SETTING UP A LEARNING PRACTICE BASE TRANSCEIVER STATION (BTS) AT MSU MAIN CAMPUS.

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HTEL 438 DISSERTATION

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ABSTRACT

The evolution of technologies in the cellular wireless communication from first generation (1G) to LTE has taken a giant step that other sectors of the industry, social, academia to name but a few, especially in the developing world are struggling to cope. Some countries in the third world are still using 1G and 2G equipment, three or four steps behind LTE, which is more than a quarter of a century lag. The need for engineering students to have hands-on experience on equipment and machinery used in their different disciplines is a pertinent aspect of any learning process. This called for the need to find relevant practical aid equipment for students to practice on and appreciate their operation in real industrial set-up. Since there was a shortage of practical training aids that speak to the contemporary expectations of the electronics and telecommunications industry at MSU in the Department of Applied Physics and Telecommunications, this project bridged that gap. The fast changing high-tech ICT (Information Communication Technology) industry the world over, against the backdrop of lack of relevant demo equipment at MSU laboratories, there was dire need to have at least some currently used equipment like a 2G BTS and its allied equipment to be installed in the university laboratory to mitigate the challenge. The project will help students to be conversant with cellular wireless communications equipment before they go for their work related learning and work after completion of their studies. With further follow-up collaborations, it is possible the department will get later versions of the technologies trending in industry.

DECLARATION

I Leonard Jukwa (R145432Z) as the sole author of this dissertation entitled "Setting up a learning practice base transceiver station (BTS) at MSU Main Campus", authorize the usage of this documentation at the Midlands State University for academic purposes only.

Supervisor………………………… Date………………………

APPROVAL

This dissertation entitled "Setting up a learning practice base transceiver station (BTS) at MSU Main Campus" submitted by Leonard Jukwa meets the regulations governing the award of the degree of BSc Telecommunications Honours of the Midlands State University and this is approved for its contribution to knowledge and literal presentation purposes,

Supervisor………………………… Date………………………

DEDICATION

This document is dedicated to my father Josphat Jukwa Mashoko who passed away during the course of my studies and his words of wisdom were an inspiration up to this end.

ACKNOWLEDGEMENTS

My sincere gratitude is to the Almighty God for the gift of life, intellect and grace to complete this dissertation. I would also want to acknowledge my supervisors Dr. C. Nyamhere and Mr. Mazunga, and other MSU staff for their invaluable guidance, suggestions and interrogation for the project to come to fruition. Also I would like to express my heartfelt thanks to Econet engineers, Messrs Kunaka, Ncube, Juke, Chipunza, Mhundwa and Raradza for their sterling support in having the project becoming a reality. Last but not least I would like to thank my wife Constance and daughters Clara, Carol, Cecelia and Charity for their prayers and moral support.

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CHAPTER 1: INTRODUCTION

1.0 INTRODUCTION.

This project seeks to augment the thrust of the Department of Applied Physics and Telecommunications goals and objectives by providing a laboratory that will give the learners hands experience and practical understanding of contemporary cellular wireless communication equipment used in the industry. The project endeavours to give the students a chance to appreciate real equipment used in the field of telecommunications engineering. The laboratory will also be used by students when doing their projects that can ride on the equipment, such as RF energy harvesting, cellular systems programming, antenna directivity, RF cell planning and frequency reuse, etc. The project set out to create and promote academic and research collaboration between these two organisations largely for the practical benefit of students. The world over such cooperation have brought about new industrial and technological inventions and innovations that have revolutionised their socio-economic systems and spurred platforms for large scale scientific and engineering research and development. The project will be rolled out through negotiations for donation of equipment by Econet Wireless Zimbabwe to Midlands State University. The student will play a pivotal role throughout the negotiation process and equipment delivery, installation and commissioning.

1.1 Donation contract parties.

Midlands State University (MSU) was established by an Act of Parliament, that is, the State University in the Midlands Act of April 1998. MSU is a government owned university in Zimbabwe. In the Faculty of Science and Technology at Midlands State University, the faculty has several departments namely, Computer Science, Applied Physics, Surveying and Geomatics, Food Science and Nutrition, Information Systems, Applied Biosciences and Biotechnology, Chemical Technology, Applied Statistics and Mathematics. The Department of Applied Physics & Telecommunications prepares students for academic and industrial careers at the forefront of engineering, science and technology. Teaching and research spans from basic physics underlying most engineering developments to cutting edge application fields such as wireless communications, optoelectronics, semiconductor devices, nanotechnologies, energy conversion, and instrumentation [1]. The thrust of the Department is to produce professional scientists, engineers and researchers who understand analysis complex problems and come up with creative and innovative solutions in any technical field. The Department offers two unique degree programs, namely the BSc. (Hons) Applied Physics & Instrumentation (HAPI), and the BSc. (Hons) in Telecommunications (HTEL) [1]. Econet Wireless is a diversified telecommunications group with operations and investments in Africa, Europe, South America and the East Asia Pacific Rim, offering products and services in the core areas of mobile and fixed telephony services, broadband, satellite, optical fibre networks and mobile payment. The group's subsidiaries include Econet Global, Econet Wireless Africa, Econet Wireless Global, Econet Enterprises, Liquid Telecom Group and Econet Media [2].

1.2Background

Since the introduction of the BSc Honours Degree in Telecommunications at Midlands State University it was observed that there are limitations in practical simulator laboratories capable of simulating a real and typical industrial environment. Having realized that Econet Wireless was decommissioning some of its older versions Base Transceiver Station (BTS) equipment (2G and 3G) for later versions (4G and LTE), this was seen as an opportunity to ask for the decommissioned equipment and install it at MSU as learning aids since the same equipment modules still have the underlying principles and aspects of telecommunications engineering and could be used for practical lessons by students in the HAPI, HTEL and HCSC (BSc Honours Computer Science) programs. It is also of note that some of this decommissioned equipment here in Zimbabwe was the same equipment which was being recommissioned in countries like Burkina Faso, Burundi, Djibouti, Somalia and other countries in Africa who are still lagging behind in the use of mobile cellular communication systems. The decommissioning of the equipment from Base Stations (BS), rigging, transfer, reinstallation and recommissioning of the equipment at MSU will provide an opportunity to have an insight into what exactly is involved in setting up mobile cellular equipment and project management issues involved in similar projects.

1.3 Problem Statement

Looking at the need for engineering students to have hands-on experience or at least an appreciation of the equipment and machinery used in their different disciplines, it was observed that MSU was lagging behind in that perspective. The Department of Applied Physics and Telecommunications at MSU has limited if any practical aids for use by students during their time of study at the university. This called for the need to find relevant practical aid equipment for students to practice on and appreciate their operations in the practical domain.

1.4 Aim of the project

Since there was a shortage of practical training aids that speak to the contemporary expectations of the electronics and telecommunications industry at MSU in the Department of Applied Physics and Telecommunications, this project sought to bridge that gap. Considering that the high-tech ICT (Information Communication Technology) industry the world over is fast changing and with lack of relevant demo equipment at MSU laboratories, there was dire need to have at least some currently used equipment like a 2G BTS and its allied equipment to be installed in the university laboratory to mitigate the challenge at hand. The project will help students to be conversant with cellular wireless communications equipment before they go for their attachment and ultimately work after completion of their studies.

1.5 Objectives

1. To setup a telecommunications BTS laboratory with suitable equipment covering over 75% of contemporary technologies in the wireless and cellular network systems.

2. To explore ways in which companies and learning institutions can collaborate in enhancing better practically oriented learning environment relevant to industry and produce about 50% practical scope for students' field study before going for attachment.

3. To undertake a 100% in-depth analysis of project management in mobile network service industry in Zimbabwe.

4. To produce a 100% comprehensive work related learning material for students covering detailed feasibility study, technical information, policy issues and regulations governing the installation and use of cellular equipment in Zimbabwe

1.6Scope

The research will establish a BTS training laboratory on campus together with reference literature to use during practical lessons and further research work.

1.7 Timeframe

	Description of Work	Start and End Dates
Phase One	Negotiations for equipment donation and preparation of workshop/laboratory/BTS.	01/08/2016-30/12/2016
Phase Two	Decommissioning, transportation and delivery of equipment.	01/01/2017-31/03/2017
Phase Three	Installation and recommissioning of BTS equipment at the MSU Gweru campus.	01/04/2017-31/05/2017

1.8 Project Budget

	Description of Work	Anticipated Costs
Phase One	Negotiations for equipment donation and preparation of workshop/laboratory/BTS.	$2000.00
Phase Two	Decommissioning, transportation and delivery of equipment.	$1500.00
Phase Three	Installation and recommissioning of BTS equipment at the MSU Gweru campus.	$2500.00
	Total	**$6000.00**

Estimated total cost of negotiated equipment to be donated and deployed is about $250 000.00 (Two hundred and fifty thousand dollars).

1.9 Key Stakeholders

Client	Midlands State University
Sponsor	Econet Wireless Zimbabwe
Project Manager	Leonard Jukwa-Telecommunications Engineering Student
Project Engineers	Econet Technical Team
Supervisors	Dr. A. Nechibvute, Dr. C. Nyamhere, Mr. F. Mazunga-MSU Telecoms Dept.

1.10 Methods Employed (Monitoring and Evaluation)

Project management principles are going to be employed in undertaking this project. The project has three phases: the design phase, the construction phase, and installation and commissioning phase.

1.11 Brief Literature Review

The Base Transceiver Station (BTS)

Base stations, which are also called base transceiver stations (BTSs), are the most visible network elements of a Global System for Mobile Communication (GSM) system. Compared to fixed-line networks, the base stations replace the wired connection to the subscriber with a wireless connection, also referred to as the air interface [3]. The base stations are also the most numerous components of a mobile network. In theory, a base station can cover an area called a cell with a radius of up to 35km. Practically a base station can simultaneously serve a limited number of users, thus cells are much smaller in practice, especially in densely populated environments like urban areas. In residential and business areas, cells cover areas within a radius of between 3km and 4 km and down to only several 100meters with minimal transmission power in heavily frequented areas like shopping centres and downtown streets.

Neighbouring cells have to transmit on different frequencies, as transmissions of different base stations of the network must not interfere with each other, thus, only a limited number of different frequencies can be used per base station to increase capacity. To increase the capacity of a base station, the coverage area is usually split into two or three sectors, which are then covered on different frequencies by a dedicated transmitter. This allows a better reuse of frequencies in two-dimensional space than in the case where only a single frequency is used for the whole base station [4]. Each sector of the base station, therefore, forms its own independent cell. This project has not been done before at MSU and is the first of its kind and in particular to the Applied Physics and Telecommunications department. It is hoped to open up new avenues for further researches when the equipment is finally deployed on campus. The project seeks to challenge the culture of usual small prototype kind of project portfolios that puts certain theoretical concepts into practice at a micro scale. It endeavours open up to the concept of joint research of real big projects in collaboration with industry and probably that can involve a whole class to accomplish it. The proposed laboratory can be further augmented with more equipment and accessories that can be donated or purchased, for the university to fully benefit from it. The department can have students making accessory equipment like signal finders, frequency synthesisers, signal trackers, RF controlled modules, power rectifiers and experiment with it riding on the installed BTS.

Fig 1.0 A typical antenna of a GSM base station. The optional microwave directional antenna (round antenna at the bottom of the mast) connects the base station with the GSM network [4].

1.12 Materials to be used

1. BTS and auxiliary equipment-complete set from service provider (Econet).

2. Installation site (MSU Main Campus)

3. Installation tools (MSU and Student)

1.13 Approval Signatures

[Name], Project Client	[Name], Project Sponsor	[Name],Project Manager

1.14 Conclusion

The successful feasibility study, analysis of the regulatory framework and implementation of this project at MSU will go a long way in providing relevant and contemporary study materials in the Faculty Science and Technology and in particular the Department of Applied Physics and Telecommunications. This laboratory can also be used for demonstrations during career guidance and open days when school children come to the institution enhancing the STEM agenda.

1.15 References

[1] http://www.msu.ac.zw

[2] http://www.econet.co.zw

[3] Andreas F. Molisch, Wireless Communications, Second Edition John Wiley & Sons Ltd, 2011.

[4] Martin Sauter, From GSM to LTE: An Introduction to Mobile Networks and Mobile Broadband, John Wiley & Sons, Ltd. 2011.

CHAPTER 2: THEORETICAL ASPECTS

2.0 INTRODUCTION

Global **S**ystem for **M**obile Communication (GSM) is a digital cellular technology that is used for transmitting mobile data and voice services. The concept of GSM started in the early 1970s at Bell Laboratories, from a cell-based mobile radio communication system [1]. It is a common European mobile telephone standard established in 1982 and is the most widely accepted standard implemented globally in telecommunications engineering.

2.1 GSM - Overview

GSM is a circuit-switched system that divides each 200 kHz channel into eight 25 kHz time-slots. It operates on the mobile communication bands 900 MHz and 1800 MHz in most parts of the world. In the US, GSM operates in the bands 850 MHz and 1900 MHz. GSM makes use of narrowband Time Division Multiple Access (TDMA) technique for transmitting signals, was developed using digital technology and has an ability to carry 64 Kbps to 120 Mbps of data rates [2]. It digitizes and compresses data, then sends it down through a channel with two other streams of user data, each in its own timeslot. According to the International Telecommunication Union, presently GSM supports more than one billion mobile subscribers in more than 210 countries throughout the world. GSM provides basic to advanced voice and data services including roaming service. GSM owns a market share of more than 70 percent of the world's digital cellular subscribers [3].

2.1.1 Why GSM?

Listed below are the features of GSM that account for its popularity and wide acceptance.

- It has improved spectrum efficiency
- Has international roaming capabilities
- Makes use of low-cost mobile sets and base stations (BSs)
- The signal has high-quality speech or fidelity
- It has forward and backward compatibility with Integrated Services Digital Network (ISDN) and other telephone company services
- It can easily integrated to support new services

2.1.2 GSM - Architecture

A GSM network is comprised of four main functional units:

- The Mobile Station (MS)
- The Base Station Subsystem (BSS)
- The Network Switching Subsystem (NSS)
- The Operation Support Subsystem (OSS)

A simple GSM architecture.

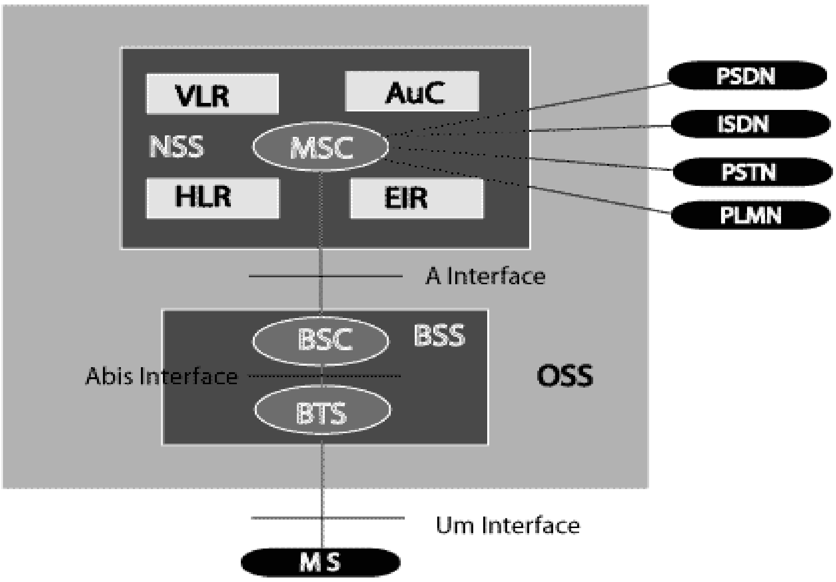


Fig. 2.0 GSM architecture

The additional components of the GSM architecture comprise of databases and messaging systems functions:

- Home Location Register (HLR)
- Visitor Location Register (VLR)
- Equipment Identity Register (EIR)
- Authentication Center (AuC)
- SMS Serving Center (SMS SC)
- Gateway MSC (GMSC)
- Chargeback Center (CBC)
- Transcoder and Adaptation Unit (TRAU)

The GSM network and the additional elements:

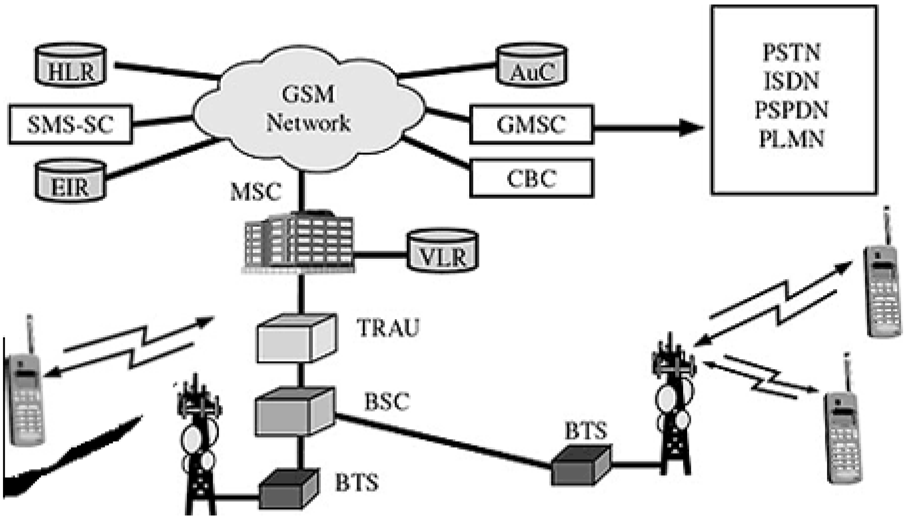


Fig 2.1 GSM Network

The MS and the BSS communicate across the Um interface, also known as the *air interface* or the *radio link*. The BSS communicates with the Network Service Switching (NSS) centre across the *A* interface [1].

