DESIGN OF AN FM TELEPHONE TRANSMITTER

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Abstract

There exist today an increasing need for global security; as such there is a need to monitor conversations between entities. In this work we design an FM Telephone Transmitter which connects in series to a phone line, steals power from the phone line and consequently transmits both sides of a conversation over the telephone to an FM [frequency modulated] Radio tuned to between 90 and 105MHz. The FM Telephone Transmitter as the name implies, is an embodiment of three different units which are coupled together to achieve our aim. The principal mode of operation of this telephone FM transmitter is to transmit the audio signal coupled from the telephone. In other words, the conversation between two parties is transmitted to an FM band and broadcast over the radio wirelessly. The receiving end uses a receiver tuned between 90Hz and 105Hz to receive the signal. In this case we tuned the receiver FM band to 97.8MHZ and 98.2MHZ and signals were picked. However, the signal was found to be more stable at 98.2MHz. In summary this work presents an ingenious, portable and yet affordable means of monitoring conversation by coupling our devise unto a telephone line so that all conversations is transmitted unto an FM band and broadcast wirelessly.

Keywords: FM, Transmitter, Radio, Security.

1 INTRODUTION

The FM Telephone Transmitter is a simple, yet Ingenious device that connects in series to a phone line, steals power from the phone line and consequently transmits both sides of a conversation over the telephone to an FM [frequency modulated] Radio tuned to between 90 and 105MHz.

It may be required for the intelligence department of the security services or security operatives to keep track of every communication. This devise is handy to provide such back up services by broadcasting to a dedicated channel over a transistor radio from where recording can be made. This can also be used to provide security alertness, provided every security post of a security network has her radio tuned to the required FM band. In an industrial layout, where the control room is far away from the men at work, it may be required to disseminate certain instructions that need to be executed; this devise can provide the services of reaching them without stress.

2 RESEARCH METHODOLOGY

The FM Telephone Transmitter is designed in blocks of different modules as shown in figure 1. The functional block diagram units relate as shown by the arrows. The subsequent sessions describe the various modules that make up the FM Telephone Transmitter.

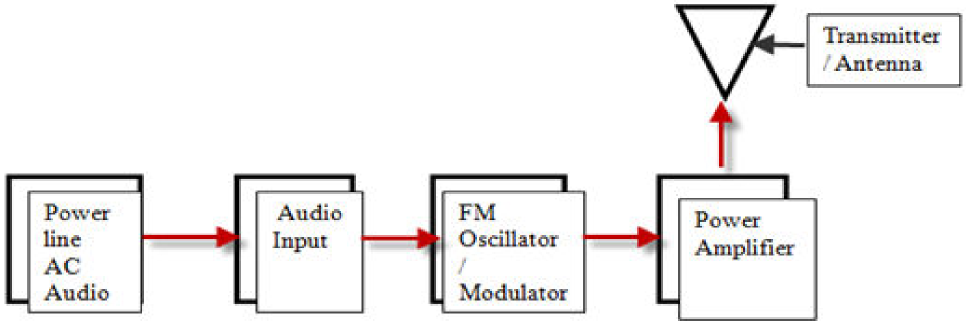

Fig.1. Block Diagram of an FM Telephone Transmitter

2.1 Design of the audio input

This is where the audio signal from the telephone line is fed into. R1, R2, R3 form part of the biasing and stabilization circuit of the FM transmitter. The values where carefully selected from standard circuit to ensure a proper operating point otherwise a part of the negative half-circle of the signal will be cut off in the output. The capacitor C2 is an electrolytic capacitor used to couple the signal to the base of the amplifying circuit to filter dc components.

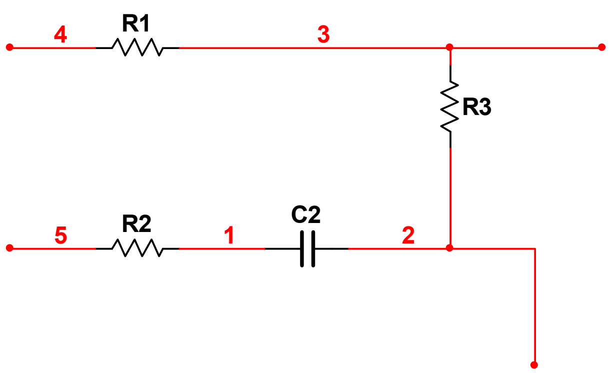

Fig. 2 Circuit diagram of an audio coupling network.

The basing current $I = \frac{V_{DC}}{R_2}$

The audio signal is coupled to the input of the oscillator/modulator stage through C2

2.2 Design of the Oscillator/Modulator

A. Oscillator

The oscillator is an electronic circuit that produces a time varying signal without an external input signal using positive feedback [1]. In other words, it is that circuit which produces a repetitive waveform on its output with only the dc supply voltage as an input. The output voltage can be either sinusoidal or non-sinusoidal, depending on the type of oscillator used.

