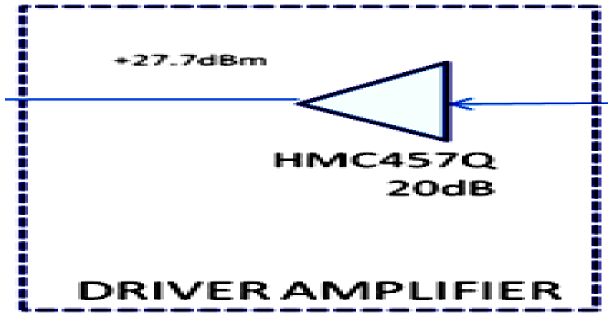

Fig. 3 Driver RF amplifier block

C. Main Amplifier

The main Amplifier is realized using NXP make 50W device. The device output will be limited to 10W by limiting the input and supply current. The output from the device during normal operation will be 10Watt. The IMD at this power level is measured 30dB approx. The device offers a gain of 13dB. The input to the amplifier is sensed with a directional coupler and used for display of RF drive level. Bias sequencing circuit is built in the amplifier which protects the device from wrong sequence of DC power switching ON and OFF. The Bias sequencing board also protects the RF device from over current.

Choosing the bias points of an RF Power Amplifier can determine the level of performance ultimately possible with that PA. By comparing PA bias approaches, can evaluate the

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tradeoffs for: Output Power, Efficiency, Linearity, or other parameters for different applications. The Power amplifier Class determines the type of bias applied to an RF power transistor.

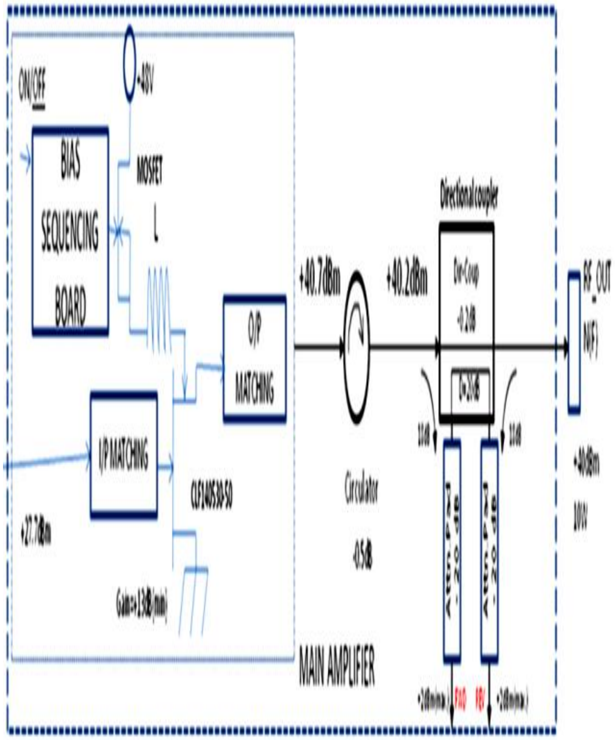

Fig. 4 Main amplifier RF amplifier block

In addition to the class of operation, the overall efficiency of a Power Amplifier is affected by factors such as dielectric and conductor losses. First it is necessary to quantify any loss in the circuit, then attempt to minimize it, and finally it has to be ensured that the mechanical and thermal design is adequate under all conditions.

D. Design parameters

Table I Table of design parameters

Parameter	Specification	Remarks
Frequency of operation	(1700-2100)MHz	
small signal gain	55dB	
1dB Bandwidth of input signal	18MHz	
Output power (P1dB)	10Watt	
Input power	-15dBm	
IMD3	25dBm	1MHz spacing of carriers with 6dB OBO
Power setting	1-10 Watt	
Monitoring parameters	Output power Reflected Power	
Indications	DC Voltages OK/Not OK RF Drive OK/Not OK Fault Present/Not	
Protections	Over current High reflected power High temperature	
Remote operation	TCP/IP	

E. Monitoring Parameters

1) Presence of supply voltages +48V,+5V by an LED glow
2) Presence of RF input by an LED glow
3) Presence of RF drive by an LED glow
4) Presence of RF output by an LED glow
5) Presence of Temperature FAULT by an LED glow
6) Presence of VSWR FAULT by an LED glow
7) FWD power voltage for display in control unit
8) REV power voltage for display in control unit

F. Protection Circuits

1) Protection from feeding DC Supply in reverse polarity
2) Protection from high current (over load) drawn by Main Amplifier
3) Switch OFF the module if base plate temperature exceeds 80degC
4) Switch OFF module if reverse power exceeds the set limit
5) Open and Short circuit protection.

