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Design and Construction of a 18 dbm Frequency Modulated Radio Transmitter to Cover 1375 m Radius

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Abstract: *Communication is the transfer or exchange of information between two or more parties. An electronic transmitter enables information to be transferred through long distances by the use of relevant electronic circuitry. In previous literature, the power of the transmitter required to cover an area of* $5.94 \times 10^6 m^2$*was found to be 18dBm. In this research, the radio transmitter required to give the output power is designed, constructed and tested. After testing it was concluded that the radio transmitter with an output power of 18dBm with a telescopic antenna placed 10m above the ground and broadcasting at a frequency of 102MHzcanfavourably cover the area of 1375m radius.*

Keywords: *Modulation, Frequency Modulation, Transmitter, Electromagnetic Wave, Communication, Telecommunication, Radio, Antenna*

1. INTRODUCTION

Communication involves transmission of verbal and non-verbal messages Munodawa (2018). According to him, communication consists of a sender, a receiver and a channel of communication. In his argument however he skipped a very important component of communication which is the message being communicated. The transmission of signals over long distances such as by telegraph, radio or television is called Telecommunication (Freeman, 1999) ,Telecommunications may also be seen as the suite of technologies, devices, equipment, facilities, networks, and applications that support communication at a distance (Lucky & Elsenberg , 2006).A transmitter is an electronic device, which, with the aid of an antenna, propagates an electromagnetic signal such as radio, television or other telecommunication signals (Ogbuanya et al., 2017). To achieve transmission, the signal to be transmitted has to be first converted to electrical signal if it is not already in the electrical form by the use of transducers. To enable the signal travel large distance with minimal loss, the signal is joined with a stronger signal known as the carrier signal through a process known as modulation. In electronics and communication, modulation is the process of varying one or more properties of a periodic waveform called the carrier signal, with a modulating signal that typically contains information to be transmitted. There are different types of modulation that are applicable to digital and analog signals. Since voice is an analog signal, more emphasis is made on analog modulation. There are three types of analog modulation namely: Amplitude Modulation**:** In this type of modulation, the maximum displacement of the carrier signal is varied in accordance with that of the modulating signal, Frequency Modulation**:** In frequency modulation, the frequency of the carrier signal is varied in accordance with the frequency of the modulating signal. Phase Modulation: In this type of modulation, the phase (the initial angle of a sinusoidal function at its origin) of the carrier signal is varied in accordance with that of the modulating signal. Of all three types of modulation, frequency modulation is the most suitable for the type of broadcasting required for this project due to its not too complicated circuitry and other advantages like resilience to noise, resilience to signal strength variations (Couch, 2009). Radio is the use of electromagnetic waves to carry information such as sound by systematically modulating some property of electromagnetic energy waves transmitted through space such as amplitude, frequency, phase or pulse width (Farlex, 2014)..Radio frequencies occupy the range from 3 kHz to 300GHz, although commercially important uses of radio use only a small part of this spectrum. A radio system sends signals by radio (Smith & Gervelis, 2003). It has been estimated that a Frequency Modulated Transmitter of 18dBm output power will be a able to cover 1375m radius (Iyen *et al.*, 2017). Different techniques for construction and uses have been discovered for the F.M Transmitter (Okae & Anquandah, 2013; Acharya & Biswas, 2015; Popleteev *et al.*, 2010: Niedev, 2000; Moslehpour *et al.*, 2010; Lemunyan *et al.*, 1959)

2. MATERIALS AND METHODS

2.1. Materials

Transistors: (BC107A, 2N2222A, 2N3866),

Resistors: $8k\Omega, 178k\Omega, 55k\Omega, 10k\Omega, 365k\Omega, 62k\Omega, 100\Omega, 2.8k\Omega, 2k\Omega, 180\Omega, 117\Omega, 10k\Omega,$

Electric Microphone, Telescopic antenna, $3.2\mu F$ *Electrolytic Capacitor*, Ceramic Capacitors: $0.01\mu F, 9.5\mu F, 1nF, 15pF, 4.7pF, 155pF, 24pF, 218\mu F$, $0.2\mu H$ *Inductor*, Light Emitting Diode, 12Volts Power Supply DC Battery, $10 - 20pF$ *Variable Capacitor*, Bread board, Vero board, Soldering Iron, Soldering lead, AutoCAD Software, F.M radio receiver, Oscilloscope, Frequency Counter, RF watt meter, Multimeter, Jumper Wires, Bolts and nuts, Plastic Casing, Plastic bending device

