FM Transmitter Design and analysis

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By

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Introduction

FM transmitter is an electronic device, which produces frequency-modulated waves with the help of an antenna. A transmitter generates FM waves for various purposes such as communication, broadcasting a message, etc. Furthermore, FM signals are less prone to interference as compared to AM signals due to higher bandwidth. Also, it is less susceptible to noise. The signal transmitted has a limited range for its reception, as we increase our distance from the source, the signal received is merged with noise, and the noise component dominates the signal transmitted hence the message cannot be received successfully after a certain distance due to obstacles. The information that is provided to the transmitter is in the form of an electronic signal. This includes audio from a microphone. The transmitter combines the information signal to be carried with the RF signal (the carrier). This is called modulation. In an FM transmitter, the information is added to the radio signal by slightly varying the radio signal's frequency.

Literature Survey

When audio signals are transmitted over thousands of kilometers through radio transmission, the audio frequencies that lie within the frequency range of 15 Hertz to 20 Kilohertz have very small signal power and thus cannot be transmitted via the antenna for communication purposes. The radiation of electrical energy is only possible at frequencies above 20 Kilohertz. The main advantage of high-frequency signals is that they can be transmitted over very long distances by dissipating very small power. Thus, the audio signals must be sent along with the high-frequency signals for communication.

In high frequency transmission Frequency modulation techniques are popular because of less interference noises. FM transmitter has multiple parts, the most common one is the carrier generator which contains LC circuit or Crystal oscillator then its modulator using varactor diode or transistor reactance techniques and then it's amplified for transmission .

Problem Statement

This Project is for designing a Frequency Modulated Transmitter considering the aspects: Efficiency of the design ,Portability and Cost

Objectives

- Understanding the working and implementation of Frequency modulation techniques
- To make a small, portable, and cost-effective efficient FM transmitter for audio transmission Efficient
- Transmission of audio for longer ranges with circuit efficiency
- The reliable audio quality for sending clear audio

Methods

The Softwares used for simulations are :

- Simulink [Analytical Usage]
- LTSpice XVII [Circuit Simulation]
- Matlab

We did multiple structured stages for implementing a full-fledged FM transmitter

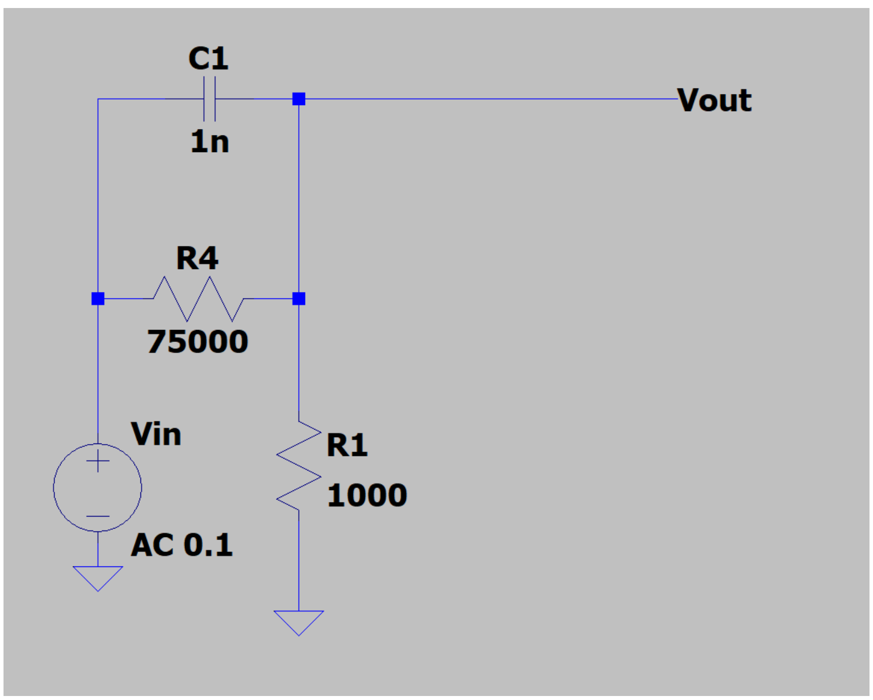
Stages of Circuit Implementation

- Pre Emphasis: Boosting Audio Signal with respect to their frequency
- Audio Frequency Pre Amplifier
- Carrier Generator
- Frequency Modulator
- Radio Frequency Power Amplifier

Results & Discussion

Pre-emphasis [Frequency Boost]

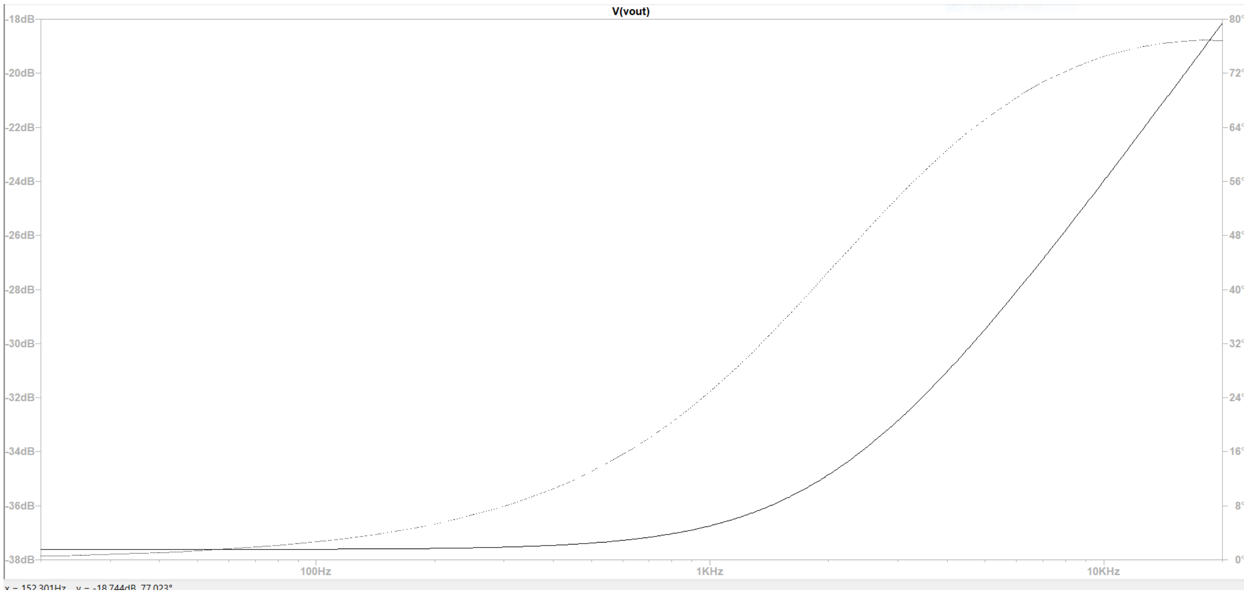
To boost only the signal's high-frequency components, while leaving the low-frequency components in their original state. Pre-emphasis operates by boosting the high-frequency energy every time a transition in the data occurs. The data edges contain the signal's high-frequency content. The signal edges deteriorate with the loss of the high-frequency signal components. It boosts audio frequency above 1 kHz which gives proper staging for the speech band.



