Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In re:	)	
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Hearing Aid Compatibility Requirements for Wireless Telecommunications Devices	)	WT Docket No. 06-203
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To: The Wireless Telecommunications Bureau

Comments of the
Alliance for Telecommunications Industry Solutions ("ATIS") on behalf of the
ATIS Incubator Solutions Program #4-Hearing Aid Compatibility

January 12, 2006

Alliance for Telecommunications
Industry Solutions, Inc.
AISP.4-HAC
1200 G Street, NW
Suite 500
Washington, D.C. 20005
Ph: 202.628.6380
Fax: 202.393.5453

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I. INTRODUCTION

The Alliance for Telecommunications Industry Solutions' ("ATIS") Incubator Solutions Program #4 – Hearing Aid Compatibility offers these comments addressing key issues that have emerged in the quest to provide consumers wireless handsets that achieve a high level of electromagnetic compatibility with hearing aids. The wireless industry through the AISP.4-HAC is working with groups representing hearing aid consumers to develop an alternative to the FCC's fifty percent rule, 47 C.F.R. § 20.19(c)(1)(ii) and (3)(ii) (2006). These efforts have resulted in a great deal of work and significant progress. The AISP.4-HAC members hope that this work will result in a consensus proposal to present to the Commission and look forward to continuing this collaborative dialog with representatives of the hearing impaired community in pursuit of this goal.

Meeting the worthy goal of compatibility between hearing aids and wireless devices requires the application of not only an in-depth understanding of the electromagnetic interactions that characterize the operation of the two classes of devices, it also calls for insight into how consumer preferences affect the acceptance of design choices that must accommodate engineering realities. For the reasons discussed in this paper, the Commission should revise its HAC rules for wireless devices in order better to achieve the goal of offering the hearing impaired community a wide choice of devices without unduly compromising the innovation that has been the hallmark of wireless development in the United States.

II. SUMMARY

The current fifty percent requirement set forth in Section 20.19 of the Commission's Rules will not meet the agency's goal of providing consumers with choices of price range and design options in wireless devices. Strict enforcement of the fifty percent requirement as now imposed will frustrate many of the key objectives the

Commission embraced in adopting the hearing aid compatibility ("HAC") rules and, more importantly, fail to yield the technology choices that hearing impaired users have sought. To foster the development of a meaningful selection of HAC compliant wireless devices, while not impeding the development of new technologies for all consumers, the Commission should revise its rules in a manner that enables manufacturers and carriers to know well in advance and with a greater degree of precision the number of HAC compliant wireless devices that would be required in February 2008 and thereafter.

III. BACKGROUND

A. Wireless Device Hearing Aid Compatibility

The Commission's *Report and Order* ("R&O") established new rules partially lifting the statutory exemption from hearing aid compatibility requirements for wireless phones.[1] In the R&O the Commission adopted the American National Standards Institute ("ANSI") C63.19 standard for measuring and rating the compatibility of wireless devices with hearing aids,[2] and required manufacturers and service providers to make available a minimum number of HAC-compliant wireless devices.[3] Importantly, the Commission recognized that the 2001 ANSI C63.19 standard remained a work in progress subject to

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[1] Section 68.4(a) of the Commission's Rules Governing Hearing Aid-Compatible Telephones, Report and Order, 18 FCC Rcd 16753 (2003) ("R&O"). See also Section 68.4(a) of the Commission's Rules Governing Hearing Aid-Compatible Telephones, Order on Reconsideration and Further Notice of Proposed Rulemaking, 20 FCC Rcd 11221 (2005) ("Reconsideration Order" or "FNPRM").

[2] American National Standards for Methods of Measurement between Wireless Communications Devices and Hearing Aids ANSI C63.19-2001 ("C63.19 Standard").

[3] The Commission also established labeling requirements for HAC-compliant devices, and mandated in-store consumer testing to allow prospective purchasers to try HAC-complaint handsets at retail outlets.

further revisions, and acknowledged that its rules would need to accommodate such revisions.[4]

Key future requirements adopted in the R&O are set forth in Paragraph 66:

> In addition, by February 18, 2008, the date on which wireless carriers may discontinue providing analog service in accordance with the *Analog Sunset Order*,[5] we require 50 percent of all phone models offered by digital wireless phone manufacturers and service providers to meet the U3 performance level for acoustic coupling as a reasonable step toward manufacturers' incorporation of hearing aid compatible functions into their phones. For purposes of calculating this 50 percent compliance percentage…, we require wireless carriers and handset manufacturers to base their calculations on the total number of unique digital wireless phone models they offer throughout the nation. These requirements constitute steps toward our goal of having wireless phone manufacturers and service providers implement acoustic coupling capability ("U3") in all digital wireless phones at some point in the future.[6]

The Commission concluded in the R&O that its HAC requirements: .[7]

- are technically feasible,
- should be technology neutral,
- would not impact core designs for mobile phones,
- would give consumers an informed choice based on ratings developed in ANSI C63.19, and
- would not increase the cost of development to the point a phone could not be marketed

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[4] *See* R&O at ¶ 63.

[5] Year 2000 Biennial Regulatory Review – Amendment of Part 22 of the Commission's Rules to Modify or Eliminate Outdated Rules Affecting the Cellular Radiotelephone Service and other Commercial Mobile Radio Services, Report and Order, 17 FCC Rcd 18401, ¶22 (2002) ("Analog Sunset Order").

