RF Interoperability

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Revision History

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1.0	11/18/2005	K. Adkins	Minor spelling and format changes
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1.2	11/09/2010	J. Hallsten	Updates to reflect latest RF hardware products
1.3	10/21/2013	J. Cunningham	Fixed typo on page 10 from 64 to 74 for channel to use above Wi-Fi channel 11

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Introduction

The purpose of this document is to provide a technical background and overview of the radio frequency (**RF**) operation of the Turning Technologies RF keypads and RF USB dongle devices. Specifically, this document seeks to address RF interoperability of the Turning Technologies devices with other electronic devices and systems that operate in the same frequency bands. RF interoperability is the ability for different RF devices to coexist in the same proximity and operate without significant performance degradation. The main contributing factor to loss of performance is RF interference or "collisions" from other device types. Interference is caused when two or more RF devices transmit at the same frequency at the same time. This causes over-the-air collisions which can corrupt data packets and cause loss of information.

Regulatory Agencies and the 2.4GHz ISM Band

RF communications devices sold commercially are subject to rules governed by regulatory agencies around the world. These rules are defined by and in some cases enforced by standardization bodies such as the Federal Communications Commission (**FCC**) in the United States, Industry Canada (**IC**) in Canada, the European Telecommunications Standards Institute (**ETSI**) and the European Union (**EU**) in Europe, the Australian Communications Authority (**ACA**) in Australia and New Zeeland, the Association of Radio Industries and Businesses (**ARIB**) in Japan, and others. The regulatory agencies for each country have allocated certain portions (bands) of the available RF spectrum for licensed and unlicensed commercial use. The unlicensed frequency bands are often referred to as Industrial, Medical, and Scientific (**ISM**) bands and are generally subject to limited range and power levels.

The Turning Technologies RF devices operate at frequencies in the 2.4GHz (2.4 gigahertz) ISM band. This band is very popular for commercial use because it is a worldwide ISM band and therefore allows compliant products to be marketed and used throughout the world. Today there are many commercially available products that operate in the 2.4GHz ISM band. With the number of these devices increasing every day, some manufacturers and end users are concerned that radio interference and product performance degradation could become a major problem. It is the intent of this document to address the interoperability of the Turning Technologies RF devices with other products that operate in the 2.4GHz band.

Fixed Frequency vs. FHSS and DSSS

For commercially available devices that operate in the 2.4GHz ISM band, there are two major operational modes used for the RF transmissions. They are fixed frequency and spread spectrum. For spread spectrum, there are two major types: frequency-hopping-spread-spectrum (**FHSS**) and direct-sequence-spread-spectrum (**DSSS**).

Fixed frequency devices operate at a single relatively narrow-band frequency or "channel" that can be anywhere within the ISM band, but often is centered at the middle of the band. Bandwidth of the fixed channel varies depending on the type of device, its transmit power level, and the channel it is operating on.

FHSS devices dynamically change their operational frequency to multiple relatively narrow-band channels across the whole ISM band. They "hop" in a sequence that is known by both the transmitter and receiver. Some "frequency agile" devices can even dynamically change their hop sequence based on detection of other RF "traffic" in the band. Typical channel bandwidth for FHSS devices is 1Mhz to 5Mhz.

DSSS devices are similar to FHSS devices, but they use a single sub-band of the overall ISM band to "spread" their energy. The sub-band is a relatively wide-band channel that does not change. The DSSS device modulates its transmitted signals onto several narrow-band frequencies within the fixed sub-band. Typical channel bandwidth for DSSS devices is 3Mhz to 30Mhz.

The FCC and other regulatory agencies generally allow higher transmit power levels for FHSS and DSSS devices because they affectively spread their energy over a wider bandwidth and therefore are less likely to cause RF interference or be affected by RF interference.

2.4Ghz ISM Band Devices and Standards

Below is a list of some of the different RF devices and standards that operate in the 2.4GHz ISM band. A discussion of each of these devices follows and then a more comprehensive look at a few of the major ones is provided in the next section.

