BINGHAM McCUTCHEN

Catherine Wang
Timothy L. Bransford
Direct Phone: (202) 373-6037
Direct Fax: (202) 424-7645
catherine.wang@bingham.com
timothy.bransford@bingham.com

December 13, 2006

Bingham McCutchen LLP
Suite 300
3000 K Street NW
Washington, DC
20007-5116

202.424.7500
202.424.7647 fax

bingham.com

Boston
Hartford
London
Los Angeles
New York
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Walnut Creek
Washington

VIA ELECTRONIC FILING

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: **NOTICE OF *EX PARTE* MEETINGS**

ET Docket No. 04-186; Unlicensed Operation in the TV Broadcast Bands

Dear Ms. Dortch:

On December 12th, 2006, Shure Incorporated ("Shure") met with Julius Knapp, Bruce Romano, Ron Chase, Ira Keltz, Alan Stillwell, Geraldine Matise, Rashmi Doshi, Hugh Van Tuyl, Steve Martin, Saurbh Chhabra, Ahmed Lahjouji, and Thomas Phillips from the Office of Engineering and Technology ("OET") to discuss ET Docket No. 04-186. Attending this meeting on Shure's behalf was Jeff Krull, Vice President, and Edgar Reihl, Principal Engineer, along with Catherine Wang and Timothy Bransford of Bingham McCutchen, outside counsel to Shure. During this meeting we discussed Shure's position and concerns with respect to how emissions from unlicensed devices have the capacity to interfere with Part 74 wireless microphones and related devices, the implementation of potential interference avoidance techniques under consideration by the Commission, and potential testing and certification schemes applicable to the proposed unlicensed devices.

A presentation that discusses Shure's research regarding the effects of interference on Part 74 devices and describes potential interference avoidance strategies was presented to OET, and is attached to this filing.

If you have any questions regarding these meetings, please do not hesitate to contact the undersigned.

Very truly yours,

/s/

Catherine Wang
Timothy L. Bransford

cc (by email): Julius Knapp
Ron Chase
Bruce Romano
Ira Keltz
Alan Stillwell
Geraldine Matise
Rashmi Doshi
Hugh Van Tuyl
Steve Martin
Saurbh Chhabra
Ahmed Lahjouji
Thomas Phillips

Mitigating Interference from Unlicensed Devices in the TV Broadcast Bands

Re: FCC NPRM ET Docket No. 04-186

SHURE INCORPORATED

December 12th, 2006

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Purpose of Discussion

Four goals:

- Review the impact of unlicensed device interference on wireless microphones and other authorized Part 74 services.
- Discuss the various interference mitigation proposals that are being worked on within IEEE and industry groups.
- Discuss the test plan for verifying that proposed unlicensed devices can operate without causing interference to Part 74 devices.
- Discuss the arrangements and timetable for testing and how Shure can be involved.

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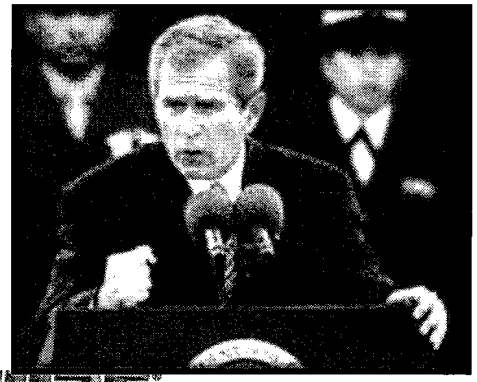
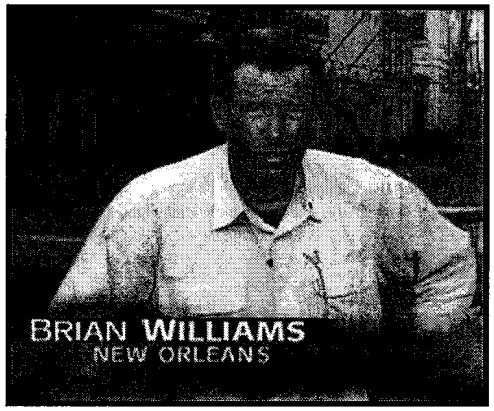
Wireless Microphone Characteristics

What are wireless microphones, and how are they used?

- Wireless microphones are part of a larger category of wireless audio products that also includes In Ear Monitors, wireless intercoms, wireless assist video devices (WAVD's), and wireless cueing (IFB) systems.
- Wireless microphones are essential to today's dynamic Radio and TV programming.
- Large productions like the Super Bowl, or a major political convention, require as many as 200 wireless audio channels to operate simultaneously.
- Because of their low power and mobility, wireless microphones require a known, stable spectrum environment to operate well.
- Professional sound users expect the highest sound quality from their wireless microphones.
- Users typically expect wireless microphones to last 7-10 years.