Vout/Vin = 1000/{1000+[75000/(1+75000*2pi*f)]}

Vout/Vin = 1/[1+75/(1+75000*2pi*f)]

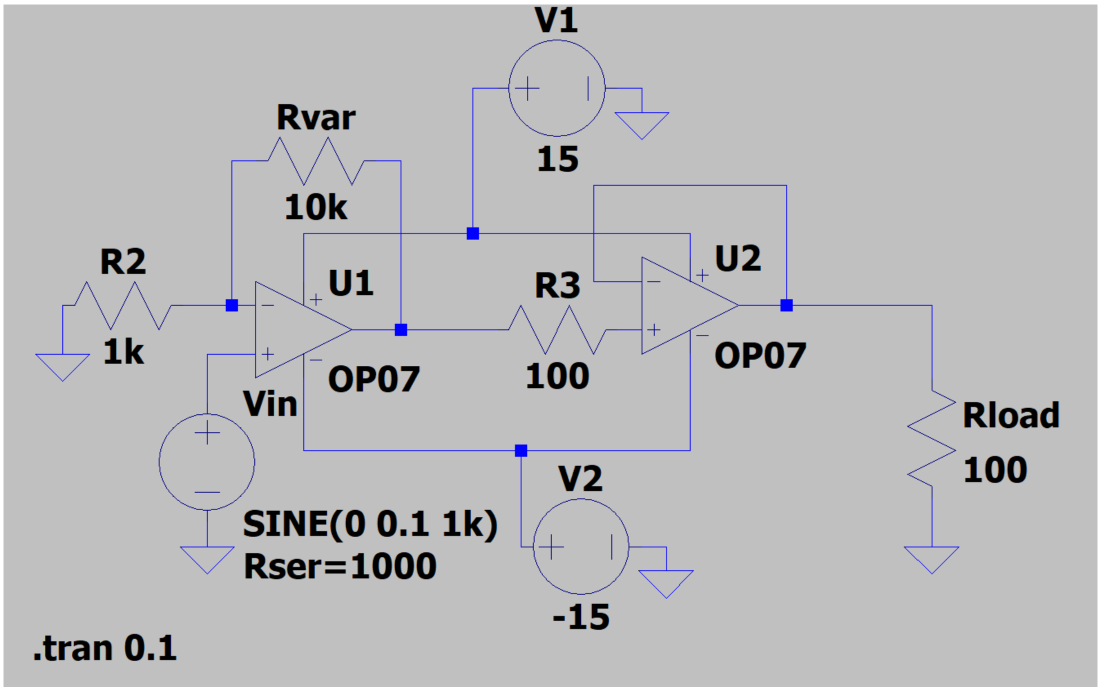
Pre Emphasis Frequency response



Audio Frequency Preamplifier

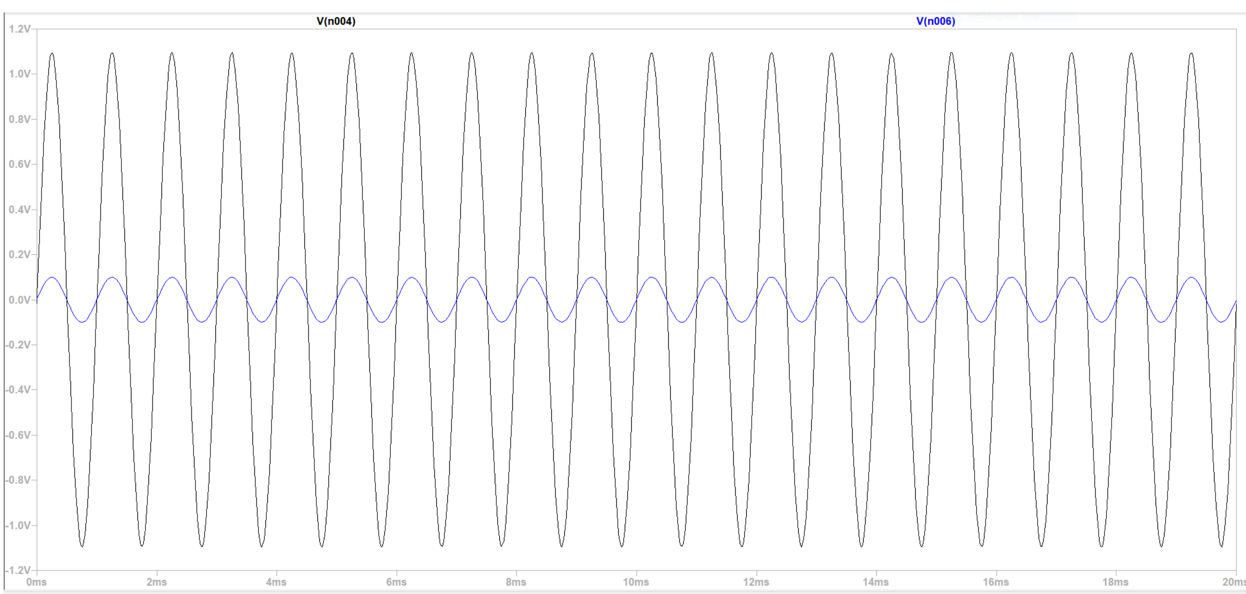
Preamplifier for handling switching between different line-level sources and boosts the signal before sending it to the modulator. A weak electrical signal becomes strong enough for additional processing, preventing noise and offering cleaner modulation.

