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Research article

# Development of a Hibernation Scheme for Reducing Energy Consumption in a Communication Base Station

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ABSTRACT

*This paper "Development of a hibernation scheme for reducing energy consumption in a communication base station" is aimed at reducing energy consumption in communication network base stations considering the rising cost of energy in our country, Nigeria today. The scheme was developed using models that by calculations detects when any of the system components is in inactive mode. Such system component will be switched off to avoid energy wastage. The preliminary energy consumption evaluation carried out identified the power amplifiers as the component that consumes the highest energy at the station and yet it's not all the time active. When the developed scheme was simulated, the results showed that during data transmission process, low noise amplifier (at the receive node) was not all the time active and power of 1250W was conserved. Also, in the receiving end the result showed that the RF power amplifier was in hibernation mode on many occasions and about 950W of power was conserved. The overall power consumed with the hibernation scheme is 5421W and of the evaluated without the scheme is 7321W. The percentage save with the hibernation scheme is 25.9%. The overall objective is to be able to run base stations in Nigeria with small generating plants and reduce also emissions from big generating plants.*

***Keywords:*** *Communication Base Station; Hibernation Scheme; Energy Consumption; Power*

**Introduction**

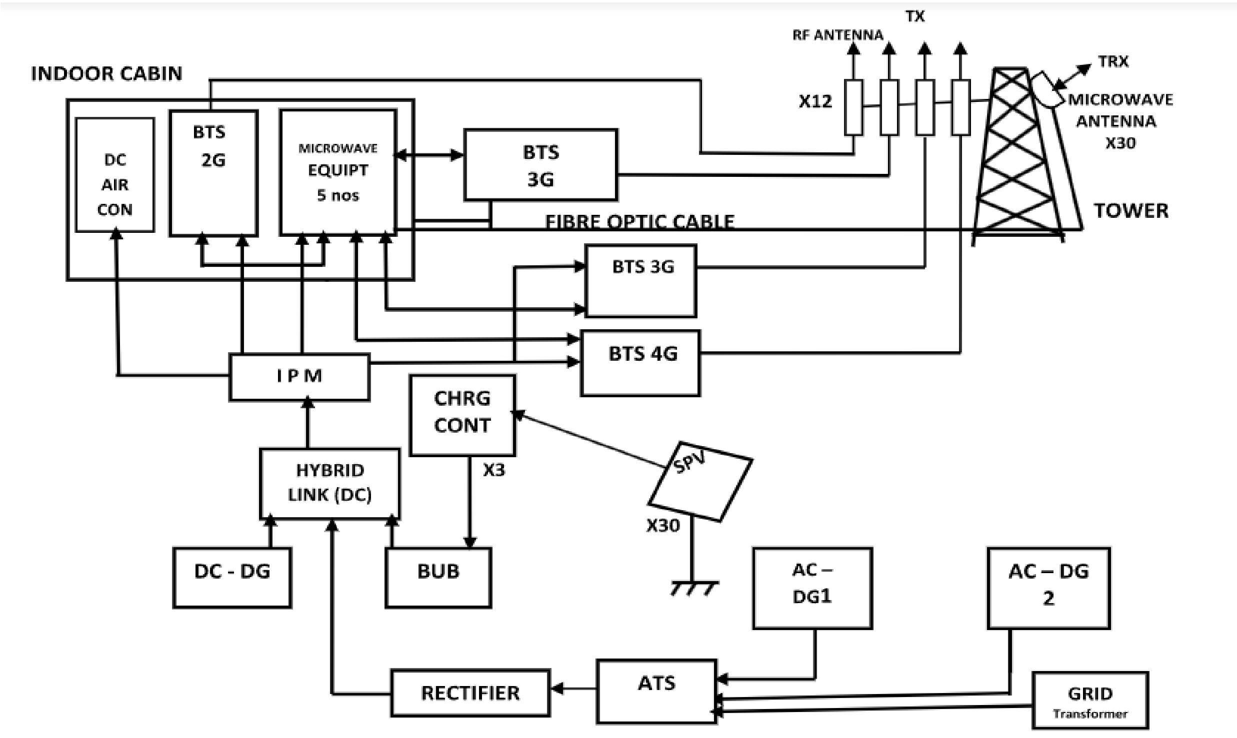
Energy efficiency has now become a key pillar in the development of communication networks with millions of inter connected devices on daily basis communicating with each other online. Today the increase in the usage of data coupled with the advancement of internet of things has also increased the connectivity of all sort of hardware and software-based system to the cloud. These communication network activities tend to increase energy consumption at base stations which contributes to high energy cost (Dini et al., 2013). The rapidly increasing energy consumption by the communication equipment is a significant economic and environmental problem that needs to be addressed

There are two important factors which motivated this research. Firstly, the need to reduce the rate of energy consumption in wireless communication networks, especially in this era where the size of the network keeps growing with the explosion of data traffic. This trend could adversely affect the rate of energy efficiency of Information and Communication Technology (ICT), at the forefront of technology. In order to drastically reduce the rate of energy consumption of today's wireless communication, radical new approaches are needed. Recent research works have identified a gap between rapid network development rate and the history of ICT equipment improvement, which is a research gap promising to be improved in over time (Winters, 2018).

Technologies in use today even considering best case project energy efficiency improvement are not expected to be sufficient to check the rate of energy consumption over the long term. The vision of this research is to develop energy efficiency in wireless communication networks and technology which enables sustainable approach that improve the efficiency of power consumption in the ICT sector. This will go a long way to save cost, improve life span of devices, and overall operational efficiency.

**Theory of Work**

Communication network consists of three elements, a core network that takes care of switching, base stations providing radio frequency interface (Fig. 3,1) and mobile terminals used to make voice and data connections, of these base stations alone contributes 60% to 80% of the whole network energy consumption in a communication system.