2.1.3 GSM network areas

In a GSM network has the following defined areas:

- **Cell**: The basic service area; one BTS covers one cell. Each cell is given a Cell Global Identity (CGI), a number that uniquely identifies the cell.
- **Location Area**: A group of cells form a Location Area (LA). This is the area that is paged when a subscriber gets an incoming call. Each LA is assigned a Location Area Identity (LAI). Each LA is served by one or more BSCs.
- **MSC/VLR Service Area**: The area covered by one MSC.
- **PLMN**: The area covered by one network operator is called the Public Land Mobile Network (PLMN) and can contain one or more MSCs [1].

2.1.4 GSM - The Base Station Subsystem (BSS)

The BSS is composed of two parts:

- The Base Transceiver Station (BTS)
- The Base Station Controller (BSC)

The BTS and the BSC communicate across the specified Abis interface. This enables operations between components that are made by different suppliers. The radio components of a BSS may consist of four to seven or nine cells. A BSS may have one or more base stations. The BSS uses the Abis interface between the BTS and the BSC and a separate high-speed line (T1 or E1) is then connected from the BSS to the Mobile Switching Centre (MSC) that connects the system to the rest of the public network [4].

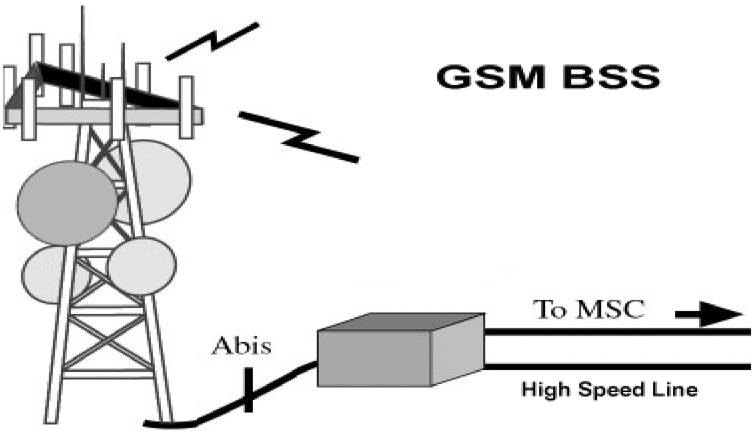


Fig 2.2 GSM Base station subsystem

2.1.5 GSM - Operation Band

SYSTEM	P-GSM 900	E-GSM 900	GSM 1800	GSM 1900
Frequencies - Uplink - Downlink	 890 - 915 MHz 935 - 960 MHz	 880 - 915 MHz 925 - 960 MHz	 1710 - 1785 MHz 1805 - 1880 MHz	 1850 - 1910 MHz 1930 - 1990 MHz
Wavelength	~33 cm	~33 cm	~17 cm	~16 cm
Bandwidth	25 MHz	35 MHz	75 MHz	60 MHz
Duplex Distance	45 MHz	45 MHz	95 MHz	80 MHz
Carrier Separation	200 kHz	200 kHz	200 kHz	200 kHz
Radio Channels	125	175	375	300

Table 2.1 GSM bands

Absolute Radio Frequency Channel Number ARFCN

- GSM900 :
    - Fu (n) = 890 + 0.2×n MHz
    - Fd (n) = Fu(n) + 45 MHz, 01≤ n ≤ 124
- GSM1800 :
    - Fu (n) = 1710.2 + 0.2×(n-512) MHz
    - Fd (n) = Fu(n) + 95 MHz, 512 ≤ n ≤ 885

2.2 Base Transceiver Station (BTS) System.

The BTS houses the radio transceivers that define a cell and handles the radio link protocols with the MS [2].

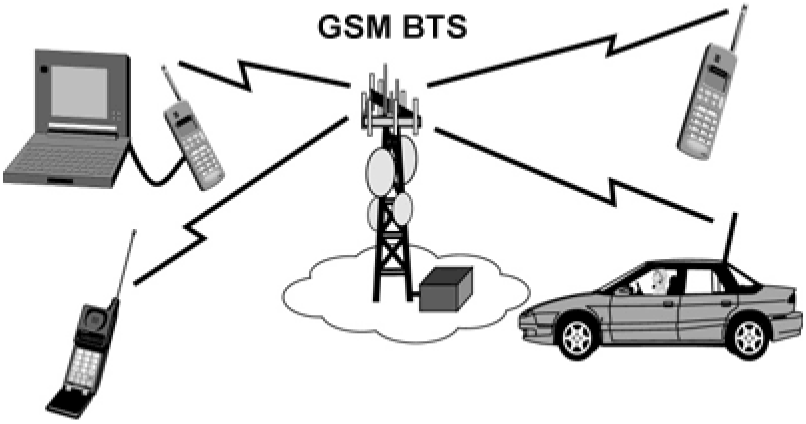


Fig. 2.3 GSM BTS system

The BTS corresponds to the transceivers and antennas used in each cell of the network. A BTS is usually placed in the centre of a cell. The size of a cell is defined by its transmitting power. Each

BTS has between 1 and 16 transceivers, depending on the density of users in the cell and serves as a single cell. It also includes the following functions:

- Encoding, encrypting, multiplexing, modulating, and feeding the RF signals to the antenna
- Transcoding and rate adaptation
- Time and frequency synchronizing
- Voice through full- or half-rate services
- Decoding, decrypting, and equalizing received signals
- Random access detection
- Timing advances
- Uplink channel measurements

The Base Transceiver Station (BTS) consists of a single rack or cabinet that houses the necessary, elements for a point to multi-point RF communication network. A single BTS may contain 1 or 2 Radio Base Units (RBUs). Each RBU contains all necessary Transmit/Receive equipment required for the operation of a single sector or cell [2]. The architecture of the system is flexible, and can accommodate small or large numbers of subscribers. It can also be adapted for use in rural, suburban, and urban environments. Specifically, it employs direct sequence, spread spectrum based, Synchronous CDMA (SCDMA) techniques over the air link to provide local access to subscribers. It offers very high quality, highly reliable service at costs that are very competitive with the wireline solutions. The system has very high spectral efficiency and thus can provide wireline quality service with limited available bandwidth. Its large dynamic range allows it to be deployable in virtually all environments, meeting specific needs of dense urban, suburban, and rural communities in an economical way.

Key attributes of the system are:

- Wireline voice quality delivered at 32 or 64 kbps.

- High throughput for data and fax applications with 32 or 64 kbps throughput.

- High service reliability with good tolerance for noise and ingress.

- Secure air link that is virtually impossible to break into or eavesdrop.

- CLASS services are supported.

- Enhanced services like priority/emergency calling - both inbound and outbound.

- Full switching services available.

System benefits to the network operator:

- Advanced graphical operator interface.

- Equipment cost per access line is low and very competitive with average wireline costs.

- In typical deployments, over 70% of the per line equipment cost is on the subscriber end.

- Quick and easy installation and provisioning process.

- Low maintenance costs reduce the life cycle costs and total cost of ownership.

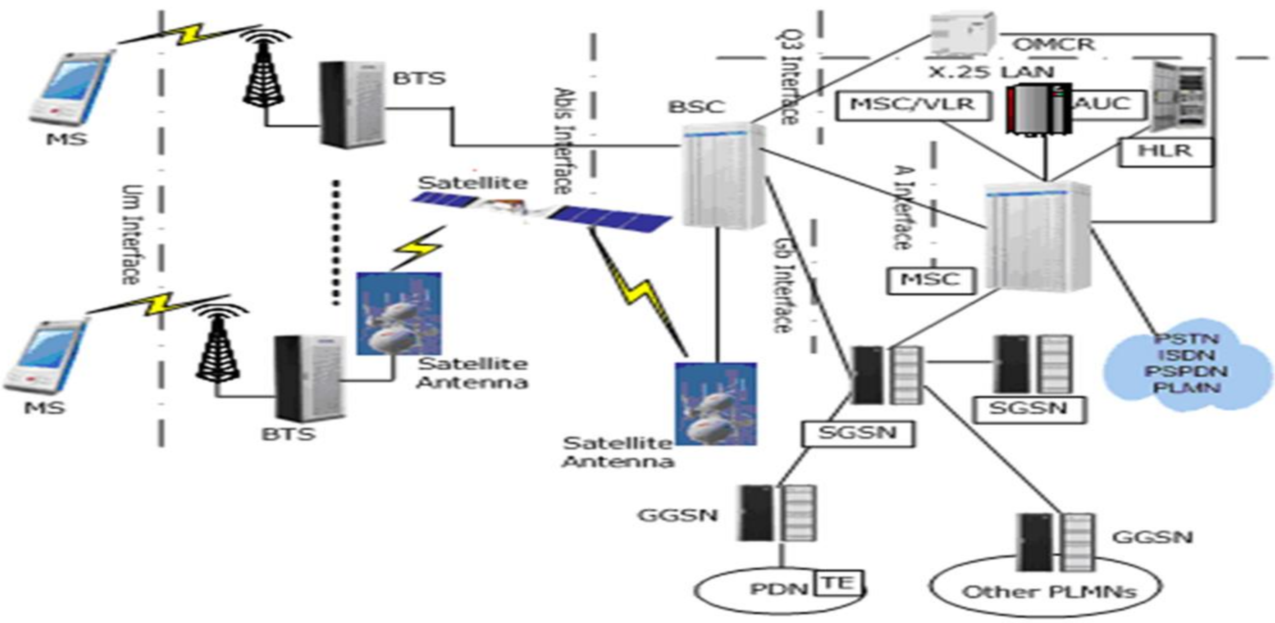
- Theft deterrent system (stolen or misused equipment will not operate). With properly implemented procedures, even installation/maintenance staff cannot beat the system.

- Provides high quality digital data services at 64 to 256 kbps and beyond.

- Economically viable over a wide range of subscriber densities and hence can be used for stand-alone as well as overlay networks.

- The system can easily grow with the subscriber population, will also grow with customer needs and be able to provide higher bandwidth data/video services.

2.2.1 General Elements Position in Mobile Network



BTS System Elements [2]

Fig. 2.4 BTS system elements

General Description

The design philosophy has been to use advanced technology in order to create a point to multi-point system with high bandwidth efficiency, and comparatively large range. Attention has been paid to expandability of future services and requirements, high reliability, service security, fraud prevention, emergency services, and many other features [4].

Logical structure

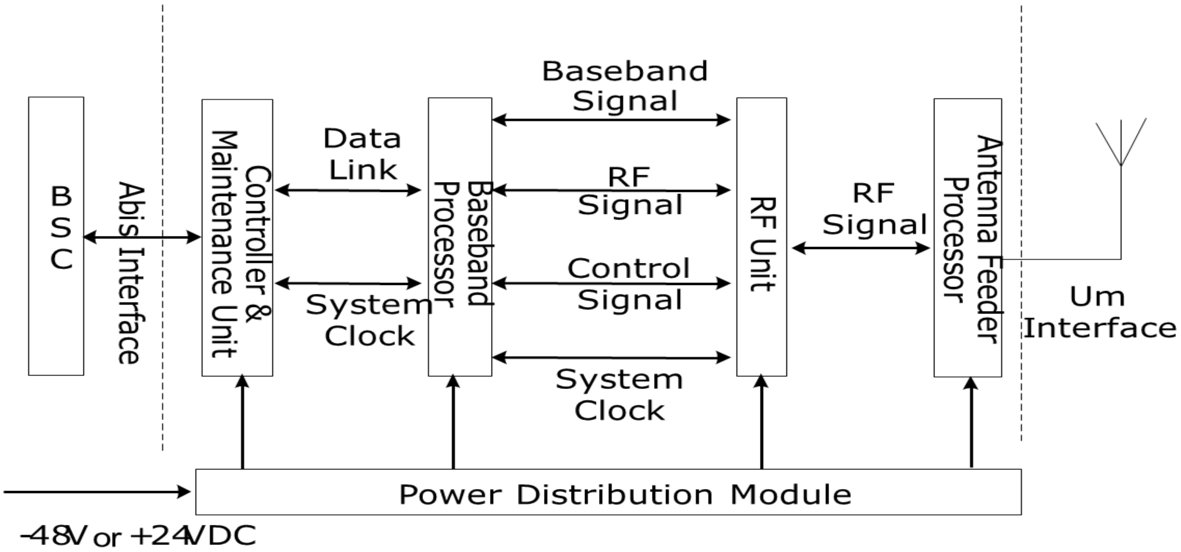


Fig. 2.5 BTS logical structure

2.2.2 BTS Block diagram

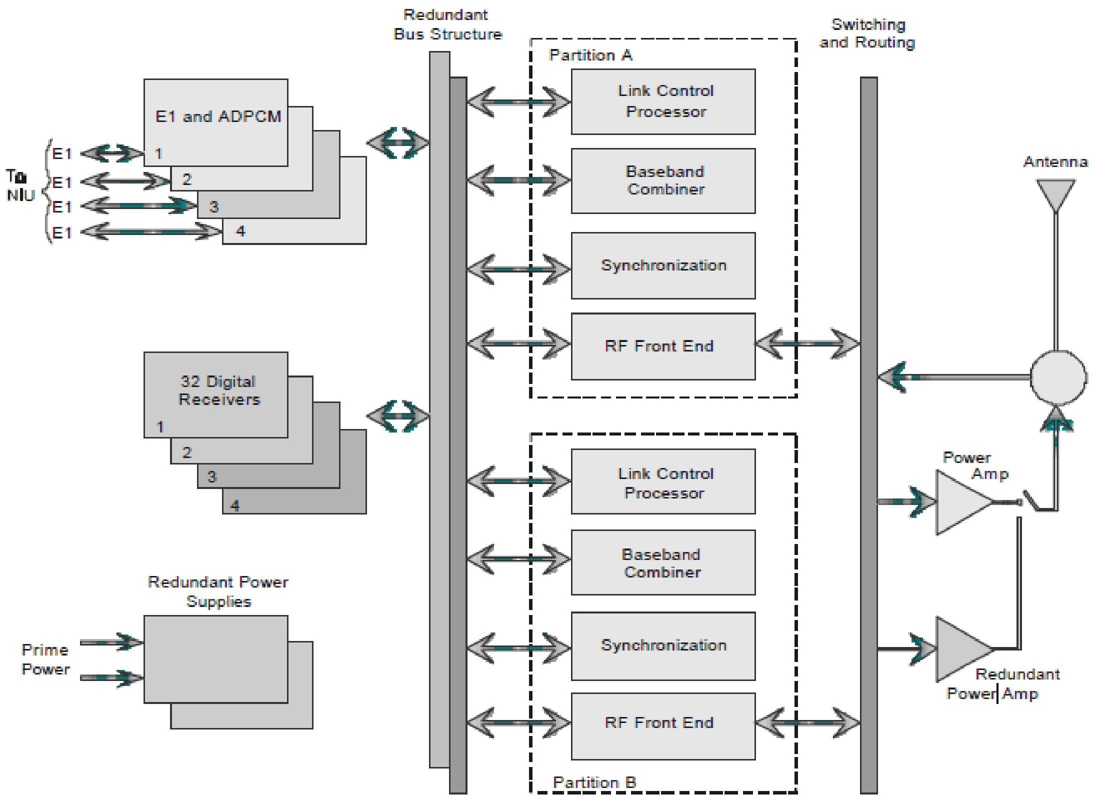


Fig. 2.6 BTS block diagram

Multiple RBUs may be co-located to configure local cells or scattered to form multiple cells. Two RBUs can be located in each Base Transceiver Station Cabinet. Each RBU uses a separate RF transmitter and receiver front end but may share a single Omni antenna with other RBUs or use a dedicated antenna [3].

An RBU is configurable such that it is capable of operation in a contiguous cell deployment wherein the operation of any one cell does not prohibit the operation of any adjacent cells.

The modular nature of the RBU accommodates a combination of redundant and high reliability hardware to provide the necessary resiliency to provide a high MTBF. The RBU interfaces with the Network Interface Unit (DSCO) via one to four E1 connections. This E1 connection may be implemented via various interface links such as wire, optical fibre, or microwave radio. An Operation, Administration, Maintenance, and Provisioning (OAM&P) interface is provided for each RBU, but the standard OAM&P interface is to the DSCO. All external signal cables and field replaceable modules are accessible from the front of the Base Transceiver Station, with the exception of the antenna cables, which are accessible from the top of the Base Transceiver Station [5].

