

Low Cost RF Amplifier for Community TV

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Abstract. The capability of television to deliver audio video makes this media become the most effective method to spread information. This paper presents an experiment of RF amplifier design having low-cost design and providing sufficient RF power particularly for community television. The RF amplifier consists of two stages of amplifier. The first stage amplifier was used to leverage output of TV modulator from 11dBm to enable to drive next stage amplifier. CAD simulation and fabrication were run to reach optimum RF amplifier design circuit. The associated circuit was made by determining stability circle, stability gain, and matching impedance. Hence, the average power of first stage RF amplifier was 24.68dBm achieved. The second stage used RF modules which was ready match to 50 ohm for both input and output port. The experiment results show that the RF amplifier may operate at frequency ranging from 174 to 230MHz. The average output power of the 2nd stage amplifier was 33.38 Watt with the overall gain of 20.54dB. The proposed RF amplifier is a cheap way to have a stable RF amplifier for community TV. The total budget for the designed RF amplifier is only a 1/5 compared to local design of final TV amplifier.

1. Introduction

TV programs take a role in spreading information in form of voice and picture to society. TV programs are advantageous. Hence, they can be functioned to entertain, to advertise some products of local home industries as well as to improve the human resources quality. The capability of television to deliver voices and pictures makes this media become an effective tool to educate people.

TV broadcasts are grouped into commercial TV and community TV. The programs in the community TV are independent, no advertisement, and have special target of viewers. Community TV is built by a particular community such as campus or some group with same interest [1].

Solid state of RF amplifier at UHF and VHF analog TV Transmitter has been introduced. It uses FET transistor for RF amplifier [2]. Optimizing performance of RF buffer by using current-reusing with active inductor technique has been investigated. It can reduce power dissipation and increase the power generated [3]. A reliable linearization method is used to reduce noise in power amplifier transmitter. It has been investigated for frequency UHF (225 MHz-400 MHz) and VHF (118 MHz-144 MHz) [4].

The design and implementation of DVB-T technology with high power amplifier for television broadcast community have developed. It has worked in UHF frequency with omnidirectional radiation pattern [5][6]. Community TV Broadcast is designed to serve the campus community.



In this paper, a series of experiments is presented related to design RF amplifier. The RF amplifier consists of two stages of amplifier, and uses MOSFET transistor. The first stage amplifier is used to leverage output of TV modulator to drive next stage amplifier. RF amplifier works in band III TV VHF at frequency of 174 – 230 MHz. It is easy to be used and operated by a particular community, and low cost in manufacturing.

2. Method

The RF amplifier especially for community television should be at low cost, and exhibits sufficient RF output power. Originally, TV modulator has relatively covered short distance due to weak power of the modulator output. RF power amplifier is functioned to boost the signal in order to extend the coverage area with the sufficient power.

In this work, the RF amplifier consisted of two stage of amplifier. The first stage amplifier was used to gain output of TV modulator from less than 11dBm to enable to drive next stage amplifier. Such CAD simulation and fabrication were run to reach optimum RF amplifier design circuit. CAD simulation was provided by using free evaluation software of ADS (Analog Design System). The associated circuit was made by determining stability circle, stability gain, and matching impedance.

The diagram block of experiment is shown in figure 1.

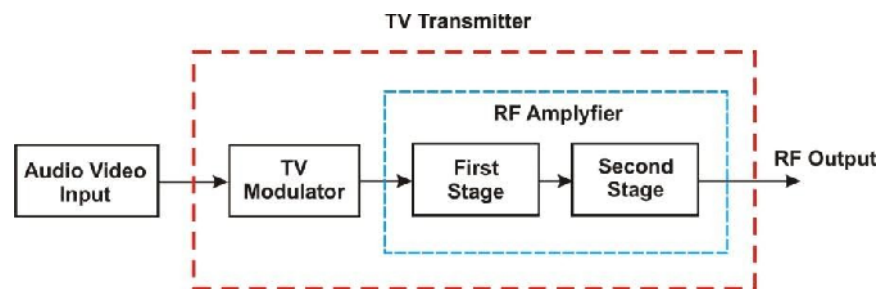


Figure 1. Diagram block of TV transmitter.