[6] R&O at ¶ 66. In later versions of ANSI C63.19, the term "U rating" has been replaced by "M rating" and the term "UT rating" has been replaced by "T rating."

[7] *See* R&O at ¶¶ 29, 38, 50, 54, 72, and 76.

While the Commission's efforts have contributed to the availability of substantially greater numbers of HAC compatible phones using the CDMA, iDEN, and GSM air interfaces, the underlying assumptions set forth in the R&O, to a great extent, have proven to be incorrect with respect to GSM handsets. Because of concern over the efficacy of the HAC regulations, various stakeholders including manufacturers, carriers, academics, and representatives of the hearing impaired community have worked since adoption of the HAC rules to assess the effectiveness of these requirements and to examine possible changes that would yield solutions to the HAC compliance challenges. Much of this work has been carried out through the AISP 4-HAC.

B. ATIS and the AISP.4-HAC Incubator

ATIS is a technical planning and standards development organization accredited by the American National Standards Institute ("ANSI") and committed to rapidly developing and promoting technical and operational standards for communications and related information technologies worldwide using a pragmatic, flexible and open approach. Industry professionals from more than 350 communications companies actively participate in ATIS' open industry committees and other forums. The ATIS membership spans all segments of the industry, including local exchange carriers, inter-exchange carriers, wireless equipment manufacturers, competitive local exchange carriers, data local exchange carriers, wireless providers, providers of commercial mobile radio services, broadband providers, software developers and internet service providers.

The ATIS Incubator Solutions Program offers the industry a "fast-track" process for resolving technical and operating issues. By striving for consensus on technically challenging matters, it is an alternative approach toward solutions development. The ATIS incubator concept was launched from an idea developed by ATIS's own membership — leading service providers, manufacturers, wireless companies, carriers, software designers, Internet Service Providers, consultants, and other companies.

AISP.4-HAC was created to investigate performance between hearing aids and wireless devices to determine methods of enhancing interoperability and usability for consumers with hearing aids in order for those in the hearing aid and cellular wireless industries to meet the requirements of the FCC's HAC requirements. This incubator focuses on the technical issues addressing interoperability and compatibility of wireless devices with hearing aids, including the evaluation and test methodology set forth in the ANSI C63.19 standard. AISP.4-HAC is composed of technical experts from the wireless industry representing wireless manufacturers and service providers, as well as technical experts representing the hearing aid industry. Representatives from consumer advocacy and disability groups also actively participate in open AISP.4-HAC meetings.

The AISP.4-HAC has the following membership as of January 12, 2007:

Alltel
Brookings Municipal Utilities d/b/a Swiftel Communications
Carolina West Wireless
Cingular Wireless LLC
Corr Wireless Communications, LLC
Cricket Communications
Kyocera Wireless LP
Leap Wireless
LG
Motorola, Inc.
Nokia
Panasonic
Qwest Wireless
Research In Motion, Ltd
Dobson Cellular Systems, Inc./American Cellular Corporation
Epic Touch
Hewlett Packard
Immix Wireless
Key Communications
Keystone Wireless
Samsung Telecommunications America
Sprint Nextel
Sony Ericsson Mobile Communications (USA) Inc.
Suncom
T-Mobile USA
UTSTARCOM
Verizon Wireless

The hearing aid and digital wireless industries face complexities and challenges in attempting to make their products compatible. Through an open and impartial consensus process, AISP.4-HAC has investigated and developed recommendations to the C63.19

standards committee for measuring hearing aid immunity and interference caused by wireless devices. Stakeholders in the hearing aid compatibility arena are represented in the incubator. In reviewing HAC solutions, this group has had to examine the fundamental interactions between wireless handsets and hearing aids. The recommendations in this white paper are the result of that examination.

C. <u>The Basic Physics</u>

In order to communicate, wireless devices emit radio frequency energy, which is generated in very close proximity to hearing aids.[8] Electromagnetic fields conveying this energy can induce currents in hearing aid circuits. Components in hearing aids detect this energy and change it from radio frequency to audio frequency signals. These signals are then passed on to the amplifier in the hearing aid and reproduced by the transducer as noise. Thus, the electrical noise received by the hearing aid from the wireless handset is converted within the hearing aid to acoustic noise that adversely affects the ability of the user to recognize speech and other sounds.

The problem of unwanted electrical noise is as old as radio technology itself and has long been a factor relevant to the performance of hearing aids. With the advent of digital transmissions, however, the potential for undesirable interactions to occur between hearing aids and wireless devices increased due to the fact that digital signals, by their nature, involve sharp transitions from one signal state to another thereby increasing the potential for transient signals that hearing aids are more likely to perceive as noise. As discussed below, some digital modulations employed for wireless transmissions produce

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[8] Cellular and PCS wireless handsets contrast greatly with typical wireline telephones. In the wireline context, the handset is usually separated from active electronics. Even when electronic circuits are part of the handset, high levels of RF energy are normally not produced.

noise in hearing aids that is more objectionable than that generated by other modulations. In light of the move from analog transmissions to more spectrally efficient digital services, the Commission's hearing aid compatibility regulations for wireless devices seek to assure a high measure of acceptable performance when hearing aids users employ digital wireless handsets.

