Mitigating the Effects of Unlicensed Devices on Wireless Microphones

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Agenda

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- Abstract
- The Effects of the NPRM on Wireless Microphone Operation
- Proposed Interference Mitigation Solutions
- The Wireless “Smart Beacon” in Detail
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Abstract

- In May 2004, the Federal Communications Commission released ET Docket 04-186, a proposal that would allow unlicensed devices to operate in the TV broadcast bands in locally unused channels.

- However, these channels are already being actively used by wireless microphones and other licensed secondary users.

- Without effective interference protection, wireless microphone users may be unable to operate their equipment successfully once new unlicensed wireless systems are deployed.

- A “smart beacon” is one approach that could help ensure that wireless microphone transmissions are successfully identified and that harmful interference from unlicensed wireless devices is avoided. Two additional approaches will also be described in this paper.

The Effects of the NPRM on Wireless Microphones

Wireless microphones present unique challenges.

- Wireless microphones are licensed secondary users of the TV spectrum.
- They are classified by the FCC as “Low Power Auxiliary Stations”.
- Most wireless microphones use analog FM transmission, although there are some digital units.
- Occupied bandwidth is limited to 200 kHz by FCC rules.
- Power output is limited to 250 mW or less on UHF and 50 mW on VHF.

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.
- Frequency planning and coordination is vital to successful operation.
- Professional sound users expect the highest sound quality from their wireless microphones (50 Hz – 15 kHz with 100+ dB of dynamic range).
- Wireless microphones are at the front end of the audio chain and set the overall sound quality of the program. They are often used **live!**

The Effects of the NPRM on Wireless Microphones

To a broadcaster, reliability is even more important than sound quality.

- For reliable operation, wireless microphones must operate in a *known, stable, interference-free environment.* The TV bands have provided this up to now.
- Interruptions in any audio transmissions are not acceptable in television and radio broadcasting.

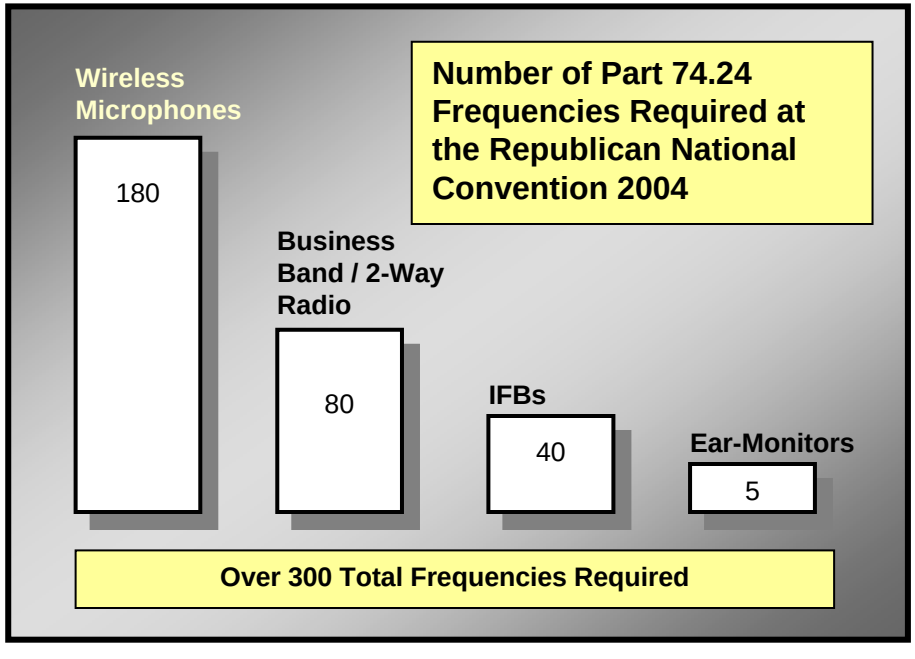
The biggest challenge faced by program producers is the shrinking pool of spectrum for wireless microphone operation:

- The FCC has chosen to consolidate TV broadcasting into a “core” TV band of channels 2-51. Thus, 18 channels or 108 MHz of spectrum has been lost.
- In addition, during the DTV transition each full power analog TV station received an additional channel to use for DTV.
- The net result: Twice as many TV stations are on the air in ¾ of the spectrum!
- Besides wireless microphones, there are wireless In Ear Monitors, IFB monitors, wireless intercoms, and wireless audio video devices (WAVD’s) using the “vacant” TV channels.

