Design of a GSM phone booth for low cost rural communication

F.E Idachaba and F.O Edeko

Abstract -The GSM phone booth was designed as a mobile phone with solar arrays on the roof. These arrays are for charging the phone batteries and powering the booth during the day while the batteries which can be bigger, powers the phone at night or in the absence of sunlight. The cell phone platform was integrated into the booth such that when a SIM card is inserted it can be used as if it were a personal phone. The SIM card holder was designed in such a way that the user carries it along to the phone booth and slots it into the provided slot on the booth before making a call. It was also designed to switch on or off the phone booth such that when the card is removed the booth is switched off while the battery continues to charge. This is another mean by which the battery life is extended. The design provides a low cost approach for extending mobile communication to rural areas and also for campuses and public areas.

Key words – GSM Phone booth, Rural area, Solar cells, SIM card

1 INTRODUCTION

The rural populace which constitutes the greater portion of the population in developing countries is plagued with poor infrastructure, unstable or nonexistent power supply etc. The lack of a stable power supply denies the inhabitants the benefits of modern communication technologies as these technologies require stable and consistently available public power supply systems. The GSM phone booth aims at providing communication services to rural areas without GSM coverage at minimal cost to both the rural dwellers and the mobile communications companies. It also can be used in schools where the use of mobile phones is not allowed. It eliminates the need for the acquisition of personal handsets and all the problems associated with having personal mobile phones.. The phone booth is designed in accordance with the GSM standard and it operates as a fixed terminal so system design is simplified as distance between the phone booth and the nearest base station is fixed.[1-3] The cellular phone platform used is integrated into the phone booth and powered by both the solar cells and cheaper, larger sized batteries

- *F.E Idachaba is with the Department Of Electrical And Information Engineering Covenant University Ota Ogun State Nigeria*
- *F.O Edeko is with the Department of Electrical and Electronics Engineering, University Of Benin. Edo State Nigeria*

Interference is also reduced due to the use of Space division multiplexing since the various phone booths are placed in different location with antennas facing the nearest base station.
The SIM card is integrated into a specially designed cardholder such that the card activates the phone booth when inserted and deactivates the phone booth when it is removed from its slot. The system can be configured by the service provider such that the called party pays for the call. This option enables students to reach their parent or aged parents to reach their children in the cities.

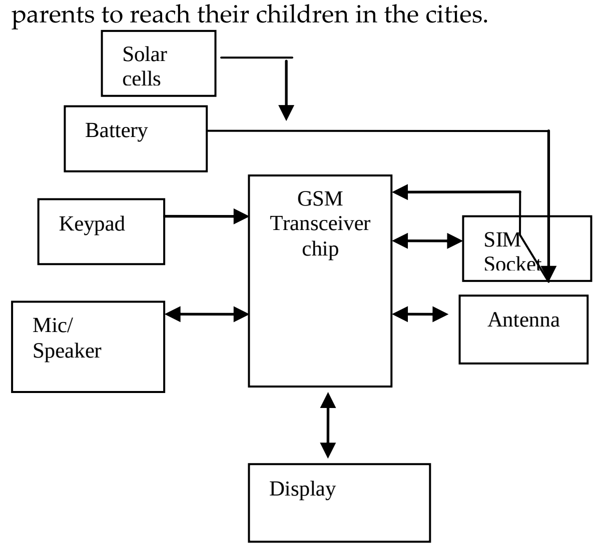

Figure 1 Block diagram of the Phone booth

The Phone booth is made up of the hand held unit and the base unit integrated into the booth. The hand held unit which consists of the microphone and the speaker can be made detachable, semi detachable or non detachable It serves as the interface between the users and the phone booth. The base unit is built around a Transceiver chip which is responsible for the encoding, modulation, A/D conversion and other associated process performed on the signal before transmission via the antenna and after reception via the same antenna.

2 Description of the various components of the phone booth

2.1 The Solar Cells

The solar cells which are to be placed on the roof of the phone booth will be required to provide power for the phone booth equipment and also to charge the battery. It will be required to provide a terminal voltage of up to 5VDC.

