

Methods and Implementations: *Robust, Wireless Digital Audio Delivery*

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This paper describes the methods used by Focus Enhancement’s FS848 HD Wireless Audio Integrated Circuit (IC) to provide high quality wireless surround audio without experiencing the interference, static, or dropouts common to other wireless audio solutions.

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Overview

The FS848 Wireless Audio IC is a premium audio solution designed specifically for Home Theater audio systems. The FS848 was designed to solve Home Theater audio setup and distribution difficulties by delivering innovative features and capabilities in three key areas:

- **High Quality Audio:** Extracts the highest audio fidelity possible from the speaker drivers and cabinets through programmable filters and crossovers tuneable to each speaker's characteristics.
- **Ease of Setup:** Automatic Home Theater audio setup and single button audio sweet spot location programming.
- **Robust Wireless Network:** Provides a noise free, interference resistant wireless network between the master and up to eight speakers, with 2 ms latency.

This white paper focuses on the FS848 techniques and technology to enable the ***Robust Wireless Network***. Please refer to the complete set of white papers about the FS848 HD Wireless Audio IC solution.

Technical Challenge

A key challenge for wireless Home Theater audio solutions is to provide sufficient resilience (robustness) to lost audio information caused by:

- Interference from other RF sources in the house,
- multi-path distortions,
- and disruptions to the RF signal from people or objects moving within the room.

Competitive wireless audio solutions address the wireless robustness through a variety of techniques, but typically the added resiliency is provided at the cost of audio fidelity and latency. Some of the techniques commonly used by competitors include:

| Competitive Solutions | Focus Enhancements FS848 |
|---|---|
| Uses the 2.4 GHz Wireless Spectrum that competes with many common devices including Wi-Fi access points, Bluetooth, microwave ovens, and cordless phones. | Uses the newly opened 5 GHz U-NII band spectrum that is relatively free of congestion. 23 non-overlapping channels available. |
| Reduce data by compressing the audio or reducing to 16-bit data samples. | Supports 24-bit, 48 KHz, uncompressed audio resulting in no loss of fidelity for DVD or other high quality audio content. |
| Resends lost data at the expense of end-to-end latency, noticeable lip-synch issues and provides an unsatisfactory gaming experience. | Forward Error Correction (FEC) and other techniques mitigate the need for resending lost data. Low 2 ms end-to-end latency produces no discernible lip-synch issues, and supports gaming use. |
| Continually transmits at highest permitted power level, which can interfere with operation of other devices using same spectrum. | Provides power agility that enables the FS848 to transmit at the lowest possible power level and be a “good citizen” to neighbouring devices. |

FS848 Robustness Methods

The FS848 HD Wireless Audio IC provides a high quality wireless data infrastructure for a Home Theater system by ensuring that audio data is transmitted to speakers with no discernible audio artifacts introduced by interference with other devices in the home, or disruptions to the wireless link from movement of people and objects.

Focus Enhancements has designed the IC with eight overlapping levels of link protection to ensure that the audio played at each speaker enables consumers to experience the richness of surround sound audio.

All eight levels are always available and enabled. There is no delay for buffering or retransmission. The transport has a fixed latency of 2 ms when using some or all of the robustness techniques shown in Figure 1.

| Level | Robustness Method |
|-------|--|
| 1 | Reduce interference -- <i>U-NII Band Spectrum</i> |
| 2 | Reduce multi-path distortion – <i>Orthogonal Frequency Division Multiplexing (OFDM) Modulation</i> |
| 3 | Minimize lost data – <i>Forward Error Correction (FEC)</i> |
| 4 | Optimal RF reception – <i>Antenna Diversity</i> |
| 5 | Avoid congested frequencies – <i>Dynamic Frequency Selection (DFS)</i> |
| 6 | Avoid interfering with other systems – <i>Transmit Power Control (TPC)</i> |
| 7 | Data recovery -- <i>Interpolation</i> |
| 8 | Fail safe – <i>Active muting</i> |

Figure 1: Eight Levels of Robustness

Level 1: U-NII band

The easiest way to avoid interference is to operate in an area of the RF spectrum that is less congested with other interferers common in the home environment. The U-NII band, which extends from 5.1 GHz to 5.7 GHz, is largely unused compared to the 2.4 GHz space, which is filled with Wi-Fi devices and microwave interference. The U-NII band also avoids the interference from cordless phones and other unlicensed transmitters in the crowded 5.8 GHz space. The U-NII band is supported worldwide, making it possible to ship a single product anywhere in the world. This band has up to 23 non-overlapping channels (country dependent), allowing the system a lot of flexibility in choosing free space. U-NII band rules are strict; requiring devices to monitor channels and move if another device is transmitting on a channel, thus further reducing the chance of interference.

