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Study of Ism Band Technologies

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Abstract: *The ISM band is a general purpose part of the radio spectrum that can be used without a license. The only requirement for developing products in the ISM band is compliance with rules governing this part of the frequency spectrum. These rules vary from country to country. In the United States, the FCC defines these rules, while ETSI is the governing body in Europe. Mostly used ISM bands are the 2.4GHz band and the sub-1GHz bands. Because of the cluttering in the 2.4GHz bands, some activities have been seen in the 5GHz band, but they remain very limited because of achievable range concerns. The last few years have witnessed the emergence of several wireless standards operating in the ISM band. These standards along with proprietary solutions provide huge opportunities for developing a wide range of wireless products. These standards differ from one another by their data rates, communication ranges, application domains and the modulation techniques used. This article presents an overview of popular ISM bands in different regions of the world. Furthermore, analysis of some most prominent wireless standards available today like Bluetooth, Wi-Fi, Zigbee and IEEE 802.15.4 is given.*

Keywords *- IEEE, ITU, WDCT, NFC, WLAN, RF, RFID, UNII, Ptmp, HUMAN*

I. Introduction

Wireless communications is, by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public. these systems are gaining popularity in the license-free industrial scientific, and medical (ISM) frequency bands. One such emerging trend in ISM frequency bands is home automation. Many standards like 802.11 and Bluetooth are available based on which these devices communicate, but the present standards fail to provide sufficient data rate, when the user is moving at high speed. For future mobile wireless communication systems, the present standard, 802.16e has been proposed by Institute of Electrical and Electronic Engineers (IEEE). Many new applications, including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine, are emerging from research ideas to concrete systems. The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers indicate a bright future for wireless networks, both as stand- alone systems and as part of the larger networking infrastructure [1].

In telecommunication and radio communication, spread-spectrum techniques are methods by which a signal (e.g. an electrical, electromagnetic, or acoustic signal) generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth. These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise and jamming, to prevent detection, and to limit power flux density (e.g. in satellite downlinks). Spread-spectrum telecommunications is a technique in which a telecommunication signal is transmitted on a bandwidth considerably larger than the frequency content of the original information. Frequency hopping is a basic modulation technique used in spread spectrum signal transmission [2].

Unlicensed spectrum is open to everyone. It allows spectrum sharing and reuse for variety of applications to serve the market with speed and flexibility. On the other hand, there is a potential problem of mutual interference. The simplest approach to this problem of mutual interference is that the government divides the spectrum and distributes licenses. As a result, a license recipient has an exclusive right to use the frequency spectrum and air space in a geographical area. By exclusive access to the frequency and air space, the problem of mutual interference may be solved. However, with this traditional spectrum licensing, spectrum often sits idle, and no one else can use it due to exclusivity. Clearly this is not efficient. The licensing by central planning does not solve the problem of spectral efficiency. A licensee has an exclusive right to use the air space. For unlicensed spectrum, no one has exclusive right to use air space as it is open to everyone. The main goal of this paper is to review the ISM band and technologies used.

II. Ism Band

2.1. Overview of ISM Band

The ISM frequency bands are scattered from 6. 78 KHz to 245 GHz in the radio spectrum, has been reserved for industrial, scientific and medical purposes . The ISM bands are defined by the ITU-R in 5.138, 5.150, and 5.280 of the Radio Regulations. Examples of applications in these bands include radio-frequency process heating,microwave ovens, and medical diathermy machines. The powerful emissions of these devices can create electromagnetic interference and disrupt radio communication using the same frequency, so these devices were limited to certain bands of frequencies. In general, communication equipment operating in these bands must tolerate any interference generated by ISM equipment, and users have no regulatory protection from ISM device operation. Unlicensed operations are typically permitted to use these bands. The ISM bands share allocations with unlicensed and licensed operations. Licensed use of the bands is typically low.

Despite the intent of the original allocations, and because there are multiple allocations, in recent years the fastest-growing uses of these bands have been for short-range, low power communications systems. Cordless phones, Bluetooth devices, near field communication (NFC) devices, and wireless computer networks all use frequencies allocated to low power communications as well as ISM. Individual countries' use of the bands designated in these sections may differ due to variations in national radio regulations. Because communication devices using the ISM bands must tolerate any interference from ISM equipment, unlicensed operations are typically permitted to use these bands, since unlicensed operation typically needs to be tolerant of interference from other devices anyway.

Most emerging radio technologies for Wireless Personal Area Networks such as the Bluetooth protocol is designed to operate in the 2.4 GHz ISM band. Since both Bluetooth and IEEE 802.11 devices use the same frequency band and may likely come together in a laptop or may be close together at a desktop, interference may lead to significant performance degradation. FCC allocated Part 15.247 (ISM band) in the late 80"s with the continued pioneering spirit of effective spectrum utilization for public communication services. This was a bold experiment with tremendous success. It spurred enormous development activities of numerous and diversified products and applications.