We used NE5532 Texas instruments' IC which is a Dual Low Noise Op-Amp in an 8-pin package commonly used as amplifiers in audio circuits for its noise immunity and high output drive capability. The Op-Amp is internally compensated for high unity gain with maximum output swing bandwidth, low distortion, and high slew rate



Gain = (1 + Rvar/R2)

Amplified Audio Simulation

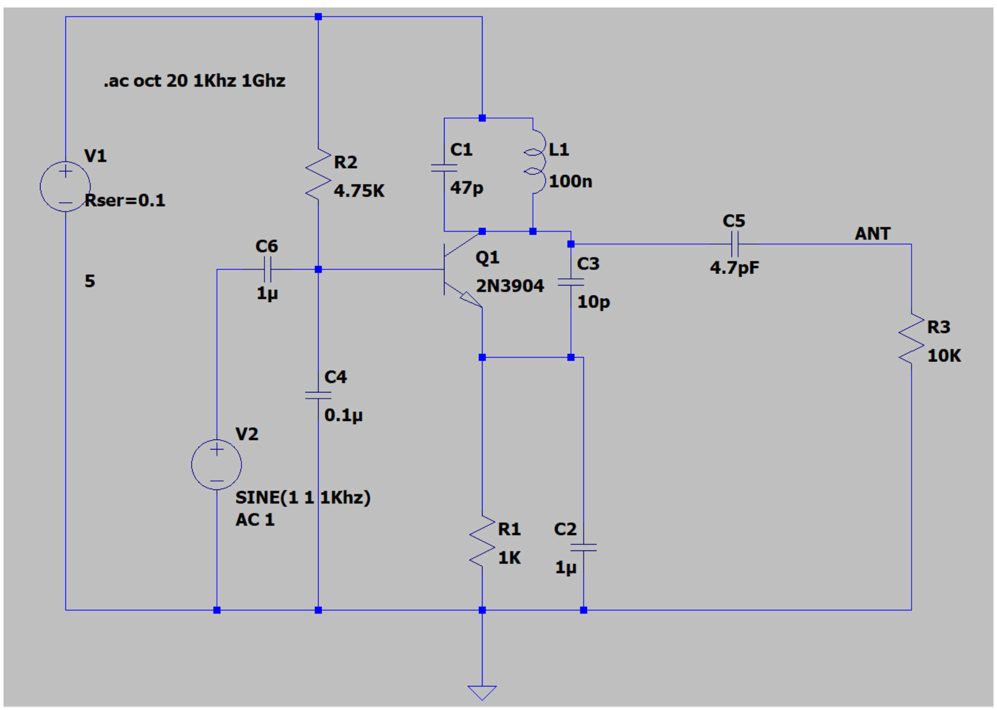


Carrier Generator and Reactance Modulator(Frequency Modulator)

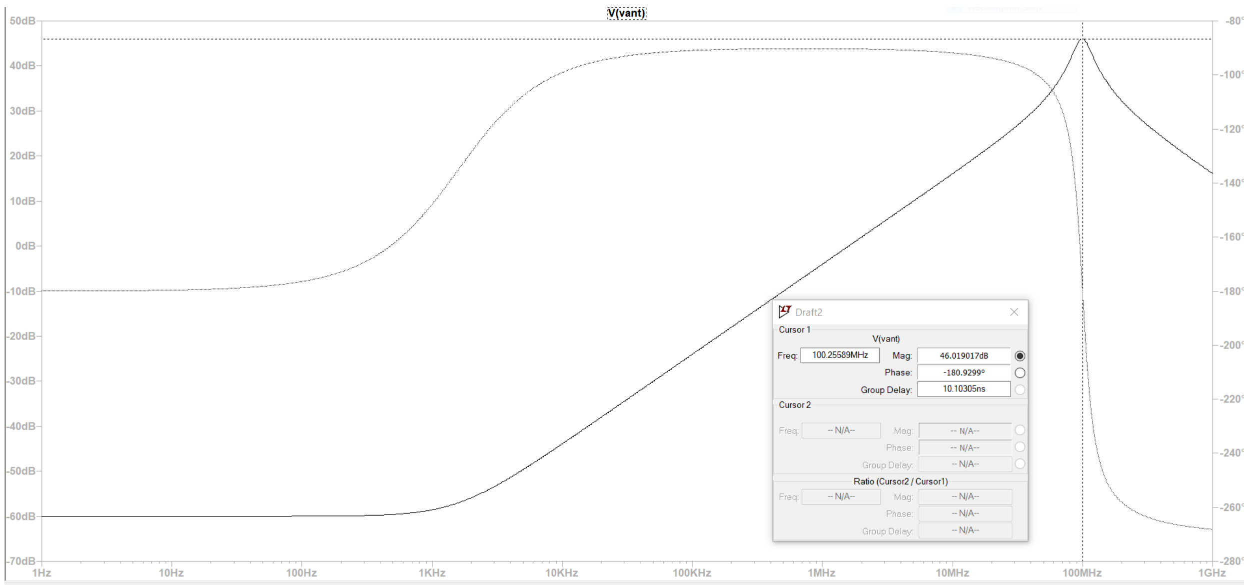
A reactance modulator changes the frequency of the tank circuit of the oscillator by changing its reactance in this circuit .

