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The Design and Construction of a Frequency Modulated (FM) Transmitter with Output Capacity of 10 Watts and Range above 4km

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Abstract

A rapidly growing demand for the use of FM transmitter exists among individuals and institutions. The FM transmitters are however complex equipment demanding high power supply high voltage system design critical maintenance and exorbitant price. These problems of the transmitter constitute major impediments to individuals and institution that may wish to adopt radio broadcast as means of electronic media. The study was therefore carried to design and construct an FM transmitter that is cheap in price, simple in maintenance, efficient in use yet operate on low power supply. The study was to design and construct a 10 watt FM transmitter to be received at a range of about 4km in free air. Research and development (R &D) was used for the study, the necessary tools and materials were acquired. Design procedure involving the modification of an output of a transmitter was adopted. Based on the procedures adopted and the tests carried out, the specific findings include, appreciable range with stable frequency of transmission obtained on power source devised from 12v lead acid battery. Various instructional applications and mass production strategies were outlined. The successful completion of this study has indicated that practical frequency modulated FM transmitter requiring low power can be designed and constructed. Though appreciable range of FM transmitter on low power supply has been achieved in this works, further studies in areas of signal coupling technique need to be carried to improve the range of transmission.

INTRODUCTION

The world has entered an era known as "information age" when electronics communication systems influence most of human activities. These electronics communication systems consists of three major aspects; the receiver, the channel and the source, which is the transmitter. A transmitter is an electronics device, which, with the aid of an antenna, propagates an electromagnetic signal such as radio, television or other telecommunications. In the early days, signal energy was generated in transmitting plants using arcs or mechanical alternators (Farlax, 2005). However, today a transmitter usually has a power supply, an oscillator, a modulator and amplifiers for audio frequency (AF) intermediate frequency (IF) and radio frequency (RF). Transmitters are sometimes classified according to the signal information they process and radiate. Television transmitters processes sounds and picture signal while radio transmitter processes only sound. Lycons (1987) defined radio transmitter as a generator of high frequency electric current whose characteristics of amplitude, frequency, or phase may be altered or modulated in accordance with the intelligence to be transmitted. Lycons further adopted the mode of modulation to classify radio transmitters. In amplitude modulated (AM) transmitter which is usually employed for broadcast purposes at the medium frequency, the amplitude of a carrier wave is varied in accordance with the amplitude and frequency of modulating wave.

Walter (1987) and Anaemena (2011) observed that frequency modulation (FM) transmitter provide greater signal to noise ratio than amplitude modulated (FM) transmitter for the same antenna input. They also highlighted other advantages of FM transmitter operating at a very high frequency where noise is considerably reduced. In frequency modulation, Anaemena (2001) maintained that the frequency of the modulated signal is constant, therefore, the entire FM system is arranged to be insensitive to amplitude disturbances. These high scores have created a rapidly growing demand for FM transmitter as a means of radio broadcast. FM transmitter is now vigorously adopted by state governments that employ it as a means of radio broadcast for public enlightenment campaigns, news and educational programmes. FM transmitter has also attracted the interest of tertiary constitute and private individuals that are attempting to engage in electronic media.

Despite its lofty qualities and the rapidly growing desire for its application in radio broadcast, FM transmitter for practical broadcast is bedeviled by some of the major problems that afflict all other transmitters. Walter (1987) complained that the high power supply and high voltage system design are probably the major problems for any new transmitter type. Safety interlock circuits and warning lights need to be employed extensively. Automatic discharge capacitor is important, otherwise the maintenance or service personnel is

endangered. Farlex (2005) maintained that transmitter of larger power requires large current flow with high voltage up to 20kv. The transmitting plants are also exposed to increased over voltage risk due to the usually exposed radio tower.

Olaitan (1996) remarked that Nigeria has not contributed significantly to technological development. Against this background, the researchers feels that, engineers and others in electronics field in particular take up the challenge to design and construct engineering equipment and gadget that are fee from such technical problems as afflict radio transmitters.