**DC – DG:** Direct Current – Diesel Generator **ATS:** Automatic Transfer System

**AC – DG:** Alternating Current– Diesel Generator
**GRID:** Public Power Supply (EEDC)
**BUB:** Back-Up Battery
**TX**: Transmitter
**SPV**: Solar Photovoltaic
**IPM:** Intelligent Power Manager
**BTS:** Base Transceiver Station
**TRX**: Transceiver
**CHRG CONT**: Charger Controller
**RF**: Radio Frequency

**Fig. 1:** Block diagram of the base station under study

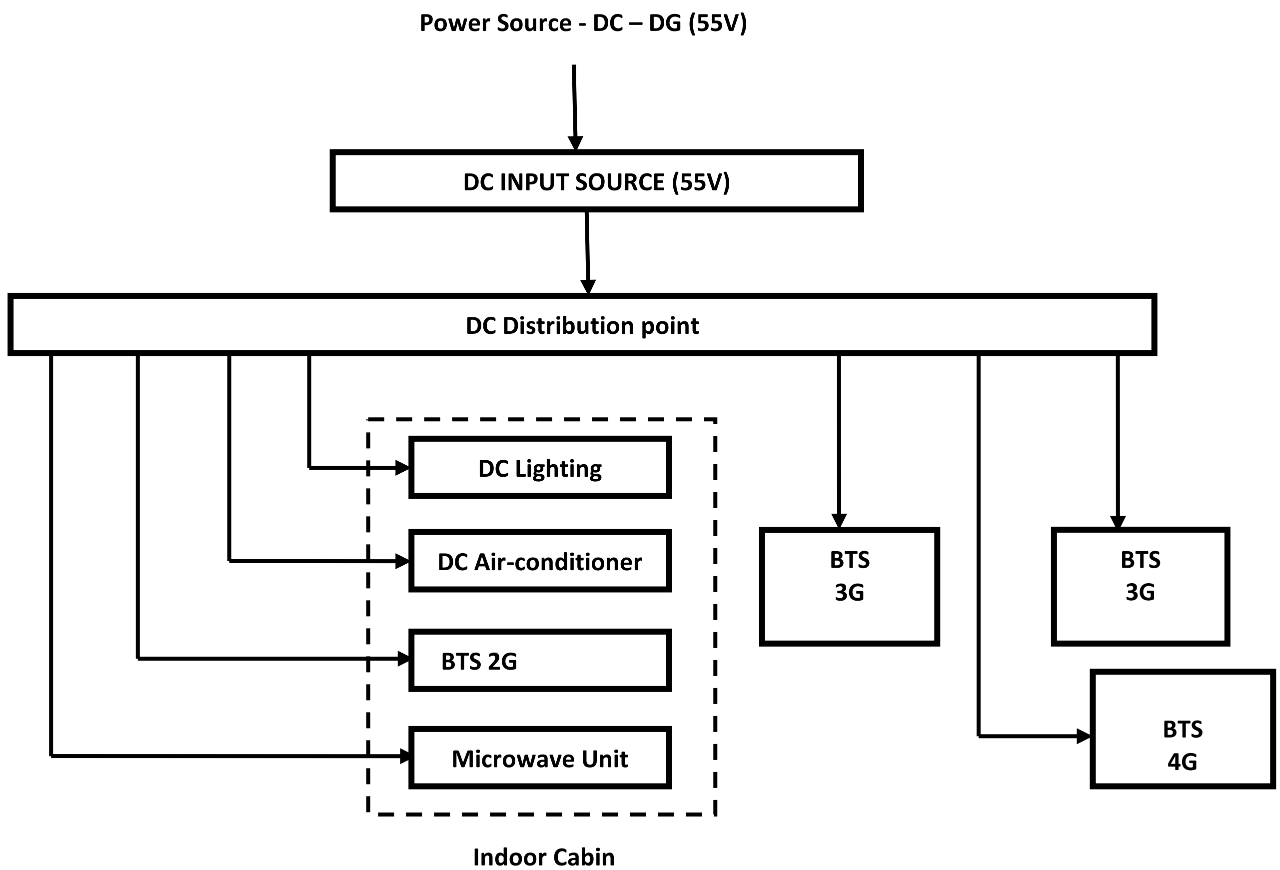



**Fig. 2:** Block Diagram of Power Supply Architecture of the base station

In the base station the major components that make up the base station equipment are basically microwave unit, radio equipment, air condition and lighting. This is further broken down with their power consumption rating as given in Table 1. Of these energies consumed rating by the base station components, it can be seen clearly that power amplifier component utilizes 65% of energy consumed at the base station (Wang et al., 2018).

**Table 1:** Power consumption rating of the components of the base station

| *Components* | *Ratings (%)* |
| --- | --- |
| *Power supply* | 7 |
| *Power amplifiers* | 65 |
| *Air conditioning* | 18 |
| *Signal processing equipment (MAC, baseband, IF, Dual frequency, RF/IF converter,* | 10 |

This statistic is further analyzed as shown in Fig. 4

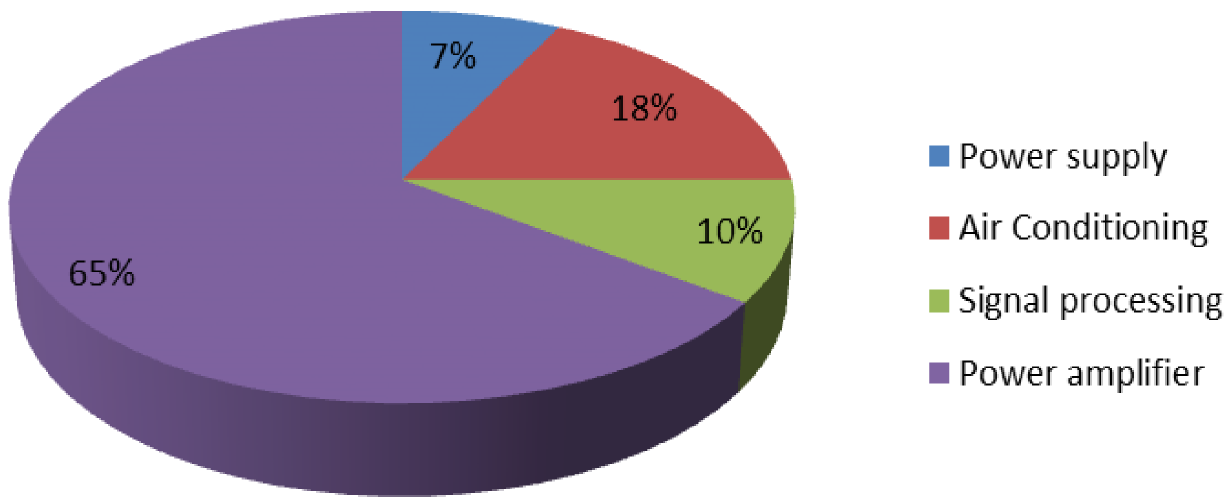



**Figure 3:** Energy consumption pie chart for the study field base station (Wang et al., 2018).

## 3. Methods

### Evaluation of the Energy Consumption Level at the Study Field

This research was conducted at a GSM base station owned by MTN at Nsude, Udi LGA, Enugu State of Nigeria. As shown in Table 1 the amplifier consumes most of the power at the base station.