Large Mobile Wireless Microphone Venue - Example

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

- Over 300 frequencies for wireless audio required



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

Will Unlicensed Devices Interfere?

In the NPRM, the FCC suggested that interference to wireless microphones would not be a problem due to:

- Relatively high power output of up to 250 mW (UHF) and 50 mW (VHF)
- Relatively short working range (300 feet)
- Operation of FM “Capture Effect”

What are the problems with these assumptions?

- Almost all wireless microphones operate with <50 mW ERP due to battery life expectations and antenna efficiency. Lower power also promotes better spectrum efficiency. (A typical unit may radiate only ~1 mW due to body absorption).
- Obstructions and reflections can weaken wireless microphone signals even at short distances, such that the Desired-to-Undesired (D/U) signal ratio drops below minimum requirements for interference-free operation.
- The FM “Capture Effect” is far from complete.

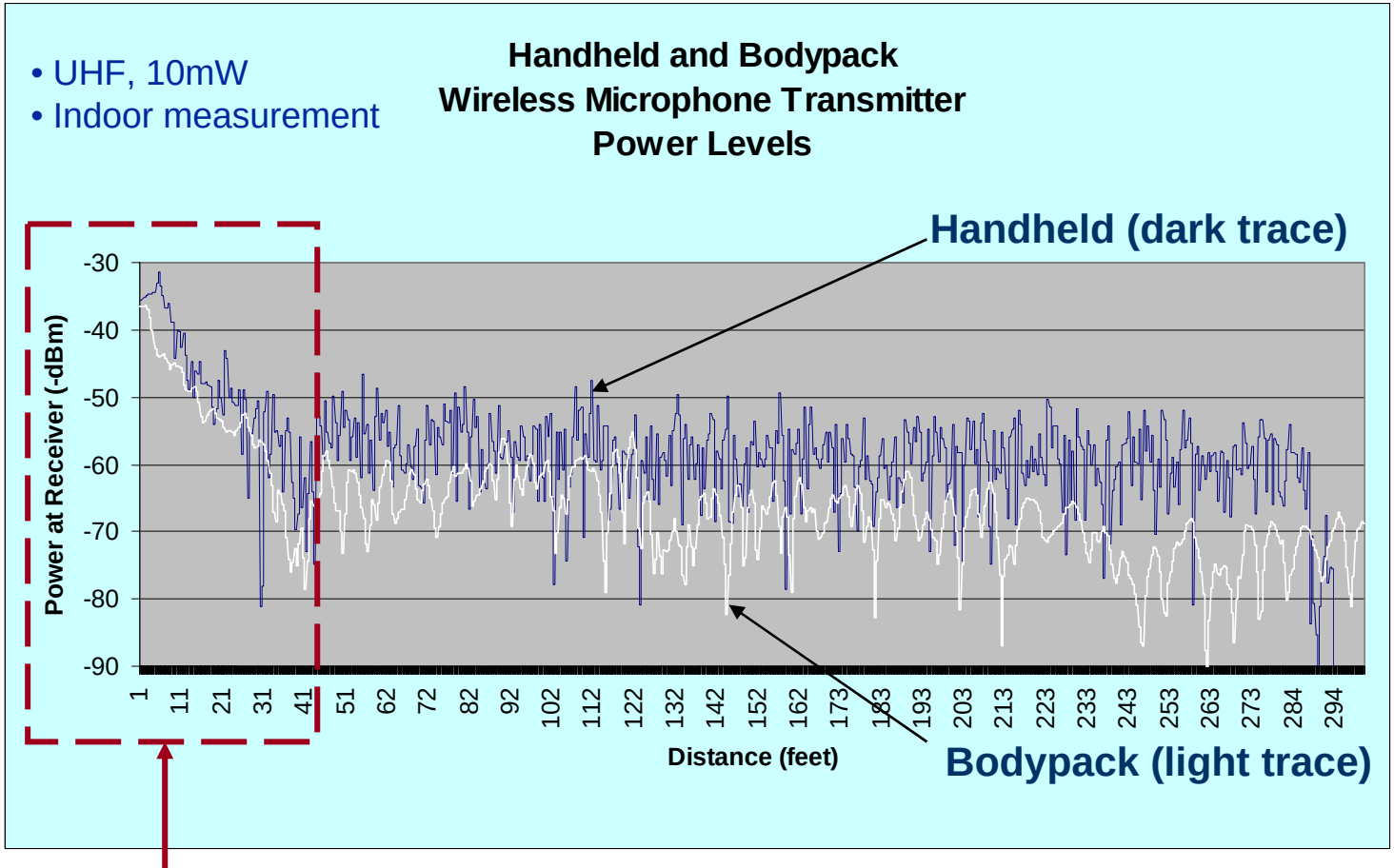
Interference Study - Overview

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.

Interference Study – Propagation Measurements

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



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

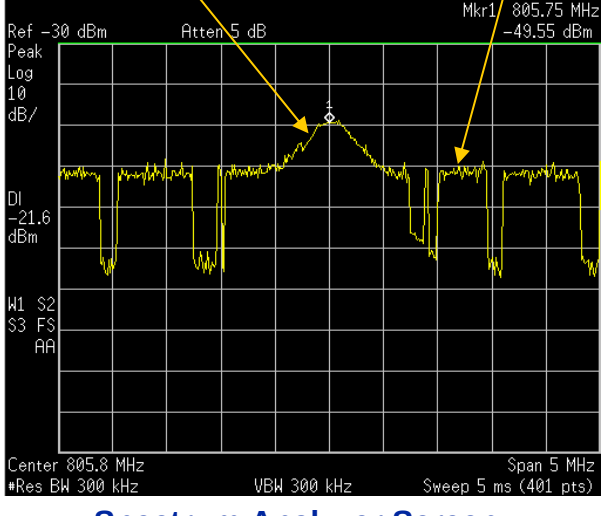
Interference Study – Radiated Testing Configuration