Design as a process can take many forms depending on the object being designed and the individual participating. Farlex (2005) described design as the process of originating and developing a plan for an aesthetic and functional object, which usually requires considerable research through modeling, interactive adjustment and re-design. Design is also used both for final plan of action or the result of following that plan of action (the object produced). According to Longman (1995) design is to make drawing or plan of something that would be built. It is also to develop or plan something for scientific purpose. The essence of any design is to build or construct something. Longman further stated that construction is the process or method of building or making something using many parts.

This study is a design and construction project conceived to produce an FM transmitter free from the major technical problems highlighted, but of appreciable range for practical application. The design of this FM transmitter will incorporate, at the output stage, the very high frequency (VHF) power transistor no 2c 1971 (NTE343) which has produced excellent results in other circuits.

Statement of the Problem

A rapidly growing demand for the use of FM transmitter exists among individuals and institutions. For example universities and other tertiary institutions need to broadcast educational, entertainment and even news programme that are particularly designed for campus audience. Franco FM is an FM transmitter attempting to satisfy this need in university of Nigeria, Nsukka. Private individual also wish to provide a view of local and community news that is independent government stand. These plants are however complex equipment demanding high power supply, high voltage system design, critical maintenance and exorbitant price. Farlex (2005) stated that transmitters of large powers require large current flow with high voltage up to 20kiv and transmitting plants are exposed to increased over voltage risk due to the usually exposed tower. Walter (1987) complained that the power supply and high voltage system design are probably the major problems for any new transmitter type.

These problems of the transmitter constitute major impediments to individual and institution that may wish to adopt radio broadcast as means of electronic media. The private individual and organizations lack resources to purchase and maintain complex transmitting plant whose price is exorbitant and requires critical maintenance. The solution to this dilemma is the design and construction of FM transmitter where power supply is derived from low voltage system which is inherently safe to handle. The present project is design to make use of 12VDC supply, yet produce the range as required for local broadcast. If effort is not made to produce an FM transmitter that is cheap in price, simple in maintenance, efficient in use and yet operate on low power, individual and private organization may not achieve their desire in radio broadcast.

METHOD

Design of the study

The design of this study is research and development (R&D). According to Nworgu (1991) R & D is a process whereby educational products such as textbooks, equipment, or curricular are developed and trial tested in the field to ensure effectiveness. The approach of the design is purely constructional, depicting step-by-step procedure for the planning and fabrication of products and gadgets.

Materials and tools

The materials and tools that were used for the design and construction of FM transmitter include: copper laminate plate Gross paint (Resis), Nitric acid menthylene chloride, detergently electric technician knife, soldering iron (40-watts) alloy lead, file halksaw pliers, etc.

Components

The various components to be used for each part of the project are listed. To facilitate adequate understanding of their operations the major components in this circuit with respects to the characteristics were discussed.

s/n	Component description	Specification
1	Resistor R1	22k
2	Resistor R2	100k
3	Resistor R3	1k
4	Resistor R4	100Ω
5	Resistor R5	390Ω
6	Resistor R6	330Ω
7	Resistor R7	1kΩ
8	Resistor R8	100Ω

9	Resistor R9	1k
10	Resistor R10	15
11	Resistor R11	10k
12	Resistor C1	1n
13	Resistor C2	100n
14	Resistor C3	1n
15	Resistor C4	47pf
16	Resistor C5	10pf
17	Resistor C6	100uf/25ve
18	Resistor C7	100pf
19	Resistor C8	47pf
20	Resistor C9	47pf
21	Resistor C10	1n
22	Resistor C11	10pf
23	Resistor C12	3 pf
24	Transistor Q1	Bc 548
25	Transistor Q2	Bc 548
26	Transistor Q3	Bc 548
2	Transistor Q4	NTE 342 or 2c1971
28	Inductor L3	Turns 22 swg
29	Balunl	Transformer
30	Feeder wire	300Ω TV feeder
31	Antenna	Dipole
32	JPI to JP5	Jumper wire
33	Balunl wire	Jumper wire