IV. RESULT

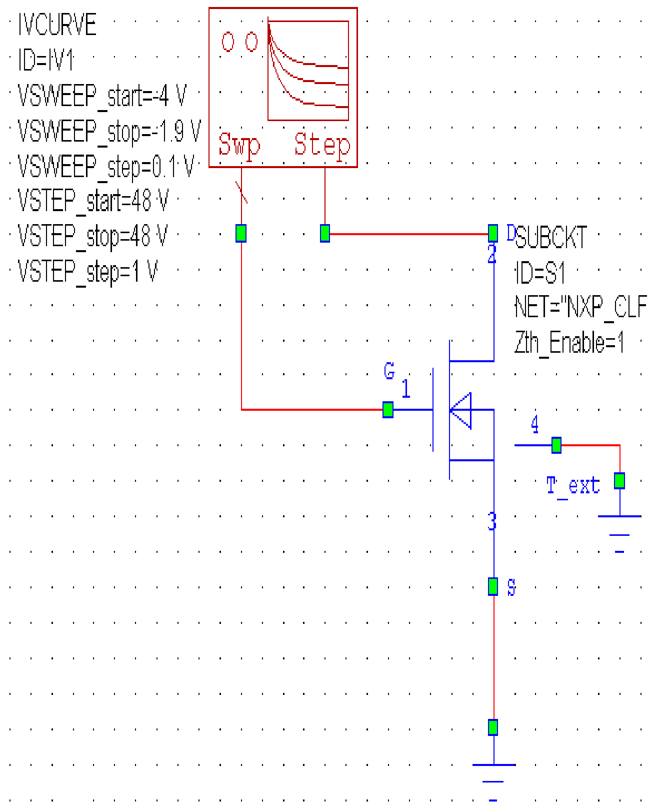

Fig. 5 Biasing CLF1G0035-50 transistor Circuit

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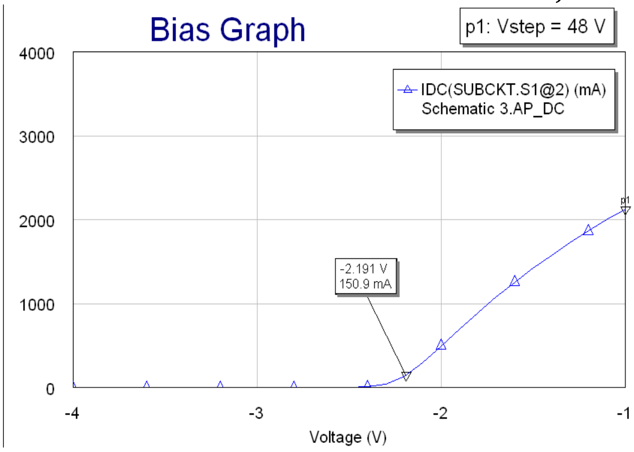

Fig. 6 VG graph of CLF1G0035-50 transistor bias circuit

The figure 6 shows the biasing point of CLF1G0035-50 transistor. It gives an idea of how much negative voltage must be applied to CLF1G0035-50 transistor.

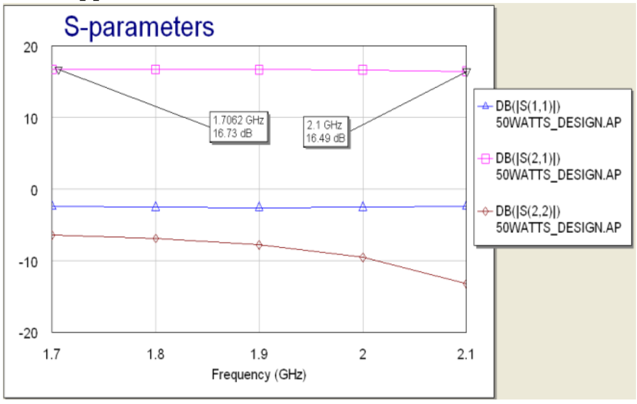

Fig. 7 S- Parameter output of the main amplifier design

The above figure 7 shows the S-parameter (electrical behavior of device) values at different ports of RF Amplifier like input return loss, gain and output return loss respectively.

