RF IMMUNITY (RFI)

AND

ELECTROMAGNETIC COMPATIBILITY (EMC)

OF SENNHEISER INSTALLED SOUND MICROPHONES:

BACKGROUND, PROCEEDURES, AND RESULTS

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BACKGROUND

Introduction

Electromagnetic interference (EMI), also referred to as radio frequency interference (RFI), between wireless electronic devices and other system components is a growing problem in virtually every venue where a sound system is used. While anecdotal evidence shows that the critical functions of most systems are relatively immune to wireless RF emissions, the potential for disruption does exist.

The RFI problem has existed for many years caused mostly by standard radio and TV broadcasting and mobile radio communication transmissions. It has been overcome or alleviated through the use of good installed wiring practices and by selecting well-engineered products and components. RFI emissions have become more of a problem since the wide spread deployment of wireless data and telephone devices such as the BlackBerry®, PDAs, and cellular telephones. These personal portable devices are finding their way into facilities and coming into close proximity to systems and subsystems, increasing the likelihood of adversely affecting such system.

Many facilities, such as churches and auditoriums, have developed policies and procedures that minimize or prevent wireless interference by creating certain areas to allow wireless usage, or by banning the use of such devices altogether. Other facilities, such as board rooms and conference centers, have established proximity rules for the use of these devices. Their use is not allowed in close proximity to system components and is governed by minimum distance rules.

Since Sennheiser manufactures microphones engineered for applications in these facilities, it is important to know and understand their resistance to electromagnetic interference. This paper describes the testing that was performed on the Installed Sound Series of microphones.

What is EMI?

Electromagnetic interference (EMI) occurs when one or more electronic devices adversely interfere with the operation of another electronic device. Any radio frequency (RF) transmitting device, such as a broadcast station, two-way radio, or a cell phone, has the potential to interfere with the operation of another electromagnetic device because of the physics governing radio waves: as electrons move, they create electromagnetic fields that propagate through space and potentially interact with each other.

Electromagnetic compatibility (EMC) is the opposite of EMI. EMC means that the device is compatible with (i.e., no interference caused by) its Electromagnetic (EM) environment and it does not emit levels of EM energy that cause EMI in other devices in the vicinity.

Factors Affecting Wireless EMI

Tests show that the majority of wireless EMI occurs when wireless devices operate at high power and in close proximity to sensitive areas such as next to a rack of equipment or next to an active microphone. The three main factors identified as influencing the potential for EMI are:

1. Power output of the device: the greater the electrical field strength generated by the transmitting device, the higher the potential for interference.
2. Proximity: the smaller the distance between devices, the greater the field strength, and the greater the chance for EMI. As distance increases, field strength emissions decay rapidly.
3. Frequency: certain sound system components may be more susceptible to interference from specific frequencies.

Shielding Standards

Most professional sound equipment today has some form of EMI shielding. However, different shielding standards have existed at different points in time, with standards becoming more stringent over the years in response to changes affecting the electromagnetic environment. In 1993 and in 2002, the International Electrotechnical Commission (IEC) introduced the current more rigorous shielding standards. A key shielding difference between the current and 1993 versions of the standard is the immunity requirement for critical and life support medical devices. The 2002 standard sets immunity requirements for critical devices at field strength test levels of 10 V/m, and at 3 V/m for other equipment.

Every Venue has a Unique Electromagnetic Environment

The risk of wireless EMI increases with the complexity of the electromagnetic environment and the type of wireless services active in the environment. No amount of testing by manufacturers can predict or account for the variety of wireless devices used in a facility, their use of the frequency spectrum, or their power output when transmitting. Different combinations of RF transmitters, system shielding, and reflecting environments can produce different interference effects. It is not feasible or possible to design a comprehensive EMC solution, as no one single manufacturer has control over the components and materials used in the installation.

Wireless Wide Area Networks (WWAN)

Wireless Wide Area Networks are carrier-operated cellular networks consisting of interlinked base stations covering large areas and linked together into networks spanning wide geographic regions. WWANs deliver near-continuous coverage of voice and data traffic to subscribers, enabling widespread access and device roaming throughout the network area.

Because WWANs offer national and international wireless coverage and multiple handheld device capability, they have become the principal communication network for business and personal use.