Empirical measurements of the power consumption at the base station were conducted at the station every hour for three weeks on each of the components in both transmission side and receiving side. The average of the three weeks measurements was finally calculated and the result shown in Table 1

**Table 2:** Summary of the empirical measurement of energy consumption at the base station of study

| *Components* | *Transmission Power (W)* | *Receiver power (W)* |
|---|---|---|
| *MAC* | 125 | 125 |
| *Baseband* | 103 | 103 |
| *IF mode* | 800 | 800 |
| *Dual frequency* | 90 | 40 |
| *RF/IF converter* | 500 | 200 |
| *Low noise amplifier* | 950 | 135 |
| *RF amplifier* | 2700 | 1250 |
| *Total* | 4668 | 2653 |

The pie chart of Fig. 2 demonstrates the comprehensive review of the power consumption rate of each component at the base station during the transmission process.

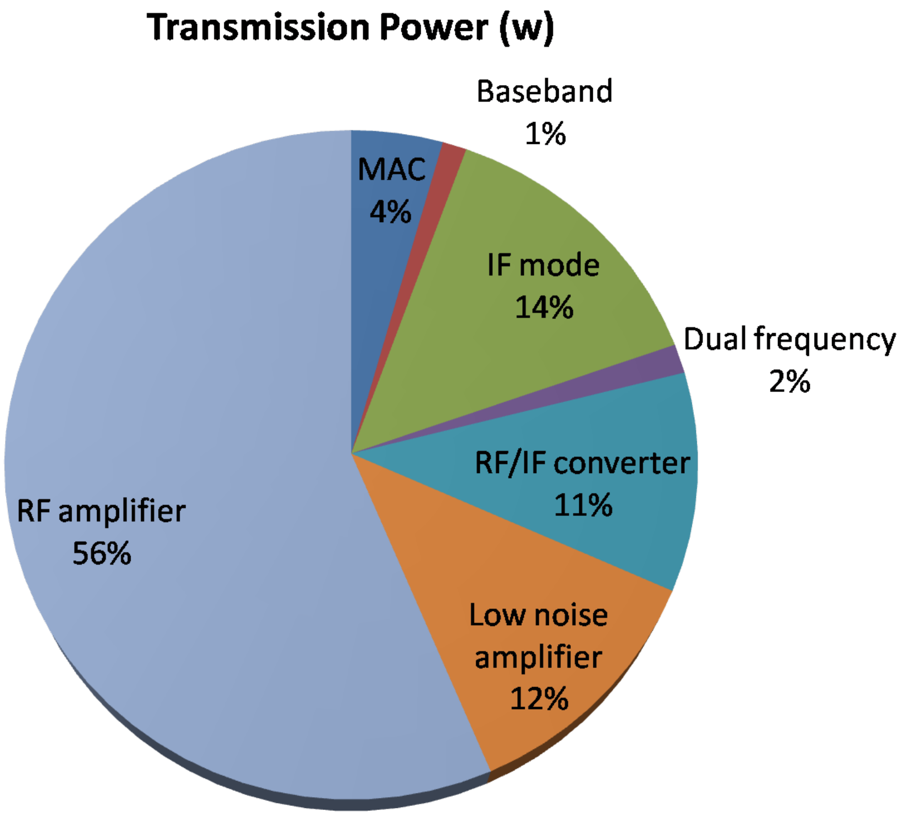



**Figure 4:** power consumption rates of the base station components by the transmit nodes

Analysis of Fig. 4 shows that during transmission process, the RF amplifier consumed 56% of the overall power need for the station, while the other components share the remaining 44%.

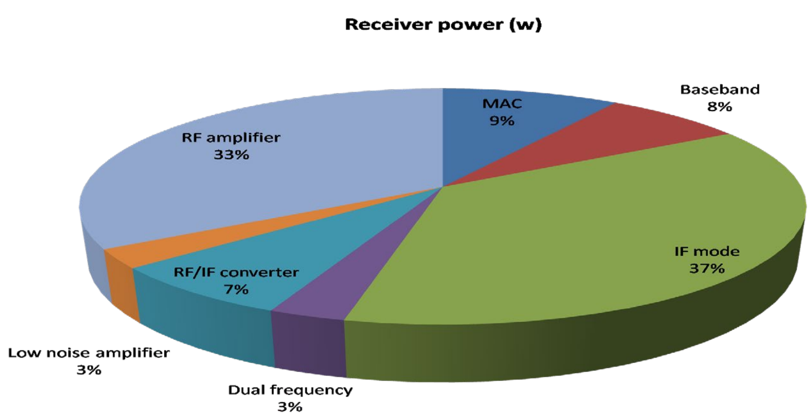



**Figure 5:** Power consumption rates of the base station components by the receiving nodes

Analysis of Fig. 5 shows that during reception process, IF receiver consumes 37% of the total power need of the station, while the RF amplifier consumed 33%.

The implication of these results is that certain components of the system consume power even though they actively contributed nothing at certain periods within the transceiver activities. According to Frenger et al. (2011) during data transmission the low noise amplifier contributes nothing to the transmission process and yet consumes 12% of the total power needed for the process, while at the receiver end, the RF amplifier contributes nothing to the demodulation process, but yet consumes 33% of the overall power used. This has been a major problem and has incurred high cost overtime. This research seeks to provide solution to this cankerworm via the development of hibernation algorithm to control power consumption of certain components during communication process.

**Development of the Hibernation Scheme**

To achieve energy reduction in the system the system components that are not in use at all times must be identified and switched off and must be switched on when they are to be used. To achieve that the system design was developed using mathematical models of the data usage in the network, power consumed per user equipment, total power consumed, energy efficiency model and the model for computing the cost of power used. The model of the proposed hibernation algorithm was also developed as presented in Fig. 6

**Model for Data Usage Evaluation**

This is model was used to describe the relationship of the rate of transmitted packets of data from each network equipment (node) is propagated to the cloud per given time. This was presented using the model of equation 3.1 (Combes, et al., 2015)

$$\text{Throughput} = \frac{1}{T}\sum_{t-1}^{T}\sum_{i-1}^{I} p_{trm(t)c} \qquad 3.1$$

Where I is the total number of users equipment, T is the total data transmission and receiver time, $p_{trm}$ is the number of transmitted bits per seconds, c is the user equipment (UE)

**Energy Efficiency ($EE$) Evaluation Model**

This model is used to alert the system when the energy consumption of the system is low and to ensure that energy is conserved by causing inactive components to go into hibernation state; This is achieved using the mathematical model of equation 3.2 (Combes, et al,2015)

$$EE = \frac{Tf(y)}{T(u+P)} \qquad 3.2$$

Where T is the time taken for the communication process, f function of signal to noise ratio, y is the data, u is the reciprocity of efficiency of the transmitting power in the amplifier, power and P is the dissipated power.