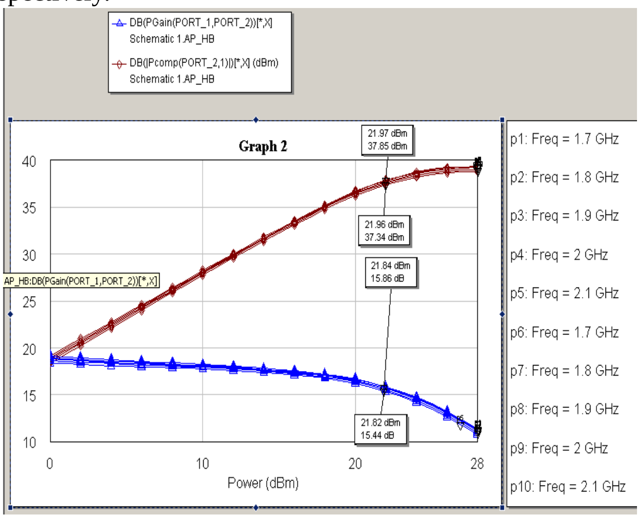

Fig. 8 Power gain and compression output of the main amplifier design

The above figure 8 shows the power gain and compression of the designed main power amplifier block for the frequency range of 1.7GHz to 2.1GHz.

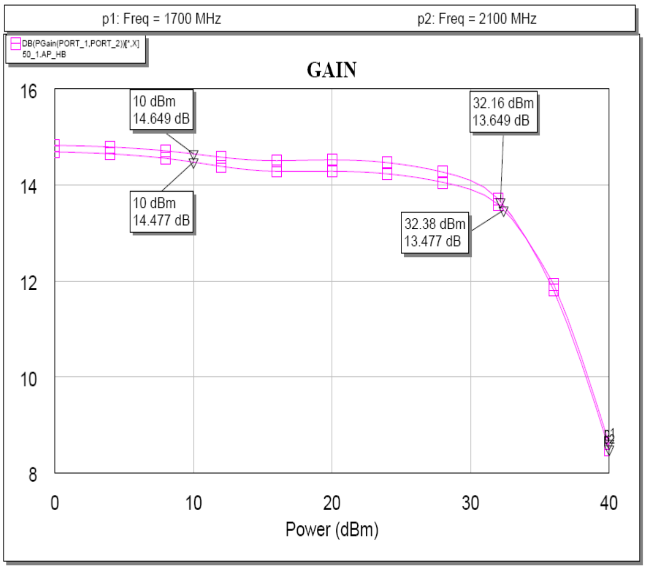

Fig. 9 Gain output of the amplifier design

The above figure 9 shows the gain of the designed 10W power amplifier for the frequency range of 1.7GHz to 2.1GHz.

A. *Output from the simulations*

1) Output power P1dB: 40W.
2) Gain: 14dB.
3) Efficiency: 45%.
4) IMD3 :25 dB
5) PCB material : Teflon
6) Size of PCB : 60 mm x 140 mm
7) Dielectric constant (€r): 3.5, constant all-through the PCB.
8) Thickness of the PCB substrate , H : 0.76 mm
9) Thickness of micro strip line (copper), T : 0.35 mm
10) Valued of lumped elements such as R, C & L.
11) Spacing between the elements.
12) Length and width of Transmission line.

V. CONCLUSION AND FUTURE ENHANCEMENT

The preliminary design is verified using the RF/Microwave simulation software-AWR. The design is further optimized to meet and exceed the customer expectation. The optimized design is converted to actual product through PCB manufacturing process.

All the RF components as obtained from the simulation are assembled and tested. The 10W final amplifier section was capable of delivering 13dB gain. The gain measurement is checked with Network Analyzer. Harmonics levels are checked using spectrum analyzer.

The high peak-to-average ratios of the digital modulation schemes used in 3G wireless systems require that the RF power amplifier should maintain high linearity over a large range while maintaining its high efficiency. These two requirements are often at odds with each other. Thus, a simplified and easy design of RF power amplifier has been proposed and implemented with the low-power consumption and over specified frequency range of 1.7 – 2.1G Hz, thus RF power amplifier is designed to deliver the output power of 10W.

For future enhancement this Power Amplifier design can be modified for difficult scenarios:

1) Broadband Applications.
2) Future Wireless Communication Infrastructure.
3) Aerospace and Defense Channel.
4) Jamming and RADAR Applications (Ground based, Shipboard and Airborne)
5) Medical Applications

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