LC tank circuit decides the carrier frequency and the modulation index depends on the transistors reverse-biased collector-base junction capacitance variance more variance means a bigger modulation index so transistor 2N3904 has been chosen which has good CB capacitance variance.

fc=1/2pi*sqrt(L*C)



Simulation



Simulink Modeling

Mathematical Expression for FM

SFM(t)=Ac$cos[2\pi fc\ t + 2\pi kf \int m(t)dt]$

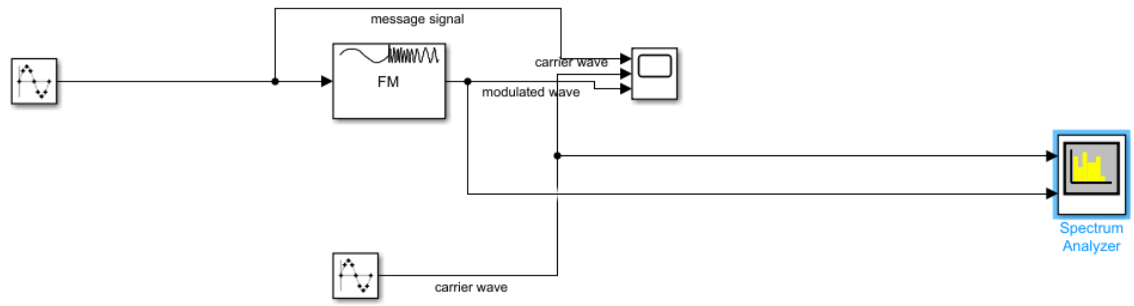
Where,

Kf: is the frequency sensitivity of FM modulator

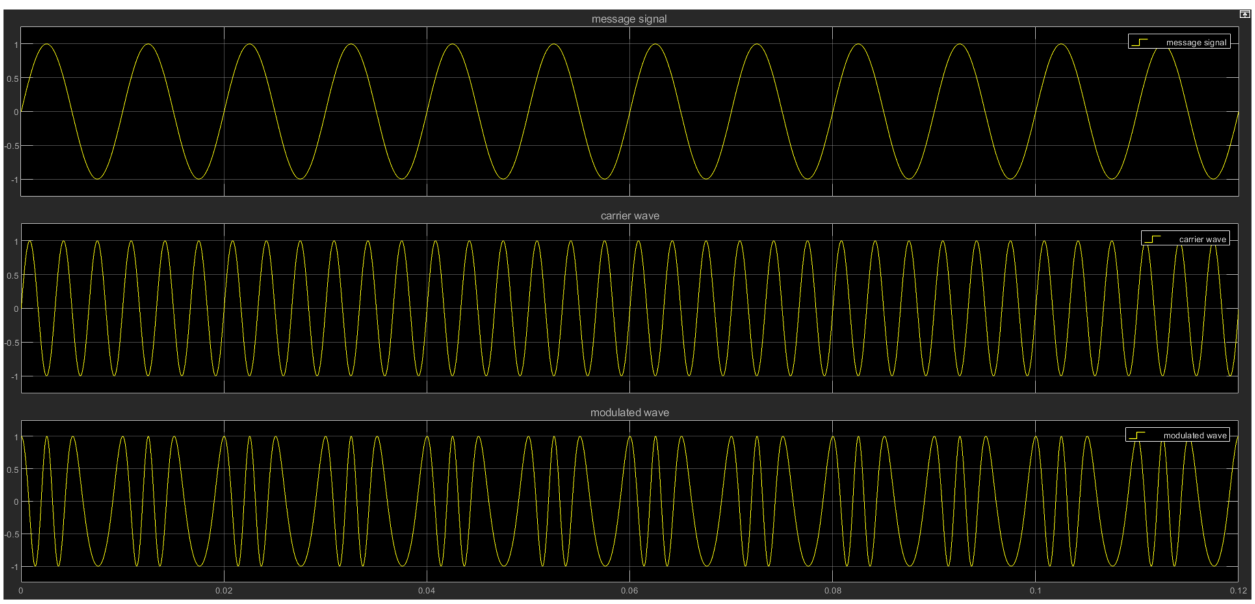
m(t): Message Signal m(t)=Amcos($2\pi fmt$) c(t):

Carrier Signal c(t)=Accos($2\pi fc\ t$) β:

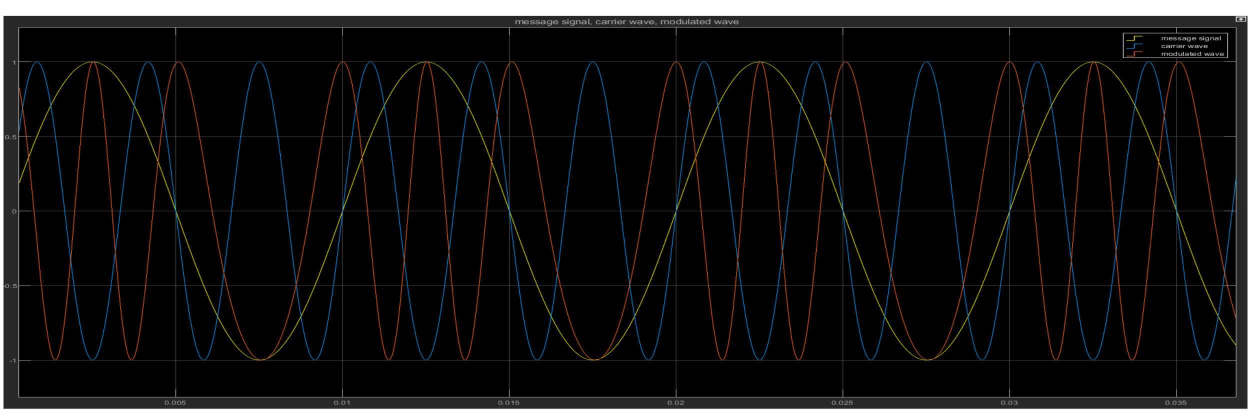
Modulation Index SFM(t)=Ac$cos[2\pi fc\ t + \beta \sin(2\pi fmt)]$.