D. Initial Benchmarks

The HAC rules establish a series of benchmarks for handset manufacturers and service providers. By September 16, 2005, manufacturers of handsets were required to offer to service providers at least two models for each air interface offered that at least met the M3 performance level as measured under the ANSI C63.19 standard. Tier I service providers were required to offer by September 16, 2005, at least four handset models per air interface employed (and at least five by September 18, 2006) and to make these models available for in-store testing by consumers in each store owned or operated by the carrier. All other carriers were required to offer at least two M3 or higher handsets by September 16, 2005, and to make these available for in-store testing in each retail outlet owned or operated by the carrier. Effective September 18, 2006, each handset manufacturer was also required to offer to service providers at least two models per air interface offered that met the T3 performance level of the ANSI C63.19 standard for inductive coupling to hearing aids that employ a T-coil to by-pass the microphone in the hearing aid. Each provider of public mobile service was required to include in their handset offerings at least two such T3 models per air interface offered in each retail store owned or operated by the provider for consumers to test in the store.[9] In theory, a

[9] The HAC rules also imposed a requirement that the HAC rating of compliant phones be included on the label of the packaging of the handset and that an explanation of the ANSI

consumer would be able to use this ANSI rating to determine which handsets best might function with a given hearing aid.

The ANSI rating scheme rests on the assumption that consumers can add the HAC rating of a wireless device to that of a hearing aid such that if the sum of the devices' numerical indicators is four or greater, satisfactory performance would be predicted. The scheme facilitated by the measurement standard recognizes that achieving a high measure of electromagnetic compatibility between hearing aids and wireless devices is a systems problem involving not only limiting emissions from wireless devices, but also improving the immunity of hearing aids to electromagnetic interference. Indeed, the statute itself requires compatibility only with hearing aids designed for compatibility.[10]

Unfortunately, consumers typically do not know the HAC rating of hearing aids as this information normally is not made available. Moreover, as detailed below, improvements in the immunity of hearing aids means that consumers can now often achieve satisfactory performance with handsets rated below M3. It is also possible that some consumers will find performance to be unsatisfactory even when a phone is rated M3 or better. Accordingly, while the last three years have witnessed great improvements in the hearing aid compatibility of wireless devices, fundamental technical issues continue to affect adversely the compatibility of many wireless devices with hearing aids, especially those handsets that employ the GSM air interface. The reasons for this lie not

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C63.19 rating system be included in the owners manual or an insert supplied with the handset.

[10] 47 U.S.C. § 610(b)(1) ("all essential telephones [shall]…provide internal means for effective use with hearing *aids that are designed to be compatible* with telephones") (emphasis added).

in a lack of effort by all concerned but in the inherent nature of the GSM signal. As discussed herein, the assumptions underlying the R&O have been significantly undermined in practice because of these technical realities.

IV. KEY PRINCIPLES AND ASSUMPTIONS

In establishing HAC requirements for wireless phones, the Commission was guided primarily by the provisions of the Hearing Aid Compatibility Act of 1988 ("HAC Act").[11] In promulgating the HAC Act, Congress specifically exempted certain telephones, including wireless phones, from the "essential phones" designation.[12] Congress at the time considered the exempted phones to be "secondary," meaning that such phones were viewed to be complements for the "essential phones" it identified.[13] However, the Commission was granted authority to revoke or limit the exemption for wireless phones.[14] Specifically, the statute authorizes the Commission to "revoke or otherwise limit" the exemptions if: (1) such revocation or limitation is in the public interest; (2) continuation of the exemption without such revocation or limitation would have an adverse effect on hearing-impaired individuals; (3) compliance with the requirements of [the rule] is technologically feasible for the telephones to which the exemption applies; and (4) compliance with the requirements of [the rule] would not

[11] Hearing Aid Compatibility Act of 1988, Pub. L. No. 100-394, 102 Stat. 976, amending Section 710 of the Communications Act of 1934, as amended (codified at 47 U.S.C. § 610(b)).

[12] *See* 47 U.S.C. § 610(b)(4)(A). Congress defined the "essential phones" required to comply as "only coin-operated phones, telephones provided for emergency use, and other telephones frequently needed for use by persons using [compatible] hearing aids."

[13] *See id*., § 610(b)(2)(A).

[14] *See id*., § 610(b)(2)(C).

increase costs to such an extent that the telephones to which the exemption applies could not be successfully marketed.[15]

In adopting HAC requirements in the 2003 R&O, the Commission determined that each of these prongs of the exemption had been met and therefore the Commission was required to take action to establish HAC requirements for digital wireless phones. These regulations were based on key principles and assumptions: (1) as developed, the rules were technologically feasible for digital wireless phones; (2) the technical requirements were agnostic with respect to wireless air interfaces; (3) impact on form factors and handset core design would not be adversely affected; (4) consumers would be able to make a handset choice based on ANSI C63.19 ratings; (5) the marketability of HAC compliant devices would not be impacted.

Since the adoption of the HAC requirements in 2003, manufacturers and service providers have expended considerable resources in attempting to develop and deploy HAC compliant wireless phones. This experience has shown that the key assumptions and principles that were the foundation of the HAC decisions may not have been accurate. In particular, for the GSM air interface many of the current regulations are either technologically unachievable or only achievable through development of unmarketable products. Further, the ANSI C63.19 ratings have been demonstrated to be an inexact measure of the acceptability of a wireless phone for hearing-impaired consumers.