Table 2 describes four leading WWAN technologies.

Table One: Predominant WWAN Technologies

Technology	Frequencies	Business Process
Global System for Mobile Communications (GSM)	900, 1800, 1900 MHz	Digital voice, short message services, short data transactions between field terminals and back-office servers
General Packet Radio Services (GPRS)	900, 1800, 1900 MHz	Voice, messaging, email, and wireless web on BlackBerry and other phones, pagers, and PDAs from Cingular, T-Mobile, etc.
Code Division Multiple Access (CDMA)	800, 900, 1700, 1800, 1900 MHz	Digital voice, short message services, PCS, wireless web on WAP Phones
CDMA2000/1X	450, 800, 1700, 1900, 2100 MHz	Voice, messaging, email, and wireless web on Smartphones and other phones, pagers, and PDAs from Sprint, Verizon, etc.

WWAN radio signals operate in the licensed spectrum at frequencies of 450 MHz, to 2.1 GHz. The two main technologies supporting WWANs are GSM and CDMA. Enhanced WWAN technologies such as GPRS are comprised of digital voice networks that have been upgraded to carry data and personal communication services.

- GSM™ (Global System for Mobile communication): an all-digital cellular network used extensively in Europe and across the world. A GSM network can provide, besides telephony services, short messaging services (SMS) and data communication operating at the 900 MHz, 1800 MHz or 1900 MHz frequency bands.
- GPRS (General Packet Radio Service): an enhancement to GSM enabling higher data transmission speeds. GPRS supports packet-switching, using the network only when data is to be sent, and acting as an “always on” technology enabling constant connectivity.
- CDMA (Code Division Multiple Access): a digital cellular technology first commercialized by Qualcomm. Each CDMA transmission is identified by a unique code, allowing multiple calls to use the same frequency spread.

WWAN Handheld Devices

Handheld devices operating on WWANs generally transmit at average power levels of 0.6 watts, reaching levels of 1- 2 watts at peak power. Many WWAN handhelds have power controls and transmit at drastically reduced power levels when operating in the presence of a strong base station signal. It is the proximity of these devices to an audio system, not the base station signals that have caused the current concerns.

SETUP AND TESTING PROCEDURES

Given the current potential for disruption from harsh RF environments, Sennheiser took on the task of performing exacting tests on its Installed Sound Series of wired microphones to determine their immunity to EMI. These tests were performed in Sennheiser labs under the following protocols and conditions.

The IEEE/ANSI C63.18-1997 Standard

Standard C63.18-1997 published by the IEEE provides ad hoc testing procedures for evaluating the radiated RF electromagnetic immunity of critical medical devices to the radiated RF electromagnetic energy emitted from commonly available RF transmitters. This standard was chosen as protocol for Sennheiser tests because of its defined higher level for measurements. The standard applies (among others) to critical medical devices used in health-care facilities and to portable transmitters with a rated power output of 8W or less.

Test Conditions

Tests were performed on the ME35 and ME36 IS modular microphone capsules with a short gooseneck inside a GTEM-Cell (Gigahertz Transverse Electro Magnetic Chamber). The following Test equipment was used during the test:

- 2 Bonn RF-power amplifiers
  - a 100W for 25 - 1000MHz
  - a 40W for 1 - 3 GHz
- Integrated Test system Rohde & Schwarz IMS (switch/signal generator/amplifier)
- Rohde & Schwarz UPL Audio Analyzer (DC...110kHz)
- GTEM Cell 750 by Schaffner
- A Sennheiser phantom power adapter (MZN 16 P48)
- HF-Filter

This hardware was under control of the following software:

- EMC32 (EMS/EMI-) test suite by Rohde & Schwarz

The DUT (device under test) for the comparative measurements were:

Sennheiser ME35 (super cardioid) with short gooseneck MZH3015
Sennheiser ME36 (short interference tube) with short gooseneck MZH3015

Preparation

The EMI measurements for RF-immunity were taken inside the Schaffner GTEM-cell 750. Since the IEEE standard provided no specifications for the orientation of the devices under test, the test orientation conditions were randomly assigned. The axis of the microphones were carefully aligned with the electric field lines in accordance with the established coordinates of the GTEM-Cell (Alignment in the X-axis the field lines were perpendicular to the diaphragm).