Before designing the matching network for the amplifier to reduce the input signal reflection at the input interface of the amplifier, an appropriate biasing circuit was needed to make the transistor operate in proper condition. The detailed procedures to design the biasing circuit and input matching network are shown below step by step. The first stage of RF amplifier circuit used RD15HVF1 type transistor. The transistor was specifically designed for VHF/UHF High power amplifiers applications with High Efficiency: 60% type and 55% type respectively on VHF and UHF Band. The biasing circuit, V_{gs} (The gate-source voltage) and V_{dd} (drain-drain Voltage), was chosen to be 5 V and 12.5V respectively as datasheet stated. This biasing circuit was to guarantee the sufficient current I_{dd} (drain- drain current) to be less than 1 Ampere.

After designing the suitable biasing circuit, the procedures were: designing impedance matching network for both input and output. Firstly, we needed to extract S-parameter of the RD15HVF1 as input parameter of CAD simulation, then checked the stable region, S11 (return loss) position, and gain circles for the transistor as shown in figure 2. Hence, the first stage met the specified goals of minimizing the input reflection coefficient and constant gain while the stability requirement fulfilled.

In figure 2, the region below the blue lines is the stable region. The region within the pink circles is gain circle at 20 dB from 50 to 550 MHz. The red line is the location of S11 plot. Notice that at center frequency operation of 200 MHz, the amplifier will be stable (m2 marker) and the gain stays relatively flat (m3 marker), but the impedance input (m4) $Z_{in} = Z_0 \cdot (0.14 - j0.035) = 7 - j1.7 \text{ ohm}$ is not near 50 ohm.

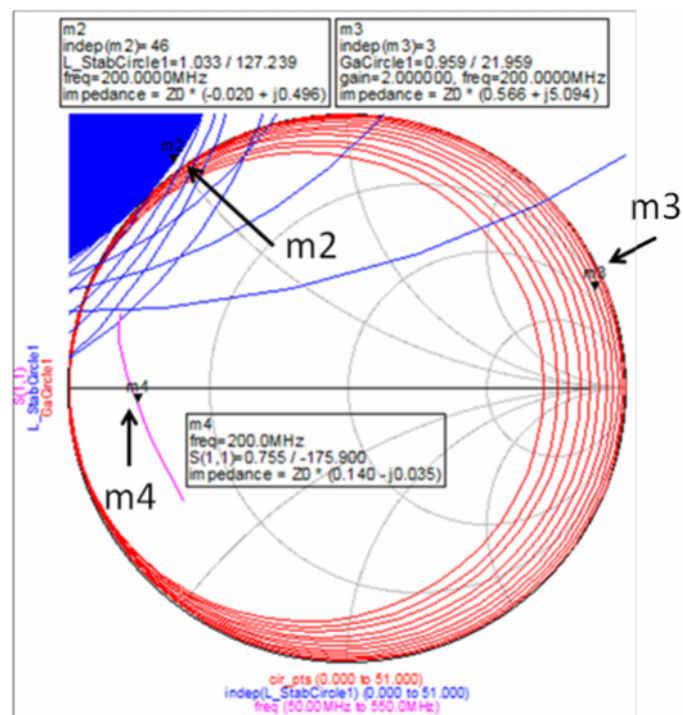


Figure 2. Simulation for transistor stability, gain and impedance.

The design of impedance matching network could be started from input part or output part with frequency center at 200 MHz. Passive inductor (L) and capacitor (C) networks are usually used to match impedances between the source (generator) and load. In this work, input matching networks were designed by using combinations of C (capacitors) and TL (transmission line) instead of inductors as depicted in figure 3.

