EUROPEAN ACADEMIC RESEARCH, VOL. I, ISSUE 8/ NOVEMBER 2013
ISSN 2286-4822, www.euacademic.org
IMPACT FACTOR: 0.485 (GIF)
DRJI VALUE: 5.9 (B+)

An FM Transmitter Bug for Baby Monitoring

PERCY OKAE
Computer Engineering Department
University of Ghana, Legon, Accra
Ghana
JOSHUA EKOW ANQUANDAH
Computer Engineering Department,
University of Ghana, Legon, Accra
Ghana

Abstract:

The FM transmitter bug is a very sensitive miniature FM microphone transmitter that can be constructed from basic electronic components such as resistors, capacitors, inductors, and diodes. Basically, it serves as a detective device to covertly monitor conversations and can be considered as a surveillance device since it is hidden from sight to avoid easy identification. The FM bug receives sound waves preferably human voice through a microphone. The sound waves are then converted into electrical energy and then back to audio signal (sound energy) at the output end. Next, the sound waves are amplified to a level that can be modulated over RF waves. The electromagnetic waves that are constantly generated at the FM oscillator stage are buffered with adequate power supplied to be transmitted strongly through the antenna. Finally, the input audio signal from the transmitter is output and retrieved from a broadcast FM radio receiver. When it is installed at a premise assuming conditions are favourable, one can tune in to any idle FM band and listen to the output sound. In this research work, we seek to build a FM bug tuned to a frequency of 101.6 MHz and operable within a range of 50 - 500 m. The design metrics are simulated using PSpice. At the end of this design, the bug is embedded in a plastic toy meant for toddlers so that the progress of the child while in the care of baby-sitters when parents are away can be followed.

Key words: FM Transmitter bug, RF, FM radio receiver, PSpice, Transistor, Inductor, Capacitor.

1. Introduction

Major Edwin Howard Armstrong invented the wide band Frequency Modulation (FM) in 1933. He advanced to the experimental transistor which is the FM transistor. Later General Electric and Zenith took out the licenses from Armstrong to manufacture FM receivers. The FM band was originally authorized by FCC in 1941 to occupy 42-50 MHz, but by 1942 the FCC at the instigation of RCA/NBC and CBS moved the FM band to 88-108 MHz. This precipitated the invention of radio and FM devices of which the wireless FM bug is one.

According to the Institute of Electrical and Electronics Engineering (IEEE) laws, the FM bug is a "free-use" device without license. The law is important since the usage of the device could invade privacy by retrieving other people's voices. There was then the need to protect the rights of users who were not detectives.

1.1 Advantages of FM

- There is superior immunity to noise which is made possible by the clipper limiter circuits in the receiver.
- There is effective stripping off of all the noise variations which leaves a constant- amplitude FM signal.
- The electromagnetic wave generated at the oscillator stage is very strong and can penetrate through walls because of the transistor type BF199 VHF/ UHF RF transistor features.
-

1.2 Weaknesses of the FM bug

The bug would not be able to transmit to longer distances. This is because of the detective qualities and sensitivity which limits its distance. The limited reach is caused by transmission capabilities of the antenna and the amount of power supply to the FM bug. The range of the FM bug is 50-500 meters. Anything beyond the range will not be transmitted over the radio clearly and will be quite noisy. This is as a result of distortions caused by obstacles. An open field that is beyond 500 meters will still be transmitted effectively because there will be no obstacles such as trees, buildings and bad weather. The power supply to the bug is 9v DC. The battery power starts decaying after 8 hours of constant supply. This means transmission range will be considerably reduced thus affecting its effectiveness. Hence a circuit switch is included in the design to preserve energy during its idle time.

1.3 Description of some components used

1.3.1 Microphone

The type of microphone used is the 'Dynamic microphone'. It is made up of carbon and a semiconductor material such as silicon. The surface of the microphone is covered with a very thin dielectric diaphragm. We refer to this microphone as a current control microphone. This is because the sensitivity depends on the amount of current flowing through the terminals. The terminals the (-) negative and (+) positive polarities. The positive terminal is connected to R1 and C1. This shows that the positive end is the main terminal. Meanwhile, the negative terminal is always connected to the ground plane of the supply voltage. Since the bug is a small device and should be concealed there is a need to use a small type of microphone.

