Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
	)	
Revisions to Rules Authorizing the Operation of Low Power Auxiliary Stations in the 698-806 MHz Band	)	WT Docket No. 08-166
	)	
Public Interest Spectrum Coalition, Petition for Rulemaking Regarding Low Power Auxiliary Stations, Including Wireless Microphones, and the Digital Television Transition	)	WT Docket No. 08-167
	)	
Amendment of Parts 15, 74 and 90 of the Commission's Rules Regarding Low Power Auxiliary Stations, Including Wireless Microphones	)	ET Docket No. 10-24

COMMENTS OF
SENNHEISER ELECTRONIC CORPORATION

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Sennheiser Electronic Corporation responds to the public notice released on October 5, 2012, in the above-captioned proceedings.[1] Sennheiser is also filing comments today in the Commission's pending "Incentive Auction" proceeding,[2] in which some issues overlap those in the *Public Notice*.

About Sennheiser. Sennheiser Electronic Corporation is a wholly-owned subsidiary of Sennheiser electronic GmbH & Co. KG, headquartered in Germany. The parent company is a global leader in microphone technology, RF-wireless and infrared sound transmission,

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[1] *The Wireless Telecommunications Bureau and the Office of Engineering and Technology Seek to Update and Refresh Record in the Wireless Microphones Proceeding*, WT Docket Nos. 08-166, 08-167, ET Docket No. 10-24, Public Notice, 27 FCC Rcd 12067 (Wireless Telecom. Bur. and Office of Engineering and Technology 2012) (*Public Notice*).

[2] *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Docket No. 12-268, Notice of Proposed Rulemaking, 27 FCC Rcd 12357 (2012).

headphone transducer technology, and active noise cancellation. The U.S. subsidiary, based in Old Lyme, Connecticut, represents Sennheiser products in the United States and distributes a variety of other professional audio lines. Sennheiser is a leading manufacturer of wireless microphones used in the United States.

A. SUMMARY

Wireless microphones operating in the TV bands are an essential tool for the creation of nearly all entertainment, news, and sports programming and motion picture production. U.S.-made content, including television, music, and films, is not only acclaimed as the best in the world, but is part of the category having by far the highest export-to-import ratio of all U.S. goods and services. To date, only wireless microphones that operate in the TV bands have been able to deliver the fidelity, reliability, compact size, and low latency that the industry requires.

Sennheiser supports expanding the list of those eligible to hold licenses for wireless microphones under Part 74. (The Commission may, however, wish to regulate non-traditional users under a different rule part). We suggest objective, easily applied criteria that accurately identifies users and venues requiring higher power or more reliable operation than are available under Part 15, and which should be entitled to licensing. We explain why other proposed criteria, including "professional quality" of productions, the number of microphones required, and the guidelines in the Commission's *Public Notice on Registration of Unlicensed Wireless Microphones*[3] are unsuitable. Our suggested new candidates will be fully qualified to satisfy their obligations as licensees.

Under the pressures of the marketplace and changes in available TV spectrum, wireless microphone technology is steadily evolving toward spectrum efficiency. The Commission

[3] ET Docket No. 04-186, Public Notice, DA 12-1514 (released Sept. 19, 2012) (*Registration Public Notice*).

should let that process continue free of unnecessary and artificial spectrum efficiency requirements.

B. INTRODUCTION

TV band wireless microphones are more than a convenience. They are vital to a major component of the U.S. economy.

Wireless microphones are ubiquitous in all aspects of the entertainment business, in news reporting, in sports, and in U.S. commercial, civic, and religious life. They are essential to the production of virtually all non-studio broadcast events, and to nearly all studio-produced programs as well. These include team sports from local college broadcasts to the Super Bowl, the World Series, the Final Four, and the Stanley Cup; the Democratic and Republican political conventions; post-election national and local coverage; the Oscar, Emmy, and Grammy Awards shows; events such as the Olympics, NASCAR races, the Kentucky Derby, and major golf and tennis tournaments; and on-the-scene news reporting of all kinds. These broadcasts routinely attract millions of viewers.

