Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
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Sennheiser Electronic Corporation, Request for Amendment of Part 74 of the Commission's Rules to Advance the Use of Spectrum Efficient Wireless Microphone Equipment	))))	RM- _________________

PETITION FOR RULEMAKING

Sennheiser Electronic Corporation respectfully submits this Petition for Rulemaking pursuant to Section 1.401 of the Commission's rules.

A. SUMMARY

Section 74.861(e)(5) of the Commission's rules limits low power auxiliary stations (including wireless microphones) in the TV bands and the 600 MHz duplex gap to a maximum bandwidth of 200 kHz.

An emerging technology that uses a full 6 MHz channel can carry more wireless microphone devices in the channel than is possible under the existing rule. The technology will improve spectrum efficiency and help to counter a severe spectrum shortage. We do not see any downside.

We ask the Commission to amend its rules so as to permit the use of this technology, and similarly, to clarify that advanced wireless microphone equipment in the 941.5-952 MHz and 1435-1525 MHz bands can use 6 MHz channels.

B. ABOUT SENNHEISER

Sennheiser is the world's leading manufacturer of high-end professional wireless microphones. (Ninety percent of the microphones used on Broadway come from Sennheiser.) The company has won Emmy, Technical Grammy, and Academy Awards.

Founded in 1945, Sennheiser employs more than 2,000 people worldwide with annual sales of $800 million. The company has sites in Germany and Ireland, and three in the United States: Old Lyme, CT (sales and marketing); Palo Alto, CA (advanced R&D); and Albuquerque, NM (manufacture of wireless microphones for North and South America, Asia, Australia, and New Zealand).

C. WIRELESS MICROPHONES AND SPECTRUM USE

Licensed wireless microphones are regulated under Part 74, subpart H as low power auxiliary stations. The equipment takes different forms:

- the performers' familiar handheld "stick";
- body-worn microphones, both visible lapel mics and mics hidden in clothing;
- performers' in-ear monitors;
- interruptible fold back (IFB) for cueing to on-air talent;
- intercom systems for backstage communications; and
- intercom systems for coaching staff and crew at sporting events.

Networks and content creators routinely use dozens of wireless microphone frequencies for a typical daily production. Major events often use hundreds. Broadway theaters together use over 1,600 coordinated frequencies each night (including lapel mics, intercoms, etc.) The Super Bowl needs over 1,500 coordinated frequencies.

Two main categories of wireless microphones have different spectrum requirements.

The microphones and in-ear monitors used by performers need the best possible audio quality. In addition, the total latency (delay) through the entire loop from microphone back to ear monitor must be unnoticeable to the performer, and so cannot exceed a very few milliseconds.

The combination of high quality and low latency requires a channel 200 kHz wide—the same as for broadcast FM signals.

The radio-frequency bandwidth needed for a given quality of signal is approximately the same whether the signal is in uncompressed digital or analog form.[1] Digital modulation does facilitate data compression, which contributes to spectrum efficiency, but always at a cost: compression that significantly reduces needed bandwidth also impairs audio quality or adds latency, or both. (In cell phones, the poor sound quality and the annoying delay are due mostly to high compression.) Performance microphones and in-ear monitors cannot tolerate even moderate digital compression—hence the present 200 kHz bandwidth specification.

Intercom and IFB systems need clear, reliable voice communication, but usually do not need not top audio quality. Most can tolerate limited frequency response and dynamic range, limited distortion, and some latency. These functions can work adequately in smaller bandwidths, typically 25 kHz.[2]

Most productions need both kinds of functions. The specifics vary. A Broadway musical needs several best-quality audio channels. A news outlet coordinating several teams covering a political convention needs, in addition, multiple channels for intercom systems and interruptible