**Power Consumption ($P_k$) Model Evaluation**

This model was used to compute the power consumed by the UE at both active mode and hibernation mode. The model was developed using the relationship between the UE on load (active) and on hibernation model per time period as shown in equation 3.3 (Elayoubi et al, 2018)

$$P_k = \sum_{i=1}^{N_e} T_i p_{k,Tx}(S_{k,Tx};\ u_{k,Tx};\ L_{k,Tx}, L_{k,Tx-1}) \qquad 3.3$$

Where Ne is the number of user equipment (UE) service request and other activities

Ti is the time between data transmission and reception,
$P_k$ is the power consumed at the user equipment,
$S_{k,Tx}$ is the state of the UE,
$L_{k,Tx}$ is the UE on load,
$L_{k,Tx-1}$ is the UE on sleep mode.

**Model for evaluation of total power consumption ($P_t$)**

$$P_{t= p_a + p_b} + p_c + p_d + p_{e+}p_f + p_g \qquad 3.4$$

Where $p_a$is MAC, $Pbis\ baseband, p_b\ is\ IF\ mode, p_c is\ dual\ frequency, p_d\ is\ RF\ converter,$

$p_e$ *is low noise amplifier*, $p_f$ *is RF amplifier*

3.3 Phase Tracking Reference Signal (PT-RS) for time resource control
PT-RS is the phase tracking reference signal that has a low density in the frequency domain and a high density in the time domain. This is used in the network for tracking the activity of user equipment to determine when data want to transmitted or received. This comes in when FTP, or Http is transmitted.

**Frequency Domain Resources Control (FDRC)**
This is a method used for the detection of resource block, channels, or band via which data is transmitted in the network. This is also used to detect the packet type to be transmitted in the network so as to enable the hibernation algorithm for FTP and Http data.

**Development of the Monitoring Algorithm**
The monitoring algorithm developed from the monitoring flow chart of Fig.3.5 was used to make the hibernation algorithm intelligent and also decide when it was initialized. The algorithm uses frequency and time control function to monitor the behavior of the wireless device and then activate the hibernation algorithm when necessary. The pseudo code of the algorithm is presented below;

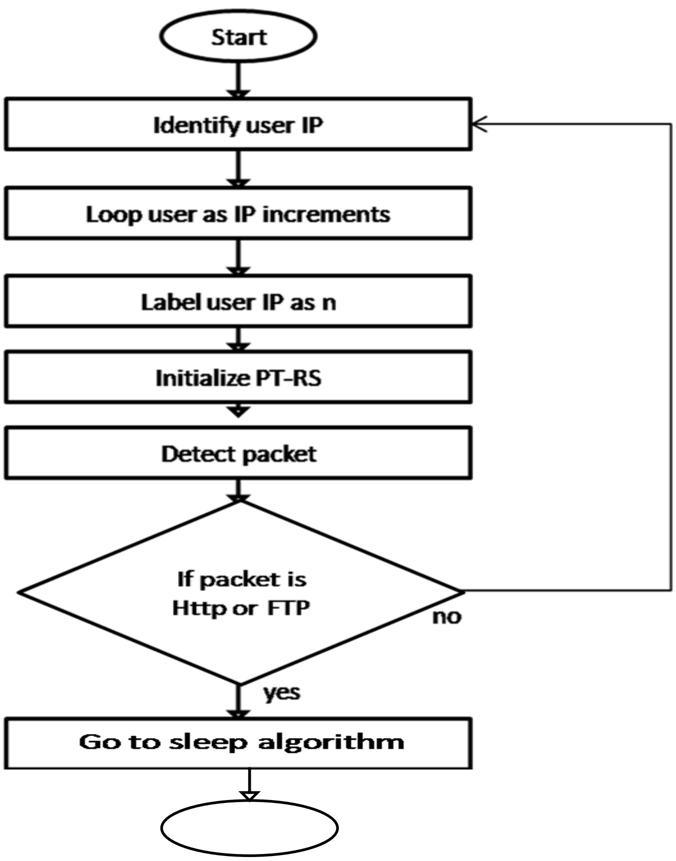



**Fig.6:** The monitoring algorithm flow chart

**Pseudo Code of Monitoring Algorithm**

Start
Identify user with n
Loop n as user increments
While n = 20

Initialize time control Phase Tracking Reference Signal (PT-RS)
Detect packet using frequency domain resource control
If packet is Voice
Return
Else if
Http, FTP is true
Activate sleep algorithm.
End
The flow chart of the monitoring algorithm is presented as shown in figure 6;

**Development of the Model for Inactive Component Hibernation Scheme**

The data flow chart for the algorithm is presented as shown below;