Motion-picture production, from Hollywood blockbusters with nine-digit budgets down to student work at the local community college, relies heavily on wireless microphones for clear, accurate audio. Live events like outdoor concerts and Broadway productions need wireless microphones to reach the back row. Presenters in large auditoriums, lecture halls, and houses of worship find them indispensable.

Other major uses of TV spectrum—broadcast television and TV Band Devices (TVBDs), also called "white space devices"—chiefly benefit the *consumption* of content.[4] Wireless

[4] TVBDs in fact can be used to upload original content to the Internet. But apart from informal, consumer-created content, such as that on Facebook and Twitter, we expect this use

microphones have a different role: the *creation* of content. The U.S. public has come to expect the very highest standards of production quality in all forms of television, radio, film, and live entertainment. Driven by these expectations, U.S. news and entertainment content is globally acknowledged as the best in the world. The widespread popularity of these products has made entertainment content not only a major domestic industry,[5] but also one of the nation's leading exports. Indeed, "Royalties and Licensing Fees" is the category having by far the highest export-to-import ratio of all U.S. goods and services.[6] Wireless microphones are one of the production tools that fuel these successes.

Users of wireless microphones have no adequate substitute for UHF TV frequencies. Unlicensed products are available in the 49 MHz, 902-928 MHz, and 2.4 GHz bands, but these are generally unsuited to professional applications.[7] Many are little more than toys. The low available power and high interference levels for unlicensed operation in these bands leads to unreliable performance, while the narrow bandwidth of most units impairs audio quality. Users have migrated to professional-grade TV band microphones because they simply have no choice.

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will make up only a very small fraction of TVBD traffic—as indeed, it currently makes up only a small fraction of Internet traffic overall.

[5] "Core copyright" industries (including TV, film, radio, and recorded music) are responsible for over 5 million private industry jobs (almost 5% of total U.S. employment, with compensation per employee 27% higher than the nation average) and add nearly $1 trillion to the economy, or 6.36% of the national GDP. Stephen E. Siwek, *Copyright Industries in the U.S. Economy: The 2011 Report* at 15 and Appendix A (Economists Incorporated 2011). Available at http://www.ei.com/downloadables/2011CopyrightSiwek.pdf

[6] U.S. Census Bureau, U.S. Bureau of Economic Analysis, *News: U.S. International Trade in Goods and Services, November 2012* at 3-4 (U.S. Dept. of Commerce, released Jan. 11, 2013). Available at http://www.census.gov/foreign-trade/Press-Release/current_press_release/ft900.pdf

[7] This discussion does not apply to wireless microphones operating in the TV bands as unlicensed devices under waiver. *See Amendment of Parts 15, 74 and 90 of the Commission's Rules Regarding Low Power Auxiliary Stations, Including Wireless Microphones*, Report and Order and Further Notice of Proposed Rulemaking, 25 FCC Rcd 643 at ¶¶ 81-90 (2010).

The producers of a Broadway musical, for example, need microphones having both the highest quality sound reproduction and absolutely reliable performance, with no drop-outs. These users are ineligible for a license under Part 74, and until the recent waiver, could not operate adequate microphones under Part 15. (For larger venues, such as stadium concerts, the Part 15 power levels allowed under the waiver may be inadequate.) Having no workable option, the producers do what they must.

Given the widespread need for wireless microphones and the lack of alternative frequencies, it is very much in the public interest for the Commission to ensure they will continue to have adequate spectrum for successful operation. The Commission should also conform its rules to necessity by expanding the legitimate use of wireless microphones to certain presently ineligible parties, and should make permanent the provisions allowing unlicensed use at lower power by other segments of the public.

C. THE COMMISSION SHOULD EXPAND ELIGIBILITY FOR LICENSING WIRELESS MICROPHONES UNDER PART 74.

Sennheiser favors a moderate, controlled expansion of eligibility for licensing. In general, operation should be limited to venues requiring higher power and/or more reliable operation than are available under Part 15.