A. <u>Technological Feasibility</u>

In establishing the requirements that one half of wireless phone models be HAC compliant by February 18, 2008, the Commission concluded that this goal was feasible

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[15] *See id*., § 610(b)(2)(C); 47 C.F.R. § 68.4(a)(4).

and desirable.[16] The Commission asserted that as handsets were tested and more attention and resources were focused on the issue of compatibility of wireless devices with hearing aids, the wireless industry would find ways to achieve this goal and that it might become easier over time.[17]

B. <u>Technology Neutrality</u>

In addition to technological feasibility, when requiring the wireless industry to comply with federal mandates the Commission has attempted to keep such requirements "technologically neutral" so as not to burden unfairly any particular technology choice or to pick artificially technology "winners" in defining the requirements applicable to wireless technology. HAC compliance was such a mandate and the FCC noted when adopting HAC requirements that they may be more difficult to implement for some air interfaces than others.[18] In particular, the agency noted the difficulties presented by GSM technology with respect to reducing RF emissions to levels required under ANSI C63.19.[19] Regardless of these apprehensions, the Commission imposed the requirements across all transmission technologies based on its commitment to technological neutrality.[20]

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[16] *See* R&O at ¶ 73.

[17] R&O at ¶ 73.

[18] *See id.* at ¶ 76.

[19] Id.

[20] *See id*. at ¶ 28.

C. <u>No Impact on Core Designs</u>

The Commission recognized that some handset design changes might be necessary to comply with the new HAC requirements.[21] To ensure that these design changes would not affect the core design of the handsets, the FCC allowed three years for manufacturers to make design changes to deliver phones that complied with the T-coil coupling requirements and two years to allow for manufacturers to produce and label digital wireless phones to comply with the U3 (now M3) level for reduced RF emissions.[22] The Commission anticipated that most phones would not require a change to their core design to meet the U3 rating.[23]

D. <u>An Informed Choice for Consumers Would Emerge Based on ANSI C63.19 ratings</u>

When creating the HAC compliance requirements, the Commission believed that provision of ANSI C63.19 ratings would allow consumers to better understand the rating system and could help frame the consumers' expectations with regard to the performance of the handset.[24] Moreover, the FCC believed that an explanation of the rating would provide consumers with information needed to aid audiologists in providing a hearing aid that works well with a wireless telephone.[25]

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[21] *See id.* at ¶ 71.

[22] R&O at ¶ 71.

[23] *Id.*

[24] *See id.* at ¶ 86.

[25] *Id.*

E. Development Costs Would Not Increase to the Point that a Phone Could Not Be Marketed

The Commission, in developing its HAC requirements, sought to tailor its rules to ensure that compliance would be achieved in competitively-priced digital wireless phones[26] The FCC noted that there were digital wireless phones already available that met the U3 performance level of the ANSI C63.19 standard and there were some digital wireless phones that approximated the magnetic field intensity for wireline telephones specified in Section 68.316 of the Commission's rules.[27] The Commission argued that it did not believe that development of wireless handsets that met the U3T performance level would be too costly to market; as such development would not entail significant research and development or production costs.[28] Finally, the FCC asserted that demand for HAC-compliant handsets would drive down the cost per unit and increase the likelihood that these phones could be successfully marketed.[29]

V. PROGRESS TO DATE

Since the development of the HAC compliance rules, the wireless industry has expended extensive resources in seeking to develop and deploy handsets that fully meet the HAC requirements. Service providers and manufacturers have met the interim HAC benchmarks, with some limited waivers related to timing[30] and have endeavored to meet

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[26] *See id.* at ¶ 51.

[27] *Id*.

[28] *R*&O at ¶ 51.

[29] *Id*.

[30] See Section 68.4(a) of the Commission's Rules Governing Hearing Aid-Compatible Telephones, Cingular Wireless LLC Petition for Waiver of Section 20.19(c)(3)(i)(A) of the Commission's Rules, Memorandum Opinion and Order, 20 FCC Rcd 15108 (2005); Section 68.4(a) of the Commission's Rules Governing Hearing Aid-Compatible

the February 18, 2008, requirements for 50% of all handsets meeting the M3 or M4 rating. ATIS filed its sixth status report on HAC progress on November 17, 2006. The *Status Report* clearly summarizes and documents the wireless industry's progress toward the HAC requirements.[31] As of November 17, 2006, the manufacturers of wireless devices had more than 108 models certified as M3 or M3T3 or higher ratings on the market in the United States and service providers were offering 93 models with FCC-granted M3 or M3T3 or higher ratings.[32] The *Status Report* provides documentation on all air interfaces, including CDMA, GSM, iDEN, UMTS and GSM/WCDMA models. For purposes of these comments, it is important to address the progress and challenges facing the two air interfaces – CDMA and GSM – most prominently employed in the United States.

A. <u>CDMA</u>

CDMA service providers and handset manufacturers have been very successful in developing and deploying HAC compliant products. According to the *Status Report*, ATIS participants submitting reports as part of the consolidated ATIS Industry filing report that: (1) 53 of 97 handset models offered by service providers (or 55% of models) met the M3 or M3T3 or higher rating; (2) 69 of 78 handsets offered by manufacturers (or 88%) met the M3 or M3T3 or higher rating.[33] CDMA's technical operating parameters,

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Telephones, T-Mobile USA, Inc. Petition for Waiver of Section 20.19(c)(3) of the Commission's Rules, Memorandum Opinion and Order, 20 FCC Rcd 15147 (2005).