2.2.3 BTS – Hardware structure

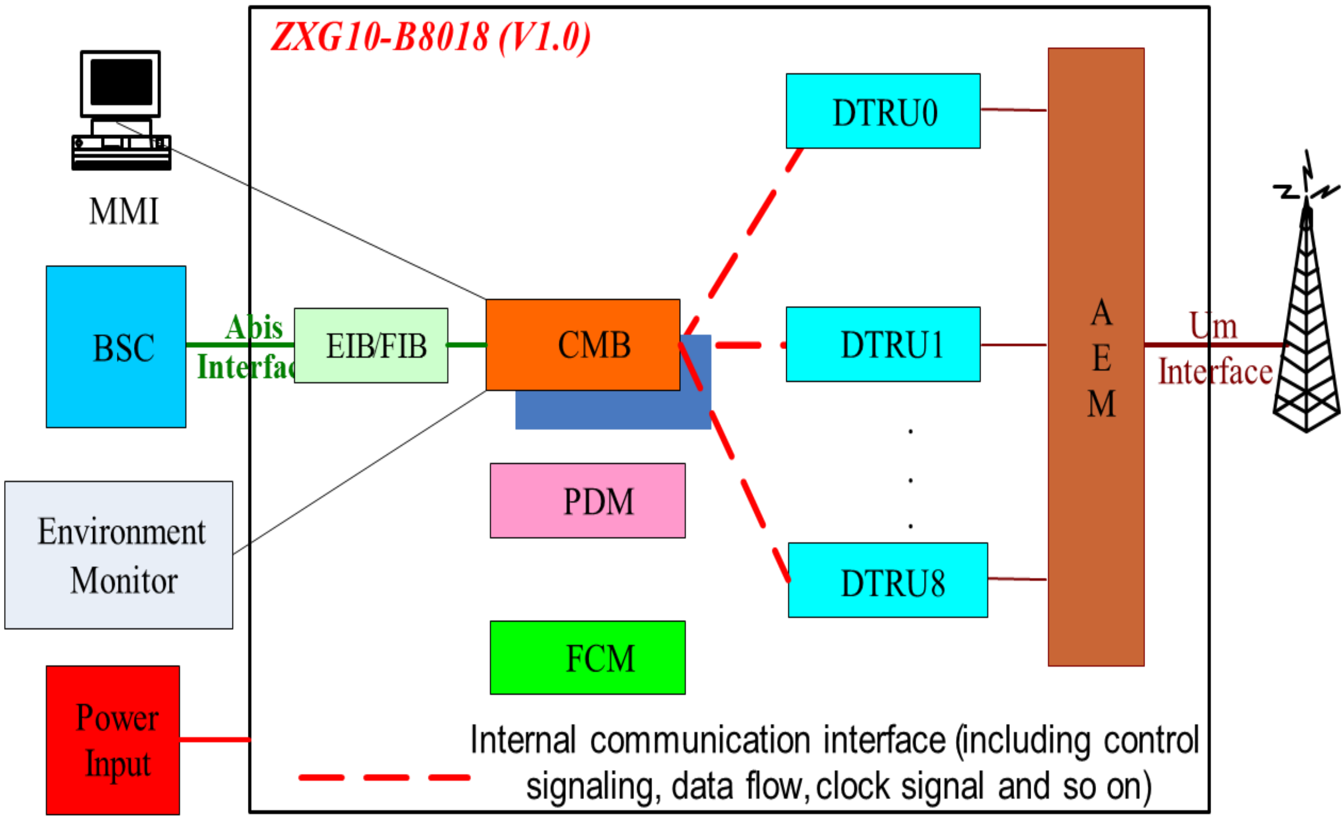


Fig. 2.7 BTS hardware structure

The antennas can be located up to 100 meters from the BTS using a 50 W coaxial cable. The antenna location is chosen to optimize transmission characteristics to the served SUs (principally line of sight).

The RBU is fully redundant and all field replaceable units are hot-swappable. RBU accepts -48V DC power with 15% tolerance [6].

2.2.4 Rack Structure ZXG10-B8018(V1.0) BTS.

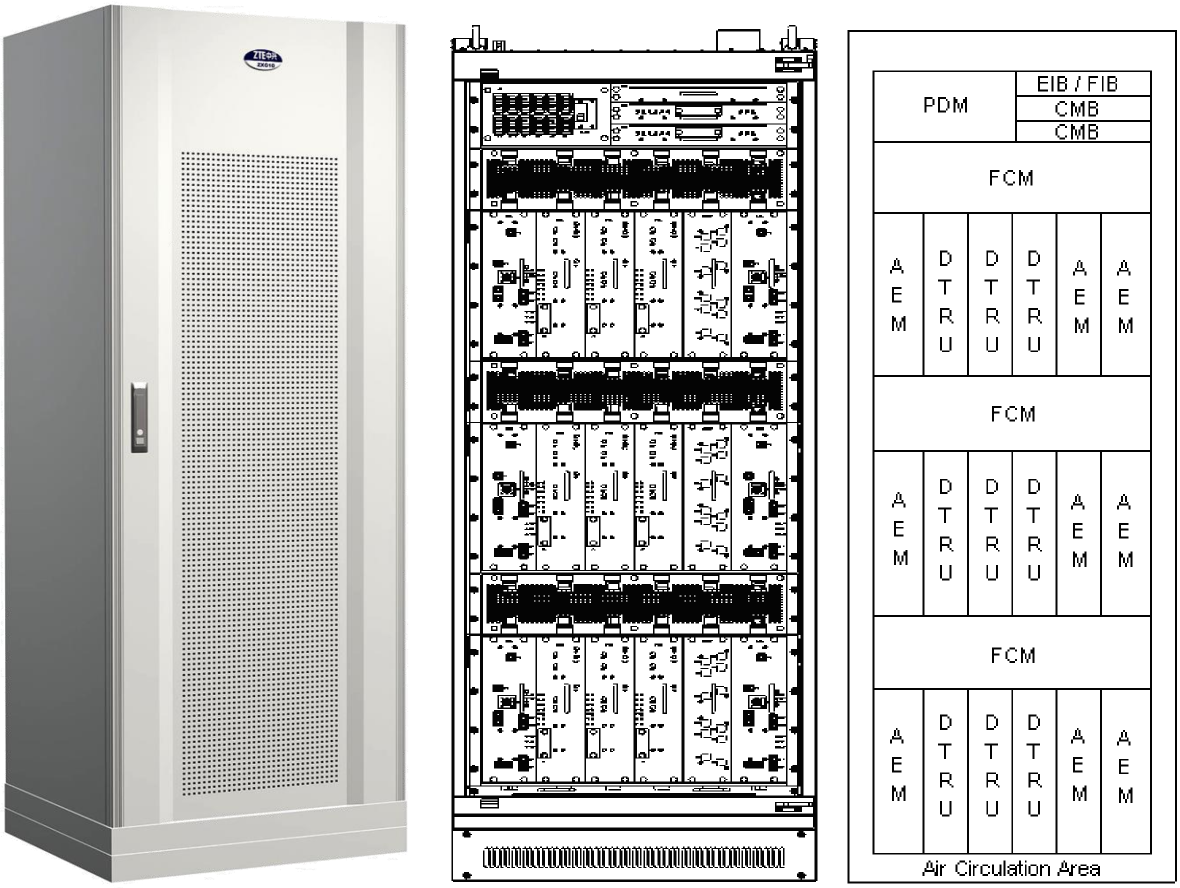


Fig. 2.8 2G BTS rack structure

Technical Features

Large system capacity and high performance.

Capacity: 18 TRX/rack.

Largest site type: O54 or S18/18/18.

Support 6 cells.

Ability of cascades: Support 4-level cascaded networking.

Support 8 E1/T1 interface.

Supports functions and channel encoding modes of GPRS CS1 - CS4 and EGPRS MCS1 - MCS9.

Supports the following circuit-type voice services: Full-rate voice service, Enhanced full-rate voice service, half rate voice service and AMR voice service.

Supports the following circuit-type data service: 9.6 kbps full-rate data service, 4.8 kbps full-rate data service and 2.4 kbps full-rate data service.

Compatible with the following standards: GSM Phase I, GSM Phase II and GSM Phase II +

Supports modules of different frequency bands in one cabinet.

Supports GMSK and 8PSK modulation.

Supports automatic bridge circuit protection.

Employ Dual Transceiver Unit (DTRU) technology.

Support combined cabinet capacity expansion with ZXG10-BTS (V2)

Support 4-way diversity reception.

Support Tandem Free Operation (TFO) version 5.

Provides common BCCH support, that is, same cell supports carrier frequency of two frequency bands sharing one BCCH.

Abis interface supports following networking modes: Star, Chain, Tree and Ring.

Um interface supports A51/A52 encryption algorithm

Support Dual Power Combining Transmission (DPCT)

Support Delay Diversity Transmission (DDT)

Advanced IP based Abis Interface.

Safe and agile power management subsystem [7].

2.2.5InternalConnections

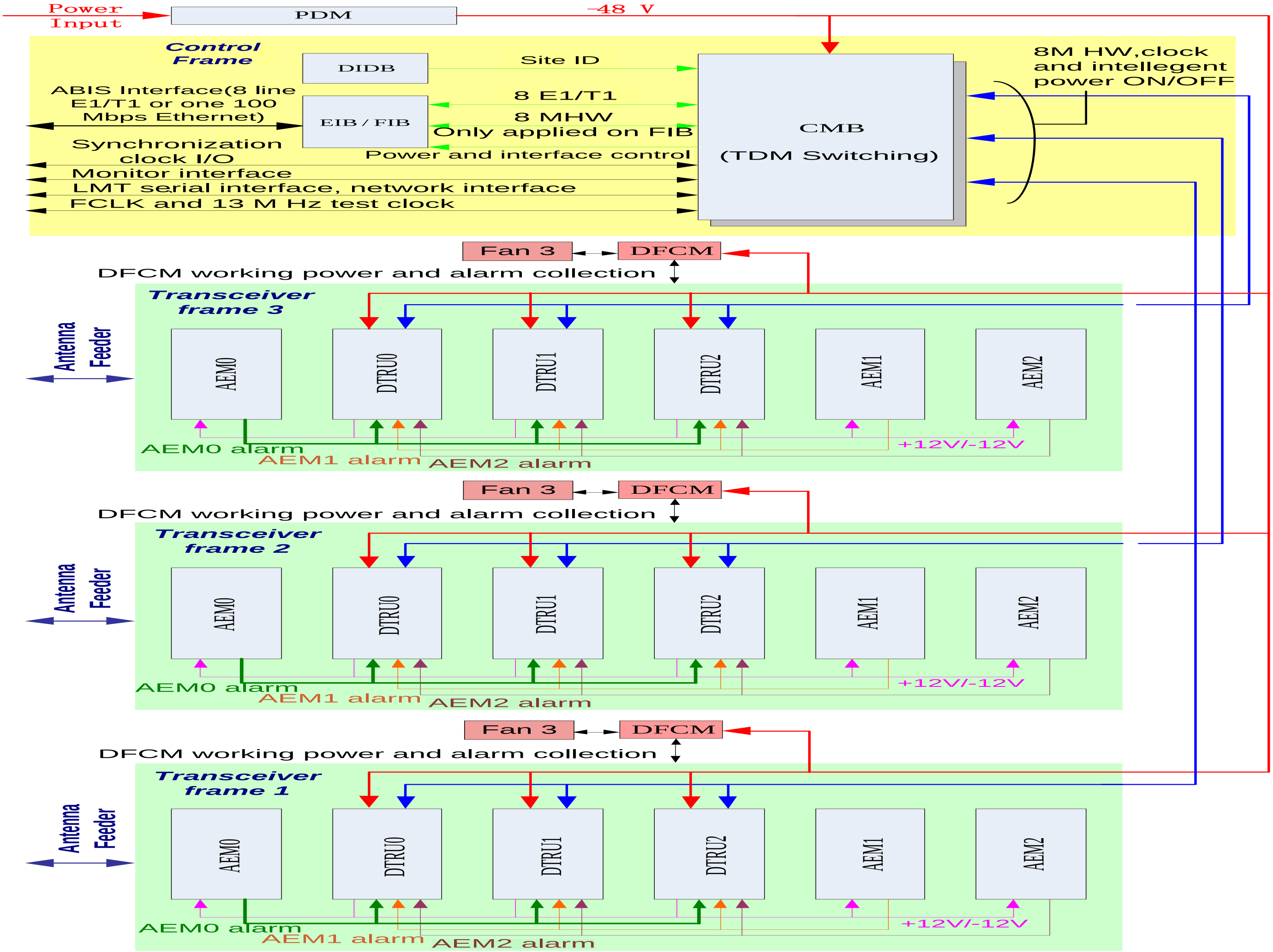


Fig. 2.9 BTS internal connections

Function of CMB

- Provides eight E1/T1 interfaces.
- Implements switching of thirty-two 2 M HW time slots with 2 bit switching array.
- Provides transparent passage for external environment alarm.
- Provides all kinds of clock needed in BTS; including clock signal of 13 MHz, 2.048 MHz, 60ms, 8K_8MW, 8 MHz, 16 MHz and so on.
- Detects, controls, and maintains the whole BTS system, support near-end and far-end management interface.
- Monitoring and control of each board running status
- Board provides active/standby switching [7]

Functional structure of CMB

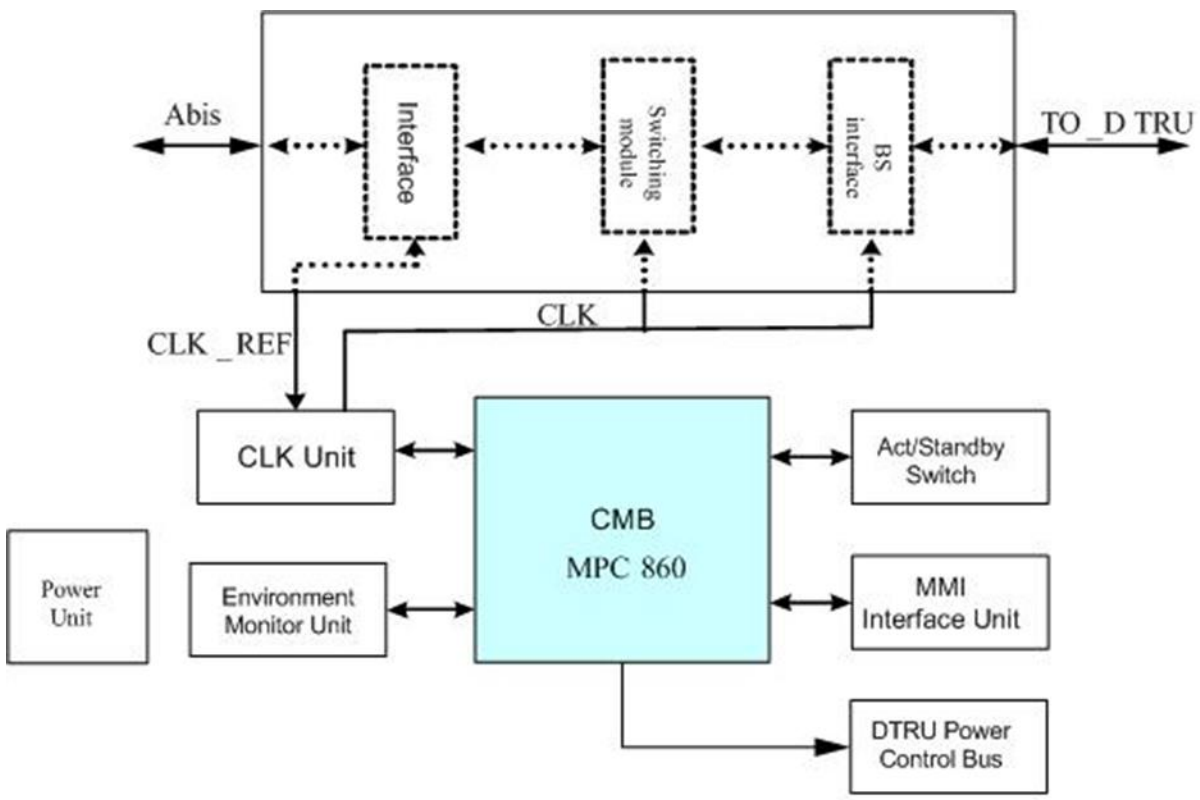
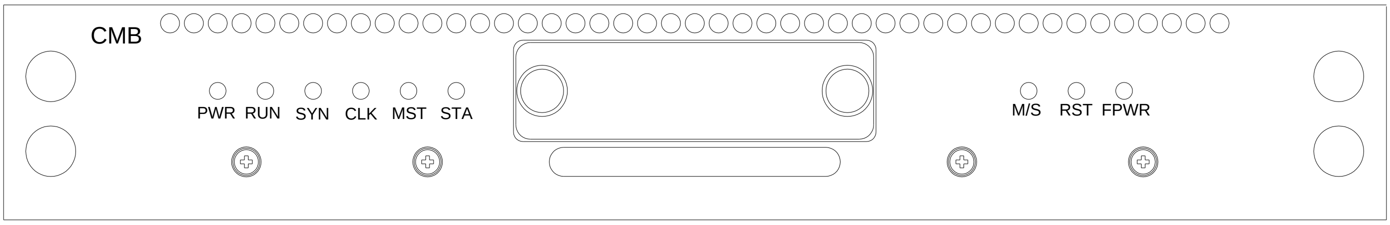