Modified output stage

S/n	Component description	Specification
34	Capacitor 13/14	22 pf
35	Capacitor 14	120 pf ceremanic
36	Capacitor 15	22 pf ceramic
37	Capacitor 16	39 pf ceramic
38	Coil	Coil
39	Resistor	Choice

Design procedure

The design procedure for the project hinged on an existing frequency modulated (FM) transmitter circuit. This transmitter circuit, which the researchers constructed and tested, exhibited some desirable characteristics that qualiofied it as a base for further design. Operating efficiently on a low-power 12 vdc which process minimal safety problem, the transmitter produced sound output with optimum signal-noise ratio (SNR) and high fidelity comparable to practice broadcast transmitter. However, the transmitter incorporates a low power (250mw) output stage using transistor 2N2369 which produces a range too short for practical application. The design procedure then involved the calculations experiments and exercises required to successfully replace the low output of the existing transmitter with medium output stage of useful broadcast value. The output stage of the existing transmitter starting from C9 to BALLUN was cut off as shown in fig. 3b and replaced with a specially designed medium power output stage consisting of VHF NTR 342 transistor circuit.

Design calculation

Design calculation

For stage 1 (Q1);

Applying Kirchoff's voltage law to the base side and taking resistance in KΩ and current in MA we have.

Vcc = IBRB + VBE + RE X IE

12v = 1b X RB + O + RE x 1E (Neglecting VBE)

12 = 100 x 1B x IB + IE x 1

12 = 100IB + (IC + IB)

12 = 100IB + (00IB + IB) for $\beta = 100$

12 = 00IB + 101 IB

12 = 201IB

Fabrication of Printed circuit board

The fabrication process of the printed circuit board starts from screening/filming. The folwing materials were used at the screening stage; steizer, emulsion transparent glass, hard book, foam water mesh (silk) and sun light. The following sequence were carefully followed to ensure quality transfer of the master printed circuit pattern to the copper side surface.

Procedure

(1) **Mixture:** Steier and emultion were mixed and poured on the mesh (silk). A smooth piece of plastic was used to rub the mixture repeatedly on the silk until the mixture had vanished on this side. The mixture then reappeared on the opposite side, and turning tot hat side, and using the plastic material the mixture ran gently along this side

until it vanishes and reappeared at the initial side. The process of turning and rubbing stopped when the mixture was completely absorbed and could not significantly appear on either side.

When the mixture disappeared from either side, the silk was allowed to dry thoroughly for about 30 minutes. The terms coating and curling are used to describe the vanishing and reappearing of the mixture at both sides of the mesh. It was done under a shade so that light rays did it fall on it.

(2) **Screening:** The film (the bold black master print pattern) was be placed on the silk. The transparent glass, rectangular in shape, was placed under the silk directly opposite the film. The entire arrangement constitutes the assembly. The assembly was brought to reach the degree of polymerization was dependent on the light intensity.

(3) **Dispatch:** After the thirty seconds count to the sun was certified, the assembly was carefully returned to the shade and dispatched (de coupled).

(4) **Developing:** After de-coupling the assembly, a foam was dipped into clean water and squeezed into the mesh repeatedly for three minutes. The foam was gently rubbed on the silk so that a bright white line of the pattern showed up.

(5) Having ascertain the appearance of the film (on the silk) water was poured continuously on both sides of the silk. After a while the foam was rubbed on the wetted side, and the appearance of the pattern increased. This recycling event continued until the entire printed circuit diagrammatic pattern was fully cured the silk was allowed to dry completely.

(6) When the mesh had completely dried, a proportionate amount of ink called sticker ink was poured on the coated side of the mesh. The resist coated copper surface was placed opposite directly under the coated csilk on a flat surface. The ink was run evenly along the silk with plastic materials, then the diagrammatic pattern appeared unto the resist copper side and the silk was removed to dry the board completely. Initially the copper side surface was coated with a gray coloured resist material. An electricians knife was used to remove to the resist material from areas not covered with the conductor routing imaged pattern.

(7) Finally, the board was thoroughly washed with detergent and rinsed with much water then allowed to dry completely. It was then ready for etching.