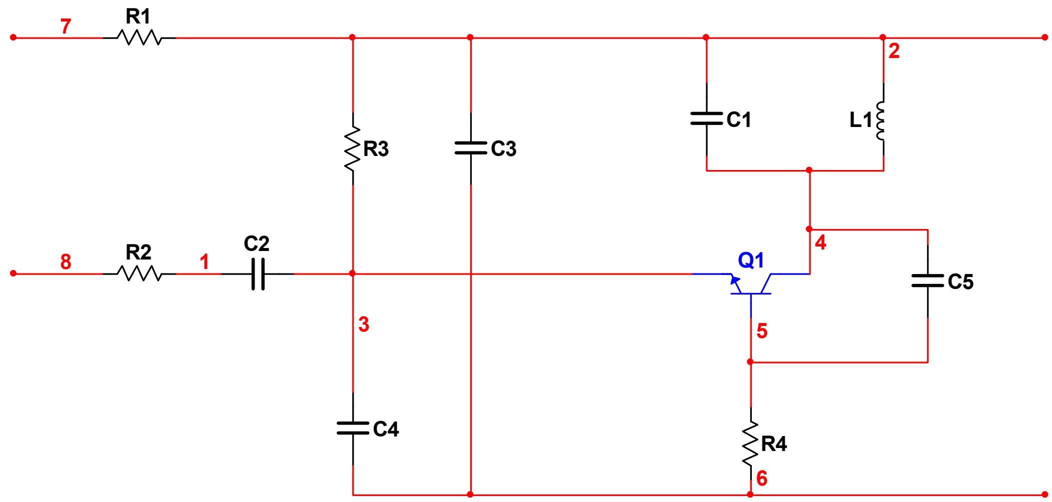

Fig. 3 Circuit diagram of the common base oscillator.

One other function of the oscillator is to provide a high frequency signal called carrier wave.

Due to the high frequency of operation, a common-base oscillator was utilized as it provides the best performance of such frequencies (> 80MHz) [2].

In figure 3 above, Q1 was configured as a common-base oscillator, CBO, with C4 (1nF) providing AC path to ground for the oscillator. R3, a 47KΩ resistance provides base bias current for Q1, the input audio signal was coupled into the base-emitter junction of Q1 by an RC network comprising a 10KΩ resistance R2 and 0.1µF capacitance C2. The RC network forms a 'High pass filter of lower 3dB (FD3B) cut-off frequency

$$F = \frac{1}{2\pi Rc} = \frac{1}{2\pi \times 10{,}000 \times 1 \times 10^{-6}}$$

$$= 159 Hz$$

The frequency determining tank circuit was selected to oscillate at about 98.5MHz.

The circuit is basically a radio frequency oscillator that operates between 93MHz-105MHz. C1, L1, Q1, from the FM oscillator. Every transistor needs an oscillator to generate the Radio Frequency (RF) carrier waves.

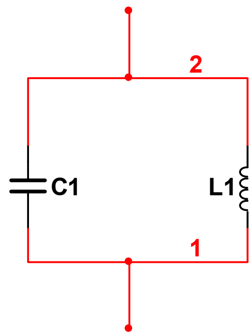

Fig. 4 Thank circuit of the oscillator

From the equation, $F = \frac{1}{2\pi\sqrt{LC}}$, the value of the inductance needed for oscillating of an un-modulated carrier frequency Fc of 98.5MHz for a 22pF capacitance, is:

$$L = \frac{1}{4\pi^2 F^2 c} = \frac{1}{(4\pi^2)\times(98500000)\times 22\times 10^{-12}}$$

$$= 118.7nH$$

$$\cong 119nH$$

$$At\ resonance, X_L = X_C$$

$$X_c = \frac{1}{2\pi fc} = \frac{1}{2\pi \times f \times c}$$

$$= \frac{1}{2\pi \times 98500000 \times 22 \times 10^{-12}}$$

$$= 73.44\Omega$$

Since at resonance, $X_L = X_C$ and in an ideal resonance circuit, $I_L = I_C$ but opposite in phase and hence will cancel each other [3]. Hence, an ideal Circuit offers infinite impedance and acts as an 'open circuit'.

To calculate the number of turns used, we shall employ the expression:

$$L = \frac{N^2 \mu A}{l}$$

Where:

L = Inductance in Henry

μ = Permittivity of Air

A = Area of Cross-section

l = Length of Copper Wire Used

A 21.5 SWG wire of diameter 0.015mm was used for forming the winding.