Through pre-test measurements on the ME 36 in all three dimensions, the largest influence from orientation could be observed for both microphones. For this reason all measurements were conducted using this alignment.

To attenuate environmental noise, all openings of the microphone capsules were closed to audio signals using a fabric based adhesive tape. The capsules were then attached to the gooseneck and inserted completely into a sound isolating tube. The sound isolating tube was then placed floating in the test environment (a homogeneous electric field) of the GTEM-cell between the septum and the ground plane.

The phantom power adapter, together with the RF-filter components, were placed outside the GTEM-cell so as not to disturb the field inside the measurement environment the. The high-frequency RF filters were necessary to block potential cable-induced RF.

Measurements

Initial tests followed the International Electrotechnical Commission standard, IEC 60268-4:2004 “Sound System Equipment – Part 4: Microphones” (also adopted as European Norm 60268-4). In sections 18.6 “Equivalent Sound Pressure Level for Electromagnetic Interference”, and further in 18.6.2 “Measurement Methods“, the following conditions are established:

- If present, any controls are set to their “normal” position
- The RF generator is amplitude modulated for the first test run with a 1000 Hz sine wave tone at 30%, and during the second test run frequency modulated with a 1000 Hz sine wave tone and a deviation of 22.5 kHz.
- The field strength shall be 10 V/m.
- The signal at the output of the microphone under these conditions is measured as weighted noise (quasi-peak detection), referenced to the free field sensitivity of the microphone and expressed as the equivalent sound pressure level.

Close Proximity Testing

Additional testing deviated from these standards to simulate much harsher conditions used in evaluating critical medical devices. These tests were conducted with amplitude modulation of the RF-generator with 1kHz and 80%. Since the FM (frequency modulation) tests did not produce any interference, no further measurements with this type of modulation were made. The measurements were taken with carrier frequencies between 80MHz and 3GHz. The software suite controlled the details of the following settings:

- Measuring range 1: 80MHz – 1GHz (100W RF-amplifier)
- Measuring range 2: 1GHz - 3GHz (40W RF-amplifier)
- Modulating signal: 1kHz
- 80 % AM
- Frequency sweep in logarithmic steps of 1 %
- Electric field strength: 10 V/m (***the standard for critical medical devices***)
- Power regulated with a tolerance of +/- 0,2 dB
- Dwell time per step: 1 second
- Calibration data of the Cell and cables are stored as tables and corrected for through the software.
- Quasi Peak detection with CCIR weighting filter

These harsh environment tests were conducted in the four frequency ranges used by cellular telephone services 850MHz, 900MHz, 1800MHz, and 1900MHz (see Table 1). As these frequencies are not well covered through logarithmic sweeps in 1% steps, additional high-resolution measurements were taken around these frequencies with linear sweeps in steps of 1kHz.

RESULTS

The following values were calculated:

1.) Difference between output level at 1 Pa SPL (1 Pa = 94 dB SPL) and level of interference signal. (defined as noise level difference)
2.) Difference between output level at rated maximum SPL and level of interference signal (defined as Signal-to-noise level)
3.) Equivalent noise level = equivalent SPL for the interference signal.

The results are summarized in the following tables.

Microphone	Sennheiser ME35	Sennheiser ME36
Free field sensitivity per manufacturer's specifications		
dBV for 1Pa (1Pa = 94 dB SPL)	-40.00	-35.00
mV/Pa	10.00	18.00
Maximum SPL for 1% THD		
dBSPL (per manufacturer's specifications)	134.00	130.00
V	1.00	1.14
dBV	0.99	1.13
Maximum Interference		
Frequency/MHz	1051.01	871.40
dBV	-75.83	-60.94
mV	0.16	0.90
Noise level difference (output level at 1Pa – noise level) in dB	35.83	25.94
Signal-to-noise level (output level at maximum SPL – noise level) in dB	75.85	62.07
Equivalent noise level (94dB SPL– noise level difference) in dB	58.17	68.06

Table 2. Standard Measurements

Notes to Table 2.

Noise Level Difference. The manufacturer's microphone sensitivity measurement for the ME35 at 1 kHz is 10mV/Pa, or –40 dBV. As measured in the test, the maximum interference signal level was measured at –76 dBV. This results in a noise level difference of [-40dBV – (-76dBV)] = 36dB. This means that the output level due to RF interference is 36 dB ***below*** the output level of the microphone for an SPL of 1Pa.