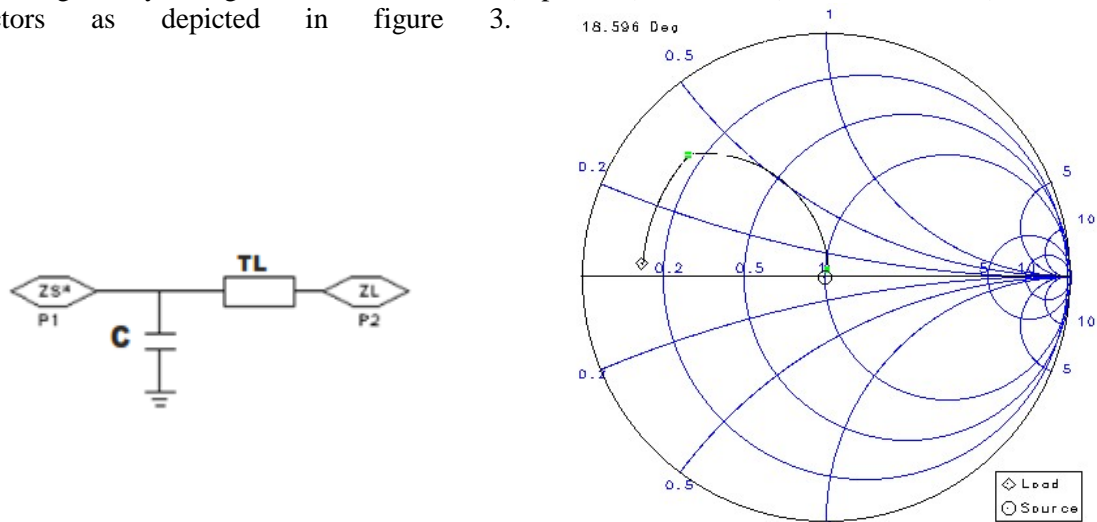


Figure 3. Matching network C and TL topology.

Figure 4. Input matching network using transmission line TL and capacitor C.

As illustrated in figure 4, a transmission line (TL) $Z_0 = 50$ ohm moved toward Z_{source} 50 ohm starting from Z_{in} about 18.595 degree long. The 50 Ohm match was achieved by placing C capacitor 32

pf at the end of the transmission line. Similar procedure was applied to reach better impedance matching for the transistor output part. The appropriate capacitor and transmission line values of the matching networks are important. After several times of the optimization, the complete input and output matching network for amplifier is shown in figure 5.

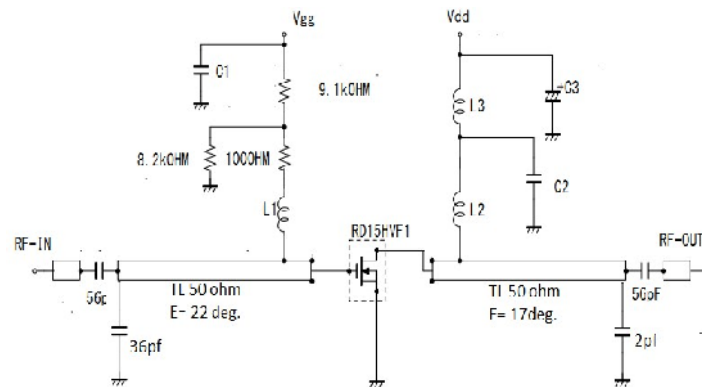


Figure 5. Complete circuit of matching network and biasing for both input output part.

To clearly see the response of this network, the following graph, shown in figure 6, provides the simulated gain and input reflection coefficient of the designed amplifier after optimization. It shows that S11 was significantly matched from -2.44dB to -25dB. This means all RF power from source was mostly delivered to the transistor. First stage amplification S21 had improved from 15 dB to 19 dB gain at 200 MHz. Therefore it can be summarized that both of the gain (S21) and input return loss (S11) fulfilled the previous set goals.

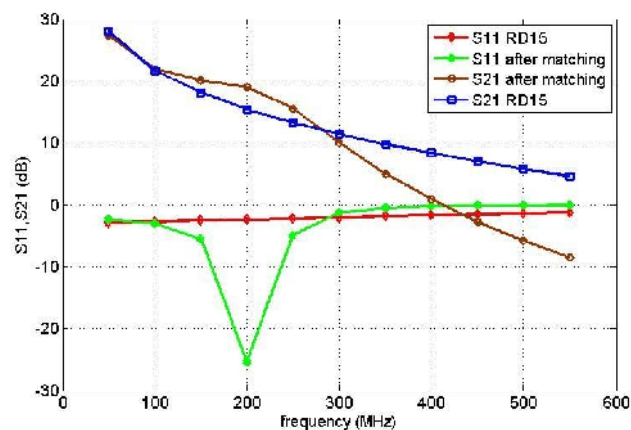


Figure 6. Simulation result of S21-S11 for first stage circuit were applied matching network.