The diameter of wounded coil was 0.5cm

$$Area = \pi r^2 \Rightarrow \frac{\pi d^2}{4}$$

$$= \frac{\pi \times \left(5 \times 10^{-3}\right)^2}{4}$$

$$= 19.634 \times 10^{-6} m^2$$

$$= 4\pi \times 10^{-7} wb / Am$$

$$= 0.015m$$

$$N^2 = \frac{L \times L}{\mu \times A}$$

$$= \frac{119nH \times 0.015m}{4\pi \times 10^{-7} \times 19.634 \times 10^{-6}}$$

$$= 72$$

$$N = 8.4 \approx 8 Turns$$

But a 7-turn of wire was used and was extended to achieve the centre frequency of 98.5MHz, since fine tuning will also be needed to be achieved.

An oscillator requires positive feedback to start up and to maintain oscillation [4]. In the modulator circuit, positive feedback is affected by a 5.6pF capacitor C5 connected between the collector and the emitter of Q1.

Since a common-base (CB) amplifier provides no phase inversion, the output current is fed back from the collector of Q1. Thus Q1 is in phase with the emitter input signal.

The oscillator current feedback through the 5.6pF capacitance develops a voltage across a 390ohm resistor C5. The output voltage is fed through a 5-6pF coupling capacitor into the RF stage.

B. Modulator

Since an un-modulated carrier frequency contains no information, modulation is consequently indispensable for transmitting the audio information superimposed on the DC voltage from the full ware rectifiers connected to the tip and ring of the phone box. FM modulation implies the variation of the centre frequency with respect to the instantaneous amplitude of the input signal. As one of the principal methods of FM generation, the direct Fm generation was employed. The FM wave is directly generated by altering a frequency determining component of IC tank circuit.

Direct FM generation can be categorized as or into two namely:

i –Base reactance modulation,

ii – varactor diode modulation

In (i), the effective tank capacitance is altered in consonance with the modulating input signal. In a BJT transistor, the collector emitter capacitance is a function of I_c. Since I_c is directly related to I_B changes in I_c charges the collector emitter capacitance and since this capacitance appears in parallel with the tuned circuit, the total tank circuit capacitance is altered by altering I_c.

With no applied modulating voltage, I_B is constant; I_C is also constant and collector emitter capacitance assumes a mean value. If an audio input signal is fed into the base-emitter junction of the oscillator, I_B is varied with varying I_C.

The variation in I_c alters the effective capacitance seen by the tank circuit.

With a steady I_c:

$$F\Delta sc = \left\{ \frac{1}{2\pi\sqrt{L(c + C_{CE})}} \right\} Hz$$

With changing I_c

$$F\Delta sc + \Delta F\Delta sc = \left\{ \frac{1}{2\pi\sqrt{L(c + \Delta CE)}} \right\} Hz$$

$\Delta Fosc$ causes the change in centre frequency corresponding to the information content of the transmitted carrier frequency.

2.3 RF Power Amplifier Stage

A power amplifier is designated as the best amplifier in transmission chain and is the amplifier that typically requires most attention for power efficiency [5].

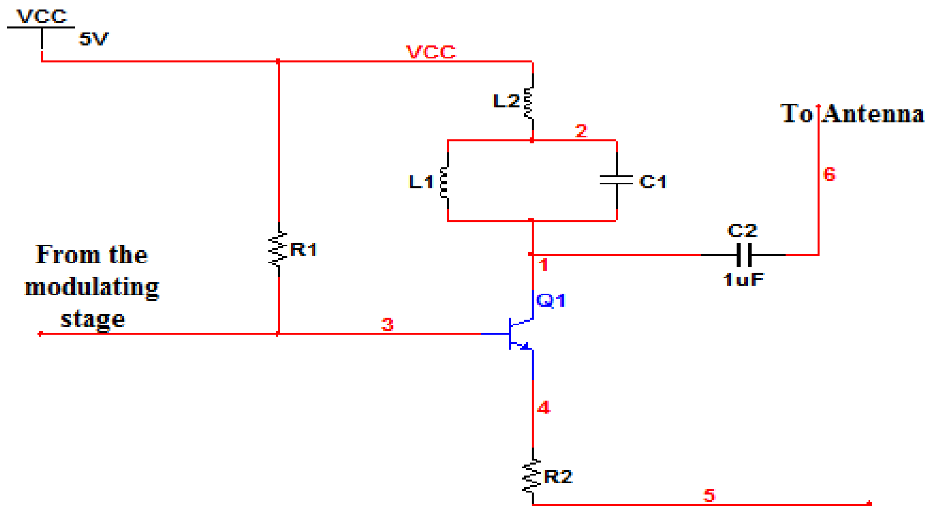

Fig 5 is the RF amplifier stage that drives the antenna.

It is a single stage RF amplifier. It was used for increasing the output drive to the antenna.