2.2 The battery

The batteries can be the cheaper NiCd or the Lead acid batteries with terminal voltages at 5VDC.The size limitations imposed on hand held /portable designs are not required in the phone booth design, this permits the use of cheaper, bigger, higher capacity batteries. The battery will be required to power the booth in absence of sunlight or shadowing of the sunrays due to rain or any other temporary occurrences.

2.3 The SIM socket

The SIM socket which is placed near the transceiver serves as an interface between the SIM in the SIM card holder and the Transceiver chip. It has connections which enable a pin by pin link of the various contacts on the SIM card to the transceiver chip.

2.4 The Transceiver chip

The transceiver chip used in this design is an application specific Integrated circuit (ASIC) designed for the DCS1800 standard. It is a cheaper option when compared with the use of discrete components. The transceiver chip controls the other component parts of the system which include the keypad, the display, and the antenna drivers. It also has ports for the microphone and the speakers. The use of the ASIC chip simplifies the design and enables mass production of the phone booth.[4]

2.5 SIM card holder

The SIM card contacts were extended such that it was integrated into a card holder. Power control pins were also integrated onto the holder for efficient power management of the phone booth, switching the phone booth on only when the card is inserted into the holder and off when the card is removed.

2.6 The antenna

The antenna needed for the implementation of the design was required to have a very high directivity, so the parabolic dish reflector or the yagi antenna can be used. The high gain of the antenna reduces the power output requirement of the power amplifier stage of the base unit.

3 METHODOLOGY

From the diagram in figure 2 the phone booths can be placed at different points in the user communities. A limiting factor for their placement is the amount of path loss that will be encountered by the signal along the chosen path. From the radio link diagram in figure 2,

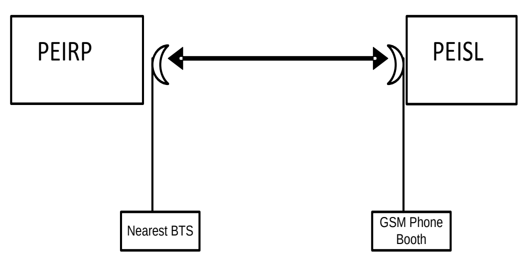

Figure 2 Radio link

PEISL= equivalent isotropic sensitivity level. This is defined as the sensitivity a receiver would need if connected to an ideal lossless omni directional antenna to provide the same receive quality (BER) as with a receiver connected to a directive antenna with the main beam focusing on the transmitter. This represents the effective usable sensitivity offered at the air interface and it includes all gains and losses in the RF and digital path of the receiving system

PEIRP = effective isotropic radiated power from the transmitter. It is a function of the Power amplifier (PA) output feeder losses and the gain of the transmitting antenna.[5-7]

The maximum acceptable pathloss for the link the becomes

Lpath (DB) =PEIRP – PEISL….1

The PEISL which is also the sensitivity of the phone booth is selected to be -100dBm in accordance with the DCS1800 specifications.

3.1 Calculation of the pathloss using the cost 231-Hata model.

The hata model which was originally developed to estimate pathloss in the 200MHz to 1500MHz range was modified by the European committee on scientific and technical research to extend its range to 2GHz.This model now known as the COST231-Hata model is used extensively in pathloss prediction in the DCS band for urban areas with factor built in for rural area pathloss estimation.[8-13] The specified parameters for the model include

Frequency range =1500MHz to 2000MHz
Distance from the base station= 1km to 10km
HT =base station antenna height=30m to 200m
HR=mobile station antenna height=1m to 10m

The model defines path loss as

PL(urban) = 46.3 + 33.9 Log Fc + (44.9 + 6.55 Log Ht) Log D – a(HR) -13.82 Log Ht +Cm

Cm= 0 DB for medium cities and suburban areas

Cm = 3 DB for urban centers

PL(suburban) = PL(urban) – 2[log (Fc/28)]^2 -5.4

PL(rural) = PL(urban) – 4.78[log (Fc)]^2 + 18.33 log Fc – K

Where K is a constant ranging from 35.94 (country side) to 40.94 (desert)

a(HR) =mobile antenna correction factor = (1.1log(Fc) – 0.7)HR –(1.56log (Fc) -0.8)dB

Generating the pathloss for the following specifications

Fc =1800MHz
Hr =1.5m
Ht= 30m
D= 10km

4 RESULTS AND DISCUSSION

Since both the phone booth and the base station antennas have appreciable gain, the range equation will be used

$$\mathrm{Pr} = PtGtGr\left(\frac{\lambda}{4\pi D}\right)^2 \text{ ……….2}$$

The limiting factor for any wireless link is the required signal to noise ratio required by the receiver for useful reception.