2.2. Methods

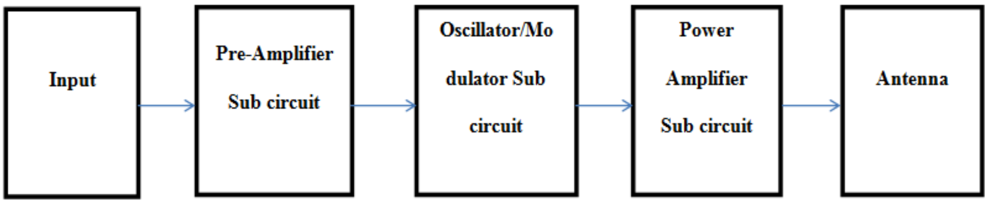

Figure1. *Block Diagram of a Transmitter*

An electronic amplifier is an electronic device that can increase the power of a signal (Cova et al., 1991). Works have been carried out on types of amplifiers, their design and uses (Gene, 1987; Cova *et al.*, 1991; Goldan & Goto, 1974; Smith *et al.*, 1968; Sapna *et al.*, 2004; Dimitry, 2015).An electronic Oscillator is an electronic circuit that produces a periodic oscillating electronic signal often a sine wave or a square wave (Snelgrove, 2011).An antenna is used for converting Radio waves into electrical signals and vice versa (Schantz& Gregory, 2003). Alot of literature cover the types of antenna and their uses (Hartzell *et al*,, 2013; Harvey, 2010; Landecker *et al.*, 1997; Sayeed and Kim, 2009)

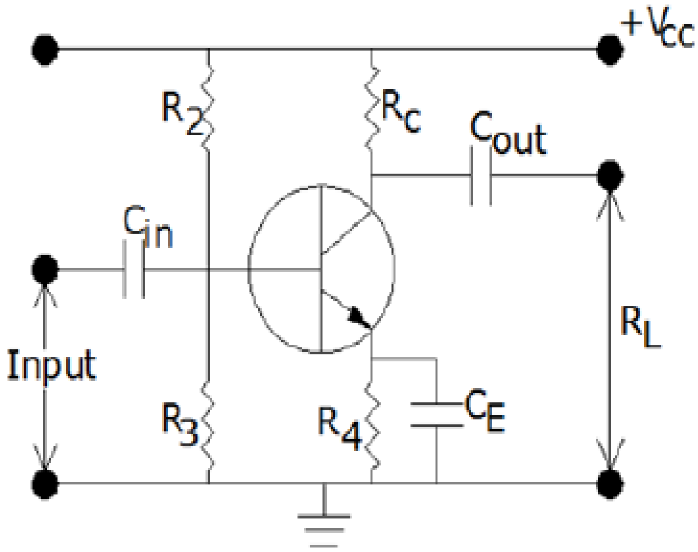

Figure2. *Reference Diagram for an Amplifier*

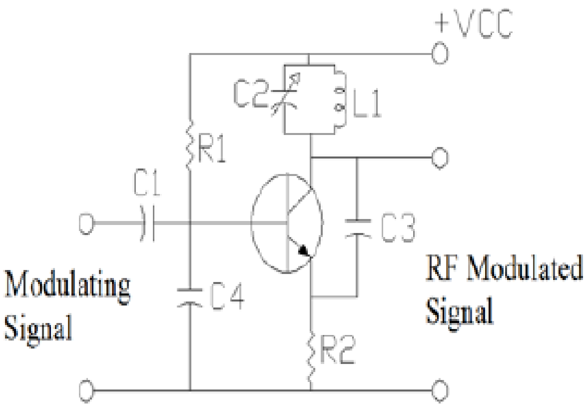

Figure3. *Reference Diagram for a Modulator / Oscillator Circuit*

2.3. Preamplifier Circuit

By using KVL on the amplifier reference circuit shown in Figure 2 we obtain $R_c = 10k\Omega$

By using the Rule of Thumb$\frac{V_E}{V_C} = \frac{0.1}{0.55}$, we obtain $V_E = 0.36V$

By Employing Ohm's Law and knowing that $I_E \approx I_C = 0.001A$ we obtain

$R_E = \frac{0.36}{0.001} = 364\Omega$

Using the relation

$V_B - V_{BE} = V_E$

We obtain $V_B = 1.06\, Volts$

2.3.1. Choosing a Transistor

For the preamplifier transistor, we choose a general purpose transistor which can handle the voltage levels, for the preamplifier, we choose BC107A which is a general purpose NPN transistor with $Ic\ max$ of 200mA and a current gain $\beta = 200$