Removing resist: The purpose of the resist coating is to prevent the circuit pattern on the board from being removed by the nitric acid. The resist will be completely removed from the surface easily and quickly by applying methylence chloride solution.

Drilling of Holes

Holes were drilled to produce openings through the printed circuit board in order to form electric connections between conducting pathways. The holes were drilled in such ways than only one conductor's lead or wire passes through.

Reference designation: Components generally were inserted opposite copper side so that their terminals would not bridge or short circuit. To show the position each component enters; reference designation was drawn opposite copper surface to correspond with the circuitry opposite.

Component layout: The design of electronic circuit wiring takes into account, most importantly, component placement, wiring density and the functional performance of the entire system the parts and component of this design were carefully spaced to provide even diagram balance between blank spaces and lines. Enough spaces were left in the area near symbol to avoid crowding of reference information.

Resistor diodes, transistors and capacitor were inserted into their reference designation using terminal and polarity identification techniques. All components were mounted approximately 5mm above the panel and excess leads of wires were cut to about 2mm above the copper side surface. The cutting or trimming of the excess leads was done after soldering has been completed.

The researcher must take certain precautions when inserting components into holes. These precautions according to Cole (1988) include:

1) Mastery of resistors colour codes to ensure that the desired values of resistors will be fitted to their correct reference designation.
2) Mastery of non-electrolytic colour coded capacitors in order to be able to interpret the decimal numbers.
3) Ensure that transistors are fitted correctly.
4) Mount the power transistors on heat sink. The function of the heat sink is to remove dissipated heat from the transistors to avoid thermal run away.
5) Note the position of the pins and sign for the ICS.

Soldering procedure: Every component inserted on the printed circuit board PCB were carefully and neatly soldered to avoid being pulled out. The soldering iron was allowed to heat properly to ensure quick melting of the alloy (60/40) lead. A 40 watt soldering iron was used to avid overheating the components. Soft soldering was used because it is more suitable for light points in steel, copper, brass and electronics works. It is not used were much strength is required or in cases where the point will be subjected to vibrations or heat, as the solder is comparatively weak and has low melting point (Chapman, 1988).

Casing (Cabinet) Construction

Several materials can be used for constructing the case of an FM transmitter both for commercial and instructional purposes, but sheet metal was adopted for this project.

Technical and aesthetic consideration guided the choice of material for the cabinet. Since the production of electronic systems demand the application of different kinds of primary inputs a skilled sheet metal technicians at Government to science technical college Abuja produced the cabinet. The researchers however, submitted the specification (250 x 200 x 150).

Testing techniques

Every new assembly requires testing before it can be connected to the power supply in order to ensure that it will function correctly and safely (IEE Regulation, 1988).

1. The following tests were carried out on this device.
2. Continuity test is required to detect all section that have open circuits.
3. Polarity test is required to ensure that every live terminals are done in such a way that there is no bridge between the terminals.

In this chapter, the required tools and materials have been presented. The components have been listed with the design calculations of some of these component carried out to ascertain their performances in the circuit. The fabrication ahs been explained with emphasis on printed circuit board and soldering techniques.

Fabrication and testing

In this chapter, the description of the procedures leading to the construction of an FM transmitter is given. Brief explanation on the manufacture of printed circuit board starting from circuit diagrammatic pattern (artwork) to etching has been presented. Many testing procedures required for effective operation of this project beginning from continuity test to transmitter range test have been outlined.

Printed circuit board

Of all the construction steps that this project demand, printed circuit board required the greatest amount of thinking and skill in its preparation. Small-scale production can be achieved by following the procedures outlined.

To produce the layout diagram and the pcb artwork is perhaps the most difficult of this method of construction. The development of the template for the printed bard was achieved through series of careful design of electrical circuit.

Several methods are used to transfer the artwork onto the surface of the board for example etch-resist pen, etch resist transfers and photographic method. Etch resist transfers is used to mark out the layout tracks unto the surface of the board. The result is neat and precise artwork which, when etched gives very professional finish.