SNR = Pr/N…………………………………… 3

SNR = Pr(dBm) – N(dBm)

The power received by the Phone booth becomes

$$\mathrm{Pr} = \left[\frac{PtGtGr}{PL}\right] \text{ ………………………..……. 4}$$

Pr (dBm) = Pt(dBm) + Gt +Gr – PL

Where PL is the path loss over the channel.

Considering only the thermal noise since the are in line of sight

N = K To B F …………………………..…….. 5

N (dBm) = -174 dBm +10 logB + F

Where K = Boltzmann's constant
To = ambient temperature
B = receiver bandwidth
F = Noise figure

From the DCS specifications,
B = 200 KHz
F = 10dB

N(dBm) = -174 + log 200K + 10dB =-110.98dB

PL(d) =PL(Do) + 10γ

$$\mathrm{PL\ (d)} = \left[\frac{4\pi Do}{\lambda}\right] \text{ …………………………..….6}$$

Where Do is given to be 1km for outdoors (1)

γ = pathloss exponent.

Using the formula above to compute the pathloss for an environment with pathloss exponent of 3.3,

γ = pathloss exponent. = 3.3 (Benin city)

λ= c/f

$$PL(Do) = \left[\frac{4\pi 1000\, m}{0.167\, m}\right] = 97.53 \text{ dB}$$

$$PL(d) = 97.53 \text{ dB} + 10(3.3) \text{ Log} \left[\frac{d}{Do}\right] \quad \ldots\ldots\ldots 7$$

Using an 18dB parabolic antenna with the phone booth, and assuming an 18dB antenna at the base station with a +43dBm transmit power

Pr = 43dBm +18dB +18dB – PL(d)

From the pathloss equation (7), at 10km the pathloss will be

$$PL(d) = 97.53 \text{ dB} + 10(3.3) \text{ Log} \left[\frac{10000\, m}{1000\, m}\right]$$

= 130.53 dB

The power received at the phone booth will be

Pr = 43dBm +18dB +18dB – 130.53dB

= -51.53dB

The noise level is calculated to be -110.98dB. From the equation below,

$Pr \geq SNR + N$ …………………8

SNR = 18.8dB (DCS standard)

Pr = 18.8 dB + 110.98 = -92.2dB

The minimum signal level required to ensure reliable communication is calculated to be -92.2 dBm and the actual received power from the base station 10 km away transmitting at +43dBm is -51.53dBm.

3.2 Implementation

The Transceiver of choice used in the design is the Broadcom BCM2133 EDGE/GPRS/GSM single chip base band multimedia processor.

The processor offers a small foot print base band solution for the development of Phones and smart phones. Interface functions and drivers are integrated to enable auxiliary components such as handset, microphones, speakers (up to 400mW into 8 ohms) and 3.0V/1.8V switching SIM to connect directly to the chip.[4]

The SIM sockets, the keypad the display are all linked to the processor using the provided ports. The antenna is linked to the chip via an RF transceiver chip which is a associated subsystem to the chip

