Summer Internship May-July 2007

Analysis Of WiMAX and Design of Transceiver & Front End Part of WiMAX System

PRESENTED BY:

1.PIYUSH KESHRI(2ND Year,IIT KANPUR)
2.HIMANSHU GUPTA(2ND Year,IIT KHARAGPUR)

Acknowledgement

We are extremely thankful to **Prof. Girish Kumar, Professor, Electrical Engineering, IIT Bombay** for providing us this great opportunity to work in the Microwave and Antenna Lab, Dept of Electrical Engineering, IIT Bombay under his valuable and generous guidance. Working under him has really helped us move to next step in the ladder of the field of Wireless Communication and broadband access.

We would also like to extend the credit of successful completion of the entire Internship project to all the senior students and staff working in the lab who were always ready to offer help at every step of the project.

Himanshu Gupta	**Piyush Keshri**
2nd year,	**2nd year,**
B.Tech,IIT Kharagpur	**B.Tech(EE),IIT Kanpur**

Certificate

Certified that this internship report titled

“ **WiMAX : Worldwide Interoperability for Microwave Access** “

By

Piyush Keshri
&
Himanshu Gupta

Is approved by me for submission .Certified further that the report represents the work carried out by the student in Antenna Lab under my guidance and support during May 14th – July 13th 2007.

Date : **Prof. Girish Kumar**

Abstract

The technology called WiMAX based on IEEE 802.16 standard is on the way and is expected to provide affordable broadband for all and improve the quality of life. WiMAX is a long –distance fixed wireless solution which is expected to outpace the growth of broadband wire line options as cellular phones have supplanted many land line users. This report will provide a very strong introduction about WiMAX technology, deployment status of this technology, its advantages as a last mile solution and backhauling, its challenges for end user connectivity, its market review, prominent players and its scope .

This project was aimed at the Analysis of WiMAX System (Market Analysis and Technical Analysis) and to Design the circuit Of Transceiver Chipset And RF Front End and also to design two band pass filters in the frequency ranges: 5-5.9 GHz and 2-3 GHz respectively.

The Project was divided into two parts. The 1st part deals with the introduction, technical overview and Market analysis Of WiMAX.

The second part of the project deals with the design of Transceiver circuit and RF Front End circuit of the WiMAX system. The latter part of the project was aimed to be accomplished with the development of RF Front End Module by Himanshu Gupta and Transceiver Module by Piyush Keshri. During the project period, Himanshu has simulated the Band Pass Filter (4.9-5.9 GHz) in IE3D.

Table of Contents

Page No.

List Of Figures

List Of Tables

APPENDIX

Chapter 1 Background Of WiMAX

1.1 Definition

WiMAX is defined as Worldwide Interoperability for Microwave Access by the WiMAX Forum, formed in June 2001 to promote conformance and interoperability of the IEEE 802.16 standard, officially known as Wireless MAN.[1]

1.2 Introduction

WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL(Digital Subscriber Line).[1]

WiMAX will provide fixed, nomadic, portable and mobile wireless broadband connectivity without the need for direct line-of-sight with a base station.[1]

It can be implemented in the Frequency range -:2 GHz – 66 GHz.

It is a more innovative and commercially viable adaptation of a technology already used to deliver broadband wireless services in proprietary installations around the globe. As, wireless broadband access systems are already deployed in more than 125 countries.

1.3 Importance of WiMAX

WiMAX has been immensely helpful in critical situations even though this is an emerging technology and is currently in preliminary stage.One such example is as follows:-

- WiMAX access was used to assist with communications in Aceh, Indonesia, after the tsunami in December 2004. All communication infrastructures in the area were destroyed making the survivors unable to communicate with people outside the disaster area and vice versa. WiMAX provided broadband access that helped regenerate communication to and from Aceh so that the condition post-tsunami could be retrieved.[1]

1.4 Applications of WiMAX

The WiMAX has huge range of applications ranging from telecom applications to wireless broadband access systems.

The bandwidth and reach of WiMAX make it suitable for the following potential applications:

- **Residential and SOHO High Speed Internet Access**
  - WiMAX provides an alternative to existing access methods, where it is not feasible to use DSL or Cable Internet.
  - Typical application will be in remote areas where it is not economically feasible to have a DSL or Cable Internet.
  - Expected to be more reliable due to wireless nature of communication between the customer premises and the base station.
  - Particularly useful in developing countries where the reliability and quality of land-line communications infrastructure is often poor.

- **Small and Medium Business**
  - WiMAX WBA is well suited to provide the reliability and speed for meeting the requirements of small and medium size businesses in low density environments.
  - A diverse source of Internet connectivity as part of a business continuity plan.

- **WiFi Hot Spot Backhaul**
  - A WiMAX backhaul provides full wireless solution to these wireless networks.
  - Connecting Wi-Fi hotspots with each other and to other parts of the Internet.

- **Areas of low population density and flat terrain**
  - Particularly suited to WiMAX and its range.

- **Interfacing with portable MP3 audio players and digital cameras**
  - MP3 audio players and digital cameras rely on PC households to synchronize or transfer content.
  - Mobile WiMAX connects these multimedia devices to the Internet, enabling new revenue sources for operators and content owners while providing convenience and valuable new services for consumers.

- **Promoting Media Libraries and lessening Storage Requirements**
    - Consumer electronics devices that currently store music and video content can lessen their storage requirements by streaming media to the subscriber from home media libraries or e -commerce portals.
    - New content can be leased to consumers instead of purchased. This leasing model of micro-payments creates new revenue sources for the network operator as well as the content owner.

Chapter 2 Technical Overview Of WiMAX

2.1 Types of WiMAX

There are two types of WiMAX system:-

- Fixed WiMAX
- Mobile WiMAX

2.1.1 Fixed WiMAX

- Fixed WiMAX refers to the system built using 802.16-2004 ('802.16d') as the air interface technology.[1]
- Line Of Sight transmissions use higher frequencies upto 66GHz.
- The fixed version of WiMAX, based on 802.16-2004, can provide data rates up to 75 megabits per second (Mbps) per four-sector base station (18.7-Mbps peak data rate per sector) with typical cell sizes of 2 to 10 kilometers in urban and suburban areas (50 km in rural areas).
- This is enough bandwidth to simultaneously support (through a single base station) more than 60 businesses with T1/E1-type connectivity and hundreds of homes with DSL-type connectivity.

Fixed Mobile is suitable for fixed Wireless Landline communications and fixed computers to provide broad band wireless network.

2.1.2 Mobile WiMAX

- Mobile WiMAX refers to the system built using 802.16e-2005 as the air interface technology. "Mobile WiMAX" implementations are therefore frequently used to deliver pure fixed services.[1]
- WiMAX uses a Lower Frequency Range – 2 GHz to 11 GHz (Similar to WiFi).
- Since, Lower-wavelength transmissions are not as easily disrupted by physical obstructions --they are better able to diffract, or bend, around obstacles. Hence, lower frequency ranges are suitable for mobile communication and mobile wireless internet service.

Mobile WiMAX is suitable for Mobile communication and mobile wireless broadband service in cell phones, smart phones and laptops**.** It allows people to communicate while walking or riding in cars and provides a mobile voice over IP (VoIP) and higher-speed data alternative to the cellular networks (GSM, TDMA, CDMA).

2.2 WiMAX Network Description

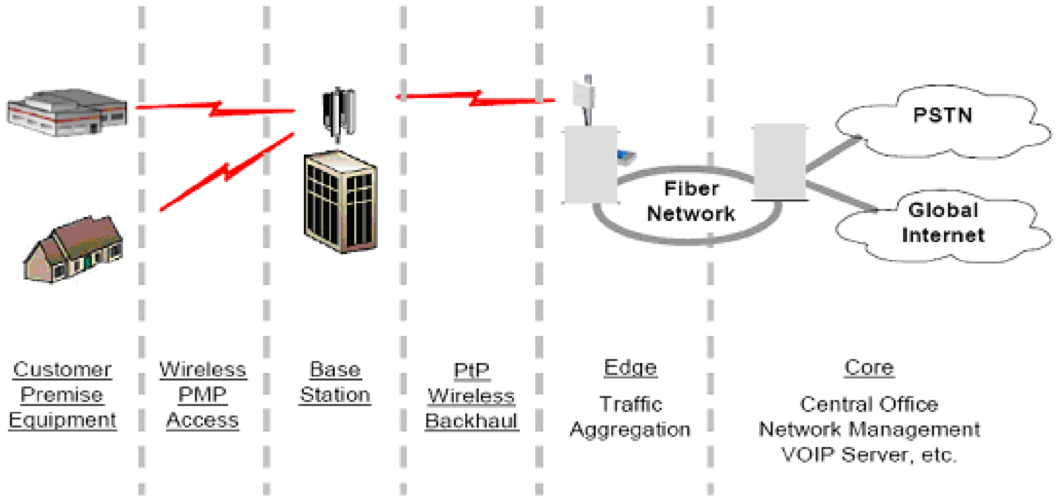


Fig.2.1 Network Description

2.3 Parts Of WiMAX System

Typically, a WiMAX system consists of two parts:

1. WiMAX Base Station
2. WiMAX Receiver (subscriber Unit)

WiMAX Base Station

- Base station consists of indoor electronics and a WiMAX tower. Typically, a base station can cover up to 10 km radius (Theoretically, a base station can cover up to 50 kilo meter radius or 30 miles, however practical considerations limit it to about 10 km or 6 miles). Any wireless node within the coverage area would be able to access the Internet.
- Several base stations can be connected with one another by use of high-speed backhaul microwave links. This would allow for roaming by a WiMAX subscriber from one base station to another base station area, similar to roaming enabled by Cellular phone companies.

2.3.2 WiMAX Receiver (Subscriber Unit)

- Is the Digital Base band Receiver that processes the I /Q Data .

- The receiver and antenna could be a stand-alone box or a PCMCIA (Personal Computer Memory Card International Association) card that sits in your laptop or computer. Access to WiMAX base station is similar to accessing a Wireless Access Point in a WiFi network, but the coverage is more.

2.4 WiMAX Base Station Architecture

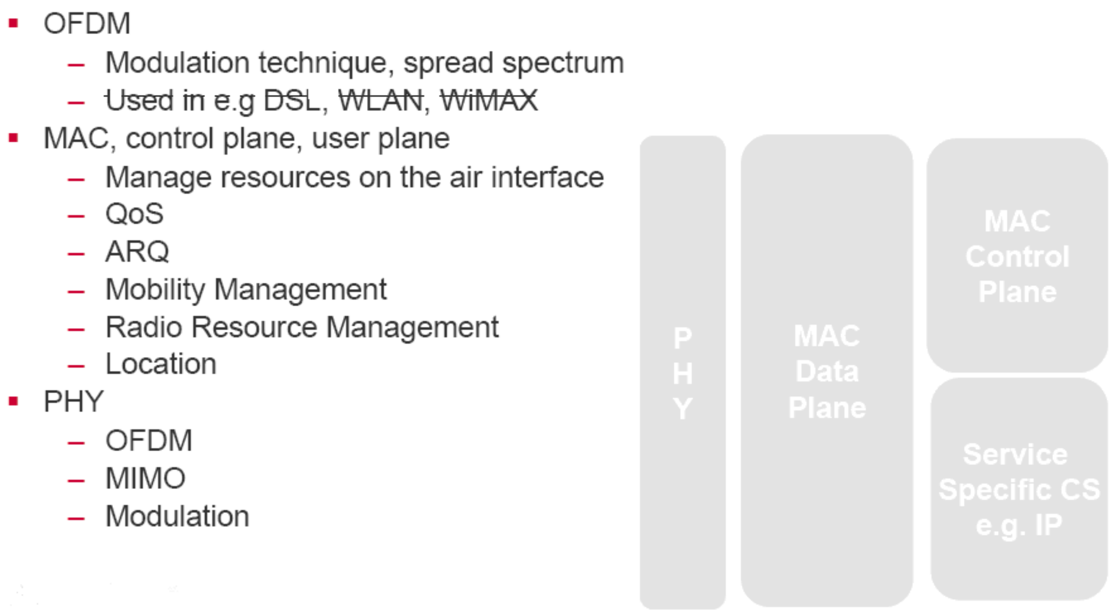


Fig.2.2 Base station Architecture [17]

2.4.1 OFDM (Orthogonal Frequency Division Multiplexing)

- It is a digital encoding and modulation technology.
- It achieves high data rate and efficiency by using multiple overlapping carrier signals.
- Key advantage of OFDM over single carrier modulation schemes is the ability to deliver higher bandwidth efficiency. Hence, higher data throughput even in NLOS links suffering from significant degradation due to multi path conditions.

