June 2007

Audio-Technica White Paper
SpectraPulse™ Ultra Wideband Wireless Microphone System

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SIMPLE

Sometimes, the most revolutionary ideas are those that in hindsight appear quite obvious and simple. The technology behind the SpectraPulse™ ultra wideband wireless microphone system is just that – revolutionary and simple in concept.

Consider that something as simple as a miniature switch is part of what was behind the technology revolution of integrated circuits. The engineering skill and effort it took to implement this simple idea was extremely difficult, but this simple idea changed the world. Once it worked, it became ubiquitous.

The Audio-Technica U.S., Inc. SpectraPulse development has been such a project. Many companies have tried to implement ultra wideband (UWB) wireless into products, but we have been the first to succeed in incorporating UWB into the world's first commercially viable audio product.

Ultra wideband wireless is a naturally simple idea. It consists of very rapidly pulsed signals, each one a short burst over a very wide instantaneous bandwidth of frequencies. In early conception dating back to Marconi in the late 1800's, a UWB signal was a spark-gap transmission that was used for long range communications. These early communications systems were replaced by more efficient, longer pulse duration, narrowband techniques.

Short pulse technology was only revisited nearly 80 years later in the mid 1960's. At this time, as technologies, methods and materials allowed engineers to work in much higher frequency ranges, UWB began to emerge as a novel form of communications due to its low probability of detection characteristics. The successful use of UWB by the U.S. government and military led to the FCC's groundbreaking rule-making that permitted unlicensed commercial use of the technology for the very first time. They set the definition of an ultra wideband signal as having an instantaneous bandwidth of at least 500 MHz (where the spectrum is defined as the 10 dB down points from the center of the transmission) – or – a signal with a >20% fractional instantaneous bandwidth. (500 MHz is approximately 20% of a 2.4GHz center frequency signal. 2.4GHz is a popular wireless frequency with many available parts, and many engineers have experience working at this frequency.)

SECURE

The FCC has mandated both peak and average output power limits for unlicensed UWB products in order to ensure that they will not interfere with other wireless and security devices. The UWB signal must be lower than the spectral power density emission limit of - 41.3 dBm/MHz, which is also the limit applied to *unintentional* radiators in Part 15 of the FCC codes. We, however, are *intentionally* radiating at these very low levels and must still maintain reliable operation and range. Although higher power has advantages, the method in which the SpectraPulse system works allows us to accomplish extremely reliable and safe communication that is also inherently secure.

The nanosecond duration burst signal is one of the keys to UWB operation. The pulse for the SpectraPulse system is approximately two nanoseconds in duration and occupies a bandwidth of about 500 MHz during the limited transmit duration. The detection of this limited-duration signal is extremely difficult even with expensive test equipment, since these very short pulses are so close to the ambient noise floor. In comparison, traditional FM signals are always on, meaning that the carrier is always present and signals are easily detected and decoded. Traditional FM microphone systems transmit about 50 milliwatts of average power. The SpectraPulse system transmits 40 nanowatts average power. This is approximately one million times lower than an FM system.

Although SpectraPulse is inherently secure and basically “invisible” to anyone scanning the environment looking for communications, some highly sensitive applications may require added assurance to prevent detection and decoding of the signal. For applications such as this, A-T has developed an optional 128-bit encryption feature. This feature permits the microphone and audio control interface to be encrypted and keyed to each other so that even someone with another SpectraPulse system would not be able to decode the signals. The computer-controlled encryption software allows the user to check the status of encryption and to change the encryption code as often as desired.

REVOLUTIONARY

Sometimes it is easier to describe why something is revolutionary by comparing it to more traditionally used technology.

Those familiar with traditional FM wireless use are also familiar with a host of problems that accompany this method. What makes SpectraPulse revolutionary is also part of what makes it simple. For example, there are no traditional wireless set-up issues to worry about. SpectraPulse does not require frequency selection or coordination, there is no intermodulation distortion, no multi-path, no varying signal strength resulting in pops, clicks, fades or drop-outs. The system is fully digital, has under 2ms latency, and does not use a compander, so the sound quality of the microphones with a SpectraPulse wireless is comparable to a wired condenser microphone. The system does not have to use squelch or pilot tones to keep out interference and signals cannot break in to an “open” receiver. You can use two transmitters adjacent to each other without mutual interference. The diversity used in the SpectraPulse system is digital and it is optimized for maintaining a selected bit error rate. This novel diversity feature has nothing to do with the audio signal, and as such we have eliminated diversity switching noise, pops, fades and level differences.

SpectraPulse is designed with high speed digital components and solid-state RF devices. Therefore, SpectraPulse does not need “alignment.” It works reliably because of how it is designed and built. It cannot go out of alignment, and it does not need adjustment over time or use by either the end-user or the factory.