- Bluetooth: based on the Bluetooth SIG standards
- Wi-Fi or WLAN: based on the IEEE 802.11b, 802.11g, and 802.11n standards
- Zigbee: based on the IEEE 802.15.4 standard
- Wireless keyboards and mice: based on proprietary standards
- RFID (radio frequency identification) devices: based on ISO and EPC Global standards
- Cordless telephones
- Microwave ovens

Cell Phones

Some OEMs and end users might be concerned about RF interference from cell phones. Cell phones were not included in the list above because their main transceivers do not operate in the 2.4GHz band. There are several bands throughout the world used for CDMA and GSM mobile phone services. The main ones are 850MHz, 900MHz, 1.8GHz, and 1.9GHz. Even so, this does not mean that cell phones do not pose any interference risk. Some more recent cell phone handsets include Bluetooth interfaces for operating with hands-free wireless headsets or for syncing with a computer. Some “smart phones” even include 802.11 WLAN interfaces. Therefore cell phones can be a source of concern, but only ones that have Bluetooth or WLAN interfaces built in. Those interfaces and their interoperability are covered in this document.

Bluetooth Devices

A group of companies known as a special interest group, or SIG, has developed a set of standards called Bluetooth that define the operational parameters for a short-range wireless communications link. Devices that follow the Bluetooth standards operate in the 2.4GHz ISM band using FHSS. Small wireless networks called “piconets” of up to 7 devices can be established. However, Bluetooth is really not designed to be a networking protocol as much as it is targeted at “cable-replacement” applications where data transfer rates are less than 1Mbps.

Devices with Bluetooth interfaces have become very popular in recent years. Cell phones, PDAs, pocket and tablet PCs, wireless headsets, and printers are a few of the many products that may utilize a Bluetooth interface today. Although probably less likely than with WLAN hotspots, it is still likely that the Turning Technologies RF devices will have to coexist and operate along with Bluetooth devices.

IEEE 802.11 WLAN Devices

The IEEE 802.11 standards define the operational parameters for wireless local-area-networks (**WLAN or Wi-Fi**). Devices that follow these standards can operate using FHSS or DSSS, but most commercially available products use DSSS. 802.11b, 802.11g, and 802.11n devices can operate in the 2.4GHz band. 802.11a and 802.11n devices can operate in the 5GHz ISM bands. Some WLAN hardware vendors offer devices that can support multiple 802.11 standards so that newer 802.11 devices can still operate along with legacy devices.

WLANs are everywhere – in businesses, educational institutions, retail establishments such as internet cafés and hotels, and homes. Many desktop computers, laptop computers, pocket PCs, PDAs, and smart phones come with WLAN interfaces built-in. For those that do not, there are many accessories on the market now that make it easy to add WLAN capability to almost any computing device. Since WLANs are so popular now, it is very likely that the Turning Technologies RF devices will have to coexist and operate along with 802.11 WLAN "hotspots."

IEEE 802.15.4 Zigbee Devices

A SIG similar to the Bluetooth group has developed a set of standards called Zigbee that define the operational parameters for a short-range wireless network. The Zigbee radio interface is based on the IEEE 802.15.4 specifications. Devices that follow the Zigbee standards operate in the 860MHz, 915MHz or 2.4GHz ISM bands using DSSS. Zigbee is targeted at simple, low duty cycle, low data rate, networking and control applications such as Industrial control, home control, security, wireless sensors and others.

The first revision of the Zigbee specification was ratified in early 2005 and therefore there are very few commercially available Zigbee devices at this time. However, if Zigbee gains popularity in upcoming years, it could become likely that the Turning Technologies RF devices will have to coexist and operate along with 2.4GHz Zigbee devices.

Wireless Keyboards and Mice

Wireless keyboards and mice have been on the market for more than a decade. Most of these products are designed for very short range, very low power, point-to-point RF links based on proprietary protocols. Some of these devices operate in the 2.4GHz ISM band and the percentage of them that do appears to be increasing.

Since these devices have been on the market for so long, it is fairly likely that the Turning Technologies RF devices will have to coexist and operate along with them.

Radio Frequency Identification Devices

Radio Frequency Identification (**RFID**) devices have been around for decades but have only gained wide-scale adoption in recent years. The operational parameters for most RFID devices are defined by International Standards Organization (**ISO**) and Electronic Product Code (**EPC**) standards. RFID is now finding its way into many applications such as plant and animal identification and tracking, supply chain management, barcode replacement or enhancement, and others. The growing popularity of RFID is evident by mandates imposed by Wal-Mart and the US Department of Defense in early 2005. These mandates require RFID tagging and tracking of pallets and cartons delivered by all of Wal-Mart's and the DOD's major suppliers.