Fig. 2.10 CMB functional structure

Panel and indicator of CMB

LED	Color	Name	Meaning	Working Mode
1	Green/Red	PWR	Power LED	■ Green ON: Normal ■ Red ON: Alarm ■ OFF: Power off or other reasons
2	Green	RUN	Running LED	■ Green flashing at 4 Hz: Boot is running ■ Green flash at 1 Hz: Application is running ■ Others: System is abnormal
3	Green/Red	SYN	Clock synchronization mode LED	■ Green ON: Synchronization clock of the Abis interface network ■ Green flashing at 1 Hz: Synchronization clock of the SDH network ■ Red flashing at 1 Hz: E1 frame out-of-sync alarm ■ Red ON: E1 line is broken or not connected ■ OFF: Free running
4	Green/Red	CLK	Clock LED	■ Green ON: Network synchronization is locked ■ Green flashing at 1 Hz: Locking the phase ■ Red ON: Clock fault
5	Green	MST	Active/Standby LED	■ Green ON: Active state ■ Green OFF: Standby state
6	Green/Red	STA	Status LED	■ OFF: Running normally ■ Green flashing at 1 Hz: System initialization (Low). ■ Green flashing at 4 Hz: software loading ■ Red flashing at 1 Hz: LAPD link

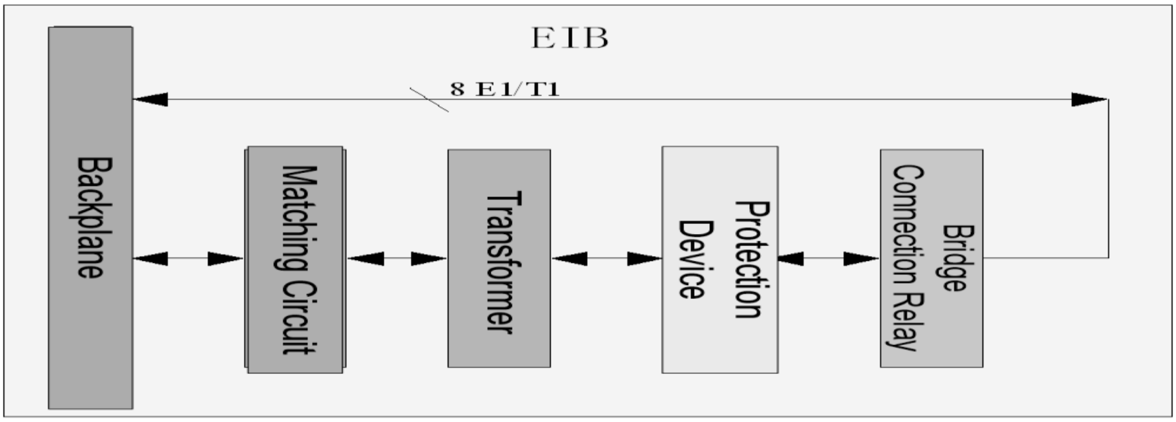
					disconnection (High). ■ Red flashing at 4 Hz: HDLC link disconnection (Low). ■ Red ON: Other alarms (such as temperature, clock and frame number alarms)

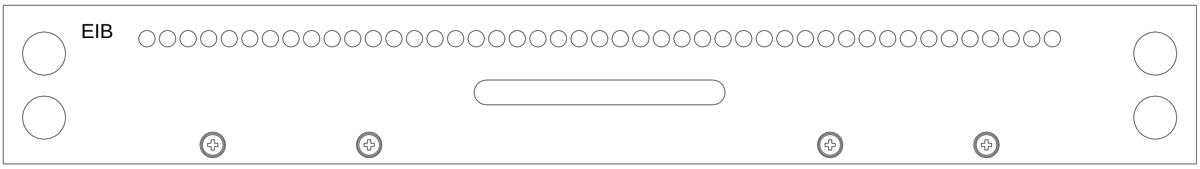


Function of EIB

- Provide line impedance matching of 8 E1/T1
- Signal isolation at IC side and line side
- Line protection at E1/T1 line interface
- Bypass function of E1/T1 line.
- Provides type information of interface board to CMU

Structure and panel of EIB

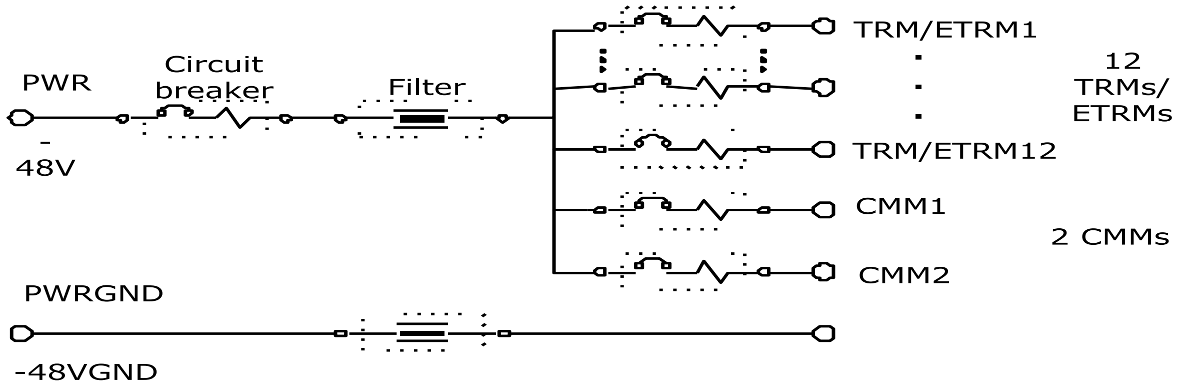




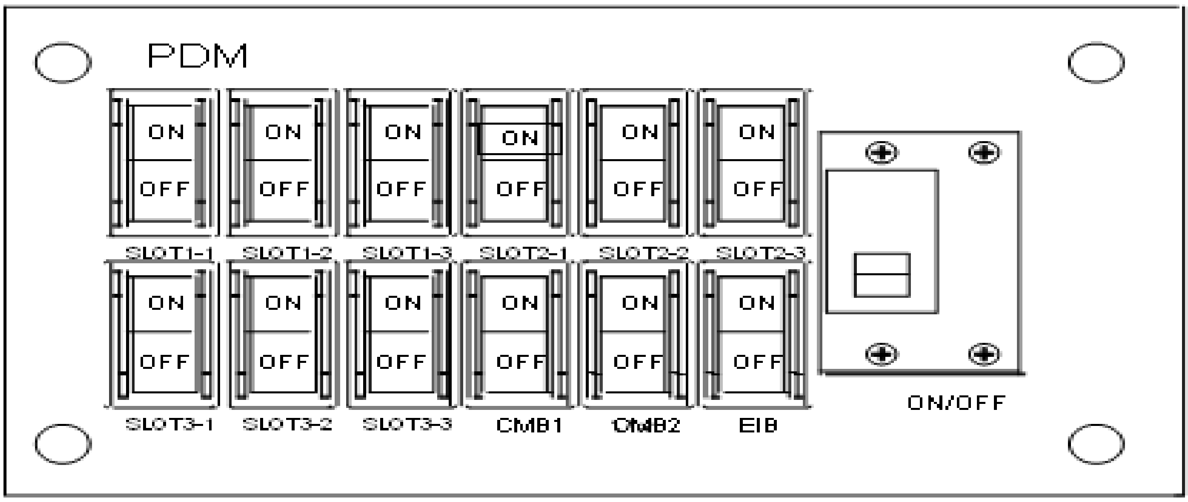
Function of PDM

- PDM distributes the -48 V power to CMBs, DTRUs and FCMs, and provides overload protection via circuit breakers. In addition to a circuit breaker for each module, a main switch circuit breaker is placed at the -48 V input end on the top of the BTS cabinet.

Functional structure of PDM



Panel of PDM



Function of DTRU

- Processes 2 carriers at maximum in downlink:
  - Complete rate adaptation
  - Channel coding and interleaving
  - Encryption
  - Generating TDMA burst pulse
  - Complement GMSK/8PSK modulation
  - Digital up-conversion of the two carriers
- Processes 2 carriers at maximum in uplink:
  - Implement uplink digital down conversion
  - Diversity combining of receiver
  - Digital demodulation (GMSK and 8PSK demodulation, equalization)
  - Decrypting
  - De-interleaving

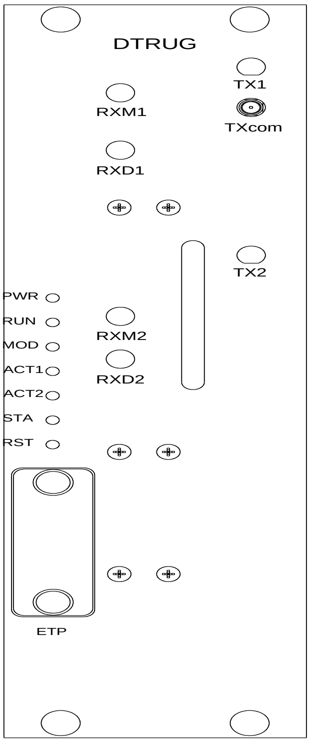
➢ Rate adaptation

- Implement processing of uplink and downlink RF signal.
- Receive switching signal of CMB to complete power ON/OFF of module.
- Support online update and load of software version, support version update of programmable device.
- Detect working state of module, collect alarm signal in real time and report it to CMB.
- Support RF frequency hopping, DPCT, downlink transmission diversity, and four diversities reception

DTRU panel and indicators

Identifier	Meaning
RXM1	Receiver 1
RXD1	Receiver 1 (for diversity)
RXM2	Receiver 2
RXD2	Receiver 2 (for diversity)
TX1	Transmitter 1
TX2	Transmitter 2
TXcom	Transmitter Combiner
ETP	Extend Test Port

Identifier	Full Name	Meaning
PWR	Power	Power LED
RUN	Run	Running LED
MOD	Model	BCCH mode LED
ACT1	Active	Channel activation LED1
ACT2	Active	Channel activation LED2
STA	State	Status LED
RST	Reset	Reset button

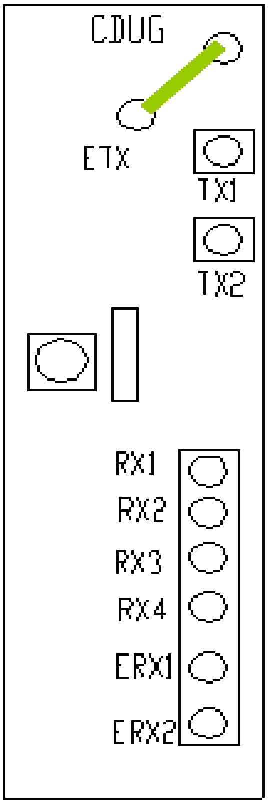


Function of AEM

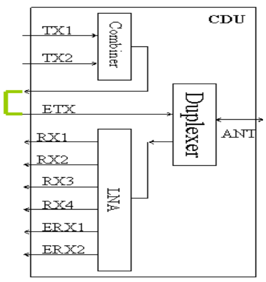
- Combines the transmit signals of multiple carriers.
- Provides bidirectional signal channels from the BTS to the antenna for the transmitting band and from the antenna to the BTS for the receiving band.
- Gives an alarm when the VSWR of the antenna port deteriorates.
- Suppresses the interference out of the working band and spurious emission.
- Flexibly configures carriers.
- Implements diversity receiving.

Panel and indicators of CDU

LED Position	Color	Name	Meaning	Working Mode
1	Green	FPO	Forward power output LED	ON: Normal OFF: Abnormal
2	Red	SWR1	VSWR level-1 alarm LED	ON: There is an alarm OFF: There is no alarm
3	Red	SWR2	VSWR level-2 alarm LED	ON: There is an alarm OFF: There is no alarm
4	Green	PWR	LNA power supply LED	ON: Normal OFF: Abnormal
5	Red	LNA	LNA alarm LED	ON: There is an alarm OFF: There is no alarm



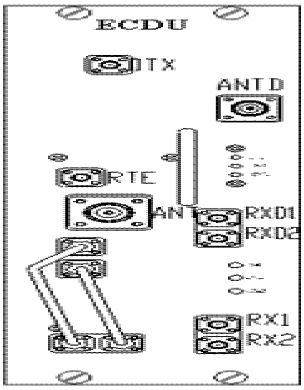
Functional structure of CDU



Identifier	Full Name	Meaning
ETX	Extended TX	Extended TX port
RTE	Radio Test Equipment	Radio test port
TX1	Transmitter 1	Combiner input 1 (PA output signal)
TX2	Transmitter 2	Combiner input 2 (PA output signal)
RX1	Receiver 1	Low noise amplifier output port 1
RX2	Receiver 2	Low noise amplifier output port 2
RX3	Receiver 3	Low noise amplifier output port 3
RX4	Receiver 4	Low noise amplifier output port 4
ERX1	Extend Receiver 1	Low noise amplifier extended output port 1

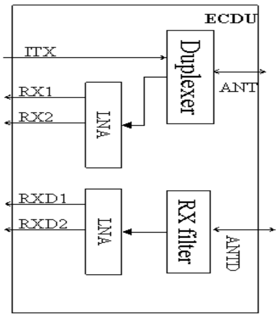
ERX2	Extend Receiver 2	Low noise amplifier extended output port 2
ANT	Antenna	Antenna feeder port

Panel and indicators of ECDU



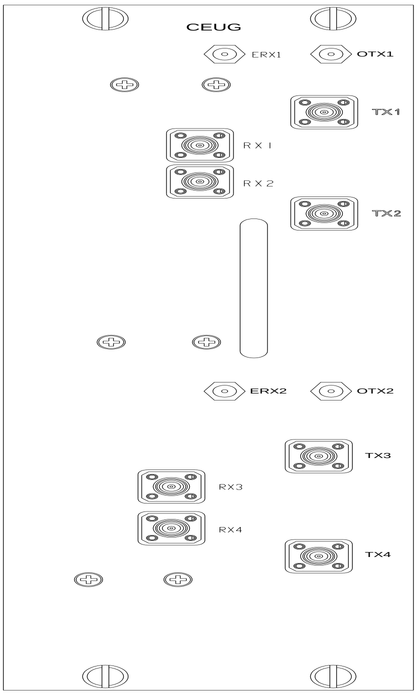
LED	Color	Name	Meaning	Working Mode
1	Green	FPO	Forward power output LED	ON: Normal OFF: Abnormal
2	Red	SWR1	VSWR level-1 alarm LED	ON: There is an alarm OFF: There is no alarm
3	Red	SWR2	VSWR level-2 alarm LED	ON: There is an alarm OFF: There is no alarm
4	Green	PWR	LNA power supply LED	ON: Normal OFF: Abnormal
5	Red	LNA1	Channel 1 LNA Alarm	ON: There is an alarm OFF: There is no alarm
6	Red	LNA2	Channel 2 LNA Alarm	ON: There is an alarm OFF: There is no alarm

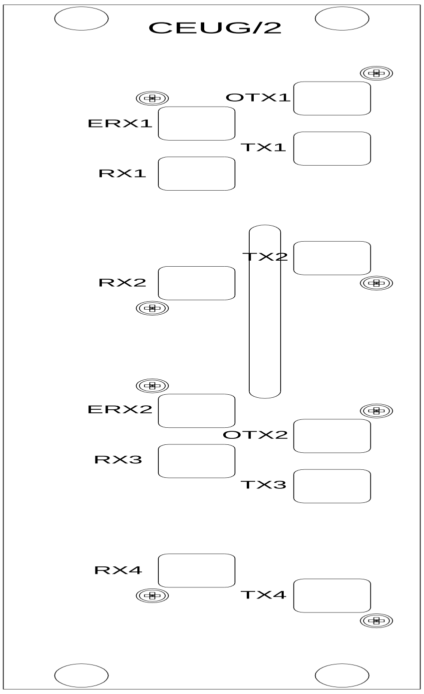
Functional structure of ECDU



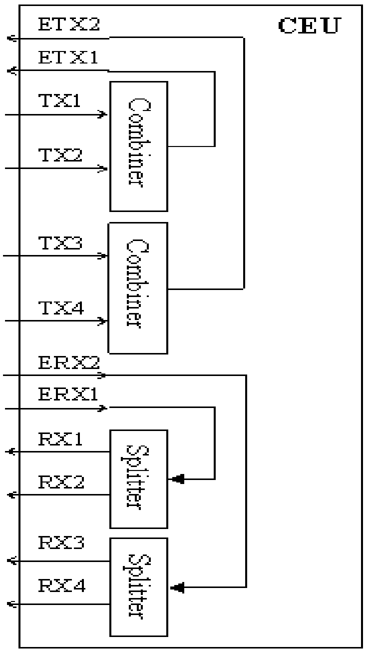
Identification Symbol	Full Name	Meaning
RTE	Radio Test Equipment	Radio test port
RX1	Receiver 1	Low-noise amplifier output port 1
RX2	Receiver 2	Low-noise amplifier output port 2
RXD1	Receiver for Diversity1	Low-noise amplifier output port 1(diversity)
RXD2	Receiver for Diversity2	Low-noise amplifier output port 2(diversity)
ANT	Antenna	Antenna feeder port
ANTD	Antenna for Diversity	Antenna feeder port (diversity)