The function of the microphone is to pick up sound or audio waves via its openings (diaphragm), which is converted into electrical energy and back to sound energy or audio signals.

1.3.2 Transistors

Basically, the transistors used for the wireless FM bug are Bipolar Junction Transistors (BJTs) and a type of the BJT which is npn transistors [1].

1.3.2.1 2N5179 VHF/ UHF RF Transistor

Choosing 2N5179 VHF/ UHF RF Transistor has tremendous advantages over the general- purpose component. It is a high frequency device with a maximum gain of 200MHz and a gain bandwidth frequency f_T up to 1.4GHz. The 2N5179 is very good for oscillator design and small signal amplification [2].

1.3.2.2 BF199/194 VHF/ UHF RF Transistor

BF 199 is also VHF/ UHF RF Transistor mostly used for small signal amplification. The gain band is 200 and the transition frequency, f_T is 400MHz. It's been noted to have high quality features when used as RF buffer amplifiers. The unity gain of this device is up to 400MHz. Making the device available for TV receivers' design and IF amplifiers design for community radios and SSB meters radios. The transition frequency is determined by the unity gain bandwidth. The D.C. gain of 220 enables the device to be used in Class A, Class B and Class C amplifiers [4][5]. High stability is guaranteed when used as buffer amplifiers in RF stage.

1.3.2.3 BC547 Transistor

The BC547 is a medium gain, general-purpose transistor purposely for signal generation, audio amplifiers applications and low power consumptions. Usually the f_T is about 250MHz and has a gain of 330. The dc gain and frequency transmission ensures wide usage.

Other features include:

- AF amplification
- Oscillation
- Switching capabilities
- TTL logic circuits

1.3.3 Diode, D1

The diode is a Light Emitting Diode (LED). The LED lights to indicate that power has been supplied to the circuit. Therefore the power is switched on [3].

2. Methodology of Research

The FM transmitter circuit developed is an RF circuit. These are circuits that generate and transmit electromagnetic waves. Virtually, all communication devices contain tuned circuits. A tuned circuit is defined as a circuit made up of inductors and capacitors that resonate at specific frequencies. There are specially made RF transistors such as the 2N5179 transistor described above that are used in building the RF circuit.

2.1 Assembling the components

To make the assembling easier, the smallest components in terms of physical size were added first before the bigger-sized ones. Also, to conserve space on the printed circuit board (PCB), all the resistors were inserted standing up on one end. In this experiment, a veroboard is used as the PCB and the dynamic microphone is inserted with the pin connected to the metal case, i.e. the earth (0 V) of the whole circuit. The electrolytic capacitor must be folded over so that the PCB will fit into its case. Also every precaution is taken to ensure that the turns of the coils are spread about 1 mm or more apart to forestall shorting in the circuit. All the components are firmly soldered onto the PCB so that anytime the transmitter is being moved around, the components remain stable. Finally, a PCB-mounted single pole double throw (SPDT) switch is included in the circuit so as to cut off power when the transmitter is not in use. Table 1 below gives the list of components assembled in this design project.

Table 1: Parts list of design components

Part No.	Quantity	Values	Description
M1	1	(12-3)dB	Microphone
R1, R3	2	22kΩ	Resistor
R2	1	1MΩ	Resistor
R8	2	47Ω	Resistor
R5, R6	2	10Ω	Resistor
R7	1	82-470Ω	Resistor
R9	1	150Ω	Resistor
R10	1	3.9kΩ	Resistor
C1	1	0.1μF	Capacitor
C2	1	10μF	Capacitor
C3, C7	2	0.01μF	Capacitor
C4	1	30pF	Capacitor
C5	1	10pF	Capacitor
C6	1	15-56pF	Capacitor
C8, C10	2	.001μF	Capacitor
C9	1	2-20pF	Capacitor
VC	1	2.2-18pF	Variable Capacitor (Varicap)
VC2	1	5.5-18pF	Variable Capacitor
Q1	1	BC547	General purpose transistor
Q2	1	BF199/ BF194	VHF/UHF amplifier transistor
Q3	1	2N5179	VHF/UHF RF transisitor
L1	1	0.0156μH	Inductor
L2	1	0.358μH	Inductor
D1	1		Light Emitting Diode (LED)
Wire	1	1.6 m	
Battery	1	9volts	DC supply
Vero	1		circuit board (strip board)
SPDT	1		switch

