ISM Band Coexistence Whitepaper

Kleer
KLR0000-WP2-1.2
December 12, 2007

Introduction

This whitepaper discusses ISM band coexistence issues for wireless audio applications, and some of the factors that should be considered in selecting a wireless audio technology.

The Industrial, Scientific, and Medical (ISM) radio bands were created as a place to relegate equipment that produces a lot of radio interference that could disrupt other radio applications that are sensitive to such noise. The license-free nature of these bands has made them attractive for use by various commercial applications/communication protocols such as Wireless Local Area Network (WLAN), Bluetooth (BT), cordless telephones, baby monitors, wireless security systems, etc. Consequently, these protocols are subject to interference from noisy equipment such as microwaves as well as from other intelligent applications competing for the same space.

ISM Band Coexistence refers to the ability of a given protocol to handle the following dual objectives:

1. Maintain acceptable performance in the presence of interference resulting from the operation of other devices sharing the ISM band.
2. Minimize the interference generated to allow other devices sharing the ISM band to also have acceptable performance.

Coexistence Mechanisms

A wireless device will experience interference, if another wireless device (the interferer) is transmitting at the same time that the device has its receiver on, the interferer's frequency overlaps with the device's receive bandwidth, and the interferer's output power is of sufficient strength and/or is near enough to the device. Therefore, a device can avoid interference by transmitting at another time - Time Division Multiple Access (TDMA), on another frequency - Frequency Division Multiple Access (FDMA), and/or at a lower power - Transmission Power Control. FDMA techniques can be further divided into Fixed Channel Assignment, Frequency Hopping Spread Spectrum, and Dynamic Channel Selection.

Time Division Multiple Access (TDMA)

TDMA is best suited to environments where competing devices are using the same frequency space and the applications only require a fraction of the total available bandwidth. That is, TDMA coexistence techniques are more suited to bursty and/or low bit rate applications because the TDMA approach assumes that the application can wait until the channel is clear before sending the data. If the application requires almost continuous use of the frequency, e.g. for streaming audio applications, TDMA loses much of its utility as a means of achieving coexistence, whereupon FDMA solutions are preferred over TDMA techniques.

As discussed in Kleer whitepaper "Wireless Digital Audio Quality For Portable Audio Applications", a wireless digital audio solution should have at least 2Mb/s of audio capacity. A 2Mb/s capacity carrying 1.4Mb/s of audio data results in a fairly high radio duty cycle such that TDMA is not the best choice for achieving coexistence. Of course, the wireless digital audio solution could reduce the duty cycle by having a higher capacity. If this is achieved using the same modulation index, then spectrum consumption will increase, offsetting the benefit of the lower duty cycle. If higher capacity is achieved using a higher modulation index, then receive sensitivity will go down (and power consumption will go up) again offsetting the benefit of the lower duty cycle.

FDMA – Fixed Channel Assignment

With Fixed Channel Assignment, a system administrator assigns the channel based on knowledge of the surrounding environment. This method is appropriate for fixed installations (e.g. WLAN) where the environment is relatively static, but does not work well for mobile applications. Fixed Channel Assignment is used for WLAN which relies on TDMA techniques to deal with interference. As such, WLAN interference robustness is only achieved at the expense of throughput.

FDMA – Frequency Hopping Spread Spectrum

Frequency Hopping Spread Spectrum (FHSS), as used by Bluetooth, divides the 2.4GHz ISM band spectrum into 79 channels spaced at 1MHz and rapidly hops from channel to channel on a pre-determined schedule. If a packet is corrupted when transmitted on a given channel, it can be immediately re-transmitted on the next channel if that channel is not experiencing interference. Unfortunately, the ISM band is so heavily used that there may be many channels that are not available and continuing to visit these channels will result in an effective loss of throughput.

Adaptive Frequency Hopping (AFH) was added to the Bluetooth implementation of FHSS. AFH modifies the FHSS hopping schedule based on detected interference, essentially dropping bad channels from the schedule. The Bluetooth standard requires that a minimum of 20 channels (20MHz) be used in the hopping schedule. Unfortunately, ISM band occupancy must be relatively low in order to find 20MHz of free spectrum out of the available 80MHz.

Wireless audio solutions cannot assume that band occupancy will be low. In fact, high occupancy is becoming the norm. Today, it is common to find WLAN activity in channels 1, 6 and 11 in airports, office buildings and multi-dwelling building. Figure 1 illustrates that in this situation it is not possible to find 20 Bluetooth channels that do not overlap with WLAN. Therefore Bluetooth and WLAN will interfere with each other despite the AFH mechanism.

FDMA – Dynamic Channel Selection

Dynamic Channel Selection allows for adaptive behavior in the presence of interferers. Communicating devices stay on a selected channel, monitor their effective throughput via BER/PER or retransmission counts, and can decide to switch to another channel if the interference persists.

Given the spectrum requirements of WLAN, it is ideal if the channel spectrum required for wireless digital audio is less than 5MHz so that the channel can exist between adjacent WLAN channels or at the outer edges of the 2.4GHz ISM band. With 5MHz channel spacing, the ISM band can be divided into 16 channels and this provides very good frequency diversity. Of course, the 5MHz that is available at any given moment changes due to the transitory nature of interference. Therefore channel selection must be dynamic.