The output of the first stage amplifier circuit was further amplified by second stage circuit. This circuit used RF module type RA 30H1721M as shown in figure 7. This transistor is classified as MOSFET and may operate at frequency range of 175 – 215 MHz when it is supplied with 12.5 Volt [8]. The maximum power that can be generated is more than 30 Watt. The RF module is ready match to 50 ohm for both input and output port. There is no need matching impedance for both ports.

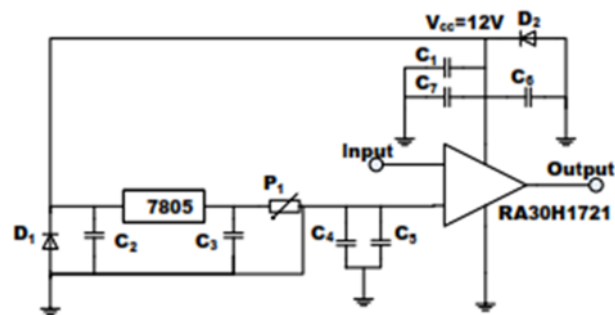


Figure 7. RF Module

Fabrication for the circuit were made on double layer PCB FR4 and placed on top of proper heatsink to desipate heat. The measurement set up is shown in figure 8.

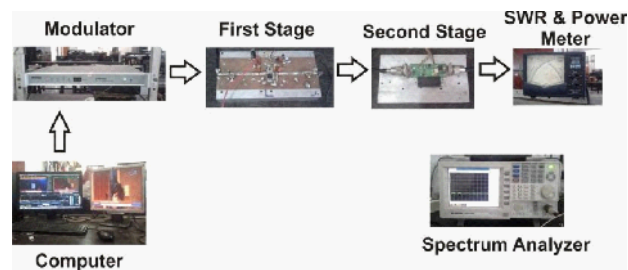


Figure 8. Experimental setup

Firstly, output power level of modulator was observed before and after modulation by using spectrum analyzer GW INSTEK GSP-830. Spectrum analysis was carried out by comparing the spectrum frequency before and after modulation. Secondly, output power of first stage amplifier was measured and analyzed as RF output of modulator was applied. Finally, stage 2 was examined to see the stability and clearness of RF signal by using power meter and spectrum analyzer. Meanwhile, the quality of broadcasted program was examined by TV monitor.

3. Result and Discussion

The output of modulator was observed before and after modulation applied. Figure 9 displays spectrum of modulator output before modulation. The level of video carrier was 11 dBm at 189.25 MHz. The level of audio carrier was -15 dBm at 194.5 MHz. Meanwhile, after modulation level of video carrier remained constant at 11 dBm but the level of audio increased to -10 dBm as presented in figure 10.

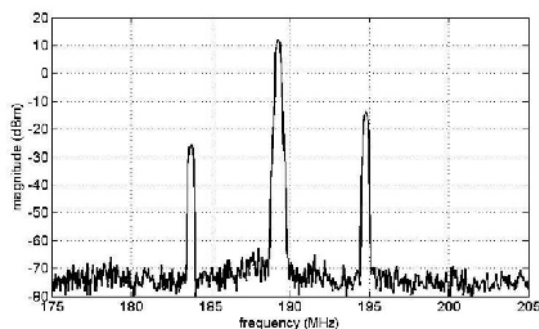


Figure 9. Spectrum of output modulator with carrier only

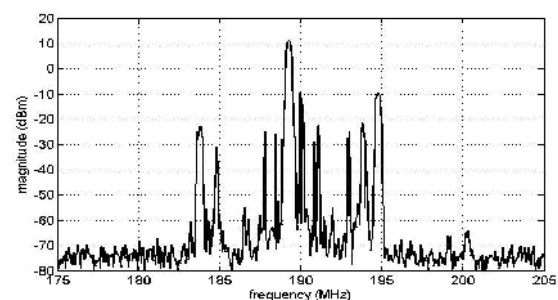


Figure 10. Spectrum of output modulator with carrier plus information.