2.4.2 MAC (Media Access Control) Layer

The main focus is to manage the resources of the airlink in an efficient manner. The MAC layer consists of three sub-layers.

- Service specific convergence sub-layer (SSCS) provides an interface to the upper layer entities througha CS service access point (SAP).
- The MAC common part sub-layer (CPS) provides the core MAC functions, including uplink scheduling, bandwidth request and grant, connection control, and automatic repeat request (ARQ).
- Privacy sub-layer (PS) provides authentication and data encryption functions.

- **MAC Layer functions**

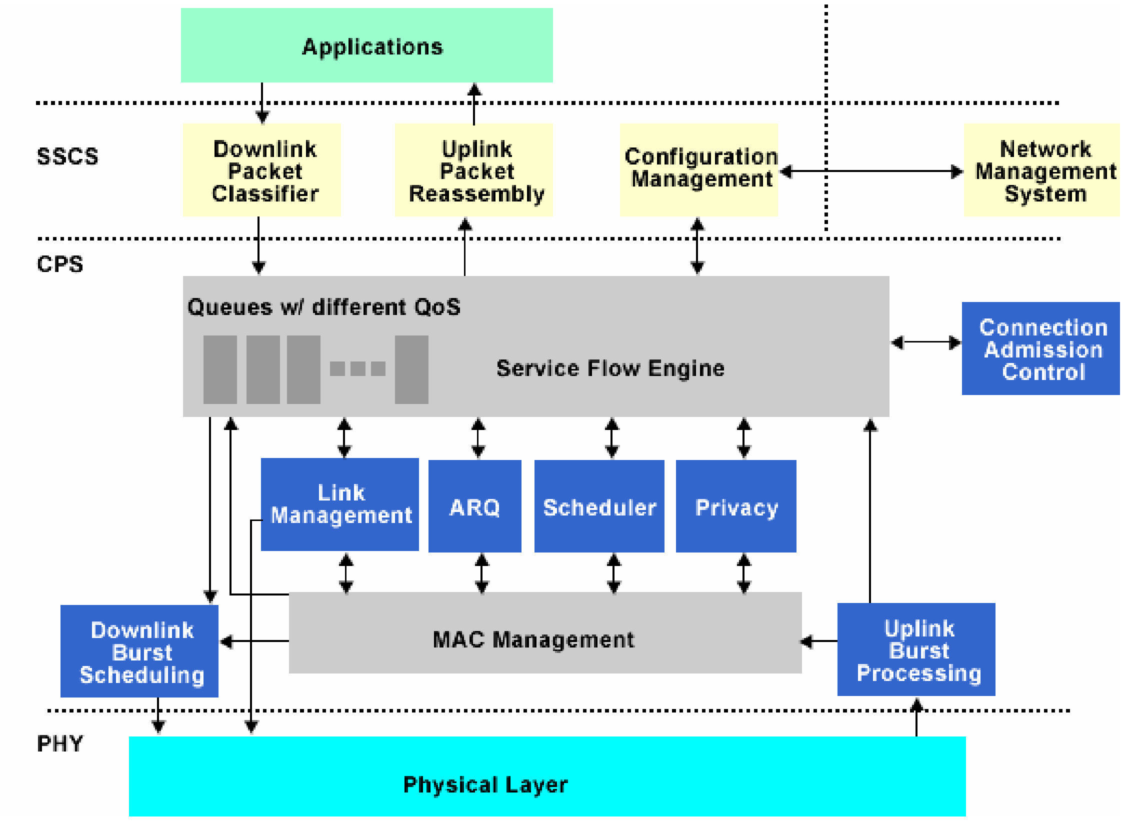


Fig.2.3 MAC Layer functions

2.4.3 PHY Layer

- This standard specifies the air interface of a fixed (stationary) point-to-multipoint (PMP) BWA system providing multiple services in a wireless metropolitan area network .
- It also specifies an optional mesh topology enhancement to the medium access control layer.

- The Wireless MAN MAC is capable of supporting multiple physical layer (PHY) specifications optimized for the frequency bands of application. The standard includes PHY specifications, applicable to systems operating below 11 GHz and between 10 GHz and 66 GHz. The 10–66 GHz air interface, based on single-carrier modulation, is known as the WirelessMAN-SC air interface.
- For frequencies below 11 GHz, the WirelessMAN-SCa, Wireless-MAN-OFDM and WirelessMAN-OFDMA air interfaces are specified.

- **PHY Layer Functions**

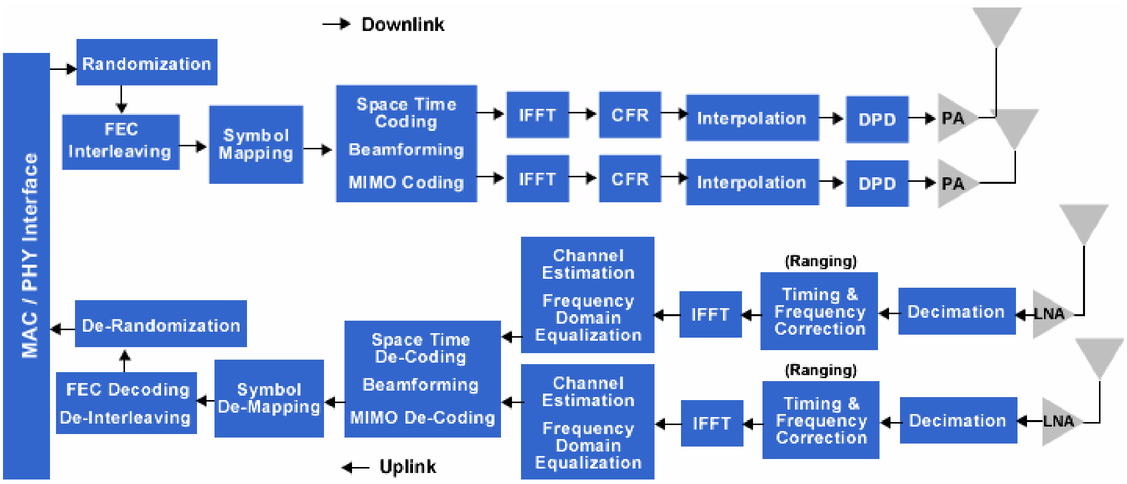


Fig.2.4 PHY Layer Functions

2.5 802.16 standards

The WiMAX Technology is based on the 802.16 standards defined by the IEEE. The various forms of the 802.16 standards which evolved with time are as follow:-

2.5.1 802.16a:-The first 802.16 standard was approved in December 2001. It delivered a standard for point to multipoint Broadband Wireless transmission in the 10-66 GHz band, with only a Line of Sight (LOS) capability. It uses a single carrier (SC) physical (PHY) standard.

2.5.2 802.16:- 802.16a was an amendment to 802.16 and delivered a point to multipoint capability in the 2-11 GHz band. , it also required a non line of sight (NLOS) capability, and the PHY standard was therefore extended to include Orthogonal

Frequency Division Multiplex (OFDM) and Orthogonal Frequency Division Multiple Access (OFDMA).

2.5.3 **802.16c**:- A further amendment to 802.16, delivered a system profile for the 10-66 GHz 802.16 standard.

2.5.4 **802.16d**:-The 802.16d standard of extending 802.16 supports three physical layers (PHYs). The mandatory PHY mode is 256-point FFT Orthogonal Frequency Division Multiplexing (OFDM). The other two PHY modes are Single Carrier (SC) and 2048 Orthogonal Frequency Division Multiple Access (OFDMA) modes.

2.5.5 **802.16e**:-It uses Scalable OFDMA to carry data, supporting channel bandwidths of between 1.25 MHz and 20 MHz, with up to 2048 sub-carriers. It supports adaptive modulation and coding, so that in conditions of good signal, a highly efficient 64 QAM coding scheme is used, whereas where the signal is poorer, a more robust BPSK coding mechanism is used. . The purpose of 802.16e is to add data mobility to the current standard, which is designed mainly for fixed operation.

2.6 IEEE 802.16 standards

IEEE 802.16 Standards

	IEEE 802.16	IEEE 802.16 Rev'd	IEEE 802.16e
Completed	December 2001	May 2004	Est. Mid-2005
Spectrum	10 - 66 GHz	2 - 11 GHz	2 - 6 GHz
Application	Backhaul	Wireless DSL & Backhaul	Mobile Internet
Channel Conditions	Line of Sight Only	Non-Line of Sight	Non-Line of Sight
Bit Rate	32 - 134 Mbps at 28-MHz Channelization	Up to 75 Mbps at 20-MHz Channelization	Up to 15 Mbps at 5-MHz Channelization
Modulation	QPSK, 16QAM & 64QAM	OFDM 256, OFDMA 2048 QPSK, 16QAM, 64QAM	Same as 802.16d, Scalable OFDMA
Channel Bandwidths	20, 25 & 28 MHz	Selectable Channel Bandwidths Between 1.5 & 20 MHz	Same as 802.16d

Table 2.1 IEEE 802.16 Standards [17]

2.7 802.11/802.16 Spectrum

Most commercial interest is in the 802.16d and .16e standards, since the lower frequencies used in these variants suffer less from inherent signal attenuation and therefore give improved range and in-building penetration.

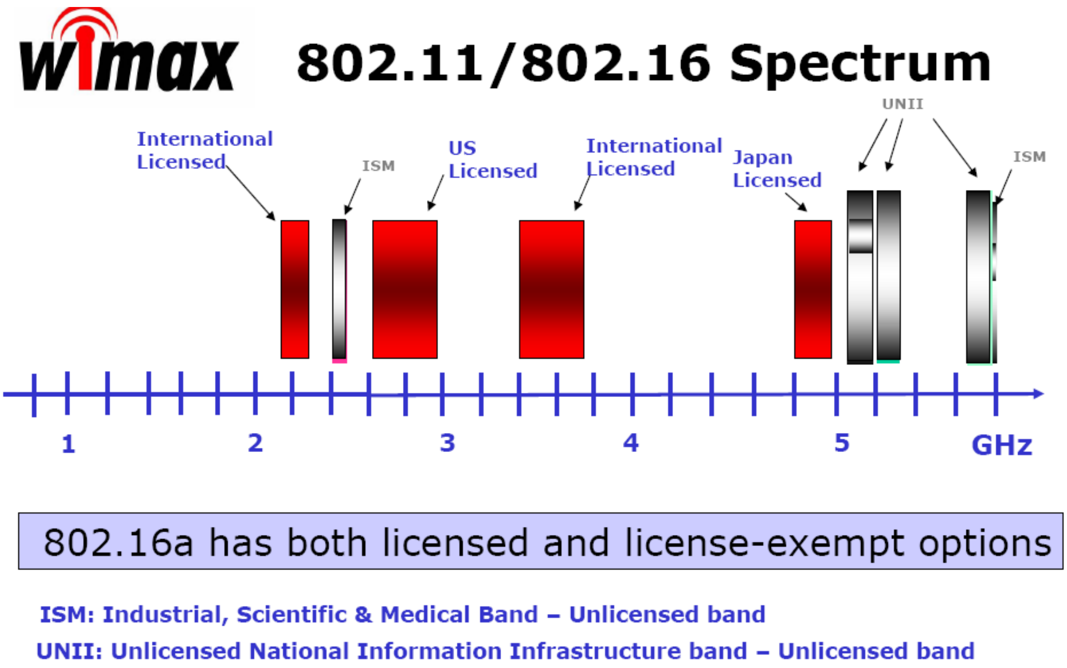


Fig. 2.5 802.11/802.16 Spectrum [15]