2.1.1 Description of the circuit

This is meant to be a RF circuit operating around 100 MHz. The audio signal that is picked up and amplified by the dynamic microphone is fed into the audio amplifier stage which is controlled by transistor BC 547. One big advantage of the FM bug is the absence of wires. The current that it also draws is in the range 5-10 mA so that two AAA cells could last for many months. The most critical part of the entire circuit is the oscillator. Thus it must not be fidgeted with in any way when the transmitter is in operation because this will detune the circuit completely. Since the coil is made of tinned copper, it does not need any form of insulation. For this design, we used four turns of coil of diameter 5 mm wound on a 3.5 mm shaft. Care is taken to wound the coil in a clock-wise direction for proper orientation and each end of the coil is terminated on the veroboard. The designed transmitter operates in a three-stage format by using a RF transistor in the output stage and a BC 547 transistor and a BF 194 transistor for the first two stages. The varicap (variable capacitor) in parallel with the coils are to ensure correct frequency tuning. The distance of transmission will be affected by the prevailing conditions such as in the open or in a building, the type of aerial used such as a single wire as adopted in this project work or a dipole to enhance the range of transmission. The operation of the three stages of the transmission is given below.

2.2 System model architecture

The system architecture will consist of a three-stage 9-V FM transmitter. The stages include:

- The audio amplifier
- The FM oscillator
- The RF Buffer/ Power Amplifier

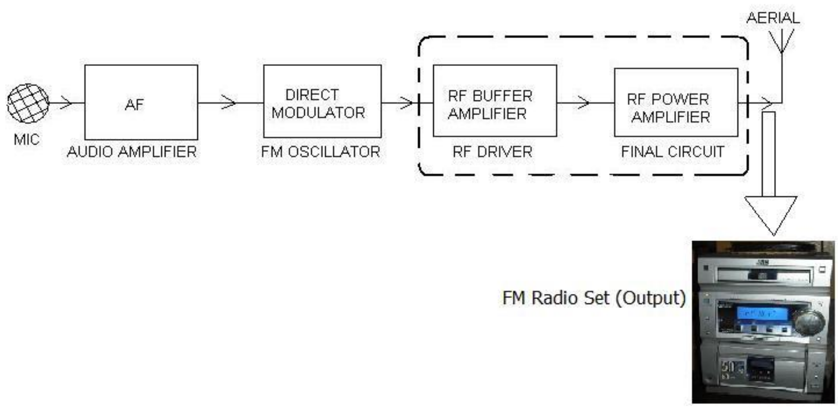

Figure 1 Block diagram of wireless FM bug showing the three stages

2.2.1 Audio Amplifier Stage

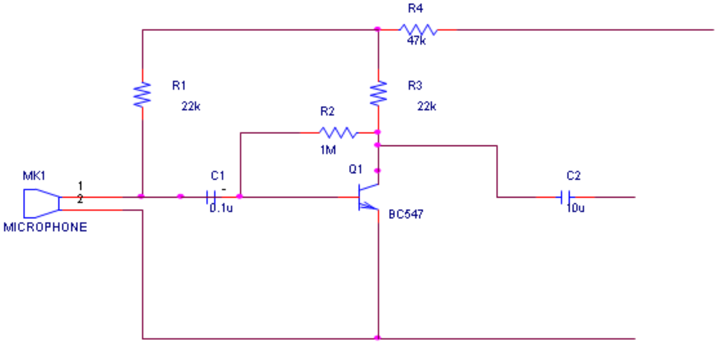

Figure 2 Audio amplifier stage

The first stage of the design, which is the audio amplifier, is a self-biasing common-emitter amplifier. The 0.1 μF capacitor isolates the dynamic microphone from the base voltage of the transistor and allows only alternating current signals to pass. Transistor, Q1 is an audio amplifier type of transistor and can also be found in any audio amplifier. C1 is coupled to the base of the BC547 transistor and the emitter goes to ground. The resistors R1 and R2 are connected to the collector side of Q1 as shown in figure 2 [6][7].