The choice of the class of amplifier made is the class C type of amplifier. This is because, class C amplifiers have high circuit efficiency of about 88-90%.hence, they are used for high frequency power switch in radio transmitters since the provide high power output at the radio frequencies where harmonic distortion can be removed by simple circuits. [6]

A C 9014 NPN transistor was used for power amplification. The device was biased by a 47Kohm base resistance R1.

The tank circuit comprises a 5-turn inductance L1 and a 5pF capacitance C1 as shown above in figure 5

The power amplifier design specifications:

The following assumptions were made:

Output power: 10mW

Maximum transmission range: 100meters.

Frequency range:98.5MHz

Modulating frequency range: 3kHz – 8kHz

Velocity of light: 3 x 10^8m/s

The C 9014 device has the following specifications [7]:

PARAMETER	NOTATION	RATED VALUE
Collector Current	I_C	150mA
Current Gain	hfe	300
Collector Base Voltage	V_{CBO}	60
Emitter Base Voltage	V_{EBO}	5
Collector Emitter Voltage	V_{CEO}	50

Using the above transistor characteristics

Vcc = 48V, VBE = 0.65V

hfe = 300

Ic = 150mA

For a class C amplifier, VE is made about ½ VCE

$$V_E = 1/2V_{CE} \Rightarrow 1/2 \times 24$$

$$= 12V$$

$$R_E = {V_E}/{I_E}, \Omega$$

$$Where I_E = I_C = 150mA$$

$$R_E = {12}/{0.15}$$

$R_E = 80\Omega$

An 100Ω resistance was used instead. The voltage across the tank circuit = $I_C \times R_C$

$$I_C R_C = V_{CC} - V_{CE} - V_E$$

$$= 48 - 24 - 8$$

$$= 16V$$

$$X_{L1} = \frac{16}{0.15}$$

$$= 107\Omega$$

$$But L_1 = \frac{XL_2}{2\pi F_O}$$

$$Where f_o = 98.5 mHz$$

$$L_1 = \frac{107}{2\pi \times 98.5 \times 10^6}$$

$$= 0.173 \mu H$$

L_2; is also 0.173φH which is a radio frequency choice (RFC) that decuples power and audio from the amplifier circuit.

The base voltage of Q_E is

$$V_{B.E} + V_E = 12 + 0.65$$

$$= 12.65V$$

$$I_B = \frac{I_C}{H_{Fe}} = \frac{0.15}{300}$$

$$= 0.00057$$

$$R_B = \left(V_{CE} - V_{BE}\right) / I_B$$

$$= \frac{48 - 0.65}{0.005}$$

$$= \frac{47.35}{0.0005} = 94.700\Omega$$

$$A\, 47K\Omega\, resis\tan ce\ was\ used\ instead$$

Power Calculation

Power intensity at a distance r(m) from the radiation source

$$P \big/ 4\pi r^2 = E^2 \big/ 120\pi \left(\omega \partial H / m^2\right) ------- (3.9)$$

$$P = \frac{4\pi r^2 E^2}{120\pi}$$

$$P = E^2 r^2 \big/ 30 ------ (3.10)$$

Then, radiated power is given by: $P = I^2R$ watts

$$I = \sqrt{P/R}$$

Putting equation 3.10 into 3.11 yields

$$I = \sqrt{E^2r^2/30R}$$

P = Power radiated by the transmitter antenna in watts

r = Maximum radius of the effectiveness of the system in meters.

E = Electric field strength at receiver antenna in V/m

R = Radiation resistance of antenna in ohms.

I = Current flowing through it in amperes

Putting r = 50 m, E = 3000 x 10^{-6}V/m into equation 1 gives

$$P = \left(\frac{300 \times 10^{-6} \times 50}{30}\right)^2 = 0.25\vartheta W$$

3 RESULTS TESTING

The testing was carried out at the Nigerian Telecommunications (NITEL) main distribution frame (MDF)/ the exchange units of the aforementioned company in Minna.

A digital transistor radio was used to determine the spots at which reception of signal faded more for optimum reception however, the closer the device is, but not less than 15 meters, the better. With the FM band tuned to 97.8MHZ and 98.2MHZ, signals were picked. However, the signal was found to be more stable at 98.2MHZ.

It should sometimes be noted that radio frequencies may not just be stable. Hence, it can be deduced that owing to frequency variation, a tolerance band of ±0.3MHZ is permitted.

From the result obtained from the test, the design is said to be in good order.

The target range of transmission was 30.5M.

The voltage level was perfect at 48Volt.

The frequency band of effective or optimum reception is 98.2MHZ with the target set at 98.5MHZ.

4 Conclusions

The signal radiated from the antenna is electromagnetic waves which are received by any receiver tuned to 98.5 MHz with the area of coverage within 31 meters. Thus the design was successful.

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