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[1] This calculation shows that digital and analog modulations have similar spectrum needs: Accurate digital audio reproduction requires sampling the sound wave at twice the highest frequency to be recorded (or higher). The upper limit of human hearing is about 20,000 Hz. A common sampling rate for high-quality wireless microphones is a little over twice that, at 44,100 times per second—the same as in audio CDs. An adequate dynamic range (softest to loudest) requires 20 bits of information to encode each sample, for a data rate of 44,100 x 20 = 882,000 bits/second. Necessary overhead for framing and coding adds nearly 50%, for a total bit rate of about 1,200,000 bits/second. Reasonably efficient radio modulations squeeze about 6 bits/second of data into each hertz of bandwidth. The necessary radio bandwidth is thus 1,200,000 / 6, or 200,000 Hz (200 kHz)—the same as for analog modulation.

[2] There are exceptions. Performers in *Cirque du Soleil* execute dangerous acrobatic stunts in close coordination, timed with voice cues over wireless, body-worn intercom systems. In that application, excessive distortion or latency can be life-threatening.

fold back. Professional sporting events, such as NFL broadcasts, require both high quality broadcast microphones and intercom systems for use by coaches.

Wireless microphones in use at the same or nearby venues cannot use adjacent frequencies, but must space their bandwidths apart in the spectrum. The problem is not unique to wireless microphones, but applies to all radio-based equipment. Even a well-designed receiver cannot completely suppress signals on nearby channels, so that channel usage must be separated either in frequency or geographically. Most wireless microphones have another limitation as well: intermodulation, in which two or more transmitted signals combine to produce undesired signals at other, nearby frequencies. Because on-stage wireless microphones are constantly moving, they create ever-changing intermodulation products as they pass by one another. Minimizing these effects requires microphones that are highly "linear" and provide aggressive filtering, both of which add to cost. Digital microphones are less subject to intermodulation, but they too are expensive.

Using the best wireless microphones available, engineers can place, at most, twelve in a 6 MHz channel.

D. SENNHEISER'S WIRELESS MULTI-CHANNEL AUDIO SYSTEM

Sennheiser is developing a Wireless Multi-Channel Audio System (WMAS) that can greatly improve spectrum efficiency. (Other manufacturers are working on similar systems.) Rather than place each device in its own separate frequency segment, WMAS digitally combines the signals from multiple devices into a single 6 MHz channel. See Figure 1.

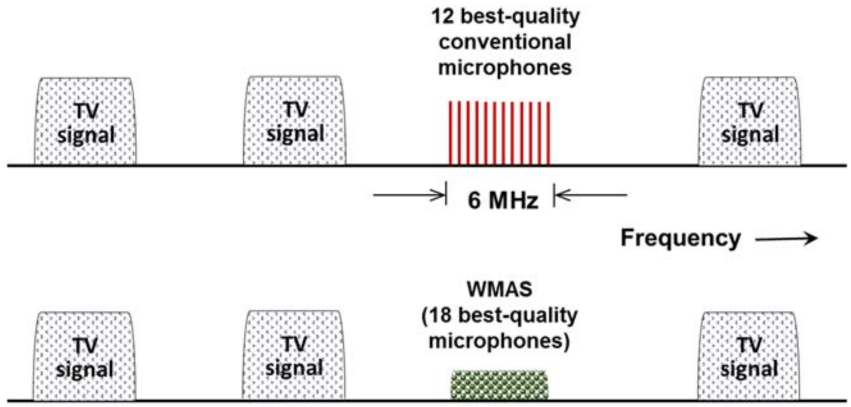

Figure 1: Conventional wireless microphones and WMAS compared

A WMAS might be configured for many possible device combinations. A few examples:

- 18 best-quality audio links (for performance microphones and ear monitors);
- 4 best-quality links and 20 intercom channels;
- 2 best-quality links, 12 mid-quality links, and 16 intercom channels that can accept higher latency.