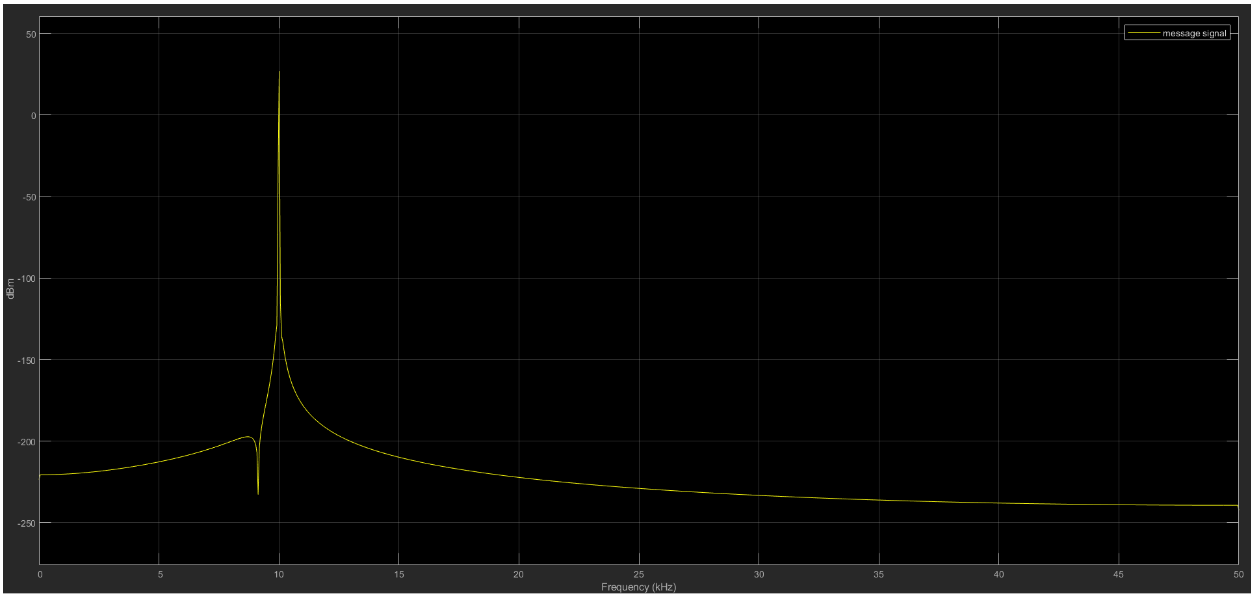
Waveforms



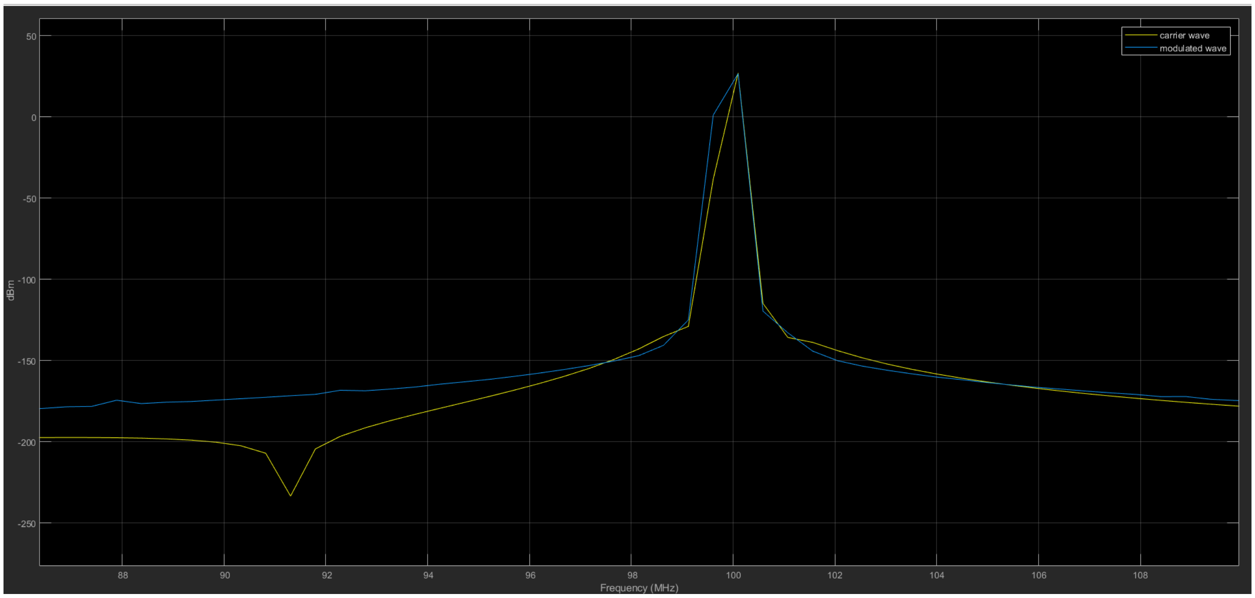
Waveforms



Frequency Response of Input



Frequency Response of Carrier wave and Frequency Modulated Wave



Rf Power Amplifier

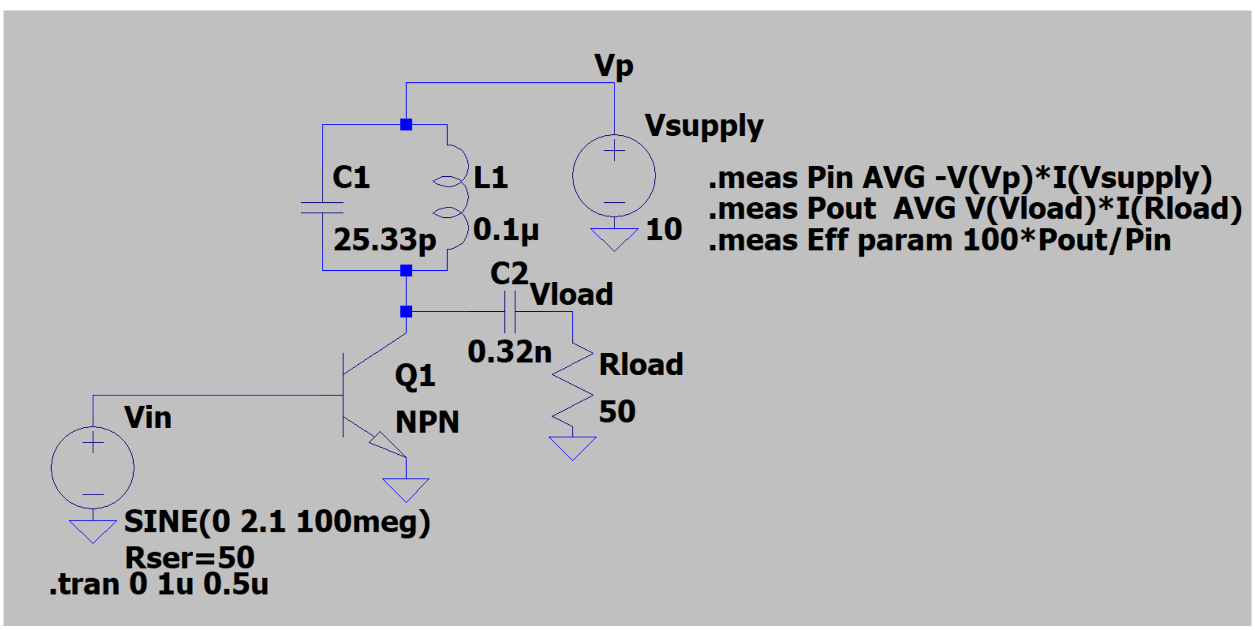
We used a Class -C amplifier for our design of power amplifier which has very good efficiency and a narrow band of operation which can act as a bandpass filter which can eliminate total harmonic distortion(2fc,3fc...) coming out of the reactance modulator and