There are a few more issues that are common concerns for most audio product users: battery life and “Blackberry” noise (noise due to picking up RF interference from Blackberries or other forms of wireless communication tools).

Despite being packed with advanced-technology devices, the SpectraPulse battery is only used during the nanosecond data bursts. The control systems of the SpectraPulse are designed to use battery power only when needed and then are placed in a “sleep” mode. Battery life with rechargeable batteries is a solid 9 hours. This is very difficult to accomplish in current FM wireless products.

Those familiar with recent “Blackberry” noise issues may know that Audio-Technica leads the field in developing RF immunity for condenser microphones. Naturally, that immunity applies to this product as well with careful filtering, grounding and shielding playing very important roles in protecting the performance of our high-quality microphone.

THE DETAILS

The concept of UWB is simple – send a known fast pulse sequence, identify the sequence by looking for the sequence and known pulse characteristics, synchronize to the pulse train and decode the audio information for a complete communication transaction. In practice, however, it is difficult to implement the jobs of detecting and coordinating the UWB pulses for use in a high-quality audio product. The SpectraPulse system required careful design and coordination.

Understanding the challenge of the task at hand, Audio-Technica began looking for a technical partner that we considered would be the world-leader in UWB technology. In 2002, we formalized our exclusive relationship with Multispectral Solutions, Inc. We have been prototyping and refining the UWB transmission/reception, along with the digital and analog circuits, interfaces and controls needed to create a world class audio product. Working in the 6 GHz range meant learning new methods and materials. This included everything from the physical microphone material dimensions, circuit board materials and grounding techniques needed to be re-defined by audio standards.

At the heart (or brains) of the system is the drm141. This unit contains 14 complete channels of digital receivers (one for each possible microphone transmitter address), a transmitter to communicate with each available microphone transmitter, (the communication of the SpectraPulse system is bi-directional) and a full digital circuit for the detection, analysis, conditioning, and coordination of all the information that is coming and going through the system. The drm also transmits logic states that are set on the back of the audio control interface (aci707) via dip switches that define the function of the push-button on the top of the mtu101 microphone transmitter.

To accomplish the silent and seamless coordination of 14 channels of digital wireless without collisions, the SpectraPulse employs a TDMA method, and advanced forward error correction with proprietary bit error rate and audio muting logic. The TDMA along with the bi-directional communication sync method allow us to operate with negligible latency and near instantaneous re-acquisition time in the event of a lost signal.

The SpectraPulse operates with an audio bandwidth of 100 – 12,000 Hz. The system uses 16 bit digital audio with a 24 kHz sampling rate and a UWB data rate of 8 megabits per second. A TDMA architecture containing 15 total time slots per frame is employed with a frame duration of 1ms. The drm transmits during the first time slot of the frame to synchronize the microphones and to send status and control. Each of the 14 mics transmit sequentially on their respective time slot to send their audio stream to the drm. Audio data is queued up by each microphone over the 1msec duration immediately prior to transmitting on its respective time slot, thus minimizing audio latency to under 1.5ms.

Another advantage of the SpectraPulse system over current wireless methods is a very sophisticated, fast and robust bi-directional linking system. The SpectraPulse will silently mute if system sync is lost, but a very robust communication link process is designed to avoid sync loss and to quickly re-acquire. This process is typically transparent to the user as reacquisition occurs in only 3ms after sync loss. A spread spectrum system that is working well may take 1-2 seconds. Many wireless microphone systems take much longer than this, and some exhibit a very noisy artifact during sync loss or re-sync. A traditional FM wireless system may make noise when it loses communication connection, and typical re-acquisition of audio time is around 4ms (some are longer with slower audio ramp-up times to prevent audible noises).

A versatile control unit is linked via a single shielded CAT5 cable to the drm141. The aci707 audio control interface send signals to, and receives signals from, the drm141. It also supplies power (24VDC) to the drm141 via the cable. The aci707 takes the multiplexed 14 channels of digital audio data from the 14 receivers in the drm141 and demultiplexes them in 7 channels of analog audio. Switches on the back of the aci707 allow the user to set the audio output of the channels to 1-7 or 8-14. For 14 full analog audio outputs, you simply link 2 aci707s via a supplied cable. The aci707 acts as an interface into the site audio system (mixer, speakers, conferencing equipment, etc,) and also as a gateway for control of the microphones from the rest of the audio equipment. System settings (set via DIP switches on the rear of the aci707) and control information is converted to digital data and passed back to the drm141 via the shielded CAT5 cable. The drm141 includes this information when transmitting instructions to each mtu101 boundary microphone transmitter for seamless control.