1. The Commission should expand the list of proposed eligibles under Part 74.

Sennheiser proposes this list of additional Part 74 eligibles:

- Assembly areas where audible communications are integral to the use of the space, and which have (a) fixed seating and (b) either an audio amplification system or an occupancy of 50 or more. (See the explanation below.)

- Federal, state, and local governmental events.

- Outdoor public or trade events with a capacity of 1,000 or more spectators (*e.g.*, air shows, over-water sporting events, and outdoor concerts such as those occurring in New York's Central Park).

- Rental companies that supply equipment for eligible users. (The license to a rental company would be valid only for otherwise qualifying venues.)

Explanation: The first bullet above tracks the list of facilities that, under the Americans with Disabilities Act ("ADA"), are required to have permanently-installed assistive listening systems.[8] This list is a good approximation of facilities for which audio quality and reliability are important enough to warrant Part 74 licensing. Importantly, this list is well understood by facilities operators through experience under the ADA. Wireless microphones are often used as input devices to assistive listening systems, so that licensing wireless microphones where these systems are required will help to further the purposes of the ADA.

We propose two departures from the ADA list: dropping motion picture houses, and adding houses of worship.[9] Other examples of qualifying facilities would include theaters, concert halls, stadiums, auditoriums, business facilities (as used for large shareholder meetings and new-product launches), convention centers, lecture halls, and other places of exhibition, entertainment, or public gathering.[10]

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[8] 28 C.F.R. Part 36 Appendix A § 4.1.3(19)(b).

[9] Houses of worship are exempt from ADA requirements under 28 C.F.R. § 36.102(e), but should have access to licensed wireless microphones if they otherwise qualify.

[10] This list of examples is adapted from the ADA regulations at 28 C.F.R. § 36.104 (definition of "place of public accommodation" ¶¶ (3), (4)), with the modifications noted in text.

A facility must meet three distinct requirements to qualify under the first bullet: it must constitute an "assembly area[] where audible communications are integral to the use of the space," have fixed seating, and have either a sound system or a capacity of fifty or more.[11]

The second, third, and fourth bullets above are self-explanatory.

Inasmuch as the users we propose to include are not broadcasters eligible for traditional Part 74 auxiliary broadcasting licenses, the Commission may prefer to authorize their operations under a different part of the rules. Sennheiser has no objection to this option, so long as the technical rules track those now in Part 74.

2. Other suggested criteria are not appropriate for Part 74 licensing.

The Commission asks, among other questions, whether the "professional quality" of a production or the number of microphones needed should be factors in determining Part 74 eligibility.[12]

"Professional quality" is far too subjective to be a useful criterion. Surely the Commission does not want to adjudicate disputes over whether a particular production qualifies. The first and third categories we propose above will capture the Commission's examples: major production events that take place at such venues as Madison Square Garden or Broadway theaters in New York City, the Kennedy Center in Washington, DC, and the Grand Ole Opry in Nashville.[13] We urge the Commission to rely on wholly objective criteria.

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[11] The ADA criterion of a sound system is self-enforcing here, as a facility without one would have no need for a wireless microphone.

[12] *Public Notice* at 4.

[13] *Id*.

The number of microphones needed for a given event is likewise unsuitable as a requirement for eligibility. Even facilities or productions using only one or two microphones may justifiably need the higher power and interference protection that licensing provides. A one-man show on Broadway, a comedian at an outdoor amphitheater, a Nobel laureate lecturing in a big university auditorium—each of these uses should qualify for licensing despite the need for only a single microphone.