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Wireless Facts - Operating Characteristics

Wireless Microphones have several unique characteristics

- **Real time operation**
  - 100% duty cycle necessary for live entertainment
  - Maximum 5 to 20 millisecond latency
- **High quality audio**
  - Up with CD quality
  - Greater than 100 db dynamic range
  - Nominal channel bandwidth ~ 200 kHz
- **Radiated power**
  - Typically 10 to 50 mW
  - Typical range of 300 feet

Current alternative technologies are unable to perform at this level

- Bluetooth and Wi-Fi have latency and range issues.
- Digital wireless microphones are not an option at present due to latency issues.
- Even if they were, multi-channel systems would still require significant amounts of spectrum to operate successfully.

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Wireless Microphone User Model

Wireless Microphone User Model

	User Description		Venue	Wireless Frequencies
LARGE	**MOBILE** = Large numbers of wireless used for a period of time (hours – days) at a temporary location	**MOBILE**	**Sports** Production **Film** Production **Political** Conventions **Shareholder** Meetings **Entertainment** Tours **Music** Festivals	**30 – 100 Frequencies** (10-30 mW, typ.)
LARGE	**LARGE FIXED** = Large numbers of wireless repeatedly used a permanent location	**LARGE FIXED**	**TV and Radio** Broadcasting **Houses of Worship** (Large) **Theme / Amusements** Parks **Hotels** (Large) **Government** Offices	**20 – 50 Frequencies** (10-30 mW, typ.)
SMALL	**FIXED** = Fewer numbers of wireless repeatedly used at a permanent location	**FIXED**	**Schools / Universities** **Houses of Worship** **Music** Clubs **Individuals** **Corporate** Offices **Hotels** (Small)	**1 – 10 Frequencies** (10-50 mW, typ.)

Typical Number of Wireless Used at an **LARGE FIXED** Venue (Large House of Worship):

- ☐ **20** Wireless Microphones
- ☐ **15** Wireless Personal Monitors
- ☐ **10** Wireless Intercoms

⇨ **45** Frequencies Required

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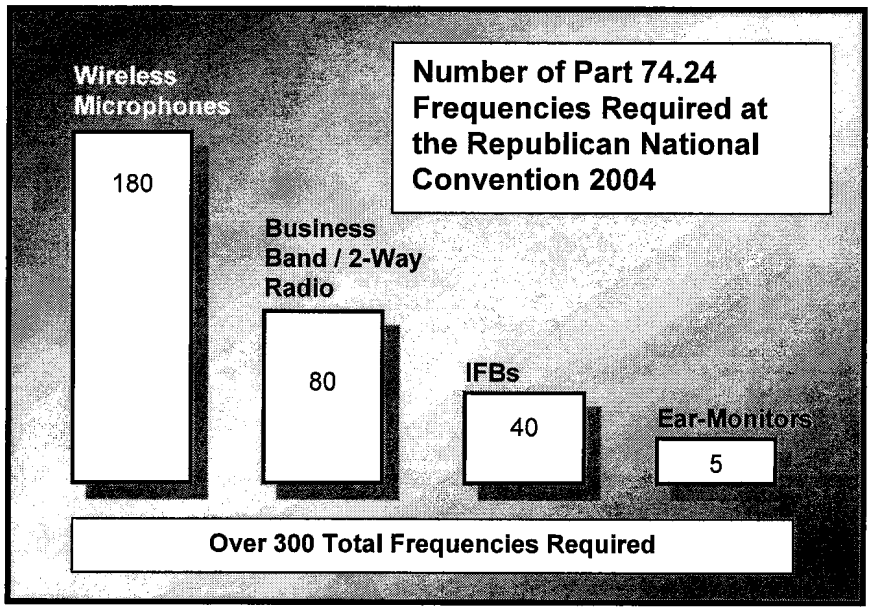
Large Mobile Wireless Microphone Venue - Example

"Republican National Convention – New York, Aug.30 – Sept.2, 2004"

- Over 300 frequencies for wireless audio required
- Used VHF CH. 7-13, UHF CH. 20-69 (excl. 37)



Waiver of Separation Requirements of 47 C.F.R. 74.802 and Special Temporary Authorizations

- Granted May 26, 2004 to enable 300 frequencies used in Madison Square Garden

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Interference Study - Overview

To determine the "real world" impact of unlicensed devices, Shure conducted an extensive interference study:

- Surveyed 57 UHF wireless microphone models from 12 manufacturers to compile output power statistics
- Recorded wireless microphone signal propagation inside a large arena at distances up to 300 feet at both VHF and UHF (over 2000 data points recorded).
- Obtained an Experimental Part 5 License from the FCC and conducted live on-air interference tests, using a band limited 802.11g test signal.
- Translated an 802.11g wireless LAN system into the UHF band and recorded conducted interference to a wireless microphone voice signal at various Desired/Undesired ratios.
- Tested both hand held and body pack transmitters.
- Recorded signal strength and audio quality.
- Performed mathematical analysis demonstrating interference from unlicensed devices to wireless microphones in "real world" applications.