Signal-to-Noise Level. The maximum specified audio level for the microphone is 134 dBSPL. For the ME35 sensitivity, this will result in an output voltage level of 0dBV. From this value the signal-to-noise level is calculated as [0dBV – (-76dBV)] = 76dB, which alternately means that the output level due to interference is 76 dB ***below*** the output level resulting from the maximum specified SPL.

Equivalent Noise Level. The equivalent sound pressure level of the interference signal is the difference between the reference SPL of 1 Pa, or 94 dBSPL and the noise level difference which is 36dB, and is calculated as [94dB – 36dB] = 58dB.

Microphone	Sennheiser ME35	Sennheiser ME36
Interference around 850 MHz		
dBV	-101.19	-70.64
uV	8.72	293.76
Noise level difference (output level at 1Pa – noise level) in dB	61.19	35.64
Signal-to-noise level (output level at maximum SPL – noise level) in dB	101.21	71.77
Equivalent noise level (94dB SPL– noise level difference) in dB	32.81	58.36
Interference around 900 MHz		
dBV	-100.54	-79.16
uV	9.40	110.15
Noise level difference (output level at 1Pa – noise level) in dB	60.54	44.16
Signal-to-noise level (output level at maximum SPL – noise level) in dB	100.56	80.29
Equivalent noise level (94dB SPL – noise level difference) in dB	33.46	49.84
Interference around 1800 MHz		
dBV	-103.05	-99.77
uV	7.04	10.27
Noise level difference (output level at 1Pa – noise level) in dB	63.05	64.77
Signal-to-noise level (output level at maximum SPL – noise level) in dB	103.07	100.90
Equivalent noise level (94dB SPL – noise level difference) in dB	30.95	29.23
Interference around 1900 MHz		
dBV	-96.58	-96.26
uV	14.83	15.38
Noise level difference (output level at 1Pa – noise level) in dB	56.58	61.26
Signal-to-noise level (output level at maximum SPL – noise level) in dB	96.60	97.39
Equivalent noise level (94dB SPL– noise level difference) in dB	37.42	32.74

Table 3. Close Proximity Simulation Measurements

Table 3. presents the readings for the same three measurements but under harsher conditions for each of the central ranges for cellular devices in order to simulate extreme close proximity.

Furthermore the demodulated 1kHz AF interference levels measured for both microphones are depicted in the following diagrams across the entire range of carrier frequencies (80 MHz – 3 GHz), referenced to the corresponding free field sensitivity and the corresponding maximum sound pressure level.

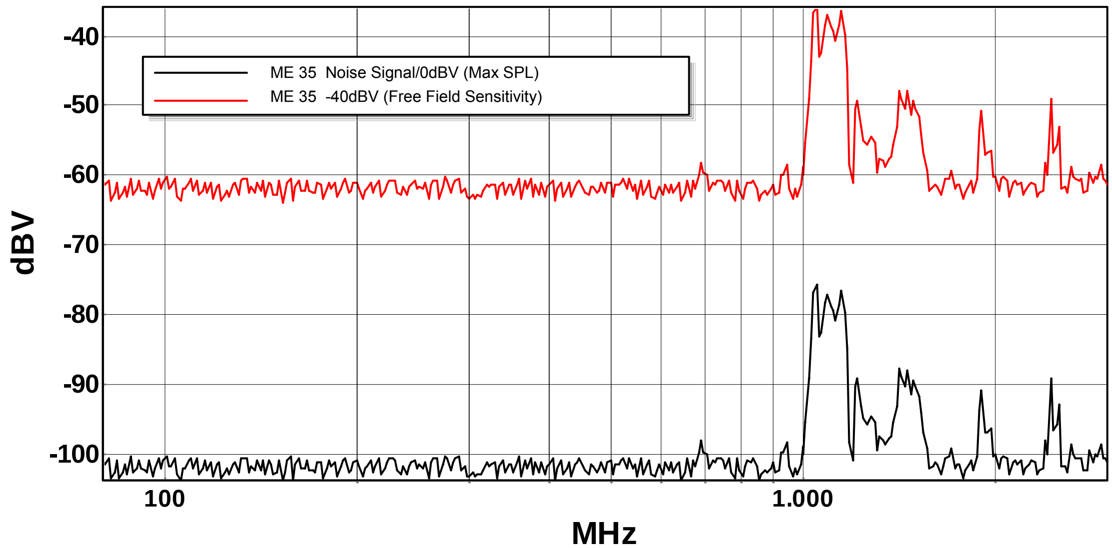

Figure 1: Level of the demodulated interference signal for the ME35 (black curve) referenced to free-field sensitivity (red curve) and to maximum SPL (identical with black curve).