The first step in process of etch-resist transfer is screening/firming. The following materials were used at this stage, - seteier, emulsion, transparent glass, hard book, foam water, mesh silk and sunlight. The following sequence was carefully applied to assure quality transfer of the master printed circuit pattern to the copper surface. Seteizer and emulsion were mixed and poured on the silk. A smooth flat piece of plastic was used to rub the mixture repeatedly on the silk until the mixture had vanished from this side.

The mixture reappeared on the opposite side and turning that side and using the material, the mixture was run gently along this side until it vanished and reappeared at the initial side. The process of turning and rubbing was stopped when the mixture was completely absorbed and could not significantly appear on either side. After coating and curling (vanishing and reappearing of the mixture) the silk was allowed to dry thoroughly for thirty (30) minutes.

In the screening, the film was placed on the silk. The transparent glass, rectangular in shape was placed over the film, and the hard book was placed under the silk directly opposite the film. The entire arrangement known as assembly was then brought under sun light for the film exposure. The exposure time required to reach the degree of polymerization was dependent on the light intensity.

After the exposure the assembly was decoupled ready for developing. In developing, a foam was dipped into clean water and squeezed unto the mesh repeatedly for three seconds. The foam was gently rubbed on the silk so that a bright white line of the pattern shown up. Having ascertained the appearance of the film, water, was poured continuously on both sides of the silk. After a while the foam was rubbed on the wet side to increase the appearance of the pattern. This recycling event continued until the entire printed circuit diagrammatic pattern was fully cured. The silk was allowed to dry completely.

When the mesh had completely dried, a proportionate amount of ink called sticker ink was poured on the coated side of the mesh. The resist copper surface was placed opposite directly under the coated skill on flat surface. The ink was ran evenly along the silk with the plastic material, then the diagrammatic pattern appeared unto the resist copper side. Then the silk was removed and the copper side surface was dried completely. Copper resist was removed from surplus copper with electrician knives. Finally, the board was thoroughly washed with detergent and dried ready for etching. Etching is the process of removing excess copper from the board. Nitric acid was used because it dissolves copper quickly.

Component designation fault

Component designation fault existed on the circuit as shown in the diagram and thus lead to wrong positioning of the component.

Component designation

Component designation faults with respect to transistor Q_2 and Q_2 existed on the circuit as shown in fig 4 and this lead to wrong positioning of the two transistors on the printed circuit board. According to this component designation fault, the population process swapped the collector and emitter terminals of these transistors. As a result, these transistors were wrongly biased in such a way that their emitters were at the highest potential followed by their base with the collectors at the lowest potentials. The emitter/base junctions were reverse biased while collector/base functions were forward biased causing very poor system performance. This was against the conventional biasing mode which is emitter/base junction forward biased, and collector based junction reverse biased for NPN transistor.

Soldering

Soldering exercise carried out with 40watt soldering iron was performed with due regard to safety. Before starting to solder the bit of the soldering iron was cleaned when hot by wiping it across a wet sponge or fine abrasive paper. Melting some solder onto the bit (known as tinning) and wiping that off in the sponge helps this cleaning process as solder contains cores of flux, which is a cleaning agent.

For a successful result, all parts of the board to be soldered were dry and free from dirt and grease. A hot soldering iron was used to produce good solder joints. The joints were made hot but not too hot to overheat it as overheating can cause damage. The soldering iron was placed so that it was touching both the lead to be soldered and the copper track to which it was to be joined. After a few-seconds the solder was applied to the track to melt and flow up around the base of lead forming a wedge. Solder flow cold to hot and therefore if either the lead or track was cold, solder would not flow and dry which would result. According to Kavacs (1989), a dry joint is one which has failed to bond sufficiently strongly with the copper track and as a result it provides a poor conducting path for current. The dry joints were put right by applying a clean soldering iron to the joint and leaving it long enough for it to melt the solder so that it flows properly.