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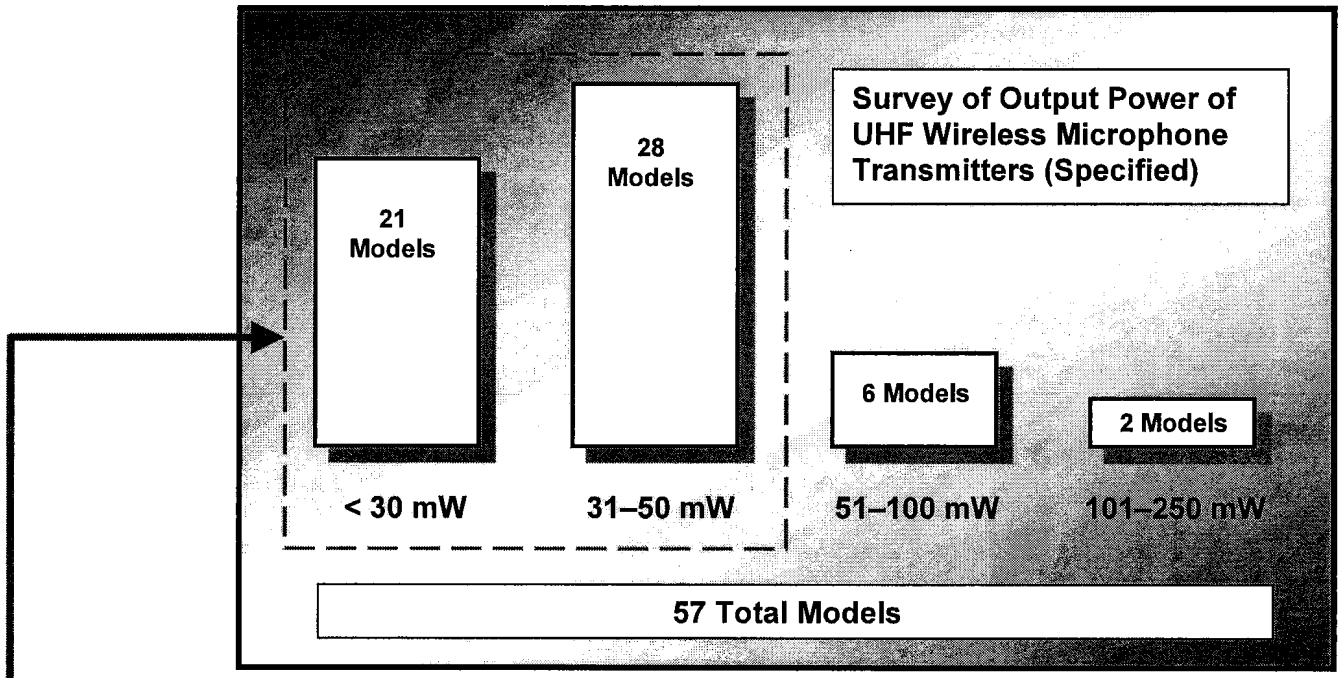
Interference Study – Wireless Microphone Power

Surveyed UHF wireless microphone transmitters to compile output power statistics

- 12 Manufacturers, 57 Models = > 95% of models on market



85% of Wireless Microphone Models Surveyed Operate with Less Than 50 mW of Output Power