Use of a WMAS offers several benefits:

- By spreading each connected device over the full width of the channel, WMAS eliminates the problem of multiple receivers each picking up adjacent frequencies, and thereby permits denser use of the channel.
- The fully digital, single-channel character of WMAS eliminates intermodulation, further increasing the practical density of use.
- Average power spectral density across the channel is lower.
- Narrowband interference into conventional equipment can cause dropouts in individual devices. Because WMAS spreads the signal for each device, otherwise damaging narrowband interference goes unnoticed.

The first two properties improve spectrum efficiency, allowing more devices in a 6 MHz channel than the channel could otherwise accommodate. See Table 1. The reduced average power spectral density allows frequency re-use at closer locations nearby, improving spectrum efficiency over a geographic region with heavy wireless microphone use, such as Broadway, The Strip in Las Vegas, and TV and movie studios.

	Single-channel	**WMAS**
Performance quality mic	8-12*	18
Intercom quality mic	24-36	96

* Density increases with equipment cost:
8 mics per 6 MHz channel @ $500-3k per mic
12 mics per 6 MHz channel @ $5-10k per mic

Table 1
Number of wireless microphone devices in a 6 MHz channel

WMAS approximately doubles the capacity of a 6 MHz channel for wireless microphones that deliver the best audio quality, and triples the capacity for intercom quality. Most productions use a mix of device types, and will see improvement between these extremes (and will occupy fewer channels overall).

As the industry struggles with the shortage of UHF spectrum following loss of the 700 MHz band, and then the 600 MHz band, this boost in spectrum efficiency is badly needed.

E. PROPOSED RULE CHANGE

Section 74.861(e) provides:

> For low power auxiliary stations operating in the 600 MHz duplex gap and the bands allocated for TV broadcasting, the following technical requirements apply:
>
> […]

(5) The operating bandwidth shall not exceed 200 kHz.

This language bars WMAS systems, which need more bandwidth.

We ask the Commission to amend the rule language to (1) define WMAS; and (2) allow WMAS systems to use 6 MHz bandwidth when providing the same or better spectrum efficiency as conventional, high-quality, single-channel systems.

Our proposed text is attached.

F. PUBLIC INTEREST

The requested rule change has the benefit of permitting the use of equipment capable of improved spectrum efficiency. In a time of ever-increasing demand on the range of frequencies suitable for wireless microphone applications, WMAS offers the ability to operate more devices in the same bandwidth.

The sole downside is the possibility of an operator connecting too few devices to realize WMAS's potential for improved spectrum efficiency. Apart from being a violation of the proposed rule, this is unlikely on economic grounds. We foresee that use of a WMAS will always be more expensive than operating the connected devices individually. The technology will be cost-effective only for the largest users, who need the extra capacity it offers.

We see no disadvantage to the Commission's interests, or to those of any party, from adoption of the proposed rule.

CONCLUSION

Sennheiser asks the Commission to adopt a Notice of Proposed Rulemaking toward adoption of the rule change discussed above.

Respectfully submitted,

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August 17, 2018

PROPOSED RULE LANGUAGE

§74.801 Definitions.

(add at the end of the section)

Wireless Multi-Channel Audio System. A system that digitally combines the signals of multiple low power auxiliary station devices onto one radio-frequency channel.

74.861 Technical requirements.

(add the underlined material)

[…]

(e) For low power auxiliary stations operating in the 600 MHz duplex gap and the bands allocated for TV broadcasting, the following technical requirements apply:

[…]

(5) The operating bandwidth shall not exceed 200 kHz, except that a wireless multi-channel audio system may have an operating bandwidth not exceeding 6 MHz when transmitting the signals of not fewer than 12 conventional low power auxiliary station devices.

(f) A wireless multi-channel audio system operating in the 941.5-944 MHz, 944-952 MHz, and 1435-1525 MHz bands may have an operating bandwidth not exceeding 6 MHz when transmitting the signals of not fewer than 12 conventional low power auxiliary station devices. Such a system may treat the 941.5-944 MHz and 944-952 MHz bands as a single band.