RFID technology exists in many forms, but the major types are passive and active. Passive applications are limited to short range (a few centimeters to a few meters). Passive devices, or "tags", do not require a local power source, but instead are powered by the RF energy generated by the "reader" which is also used for the communication link. By contrast, active tags are typically battery powered and can operate over longer ranges. Some RFID devices operate in the 2.4GHz ISM band, but most do not mainly because 2.4GHz RF energy is absorbed by water and therefore does not work well for tagging animals or liquid-based products. The majority of RFID devices today operate at low frequency (125KHz and 134KHz), high frequency (13.56MHz), or ultra-high frequency (800MHz-930MHz).

Since most RFID devices do not operate at 2.4GHz and since most RFID systems are designed for short range operation, it is not likely that the Turning Technologies RF devices will have to coexist and operate in close proximity with RFID systems.

Cordless Telephones

Cordless telephones have also been on the market for many years and have gained much popularity. Earlier cordless phones operated at 46MHz, 49MHz, 400MHz, or 900MHz, but in recent years many vendors have migrated to 2.4GHz or 5GHz products. There are no protocol “standards” that these devices follow. Each OEM has defined their own proprietary RF communications protocols. However, most cordless phones do use FHSS or DSSS techniques.

It is very likely that Turning Technologies RF devices will have to coexist and operate along with 2.4GHz cordless phones.

Microwave Ovens

Microwave ovens can be found today in almost any kitchen or cafeteria. Microwave ovens are not RF communications devices, but they do have a RF transmitter inside them. A high-powered vacuum tube device known as a magnetron is used to generate hundreds or even thousands of watts of RF energy that is used for heating food inside the oven. Most microwave ovens today operate at 2.45GHz – right in the middle of the ISM band. These ovens are intentional radiators, but they are designed to contain the RF energy to the inside of the oven cavity and so they have RF shields that keep most of the energy from escaping. As a result, most microwave ovens do not radiate high levels of 2.45GHz energy to the outside surroundings.

It is very likely that Turning Technologies RF devices will have to coexist and operate along with microwave ovens nearby.

2.4GHz ISM Band Device Operation and Interoperability

The previous section described some of the 2.4GHz radio devices that the Turning Technologies devices will likely need to coexist with. There are many factors that can contribute to the amount of interference and collisions that happen and the severity of them. These factors include transmit frequency, bandwidth and power; receive sensitivity and bandwidth, and locations of the transmitters and receivers.

Table 1 below shows a summary of some of the main RF parameters for each of these devices. **Figure 1** below shows the occupied bandwidths for the some of the major commercially available 2.4GHz wireless devices in question. The following sections describe the RF operation and interoperability of the devices with the Turning Technologies devices.

Table 1: Summary of 2.4GHz Device Operation

Device	Mode	# of Channels	Channel Width	TX Power	RX Sensitivity	Node to Node Range	Max Bit Rate
Turning Technologies	Fixed	82	1MHz	2.5mW	-80dBm to -85dBm	100 meters	1Mbps
Bluetooth	FHSS	79	1MHz	1: 100mW 2: 2.5mW 3: 1.0mW	-80dBm to -90dBm	100 meters 20 meters 10 meters	750Kbps
802.11b WLAN	DSSS	13	22MHz	100mW max	-80dBm to -90dBm	100 meters	11Mbps
802.11g WLAN	DSSS	13	22MHz	100mW max	-80dBm to -90dBm	100 meters	54Mbps
802.11n WLAN	DSSS	13	22MHz, 44MHz	100mW max	-80dBm to -90dBm	200 meters	144Mbps, 300Mbps
802.14.5 Zigbee	DSSS	16	3MHz	0.5mW	-80dBm to -100dBm	10-50 meters	250Kbps
Cordless Phones	FHSS	8 to 16	5-10MHz	100mW max	-80dBm to -90dBm?	50-100 meters	<100Kbps?
Microwave Ovens	Fixed	1 at 2.45GHz	10MHz-30MHz	Watts, but contained	N/A	N/A	N/A