[31] *See Hearing Aid Compatibility Compliance Efforts*, *Status Report #6*, submitted by the Alliance for Telecommunications Industry Solutions on behalf of The ATIS Incubator Solutions Program #4, WT Dkt. No. 01-309, filed on Nov. 17, 2006 ("*Status Report*").

[32] *See id.* at 3.

[33] *See Status Report*, Attachment A.

especially its lower output power for the wireless handset, makes compliance with the HAC regulations much more achievable. Additionally, the articulation weighting factor ("AWF") used by the ANSI C63.19 standard is less stringent for CDMA devices.

B. GSM

In contrast, GSM service providers, due to output power and AWF issues, face significant technical challenges in developing and thus deploying products meeting an M3 or M4 rating. According to the *Status Report*, ATIS participants report that: (1) 28 of 146 handset models offered by service providers (or 19% of models) met the M3 or M3T3 or higher rating; (2) 20 of 90 handsets offered by manufacturers (or 22%) met the M3 or M3T3 or higher rating.[34] GSM has significant difficulty in meeting the M3 or M3T3 ratings due to its output power and AWF.

The differences between GSM and CDMA are shown in the table below:

	AWF (dB divided by 2 for power calculation)	**Max Power (dBm)**	**Max Power in Watts (AWF 5)**
GSM Low Band (850 MHz)	2.5	33	2W
GSM High Band (1900 MHz)	2.5	30	1W
CDMA Low Band (850 MHz)	0	24 (Typically)	1/4W
CDMA High Band (1900 MHz)	0	24 (Typically)	1/4W

[34] *Id*.

Since HAC compliance varies dB for dB with total radiated power, GSM is at a 9 dB disadvantage for low band and at a 6 dB disadvantage for the high band. In addition, the 2.5 dB difference in AWF directly affects a model's HAC compliance. Therefore, GSM is at an 11.5 dB disadvantage at 850 MHz and at an 8.5 dB disadvantage at 1900 MHz. To demonstrate this difference more clearly, two nearly identical Motorola models were measured and compared – K1(GSM) and K1m(CDMA).

The figure below depicts the low band (850 MHz) electric field data. Both sets of data are plotted on the same scale axes for direct comparison, and each color represents a 3 dB step size. Computing the average difference across the 121 points for these two data sets yields a measured technology disadvantage of 10.5 dB as compared to the 9 dB difference detailed above (not including he additional 2.5 dB penalty for AWF).

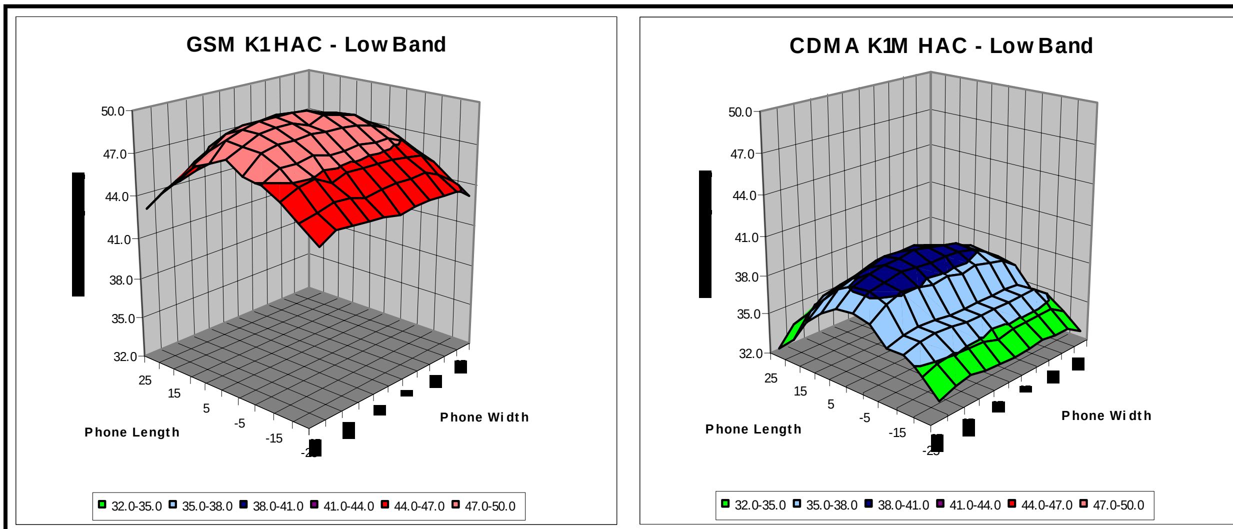

Figure 1: 850 MHz Band HAC Comparison of GSM vs. CDMA

The next figure depicts the high band (1900 MHz) electric field data. Again, both sets of data are plotted on the same scale axes for direct comparison and each color represents a 3 dB step size. Computing the average difference across the 121 points for these two data sets yields a measured technology disadvantage of 6.2 dB as compared to the 6 dB difference mentioned above (not including the additional 2.5 dB penalty for AWF). AWF only affects the scoring category limits and not the measured data in these figures.