2.2.2 FM Oscillator Stage

The next stage is the FM oscillator stage as shown in figure 3 below, with C3 acting as a decoupling capacitor.

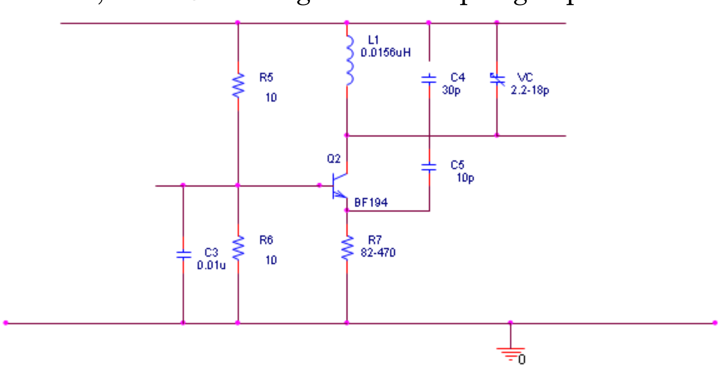

Figure 3 FM Oscillator module

The amplified microphone signal is injected into the oscillator circuit so as to modify its frequency and subsequently generate a frequency modulated (FM) oscillator. The fact is that every transmitter needs an oscillator to generate RF carrier waves. The coil, the transistor, and the feedback capacitor constitute the oscillator circuit. At this stage an input signal is not needed to sustain the oscillation given that the base-emitter current of the transistor vary at the resonant frequency. This will result in the emitter-collector current varying at the same frequency. Finally the 1.6 m antenna connected to the output of the oscillator picks up this signal and is radiated as radio waves.

2.2.3 RF Buffer/Power Amplifier module

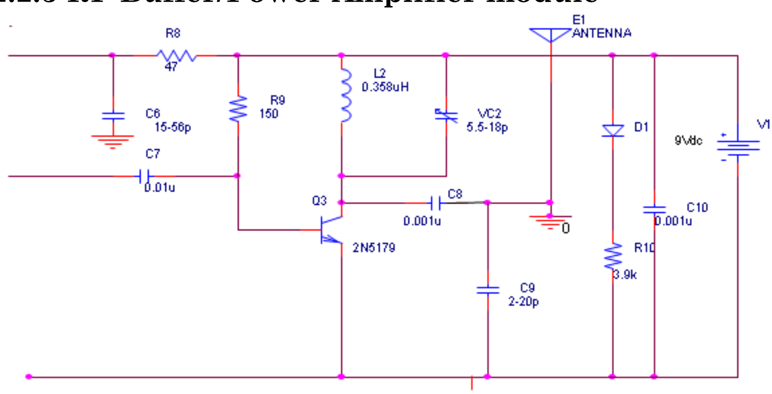

Figure 4 Schematic diagram of the RF buffer/power amplifier stage

Final amplification takes place here. An RF transistor is needed to efficiently execute this. We use a 2N5179 transistor. The portion of this last stage of the entire circuit embodying the diode constitutes a peaking circuit. The peaking circuit is simply an RF detector that uses diodes to charge capacitors. In the circuit in figure 4 above, diode D1 charges C10 so it can efficiently energize the tank circuit to generate the right frequency.

3. Implementation and Testing

3.1 PSpice Analysis of Wireless FM Bug

The wireless FM bug transmitter can be analyzed by simulating the design parameters using PSpice. Firstly, the circuit is created with the PSpice software using the tools and part list from the library. After the circuit has been designed then there is the need for intepretation. The circuit is simulated to interprete the current, voltages, power and sinusoidal wave form display. The purpose of using the PSpice to simulate the wireless FM bug is to affirm that the values of the inductors, resistors and capacitors are as accurate as possible within the bounds of tolerance [8][9]. As seen from figure 4, the current, voltages and power values were calculated at the various stages. The current, voltage, voltage differential and power markers are the respective pointers as shown in figure 5 across the circuit.