For many people, the most commonly encountered ISM device is the home microwave oven operating at 2.45 GHz. However, in recent years these bands have also been shared with license-free error-tolerant communications applications such as wireless sensor networks in the 915 MHz and 2.450 GHz bands, as well as wireless LANs and cordless phones in the 915 MHz, 2.450 GHz, and 5.800 GHz bands. In the United States, according to 47 CFR Part 15.5, low power communication devices must accept interference from licensed users of that frequency band, and the Part 15 device must not cause interference to licensed users. The ISM bands are also widely used for Radio-frequency identification (RFID) applications with the most commonly used band being the 13.56 MHz band used by systems compliant with ISO/IEC 14443 including those used by biometric passports and contactless smart cards. In Europe, the use of the ISM band is covered by Short Range Device regulations issued by European Commission, based on technical recommendations by CEPT and standards by ETSI. Also note that several brands of radio control equipment use the 2.4 GHz band range for low power remote control of toys, from gas powered cars to miniature aircraft. Worldwide Digital Cordless Telecommunications or WDCT is a technology that uses the 2.4 GHz radio spectrum. Google's Project Loon uses ISM bands (specifically 2.4 and 5.8 GHz bands) for balloon-to-balloon and balloon-to-ground communications.

2.2. Frequency Bands

ISM Bands consist of 3 frequency bands :

1) UHF ISM (900 MHz)

900 MHz band is 26 MHz wide. It includes 902 MHz to 928 MHz (frequency range). Legacy wireless networking partially allocated for Global System Mobile Communications (GSM Cellular) in parts of the world. Not being used by 802.11 devices [5].

The 820–960 MHz band (known as the 900 MHz band) is premium spectrum because its physical characteristics provide a very good compromise between being able to carry signals over long distances and penetrate buildings while also carrying large amounts of data. The band is already used to support many

important services ranging from major mobile telecommunications networks to class licensed devices including radiofrequency identification devices (RFIDs). The 900 MHz Band Plan was made in 1992.

The ACMA has been monitoring use of the band and a number of significant potential improvements to the way the band is assigned would now appear to be possible. These improvements could better facilitate new and emerging technologies, including smart technologies such as smart infrastructure, and improve the utility with which the band is used. The opportunity for improvement, and the fact that arrangements in this band have not been reviewed for nearly two decades, means it is timely to consider its re-planning. These include, but are possibly not limited to, the potential to:

a) Re-plan and reallocate the segments currently planned for global system for mobile (GSM) to improve both technical and allocate efficiency
b) Expand services, such as the 850 MHz spectrum-licensed segments or the adjacent land mobile segments, or enable new services in the 900 MHz band, such as the 850 MHz spectrum-licensed segments or the adjacent land mobile segments, using part of the digital dividend from 805–820 MHz paired with 850–865 MHz.
c) Re-plan the land mobile segments so that they may reach their highest value use.
d) Make spectrum available for smart infrastructure, or the possible expansion of the industrial, scientific and medical (ISM) segment or other services in the band.
e) Re-plan a number of segments in the band that are underutilized or unused due to allocations to outmoded technologies or unrealized applications.

2) S – Band ISM (2.4GHz)
2.4 GHz Band is 83.5 MHz Wide. It covers 2.4 GHz to 2.4835 GHz. Use defined in the 802.11-2007 standards. The 2.4GHz ISM band has become particularly popular in the last few years such that households, and virtually all commercial buildings, are likely to have equipment that operates in this band [6]. A short list of possible users & possible interferer's include:
a) 802.11b networks
b) 802.11g networks
c) 802.11n networks
d) Bluetooth Pico-Nets
e) Cordless phones
f) Home Monitoring cameras
g) Microwave ovens
h) Wi-Max networks

The 2.4 GHz ISM band allows for primary and secondary uses. Secondary uses are unlicensed but must follow rules defined in the Federal Communications Commission Title 47 of the Code for Federal Regulations Part 15 [COM] relating to total radiated power and the use of the spread spectrum modulation schemes. Interference among the various uses is not addressed as long as the rules are followed. Thus, the major down side of the unlicensed ISM band is that frequencies must be shared and potential interference tolerated. While the spread spectrum and power rules are fairly effective in dealing with multiple users in the band, provided the radios are physically separated, the same is not true for close proximity radios. Multiple users, including self-interference of multiple users of the same application, have the effect of raising the noise floor in the band resulting in a degradation of performance [7].

The impact of interference may be even more severe, when radios of different applications use the same band while located in close proximity. Thus, the interference problem is characterized by a time and frequency overlap as depicted in Figure 1. In this case, a Bluetooth frequency hopping system occupying 1 MHz of the spectrum is shown to overlap with a WLAN Direct Sequence Spread Spectrum signal occupying a 22 MHz channel. Note that, the collision overlap time depends on the frequency hopping pattern and the traffic distribution of both the Bluetooth and WLAN systems.