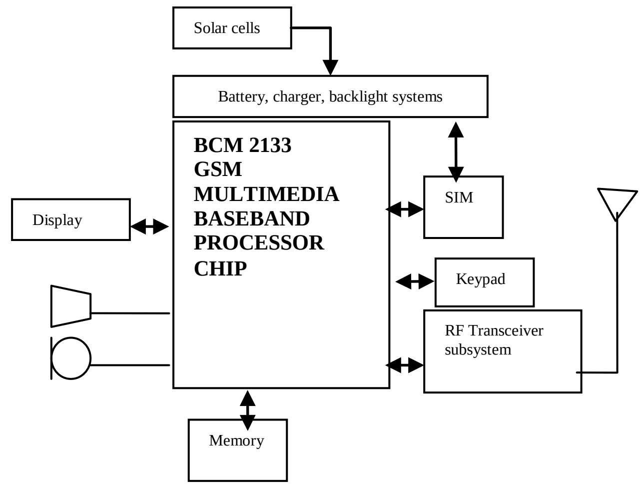

Figure 3 Final block diagram

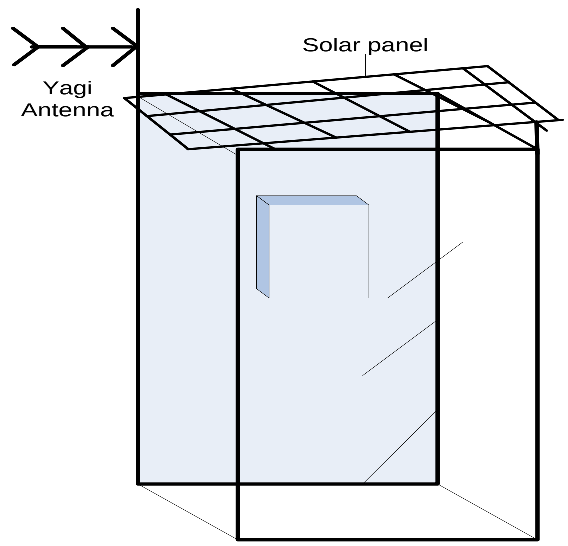

Figure 4. GSM Phone booth

Figure 4 shows the construction diagram of the GSM phone booth. The solar panel is installed on the booth while the phone containing the battery is installed in the booth. The directional antenna implemented with a yagi antenna is installed externally in the direction of the nearest BTS.

5 CONCLUSION

The GSM phone booth provides a cheap and cost effect means of extending mobile communication services to the rural areas with out GSM coverage as the use of high gain directional antenna makes it possible for the phone booth in the rural areas to link up with nearest BTS which is out of the range of the handheld mobile phones. The system also has a high probability of having the communication link established due to the fact that there is no battery life constraint on the phone and the phone booth can transmit at maximum power all the time. Mobile communication service providers deploying this service can configure the SIM cards deployed in those areas in such a manner that the rural dwellers using the phone booth enjoy a lower tariff regime due to their location. The Phone booth due to its simplicity and cost advantage will enhance the provision of mobile communication services to the populace.

REFERENCES

[1]Andrea Goldsmith. *Wireless Communication,* Cambridge University Press (2005).

[2] Jerry D. Gibson (Ed) *The Mobile Communications handbook Second Edition* CRC Press and IEEE press (1999).

[3] Clint Smith and Curt Gervalis. *Wireless Network performance handbook*McGraw hill Network Engineering (2003).

[4] Product brief 2133-pb05-R pdf www.broadcom.com

[5] John Scourias *Overview of the Global System for Mobile Communications* (1997) Jscouria @ www.shoshin.uwaterloo.ca.

[6] Timo Virtanen *Capacity Planning Of GSM Data Service* Department of Computer Science University of Helsinki (1999).

[7] Mathew N.O. Sadiku, *Optical And Wireless Communication Next Generation Networks*. CRC Press ((2002).

[8] White Paper: *Edge Repeaters, Challenges and Benefits.* AVITEC AB (2003).

[9] Aleksey Kurochkin, *Alternative RF Planning Solutions For Coverage Deficiency* Bechtel Telecommunication Technical Journal Vol 1 No 1 (2002) Pages 37-47.

[10]Alexander Neskovic, Natasa Neskovic and George Pannovic *Modern Approaches in modeling of mobile Radio system propagation environment.* IEEE (2000).

[11]Jacques C. Rudell, Jeffery A. Weldon, Jia-Jiunn Ou, LiLin, and Paul Gray. *An integrated GSM/DECT Receiver Design Specifications* UCB Electronics Research Laboratory (April 1998).

[12] John D. Kraus and Ronald J. Marhefka: *Antennas for All Applications Third Edition* McGraw Hill (2002).