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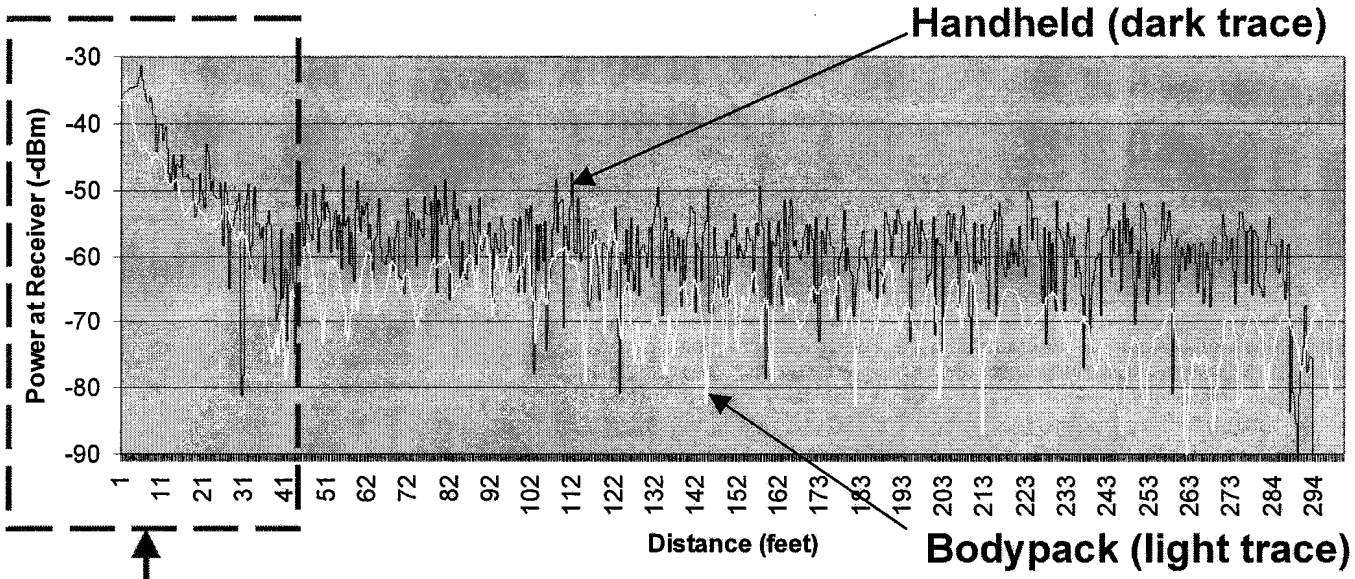
Interference Study – Propagation Measurements

Recorded wireless microphone transmitter signals inside an arena at distances of 1 to 300 feet from the receiver

- UHF, 10mW
- Indoor measurement

Handheld and Bodypack Wireless Microphone Transmitter Power Levels



Signal levels vary more than 50dB over a 40 foot distance due to multi-path and body absorption

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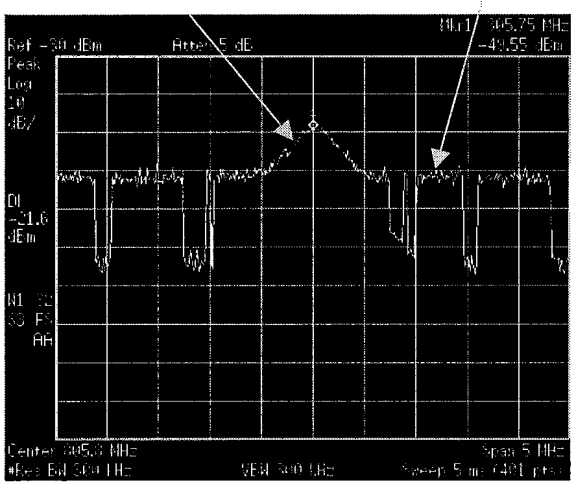
Interference Study – Radiated Testing Configuration

An 802.11g wireless LAN is translated to UHF and radiated at +20 dBm (NPRM level).*

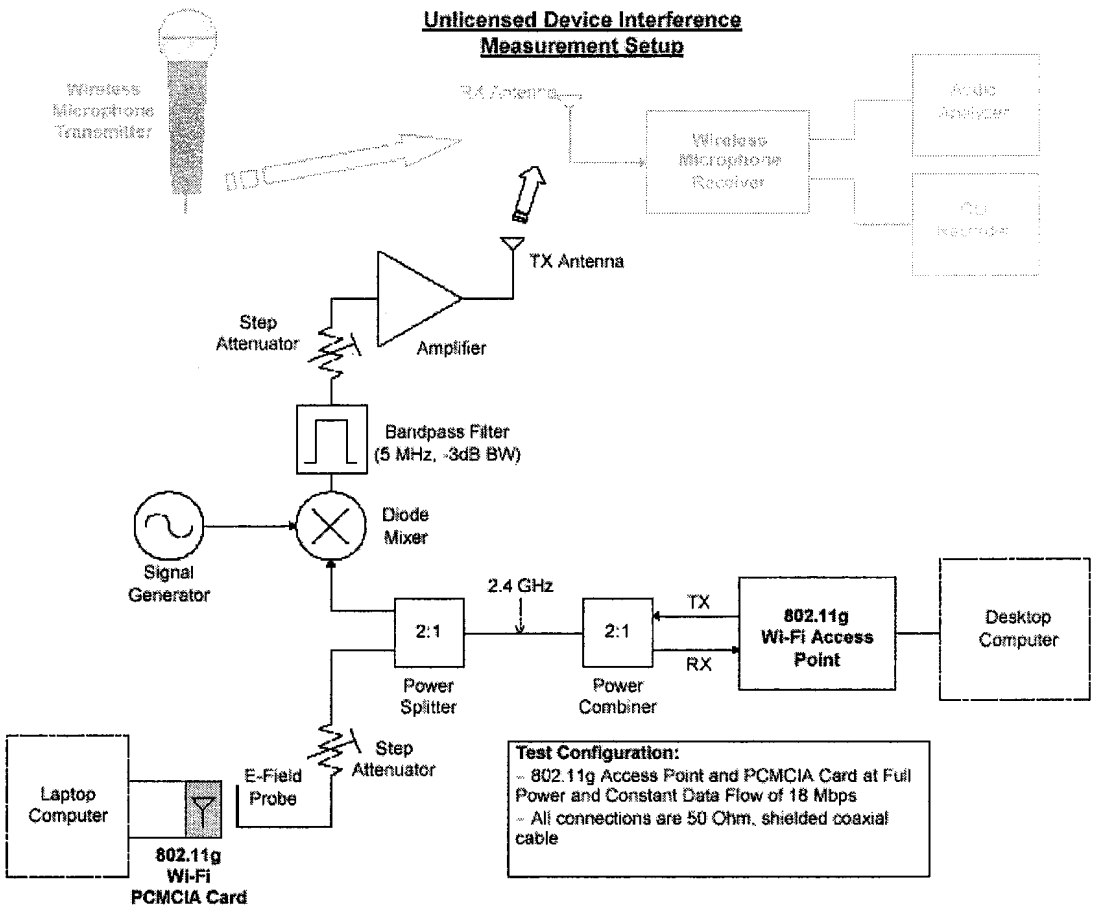
Interference to the wireless microphone is measured and recorded during normal use.