The measurement result for RF amplifier stage 1 is displayed in figure 11. It was measured at the frequency range of 175.25 to 224.25 MHz. The lowest power at frequency 175.25 MHz was 53.07 mwatt (17.28 dBm), while the highest power reached 522.38 mwatt (27.18 dBm) at frequency of 196.25 MHz. Hence, the average power that could be achieved was 24.68 dBm. Therefore, stage 1 had amplification gain around 13.5dB.

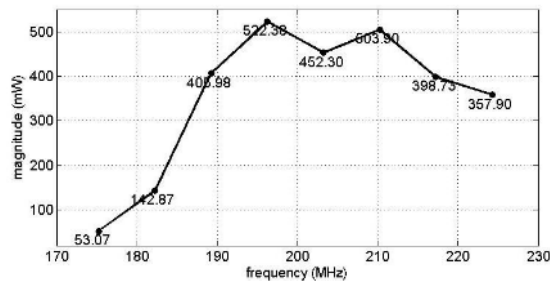


Figure 11. Level power output buffer.

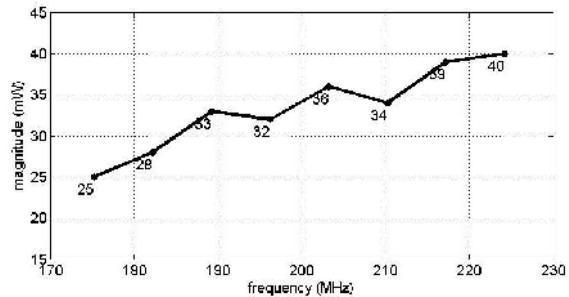


Figure 12. Level output power Amplifier.

Next procedure was applying RF output of stage 1 to stage 2 to verify RF amplifier performance. The measurement result is shown in figure 12. The average power that could be achieved was 33.38 Watt (45.23 dBm). The highest power that could be achieved at frequency 224.25 MHz was 40 Watt (46.02 dBm), while the lowest power was 25 Watt (43.98 dBm) at frequency 175.25 MHz. Table 1 shows gain calculation of stage 2 for eight channels at band III VHF TV. Parameter gain of RF amplifier could be calculated using (1).

$$G = 10^{10} \log \frac{P_{out}}{P_{in}} \quad (1)$$

G is gain in logarithmic scale (dB). P_{out} is level output power RF amplifier stage 2 and P_{in} is level input power Amplifier stage 2.

Table 1. Gain for stage 2 RF amplifier.

Frequency (MHz)	Gain (dB)
175.25	26.73
182.25	22.92
189.25	19.10
196.25	17.87
203.25	19.01
210.25	18.29
217.25	19.90
224.25	20.48
average	20.54

Based on the resulting power, it can be inferred that the RF amplifier stage 2 has met the minimum required power for the community TV, i.e less than 50 Watt. When comparing to local brand design of RF amplifier for community television, the total cost for a proposed designed RF amplifier is about only 1/5.

4. Conclusions

The designed RF amplifier especially for community television is presented. Capability of television to deliver voices and pictures makes this media become the most effective method to spread information. Television is beneficial to improve education. Programs with educative content are useful to improve the quality of human resources. The proposed RF amplifier consists of two

stages of amplifier. The first stage amplifier was used for amplified output of TV modulator less than 11dBm so that the first stage output able to drive next stage amplifier. Such CAD simulation and fabrication were run to reach optimum RF amplifier design circuit. The associated circuit was made by determining stability circle, stability gain, and matching impedance. Hence, the average power of first stage RF amplifier was 24.68 dBm achieved.

The second stage used RF modules which was ready match to 50 ohm for both input and output port. There was no need matching impedance for both ports. The experiment result shows that the RF amplifier may operate at Band III TV VHF ranging from 174 to 230 MHz. The resulting average power of the 2nd stage amplifier was 33.38 Watt with the average gain of 20.54 dB. The designed RF amplifier is cheap way to have very stable and clean signal of the RF amplifier for community TV. The total budget for a designed RF amplifier is about only 1/5 compared to local design RF final amplifier.

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