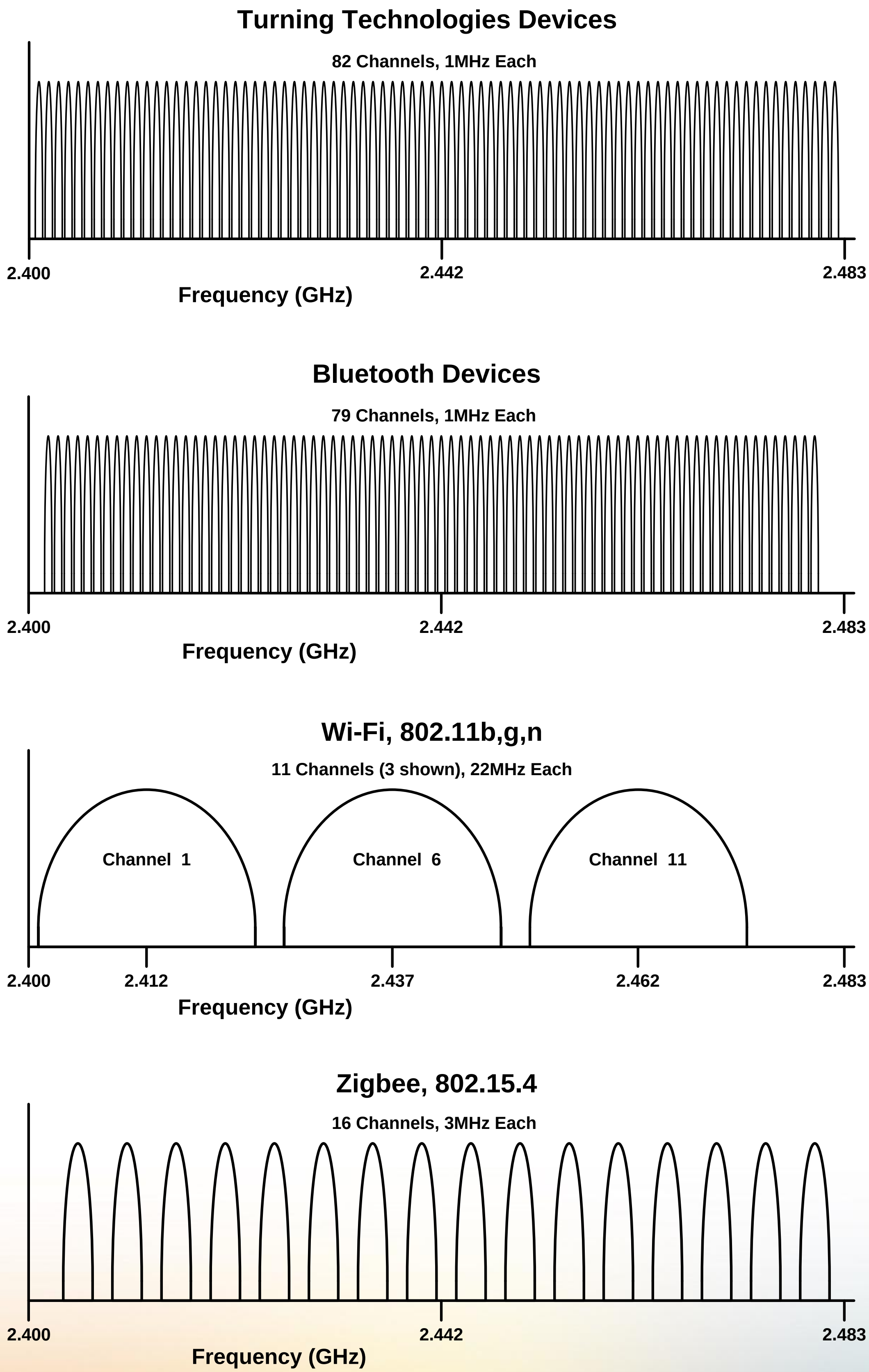

Figure 1: Frequency Channels for Various Commercial 2.4GHz Devices

Turning Technologies RF Device Operation

As seen in **Figure 1**, the Turning Technologies devices operate on one of 82 fixed non-overlapping channels in the 2.4GHz ISM band. Each channel is 1 MHz wide. The channel is user selectable (programmable), but once it is programmed it remains fixed until re-programmed. Channel 1 corresponds to 2.401GHz and channel 82 corresponds to 2.482GHz. The affective occupied bandwidth of the devices is only 1MHz, a very small portion of the 83MHz wide ISM band.

The transmit power levels for the Turning Technologies devices are very low – less than +4dBm (2.5mW). The receive sensitivity is -85dBm max. The bit transfer rate for the Turning Technologies devices is 1Mbps and with overhead, the total packet duration is less than 265usec which is a relatively short duration.

