Digi-Wave™ Technology

Williams Sound Digi-Wave™ White Paper

TECHNICAL DESCRIPTION

The Digi-Wave system allows for wireless communication in numerous scenarios, including for tour guide systems, for intercom systems and for interpretation. The communication can be one-way broadcasts or two way communication channels. Communications can be between a secured group and extremely private, or open to anyone with a receiver who may need to listen in.

This document discusses the technology behind the Digi-Wave system. For references on usage and set up, please see the user manual which is available on the Williams AV website.

Operating Frequency:

The Digi-Wave System operates on the 2.4 GHz Industrial, Scientific, and Medical (ISM) Band, which is intended for short-range, low power applications. The unlicensed ISM band is harmonized for use in most countries, however, users should always check with local radio regulations to be sure of legal operation.

The most commonly encountered devices that also operate in this band are 2.4 GHz 802.11b Wi-Fi routers and Bluetooth devices. Other devices include microwave ovens, Electro-Discharge Machines (EDM) machines, and some medical diagnostic equipment.

Frequency-Hopping Spread Spectrum:

Digi-Wave utilizes Frequency-Hopping Spread Spectrum (FHSS) to minimize interference with other wireless services operating in the same band. FHSS is a method of wireless transmission that rapidly switches a radio carrier over a number of different frequencies in a pseudo-random sequence instead of on a single, fixed frequency. By using many frequencies in the same band, the signal is “spread” over the entire band. The 2.4 GHz ISM band is sufficiently large to allow efficient spread spectrum operation. In order for a frequency-hopping system to work, the hopping sequence must be followed by both the transmitter and receiver in a process called synchronization.

FHSS has several advantages over fixed frequency transmission:

1. The signal only stays briefly on each frequency which reduces the probability of landing on the same frequency at the same time as another service (referred to as a collision). This gives strong resistance to narrowband interference on a single channel because the system is continually hopping around it. The spread spectrum signal likewise adds minimal noise to other narrow-band transmissions because of the short time interval spent on each channel.
2. Spread spectrum signals are difficult to intercept. Unlike a fixed-frequency system, where only one frequency needs to be known by an eavesdropper, the pseudo-random sequence of frequencies would need to be known.
3. More users can share the same spectrum, since within limits, they will be hopping onto different frequencies at different times, reducing the likelihood of interference.
4. Spread spectrum signals are also resistant to multipath fading. Since the signal constantly changes frequency, the wavelength also constantly changes, thus the relationships between direct and reflected signals that cause cancellations are also changing.

FHSS Channelization:

A Digi-Wave channel is represented by a 4 frequency sequence, hopping through 16 center-frequency channels between 2.402 and 2.476 GHz at a rate of 325 hops per second. The channel is divided into time slots of approximately 3 milliseconds, where each time slot corresponds to a hop frequency. The hopping sequence is pseudo-random since it follows a carefully selected fixed table of channel sequences. For security reasons, the hopping sequence algorithm is proprietary.

There are four separate channel sequences used when Digi-Wave is operated in the Tour, Hearing Assistance, or Intercom modes and 8 sequences used when Digi-Wave is operated in the Interpretation mode. Channel separation is 2000 kHz in Tour, Hearing Assistance, and Intercom modes and 5000 kHz in Interpretation mode.

Digital Modulation:

Digi-Wave makes use of Frequency-Shift Keying (FSK) modulation. Frequency-Shift Keying (FSK) is a type of frequency modulation in which digital information (binary 1's and 0's) is transmitted through frequency changes in a carrier wave.

Multiple Access or Channel Sharing:

Digi-Wave uses synchronous Code Division Multiple Access (CDMA), an encoding process which allows multiple users to simultaneously share the same channels.

Each Master transmitter is assigned a unique 64-bit group code. The group code allows transmitters and receivers to identify each other. Only transmitters and receivers sharing the same code can communicate with each other. Codes from other groups are not recognized and are ignored.

In addition, CDMA is a frequency-hopping technique. The transmitter and receiver use fixed tables of channel sequences so they can maintain synchronization by following the table. The transmitter periodically sends its current location in the table, allowing the receivers to stay in step.

By spreading the data over the frequency-hopping signal, the coded signal has a much higher data bandwidth than the original data being sent. This is referred to as spread spectrum process gain, which adds data redundancy to reduce errors, and is equivalent to increasing signal power.

As an additional benefit, a synchronous CDMA receiver can in theory completely reject strong signals using different codes due to the orthogonal relationship of the signals. Orthogonal sequences are used, because they do not interfere with each other. Orthogonal describes the mathematical relationships between the sequences where cross-correlation equals zero. Signals with a different code appear as wideband noise, reduced by the process gain.

Once the data signal is encoded by the CDMA process, the radio signal containing both the data and the frequency-hopping instruction is transmitted using Time Division Multiple Access (TDMA). TDMA divides the band access up into blocks of time. Each user takes turns sending their data, allowing more users in the same bandwidth.