2.3.2. Biasing of the Pre Amplifier

$R_3 \leq 0.1 \times 150 \times R_E = 0.1 \times 150 \times 365 = 5.5\ k\Omega$

$R_2 = R_3 \left(\frac{V_{CC} - V_E}{V_E}\right) == 178k\Omega$

2.3.3. Estimating the Input Impedance and the Value of the Input Coupling Capacitor of the Preamplifier

The equivalent AC resistance of the Emitter Diode will be given by:

$r_e = \frac{25mV}{I_E} = \frac{25mV}{1mA} = 25\Omega$

∴ The total input impedance of the amplifier will be given by:

$\frac{1}{Z_{in}} = R_1 \parallel R_2 \parallel \beta(r_e) = \frac{1}{178000} + \frac{1}{5500} + \frac{1}{(180 \times 25)} = 4.076 \times 10^{-4}$

$C = \frac{1}{2\pi f Z_{in}} = 3.2\mu F$

2.3.4. Estimating the value of the Bypass Capacitor For R_E

$C = \frac{1}{2\pi f X_C}, \quad Where\ X_C = \frac{1}{10} R_E, X_C = 36.5\Omega, \Rightarrow C = 218\mu F$

2.4. The Tank and Modulation Circuit

$f = \frac{1}{2\pi\sqrt{LC}}$

For our circuit we will be using an inductor of $0.2\mu H$. $C = \frac{1}{L(2\pi f)^2}$

For the lowest frequency of the bandwidth we obtain

$C = 16.5pF$

For the higher frequency of the FM bandwidth we obtain

$C = 10.89pF$

For our tank circuit, we therefore need a variable capacitor of between$10.9pF\ to\ 16.5pF$. Based on availability, we therefore choose a variable capacitor of between 10 to 20pF

2.4.1. Input Coupling Capacitor to the Oscillator/Modulator Circuit.

Also using similar approach as that for the preamplifier circuit, we have:

$C = 9.5\mu F$

2.5. The Power Amplifier Circuit

The output power of the transmitter is related to the collector current and the collector emitter voltage by the equation

$P = I_C V_{CE}$

Where P is the estimated output power of the transmitter which was calculated and obtained in previous literature (Iyen *et al.*, 2017) and Ic is the assumed quiescent collector current used for the amplifier design which is Ic=1mA

$0.063 = 0.001 \times V_{CE}, V_{CE} = \frac{0.063}{0.001}, = 6.3\,Volts$

As earlier known

$V_{CC} = 12\,Volts$,$V_{CE} = 6.3\,Volts\ \approx 7\,Volts, V_C = 8\,Volts, I_{CQ} = 1mA, I_{EQ} = 1mA$

To get the value for R_C we have by using Kirchoff's Voltage Law we have:

$V_{CC} - I_C R_C = V_C$

Our chosen transistor $T_1 = 2N3866$ because it is a radio frequency transistor and it can handle the expected power. From our calculations we have that:

$V_{CE} = 7\,Volts$, We know that$I_E \approx I_C, \Rightarrow I_E \approx 0.001A$

For our power amplifier, we choose to use a radio frequency npn transistor with a maximum output power of 1 Watt which is more than our anticipated output power, this is to enable us draw power from the transistor efficiently. For our power amplifier design, it is worthy of note that:

$V_B = V_{CC} \times \left(\frac{R_3}{R_2+R_3}\right)$

$V_B - V_E = 0.7\,Volts$

$\Rightarrow V_E = I_E R_E$

$$\Rightarrow R_E = \frac{V_E}{I_E}, \therefore R_E = \frac{1}{0.001} = 1k\Omega, R_L = 50\ ohms, P = 0.063W,\ V_{CE} = 0.063 \times 50, = 1.78\,Volts$$

$P = {I_C}^2 R$

$\Rightarrow 0.063 = {I_C}^2 \times 50, {I_C}^2 = \frac{0.063}{50}, {I_C}^2 = 1.26 \times 10^{-3}, I_C = 0.036A, = 36mA$

$V_C = V_{CC} - I_C R_C, Using\ V_C = \frac{1}{2} V_{CC} = 6V$

$V_C = 12 - 0.036 \times R_C, 6V = 12 - 0.036 \times R_C, 12 - 6 = 0.036 \times R_C, 6 = 0.036 \times R_C$

$\Rightarrow R_C = \frac{6}{0.036} = 167\Omega \approx 180\Omega$

From our calculation we have that:

$V_{CE} = 1.78\ Volts,$ $V_C = 6Volts,$ $\Rightarrow V_C - V_E = 1.78Volts, 6V - V_E = 1.78Volts$
$6 - 1.78 = V_E, \Longrightarrow V_E = 4.22Volts$

Using similar procedures as in other stages, we obtain that:

$I_E = 0.036A, R_E = 117\Omega, V_B \approx 5.0V$

The gain of the chosen transistor which in this case is 2N3866 is 200, Also using procedures as before we have:

$R_3 = 2000\Omega, R_2 = 2.8k\Omega$

The emitter capacitor is gotten to be $C_E = 155pF$

2.5.1. Estimating Power Amplifier Load Coupling Capacitor

Using the same formula and taking the load impedance to be 50Ω

$C = 24pF$

2.5.2. Calculating the Power Amplifier Input Coupling Capacitor

Using similar procedure as in the preamplifier stage we obtain that the power amplifier input coupling capacitor value is C=15pF

3. RESULTS

The output power of the radio when constructed was measured using an RF watt meter which gave an output power of 18dBm at a frequency of 102MHz which lies within the frequency modulated signal range of between 88-108MHz

And the antenna was placed on a roof top and signals were heard clearly for a distance of about 1 kilometer in which we were able to obtain line of sight with the transmitter antenna, the signals were blocked by obstructions and buildings at greater distances.

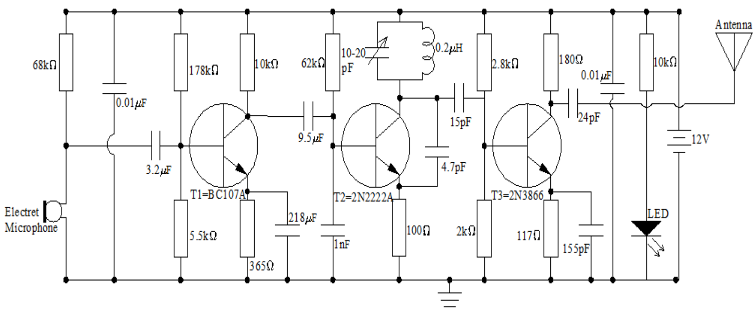

Figure4. *Final Finished Circuit of the FM Transmitter*

Figure 5: *Final Packaged Circuit*

4. DISCUSSION

Pearce (2012) built an FM transmitter which transmits at a frequency of 98.2 MHz with an output power of 6.3dBm. His transmitter was able to cover a distance of 500 metres. Likewise, Collision (2009) built an FM transmitter which transmits at a frequency of 107.2 MHz with an output power of 3.98dBm which was able to cover 206 metres.

The works referred above show that the FM transmitter constructed in this project work which transmits at a frequency of 102 MHz with an output power of 18dBm with a range of over 1 Kilometre can compete favourably with those constructed in other parts of the world.

5. Conclusion

The Design and Construction of the radio transmitter resulted in an FM Transmitter which transmits at a frequency of 102MHz with an output power of 18dBm which with a telescopic antenna at 10 meters above the ground was able to transmit to a distance of 1.3 Kilometers. This shows that Locally Designing, Construction and Packaging of FM transmitters is very feasible and much cheaper than importing the transmitters and therefore, it is highly encouraged.

References

[1] Acharya, M., Biswas, R., (2015). 'Design and Implementation of Frequency modulated transmission and reception of speech signal and FPGA based enhancement.' ACCENTS Transactions on Image Processing and Computer Vision, 1(1): 12-22.

[2] Collison, A. (2009). Estimating transmitter distance. Retrieved from: http://www.Zen2214zen.co.uk/ Analysis/efftxd.htm.14/06/2016

[3] Couch, R. (2009), Designing Vacuum Tube Amplifiers and Other Topics. Eureka, California. Pp. 8-15

[4] Cova, S., Ghioni, M., Zappa, F., (1991). 'Pre-amplifier Introduction'. Rev. Sci. Instrum, 62(11): 2596-2601.