The class C amplifier has a constant voltage level at output depending on supply voltage which can help to maintain a constant amplitude level and act as an amplitude limiter for the FM wave

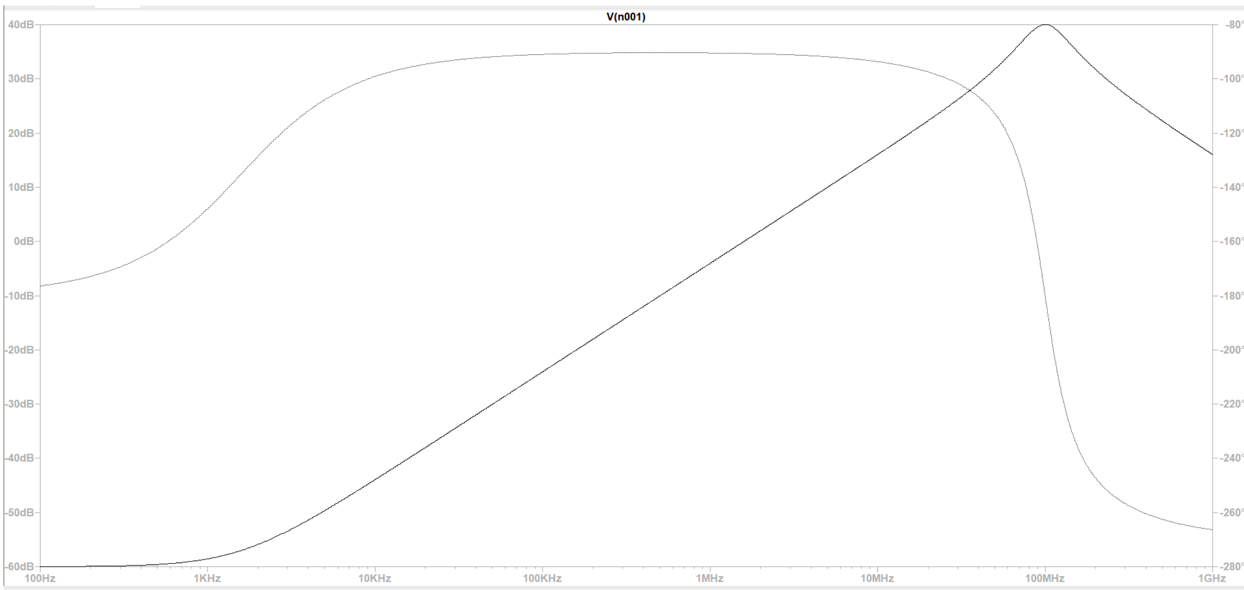
Class c amplifier Poor linearity which distorts amplitude based information but in fm information is modulated in frequency which won't be affecting information stored

Using special purpose transistor made for RF application can give better yield for overall amplifier