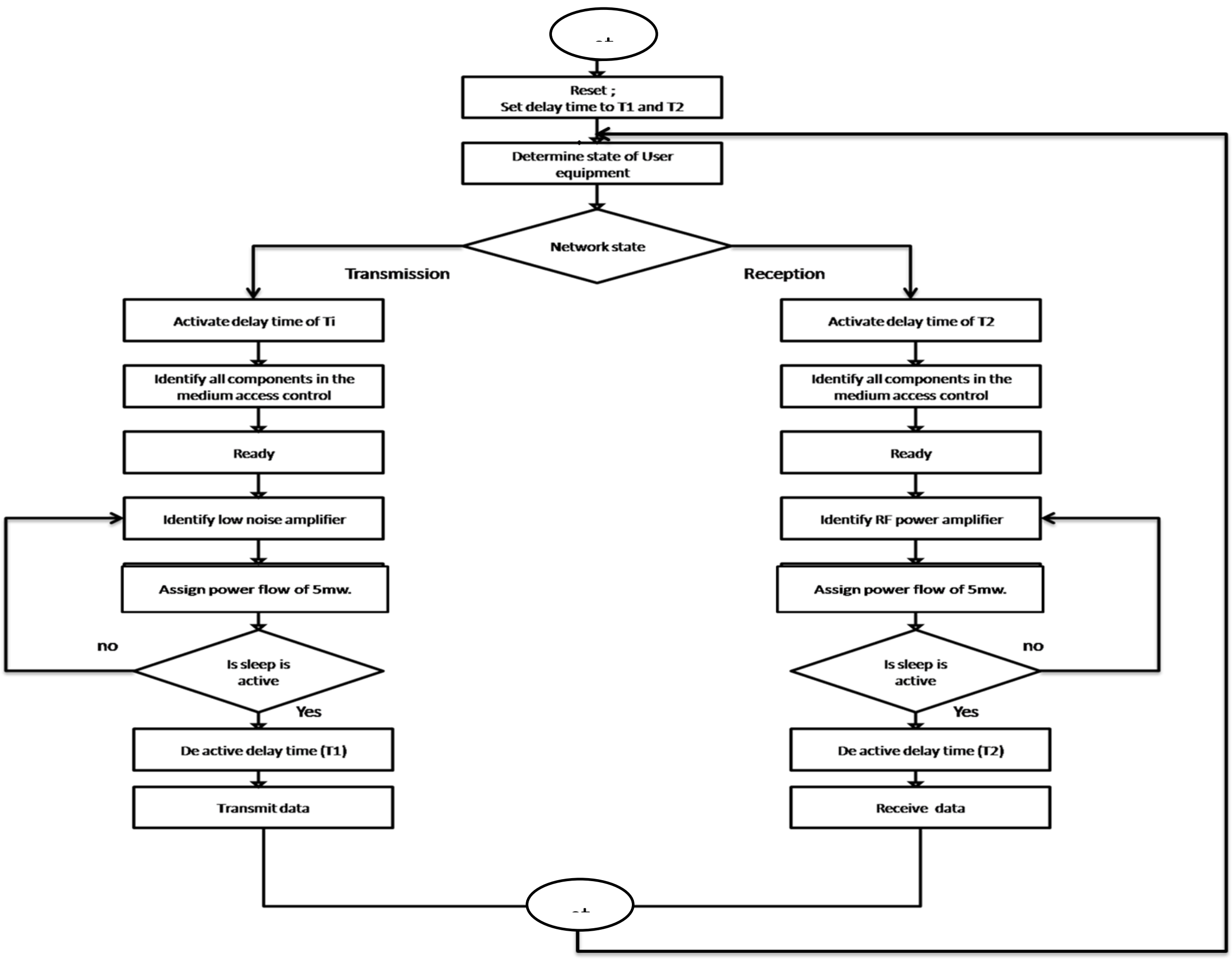



**Fig.6:** Model for inactive component hibernation process

**Simulations**

This was achieved using the various models developed and the algorithm of the hibernation model to generate source codes in Mathlab. The models were represented in each module of the code and activated using signal processing toolbox, power optimization toolbox and communication toolbox. The simulation parameter used was also presented in table 3, collected from the network setup characterized to provide a common base for comparative evaluation. The MATLAB editor for the coding is shown in Fig. 7

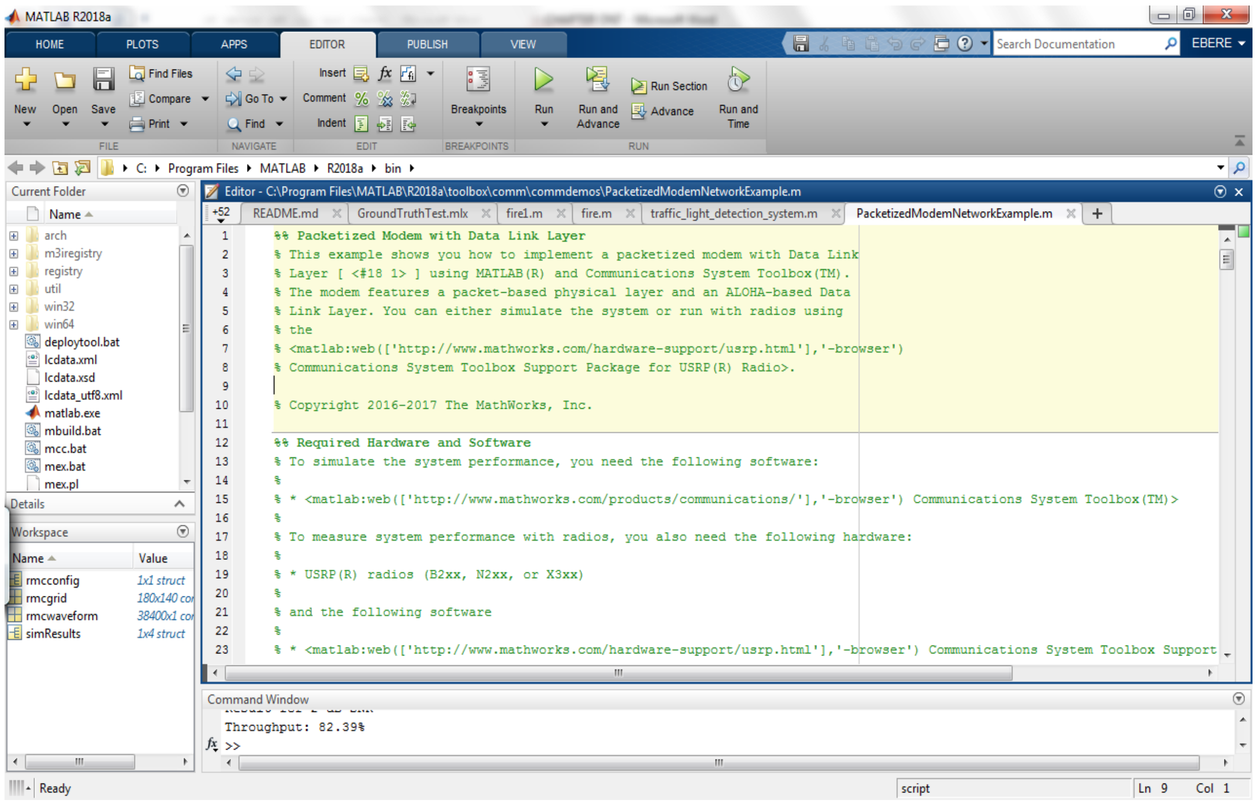



**Fig. 7:** MATLAB editor for the coding

**Table 3**: Simulation Parameters

| *Parameter* | *Value* |
|---|---|
| *Channel type* | *Wireless channel* |
| *Radio propagation model* | *Two ray ground* |
| *Network interface type* | *Wireless physical layer* |
| *MAC type* | *MAC NG* |
| *Interface queue type* | *Drop tail/ priority queue* |
| *Interface queue length* | *40* |
| *Link layer type* | *Traditional link layer* |
| *Antenna model* | *Omni directional* |
| *Value of x* | *900* |
| *Value of y* | *900* |