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

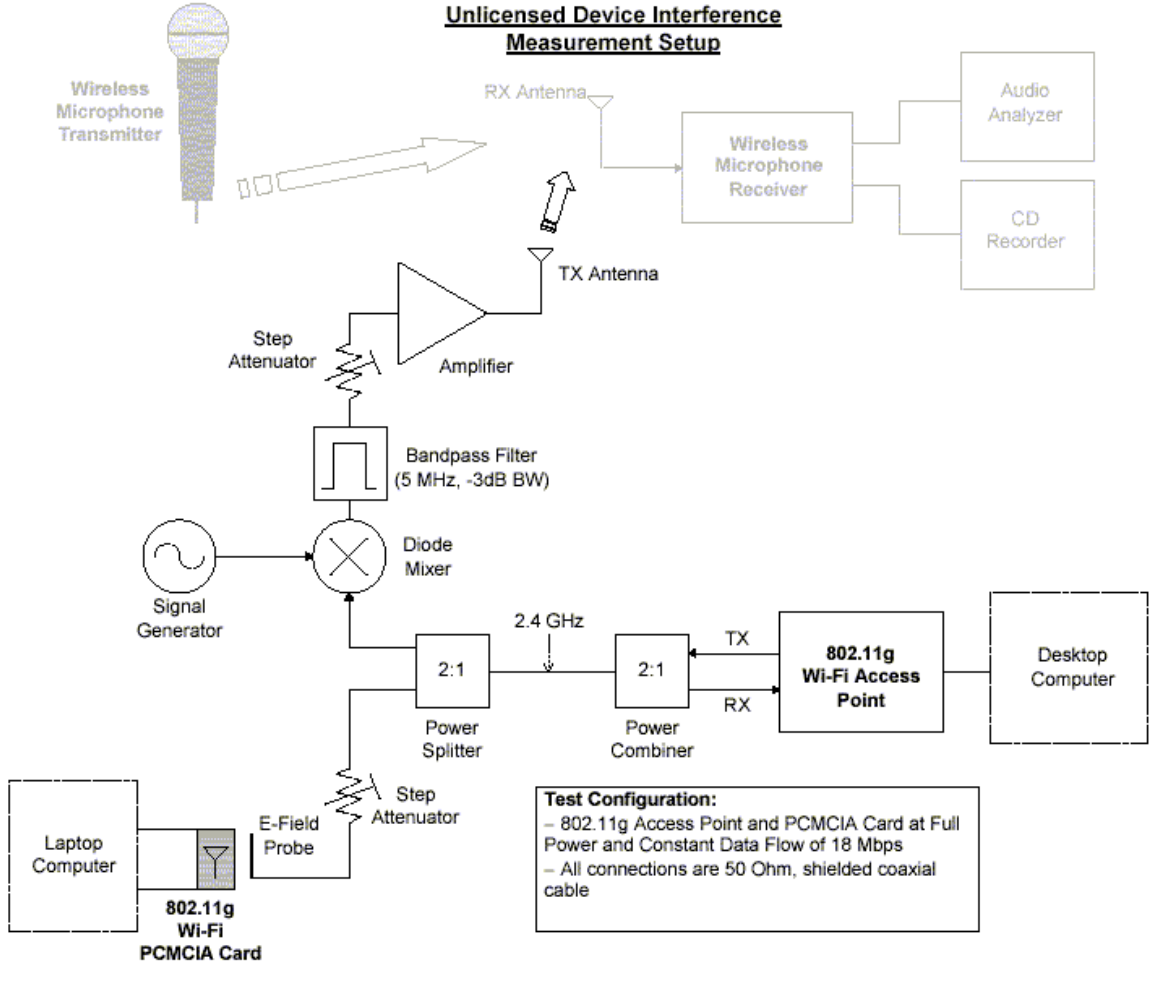
Interference to the wireless microphone is measured and recorded during normal use.

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.

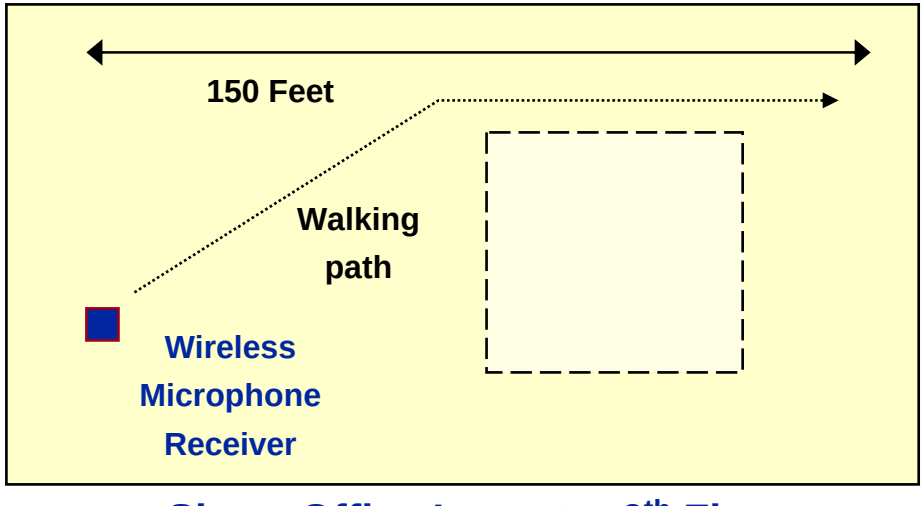
Interference Study – Radiated Test Results