A typical Turning Technologies installation might have one receiver unit and many keypad devices. All keypad devices and the receiver unit are programmed to the same RF channel. Because of their low transmit power, single frequency operation, narrow bandwidth, and very short packet lengths, it is not likely that the Turning Technologies devices will cause significant interference with other 2.4GHz devices. With some careful planning, interference from other devices can be mostly or completely eliminated therefore allowing good interoperability with these devices. This planning includes maintaining good isolation (distance) between different types of devices, and selecting the right operating channels for different devices.

Bluetooth Device Operation and Interoperability

Bluetooth devices operate on 79 non-overlapping FHSS channels in the 2.4GHz ISM band beginning at 2.402GHz and ending at 2.480GHz. Each channel is 1 MHz wide. Bluetooth devices hop from channel-to-channel in a non-sequential pattern known by each of the devices in a Bluetooth network or “piconet.” The hop rate is up to 1600 hops/second. That means the devices only stay on a given channel for 625usec before switching to another channel.

The transmit power levels for Bluetooth devices depends on the device “class”. Class 1 devices transmit up to +20dBm (100mW), Class 2 devices transmit up to +4dBm (2.5mW) and Class 3 devices transmit up to 0dBm (1mW). Most battery powered devices are Class 2 and 3 and are limited to about 20 meters of range. The receive sensitivity is -80dBm to -90dBm. The bit transfer rate for Bluetooth devices is 750Kbps max. Bluetooth data packet sizes and lengths vary depending on the type and the number of devices in a piconet.

Since Bluetooth devices are always hopping between one of 79 channels, the highest probability of collision between a Bluetooth device and a Turning Technologies system that are within range of each other is 1/79. Bluetooth devices will move to another channel if they encounter interference on a given channel, so if a Turning Technologies device is transmitting and a Bluetooth device hops to the same channel, the Bluetooth device is designed to sense the interference and avoid collision. Some newer Bluetooth devices even use adaptive frequency hopping which means they can sense when channels have sustained interference on them (such as from a WLAN or from a Turning Technologies system) and then avoid hopping to those channels at all. So in reality, the probability of collisions could be very low even if there is a large amount of Turning Technologies and Bluetooth RF activity. To reduce the probability even further, the devices should be physically located as far (several feet) as possible away from each other – especially the Turning Technologies receiver and the Bluetooth base unit which could both be connected to the same host computer. In that case it would be highly recommended that one or both devices be connected at the end of an extension cable and physically separated. The other way to reduce or even eliminate interference is by programming the Turning Technologies units to a channel that Bluetooth does not use such as channel 1 (2.401GHz), channel 81 (2.481GHz), or channel 82 (2.482GHz).

IEEE 802.11 WLAN Device Operation and Interoperability

WLAN 802.11b, g, n devices can operate in the 2.4GHz ISM band on one of 13 different overlapping DSSS channels (11 in the US) that are 22MHz wide and 5MHz apart (see **Table 2**). 802.11n devices can combine two channels into one 44MHz wide channel. Generally, a WLAN hot spot is set up for one channel and stays at that channel. Since the channels each take up about one fourth of the 2.4GHz ISM spectrum and adjacent channels will interfere with each other, typical WLAN installations operate on one of three non-overlapping channels. In the US the commonly used channels are 1 (2.412GHz center), 6 (2.437GHz center), and 11 (2.462GHz center). Between each of those channels is a 3MHz unused frequency gap or “null” and above channel 11 there is about 10MHz of unused available spectrum.

The transmit power levels for WLAN devices are up to +20dBm (100mW). The receive sensitivity is typically -80dBm to -90dBm. Max bit transfer rates are 11Mbps and 54Mbps for 802.11b and 802.11g respectively. Max bit transfer rates are 144Mbps for single channel 802.11n and 300Mbps for dual channel 802.11n. WLAN data packet sizes and lengths vary depending on network traffic levels.