## 5. Results

Transmission process energy consumption performance at the base station with the Hibernation model

The simulation result of the energy consumed by the base station in transmit mode by the components with the hibernation model is shown in Table 4

**Table 4:** Transmission energy performance of the base station with the hibernation model

| *Components* | *Transmission Power (W)* |
|---|---|
| *MAC* | 125 |
| *Baseband* | 103 |
| *IF mode* | 800 |
| *Dual frequency* | 90 |
| *RF/IF converter* | 500 |
| *Low noise amplifier* | 5 |
| *RF amplifier* | 2700 |
| *Total* | 3718 |

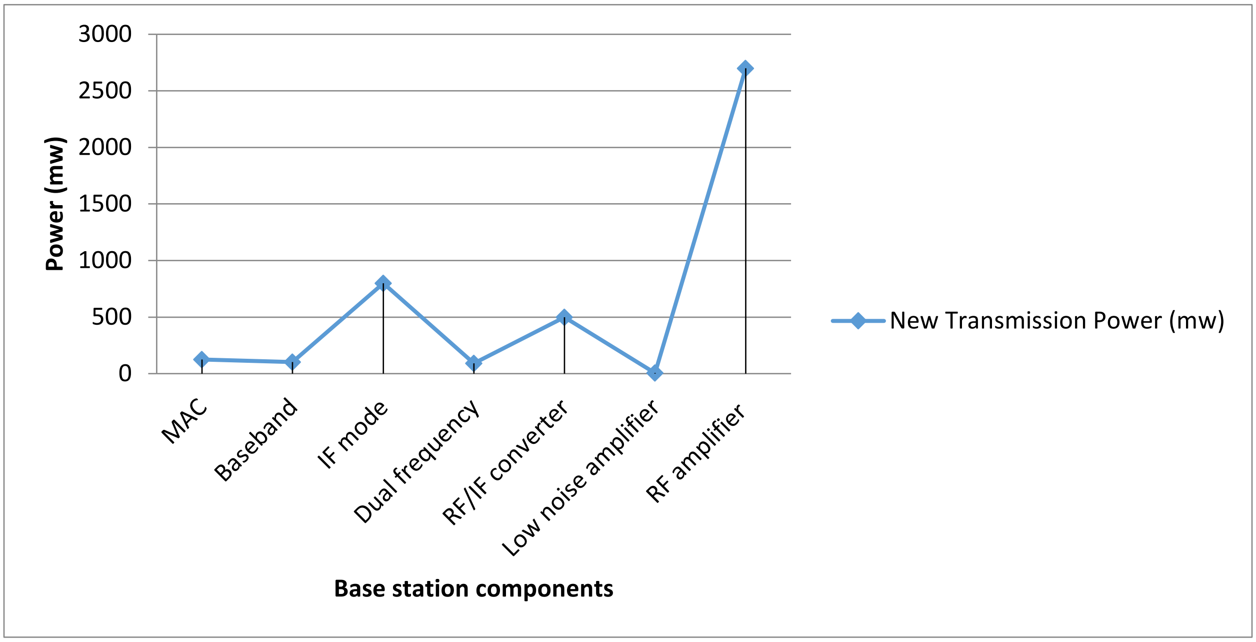



**Fig. 8:** Analysis of the energy consumed by the base station components with hibernation model during transmission process

The Fig. 8 presents the energy consumed during the transmission process at the station with the hibernation model. It can be seen that low noise Amplifier went into hibernation mode at sometimes meaning that the power that should have been consumption at those times were saved

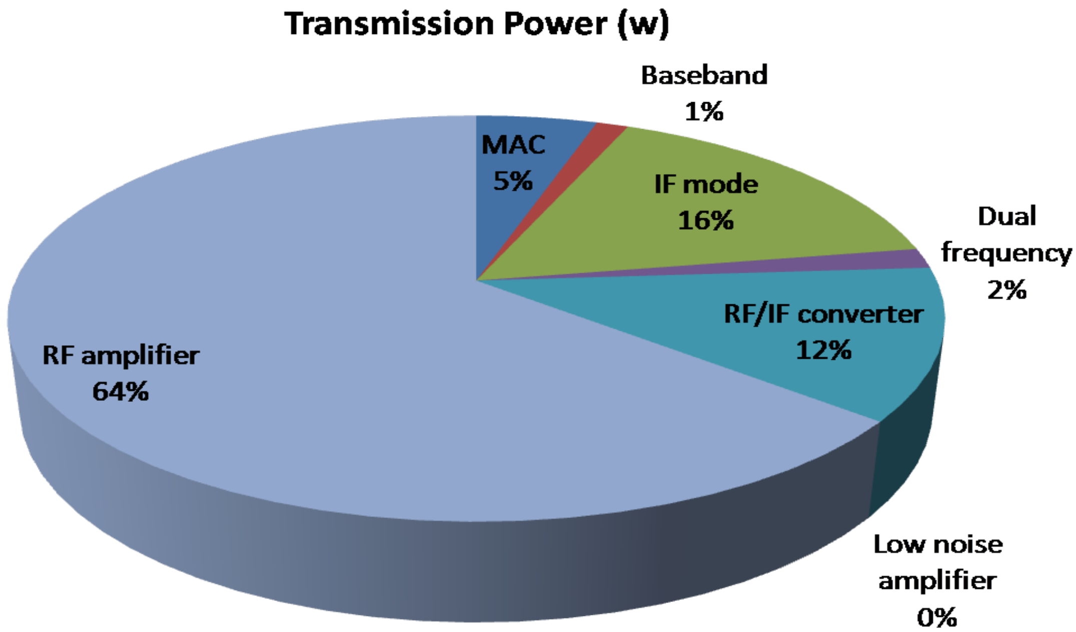



**Fig. 9:** Percentage energy consumption of the system by individual components

Further analysis of the transmission activities shows the rate of energy consumption as demonstrated in Fig. 5.2

The simulation result of the energy consumed by the base station receive nodes with the hibernation model is shown in Table 5