Wireless Microphone Signal

Interference (802.11g) Signal



Spectrum Analyzer Screen Capture



A 47 CFR, Part 5--Experimental Radio Service License was granted to Shure in July 2004 to enable this testing.

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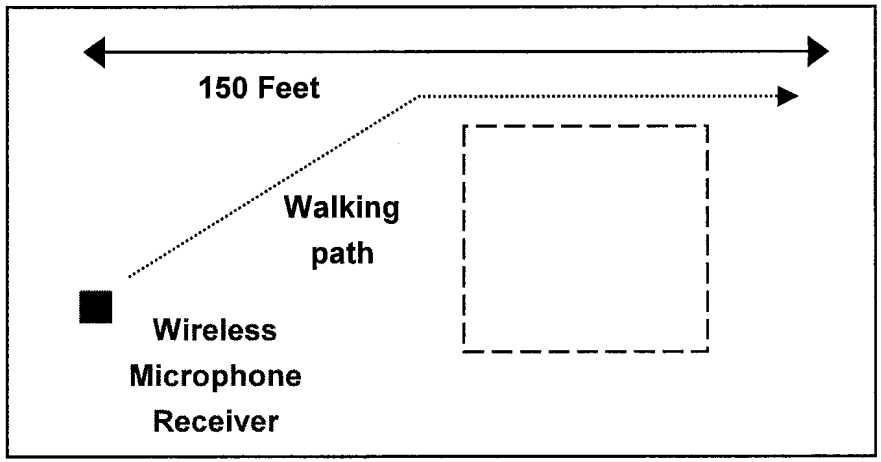
Interference Study – Radiated Test Results

Wireless Microphone Interference Tests

- Test location at Shure Incorporated office - Niles, Illinois
- Test conducted by walking wireless microphone transmitter (30mW) away from the receiver at a constant rate up to approx. 150 feet separation

Test #1: Baseline – No Interference

Walk-around Setup



Shure Office Layout – 6th Floor

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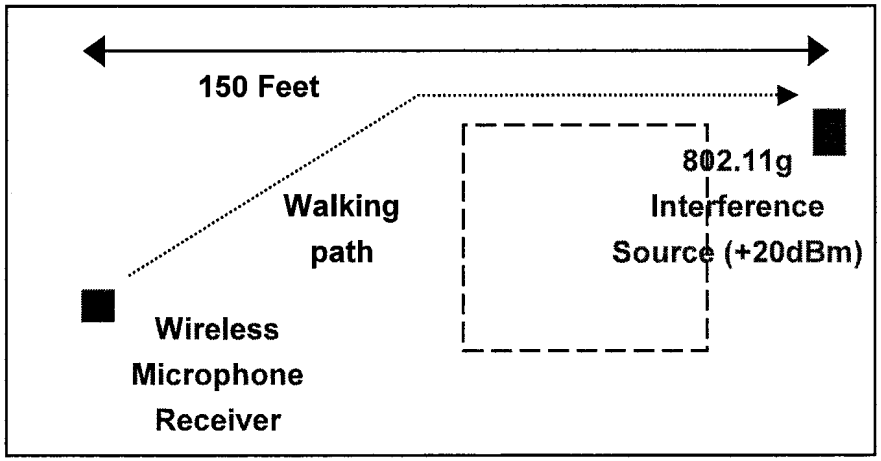
Interference Study – Radiated Test Results

Wireless Microphone Interference Tests

- Test location at Shure Incorporated office - Niles, Illinois
- Test conducted by walking wireless microphone transmitter (30mW) away from the receiver at a constant rate up to approx. 150 feet separation

Test #2: Baseline: -54 dBm Interference to Wireless Microphone Receiver

Radiated Interference Level = -54 dBm avg. power at microphone receiver



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Interference Study - Conclusions

CONCLUSION: *Wireless Microphones will not overcome co-channel interference by means of "brute force" alone, due to the fact that unlicensed device placement and operation will be uncontrolled.*

Given this fact, how can we avoid interference problems?