Apart from dry joints another problem encountered in the soldering was solder bridges linking tracks. This happened when too much solder was applied to the joint and an adjacent track was heated at the same time as the joint, perhaps by using a soldering iron bit which was too large. The situation was dealt with immediately as it occurred. Solder sucker was used to remove the hot solder. Any component that has been picked and placed in the hole was soldered immediately so that it did not fall. Soldering is one important factor in electronics systems design which if poorly done can undermine the operation of the system. Therefore, the soldering processing was carried carefully to ensure good system performance.

Transistor Testing

When constructing this FM transmitter testing was carried out on the transistors before, they were soldered on the printed circuit board. The conditions of the transistors needed to be verified because brand transistor like any other semi-conductor device could be faulty from the shelf. Many techniques technologist and engineers have complained that the new ic or transistor that they had fitted into a circuit was faulty. With the transistor out of the circuit, the two-diode junctions of the transistors were checked with digital multimeter. For an NPN transistor, the test was as follows: the positive lead of the ohmmeter was connected to the base and the negative (common) lead was connected to the emitter. This forward biased the base/emitter junction, and the ohmmeter recorded low reading. The negative terminal was then connected to the collector. This forward biased the base/collector junction and the ohmmeter recorded low reading. Then the ohmmeter reverse biased the two junction and both junctions read high. If one of the junctions read low in both conditions the junctions was shorted. If ohmmeter recorded high reading in both reverse and forward bias condition then the junction was open circuit and the transistor was bad.

Next, reading was made between the collector and emitter, the meter leads were reverse to make a second reading. Both of these readings should be high. If not, the transistor had a collector emitter junction short circuit short and was replaced. If the terminals were unknown, the base terminal was found by identifying which had a low reading in relation to the other two terminals. This terminal was the base. If the low readings were caused by the base being positive, the transistor was NPN. If the low readings were caused by base being negative, the transistor was PNP.

Continuity Test

When all the components had been soldered on the printed circuit board (PCB) continuity test was carried out before the connecting the system to power supply. The test revealed open circuit faults, which could be due to:

1. A break in the circuit.
2. The failure of a component leading to it having an unusually high resistance or.
3. An increase in the insulation at certain points caused by dirt, grease or corrosion.
4. It also revealed that short circuit faults which were due to;

5. The failure of a component leading to it having an abnormally low resistance.
6. The touching of uninsulated parts of the component terminal
7. The effects of moisture lying between conducting paths which create links of lower resistance than the component or.
8. Solder bridges between the terminals.

Static test

As soon as this project was connected to power supply, the static test involving transistor terminal voltage readings was carried out before AC signal was injected into the circuit. A tpical static test for transistor Q_1 was as follows.

VC Collector voltage with respect to region = 8v

VB base voltage with respect to ground = 1.7v

VE emitter voltage with respect to ground = 1.0

In addition to the biasing conditions, the static test also revealed faults such as open circuit and short circuits in transistors and other semi-conductor components.

Power supply

The process of construction and testing of this project showed that the most suitable power supply for the efficient operation of this transmitter is the 12 volt lead acid battery. This source of power supply is completely free from AC ripples that cause electrical noise especially in oscillation circuits. An alternative source of power supply is the highly regulated and efficiently filtered power pack circuit which is costly.

The circuit for this project consists of track-etched inductor whose reactance is determined by voltage level. Any change in this voltage level as a result of ripples or fluctuations existing in the power supply is converted to equipment change in the inductive reactance. This change in inductive reactance is converted by the circuit to variation or drift in oscillation frequency of the transmitter. In the initial test, when the transmitter was connected to ordinary 12v power supply consisting of transformer rectifier and filter circuit, its output was seriously affected by frequency drift and electrical noise.

Microphone connection

Microphone converts sound energy to electrical energy for further processing by the circuit. In this project, the microphone is connected to coupling compactor C1 to feed modulating signal to the base of the transistor Q1. With the microphone feed resistor R1 retained, the circuit worked with only undirectional microphones many of which were burnt each within a few hours of usage. The circuit only burnt but did not work with omni-directional dynamic microphone. However, with the microphone feed resistor R1 removed the circuit has been operating efficiently with omni-directional dynamic microphone without any damage. The circuit in this condition neither worked nor burnt the unidirectional microphone.