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

Interference Study – Radiated Test Results

Wireless Microphone Interference Tests

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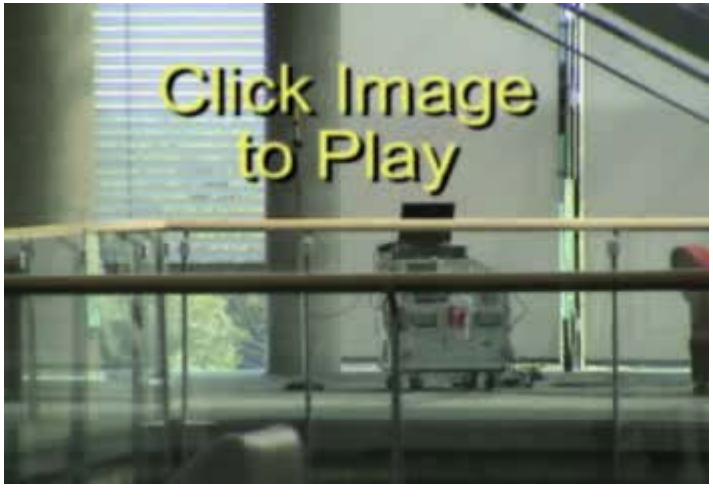
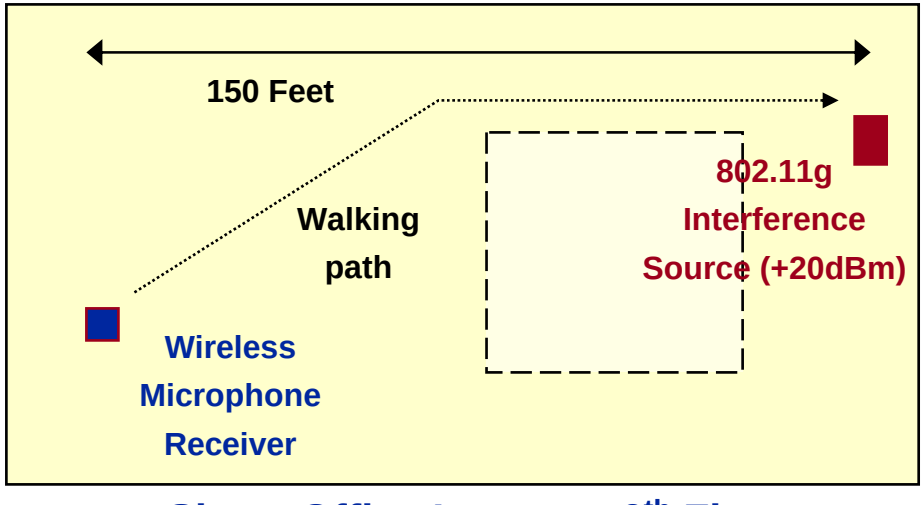
Test #2: Baseline: -54 dBm Interference to Wireless Microphone Receiver



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



Shure Office Layout – 6th Floor

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 relatively uncontrolled.***

Given this fact, how could we avoid interference problems?

- Use a cognitive radio scheme such as Dynamic Frequency Selection (DFS).
- Use a wireless microphone "smart" beacon to prevent unlicensed devices from using the same TV channels as wireless microphones.

In order to be effective, any approach that is selected must be codified into the FCC Rules.

Interference Mitigation Approaches

1. Dynamic Frequency Selection (DFS)

- Wireless microphone users are mobile, and transmissions are not scheduled. This needs to be considered in designing the parameters for unlicensed device spectrum monitoring.
- Hidden node problems are likely unless network behavior is employed.
- More effective for protection from Personal/Portable unlicensed devices, due to their lower power output as compared to Fixed/Access devices.
- Despite limitations, would still be beneficial on a “best efforts” basis.