CEU and CEU/2 panel



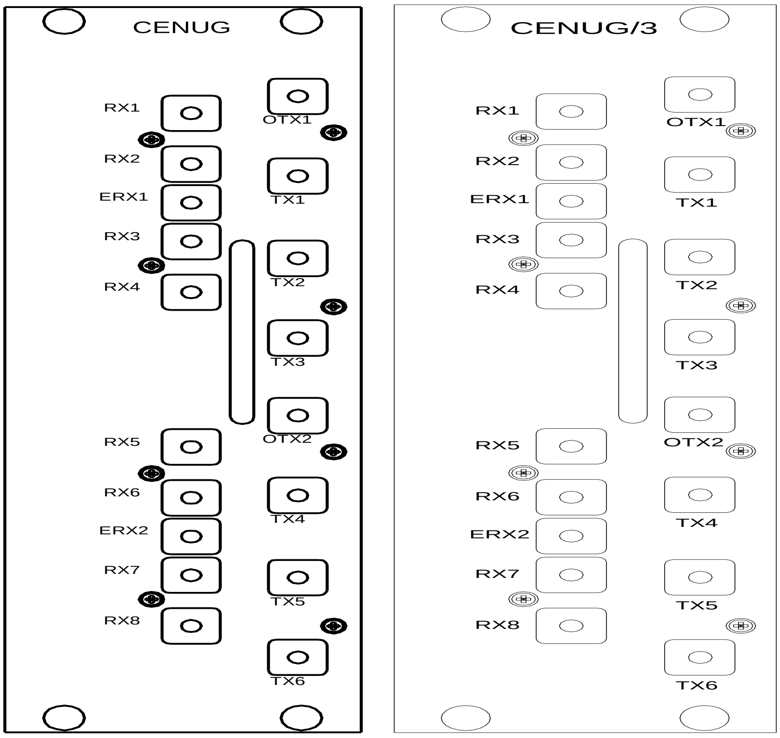


CEU functional structure

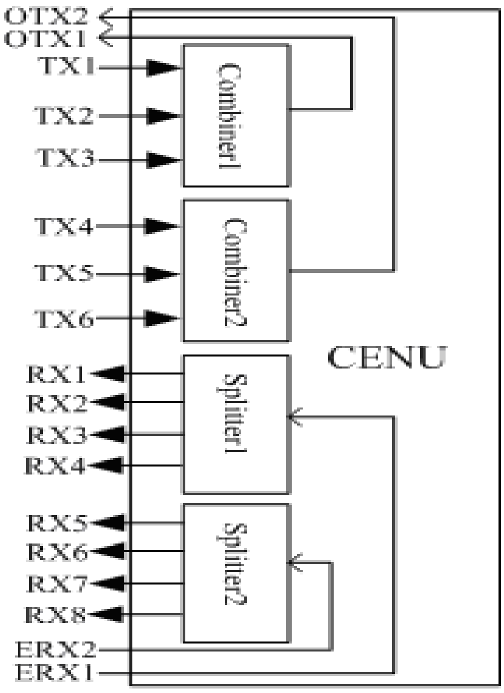


Identifier	Meaning	Description
OTX1	Output TX 1	Combiner TX output port 1
OTX2	Output TX 2	Combiner TX output port 2
TX1	Transmitter 1	Combiner input 1 (PA output signal)
TX2	Transmitter 2	Combiner input 2 (PA output signal)
TX3	Transmitter 3	Combiner input 3 (PA output signal)
TX4	Transmitter 4	Combiner input 4 (PA output signal)
RX1	Receiver 1	Splitter output port 1
RX2	Receiver 2	Splitter output port 2
RX3	Receiver 3	Splitter output port 3
RX4	Receiver 4	Splitter output port 4
ERX1	Extend Receiver 1	Splitter input port 1 (low noise amplifier extended output)
ERX2	Extend Receiver 2	Splitter input port 2 (low noise amplifier extended output)

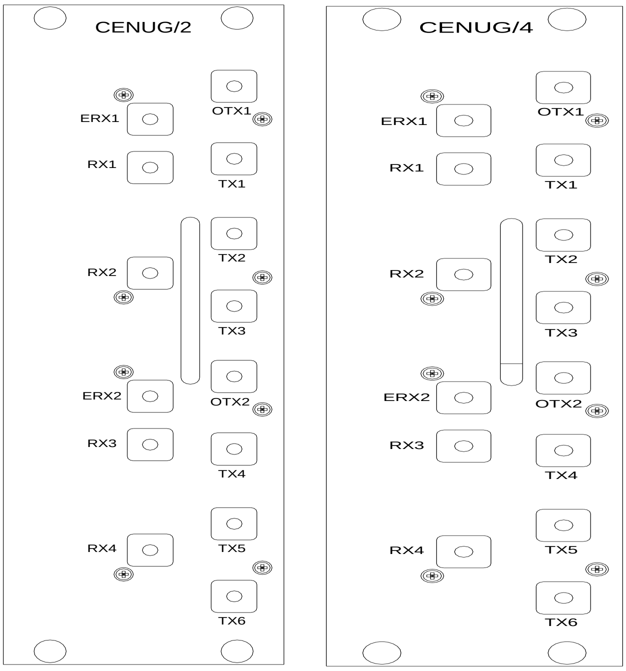
CENU and CENU/3 panel



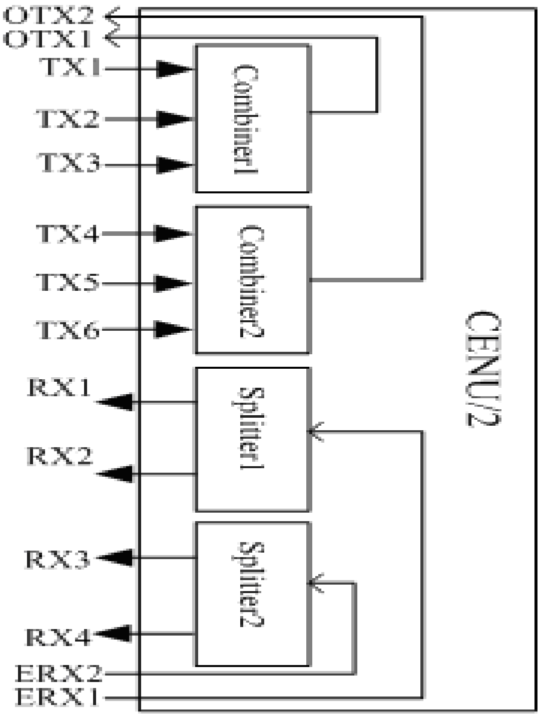
Structure of CENU and CENU/3



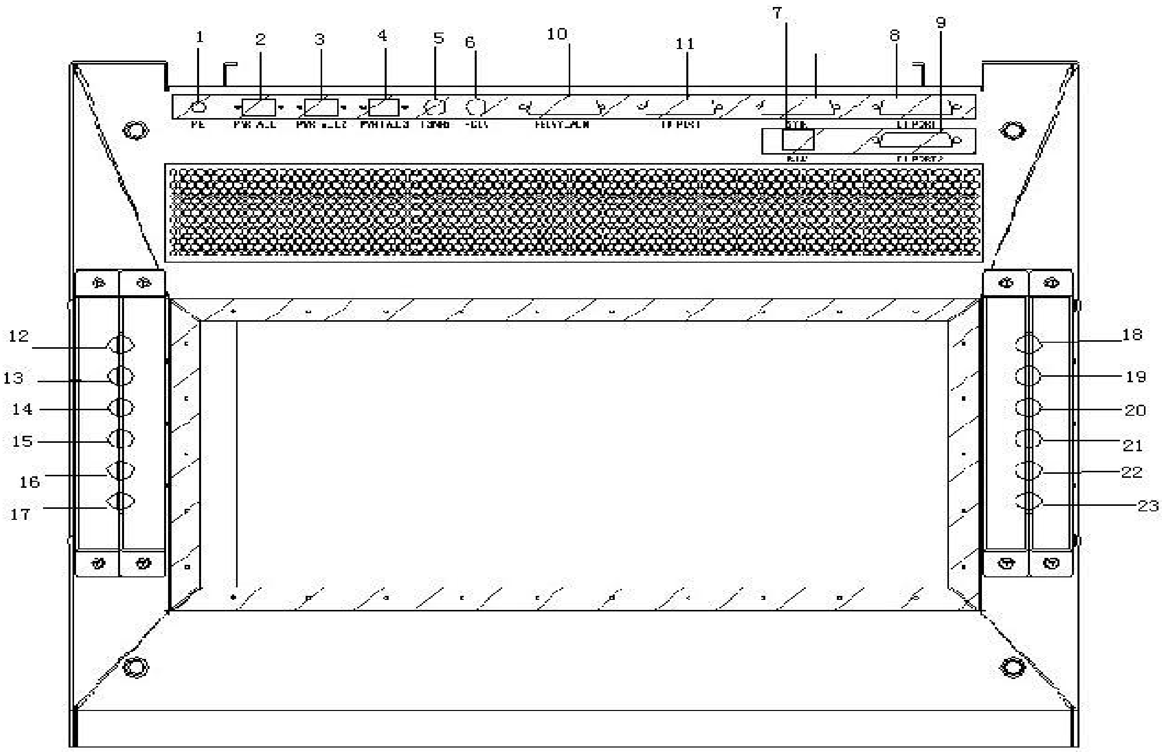
CENU/2 and CENU/4 panel



Structure of CENU/2 and CENU/4

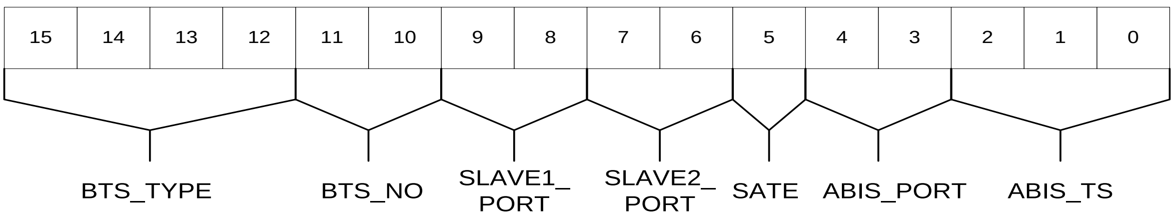


Cabinet top



1: PE
2: PWRTA_L1
3: PWRTA_L2
4: PWRTA_L3
5: 13 MHz Clock
6: FCLK
7: RJ45
8: E1 PORT
9: E1 PORT
10: RELAY_ALM
11: ID PORT
12: HYCOM1
13: HYCOM2
14: HYCOM3
15: HYCOM4
16: HYCOM5
17: HYCOM6
18: HYCOM7
19: HYCOM8
20: HYCOM9
21: HYCOM10
22: HYCOM11
23: HYCOM12

The ID switch



- BTS_TYPE
  - 1100: B8018
  - 1101: B8112
  - 1110: M8202
  - 1111: M8204
- BTS_NO
  - No. of the cabinet of the same site
  - 00: Basic cabinet
  - 01: Extended cabinet 1
  - 10: Extended cabinet 2
- SLAVE1_PORT
  - The E1 port of the basic cabinet to connect extended cabinet 1
  - 00: Port E of the basic cabinet
  - 01: Port F of the basic cabinet
  - 10: Port G of the basic cabinet
  - 11: Port H of the basic cabinet
- SLAVE2_PORT
  - The E1 port of the basic cabinet to connect extended cabinet 2
  - 00: Port E of the basic cabinet
  - 01: Port F of the basic cabinet
  - 10: Port G of the basic cabinet
  - 11: Port H of the basic cabinet
- SATE
  - Whether to use the satellite Abis link or not
  - 0: Common Abis
  - 1: Satellite Abis
- ABIS_PORT
  - O&M port number
  - 00: Port A
  - 01: Port B
  - 10: Port C
  - 11: Port D
- ABIS_TS
  - The O&M LAPD timeslot on the Abis interface
  - 000: TS16
  - 001: TS31
  - 010: TS30
  - 011: TS29
  - 100: TS28
  - 101: TS27
  - 110: TS26
  - 111: TS25

2.2.6 Software Structure

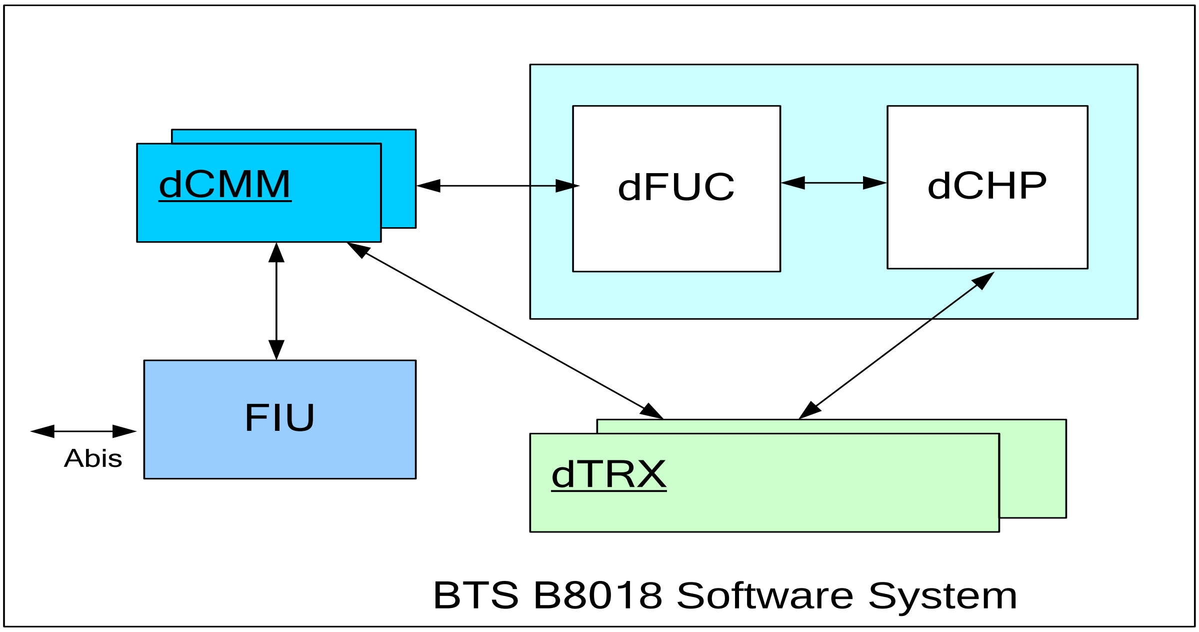


Fig. 2.11 Software system

- dCMM
  - system power-on initialization
  - downloads all board software
  - operation, maintenance and management
- dFUC and dCHP
  - service processing
  - baseband signal processing
- FIU