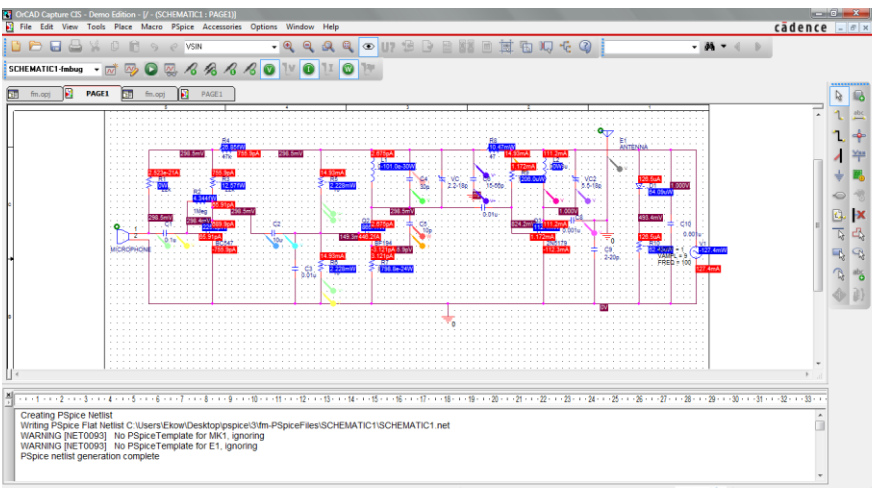

Figure 5 PSpice Circuit Analysis

3.1.1 Time Domain (Transient) Analysis

The graph in figure 6 shows the results after simulation of the three stage transmitter circuit. The sinusoidal wave represents the VHF sine wave that is radiated and transmitted through the antenna. The period is 0<t<100ms, maximum step size is 0.5ms and the voltage source is V1 [9]. The simulation is analog. Studying the graph in figure 7 shows that the current flowing through the wireless circuit stays constant.

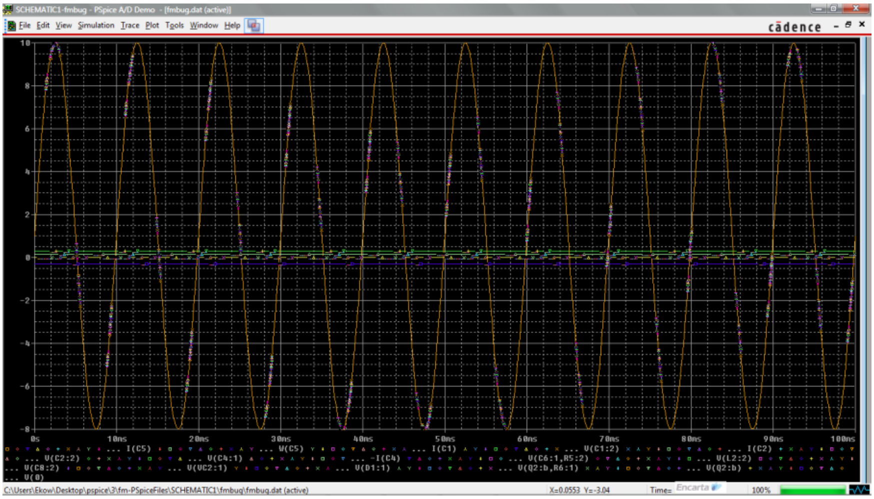

Figure 6 PSpice simulation

3.2 Testing the FM Transmitter Bug

To test the transmitter, the oscillator coil is tuned properly so that it transmits at the right frequency. This is done using a plastic aligning stick for the adjustment. The operating frequency of the oscillator is supposed to be very high so every precaution is taken to avoid the use of tools such as a metal screw driver, or even bare fingers which can detune the oscillator. Both the FM transmitter bug and FM radio receiver are switched on with the bug sited at one spot and the FM radio receiver moved within the maximum specified distance of 500 m. The radio is then tuned to the specified frequency of 101.6 MHz and a voice message is then transmitted. Instantly the background noise diminished and audible voice message is heard. This was done within a building. To further test the tenacity of the transmitter bug, the receiver is taken out into the open way beyond the 500 m transmitting range. Under this condition a voice message was still audibly received except it was weaker and weakened further as the distance from the transmitter increased.