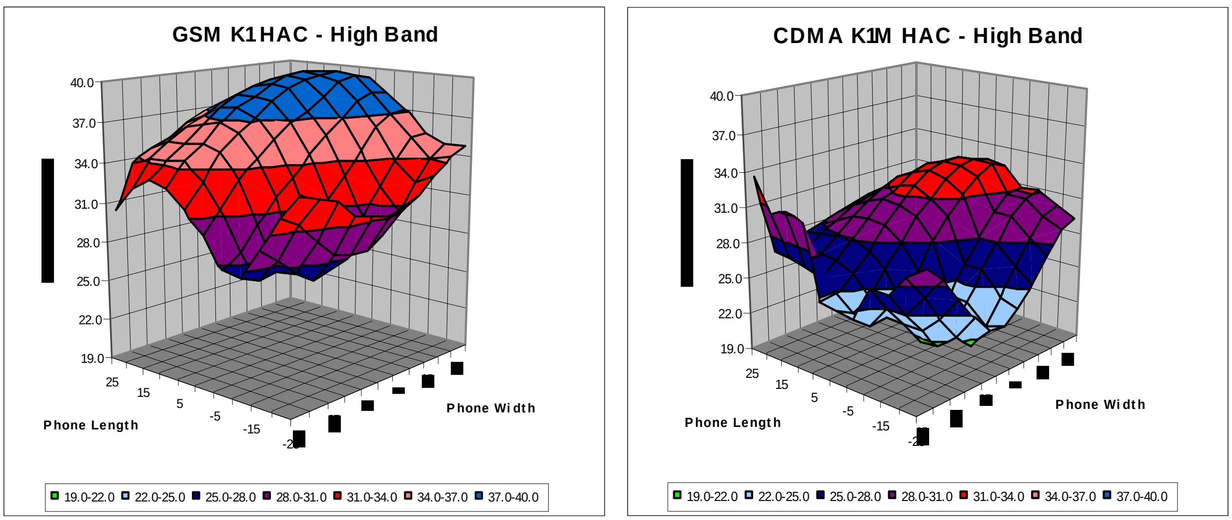

Figure 2: 1900 MHz Band HAC Comparison of GSM vs. CDMA

This data would call into question any allegation that GSM manufacturers and carriers have not put forth sufficient effort into becoming HAC compliant to the extent that the CDMA manufacturers and carriers have. In reality, as demonstrated in detail above, manufacturers that make products for both the GSM and CDMA air interface (even in the case of otherwise nearly identical product such as the K1 handset), simply face a much higher burden in meeting HAC requirements for the GSM air interface.

VI. <u>PROBLEMS</u>

The wireless industry has expended extensive time and effort to develop and deploy HAC compliant digital wireless devices. As shown above, for the CDMA air interface these efforts have been largely successful. However, the GSM air interface faces a number of significant technical challenges that have proven resistant to any efforts by manufacturers and service providers. In addition to the output power and AWF issues described above, there are a number of other market-based issues that have given rise to more technical obstacles for GSM technology to meet the HAC requirements. Frequency band effects (differences at 850 MHz and 1900 MHz, and possibly in the future at 700 MHz) are profound.[35] The market amenability of particular form factors (flip phones rather than "candy bar" shaped phones, for example) to achieve HAC compliance presents another tremendous challenge. Location of the antenna and radiating structure dictates core design changes that are not able to be addressed effectively. Each of these design issues greatly reduces the ability of service providers and manufacturers to meet the 50 percent requirement for HAC compliance in February 2008.

A. Impact of Modulation Type

The main cause of the interference experienced by a hearing aid user is the same across the different wireless technologies and hearing aids. Radiofrequency fields radiated by the handsets are detected by the small wires in the hearing aid, which act essentially as antennae magnifying the interference effects from the wireless device. These detected signals are then transmitted to the amplifier circuitry in the hearing aid. When these signals are in the audio frequency range, they are amplified and result in an audible sound. Most radiofrequency transmissions from cell phones consist of signal variations in the audio frequency range due to their individual modulation schemes. It is

[35] The 2005 version of ANSI C63.19 introduced two rating tables to accurately reflect the realities of 850 MHz impact on HAs vs 1900 MHz.

these variations that eventually result in the undesirable sound from the hearing aid. Appendix A provides a more mathematical explanation behind this effect.

Differences in the interference experienced arise due to each transmission technology's unique characteristics and the intricate details of a particular cell phone's design. GSM's use of the Time Domain Multiple Access ("TDMA") technique splits a channel into 8 time slots. A given GSM cell phone only transmits 1/8th of the time with a transmit frequency of 217 Hz. The hearing aid detects this pulsed transmission and distorts the hearing aid's frequency response particularly at 217 Hz and its harmonics. A frequency output spectrum of the hearing aid when a GSM cell phone is nearby is shown in Appendix B.

CDMA technology, on the other hand, encodes data with a special code associated with each channel and uses the constructive interference properties of the special codes to perform the multiplexing. CDMA phones characteristically have a random pulse structure for their transmission signal. This is because CDMA phones vary both the RF transmitting power and vocoder (data) rates in response to the changing network conditions. This causes interference that is static-like in nature when using a variable vocoder rate and more like white noise when using the full vocoder rate. Appendix B shows the interference spectrum from CDMA cell phones.

B. <u>Frequency Band Effects</u>

In the United States, wireless industry operations are predominantly at 850 MHz and 1900 MHz. These two frequency bands each present unique technical and operational challenges for hearing aid compatibility.