Since a WLAN hotspot occupies a fixed 22MHz or 44MHz of bandwidth in the 2.4GHz ISM spectrum, the probability of collisions between a WLAN device and a Turning Technologies device depends on their operational channels. If their channels overlap, the probability is high and if they do not overlap, the probability is near 0. So by selecting the devices operating channels carefully, interference can be completely avoided. For example, in a typical WLAN hotspot installation, there is one or more access points and routers strategically located to cover the hotspot area. If the hot spot is set up for channel 1, then the occupied band will be 2.401GHz to 2.423Ghz.This means that the rest of the ISM band, namely 2.424GHz to 2.483GHz will not be used by that hot spot. If the Turning Technologies devices are programmed at any channel between 24 (2.424GHz) and 82 (2.482GHz), then they will not likely collide with WLAN traffic in that hot spot. In some large multi-room or multi-floor WLAN installations, there might be several different WLANs operating at different channels. Typically these are set up so the channels do not overlap, such as shown in **Figure 1** where there are three channels - 1, 6, and 11 being used. To avoid interference, the Turning Technologies devices can be programmed for channels in between or above the WLAN hotspots such as channels 24, 25, 49, 50, and 74-82.

As with any 2.4GHz devices, Turning Technologies devices should be located physically far (several feet) away from the WLAN devices. Especially a WLAN access point or router and a Turning Technologies receiver which could be connected to the same host computer.

Table 2: 802.11a, g, n WLAN Channels in the US

Channel	Low Frequency	Center Frequency	High Frequency
1	2.401GHz	2.412GHz	2.423GHz
2	2.406GHz	2.417GHz	2.428GHz
3	2.411GHz	2.422GHz	2.433GHz
4	2.416GHz	2.427GHz	2.438GHz
5	2.421GHz	2.432GHz	2.443GHz
6	2.426GHz	2.437GHz	2.448GHz
7	2.431GHz	2.442GHz	2.453GHz
8	2.436GHz	2.447GHz	2.458GHz
9	2.441GHz	2.452GHz	2.463GHz
10	2.446GHz	2.457GHz	2.468GHz
11	2.451GHz	2.462GHz	2.473GHz

IEEE 802.15.4 Zigbee Device Operation and Interoperability

2.4GHz Zigbee devices can operate on one of 16 different non-overlapping DSSS channels (11 in the USA) that are each 3MHz wide and 5MHz apart (see **Table 3**). The channels are numbered 11 to 26 (channels 0-10 are reserved for 860MHz and 915MHz Zigbee devices). Generally, a Zigbee network is set up for one channel and it stays at that channel. There are 2MHz nulls between each channel. The affective occupied bandwidth of a Zigbee network is only 3MHz, a very small portion of the 83MHz wide ISM band.

The transmit power levels for 802.15.4 radios are very low – typically -3dBm (0.5mW). The receive sensitivity is -80dBm to -100dBm depending on the 802.15.4 radio. The bit transfer rates are 250Kbps max. Zigbee data packet sizes and lengths vary, but the target applications for Zigbee are low-duty-cycle and low-power so the amount of traffic on a Zigbee network will likely be relatively light compared to a Bluetooth or WLAN network.

Since a Zigbee network occupies a fixed 3MHz of bandwidth in the ISM spectrum, the probability of collisions between a Zigbee device and a Turning Technologies device depends on their operational channels. If their channels overlap, the probability is high and if they do not overlap, the probability is near 0. So by selecting the devices operating channels carefully, interference can be completely avoided. For example, in a typical Zigbee network installation, there will be one or more nodes strategically located to cover the network area. If the network is set up for channel 8, then the occupied band will be 2.4385GHz to 2.4415Ghz.This means that the rest of the ISM band, namely 2.401GHz-2.437GHz and 2.443Ghz-2.483GHz will not be used by that Zigbee network. If the Turning Technologies devices are programmed at any channel between 1-37 or 43-82, then they will not likely collide with any Zigbee traffic. Even if multiple Zigbee networks are set up nearby, the Turning Technologies devices can be programmed for non-overlapping channels because Zigbee does not require a lot of bandwidth.

As with any other 2.4GHz devices, Turning Technologies devices should be located physically far (several feet) away from the Zigbee devices. Especially the Zigbee PAN coordinator and the Turning Technologies receiver which could be connected to the same host computer.