TABLE 1: *COMPARISON OF 2.4 GHZ TECHNOLOGIES*

Technologies	Data Rate	No. of Channels	Interference Avoidance Method	Min Bandwidth Required
WiFi	11 Mbps	13	Fixed channel collision avoidance	22 MHz (static)
Bluetooth	723 Kbps	79	Adaptive frequency Hopping	15 MHz (dynamic)
WirelessUSB	62.5 Kbps	79	Frequency Agility	1 MHz (dynamic)
Zigbee	128 Kbps	16	Fixed channel collision avoidance	3 MHz (static)

3) C – Band ISM (5.8GHz)

There has been a virtual explosion in 2.4Ghz technology, the next step up in the ISM Bands from the useful 915Mhz radios which, because of the their relative tree and vegetation-penetration qualities are ideal for most low-bandwidth field data collection. The arena of 2.4 GHz has rapidly evolved into what is popularly known as the 'Wi-Fi' radio bands and services, though more accurately known as the 802.11b standard radios. While their vegetation-penetrating capabilities - as a function of both operating in higher frequencies than 915Mhz and much lower power in most products (100mw instead of 1 Watt as in Free wave radios) - make them far less suitable for field data collection through woods, or rain forests, they are useful for full motion audio-video tasks - such as our installations now on Hog Island.

The explosion in development and marketing of such higher frequency, higher bandwidth (10mbps and up) radios, has now, most recently spawned a growing number of digital radios which operate in the 5.2 to 5.8 GHz ranges. The industry is moving so fast that even now there are further standards for radios, such as 802.11a

which is in the 5.8 GHz zone, but pushes data at 56mbps. And right around the corner is 802.11g which will be in the 2.4Ghz zone, at 56mbps, but will be 'downward compatible' with the slower (10 mbps) 802.11b Wi-Fi Radios.

C Band is a brand new ISM band and is 150 MHz Wide. It includes 5.725 GHz to 5.875 GHz. Used by many non-networking devices. It should not be confused with UNII Bands. This band is rarely used in WLAN deployments The 5.8 GHz band is the best choice in terms of price and accuracy for real-time location system. It gives better signal propagation & high data rate modulation at 5.8GHz

TABLE 2: *CHARACTERISTICS OF FREQUENCY BANDS*

Frequency Bands	**Frequency Range**	**Bandwidth**	**Max Power**
ISM-900	902-928 MHz	26 MHz	1 Watts
ISM-2.4	2400-2483.5 GHz	83.5 MHz	1 Watts
ISM-5.8	5.725 – 5.850 GHz	125 MHz	1Watts (+30 dbm)

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III. Technologies Using Ism Band

There are many technologies that use different ISM band frequencies. Some of them are highlighted below: [1]

3.1. Mesh

Outdoor wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. Standards used are IEEE 802.11, 802.16. The frequency range for Mesh is 900 MHz, 2.4 GHz, 5.8 GHz (unlicensed). The advantages of Mesh are MIMO configurations, integrated antenna to handle wide range of deployment issues. Mesh design allows improved coverage around obstacles, node failures and path. Rapid deployment using unlicensed. The weaknesses are Increased delay/latency introduced by multiple hops, Increased complexity of protocols (MAC, routing management), Mesh architecture increases the cost and complexity of the network. Mesh is popularly used for last mile, broadband access in municipal and rural areas.

3.2. WLAN

Indoor wireless local area network (WLAN). Home area network (HAN). A (WLAN) is a wireless distribution method for two or more devices that use high-frequency radio waves and often include an access point to the Internet. A WLAN allows users to move around the coverage area, often a home or small office, while maintaining a network connection. WLAN is based on IEEE 802.11b/g/n. WLAN is widely used for indoor wireless LAN. Advantages of using WLAN are Low-cost chip sets - inexpensive consumer devices, Widespread use and expertise - low-cost application Development. Weakness of WLAN are Small coverage and short distances limits its widespread use, Security issues are encountered with multiple networks, Operating in same location.

3.3. Zigbee

Zigbee is a standards-based wireless technology developed to enable low-cost, low-power wireless machine-to-machine (M2M) and Internet of things (IoT) networks. Zigbee is based on the Institute of Electrical and Electronics Engineers (IEEE) Standards Association's 802.15 specification. Zigbee is built for control and sensor networks on the IEEE 802.15.4 wireless standard for wireless personal area networks (WPANs). The Zigbee WPANs operate on 2.4 GHz, 900 MHz and 868 MHz frequencies. Advantages of Zigbee are Low cost - for inexpensive consumer devices, Low power consumption - up to 2 year battery life, Self-organizing, Network can support large number of users.

IV. Conclusion

For most people the significance of wireless technologies comes from its ability to provide services like voice/video transmission or Internet access at places without cabled networking infrastructure or while being on the move. Wireless technologies have also been identified as a very attractive option for industrial and factory automation, distributed control systems, automotive systems and other kinds of networked embedded systems with mobility, reduced cabling and installation costs, reduced danger of breaking cables, and less hassle with connectors being important benefits. There is a considerable range of applications that have been identified as part of this Study that are currently using the ISM band. The main technologies that are deployed in this band are Wi-Fi (IEEE 802.11 b/g), Bluetooth (IEEE 802.14 for WPAN) and ZigBee (IEEE 802.14.4) as well as proprietary solutions, some based on these standards. s. It is possible for devices that use these technologies to effectively share the 2.4 GHz band on a no-interference, no protection basis and provide reliable communications based on inputs to this Study. However for such technologies to be effective there is a need for a minimum number of free channels to be available.

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