- connection with BSC
- working flow control
- resource configuration management

2.3 Evolution of Multi-Mode BTS

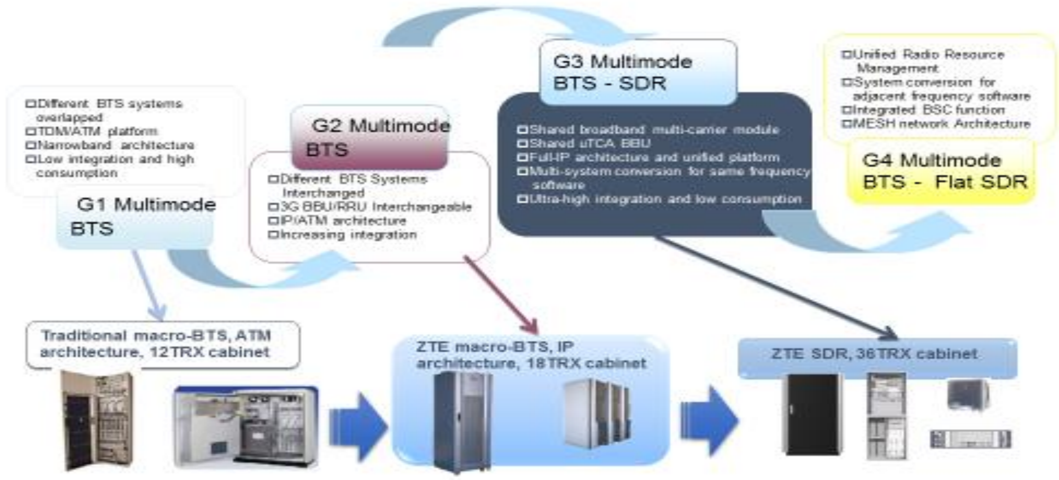


Fig. 2.12 BTS evolution

2.3.1 SDR (Software Defined Radio) Based Uni-RAN Solution Highlights

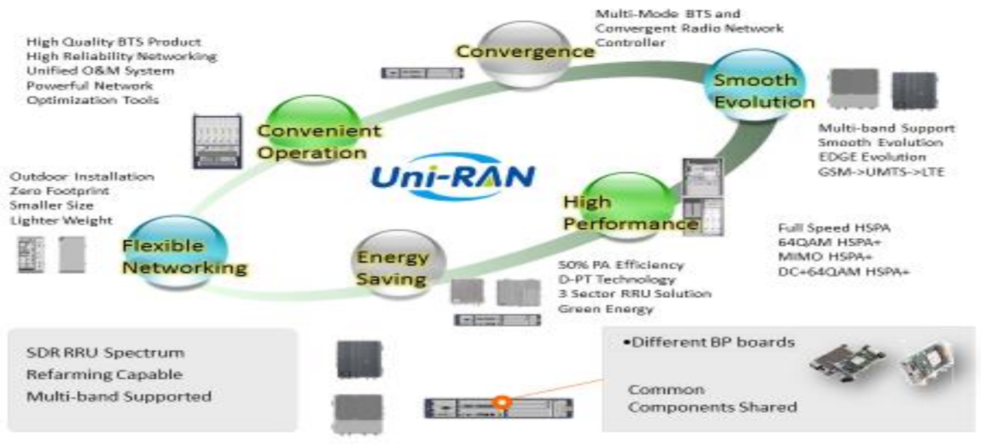


Fig. 2.13 Software defined radio

2.3.2 SDR Based Series BTSs Family

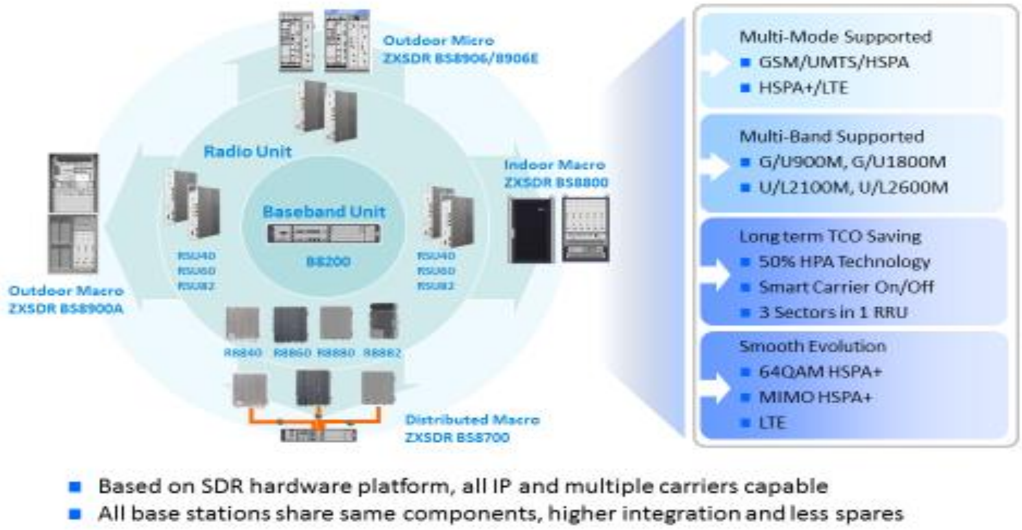
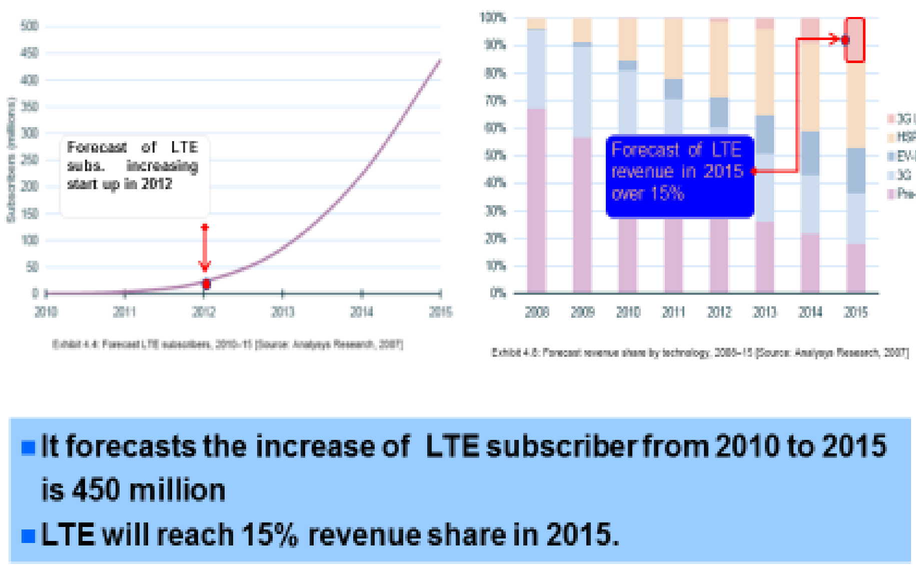
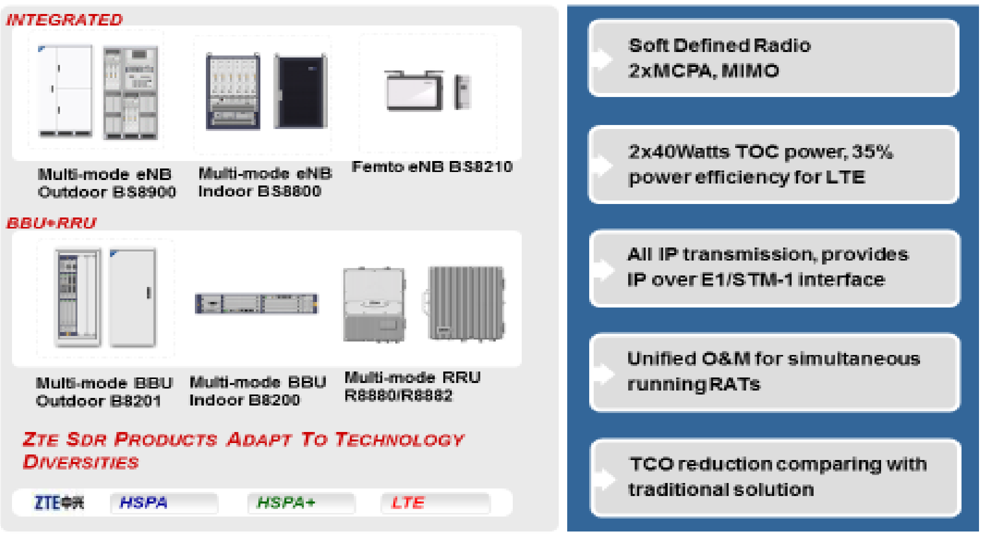


Fig. 2.14 SDR BTS family series

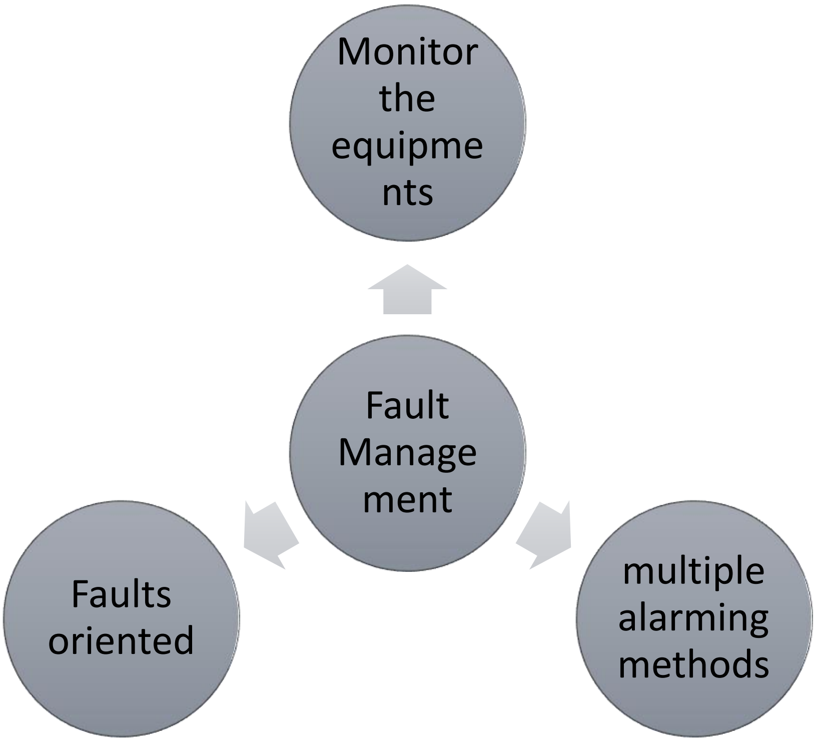
2.3.3 LTE Future Market Trend



2.3.4 LTE Product Portfolio



2.4 Operation and Maintenance



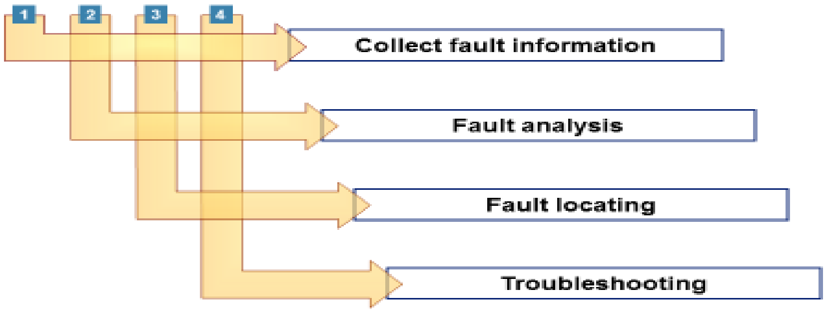
[8]

2.4.1 Monthly Maintenance Check List

Maintenance time:
Maintenance personnel:
Check whether the BTS location parameter is the same as the actual one.
Check whether the equipment is clean.
Check whether the cable tray is reliably fixed.
Check whether the E1, T1 (2.048Mbps speed) and fiber are in good condition and whether all connectors are in good contact.

Check whether all indicators are in normal status.
Spare materials and parts
Are spare materials and parts complete and undamaged?
□Yes □No
Review (performed by the person in charge).

2.4.2 Troubleshooting procedure



2.4.3 Common methods to locate faults

- Views of alarm, notification and operation log
- Analysis of status indicator
- Performance analysis
- Analysis of signaling tracing
- Analysis with instruments and meters
- Plugging/unplugging and pressing
- Isolation method
- Self-test method [9].

2.5 General BTS Characteristics

Frequency Plan	Currently available: 2.1 -2.3 GHz, 2.5 - 2.7 GHz, 3.4 –3.7 GHz, and 2.0 – 2.3 GHz
Multiple Access Method	Bi-directional Synchronous Code Division Multiple Access
Modulation Scheme	128 level QAM/QPSK, differential encoding/decoding, Direct Sequence Spread Spectrum (DSSS)
Traffic Capacity	119 voice channels per 3.584 MHz carrier
Traffic Concentration	Operator definable, up to 25:1 concentration
Users/RBU Users/DSCO	2500 voice channels 10,000 (15 RBUs)
Nominal Power	14 dBm/channel in each direction; normally 35 dBm from RBU
Power Control	None from RBU to SU; Closed Loop for SU to RBU - 50 dB in steps of ±0.25 dB
SU Antenna RBU Antenna	18 dB_{ic} gain, 22° 3dB beamwidth Omni - RH_{cp} with 8 dB_{ic} max. gain or Sectored with 11-15 dB_{ic} gain
SU Receiver RBU Receiver	-114 dBm sensitivity, -50 dBm max. input sensitivity, 6dB noise figure -114 dBm sensitivity, -30 dBm max. input
Dial Tone Delay	Less than 0.5s under non-blocking conditions
Propagation Delay	RBU to SU under 6ms
Bit Error Rate	Less than 10^{-6} when received input power is more than -111 dBm
Security	Pseudo-random Noise encoding (2.72 Mc/s per user) with randomizing, Full encryption for over the air network control channels
Subscriber Services	32 kbps voice (ITU-T ADPCM) 64 kbps fax and modem (dynamic rate change from 32 kbps) 64 – 256 kbps data (ITU-T X.21 leased line service) ISDN BRI (2B+D) 32 kbps Payphone support (battery reversal, 12/16 kHz metering)
Priority Calling	Outbound (line side) for up to five pre-set emergency numbers Inbound (network side) for local fire, police, EMS, VIP, etc. Leased line service (permanent virtual circuits)

2.6 General BTS Environmental

2.6.1 RBU and UPS (Indoor equipment)

Environment	Requirement
Temperature	-10° C to +55° C ambient air
Humidity	95% Relative humidity at 30° C, non-condensing
Air Pressure	70 to 106 Kpa
Shock	Basic shipping and handling shock
Cooling provisions	Forced air convection cooling, Fans & Filter (BTS)
Desiccants	None
Exposure	Must withstand UV radiation, water, dust, dirt, sand, etc.
EMC/EMI	per ETSI 300/339
Safety	UL and CE Mark
Coatings	Protection from humidity and corrosion

[10]

2.6.2 SU and NTU (Outdoor equipment)

Environment	Requirement
Temperature	-30º C to +55º C ambient temperature, derated for Altitude.
Weight	SU: 3.4kg max.; NTU: 340 gm; UPS: 6.8 kg
Humidity	100% RH, Condensing
Rain	150mm per hour
Ice Accumulation	10 mm on exposed surfaces
Air Pressure	70 to 106 Kpa
Wind Gusts	240 km/hr
Shock	Basic shipping and handling shock
Cooling provisions	Natural Convection Only, No Forced Air Cooling
Desiccants	No desiccants
Exposure	Must withstand UV radiation, water, dust, dirt, sand, etc.
EMC/EMI	Per ETS 300 339 as a guide
Safety	Designed to meet IEC En 60950
Coatings:	Protective coatings against humidity and corrosion

[10]

2.7 System Power Supply

The BTS and RRU are powered by a -48Vdc from the ZXD1500, 30A switch-mode rectifier. The rectifier operates from single phase 220Vac source and provides 48V/30A power to all the communication equipment such as switching systems, microwave communications equipment, data equipment and optical transmission equipment. Generally the rectifier is integrated into a telecommunication power supply system, in addition, it can work independently.

Specifications

ZXD1500 (V4.0) ZTE 1500W 48V 30A switch mode rectifier module.

1. Wide working temperature range.

2. Hot plu

3. Power factor > 0.99

ZXD1500 (V4.0) ZTE 1500W 48V 30A switch mode rectifier module

Fig. 2.15 Rectifier module

ZTE ZXD1500 30A rectifier Features:

1. Wide input voltage range: From 90V-290Vac
2. Plug-in type, easy and fast respond
3. Small Size, light weight
4. High power density 540mW/CM3

ZXD1500 ZTE Rectifier input parameters:

Input Voltage: 220v (85-295Vac), Input Current: 8A

ZTE rectifier output Parameters:

Output Power: >500W, Output Type: Single, Output Voltage: +/-48v, Output Frequency: 45-65HZ, Output Current: 30A

Rectifier Module ZXD1500 operation Condition:

Working Temp.: -5-145C, Storage Temp.: -40 -170C

Switch mode rectifier Emerson ZXD1500 V4.0 size and weight:

Weight: 6.5kg, Size: 404 x 200 x 87 mm

2.8 References

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CHAPTER 3: RESEARCH METHODS AND TECHNIQUES.

3.0 Introduction

In this chapter, a concise description of the methods and procedures for the setting up of a learning BTS at MSU Main campus are expounded. The chapter is going to give a detailed over view of the procedures and assumptions employed to archive the objectives stated in chapter one. The rolling out of this project was premised on the assumption of Midlands State University's willingness to support the idea of establishing a demo BTS for students practice and that the targeted sponsor of such a project, in this case Econet Wireless Zimbabwe (EWZ), was willing to support the idea of PPP (Private Public Partnerships) as part of their corporate social responsibility in supporting tertiary education in Zimbabwe. Taking into cognisance of the fact that, the current economic environment and the general costs of rolling out a project worth a donation of equipment which could go in excess of US$250 000.00 (two hundred and fifty thousand dollars), entailed the employment of serious goodwill negotiations to see the project being completed. Negotiations through to installation of the project equipment took about ten weeks to complete.

3.1 Project methodology

Project Management principles were used in undertaking this project as seen in the definitions. Project management is the discipline of using established principles, procedures and policies to manage a project from conception through completion. It's a temporary endeavour undertaken to create a unique product, service or result [1]. Project management, then, is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. A project is temporary in that it has a defined beginning and end in time, and therefore defined scope and resources. It is unique in that it is not a routine operation, but a specific set of operations designed to accomplish a singular goal. So a project team often includes people who don't usually work together – sometimes from different organizations and across multiple geographies [2].

To roll out the project, the project stages were categorised into six phases, that is:

1. Project proposal.

2. Project planning, analysis and design.

3. Donation contract negotiations.

4. Equipment decommissioning and laboratory preparations.

5. Equipment delivery and installations.

6. Documentation, training and commissioning.

3.1.1 Project proposal

Having observed that the Department of Applied Physics and Telecommunications at MSU did not have much in terms of real practical training aid equipment that speaks to the contemporary industrial expectations, the idea of a demo BTS was conceived. The idea was verbally sold to the department and a project to address the existing practical gap could be undertaken as part of a student dissertation. The idea was acknowledged and a written project proposal was done detailing the background to the project, its objectives, scope, timeframes, estimated budgets, key stakeholders and many other project aspects, as abridged in parts of chapter 1. This is the phase where the problem statement was defined and proposed solutions proffered.

3.1.2 Project planning, analysis and design

Upon the approval of the project proposal by the Department of Applied Physics and Telecommunications authorities, the planning, analysis and design phase commenced. A detailed plan highlighting the scope of work, project implementation tools and strategies was done. Analysis and design of the project layout and equipment setup was also done here. An engagement strategy was muted at this stage, to engage the Faculty of Science and Technology authorities and subsequently the university authorities. This also included the engagement strategy for the donors of the equipment. Alternative sponsors were also considered, but it was observed that in engaging EWZ there are better chances of getting the sponsorship and they were migrating faster to the latest technologies and thus they are likely to be having a lot of redundant equipment which can be of great use in students training. Timelines for rolling out the project were put in place utilising project management tools like Gantt charts, flow charts and time charts were employed. These provided a visual understanding of the whole project on a single platform. This subsequently enabled the crafting of the project budget in terms of the human, material and financial capital to be much easier. The Faculty and university authorities were presented with plan and the project was given the greenlight for it to be implemented at the university a letter was drafted to EWZ to initiate negotiations.