Transmitter Range Testing

Transmitter range testing involved the process required to determine the distance from transmitter its signal will be received. This test required a radio receiver with FM band, a cassette player or an assistant producing direct audio that will be feed into the microphone. The test also requires an antenna installation described below. The transmitter, cassette player and radio receiver were switched on simultaneously. The radio receiver set to FM band was tuned gradually to capture the main frequency then moved away from the transmitter to the farthest point signal could be received.

Ballun

Balanced and unbalanced transformer is necessary because the output of this FM transmitter is an unbalanced impendence of 75 which is to be coupled to an antenna of 300Ω impendence Ω (Patric 2003). The BALLUN a 1:4 balanced and unbalanced transformer, is therefore required for efficient coupling. All the coaxial cable joints to the transmitter and BALLUN were carefully made to avoid short circuit or open circuit faults that will undermine the performance of this transmitter.

CONCLUSION

So, far the test result of this project which is the outcome of construction procedures has revealed the successful achievement of the primary objective; the design and construction of an FM transmitter of appreciable range operating on 12v power supply. Because of the impressive good result, obtained from the usability test, the FM transmitter is now ready for either instructional or entrepreneur purposes. The successful completion of this study has indicated that practical FM transmitter requiring low power input can be designed and constructed.

RECOMMENDATIONS

In view of the handicap suffered by the researchers in effort to conduct this project successfully, and the general findings, the following recommendations are hereby made.

1. Students of Industrial Technical Educational and other related technical programs should be encouraged to undertake design and construction projects to enhance the technological development of Nigeria.

2. The electrical/electronics section of the Vocational Teacher Education Department, University of Nigeria Nsukka should be provided with functional materials and equipment especially in areas of test and instrumentation. These will be of vital importance to the students' training and project work activities.

REFERENCES

[1] Brindly, K. (1987). *Radio and electronic engineers pocket book*. London: Heinemann Ltd.
[2] Chapman, W.A.J. (1988). *Workshop technology part 1*. London: Arnold International Students Ed.
[3] Cole, I. W. (1988). *Foundations (ICE Works construction guides)*. London: Thomas Telford.
[4] Farex, L. (2005). *Transmitter-encyclopedia articles about transmitters.* http:wysiwgy:118/file:al;transmitter. Accessed 7/4/2005.
[5] Institute of Electronic Engineering IEE regulation, (1985). London: Savah Place Publishing Coy.
[6] Lycos, L. (1980). *Radio communication laboratory – built for transmitters* http://memberstroipor.com/rclindia/trans.html. accessed on 5/3/2005.
[7] Kavacs, E. (1989). *Workshop on electronic engineering for mechanics*. Hungar: Houghborough Printers.
[8] Lama, A. G. (2003). *The construction of high frequency audio amplifier in printed circuit.* Unpublished M.Ed. thesis, Department of Vocational Teacher Education, University of Nigeria, Nsukka.
[9] Nworgu, B. G. (1991). *Educational research: Basic issues and methodology*. Owerri: Wisdom publishers Ltd.
[10] Okafor, M. O. (1995). *Radiation fields of UHF and VHF antennas*. Unpublished M.Sc. Thesis Department of Physics and Astronomy, University of Nigeria, Nsukka.
[11] Olaitan, S. O. (1996). *Issues and analysis in vocational and technical education in Nigeria*. Onitsha: Noble Graphic press.
[12] Parson, J. (1992). *The mobile radio propagation channel*. London: The Pentech Press Ltd.
[13] Paul, H. Y. (1994). *Electronic communication techniques*. New-Jersey: Prentice Hall Inc.
[14] Roger, L. F. (1991). *Telecommunication transmission handbook*. Canada: Inter-science Publisher John Willey and Son's Inc.
[15] Walter, L. (1987). *Communication source book*. London: McGraw Hill.
[16] Watson, E. (1990). *Mastering electronic*. London: McGraw Hill.
[17] William, S. (1996). *Electronic communication system*. A complete course: New Jersey: Prentice-Hall Inc.