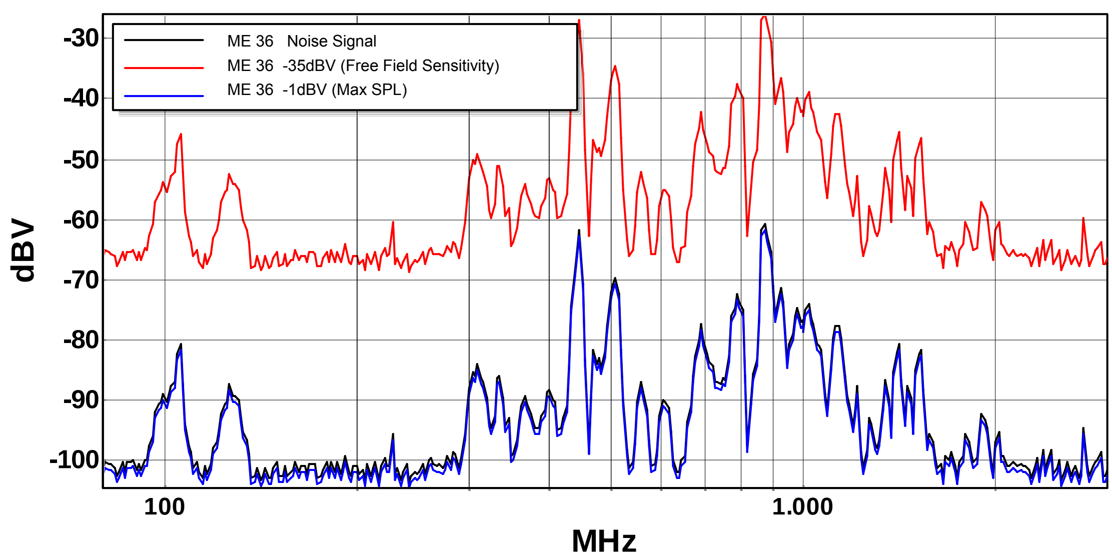

Figure 2: Level of the demodulated interference signal for the ME36 (black curve) referenced to free-field sensitivity (red curve) and to maximum SPL (blue curve)

Notes to Figure 1 and 2:

Figures 1 and 2 display the measured interference levels referenced to the corresponding sensitivity and maximum SPL. The distance between the curves and 0 dB depict the Signal-to-Noise Level and the Noise Level Difference respectively. For example, in Figure 1 the minimum distance of the red curve to 0dB is 35.83dB (at a carrier frequency of 1051 MHz experiencing the maximum interference). See also Table 1: Sennheiser ME35 Noise Level Difference.

SUMMARY

The tests performed by Sennheiser on the Installed Sound Series microphones were conducted rigorously following the IEC and IEEE guidelines. These tests establish the protocol for testing any other microphone needing RF immunity evaluation or claiming immunity in an RF environment. These tests were performed at test levels required of critical medical devices to simulate extreme close proximity.

The measurements conducted during these tests reveal a very high immunity to electromagnetic interference for the ME 35 and ME 36 capsules/gooseneck combinations, especially under close proximity conditions in cellular telephone frequency ranges.

The opposite of EMI is EMC (electromagnetic compatibility). Electromagnetic compatibility is the condition which prevails when audio equipment is performing its individually designed function in a common electromagnetic environment without causing or suffering unacceptable degradation in quality, level, or standard of performance due to unintentional electromagnetic interference to or from other equipment in the same environment.

Since operating environments now often have a high level of EMI due to new cellular technology, these tests conclude that the Sennheiser IS Series of microphones are highly immune and display strong electromagnetic compatibility even in harsh conditions.