2. Wireless "Smart” Beacon System

- A local beacon transmitter operating in an unoccupied TV channel could broadcast information to unlicensed devices operating nearby.
- The unlicensed devices would need to scan for the beacon, and avoid operating on TV channels marked as being in use by wireless microphones.
- This is essentially a variation on the Control Signal approach suggested in the NPRM that works specifically at the local level to provide a “bubble of protection” for wireless microphones. This results in much more efficient use of spectrum.

Interference Mitigation Approaches

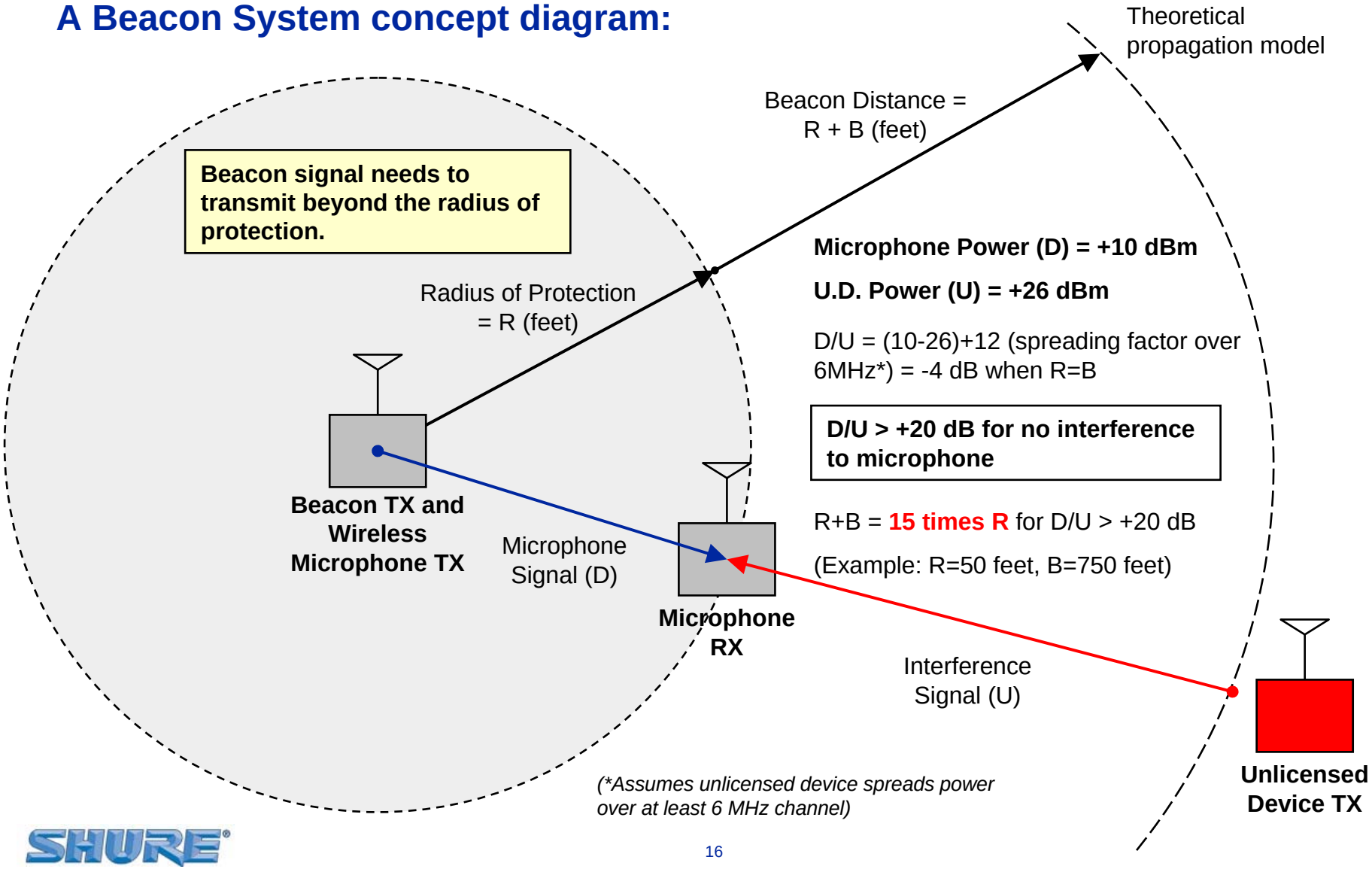
Advantages of the Wireless "Smart" Beacon:

- Provides positive, assured protection from harmful unlicensed device interference to wireless microphone operations. To enable this:
  - The beacon would operate at the maximum allowed power of 250 mW for Part 74 Low Power Auxiliary Station devices to maximize the range of the beacon signal.
  - The beacon antenna would be favorably situated at the location of the wireless microphones and other wireless audio equipment to prevent signal loss due to body absorption and reflections.
- Simplifies the task of recognizing and avoiding TV channels that are in use by wireless microphones for the unlicensed device. To enable this:
  - The beacon would transmit a digitally encoded signal that would be easy to recognize and decode.
  - The beacon signal would carry information about all of the TV channels in use at that particular location, eliminating the need for the unlicensed device to scan for other wireless microphones (or beacons).

The main limitation is that the wireless microphone system operator would need to purchase and deploy a beacon to receive protection.

The Wireless “Smart” Beacon in Detail

A Beacon System concept diagram:



The Wireless “Smart” Beacon in Detail

Conclusions from the propagation model:

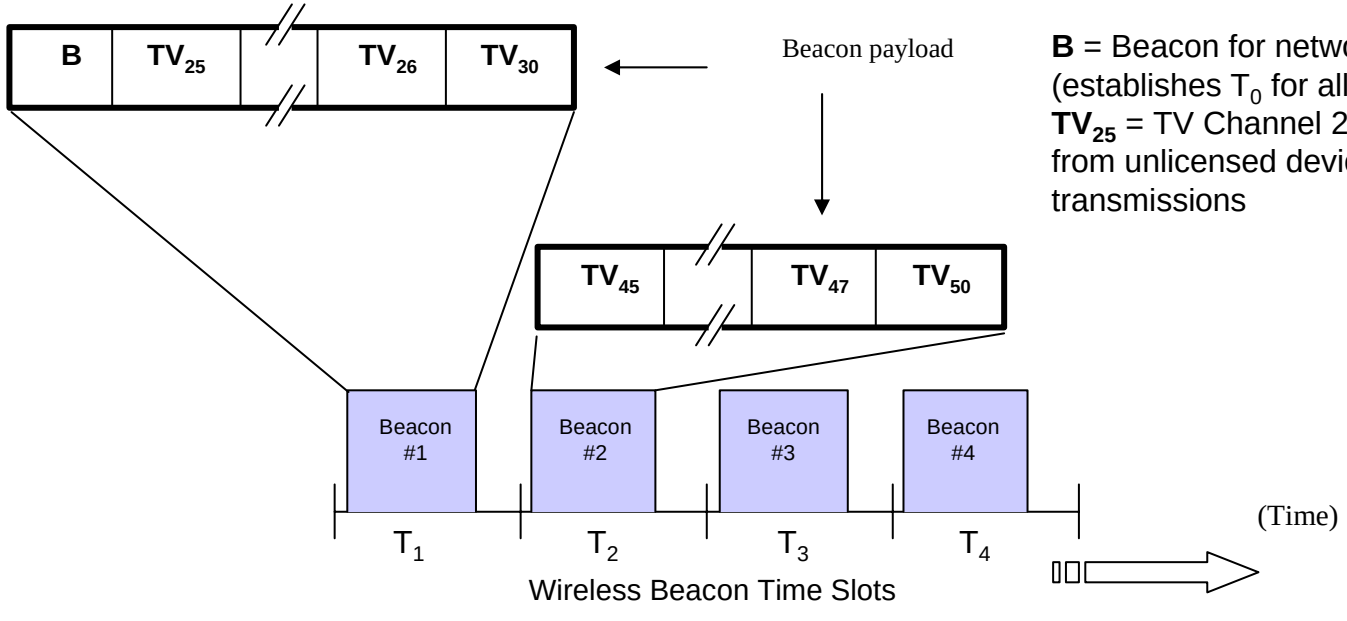
- The transmission range of the beacon (including the beacon transmit power and the unlicensed device detection threshold) is important since there is a large disparity between the wireless microphone power (10-50 mW) and the proposed power of unlicensed devices (400 mW for Personal/Portable and 4W for Fixed/Access).
- Therefore, the beacon design concept is designed to maximize the area of protection by limiting the occupied bandwidth of the beacon signal to facilitate low detection thresholds in the unlicensed devices.