3.3 Installation of the FM Transmitter Bug inside child's plastic toy

The installation of the device after successful testing is equally important. For the kind of job it is meant to do, it must not be detected by the object or target it is meant to monitor. Thus in this application, the bug is embedded inside the child's toy and hermetically sealed to avert detection. This plastic toy is then included among the collection of toys the child owns and uses in playing regularly so that any cause for doubt or suspicion is removed. The purpose of this design work is to monitor a baby's general progress over time in the absence of its parents or even in their presence as well. However, the major intent is for improvement in the care of the child. Thus the child's parents get to play back the recordings the hidden device makes over regular time intervals and make the necessary adjustments for the development of the child. This way the parents can have an aid to follow the progress of both the baby and baby-sitter.

4. Conclusions

In the end, the human voice received by the microphone was clearly heard on 101.6MHz on the FM radio receiver provided conditions for wireless communication are favourable. For efficient operation, the FM transmitter bug must be packaged in dielectric (insulator) material such as wood, plastic and ceramic to enhance the flow of the electromagnetic wave that is constantly being generated. Metal will be hazardous since electromagnetic waves cannot penetrate through metallic substances [10].

For the test of extending the range of the transmitter, one could apply a dipole antenna instead of the half-dipole antenna used in this design. We could improvise this by cutting the half-dipole antenna into two, leaving half of it soldered into the original antenna point and connecting the other half to the +9 V pad. The two wires so obtained are now connected in

opposite directions [10]. Thus a full-wave dipole antenna complementing the AA power supply will very much extend the range to which the FM bug transmitter can transmit.
Improvement in power supply would also extend the lifespan of the bug. Instead of AA cells, we could use AAA cells which naturally last several months. Moreover, the AAA cells also have a positive effect on the range to which the transmitter could work. Therefore, if the AAA cells are used together with a full-wave antenna, we can attain a transmission range of 1 km and beyond.

However, one particular factor that could cause the design to fail would be poor soldering. Thus all solder joints should be meticulously cross-checked under good lighting [10][11]. Also care should be taken to make sure all the components are in their correct positions on the PCB.

BIBLIOGRAPHY:

Boylestad, R.L. 2007. *Introductory Circuit Analysis*. Eleventh Edition. Prentice Hall. [2]

DeCarlo, R. A., and P.M. Lin. 2001. *Linear circuit analysis*. Second Edition. New York: Oxford Univ. Press. [4]

Floyd, T.L. 2007. *Electronics Fundamentals; Circuits, Devices, and Application*. International Edition. Prentice Hall. [1]

Floyd, T. L. 2007. *Principles of Electric Circuits*. Eighth Edition. Upper Saddle River, NJ: Prentice Hall. [5]

FM bug. available at http://www.electronics-lab.com/projects/rf/002/index.html; accessed Sep 10, 2013. [6]

FM Transmitter bug. available at http://www.zen22142.zen.co.uk/circuits/rf/30wvhf.htm; accessed Sep 15, 2013. [7]

Frenzel, L., *Principles of Electronic Communication System*. Third edition, 1-20, USA, 2006. [8]

Hambley, A.R. 2008. *Electrical Engineering; Principles and Applications*. Fourth Edition. Prentice Hall. [11]

Nilsson, J.W., and S. Riedel. 2008. *Electric Circuits*. Eighth Edition. Prentice Hall. [3]

Streetman, B., and S. Banerjee. 2006. *Solid State Electronic Devices*. Sixth Edition. Prentice Hall. [10]

Tobin, P., *PSpice for Circuit Theory and Electronic device*. First edition, 1-24, Morgan & Claypool, Ireland, 2007. [9]