At 850 MHz, wireless devices, especially those using the GSM air interface, operate at and are FCC-certified at up to twice the peak power of devices in the 1900

MHz band -[36]. Wireless handsets employ much higher power at 850 MHz than at 1900 MHz to take advantage of the propagation effects of the 850 MHz band. The fixed components of wireless networks are designed accordingly. Base stations operating at the exact same power levels will have a radius of operation at 850 MHz that will greatly exceed the radius of operations at 1900 MHz. As such, wireless handsets attempting to communicate with a base station at 850 MHz can possibly be many miles more distant from the base station than handsets operating at 1900 MHz. The only practical means of ensuring that wireless handsets at 850 MHz successfully complete a call, when operating at a greater distance away from a base station, is to increase the output power of the handset.[37]

At 1900 MHz, it is very difficult to control the RF current distribution, especially for form factors with limited dimensions/size. Yet, controlling the distribution of RF currents is one of the key methods of creating a product that is HAC compliant, as it is the handset's RF current distribution that determines the electromagnetic field pattern. The electromagnetic field pattern should be minimal in the direction of the head for the product to be HAC compliant. At 1900 MHz, the radio circuit board effectively becomes a significant part of the antenna, making it very difficult to control the power directed towards a hearing aid.

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[36] Details of the power differences between GSM and CDMA are described in more detail in Appendix B.

[37] The other possible alternative would be to increase the number of base stations at 850 MHz to ensure that the budget link from the handset to the base station is appropriate to a lower power level from the handset. This would be extremely costly and inefficient, failing to take advantage of the inherent propagation benefits of the 850 MHz band to decrease the amount of infrastructure necessary to deploy a wireless network.

Over time, the deployment of digital voice services in the 700 MHz, 1700 MHz, 2100 MHz, and 2500 MHz bands in the United States will exacerbate further the RF challenges faced by manufacturers and service providers in their efforts to deploy new, innovative wireless devices and services that comply with HAC requirements and provide the high service quality consumers have come to expect.

C. Form Factor Challenges

Difficulties in meeting HAC requirements via other means necessitate form factor choices, especially for the GSM air interface. The frequency issues discussed above make it extremely difficult to make a HAC compliant product for the GSM air interface in a "candy bar" or PDA-style form factor that can transmit in many frequency bands, including 1900 MHz.[38] As demonstrated in Appendix C, it is thus no coincidence that there was only one quad-band[39] GSM candy bar or PDA-style phone that was HAC compliant in the market at that point in time. All of the other HAC compliant GSM models are clamshell designs, while CDMA has some distribution of products employing other form factors such as slider, swivel or candy bar/PDA.

Furthermore, GSM devices have been dramatically forced towards clamshell designs to achieve HAC compliance. In the the chart [40] below summarizing much of the data in the attached Appendix C, the distribution of form factors for HAC compliant devices is heavily skewed towards clamshell (or "flip") form factors:

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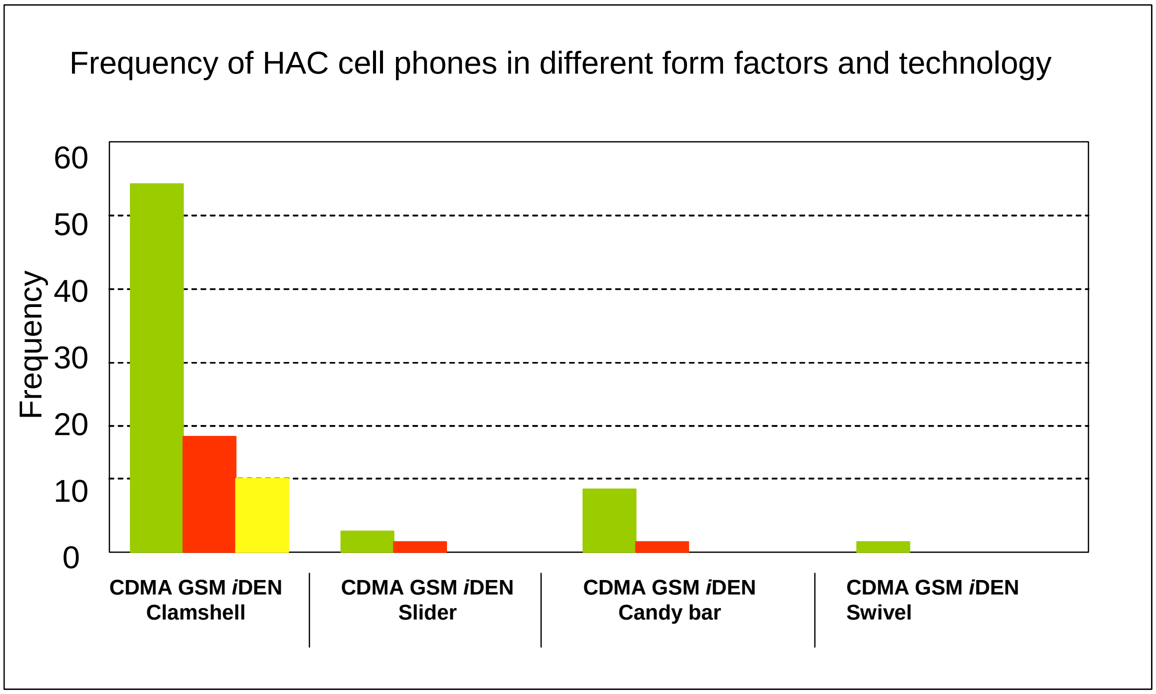
[38] See Apppendix B for data on electric and magnetic field distributions in bar and PDA style phones.