3.1.3 Donation contract negotiations

The Dean of Faculty's office drafted the letter of engagement to the Chief Executive Officer of EWZ with direct attention to the Technical Director. The Project Manager approached EWS with an official request from the Midlands State University for a donation of a student learning practice or demo BTS (Base Transceiver Station). The EWZ Technical Director agreed to the proposal after acknowledging receipt of the letter from MSU. The first meeting between the authorities of the two institutions to map up a donation contract was muted after the Project Manager met with the EWZ Technical Director, who referred all following logistical plans to the EWZ team of managers who included the Site Acquisition Manager, Radio Frequency Planning Manager and Projects Team Leader. The managers were engaged by the Project Manager to map the best approach to implement the project, to which they agreed to have MSU come up with a tentative agenda. The first meeting was held in the Dean's office, chaired by the Deputy Dean of the Faculty of Science and Technology. In attendance was the Registrar' representative, Works department representatives, Telecommunications department personnel and EWZ Site Acquisition Manager and Projects Team Leader. The meeting agreed to the agenda of the day and draft donation contract was done by EWZ and circulated, culminating in the convening of a second caucus meeting where final donation contract was agreed upon. The final donation contract was also circulated to the meeting attendees and it was signed by the EWZ Technical Director and MSU Registrar. EWZ also brought and tabled another separate business contract to install Wi-Fi hotspots at MSU's four campuses that included Main campus, Batanai, Graduate School and Zvishavane campuses. This contract is still pending, though it holds a lot of benefits to both parties.

3.1.4 Equipment decommissioning and laboratory preparations.

After the signing of the donation contract the sourcing of the requisite equipment pieces from EWZ BSC and BTS sites began. Meanwhile MSU Works and Telecommunications departments were preparing the laboratory where the equipment was to be installed. They were working on the security features, air-conditioning system, main grid power supply system and suitability features of the laboratory to house such equipment and possible future donations and other expansions. A third meeting was held in the proposed venue that would host the equipment and the EWZ General Manager Midlands, Radio Frequency Planning Engineer and the Projects Team Leader assessed the laboratory and were satisfied. The General Manager Midlands also inquired about the Wi-Fi contract proposed contract as he was now ceased with the consummation of that project, and was told that it was still with the MSU Registrar. EWZ team highlighted that they were keen to do joint researches on smaller cells technology (micro and pico cells) with the university post graduate students provided they are given the chance to install their hot spots at MSU campuses to which they will be paying agreed rentals and power consumption costs.

3.1.5 Equipment delivery and installation

The EWZ team was satisfied with the site laboratory and they drafted a scope of works document detailing deliverables, equipment, delivery plan**,** proposed timelines, responsibility matrix and required resources for the equipment installation. Sourcing and transportation of the equipment was done and installed at the university main campus' Telecommunications and Computer laboratory. The Project Manager participated in this phase as part of the technical team from EWZ and monitoring of the equipment installation was done to ensure compliance to industrial standards.

3.1.6 Documentation, training and commissioning

This stage involved the processes of compilation of literature for use by the lecturers and students in doing their practical exercises. Lecturers and instructors were trained by EWZ engineers on the use, operation and maintenance of the equipment and how it will benefit students. Commissioning of the project followed, where the equipment was handed over to the University custody and use, to enhance their academic curricular.

3.2 Research methods employed

A combination of desk research, plenary meetings and practical installations and simulations were employed to carry out this project. Hands-on training and practice was employed to build an in-depth understanding of how the BTS works and what possible practical exercises can be conducted by students during their study period as well as further researches that can be undertaken even at post graduate level, in collaboration with the project sponsor, in this instance Econet Wireless Zimbabwe (EWZ).

3.2.1 Data gathering tools and techniques

Data gathering is important in research as the information and data contribute to a better understanding of theoretical and practical concepts of any system. Data gathering tools are the different instruments used for research in collecting information which will be used for making inferences and draw conclusions to a line of research study. In this study, amongst the many tools available, the following were chosen; empirical observation, research and analysis, meetings and face to face negotiations.

- Empirical observations are important where other tools like questionnaires are difficult or not possible to use in a research. The institutional deficiencies in the delivery of practical lectures to students observed. The same old practical lessons which bear minimum relevance to contemporary telecommunications engineering workshop environments and applicability were being taught. So it was seen fit to bring in relatively newer and more relevant practical demonstration equipment for the students, for them to at least familiarise with wireless communication equipment.

- Desk research and in-depth analysis was used to compile the theory behind the BTS system, its evolution, present and future trends and technological development in the wireless communication systems. A wide range of texts and manuals were used to gather the resource material for future use by students and to provide the base information for further researches in BTS systems. This data also was compiled to help set the foundation for RF planning and network optimisation in smaller cells (micro and Pico cells) technology.

- Meetings and face to face negotiations technique was employed to create a plenary platform for open discussions between the project donors and the beneficiary institution. This proved effective in project management as it set the foundation for the successful launch and implementation of the project. Inside three meetings a donation contract was agreed upon and further research collaborations were muted, as it was seen that both organisations, MSU and EWZ will stand to gain, if the business sector partners the academia in any researches they so agree on.

- Training tool was used in understanding the applicability of the demo BTS in a learning institution, its relevance and general operating principles. Training was carried out with the EWZ engineers and technicians to teach on the basic technologies and concepts that students can benefit in utilising the donated equipment and what other areas of student researches that can ride on this equipment and further researches in-line with wireless communication systems, RF planning and network optimisation.

3.3 Cost Benefit Analysis

The cost benefit analysis (CBA) provided an empirical analysis of the benefits accrued to the parties involved with the project, in this case, the donor EWZ and the beneficiary MSU vis-à-vis the implementation of the project. For this project the donated equipment if it was to be deployed for commercial purposes it would cost in the range of $250 000.00. With this backdrop, MSU stand to benefit a lot from this project. As for EWZ they would benefit from collaborative researches if it follows through the agreed positions in negotiation meetings. It will also benefit from getting a pool of young engineers from the university who have a better understanding of their systems compared to other colleges that did not benefit from such a donation. Given this scenario, the cost of implementing the project stood to benefit both institutions as well as the student undertaking the project, as the student would have both in-depth theoretical appreciation of wireless communication systems, RF planning and network optimisation, and also on the hands-on experience of deployment of wire communication equipment in the field and its programming for live deployment.

3.4 Project Scheduling

To schedule the work plan, events and the expected time of completion of all tasks involved to enable project progress and monitoring, the Gantt chart was used.

3.4.1 Work Plan

The work plan was employed to give a general overview of what needs to be done within given probable timelines. It provides guidelines and timelines to achieve planned project events which will result in having the project rolled out and completed, if they are followed through. Table 3.1

shows the events and scheduled dates of rolling out the demo BTS project at MSU Main Campus.

	Phase	Start Date	Completion	Status
1	Project Proposal	01/08/2016	31/08/2016	Completed
2	Project Planning, Analysis and Design	01/09/2016	31/12/2016	Completed
3	Donation contract negotiations	01/11/2016	28/02/2017	Completed
4	Equipment decommissioning and laboratory preparations	01/02/2017	31/03/2017	Completed
5	Equipment delivery and installation	01/04/2017	30/04/2017	Completed
6	Documentation, training and commissioning	01/05/2017	31/05/2017	Pending

Table 3.1:Work Plan.

3.4.2 Gantt chart

A Gantt chart is a bar chart that is a visual representation of the sequencing and duration of activities on any given project [3]. The Gantt chart was used to keep track of main events and landmark activities that will delay the project if they are not completed. It provides a visual tracking of project key events. It shows whether the project is lagging or is on schedule and it is relatively easy to comprehend and use even by an inexperienced user. Gantt charts provide a standard format for displaying project schedule information by listing project activities and their corresponding start and finish dates in a calendar format. Gantt charts can be used for scheduling generic resources as well as project management [4].

PHASE/WEEK	1	2	3	4	5	6	7	8	9	10	11	12
Project Proposal	■											
Planning, Analysis and Design		■	■	■	■							
Contract Negotiations				■	■	■	■					
Equipment and Laboratory Preparations							■	■				
Installations									■			
Documentation and Training										■		
Commissioning										■		

Table 3.2: Gantt chart for the MSU demo BTS project.

KEY: ■ Time In months

3.5 References

[1] Project Management Metrics, KPIs, and Dashboards: A Guide to Measuring and Monitoring Project Performance, Harold Kerzner, Harold R. Kerzner, First Edition, John Wiley & Sons, New York, NY, 2011.

[2] A Guide to the Project Management Body of Knowledge, PMBOK® Guide, Project Management Institute; Fifth Edition, 2013.

[3]Project Management: A Systems Approach to Planning, Scheduling, and Controlling, Harold Kerzner, Ph.D., 11th Edition, John Wiley & Sons, New York, NY, 2013.

[4] The Gantt chart, A Working Tool of Management, Wallace Clark and Henry Gantt New York, Ronald Press, 1922.

CHAPTER 4: RESULTS AND ANALYSIS

4.0 INTRODUCTION

The installation and commissioning of a demo BTS at MSU Main Campus for use by students in the Telecommunications and Computer Science programs will undoubtedly improve on the quality of graduates from the disciplines. The students will definitely have a bit of exposure to some of the equipment used in the mobile cellular technology and wireless communication systems. The purpose of this chapter is to present the results obtained from the implementation of the project, practical activities and lessons that can done by students utilising the equipment and other projects and researches that can be done riding on the availability of the equipment on campus.

4.1 Results and discussions

Main parts of a wireless cellular BTS have been installed at MSU Main Campus. These amongst others include the backup battery bank, a rectifier cabinet, radio, 2G GSM module, GSM antenna, microwave antenna and all the cabling.

BTS Modules before reassembling

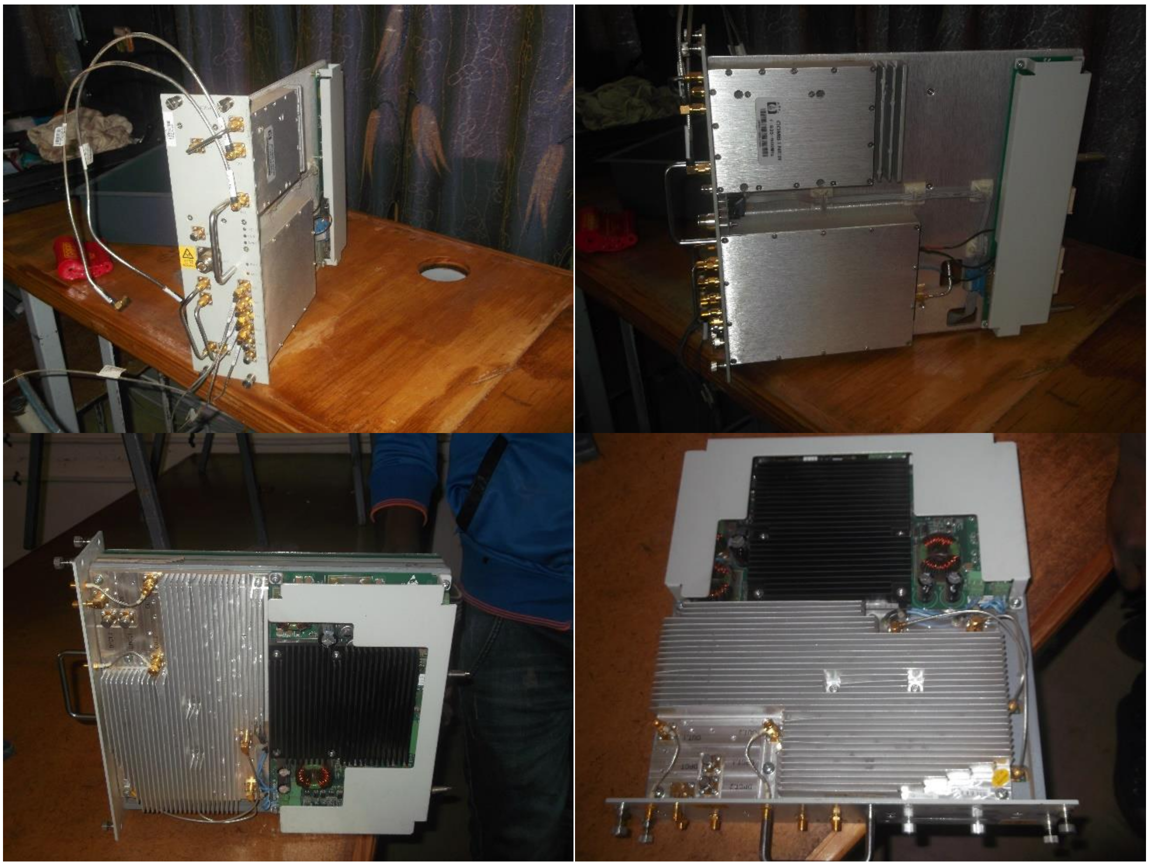

Fig 4.0 Modules before reassembling

Reassembling the modules

Fig. 4.1 Reassembling of the modules

Back-up battery bank

Fig. 4.2 Battery bank

The battery bank produces +/- 48V dc voltage, but the system uses -48Vdc for running all its systems. The negative voltage is very stable and free from interference like lightning bolts. The battery bank is there as a back-up dc power supply when ac supply to the rectifier goes off. Ceteris paribus, the battery system will keep the BTS system up for about 8 hours on full capacity, or more hours if the user traffic is low.

Rectifier Cabinet

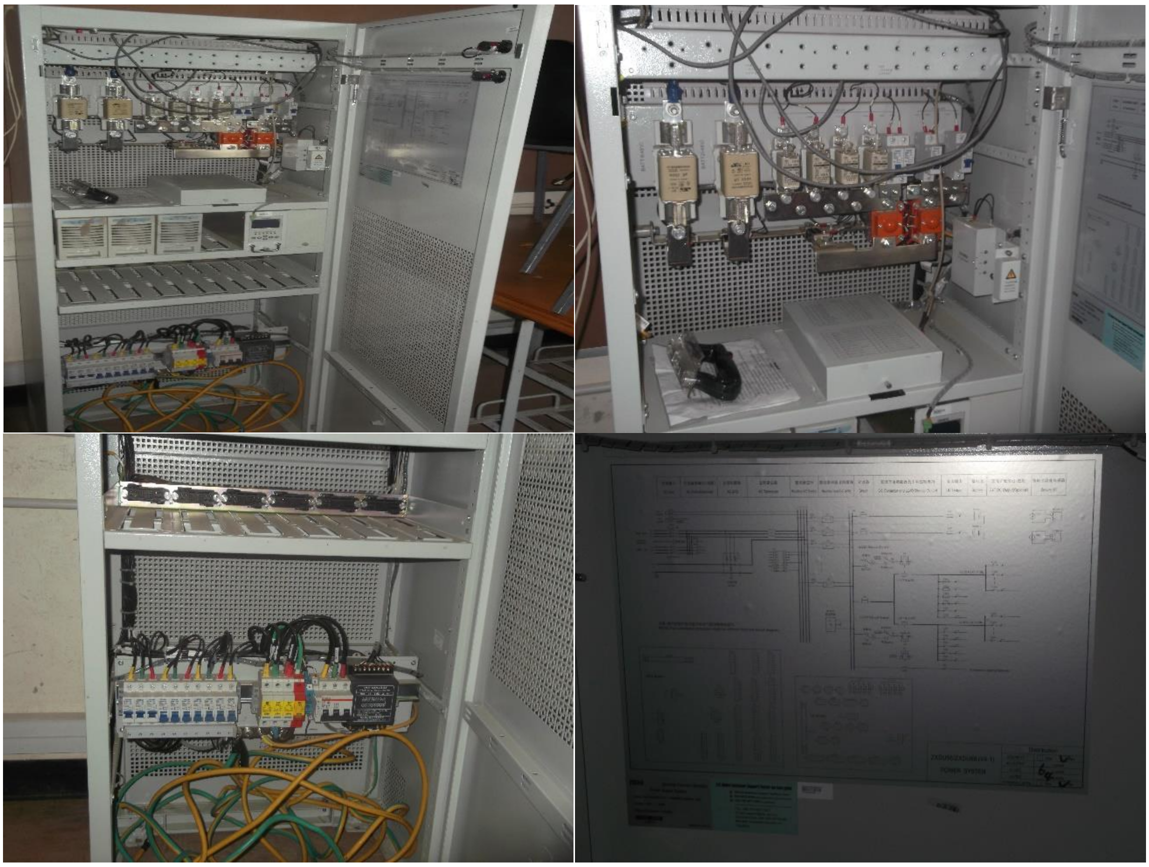

Fig. 4.3 Rectifier

The rectifier system changes the incoming 3 phase ac (380Vac) to +/- 48Vdc using rectifier modules, of which -48V dc will be tapped and used for the system components. It is an intelligent rectifier which produces up to 57Vdc depending on the flactuations of the incoming ac input voltage and produces a maximum current output of up to 300A. The system will output a dc power supply failure alarm if the dc voltage falls below a set dc cutoff point.

Microwave Radio Rack

Fig. 4.4 Microwave Radio

The radio provides linkage to other site via the microwave antenna link. It generates signals that are transmitted at ranges of 4GHz to 60GHz by line of sight im relation to hop distance. This where the up and down conversion and modulation takes place.

2G GSM Module

Fig. 4.5 2G GSM Module

The GSM module can be connected to three sectors with 3 GSM antennas each covering a 120 degrees sector.