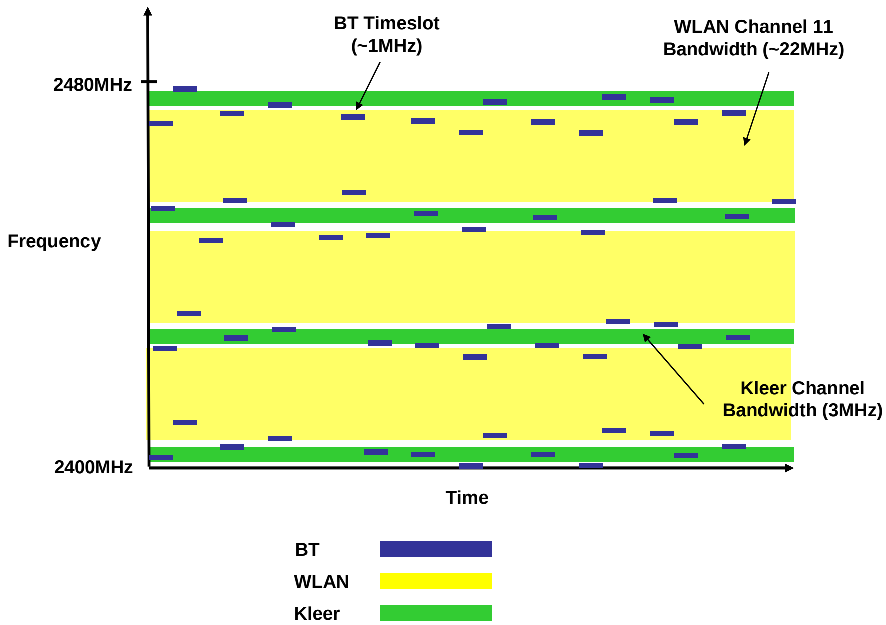

Figure 1. ISM Band Occupancy

Dynamic Channel Selection also addresses the second objective of ISM band coexistence; to minimize the interference generated to allow other devices sharing the ISM band to also have acceptable performance. It is possible to have an effect on another protocol, even if that protocol is not affecting you. Consider the hidden station scenario illustrated in Figure 2 where a laptop is downloading a large file over a WLAN connection from a relatively distance access point. The laptop is primarily receiving and only transmitting acknowledgements. In the vicinity of the laptop, a wireless digital audio source is transmitting audio to an audio sink. The audio source transmissions can severely impact the laptop reception, while the brief laptop transmissions may have a negligible impact on the audio sink reception. Furthermore, since the laptop and the access point use TDMA, they will delay transmissions if they detect the wireless audio signal, reducing the throughput of the WLAN connection, and further reducing the impact of the WLAN on the audio connection. Since the audio connection does not detect significant impairment, it does not switch channels and therefore continues to impact the WLAN indefinitely. Dynamic Channel Selection solves this problem by assessing the occupancy of other channels *before those channel are selected.*

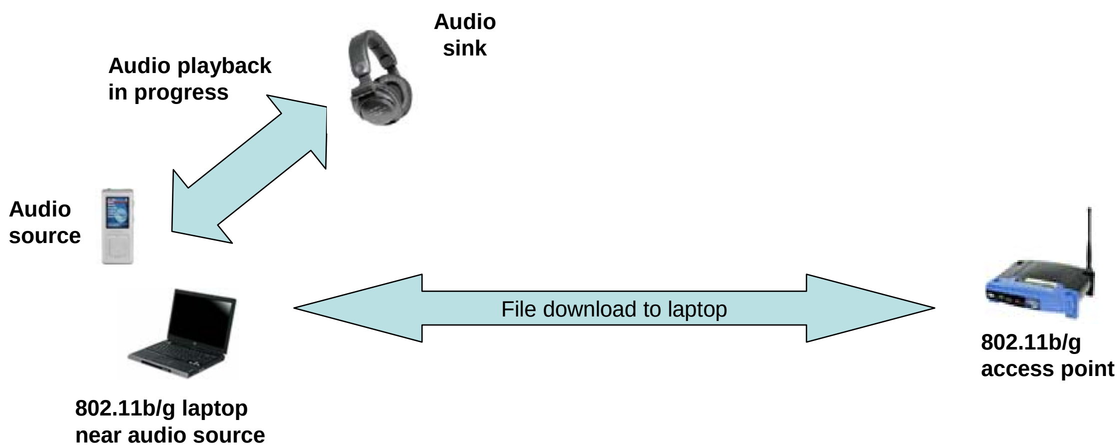

Figure 2. Hidden Station Problem

Transmission Power Control

Transmission Power Control addresses the second coexistence objective of minimizing interference on other devices sharing the ISM band by requiring that a device reduce its output power to the minimum required to provide acceptable performance. By transmitting at the lowest output power possible, the distance that a competing device must be in order to reuse the spectrum is reduced, enhancing coexistence.

Generally, Transmission Power Control requires that the transmitter have information about the quality of the signal received at the other end of the link. This information can be inferred from the signal strength of the acknowledgements received from the other end, as well as from the absence or presence of the acknowledgements themselves.

Summary

The success of wireless technology in the portable audio market depends on ISM band coexistence, audio quality, battery life, form factor and cost. This whitepaper has discussed the various approaches to achieving ISM band coexistence and determines that the best solution for wireless digital audio applications is to use a combination of Dynamic Channel Selection with Transmission Power Control.

Kleer’s wireless audio technology is the first such technology to combine high quality audio and robust ISM band coexistence with low power consumption to address portable, home and automotive audio markets. Kleer’s Audio LP technology is ideally suited for OEMs of portable audio players, iPod and other player accessories, home audio/theater systems, earphones, headphones and speakers.

Kleer’s patented sub-sampling radio architecture communicates lossless CD-quality digital stereo audio over a robust 2.4GHz radio link, while achieving 10 times the battery life of a comparable Bluetooth solution. Kleer’s dynamic narrowband channel selection with transmit power control offers unprecedented interference immunity and ISM band coexistence, while our 2.37Mb/s capacity allows lossless transmission of the audio signal with ample room for retransmission.