For the same reasons, the *Public Notice on Registration of Unlicensed Wireless Microphones* is not a suitable basis for licensing eligibility.[14] That document on its face provides for the registration of *unlicensed* microphones. Sennheiser supports the Commission's distinction between licensed and unlicensed users. To use criteria for unlicensed registration as a basis for licensing would largely eliminate any difference between the two categories. Moreover, the *Registration Public Notice* limits registration to "major events" and "large venues."[15] It categorically excludes "libraries, courthouses, schools, meeting sites, community theaters, and convention centers."[16] Sennheiser believes some of these sites—such as community theaters and convention centers—should qualify for licensing, if they otherwise satisfy the criteria we propose above.

3. The proposed eligibles are qualified to meet their responsibilities under a Commission license.

The operators of the facilities listed in Part A(1) above, as additional eligibles, are each qualified to carry out the responsibilities of holding a Commission license, to undertake frequency coordination, and where appropriate, to keep the TV Band Device database current.

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[14] *Registration Public Notice*; *see* note 3.

[15] *Id*. at 9.

[16] *Id*. at 11.

Currently ineligible users who nonetheless operate wireless microphones, such as Broadway producers, have been scrupulous about coordinating activities among themselves while avoiding interference to TV reception, even in congested markets. Smaller and occasional users no doubt will rely on rental companies, which have collectively proven their competence over the years. Overall, the audio and production communities have a long history of cooperative coexistence and non-interference. There is no reason to think this will change with the proposed expansion of those eligible to hold a license.

D. ADVANCING TECHNOLOGY IS IMPROVING WIRELESS MICROPHONES' SPECTRUM EFFICIENCY.

Wireless microphones are sometimes criticized for supposedly poor spectrum efficiency. But spectrum efficiency is not simply a matter of how many wireless microphones can share a TV channel. A more realistic assessment takes into account the device's performance requirements and the capabilities of available technology.

In some other radio services, technology has yielded impressive improvements in spectrum efficiency. But the efficiency gains achieved in broadcast digital TV and some other applications are not available to wireless microphones, at least in the near term. Among other distinctions, the wireless microphone comes at the beginning of the processing chain, while modulation of the digital TV signal comes at the very end. The bandwidth requirements of digital TV cameras, also at the head of the processing chain, are similarly much greater than for broadcast video: a digital wireless HD camera occupies about 20 MHz of bandwidth, far more than a broadcast signal.

Wireless microphones for professional use must satisfy three technically demanding criteria: very high audio fidelity, near-absolute reliability, and extremely low latency—*i.e.*, low delay in processing the audio signal. The importance of fidelity and reliability are self-evident.

The latency requirement arises because a performer on stage or in the studio is exposed to his own voice, via monitor speakers or in-ear monitors, through the same microphone system that delivers his voice to the audience. Any significant delay becomes intolerable to the performer. The practical upper limit is less than ten thousandths of a second through the entire system, from the microphone transducer all the way back to the monitor.

To achieve acceptable audio quality under current FCC rules, most wireless microphones use analog wide-band FM in 200 kHz channels. Some parties believe that converting to a digital signal would, by itself, improve spectrum efficiency. This is wrong; an example shows why. To achieve needed frequency response up to 20 kHz, a digital wireless microphone must sample the sound wave at twice that frequency or more. A commonly used sampling rate is 44,100 times per second (the same as in audio CDs). To achieve an adequate dynamic range (loudest to softest) requires that each sample occupy 20 bits of information. This gives 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 around 1,200,000 bits/second. Fitting this much data into a 200 kHz channel, allowing for room at the edges, requires use of a high order digital modulation scheme. The resulting spectrum efficiency exceeds 6 bits/second/hertz—far higher than the spectrum efficiency of broadcast digital TV.

In short: digitization alone, even with highly efficient modulations, does not result in higher spectrum efficiency, compared to an analog microphone that delivers similar sound quality.

Some digital technologies do achieve much better spectrum efficiency than their analog predecessors. Digital TV squeezes four standard-quality video channels into the 6 MHz of spectrum that formerly carried only one; converting cell phone voice traffic from analog to

digital increased the number of end users in the same spectrum by at least ten-fold. MP3 files encode audio information into much smaller files than an original CD. In all such cases, however, the gains in efficiency do not come from digitization as such, but from subsequent compression of the digital signal. (The two are sometimes confused because digitization is a prerequisite to efficient compression.)