Latency:

All digital audio systems exhibit latency – a delay due to the time required to convert the original analog audio signal into a digital signal, modulate it, transmit it, and convert it back into an analog audio signal. Digi-Wave technology provides an excellent low-latency time of less than 7 milliseconds, important for real-time, voice applications. This is substantially lower than the 25 to 40 millisecond latency for Bluetooth transmission, which introduces a noticeable delay from the source in live audio applications.

Transmit Power:

Digi-Wave Effective Isotropic Radiated Power (e.i. r.p.) is limited to 20 dBm (100 mW), the same as a Class 1 Bluetooth device. Isotropic refers to distributing power equally in all directions. Typical output is 19 dBm.

Encryption:

The Digi-Wave system by default uses 87-bit encryption, consisting of a 64 bit group code, a 16-bit security code, and a 7-bit scan code. The 87-bit encryption is backwards compatible with older Digi-Wave systems.

An Advanced Encryption Standard (AES) 128-bit encryption can be added on top of the 87-bit encryption in the 400 series. This provides extra security, but does not work with older Digi-Wave systems.

As an additional privacy measure, the Transceivers features an optional, 4-digit Secure Key Code (PIN) that can be set to create a specific group of Transceivers that will only work together. Receivers do not have Key Code capability.

Privacy vs. security: The Digi-Wave system is designed to offer a high degree of privacy in commercial communications applications. The system encoding does not support secure military or intelligence-gathering applications. As a practical matter, with 1024 possible group codes and 10,000 possible Key Code combinations, it is likely that a communication would be finished long before a "brute force," trial and error cracking attempt could be made.

Number of Users:

An unlimited number of DLR 400 Receivers can be used with a corresponding DLT 400 Transceiver. A Transceiver transmits and receives, so is capable of two-way operation.

When DLT 300 transceivers and DLR 360 receivers are used together, up to 1024 DLT's can be used with any number of DLR's. (Group number chosen should be between 0 -99).

Up to four separate groups, each using a different group number, can operate simultaneously in the same place at the same time. Adding more groups will increase the likelihood of signal collisions and loss of signal. More than 4 groups can be used if there is a physical separation of 15m (50 ft.) or more between the groups, due to the "capture effect" which causes receivers to pick up the closest, strongest signal.

Operating Distance:

Operating distance is highly dependent on environmental conditions. Under ideal conditions, with line of sight and no other 2.4 GHz services present, operating distance can be up to 274 m (900 ft.). Under very poor conditions, with many 2.4 GHz services present, operating distance can be reduced to 10 to 15 m (30-40 ft.).

In Interpretation mode, the distance can be expanded with repeaters. See the full user manual for details.

Indoor Use vs. Outdoor Use:

There is no restriction for indoor or outdoor use. In general, operating distance is greater when the system is used indoors than when used outdoors or in large, open spaces. Indoor range is generally greater due to reflections (multi-path) as the radio signal bounces off of walls, floors, and ceilings. The reflected signals can help overcome body shielding and high frequency propagation losses. The rapidly hopping frequency also helps to overcome signal loss due to frequency cancellations.

Body Shielding:

The human body is an effective shield at 2.4 GHz frequencies. If the Digi-Wave units are worn such that users are facing each other with the Digi-Wave units facing each other, operating distance will be maximized. If the Digi-Wave units are worn such that users are facing away from each other and the user's bodies stand between the units, range will be minimized. The low-power RF signal produced by the Digi-Wave transmitter is not known to pose any health risks.

Digi-Wave Antennas:

Digi-Wave Transceivers and Receivers do not have external antennas. Due to the high frequencies used, the wavelength is very short, (12.5cm or 4.92 in.) which allows the transmit/receive antennas to be built inside the products. The antennas are optimized with an elliptical output pattern. In general, maximum system range is achieved when all units are held vertically, matching antenna polarization.

Resistance to Received Interference:

All radio systems are potentially subject to interference. Digi-Wave is designed to minimize the likelihood of interference, but cannot completely eliminate the possibility. What is typically seen with Digi-Wave in the presence of many Wi-Fi signals is a reduction in system range, but not a loss of signal.

For example, an extreme situation is demonstrating the product at a major trade show where in excess of 20 Wi-Fi networks are in simultaneous operation. The DW system continues to function in this environment, without loss of voice data, but operating distance may drop to 15 m (40 ft.)

Microwave ovens and Electro-Discharge Machines operate at 2.4 GHz and can create strong interference if the Digi-wave system is used in close proximity (within 1 m or 4 ft.)

In general, other services operating in the 2.4 GHz band will not directly interfere with the Digi-Wave system, but may reduce the system range if the interference is strong enough.

Transmitted Interference:

The Digi-Wave system generally does not cause interference to Wi-Fi networks and other 2.4 GHz services. The CDMA frequency hopping operation does not disrupt Wi-Fi transmission. Network throughput may be impacted if the Digi-Wave unit is operated in close proximity to a Wi-Fi router (within 1 m or 4 ft.)

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