2.8 Frequency Band Assigned In Various Parts of the World

- The 802.16 specification applies across a wide swath of the RF spectrum.
- However, there is no uniform global licensed spectrum for WiMAX.
- In the US, the biggest segment available is around 2.5 GHz.
- Elsewhere in the world, the most likely bands used will be around 3.5 GHz, 2.3/2.5 GHz, or 5 GHz, with 2.3/2.5 GHz probably being most important in Asia and 3.5GHz is most prominent in European countries.[1]

•3.5GHz will be global licensed frequency

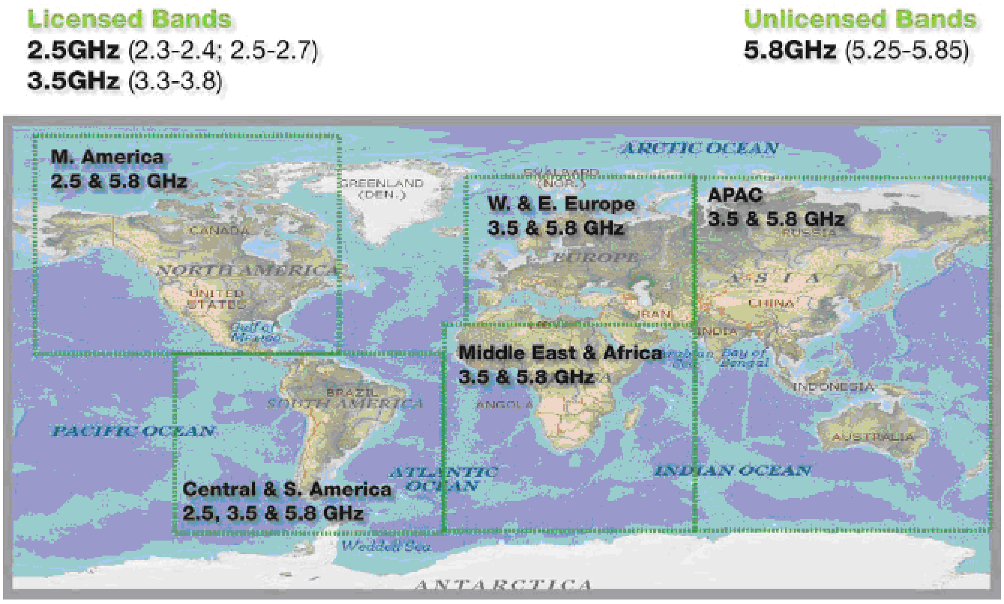


Fig. 2.6 Industry & Governments aligning Frequencies

2.9 Comparison of Relevant Frequency Bands

Band	5.8 GHz Band	2.5 GHz Band	3.5 GHz Band
Licensing	License-exempt spectrum	Licensed spectrum US, Canada, Latin America	Licensed spectrum in Europe, Latin America and Asia
Cost	n/a	Cost will vary from country to country depending on regulations, may also lease from existing license holder. Cost therefore, could be CAPEX or OPEX	
Spectrum	Up to 125 MHz available in U.S. (may vary in other countries)	22.5 MHz (16.5 MHz + 6 MHz) per license[3] in the U.S.	Assignments vary country by country
Allowable Transmit Power/EIRP[4]	US: Max Power to antenna 1 Watt, Max EIRP +53 dBm (200 Watts), Note: Limits may vary in other countries	Max EIRP +55dBW in U.S.	Per ETSI: 3 Watts (+35dBm) max to antenna (may vary in countries outside Europe)
Interference Control	Restrict deployment to less than 1/2 the	Protected by license assignment, no two operators assigned the same frequency in the	

	available spectrum, use auto channel select & coordination between operators	same geographic area
Base Stations Required	Higher BS capacity results in fewer base station sites to achieve area coverage	More base station sites to meet capacity requirements due to limited spectrum assignment
Indoor and Outdoor CPEs	Can support indoor CPEs at customer sites within ~800 meters from the base station, outdoor CPEs must be deployed elsewhere. Result: Higher average CPE cost and higher average installation costs	Will support a high percentage of indoor CPEs in capacity limited deployments. Result: Lower average CPE cost and lower average installation cost.

Table 2.2 Comparison of frequency Bands

2.10 Competing Technologies

WiMAX Main Competitors are: 3G Systems (UMTS and CDMA2000).The reasons for the conflict are:-

- Both aim to offer DSL-class Internet access in addition to phone service. UMTS has also been enhanced to compete directly with WiMAX in the form of UMTS-TDD, which can use WiMAX oriented spectrum and provides a more consistent, if lower bandwidth at peak, user experience than WiMAX.
- 3G cellular phone systems usually benefit from already having entrenched infrastructure, being upgraded from earlier systems.

Early WirelessMAN standards, the European standard **HIPERMAN** and Korean standard **WiBro** have been harmonized as part of WiMAX and are no longer seen as competition but as complementary.

2.10.1 WiMAX vs. WiFi

FEATURES	WiFi (802.11)	WiMAX (802.16e)	
	• Wide (20MHz) Frequency	• Channel Bandwiths can be choosen by the	

1.Scalability	Channels • MAC Designed to support 10's of Users	operator(e.g. for sectorization) • 1.5MHz to 20MHz width channels. MAC Designed for scalability independent of channel bandwidth • MAC Designed to support thousands of users.	**802.16a is designed for subscriber density**
2.Relative Performance	**Channel Bandwidth:** 20 MHz **Maximum Data Rate:** 54 Mbps **Maximum bps/hz:** ~2.7 bps/Hz	**Channel Bandwidth:** 10,20 MHz ; 1.75,3.5,7,14 MHz ; 3,6 MHz **Maximum Data Rate:** 63 Mbps* **Maximum bps/hz:** ~5.0 bps/Hz	**802.16a is designed for metropolitan performance**
3.Range	• Optimised for ~100 meters • No "near-far" compensation • Designed to handle indoor multi-path(delay spread of 0.8 microsec) • Optimization centers around PHY and MAC layer for 100m range • Range can be extended by crankling up the	• Optimised for up to 50 Km • Designed to handle many users spred out over kilometers • Designed to tolerate greater multi-path delay spread (signal reflections) up to 10.0 micro sec. • PHY and MAC designed with multi-mile range in mind • Standard MAC	**802.16a is designed for distance**

	power – but MAC may be non-standard		
4.Coverage	• Optimized for indoor performance • No mesh topology support within ratified standards	• Optimised for outdoor NLOS performance • Standard supports mesh network topology • Standard supports advanced antenna techniques	**802.16a is designed for market coverage**
5.Quality Of Service (QOS)	• Standard cannot currently guarantee latency for Voice,Video • Standard does not allow for differentiated levels of service on a per-user basis • TDD only - asymmetric	• Designed to support Voice and Video from ground up • Supports differentiated service levels: e.g. T1 for business customers;best effort for residential. • TDD/FDD/HFDD – symmetric or asymmetric	**802.16a is designed for class operation**

Table 2.3 Comparison between WiMAX and WiFi [15]

This clearly signifies that the WiMAX has overhand over WiFi as WiMAX has better Scalability, Range, Relative Performance, Coverage and Quality of Service.

2.10.2 Mobility & Coverage vs. Data Rate Of Different Technologies

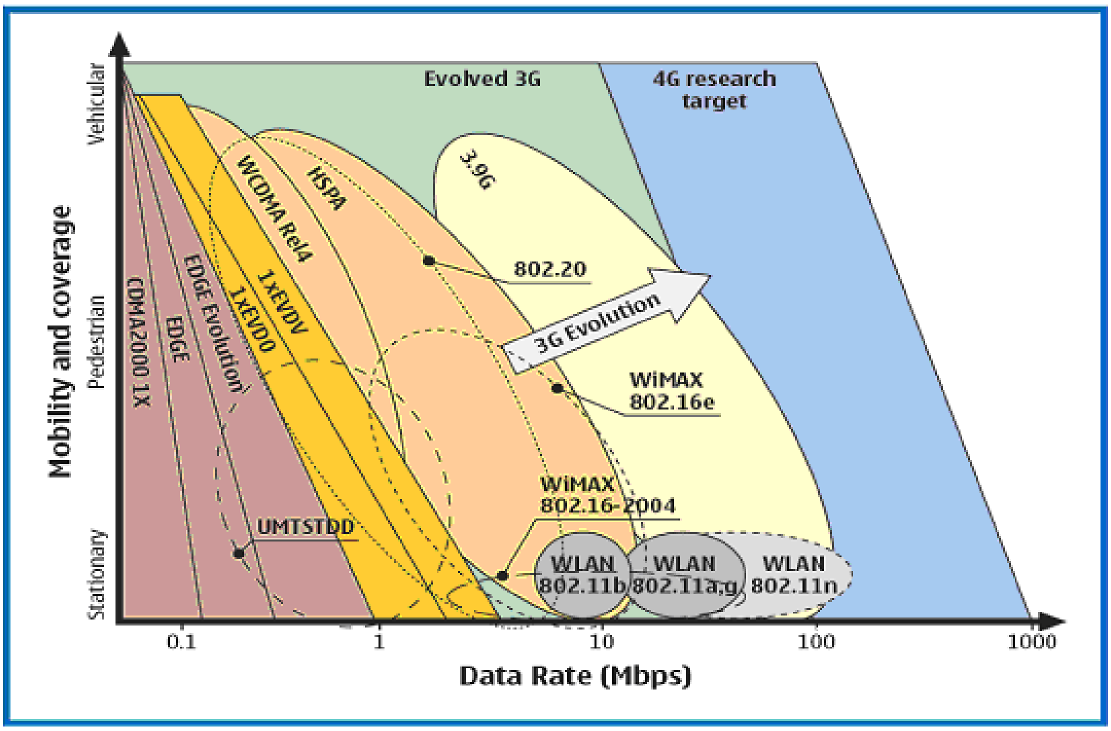


Fig. 2.7 Mobility & Coverage vs. Data Rate of Different Technologies [17]

Speed vs. Mobility of various Technologies

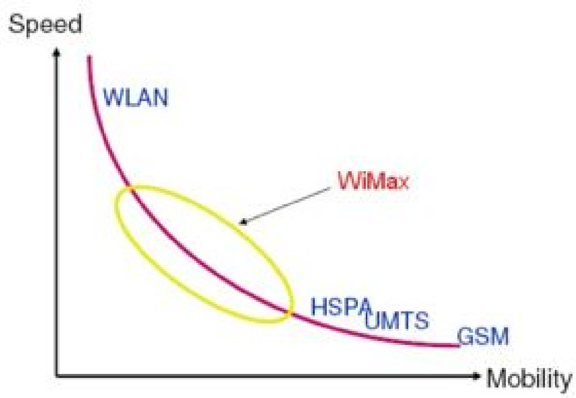


Fig. 2.8 Speed vs. Mobility of Various Technologies [1]

Chapter 3 <u>Market Potential Of WiMAX</u>

3.1 Salient Features of WiMAX Technology

- With one of the strongest technology ecosystems today, WiMAX is being promoted by more than 400 companies across the telecommunication and networking industries.
- Six of the 10 largest semiconductor companies have announced WiMAX strategies and products.

3.2 WiMAX Penetration Rate

Huge growth potential for BWA Subscribers

It has been estimated that tha WiMAX Technology will follow exponential penetration Rate and huge Growth potential is present as shown in the figure below.