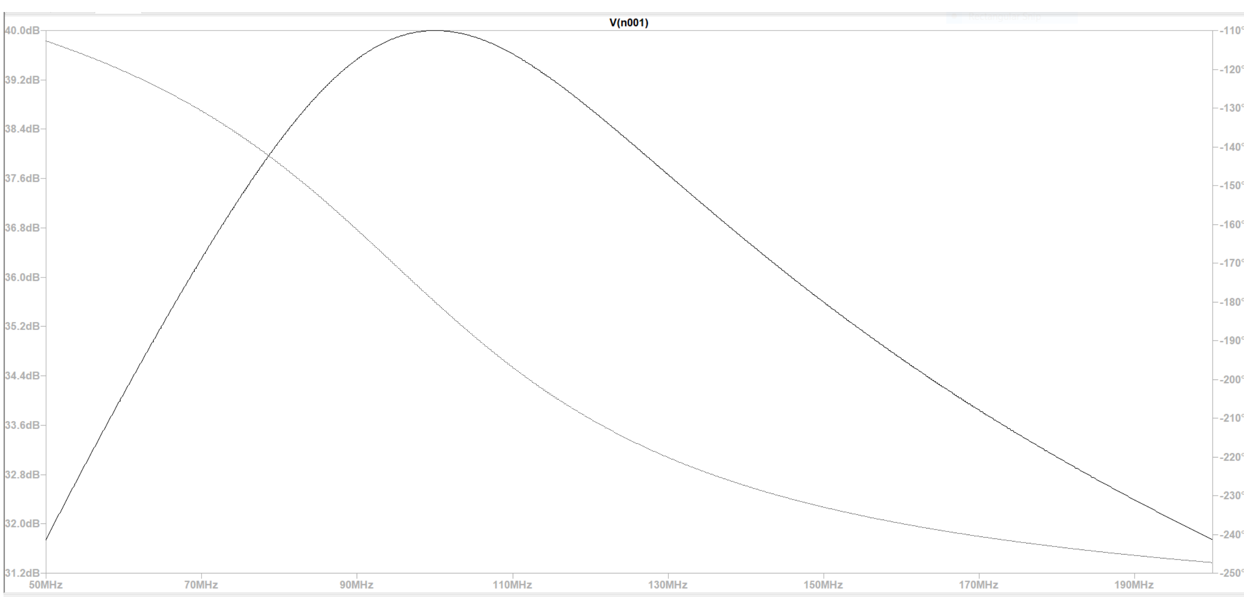
1 Watt RF Power Amplifier Circuit for 100 Mhz Operation



Decade response

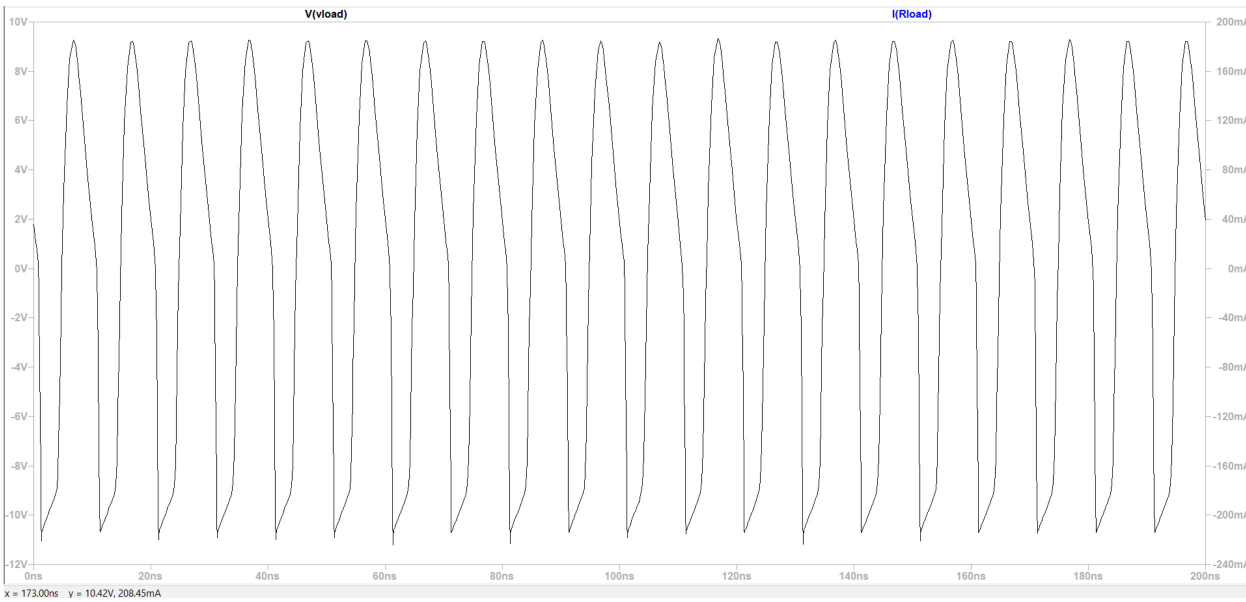


Linear response



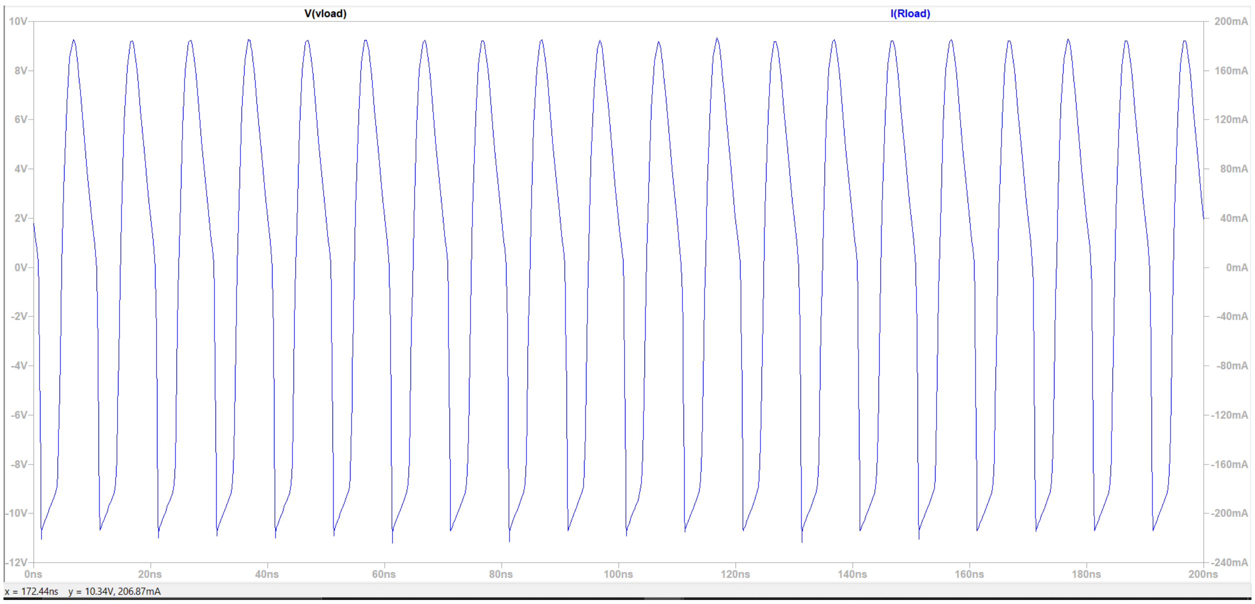
This Has very narrow band width which is around 100 Mhz for Q = 10 which is balanced in for lesser distortion/faster response and efficiency of power amplifier