- Require unlicensed devices to avoid operating on channels adjacent to locally occupied DTV channels and use those channels for Part 74 secondary operation.
- Only permit Personal/Portable unlicensed devices to operate in the TV bands if spectrum sensing can be shown to be effective. Reduce the maximum allowed transmitter power for these devices to a level that is comparable to the devices that need interference protection (e.g. 50 mW).
- Require all unlicensed devices to be able to receive a Part 74 wireless beacon and avoid operating in TV channels that are in use by Part 74 devices.

These requirements must be codified into the FCC Rules to be effective.

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Interference Mitigation Approaches

1. Adjacent Channels

- **IEEE 802.22** has determined that unlicensed devices will not be able to operate on channels that are adjacent to occupied DTV channels.
  - This decision involves consideration of interference ***to*** and ***from*** DTV broadcasting, and was driven by the the need for a balance between protection and costs of unlicensed devices.
  - Adjacent channels can be effectively utilized by wireless microphones and other secondary Part 74 devices.
  - The number of adjacent channels will vary from market to market and may be very limited in large cities.
    - Therefore, additional mitigation is required for large productions.
- Unlicensed devices must identify and avoid DTV channels.
  - Once the DTV channels are known, the adjacent channels are known.
  - DTV channel data could be sent to unlicensed devices via:
    - A control signal as proposed by the Commission.
    - Spectrum sensing techniques, if they can be shown to be effective.
    - Internet access to DTV channel data for fixed devices (e.g. WRAN systems).

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Interference Mitigation Approaches

2. Spectrum Sensing

- Spectrum Sensing may be a useful technique *if* it can be shown to be effective.
  - The power level of Personal/Portable devices **must** be reduced to make it comparable to the devices it is trying to protect (10-50 mW).
  - Many Personal/Portable devices will operate on a peer-to-peer basis, and therefore *cannot overcome* "hidden node" problems through network behavior, as a Fixed/Access WRAN system could.
- Personal/Portable devices should not be authorized to operate in the TV bands unless and until spectrum sensing effectiveness can be demonstrated.
- IEEE 802.22 has tentatively adopted a sensing threshold of –107 dBm for wireless microphones, with a channel move-out time of 2 seconds when a microphone is detected.
- Shure would like to discuss tests to ensure trouble free operation.

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Interference Mitigation Approaches

3. Wireless Beacon

- The beacon is essentially a variation on the control signal approach suggested in the NPRM that works specifically at the local level.
  - A wireless beacon operating in an unoccupied TV channel can be used to create a local "bubble of protection" for wireless microphones and other Part 74 devices.
  - It is scalable for large events such as a political convention or a major news or sporting event that requires more spectrum than an adjacent channel model can provide.
  - Especially useful in crowded urban areas such as Los Angeles or New York.
- Unlicensed devices (both Fixed/Access and Personal/Portable) must be required to scan for the beacon and avoid operating on TV channels marked as being in use by authorized Part 74 users.
- **IEEE 802.22** has a Task Group (TG1) that is working on the development of a beacon standard.