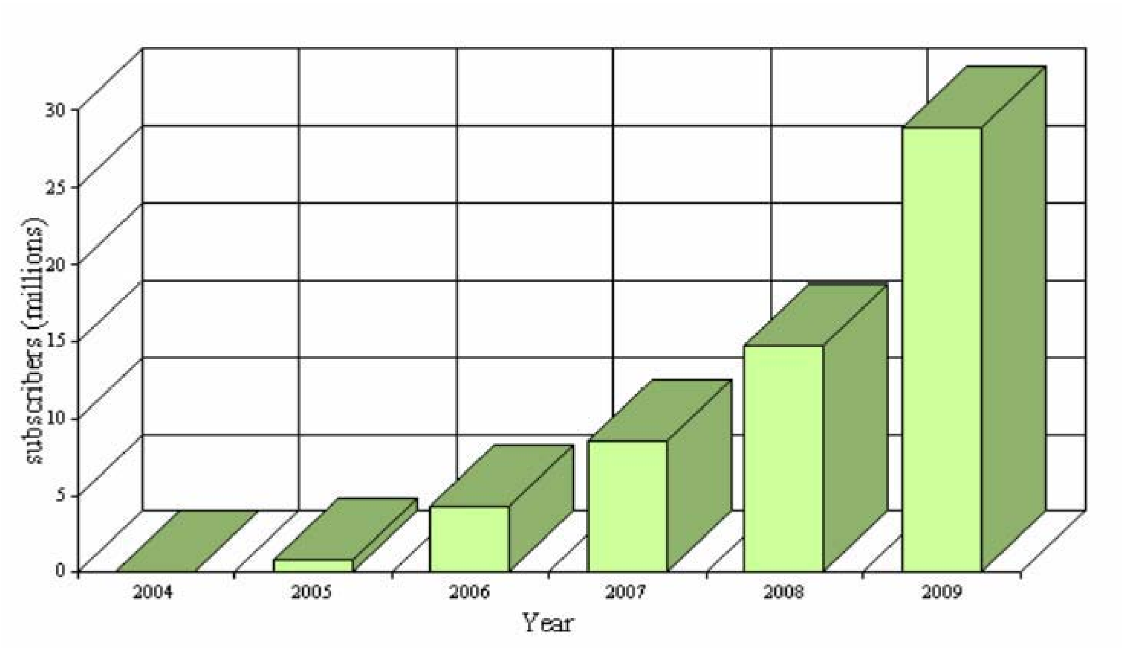


Fig. 3.1 Number of WiMAX Subscriber vs. Year [14]

3.3 Wireless Broadband Market Potential

The Wireless broad band market potential is directly linked to the WiMAX market potential since WiMAX is the frontier in the Wireless broad band access systems. Various analysts estimate huge market in the future. Some of the examples are as follow:-

- Industry analysts believe the WiMAX Market will be worth anywhere from \$3 billion to \$5 billion by 2009.
- The UMTS Forum predicts that mobile traffic volumes will grow **23** fold between 2012 and 2020.

- Monthly user averages from around 520 Mbytes in 2012 to 12 Gbytes per month in 2020.
- Many countries in Europe have long-established copper networks where up to 40 percent of the fixed-line subscribers cannot benefit from DSL because of distance limitations.
- People use their notebooks 30 percent more once they have wireless access.
- **N**otebook users averaged around eight hours of new productivity per week when they received wireless networking capability.
- 10 million BWA customers worldwide by 2008.
- Mobile WiMAX infrastructure and client devices to support the operator trials and commercial launches continue to emerge. More than 50 consumer electronics product announcements for Mobile WiMAX, from desktop customer premise equipment (CPE) to multi - mode ultra-mobile PCs to in-dash vehicle information and entertainment systems.
- Market Momentum spurred by Intel's backing and large companies on the WiMAX forum.
- Large telecommunications carriers, worldwide assessing WiMAX technology for trials and implementation in the markets they serve.

3.4 WiMAX Progress In India

Maravedis predicts WiMAX subscribers to reach 13 million in India by 2012.According to a report by research firms Maravedis and Tonse Telecom (Telecom Market Research & Analysis) India will have 13 million WiMAX subscribers by 2012. [6]

Since, India is the second largest growing country in the mobile communication network. A huge market is supposed to be available in India in coming future.Some of the measures taken by the prominent companies to introduce WiMAX in India are as follows:-

- Bharti TeleVentures, Reliance, BSNL and VSNL (Tata Group) have all acquired licenses in 3.3GHz range and are in various stages of trials and modest commercial deployments.

- VSNL to install 2,000 WiMAX base stations
    - The Tata Group-controlled VSNL is planning to roll out 2,000 WiMAX base stations across the sub-continent. The company will spend INR45 billion (USD1.1 billion) over two years on the project

- Motorola is strengthening its presence in the hinterlands through its extensive BWA projects for state governments.

- Alcatel has set up a joint venture with the C-Dot (the R&D arm of the DoT) to focus on exclusive BWA/WiMAX solutions that are tailor made for India at price points the Indian consumer is comfortable paying.

- Intel is making significant progress in working closely with the Indian Government in bringing the latter's rural broadband goals to reality. The innovative" village entrepreneur" model, together with a net-enabled community info-kiosk, is an ideal way to reach the many who are not yet connected.

3.5 Motivation for the WiMAX Markets

- **Government endorsement of initiatives**
  - South Korea's WiBro service
  - Taiwan's M-Taiwan program

  Both these projects are aimed by the governments of South Korea and Taiwan to implement WiMAX in their respective countries. These are the positive indicators for broadband wireless adoption.

- **New Revenue Sources**

  With the arrival of WiMAX technology new sources of income for the WiMAX service providing firms are generated.Some of the examples are:-

  - Consumer electronics devices can lessen their storage requirements by streaming media to the subscriber from home media libraries or e - commerce portals. New content can be leased to consumers. This leasing model of micro-payments creates new revenue sources for the network operator as well as the content owner.
  - Successful consumer electronics categories such as portable MP3 audio players and digital cameras rely on PC households to synchronize or transfer content. Mobile WiMAX connects these multimedia devices to the Internet, enabling new revenue sources for operators.

3.6 Future Developments in WiMAX

Most of the leading companies involved in the establishment and progress of WiMAX system are involved in the research & development field to move WiMAX system to the next higher level. Some of the objectives for the improvement of WiMAX are:-

- WiMAX II, 802.16m will be proposed for IMT-Advanced 4G.

- WiMAX-m concentrating on MIMO-AAS, mobile multi-hop relay networking & related developments to deliver 10X & higher Co-Channel reuses multiples.

- Mobile WiMAX based upon 802.16e-2005 has been accepted as IP-OFDMA for inclusion as the sixth wireless link system under IMT-2000. This can hasten acceptance by regulatory authorities and operators for use in cellular spectrum.

- Goal is to achieve 100 Mbit/s mobile and 1 Gbit/s fixed-nomadic bandwidth as set by ITU for 4G NGMN (Next Generation Mobile Network) systems through the adaptive use of MIMO-AAS and smart, granular network topologies.

Chapter 4 Circuit Layout And PCB Design

4.1 Prominent Manufacturers Of WiMAX Chipsets

- TEXAS INSTRUMENTS
- INTEL
- WAVESAT
- SEQUANS
- FUJITSU
- NORTEL

4.2 Texas Instruments

(WIRELESS WIMAX INFRASTRUCTURE)

The block diagram of the WiMAX solution of the Texas Instruments is given below.

4.2.1 Block Diagram

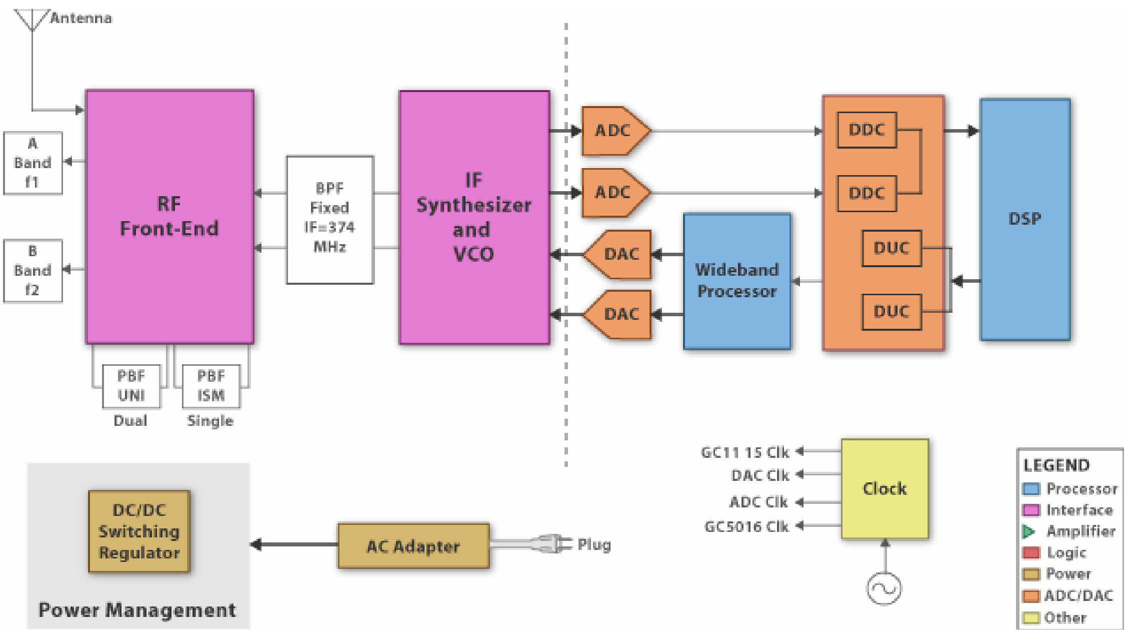


Fig. 4.1 Block Diagram Of WiMAX Module

4.2.2 TI HARDWARE SOLUTIONS

The hardware WiMAX system slution of the Texas Instruments consist of the following sections:

- RF Front End Solution (TRF2436)-for both 2.45GHz & 5.6GHz.
- Transceiver chip with DUAL VCO & IF Synthesizers (TRF 2432).
- ADC DAC interface.
- Base band Processor.
- Digital Up Converters & Down Converters.
- Integrated DSP based solutions.

4.3 TRF 2432(Dual Band I/Q Transceiver With Dual VCO Synthesizers)

TRF 2432 is a Dual Band I/Q Transceiver chip which is designed to perform the IQ conversion at 374MHz IF as well as provide an RFLO and control logic to a TI RF Front End. The TRF 2432 uses a common IF frequency for both bands,which eliminates the need for an additional IF filter.

4.3.1 Salient Features

- RF LO Frequency Range:– 2651 – 3150 MHz.
- It is a fully integrated IQ transceiver specifically for use in 802.16 d/e applications.
- Designed to perform the IQ conversion at 374MHz IF as well as provide an RFLO and control logic to a TI RFFE (Radio Frequency Front End).
- Uses a common IF frequency for both band.
- Has an internal IQ DC offset calibration function for the receive IQ interface.
- TRF2432 includes two synthesizers with VCOs, IQ modulator, IQ demodulator, anti aliasing filters; IF amplifiers receive AGC circuit, transmit power control and serial interface.
- Reference Frequency: - 40 or 44 MHz.
- IF = 374 MHz (Both Bands).

The circuit realization and the block diagram of the Wimax Transceiver chip is shown below.
The differential LO output from the RF frontend is fed directly to the TRF2432 module.
The filtered output from IF filter is fed to the differential IF inputs of Transceiver module .The details of the circuit are shown in the diagram.