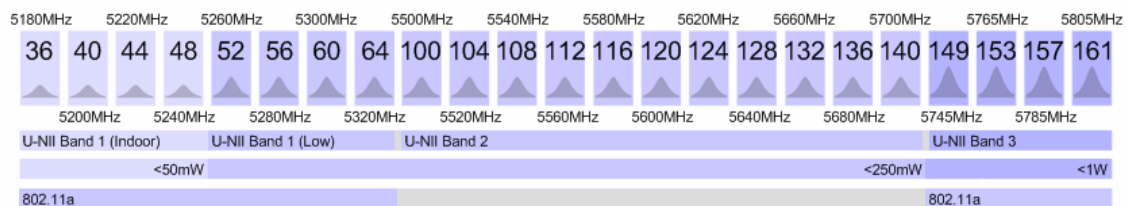


Figure 2: U-NII Frequency Spectrum

Level 2: OFDM Modulation

Our baseband processor uses an OFDM modulation with Viterbi and Reed-Solomon encoding.

OFDM is a spread spectrum technique that distributes data over a large number of carriers spaced apart at precise frequencies. This frequency spacing prevents the demodulators from seeing frequencies other than their own. Other benefits of OFDM include high spectral efficiency, resiliency to RF interference, and lower multi-path distortion.

Level 3: Forward Error Correction:

The FS848 Media Access Controller (MAC) incorporates a proprietary FEC algorithms based on Viterbi and Reed Solomon techniques optimized by Focus Enhancements Audio data. Eight bits of FEC added to each 24-bit audio sample to help facilitate the recovery of any data lost in transmission. With FEC, retransmission of lost data and its impact on latency and A/V lip-synch are avoided.

Level 4: Antenna Diversity

Diversity of up to four antennas is provided for each speaker or master. The redundancy greatly reduces the likelihood of nodes, shadows or weak spots, allowing the speaker to be placed anywhere in the room. The system constantly monitors antenna signal strength and can immediately switch between antennas on a per-bit basis to adapt to changing conditions.

Level 5: Dynamic Frequency Selection (DFS)

The FS848 MAC is designed to hop frequencies on a per-packet basis. The master continually scans all other channels to identify traffic patterns and behaviours on an out-of-band process that doesn't interfere with audio transmission. In the event that interference is detected on the current channel, the FS848 has already predetermined the next available free channel.

Level 6: Transmit Power Control (TPC)

The FS848 dynamically adapts power transmission based on two-way communication with each of the speakers in the room to ensure that the transmission power is "just enough" to reach all the speakers in the room. Changes in the signal strength from disruptions such as people moving around the room are immediately detected and managed. Use of the lowest transmitted power possible facilitates multiple FS848 systems to operate in adjacent rooms, even in dense settings like hotels and apartments.

Level 7: Interpolation

Each speaker supports up to 10 ms of audio interpolation such that a catastrophic loss of a packet data is not detected by anything other than sophisticated audio test equipment.

Level 8: Muting

In the event that more than 10 ms of packet data is lost, the speaker fades the volume of the audio interpolation, described previously, to zero until the link is restored, at which point the speaker volume is faded back up to the calibrated level. This individual speaker muting is a final measure of protection in the case of data loss, and is similar to the protocol used by CDs and DVDs to handle scratches and nicks on a disc. In everyday listening, consumers do not realize that they are integrating the silence produced by CDs and other devices during this muting period. Adopting this methodology ensures that there are no abrupt snaps, pops, or static heard from any FS848-based speaker.

Summary

The FS848 Wireless Audio IC is a premium audio solution designed specifically for Home Theater audio systems to enable an auditory experience exceeding that of comparable wired systems. One key component of the auditory experience is the requirement for the unaltered audio data to reach the speakers with reliability and robustness of a wired system.

Focus Enhancements has achieved this requirement with multiple levels of robustness and redundancy designed into the solution to ensure the source audio content is reliably transmitted to each of the speakers through techniques that do not alter or minimize the quality of the source material.

The FS848 offers up an experience that needs to be heard to be fully appreciated.

FS848 – “*Superior Surround Made Simple*”

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