Table 5: Receiving energy performance with the hibernation model

| *Components* | *Receiver power (W)* |
|---|---|
| *MAC* | 125 |
| *Baseband* | 103 |
| *IF mode* | 800 |
| *Dual frequency* | 40 |
| *RF/IF converter* | 200 |
| *Low noise amplifier* | 135 |
| *RF amplifier* | 5.0 |
| *Total* | 1703 |

The Table 5 shows the simulation result energy consumption performance of the base station during the data receiving process with the hibernation model. From the result it was observed that during data receiving process, the model ensured that the RF amplifier is put to sleep mode as shown in the graph of Fig. 10

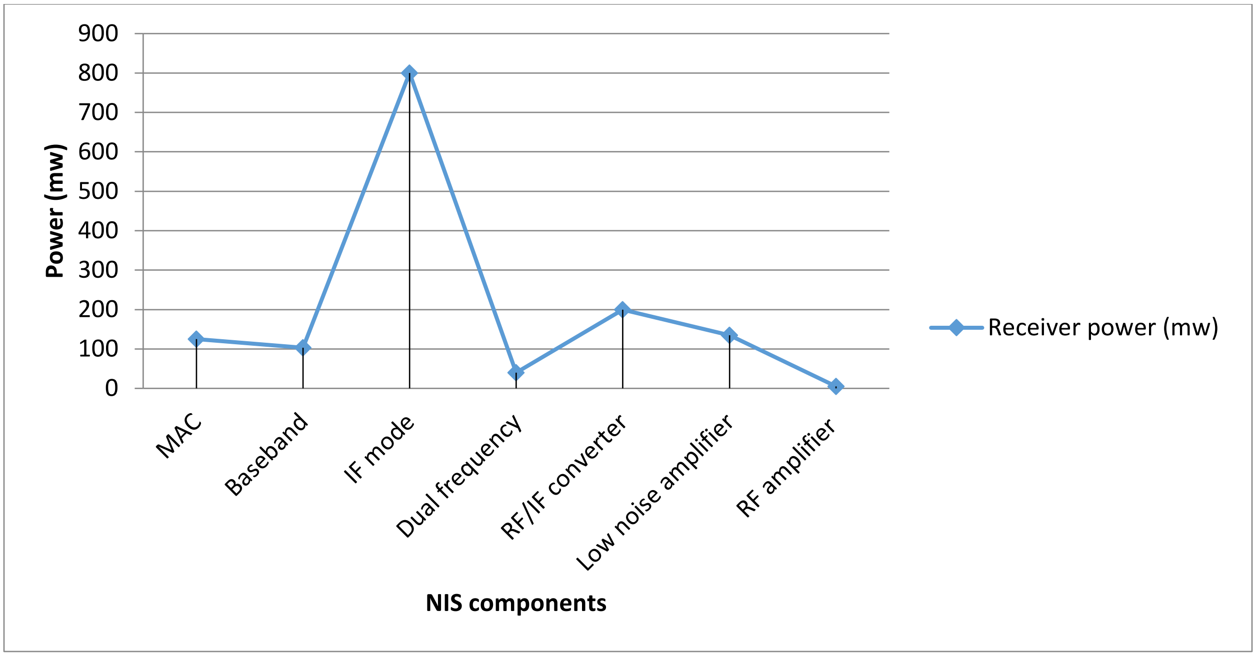



**Fig. 10**: the power at the receiver stage

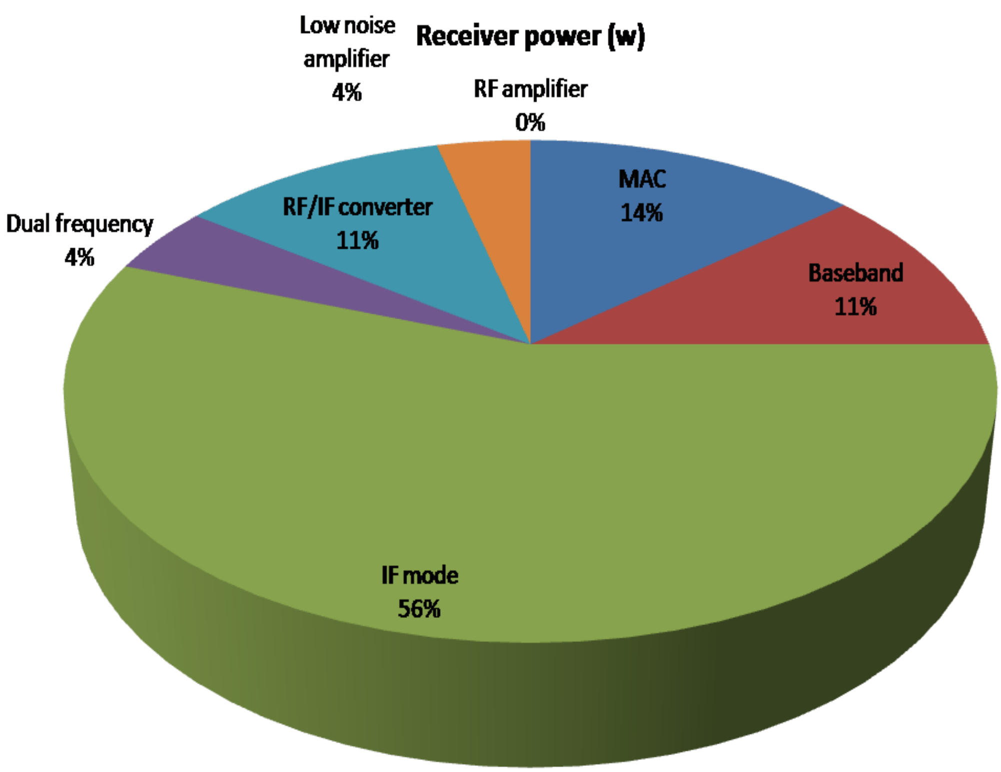



**Fig. 11:** The performance analysis of the overall power consumed at receiver end

Further analysis of the receiving process shows the rate of energy consumption as demonstrated in Fig. 11

Fig. 9 Comparative Analysis of energy consumption by the base station component with and without the hibernation model

Table 6 gives the data for comparative analysis of the energy saving effect of hibernation scheme during the transmission process in the communication base station while the analysis of the effect is shown in Fig. 5.5

Table 6: Data for comparative analysis of the energy saving effect of hibernation scheme on the communication base station during the transmission process.