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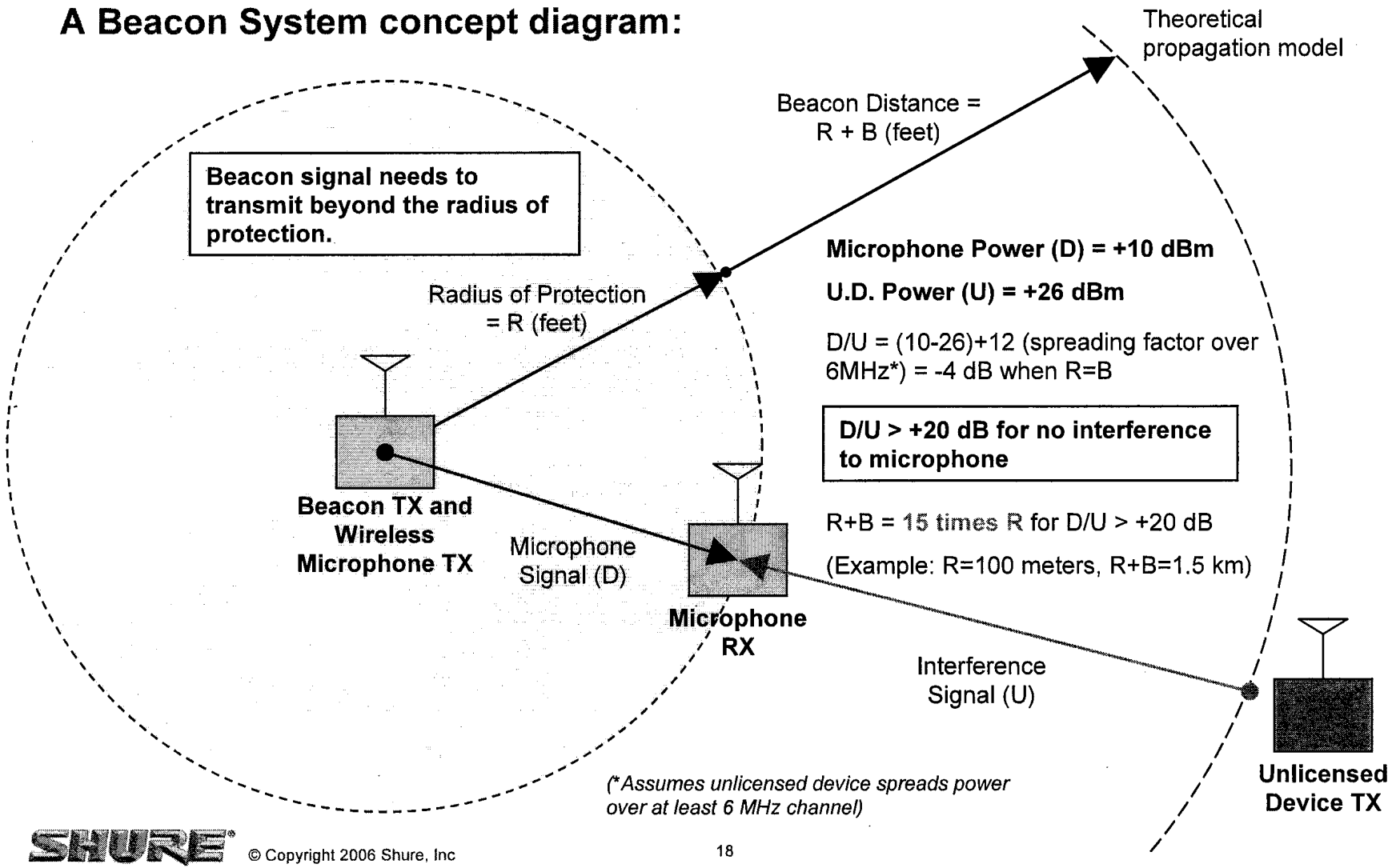
Interference Mitigation Approaches

A Beacon System concept diagram:



Microphone Power (D) = +10 dBm

U.D. Power (U) = +26 dBm

D/U = (10-26)+12 (spreading factor over 6MHz*) = -4 dB when R=B

D/U > +20 dB for no interference to microphone

R+B = 15 times R for D/U > +20 dB

(Example: R=100 meters, R+B=1.5 km)

*(*Assumes unlicensed device spreads power over at least 6 MHz channel)*

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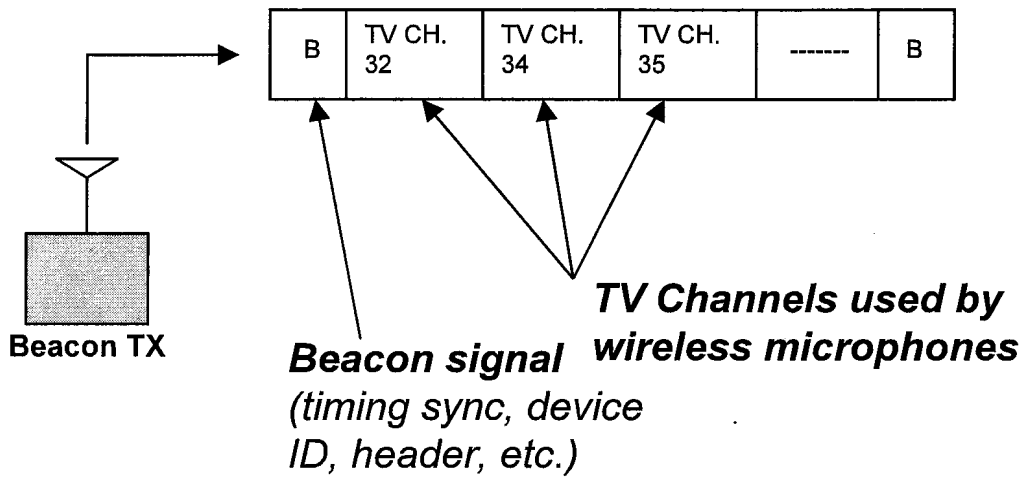
Interference Mitigation Approaches

A Beacon System concept diagram (cont'd):