Microwave and GSM antennas

Fig 5.6 Microwave and GSM antennas

The GSM antenna transmit at 900MHz and is connected to the GSM module. It is through it that mobile phone equipment communicates with the BTS. The microwave antenna is connected to the radio. The radio is linked through a line of sight microwave link to another radio at another BTS or BSC by the microwave antenna. The antennas are connected to the GSM module and radio via RF cables.

Complete assembled units

Fig. 5.7 Complete assembled units

The units that make up a BTS is composed of the power supply unit (ac mains, rectifier and battery bank), the radio, BTS module and antennas and their connection cables.

Radio log-in screens

Typical live connetion screen.

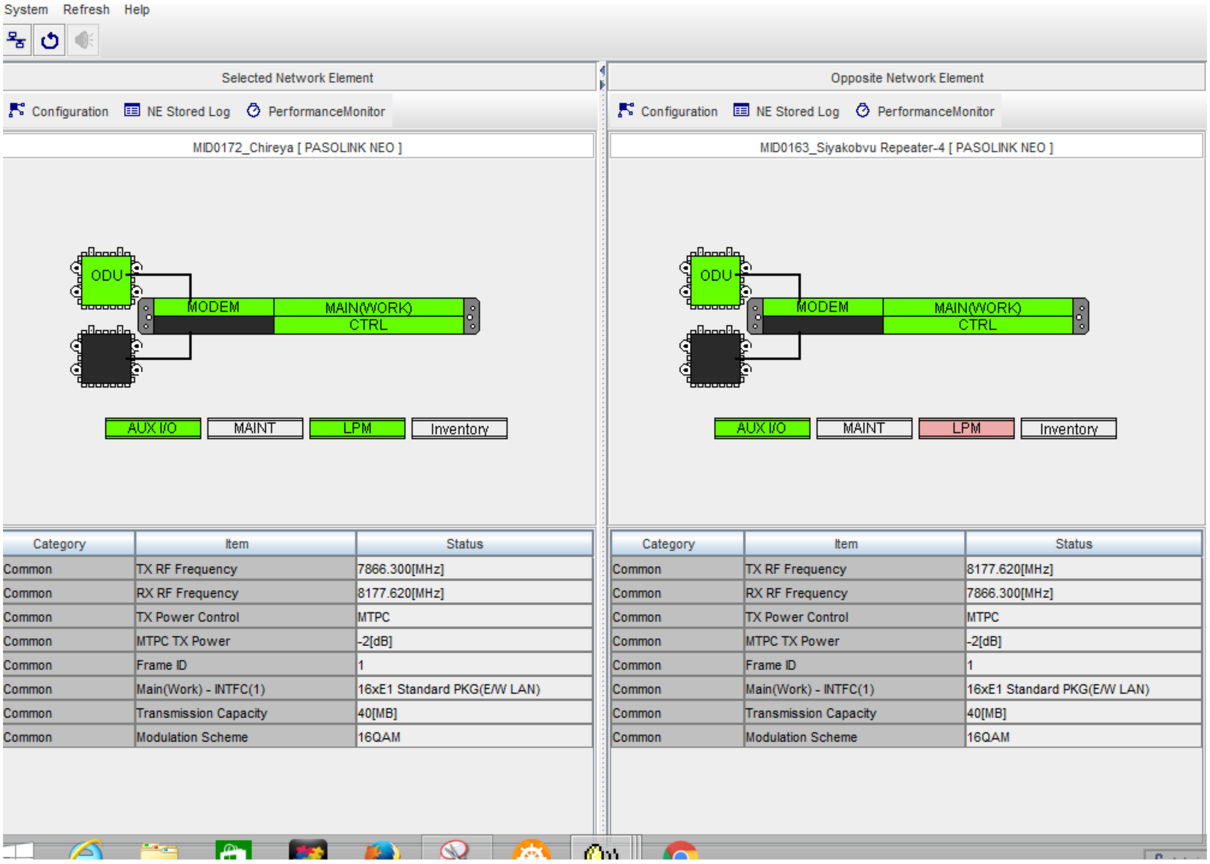

Fig. 4.8 Radio log-in screen

This is a logical screen interface for two physical radios facing each other and live connected to the BSC where you can configure the system, view alarms, link reallignment and connect remotely to other radios in the network.

Configuration screens

Screen 1

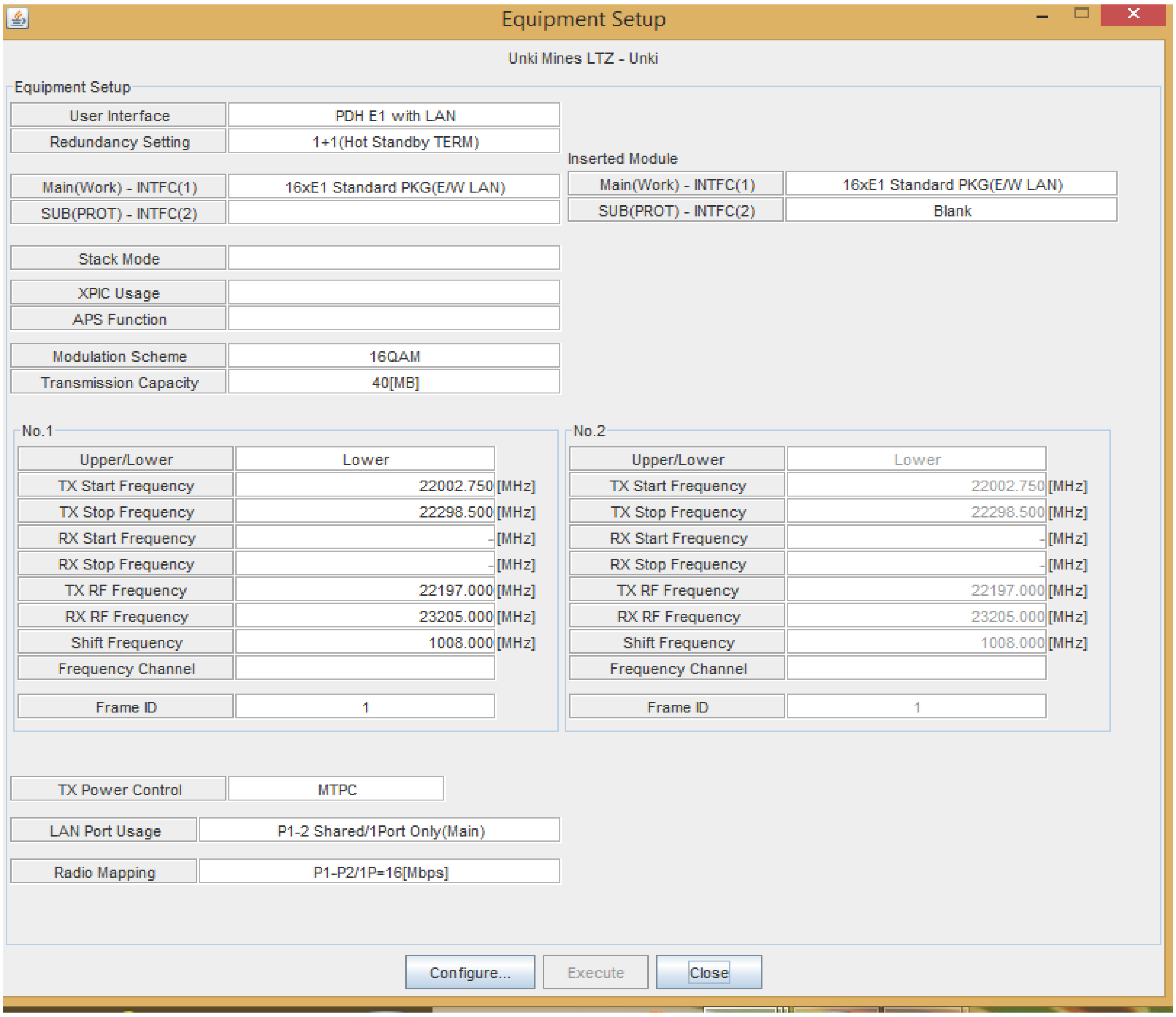

Fig. 4.9a Configuration screen

The first screen is for equipment setup, configuring the site as alloted by the planning departmen. Setup aspects like modulation scheme, transmission capacity, start/stop frequency, shift frquency, power control, radio mapping and more are configured here.

Screen 2

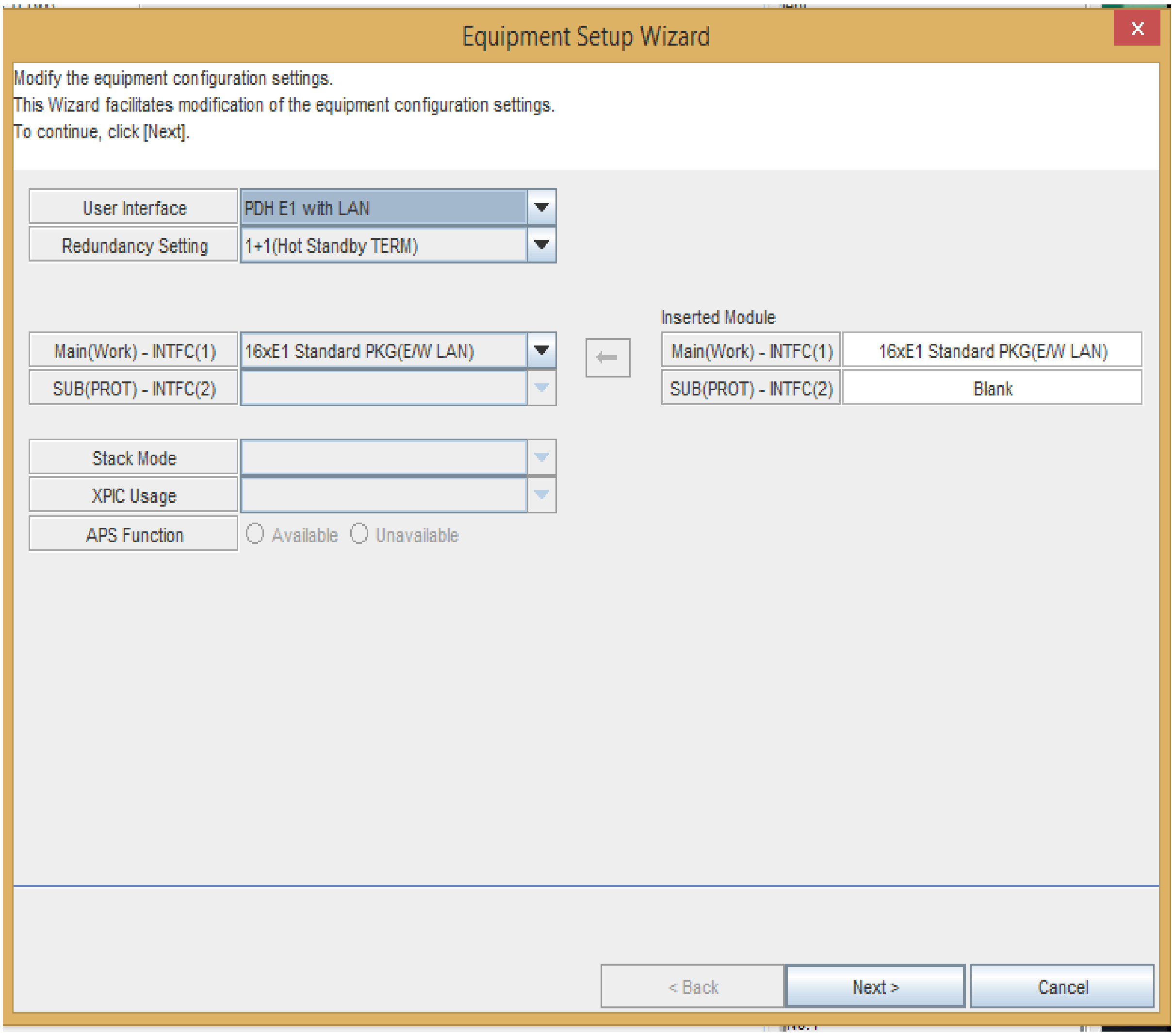

Fig. 4.9b Configuration screens

Screen two is for equipment setup wizard where you can modify equipment configuration settings such as user interface and redundancy setting.

Screen 3

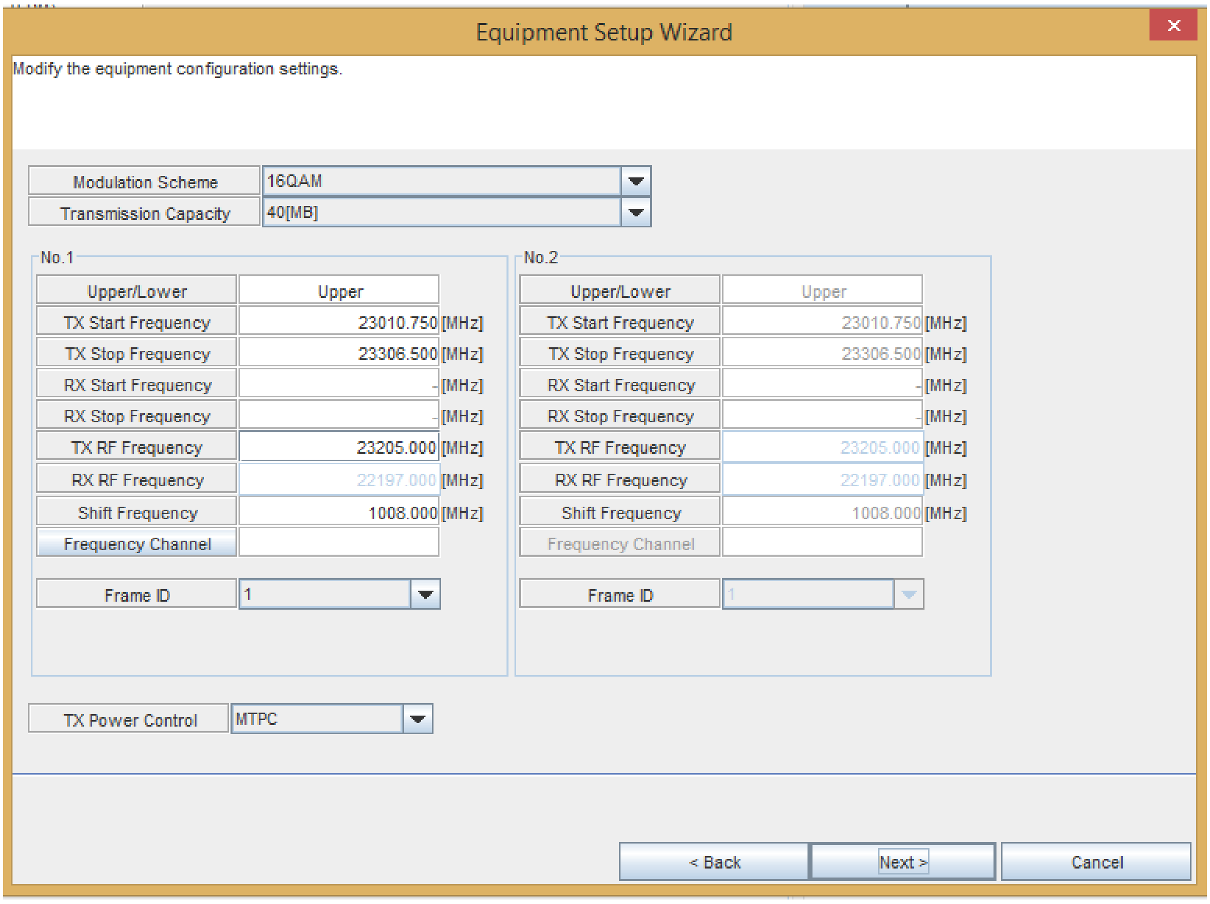

Fig. 4.9c Configuration screen

This is also an equipment setup wizard where equipment configuration can also be modified, modifying aspects like modulation scheme and transmission capacity.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.0 INTRODUCTION

The demo BTS was proposed, designed and implemented for use by students in the Applied Physics and Telecommunications and Computer Science and Information Systems Departments.

5.1 Conclusions

This project will be used for practical familiarisation and simulations by students, especially those in the Telecommunications and Computer Science disciplines. It seeks to bridge the gap between theory lectures and practical equipment that the students will be working with when it comes to their industrial and work related learning.

Typical exercises that can be done on the equipment includes among others loop tests, frequency programming of the radio, up tilt and down tilt, link budget settings and simulations, RF optimisation simulations, and many more. Other research areas that can ride on this project include any project that may need 900MHz signal, rectified power +/-48Vdc, GSM modules and GSM and microwave antennas.

5.2 Recommendations

The project is not an end in itself, but the beginning of partnership between industry and the academia. Further negotiations and deployment of later versions of the equipment is critical. A 4G system will offer more practical exposure to students as it can be configured to operate in a local mode so that the equipment sponsor will not be troubled by the authorities (in this case POTRAZ) that are deploying live BTS sites at institutions with the pretext of donating learning demo equipment. The 4G can be easily switched to live by the university lecturers in the event that they want to do live exercises and be returned to local mode after the practical lectures. Lecturers and technical instructors will be trained in how the system works and how best it can be used for practical learning. Further collaborative researches can be done in the area of cellular communication systems as the sponsor EWZ have offered to donate more equipment in exchange for agreeable win-win negotiations with MSU. They are currently rolling out automobile small cells technologies and are prepared to work with MSU in related researches in micro and Pico cells technologies. This will definitely go a long way in benefiting the students and producing best Telecommunications graduates from MSU.