| *Components* | *Power (W) without hibernation scheme* | *Power (W) with hibernation scheme* |
|---|---|---|
| *MAC* | 125 | 125 |
| *Baseband* | 103 | 103 |
| *IF mode* | 800 | 800 |
| *Dual frequency* | 90 | 90 |
| *RF/IF converter* | 500 | 500 |
| *Low noise amplifier* | 950 | 5.0 |
| *RF amplifier* | 2700 | 2700 |
| *Total* | 4668 | 3718 |

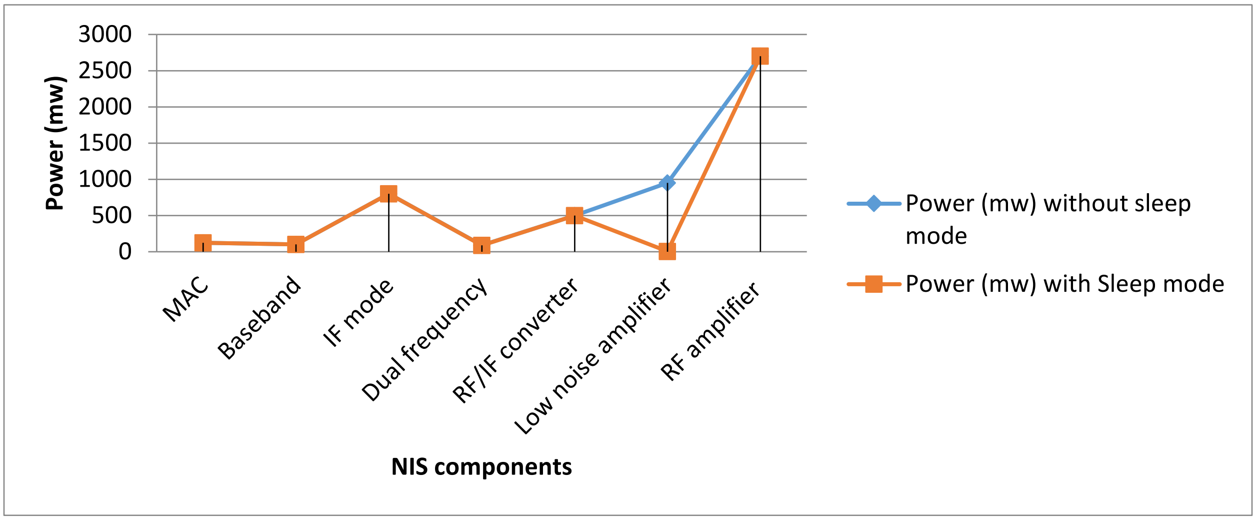



**Fig. 12:** Analysis of the energy saving effect of hibernation scheme on the communication base station during the transmission process

From Fig. 12 It can be seen that the measured energy consumption of the base station during transmission process is 4668 W, while in the consumption with the hibernation model is 3718W. The percentage difference of energy consumed with and without the hibernation model is 20.2%.

Table 7: gives the data for comparative analysis of the energy saving effect of hibernation scheme during the reception process in the communication base station while the analysis of the effect is shown in Fig. 5.4

Table 7: Data for comparative analysis of the energy saving effect of hibernation scheme on the communication base station during the reception process

| *Components* | *Receiver power (W) without sleep mode* | *Receiver power (W) with Sleep mode* |
|---|---|---|
| *MAC* | 125 | 125 |
| *Baseband* | 103 | 103 |
| *IF mode* | 800 | 800 |
| *Dual frequency* | 40 | 40 |
| *RF/IF converter* | 200 | 200 |
| *Low noise amplifier* | 135 | 135 |
| *RF amplifier* | 1250 | 5.0 |
| *Total* | 2653 | 1703 |

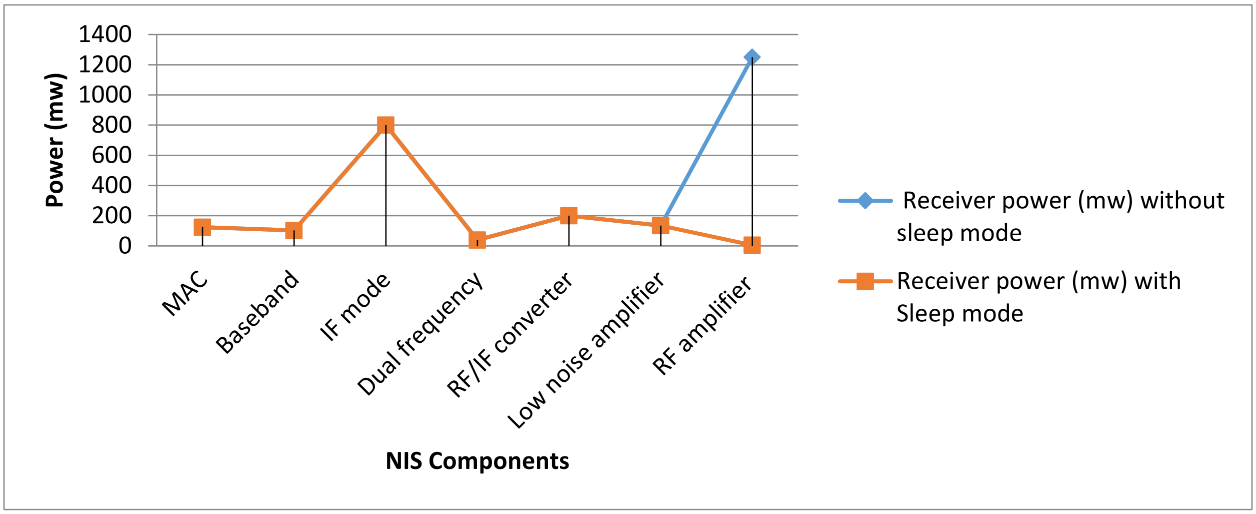



**Figure 13**: Comparative receiver power

Analysis of Fig. 13 shows that the measured energy consumption during the receiving process is 2653W, while that with hibernation model is 1703W. The implication of this result is that with the hibernation model 35.8% of energy was saved.

**Discussion**

The simulation result of the experimentations shows clearly that with the implementation of the hibernation scheme 20% could be saved during the transmission process while 35.8% of energy was saved during the receiving process. This represents a good energy saving, making the hibernation scheme a very good energy saver for base station communication equipment.

**Conclusion**

This research has successfully designed an energy conservation model which enables communication base stations to control their energy consumption during telecommunication process. This will not only reduce maintenance cost of communication equipment but also help to maintain a cleaner environment. Small power generating sets can now be used at base stations most of them located at remote locations.

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