Example Beacon signal payload

(BPSK-encoded data, transmits continuously while microphones are operating)

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Interference Mitigation Approaches

Key Beacon Facts (Agreed Items from 802.22 TG1)

- Operates as a Part 74 device; aimed at protecting licensed microphone users.
- Based on a PHY/MAC proposal from Motorola (Samsung and Phillips ideas also considered).
- Uses robust BPSK modulation spread over a narrowband channel (about 80 kHz).
- Resides at the DTV pilot frequency (309.44 kHz from the low edge of the TV channel).
  - Sync burst: for synchronization; also includes a counter to indicate timing of next payload.
  - Payload: variable sized; includes info about TV channels currently in use by incumbents.
  - Sync burst (2.5 msec) repeated until counter=0; large (40 msec) payload sent every second.
  - Some payload fields have been omitted to shorten the payload (quicker detect time).
- Includes the concept of aggregating multiple beacons within a single TV channel to a single beacon to improve spectral efficiency.
  - MAC includes procedures for "inter-beacon" communication to facilitate the aggregation.

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Interference Mitigation Approaches

Key Issues Currently Under Consideration in 802.22 TG1

- Complex modulation
  - Main alternative under discussion is QPSK.
  - Increases the data rate and enables faster capturing of beacon payload information.
  - May also enable inclusion of some FEC to improve reliability of beacon detection.
  - Resides at the DTV pilot frequency (309.44 kHz from the low edge of the TV channel).
- Aggregation across multiple TV channels
  - Offers better spectral efficiency– several beacons from several TV channels share one beacon.
  - Reduces the number of beacons that need to be purchased and setup/configured.
  - Aggregation makes beacon sensing more difficult and time consuming, but UD "Move out" time (time allowed for UD to vacate channel) could be relaxed.
- Various means to further reduce the beacon payload are being considered.

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Testing and Validation

Before the Commission authorizes unlicensed operation in the TV bands, tests must be conducted to demonstrate that interference mitigation techniques are effective.

- **Work within IEEE 802 has been limited to Fixed/Access WRAN operation.**
  - Many issues are still being investigated, including the reliability of various spectrum sensing techniques.
  - However, Fixed/Access devices have more options for resolving interference problems because they can be connected to an Internet database and because they can be professionally installed and maintained.
- Shure is not opposed to the use of Personal/Portable unlicensed devices in the TV spectrum if real world testing proves they do not interfere with incumbent users.
  - Accordingly, the Commission should not allow unlicensed Personal/Portable devices to operate in the TV bands until the effectiveness of spectrum sensing can be demonstrated.
- As a precursor to the development of Rules and Certification requirements for all types of unlicensed devices, the Commission must conduct tests of the interference mitigation capabilities of these devices to demonstrate their effectiveness.
- Shure will support the Commission's testing program by providing engineers and equipment, assuming that adequate advance notice is given.

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Testing and Validation

Shure is developing a test plan that includes the following items:

- Verification of unlicensed device (UD) transmission parameters such as power output and emission bandwidth.
- Conducted and radiated tests at a specified distance between the wireless microphone transmitter and the UD to measure the ability of the UD to detect the wireless microphone.
- Conducted and radiated tests at a specified distance between the UD and the wireless microphone receiver to measure the effect of interference from the UD.
- Characterization of the behavior of the unlicensed device when it interacts with a wireless microphone system; for example:
  - How often does the UD check for wireless microphone signals?
  - How long does it take the UD to vacate a TV channel when a microphone is turned on?
  - What happens when the only channel available to the UD is in use by a wireless microphone?
  - What happens when there is a temporary fade and the UD does not detect the wireless microphone during that time? How soon does the UD attempt to re-occupy the channel?

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Testing and Validation

Details of the testing program need to be clarified and publicized to interested parties and participants.

- Tests should be conducted and supervised by the Commission's own test lab.
- The Commission should establish a qualification process for participation in test sessions.
- Tests should include at least one representative from each of the affected incumbent user groups (e.g. TV broadcasting, TV receiver manufacturers, wireless microphone manufacturers, etc.)
- Test participants should submit a test plan to the Commission in advance of test sessions for review by laboratory staff.
- Test results should be publicly disseminated.

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Conclusions and Questions

Shure supports the Commission's efforts to establish new unlicensed spectrum as long as incumbent authorized users of the TV spectrum are protected from interference.

- Shure seeks the Commission's help in formulating Rules and Certification standards that will enable this to happen.
- Shure has proposed several interference mitigation methods that will facilitate coexistence between unlicensed devices and Part 74 users.
- Interference mitigation techniques must be demonstrated to work effectively in "real world" situations before final Rules can be written and unlicensed devices can be certified for operation.
- Shure is prepared to participate in the Commission's test program to verify the effectiveness of interference prevention mechanisms under "real world" conditions.

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