Although compression undeniably increases spectrum efficiency, it also brings two distinct downsides. One is loss of fidelity. MP3 audio files are typically compressed by a factor of 5 to 20 relative to an uncompressed audio CD, but to an experienced ear sound markedly inferior. Similarly, the sound quality of cell phone calls, which are highly compressed, is noticeably much worse than calls over a traditional circuit-switched landline.

The other disadvantage of compression is a marked increase in latency. Compression works by exploiting regularities in the audio signal over time. Necessarily, the compression algorithm must "look ahead" to find those regularities. The compressed signal is delayed behind the original by roughly the same time interval over which the algorithm looks for regularities. This delay is inseparable from the compression. Moreover, the magnitude of the delay increases with the degree of compression. The relatively high compression used by cell phone carriers, for example, results in latency amounting to a large fraction of a second. (To experience the latency first hand, simply call one's own cell phone from a landline phone, put one phone to each ear, and talk.) People communicating between two cell phones often find themselves talking over each other due to the combined delay.

The need for both excellent fidelity and—especially—very low latency rules out the more aggressive compression algorithms for wireless microphones. In consequence, microphones

must occupy more spectrum relative to other technologies (such as cell phones) that are subject to less demanding audio performance specifications.

Some gains in spectrum efficiency are possible even without compression. One hindrance to dense spectral deployment of wireless microphones has been the phenomenon of "intermodulation," in which two or more desired signals combine to produce multiple undesired signals outside the spectra of the desired signals. Intermodulation can occur among any kind of wireless device. It is a particular challenge with microphone systems, in large part because the transmitters are constantly moving. Historically, the spectra of various microphones sharing a TV band have had to be spaced in such a way that intermodulation products caused by any combination of microphones do not fall into the spectrum of another microphone signal. These spacing considerations in the past have limited a TV band to six or eight microphones, to avoid the hundreds of possible intermodulation products. Sennheiser, however, has created a line of analog microphones that partially avoid the intermodulation problem, and the company also produces a line of digital microphones that are relatively resistant to intermodulation. These products are capable of denser spectrum usage than their older counterparts, while maintaining the needed fidelity, reliability, and low latency.

To maintain reliability over longer ranges or in the presence of radio-frequency interference, a digital wireless microphone can be configured to use a more robust but less efficient modulation. Fitting the less efficient signal into the same 200 kHz radio channel requires a degree of compression. But to keep latency acceptable notwithstanding the compression, audio fidelity must suffer. The engineering trade-offs are difficult. There is no trade-off, using present technology, that provides adequate fidelity, latency, and reliability in a substantially smaller bandwidth. Sennheiser's efforts continue, and future products may perform

somewhat better. For now, however, further improvements in spectrum frequency efficiency will be extremely difficult to achieve without unacceptable degradation of quality. Any reduction in permissible occupied bandwidth will inevitably impair audio fidelity, including frequency response and dynamic range, or latency and reliability. The performance demands that professional users place on wireless microphones will continue to require access to significant bandwidth.

Opportunities for migration to other frequencies are also limited. The need for unimpaired propagation through stage sets and performers' bodies sets an upper bound on frequency, while the need for small, inconspicuous antennas sets a lower bound. The workable frequency range roughly coincides with TV frequencies. Moreover, the more efficient modulations needed for adequate fidelity, reliability, and low latency are relatively intolerant of incoming interference, which restricts the options for spectrum sharing. At least for the most demanding professional applications, wireless microphones have no ready alternative to the TV bands.

CONCLUSION

The Commission should expand Part 74 eligibility for wireless microphones as detailed above. It should not impose spectrum efficiency standards, but rather should let the technology evolve in response to the market and to changing spectrum occupancy.

Respectfully submitted,

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