4.3.2 Functional Block Diagram

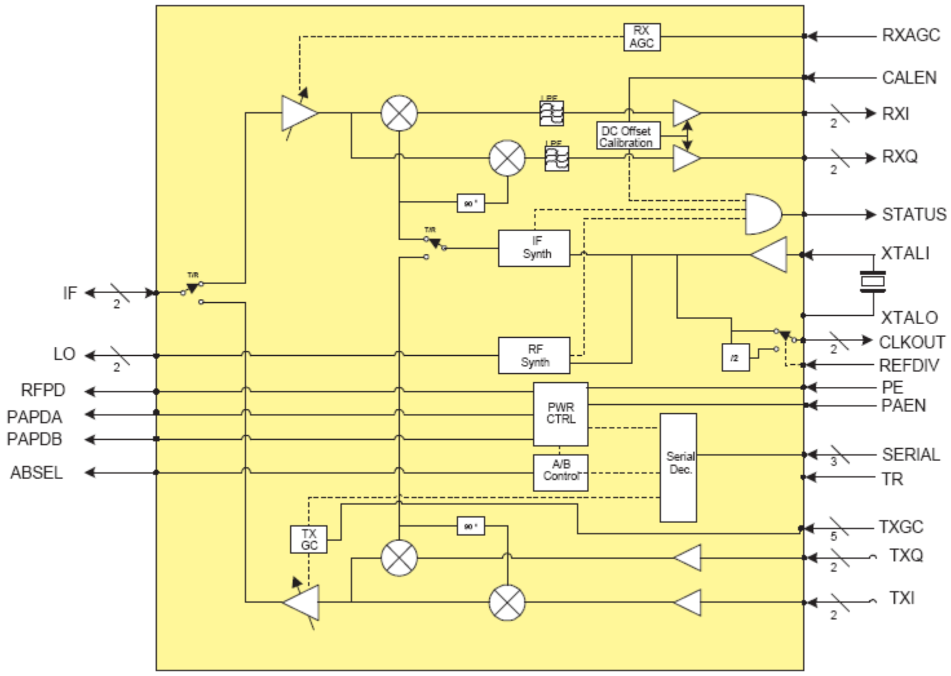


Fig. 4.2 Functional Block Diagram of TRF 2432

4.3.2 Circuit Design Of Transceiver Chipset

Refer to the appendix 1.

4.3.3 PCB Layout Of TRF 2432

- **Top Layer Of TRF 2432 PCB**

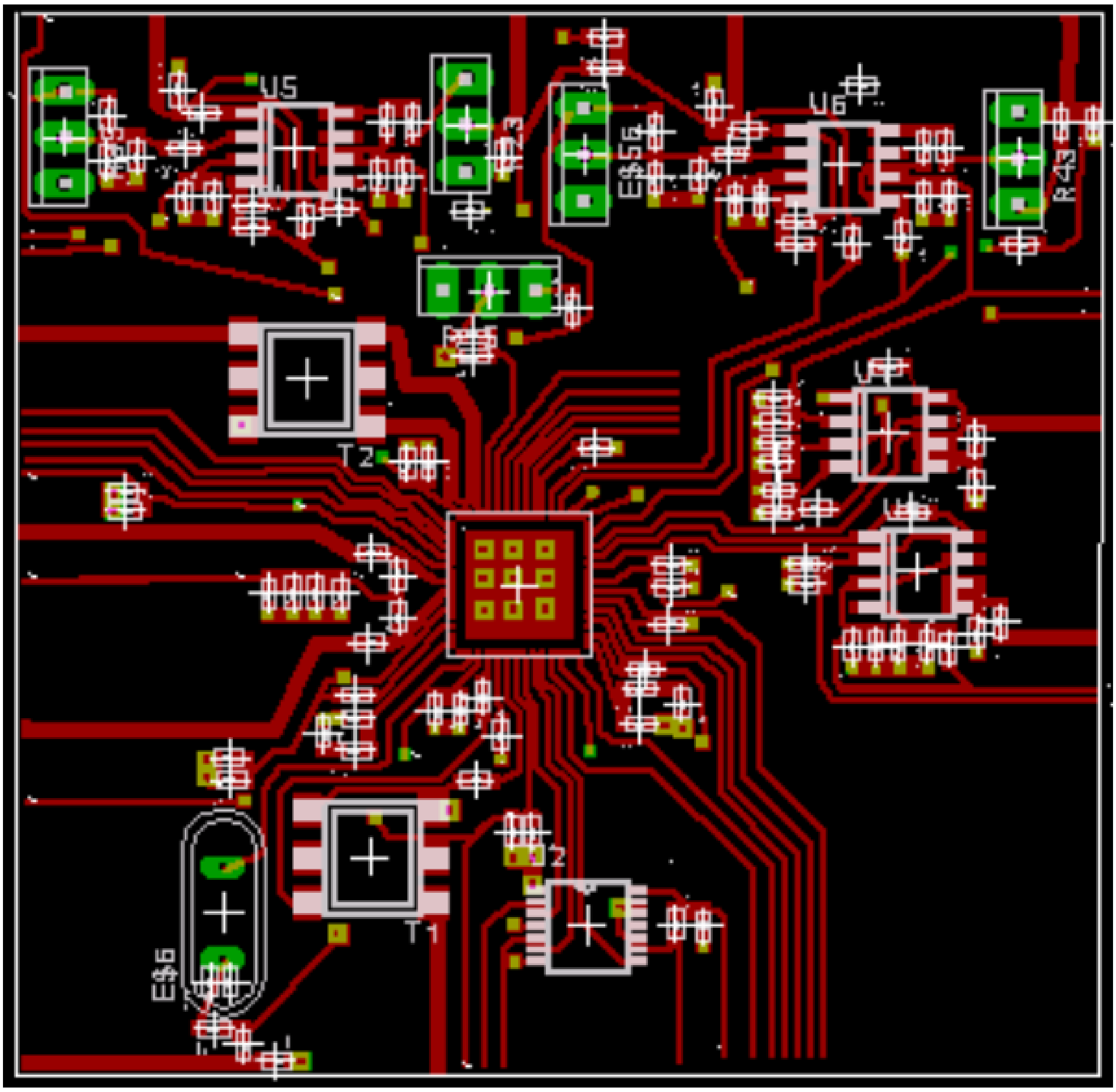


Fig. 4.3 Top Layer of TRF 2432 PCB Design

- **Bottom Layer Of TRF 2432 PCB**

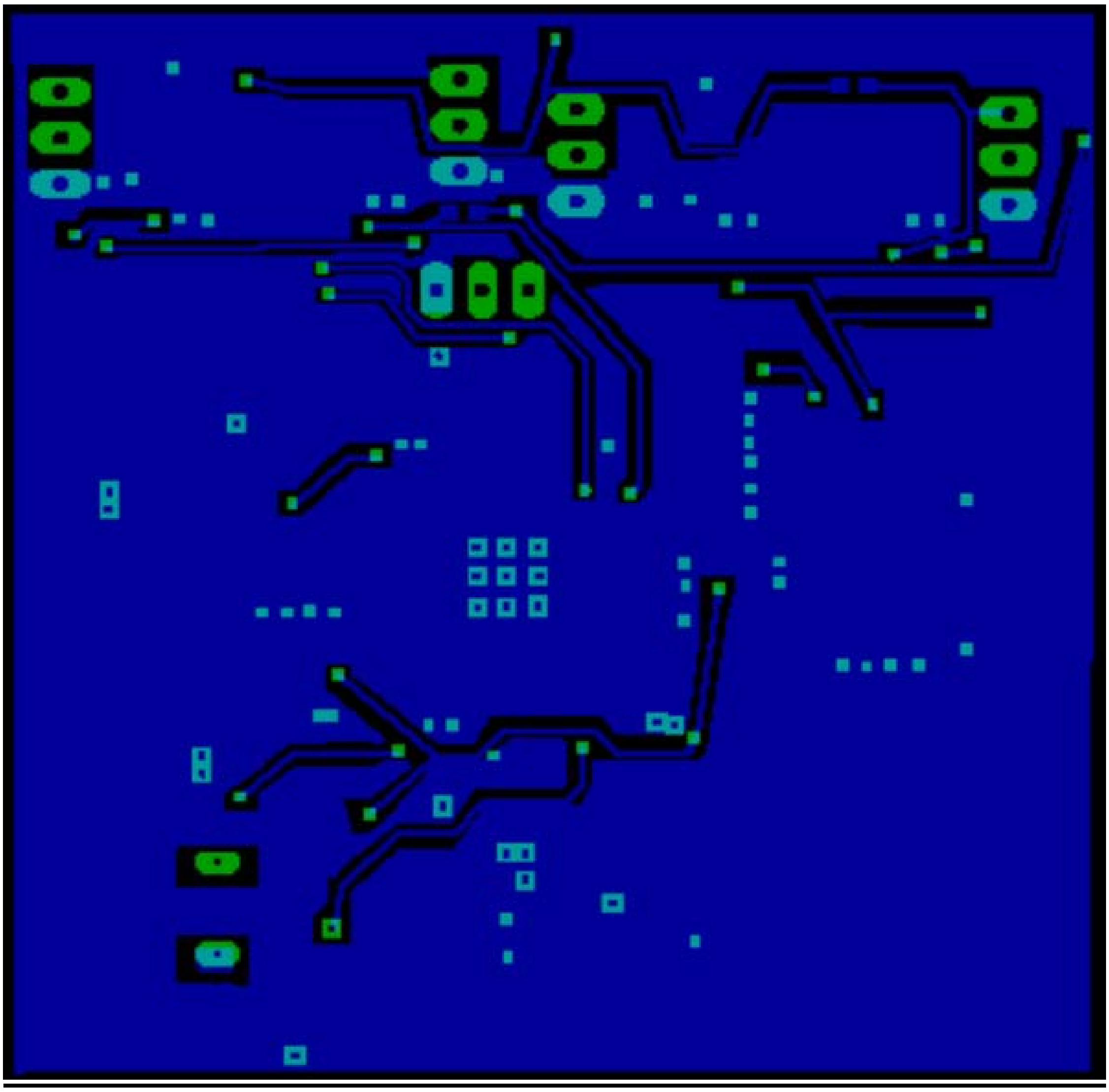


Fig. 4.4 Bottom Layer of TRF 2432 PCB Design

4.4 TRF 2436 :-High-Power Dual-Band (2.4-GHz to 2.5-GHz and 4.9-GHz to 5.9-GHz) RF Front-End

The TRF 2436 is designed to perform RF up and down conversions in the unlicensed ISM and 4.9-5.9 GHz bands. The TRF 2436 uses a common IF frequency for both bands, eliminating the need for additional IF filtering. Combined with the TI TRF 2432 IF/IQ Transceiver/Synthesizer ,the TRF 2436 completes the TI WLAN two-chip radio.

4.4.1 Salient Features

- Has highly integrated 802.16d/e compatible Radio Frequency Front-End.
- Frequency range (2.4-2.5 GHz) & (4.9-5.9 GHz).
- Contains Super Heterodyne architecture for superior Channel Rejection.
- Typical gain: 38dB TX , 20 dB RX.
- IF = 374 MHz.
- Common LO and common IF for both bands.
- Additional Power Amplifier Bias control function.
- Integrated Up/Down converters, LNA's , Transmitter/Receiver switches.
- Integrated Temperature compensated Transmitter Power Detectors.
- Noise Figure: 4 dB ISM Band, 6 dB for 5GHz band.