Table 3: 802.15.4 Zigbee Channels

Channel	Low Frequency	Center Frequency	High Frequency
1	2.4035GHz	2.405GHz	2.4065GHz
2	2.4085GHz	2.410GHz	2.4115GHz
3	2.4135GHz	2.415GHz	2.4165GHz
4	2.4185GHz	2.420GHz	2.4215GHz
5	2.4235GHz	2.425GHz	2.4265GHz
6	2.4285GHz	2.430GHz	2.4315GHz
7	2.4335GHz	2.435GHz	2.4365GHz
8	2.4385GHz	2.440GHz	2.4415GHz
9	2.4435GHz	2.445GHz	2.4465GHz
10	2.4485GHz	2.450GHz	2.4515GHz
11	2.4535GHz	2.455GHz	2.4565GHz
12	2.4585GHz	2.460GHz	2.4615GHz
13	2.4635GHz	2.465GHz	2.4665GHz
14	2.4685GHz	2.470GHz	2.4715GHz
15	2.4735GHz	2.475GHz	2.4765GHz
16	2.4785GHz	2.480GHz	2.4815GHz

Wireless Keyboard and Mouse Operation and Interoperability

2.4GHz Wireless keyboards and mice typically operate on a fixed narrow-band frequency at very low power levels in a point-to-point configuration. They use proprietary communications protocols, but their data rates are roughly 100Kbps.

Since wireless keyboards and mice operate at low power levels and are placed in close proximity to their base unit, (contained RF fields) it is not likely that they will interfere with Turning Technologies RF devices unless the different devices are placed close to each other.

To avoid interference, maintain physical separation between the devices. Also, since wireless keyboards and mice operate at a fixed narrow band, there should be many open interference free channels that the Turning Technologies devices can operate on and coexist without problems.

Cordless Phone Operation and Interoperability

Many of today's cordless phones operate at 2.4GHz and used FHSS techniques. The protocols are proprietary, but many phones use channels that are between 5MHz and 10Mhz wide. For a hopping device, that would limit the number of channels available in the ISM band to about 8 to 16.

Since most cordless phones are frequency hoppers, the probability of collision between a cordless phone and a Turning Technologies device depends on the number of cordless phone channels so it would be between 1/8 and 1/16. It is likely that cordless phones use collision avoidance techniques like Bluetooth does because multiple phones can coexist with each other in the same facility. If they do then the collision probability with Turning Technologies devices would be less for the same reasons as for Bluetooth. To reduce the probability even further, the devices should be physically located as far (several feet) as possible from each other – especially the Turning Technologies receiver and a phone's base unit. The other way to reduce or even eliminate interference is by programming the Turning Technologies units to a channel that the cordless phones do not use. This would have to be done by trial and error since cordless phone channel information may not be readily available.

Microwave Oven Operation and Interoperability

Most microwave ovens operate close to 2.45GHz fixed frequency. This frequency is right in the middle of the ISM band. The magnetrons used in microwave ovens generate RF energy that has a bandwidth of about 10MHz 30MHz.

The transmit power levels for microwave ovens are 100Watts to 2KWatts depending on the size of the oven. This energy is mostly contained within the oven chamber by RF shields, but some energy does escape and can interfere with nearby RF communications devices.

Since microwave ovens occupy a fixed 30MHz or so of bandwidth in the ISM spectrum, the probability that a microwave oven will interfere with a Turning Technologies device depends on their operational channels. If their channels overlap, the probability is high and if they do not overlap, the probability is near 0. So by selecting the Turning Technologies operating channels carefully, interference can be completely avoided. For example, a typical microwave oven will occupy a frequency band from 2.435GHz to 2.465Ghz.This means that the rest of the ISM band, namely 2.401GHz-2.434GHz and 2.467GHz-2.483GHz will not be used. If the Turning Technologies devices are programmed at any channel between 1-34 and 67-82, then the oven will not likely interfere.

As with any 2.4GHz devices, Turning Technologies devices should be kept physically far (several feet) away from microwave ovens.

Conclusions

An overview of the 2.4GHz ISM band and some technical details of devices that operate in that band and their RF characteristics have been provided. Interoperability or the ability of these devices to coexist and operate without severe interference and performance degradation has also been discussed.

Due to their low transmit power, single frequency operation, narrow bandwidth, and very short packet lengths, it is not likely that the Turning Technologies devices will cause significant interference with other 2.4GHz devices.

With careful planning and system setup, the Turning Technologies devices should be able to coexist and operate with other 2.4GHz devices without experiencing major interference from those devices. The two main ways to avoid interference and collisions are RF isolation, i.e. physically locating different devices away from each other, and proper channel selection. If these steps are taken, interoperability issues can be minimized or avoided completely.