Despite complex audio circuitry and control in the aci707, and the many advanced digital audio and control features of the drm141, the mtu101 boundary microphone transmitters are the most impressive technical accomplishment of the SpectraPulse system. These microphones are designed for performance using a technology previously only associated with RFID or lower-audio-quality military applications. One of the challenges of the SpectraPulse project was making a 6GHz digital wireless system work in such a small enclosure; an enclosure that was also shared with sophisticated digital and analog audio circuits. The impressive solid zinc die-cast microphone body and hardened steel grille house a power supply (with DC-DC converter), RF transmit and receive circuitry, transmit and receive antennas, digital control, digital audio, ground plane, analog audio, condenser microphone with pre-amplifier, circuitry for encryption and charging contacts and circuits for use with 2 x AA high-performance NiMH rechargeable batteries. Six layer circuit boards and all components still had to meet one last difficult challenge – RoHS compliance.

THE SPECTRUM

Those working with wireless today cannot avoid the “White Spaces” issue. All of the world's regulatory bodies have a challenge ahead of them. People like the freedom of “wireless.” However, the available wireless spectrum is becoming overcrowded with increasing interference, and future allocations are becoming hotly contested. This is happening around the world, not just here in the United States. Audio-Technica is dedicated to providing high-quality wireless audio, and it became obvious in the late 1990s that spectrum would become an issue if we continued to rely on traditional methods of wireless communication. Our desire was to employ digital wireless, but applying digital conversion to existing methods did not give us the improvements we needed or a solution to the impending frequency allocation problem. We investigated spread spectrum extensively and ruled it out due to some performance issues. We did not want to invest in a new technology unless it truly accomplished our goals and also met our high standards without compromise. MSSI's UWB technology clearly met our needs and we elected to invest in development even prior to the FCC rule-making on UWB.

UWB is a simple concept that holds great promise for a wide variety of applications. The SpectraPulse method is a unique method that allows us to gain the range and audio performance necessary for a multi-channel wireless system. It is important to point out where UWB fits in the frequency spectrum relative to other technologies and their specific allocations. Please see Appendix A for a chart that shows global wireless assignments. In the U.S, the FCC has authorized a very large band for unlicensed UWB use (3.1GHz – 10.6 GHz). It appears that UWB will be permitted in Europe in a similar frequency band. There is room to expand into additional frequency channels and since UWB is immune to most forms of interference and inherently not likely to interfere with other devices, it is a very secure and reliable choice.

THE NUMBERS

Frequency range	6.100 GHz – 6.600 GHz
Center Frequency	6.350 GHz
AD/DA	16 bits
Clock	24.576 MHz
Sampling rate	24 kHz
Pulse duration	3 nanoseconds
Frame length	1ms
Time slots per frame	15
UWB Rate	8 mbps
Compression	0
Companding	0
Latency	1.1 ms
Average RF power	40 nanowatts
Sync/re-acquisition time	3ms
Range	75 feet
Simultaneous channels	14
mtu current consumption	135mA
Battery life	9 hours
Mains (aci)	100-240V, 50/60Hz RoHS compliant power supply for global use
Microphone	Custom Audio-Technica RF shielded unidirectional condenser
Audio response	100 Hz – 12,000 Hz
Optional Encryption	AES level 3, 128 bit

Appendix A

Global Wireless Standards

	(GHz)
UHF	**0.75 – 0.8**

Channels 60-69 called "upper 700MHz," ruled by Congress to be reclaimed for new broadband wireless service in U.S.

ISM	**0.9 – 0.93**

Industrial, scientific & medical band – License exempt

UPCS	**1.91 – 1.93**

License exempt – personal communication services

WCS	**2.3**

Wireless communication services

ISM	**2.4 – 2.8**

Industrial, scientific & medical band – License exempt

MMDS	**2.5 – 2.7**

Multi-channel multi-point distribution service

Int'l	**3.4 – 3.7**
	4.8 – 5

Licensed bands in Europe, Latin America, Asia

Licensed band in Japan

10.15 – 10.5

Licensed band in Latin America

UNII	**5.15 – 5.25 low**
	5.25 – 5.35 mid
	5.73 – 5.83 Upper UNII

License exempt, national infrastructure band

ISM	**5.73 – 5.85**

Industrial, scientific & medical band – license exempt

UWB	**3.1 – 10.6**

U.S. UWB unlicensed band

Japan	**3.4 – 4.8 & 7.25 – 10.25**
Europe	**3.1 – 10.6** with constraints

Other technology comments:

UWB USB is in 3 GHz range

Bluetooth is 2.4 – 2.4835 GHz