Beacon operational characteristics

- The beacon proposal is based on a simple TDMA scheme similar to that found in IEEEE 802.15.4.
- Predetermined time slots would allow more than one beacon to transmit multiple protection “requests” on the same beacon frequency.
  - This feature allows more than one domain of wireless microphone users to transmit from multiple beacons in the same location – e.g. multiple networks covering a single news event such as a disaster

The Wireless “Smart” Beacon in Detail

Summary Diagram of the Beacon Protocol



B = Beacon for network sync (establishes T_0 for all beacons)
TV_{25} = TV Channel 25 to protect from unlicensed device transmissions

Figure 2. Wireless Smart Beacon Protocol Summary

The Wireless “Smart” Beacon in Detail

How the protocol would work:

- The protocol automatically expands the number of time slots to accommodate multiple beacons.
- When a beacon is powered on, it searches for existing beacons on the air.
- If none are found, it becomes the network coordinator and provides synchronization to others that may join the network via a periodic timing signal (“B” in the previous figure).
- If an existing coordinator is found, a request is sent to join the network by the new beacon.
- TV channel information would be transmitted in subsequent time slots.
- Beacons would use half-duplex communication on a single frequency to conserve spectrum.
- Beacons would continuously transmit the TV channel information in a periodic fashion while powered on to provide increased detection confidence at the unlicensed device.

The Wireless “Smart” Beacon in Detail

Proposed Beacon Modulation

- As in any radio communication system, there are tradeoffs designers must make between performance, cost, and complexity.
- The proposed beacon modulation is 2-level FSK at a signaling rate of 200-300 Hz, which allows a detection threshold of approximately -120 dBm at the unlicensed device receiver.
- The use of FSK also simplifies the transmitter design at the 250 mW output power level selected because this modulation is not as sensitive to non-linear amplification. This helps keep current drain low for portable applications.
- Other details remain to be worked out during upcoming meetings of a proposed 802.22 study group that will be investigating ways to enhance detection and identification of Part 74 devices.

Conclusions

ET Docket No. 04-186 could add thousands (or even millions) of new unlicensed devices to the TV bands.

- Wireless microphones are critically important to radio and television program production today.
- It is already difficult to find enough spectrum, especially in metropolitan areas.
- Without meaningful interference protection, wireless microphones will become unreliable for broadcast use.
- Shure has proposed solutions for mitigating interference:
  1. Require Personal/Portable and Fixed/Access unlicensed devices to use spectrum sensing to detect and avoid wireless microphones on a “best efforts” basis.
  2. Require Personal/Portable and Fixed/Access unlicensed devices to receive a wireless microphone beacon signal and avoid operating on TV channels designated as “in use” in the vicinity of the beacon.