4.4.2 Functional Block Diagram

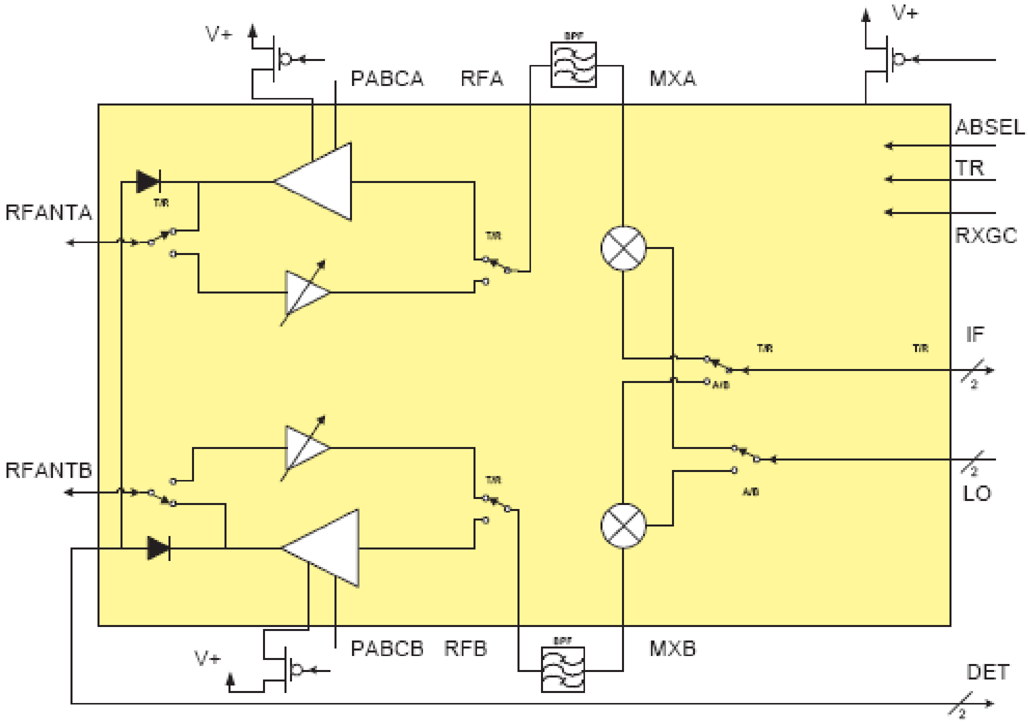


Fig. 4.5 Functional Block Diagram of TRF 2436

4.4.3 Circuit Design Of RF Front End Chipset

- Refer to the appendix 2.

4.4.4 PCB Layout Of TRF 2436

- **Bottom Layer**

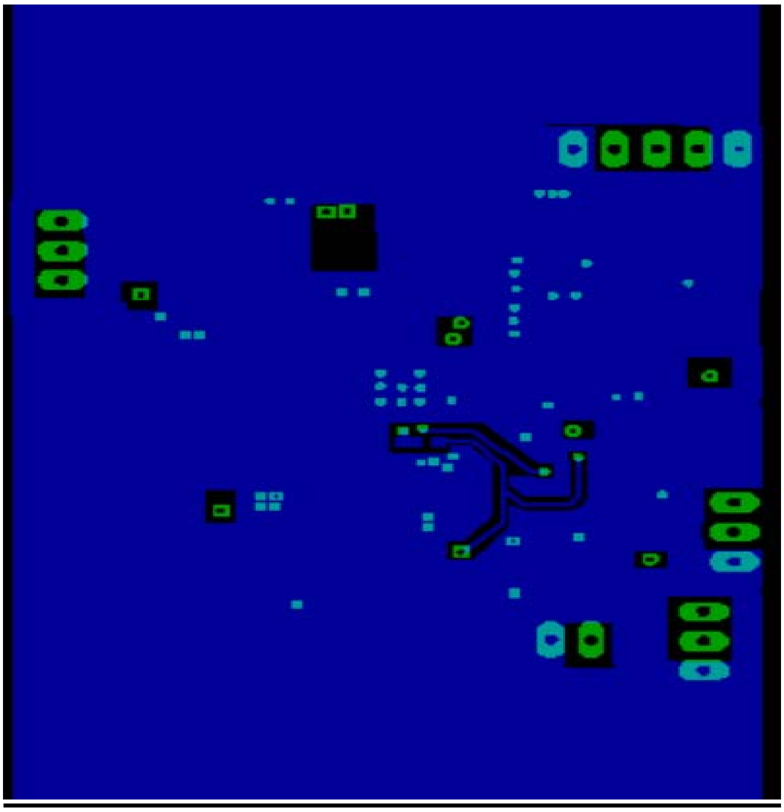


Fig. 4.6 Bottom Layer of TRF 2436 PCB Design

- **Top Layer Of TRF 2436**

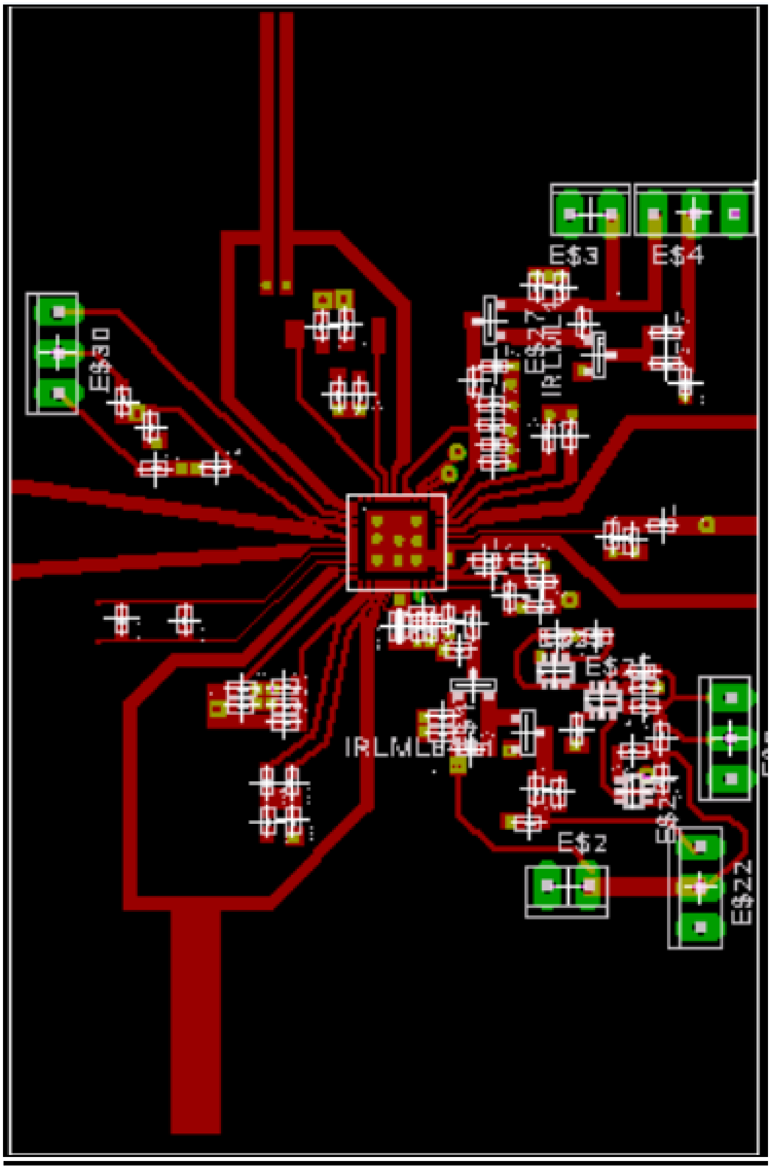


Fig. 4.7 Top Layer of TRF 2436 PCB Design

4.5 <u>Design Of Band Pass Micro Strip Filters</u>

4.5.1 Design of Bandpass Micro Strip Filter(5-5.9 Ghz)

BY HIMANSHU GUPTA

The received signal is filtered though a microstrip based band pass filter centered on 5.6GHz. In order to obtain optimum performance such as quality factor, bandwidth and matching, we choose the microstrip filter. The filter has been implemented using the half wavelength transmission lines and simulated on IE3D. Half wavelength resonator with one end open circuited has been employed. These are the preliminary forms micro strip filters .The filter is implemented as shown in Fig. 4.8

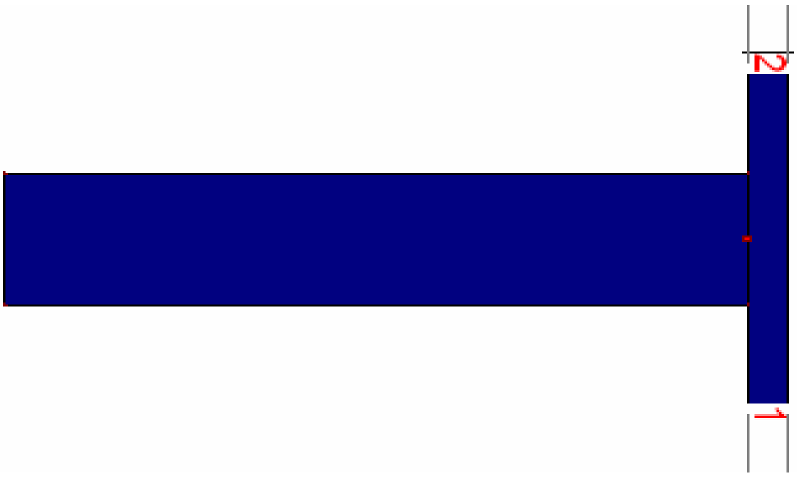
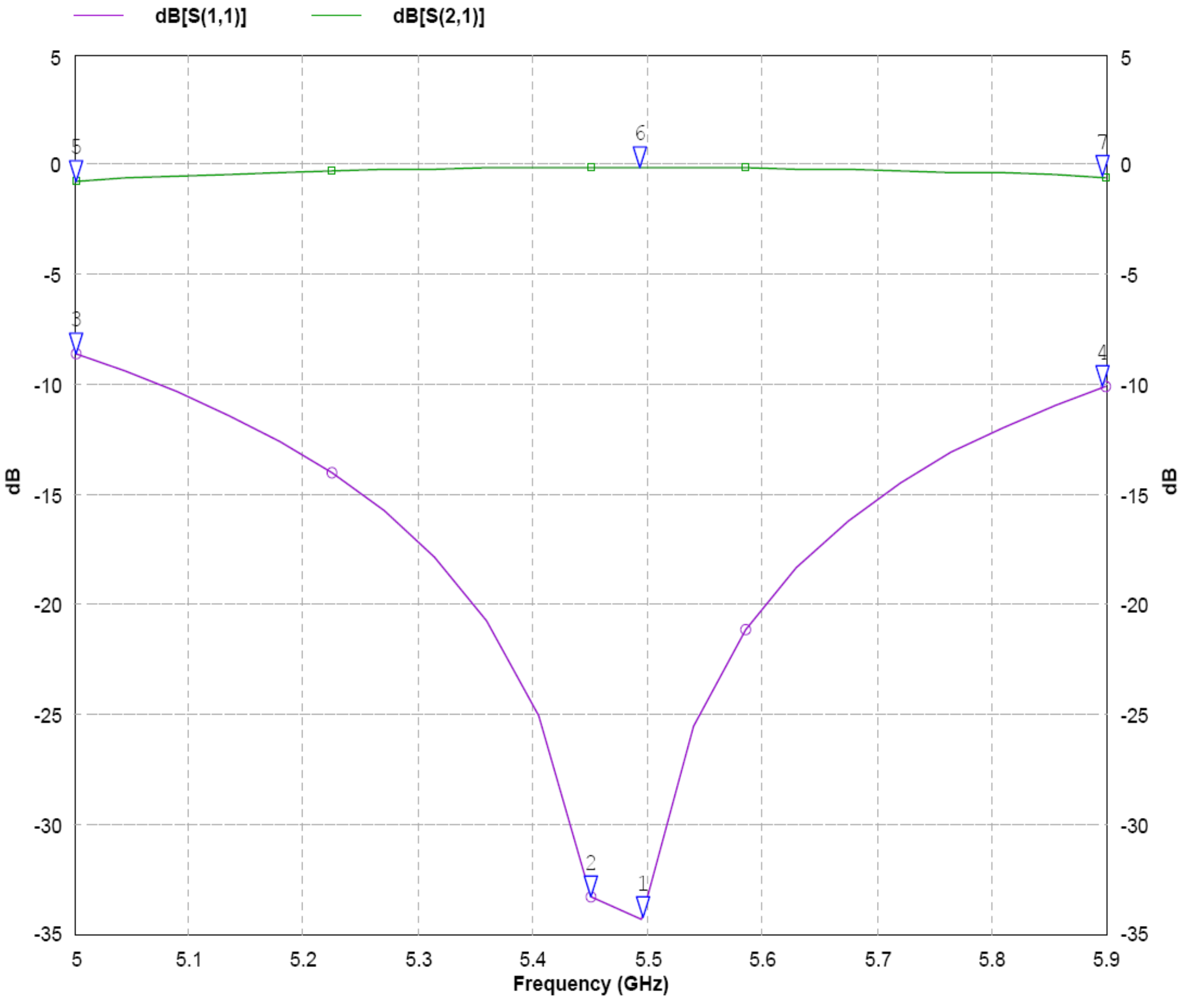