[5] Dmitry, D. (2015). How do I calculate the frequency of an FM transmitter Circuit? Retrieved from: http://electronics.stackexchange.com/questions/33435/how-do-i-calculate-the-frequency-of-an-fm-transmitter-circuit. 08/11/2015

[6] Farlex, (2014).Radio. Retrieved from: www.thefreedictionary.com/radio. 23/03/2016

[7] Freeman, R. (1999). Telecommunications. Fundamentals of Telecommunications. John Wiley & Sons, Inc., New York. p.100-105

[8] Gene, P., (1987). Amplifiers. In Glen Ballou- Handbook for Sound Engineers. The New Audio Cyclopaedia. Howard W. Sams & Co. USA Pp 100-105

[9] Goldan, P., & Goto, K., (1974). An acoustically resonant system for detection of low level infra red absorption in atmospheric pollutants. Journal of Applied Physics, 45:4350-4355.

[10] Hartzell, D., Tran, M., Black, J., Marhefka, J., Terzuoli, J.,(2013). Analysis and Feed Design of a Sparse Aperture Parabolic Reflector. IEEE Radio Science Meeting.IEEE. London Pp. 70-90

[11] Harvey, L. (2010). Microwave networks Design and Deployment . MIcrowave Transmission Networks Planning, Mcgraw Hill Professional, USA Pp 187-192

[12] Iyen, C., Umar, I., Wansah, J.F., Jaafaru, S., Iseh, A., Akeredolu, B. and Ewa, I. (2017), “Estimation of Frequency Modulated Radio Transmitter Power Required to Cover a Particular Distance Based n available Radio Receiver Sensitivity and Desired Signal Range”, International Journal of Innovative Research in Electronics and Communication, 4(2): Pp. 1-4

[13] Landecker, L., Smegal, R., Mckinley, M., (1997). Cylinderical and Conical Shrouds for the reduction of ground noise of Paraboloidal antennas. Radio Science, 32(6): 2139-2148.

[14] Lemunya, C.D., White, W., Nyberg, E., & Christian, J.J. (1959). Design of a Miniature Radio Transmitter for use in Animal Studies, The Journal of Wildlife Management. 23(1): P. 107

[15] Lucky, R.W. & Elsenberg J. (2006).Renewing U.S Telecommunications Research. The National Academic Press. Washington D.C. Pp. 4-12

[16] Moslehpour, S., Kondo, J., Alnajjar, H., (2010). FM Transmitter System for Telemetrized Temperature Sensing Project. Journal of Communication and Computer, 7(3): 64.

[17] Munodawa, D. (2008), Communication, Concepts, practice and Challenges, Health Education Research, 23(3): Pp. 369-370

[18] Nieder, A., (2000). Miniature Stereo Radio Transmitter for Simultaneous Recording of Multiple Single-Neuron signals from behaving Owls. Journal of Neuroscience Methods, 101(2000): 157-164.

[19] Ogbuanya, T.C, Abul, S., Bakare, J., (2017). The Design and Construction of a Frequency Modulated (FM) Transmitter with output capacity of 10 Watts and Range of about 4km, International Journal of Applied Engineering Research, 12(18): pp.7516-7523

[20] Okae, P., Anquandah, M., (2013). An FM transmitter Bug for Body Monitoring. European Academic Research, 1(18): 2176-2189.

[21] Pearce, D. (2012). I show you how to build a spy bug radio [Motion Picture]. Retrieved from: https://www.onlinevideotutorials.com/build-a-radio-transmitter.html. 25/05/2015

[22] Popleteev, A., Osmani, V., Mayora, O., (2010). Indoor Positioning Using FM radio. International Journal of Handheld Computing Research, 1(3): 19-31

[23] Sapna, P., Bhaskar, P., Parvathi, S., Immanuel, J., (2014). High Gain Low Noise Pre amplifier and Narrow Band-Pass Filter for Photoacoustic Spectrometer. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 3(11): 13161-13167

[24] Sayeed, I., & Kim, Y. (2009). A simple LMS Algorithm based Smart Antenna to solve the reader collsion problems in RFID systems. International Conference on Information and Multimedia Technology. IEEE Computer Society. Conference Publishing Services CPS. 2009. Pp 60-65

[25] Schantz, S., Gregory, H., (2003). Introduction to Ultra-wideband antennas. 2003 IEEE UMBST Conference ,UMBST, USA. p.20

[26] Smith, C., Gervelis, C., (2003). Wireless Networking. Wireless Network Performance Handbook. McGraw-Hill Professional. USA Pp. 304-340

[27] Smith, R., Jones, F., & Charmar, P. (1968). Measurement of Radiation. The Detection and Measurement of Infra red Radiation. Oxford University Press, London Pp. 700-770

[28] Snelgrove, M., (2011). Oscillator. McGraw HIll Encyclopaedia of Science and Technology. McGraw Hill, USA Pp. 1100-1117

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