Output Voltage

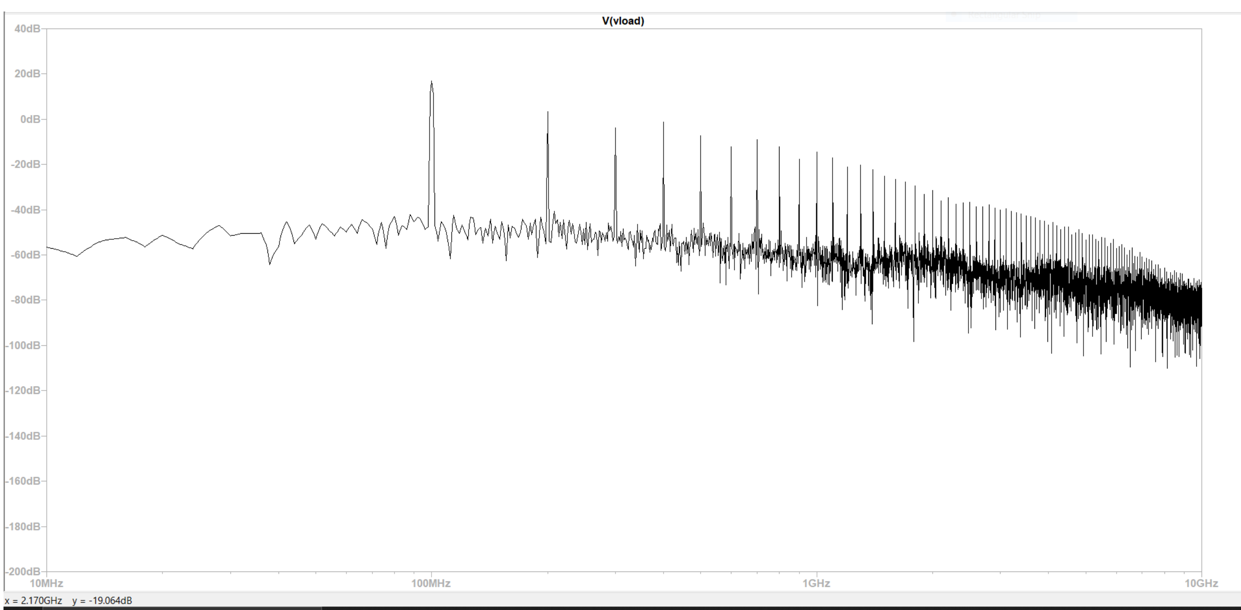


We can see half distorted outputs seeing in frequency domain could have more better picture as it is a frequency modulated wave

Output Current



FFT of output voltage



We can see that there is no distortion around carrier frequency and the amplifier doesn't distort any information contained in frequency-modulated wave

Only harmonic noises are present which are 2Fc,3Fc… can be removed using filtering if needed

Power and Efficiency

SPICE Error Log: C:\Users\ASUS\Desktop\Desktop stuff\MINI\Draft1.log

```
Circuit: * C:\Users\ASUS\Desktop\Desktop stuff\MINI\Draft1.asc

Direct Newton iteration for .op point succeeded.

pout: AVG(v(vload)*i(r1))=1.01559 FROM 0 TO 5e-007
pin: AVG(-v(vp)*i(v1))=1.18174 FROM 0 TO 5e-007
eff: 100*pout/pin=85.9404


Date: Wed May 18 10:02:51 2022
Total elapsed time: 0.081 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 22375
traniter = 22370
tranpoints = 6333
accept = 4318
rejected = 2015
matrix size = 5
fillins = 0
solver = Normal
Matrix Compiler1: 186 bytes object code size  0.0/0.0/[0.0]
Matrix Compiler2: 309 bytes object code size  0.0/0.0/[0.0]
```

Power taken from supply (Pin) = 1.18174 Watts

Power dissipated by load =1.01559 Watts

Circuit was designed for 5Ohm load and 1 watt power delivery

Load values can be changed using LC lossless impedance matching

Power can be boosted just by increasing supply voltage proportional to square of supply voltage

Efficiency = 85.9404%

We were able to achieve excellent 86% efficiency by impedance matching and class-C configuration and selection of optimum Q factor value so that both distortion and efficiency are balanced

Conclusion

- This circuit design does reliable frequency modulation and can be transmitted to longer ranges by tuning the power amplifier.
- This design has a very efficient power amplifier which is the main consumer of energy.
- Most of the components used are cheap which makes the design cost efficient and can be used anywhere.
- As our design is stage by stage implementation we can easily modify or add extra stage for improving performance

Future Scope

As Frequency Modulation has very less noise , we can transmit digital signals and this design has most of full-fledged FM Station features. It can be scaled up for creating a proper FM Station by adding some features like Frequency limiters and Amplitude limiter circuits or by changing modulator part with crystal modulator design . As our design is stage by stage implementation there is always room for modification.

References

- Deborsi Basu, Abhishek Bhowmik, "Design and Implementation of a Smart & Portable Wireless FM Transmitter for Wide Range Communication", August 2020, pp. 30-39 , DOI:10.9734/JERR/2020/v15i217142
- Abhishek Shrivastava, "Design and development of low-range frequency modulated signal (F.M.) transmitter", October 2017, pp. 31-36 , DOI:10.3126/bibechana.v15i0.18279