Fig. 4.8 Band pass filter at 5.6GHz

As the feed point position changes on the transmission line, S11 value changes. Thus we need to adjust the feed point so as to obtain perfect 50Ω matching. We also observe that as the width of the line changes or the separation distance alters the bandwidth changes drastically. The width has been approximated for 50Ω impedance. The S11 and S21 of the filter simulated in IE3D is shown in Fig. 4.9



Information List

Current Reference Mode: X Axis
Selected Dot List

No.	X	Y
1	5.49543	-34.2844
2	5.45142	-33.3453
3	5	-8.60809
4	5.89716	-10.1197
5	5	-0.756417
6	5.49401	-0.116791
7	5.89574	-0.564368

Fig. 4.9 Frequency Response Of the Filter

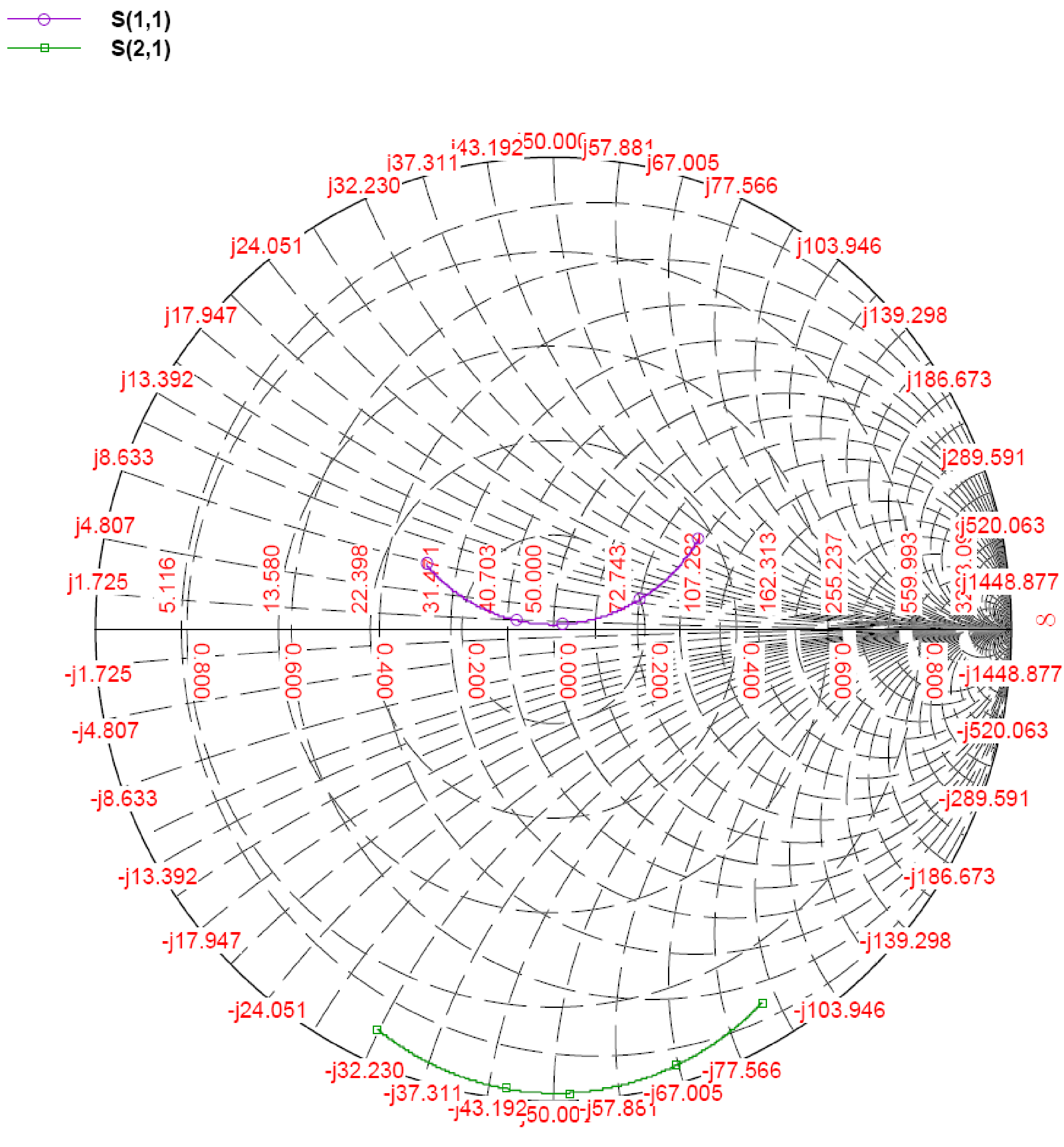


Fig. 4.10 Smith Chart

4.5.2 Design of Band Pass Micro Strip Filter (2-3 GHz)

Since the design of band pass filter (2-3 GHz) involved the use of coupled transmission lines i.e. Comb line type Micro strip Filters (a complicated design) so the design and the simulation was done entirely by our project guide Prof. Girish Kumar.

4.6 TRF 2432 + TRF 2436 (Combined system)

- **Block Diagram of Combined Circuit**

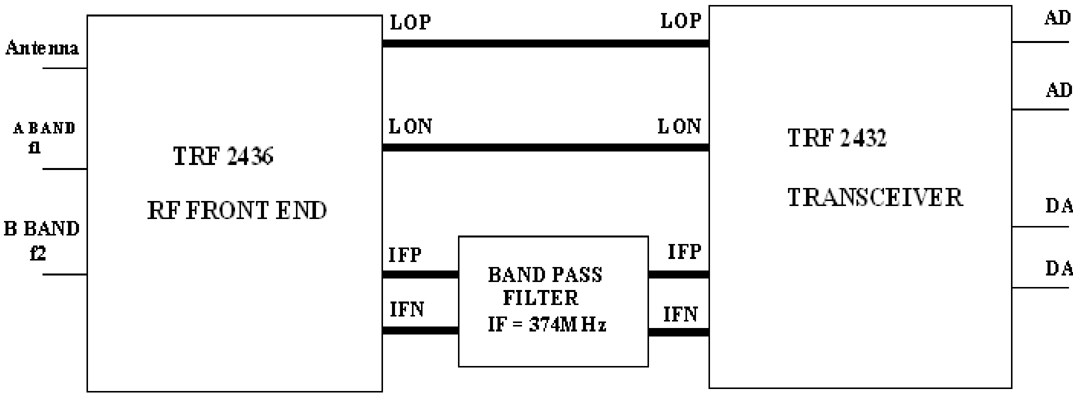


Fig. 4.11 Block Diagram of the combined PCB

LOP: Positive going LO Output
LON: Negative going LO Output
IFP: IF positive going input or output
IFN: IF negative going input or output
A BAND(f1): 2.4 GHz – 2.5 GHz
B BAND(f2): 4.9 GHz – 5.9 GHz

IF Filter(374 MHz)

The IF filter is realized using lumped L,C components(3rd order Butterworth).

- **Block Diagram of IF Filter**

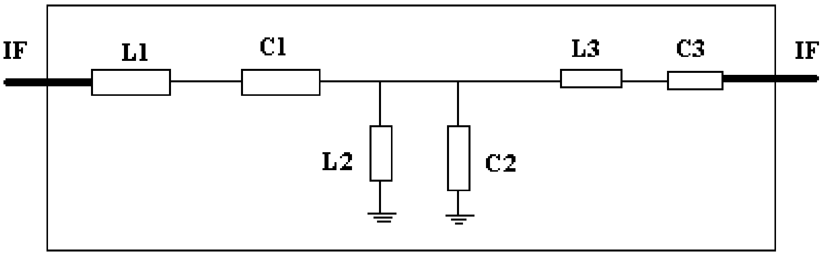


Fig. 4.12 Block Diagram of IF Filter

1. BPF (2.4-2.5 GHZ):- to be connected between Mixer A and RF output A was designed and simulated in IE3D and implemented on microstrip.Simulation results and filter design attached.

2. BPF (5.0-5.9 GHz):-to be connected between designed using combline parallel coupled filters and implemented on microstrip.

3. IF FILTER(374 MHz):- realized using lumped L,C components(3rd order Butterworth).

4.6.2 PCB Layout Of Combined System

After the design and all the simulations were completed the design was realized on a pcb using Eagle .The PCB's thus obtained after required optimation are shown below.

- **Bottom Layer Of TRF 2432 + TRF 2436**

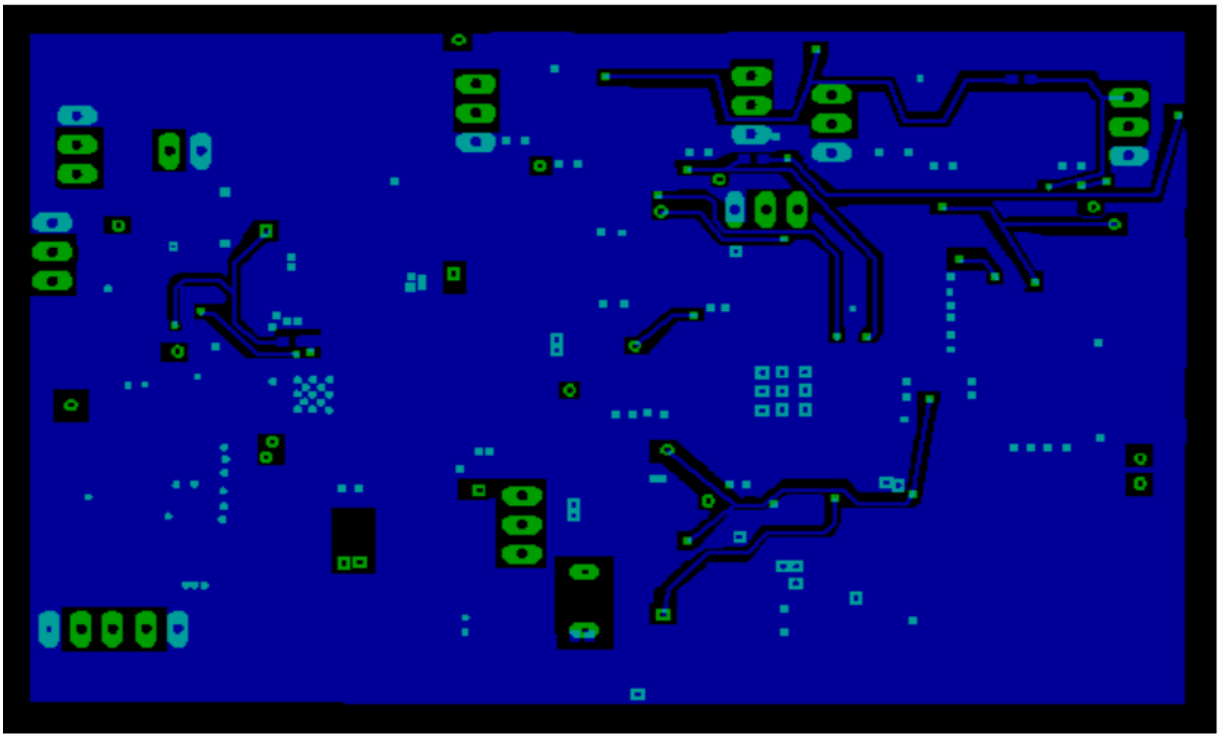


Fig. 4.13 Bottom Layer of Combined PCB

- **TOP Layer Of TRF 2432 + TRF 2436 PCB**

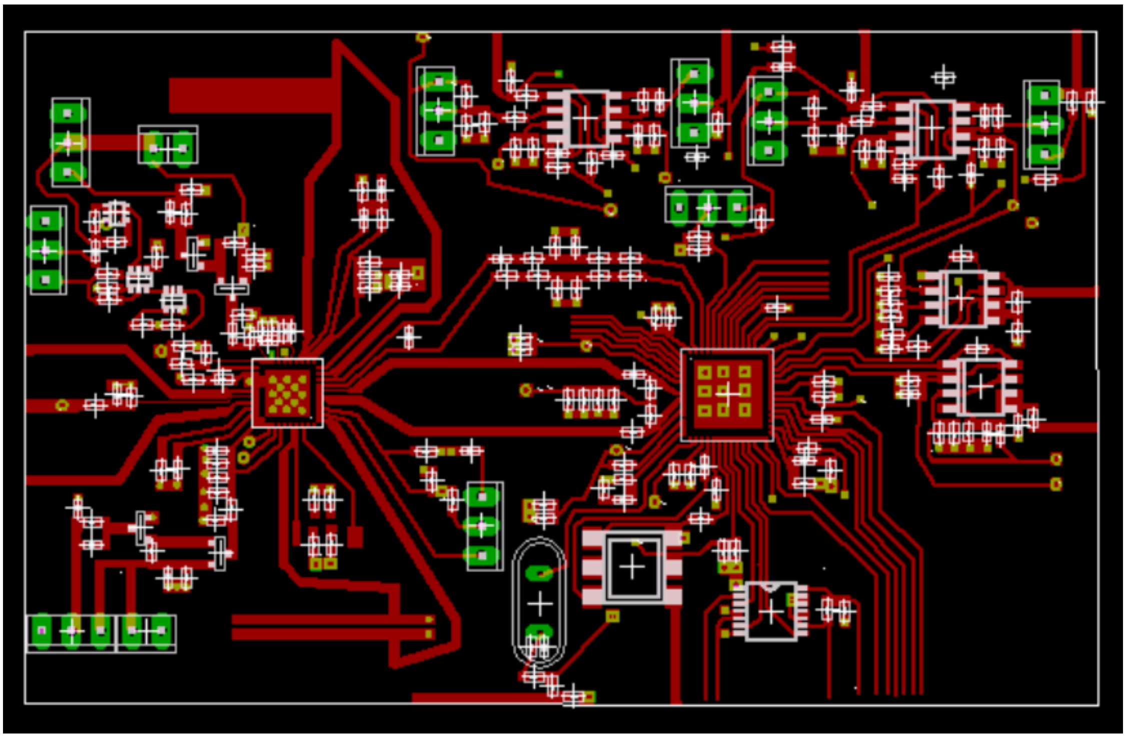


Fig. 4.14 Top Layer of Combined PCB

4.7 Considerations in the Design of the PCB for Transceiver & RF Front End

The width of 50 ohms RF line was kept 0.76mm and 100 ohms was .17mm .These widths were calculated using Line Gauge with PCB substrate thickness being .4 mm and relative permittivity being 4.4.

The length of RF lines was never exceeded beyond 3cm as length of 3cm corresponds to loss of 3dB or 50% of the input signal power loss.

The differential RF input lines corresponding to IF and LO in TRF2436were drawn tapered to remove mutual coupling.

Every possible attention was given to the fact that no power supply line or digital line in the bottom plane crosses the RF lines in the top plane as it needs ground plane throughout its extent.

Due to the space and RF lines constraint pads are provided in the analog circuitry for power supply where external wires will be soldered.

The diameters of the vias used for soldering external wires are kept 0.6mm and vias used for connecting to bottom layer are kept 0.3 mm in diameter. This is again due to the space constraints involved in converting a 4 layer PCB to 2 layer one.

- Transferring 4-layer PCB design to 2-Layer PCB Design was a difficult and tedious task.

- Placing around 200 capacitors, resistors and inductors (total) in a 2-Layer PCB of 94mm * 58.5mm was a difficult task.

- Since, the width of each pin of the transceiver chip is 0.25mm only , hence the width of the connecting wires could not be increased over 0.25mm .

- Multiple power supplies (+5V , -5V and +3.3V) and multiple jumpers made the PCB design more complicated.

- Large RF lines (50 Ohms and 100 Ohms) in the circuit made the network of connecting wires more complex and more probable for errors and power loss.

Chapter 5 Advantages & Limitations Of WiMAX

5.1 Advantages Of WiMAX

- **Spectral Efficiency**
  - 802.16-2004 (fixed) has a spectral efficiency of 3.7 bit/s/hertz, as compared to similar technologies that often are less than 1 bit/s/hertz efficient such as WiFi.

- **Nomadic Connectivity**
  - A wireless alternative to cable and DSL for last mile broadband access.

- **Enhancing Wireless Infrastructure**
  - Can enhance wireless infrastructure of developing countries in an inexpensive, decentralized, deployment-friendly and effective manner.
  - High-speed data and telecommunications services.
  - A diverse source of Internet connectivity as part of a business continuity plan.

- **Lower cost**
  - The common platform drives down costs with volume opportunity. Fixed wireless Customer Premise Equipment (CPE) will be able to use the same modem chipset used in personal computers (PCs) and PDAs.
  - The base stations will be able to use the same chipsets developed for low-cost WiMAX access points.
  - Finally increased volume will also justify the investment for higher-level integration of radio frequency (RF) chipsets, further driving down costs.

- **Wider coverage**
  - Provide excellent non line of sight (NLOS) coverage, advantages are coverage of wider area, better predictability of coverage and

lower cost as it means fewer base stations and backhaul, simple RF planning, shorter towers and faster CPE install times.

- **Higher capacity**
  - A key advantage of WiMAX is to use OFDM(Orthogonal Frequency Division Multiplexing) over single carrier modulation schemes with the ability to deliver higher bandwidth efficiency and therefore higher data throughput, with more than 1 Mbps downstream and even much higher data rates, even in NLOS with multipath condition.
- Enabling new applications that improve daily life.
- First wireless WAN protocol built from the ground up for IP networking, the same standards that the Internet is based on.
- WiMAX does not rely on low data rate, high-latency,circuit-switched voice technology.
- Quality of service (QoS) mechanisms are built into the WiMAX chipsets to support and manage multiple service flows.

5.2 Limitations Of WiMAX

- **Tradeoff Between Bandwidth and Long reach**
  - WiMAX has some similarities to DSL in this respect, where one can either have high bandwidth or long reach, but not both simultaneously.
- **Lower Gain antennas in Mobile WiMAX Products**
  - Mobile WiMAX devices typically have an antenna design which is of lower-gain by nature due to their inherent omnidirectional (and portable) design.
  - This means that in a line-of-sight environment with a portable Mobile WiMAX CPE, symmetrical speeds of 10 Mbit/s at 10 km could be delivered, but in urban environments it is more likely

that these devices will not have line-of-sight and therefore users may only receive 10 Mbit/s over 2 km.

- Higher-gain directional antennas can be used with a Mobile WiMAX network with range and throughput benefits but the obvious loss of practical mobility.

- **Bandwidth Sharing**

  - Like most wireless systems, available bandwidth is shared between users in a given radio sector, so performance could deteriorate in the case of many active users on a single sector.

- **Spectral Limitation**

  - For use in high density areas, it is possible that the bandwidth may not be sufficient to cater to the needs of a large clientele, driving the costs high.

5.3 Risks For Embedding WiMAX in Consumer Electronics

- Current Mobile WiMAX chipsets do not meet acceptable levels of power consumption and heat dissipation for integration into battery -powered handset devices.
- Large service networks do not yet exist for Mobile WiMAX. Champions of 3G data protocols for broadband wireless network adoption point to existing circuit-switched networks built over the last 10 years as the quickest path to a ubiquitous network.

- Spectrum allocations for WiMAX vary in each country. Initial consumer electronics devices will be frequency or certification profile -specific (2.3 GHz, 2.5 GHz, or 3.5 GHz, for example).

5.4 Obstacles in WiMAX Progress in India

- **Shortage Of Spectrum**

  - For WiMAX to prosper in India, license holders will need at least 20MHz of spectrum while they currently hold 12MHz or less. 20MHz is a minimum to support wide scale deployments and hence a profitable business case.

- **Low Cost End-To-End System**

    - In a country where monthly broadband ARPU is estimated at $8-10, and computer penetration is still at around 4%, BWA / WiMAX adoption will depend on very low cost end-to-end pricing for connectivity including the compute platform and CPE. The Indian telecom sector operates in a volume-driven market. If WiMAX is to succeed it will only be on the premise of huge volumes not, small deployments.

- **Non-Availability Of Bandwidth**
    - Pressure on available bandwidth is coming from operators who require allocations of the 3G/UMTS spectrum. BWA/WiMAX technologies require specific frequency bands to be opened up in the 3.5 GHz band (an internationally approved standard), which is currently allocated to the Department of Space for INSAT downlink.

5.5 Government Initiatives For The Progress Of WiMAX

- Government appears to be serious about solving the problem by releasing some of the spectrum from the departments of Space and Defense and the TRAI is currently engaged in a critical public consultation.
- The telecom ministry is initiating an ambitious project to release a total of about 45 MHz of spectrum from the Department of Defense to augment necessary spectrum for 3G services.

6. Conclusion

We have studied the technical aspects, scope and market potential of WiMAX Technology in the present scenario and in the future. And it can be easily infer from this report that the WiMAX Technology is an emerging Technology which is poised to revolutionize the world.

In the latter part of the project, we have successfully completed PCB design of RF Front End and Transceiver Modules for WiMAX System and the combined design with the use of IF Filter is ready for the final evaluation and PCB fabrication. Various precautions have been undertaken while designing the RF circuit of PCB since the project is aimed at high frequencies of the range (2.4GHz-2.5GHz & 4.9 GHz-5.9 GHz). The project also involved the design of a Band Pass Filters (2.4-2.5 GHz & 4.9-5.9 GHz) implemented on microstrip simulated in IE3D and IF bandpass filter (374 MHz) implemented using lumped components and simulated in Microwave Office.

Himanshu has simulated the Band Pass Filters (2.4-2.5 GHz & 4.9-5.9 GHz) in IE3D.

Due to time constraints the combined WiMAX System could not be accomplished. However, this project can be taken to the next higher level to form complete WiMAX system with the support from other dedicated students, so that we can come up with a complete WiMAX system which can be a boon for developing country like India in providing cheap, reliable and last mile communication system.

7. References

[1] http://en.wikipedia.org/wiki/WiMAX
[2] http://focus.ti.com/docs/prod/folders/print/trf2436.html
[3] www.wimaxforum.org
[4] http://focus.ti.com/docs/prod/folders/print/trf2436.html
[5] www.tutorial-reports.com/wireless/**wimax**/tutorial.php
[6] http://www.maravedis-bwa.com/PressRelease_WiMAX_in-India.pdf
[7] http://www.wirelessis.com/WirelessIs...WiMAX.pdf
[8] proj.sunet.se/TP13/Slides/SuNET-WIMAX.ppt
[10]www.wimaxforum.org/news/downloads/Supercomm_2004_WiMAX_Forum_Overview.pdf
[11]www.wimaxforum.org/news/downloads/supercomm_2005/WF_Day_in_a_Life_with_WiMAX_Final.pdf
[12]http://www.wavesat.com/products/dm256asic.html
[13]http://focus.ti.com/vf/docs/blockdiagram.tsp?blockDiagramId=6060&family=vf
[14]http://www.wirelessis.com/WirelessIs...WiMAX.pdf
[15]www.ceenet.org/workshops/lectures2004/Richard_Perlman/additional_materials_(wimax)/proxim-wimax.ppt
[16]http://www.ualberta.ca/~mahmoodi/wimax/Yu-WiMAX.pdf
[17]proj.sunet.se/TP13/Slides/SuNET-WIMAX.ppt

[18] David .M.Pozer," Microwave Engineering ",John Wiley & Sons,3rd Edition,2004

APPENDIX

APPENDIX 1 :- Circuit Diagram of TRF 2432 chipset

APPENDIX 2 :- Circuit Diagram of TRF 2436 chipset