[39] Quad Band refers to devices that support the 850 MHz and 1900 MHz frequency ranges used within the Americas as well as the 900 MHz and 1800 MHz bands used in other regions.

[40] Chart data were derived from www.phonescoop.com Oct 2006.



The few compliant devices for GSM that are not clamshells either use retractable antennas or have extremely large form factors, when compared to current marketplace products.

Clearly, the design choice for consumers for HAC compliant products is directly limited by the underlying physical and RF properties inherent in the particular air interfaces. Even under the interim benchmarks currently in effect, there is a direct impact on the core industrial design requirements for the phone, which has forced manufacturers to consider product portfolio decisions solely to achieve HAC compliance and irrespective of customer demand. These form factor decisions are not market driven and they present significant marketability challenges. The fifty percent requirement exacerbates these disparities between customer demand and manufacturer/carrier handset portfolios even further. Without some correction to the current regulations on HAC compliance, manufacturers and service providers will be forced to develop and deploy large, unattractive handsets with undesirable form factors as part of their market portfolio that will not be marketable nor meet the needs of the hearing impaired community.

D. Antenna Considerations

Antenna design for cellular handsets is a delicate balancing act. For candy bar phones, a measurement of the electric field tends to dominate at the top of the phone (by the receiver (i.e. earpiece) where HAC compliance is measured).[41] Magnetic fields tend to be the highest at the bottom of the phone. The high electric fields will be in the vicinity of the antenna and at the ends of the printed circuit board. Phones with antennas near the earpiece tend to perform poorly on HAC compliance. On average, typical GSM candy bar phones fail the M3 HAC requirement by 6 to 10 dB at 850 MHz and 2.5 to 5 dB at 1900 MHz.

Many clamshell phones with an internal antenna in the center of the phone (at the hinge location) can pass HAC by 0 to 2 dB at 1900 MHz. Movement of the internal antenna to the top of the mobile, near the acoustic output port, will more likely cause HAC compliance failure as a result of its location and proximity to the area that is measured in accordance with the C63.19 standard. Slider, swivel and clamshell phones present another unique challenge because they must be optimized for two use cases: open and closed.

Finally, in addition to HAC compliance, wireless handsets must meet or exceed the carrier performance targets for over the air performance with total radiated power and customer quality expectations. HAC compliance requirements create a significant design hurdle that is in direct competition with maximizing total radiated power (which is critical to ensuring call performance and service quality).

The table below summarizes the difficulty in meeting HAC compliance with different form factors and antenna location:

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[41] See Appendix D.

General Likelihood of HAC-Compliant GSM Designs			
Design Style	**Antenna Location**		
	Top	**Middle**	**Bottom**
Clam / Flip	Unlikely	May be Possible	Possible
Slider	Unlikely	May be Possible	Possible
Rotator	Unlikely	May be Possible	Possible
Stick / Candy Bar	Unlikely	Unlikely	Unlikely

E. <u>Shielding Issues</u>

The extensive efforts to explore ways to improve HAC have included numerous investigations using RF shielding techniques. Unfortunately, no marketable solutions have been identified.

RF shielding techniques can be divided into two categories: blocking and attenuating. RF blocking techniques consist of creating an isolated volume (such as a shielded, closed metallic box) or constructing an obstructing metallic wall (that reflects or re-directs RF energy). A shielded enclosure technique around the radiating currents of the handset would intrinsically prohibit the handset from radiating and was thus not considered. Metallic walls (including the extension of the handset’s ground plane) were investigated extensively. Unfortunately, in order to provide effective blockage of an electromagnetic field, the obstruction needs to be a significant portion of a wavelength (typically greater than ¼ of a wavelength). At 824 MHz, a ¼ of a wavelength is approximately 9 cm. Because the handset industry is extremely size competitive, any physical extension greater than several millimeters can often render a product unattractive in the market.

RF attenuating techniques typically consist of the incorporation of materials that are characterized by high loss with respect to RF currents (such as carbon loaded plastics or ferrite loaded metals). Unfortunately, as previously noted in this report, for the 800 MHz band the handset is half of the radiating structure. As a result, the currents on the handset are required to maintain desired levels of radiation efficiency. When RF attenuating materials are used to reduce the currents on the handset, the amount of radiation is also reduced. This effectively reduces the amount of power available to the receiving base station and may reduce the quality of the call. From a system level, this is not desired.

F. <u>Ultra-thin Phones</u>

Over the past few years, the wireless industry has seen a significant market shift in demand for thinner phones that was unanticipated at the time the HAC requirements were adopted. These ultra-thin phones present several unique design challenges for achieving HAC compliance. First, there is simply physically less available space in which to embed HAC solution elements. Second, the radiating antenna structures in ultra-thin phones are, by definition, closer to the user's hearing aid. The increased proximity of the hearing aid presents higher radiofrequency fields and more potential for interference. To illustrate this point, the figure below provides data related to an ultra-thin style phone (Motorola V3i). This figure shows two sets of electric field data from the same unit with the probe height increased by approximately 4 mm to simulate a thicker phone. The increased separation distance reduced the peak electric field by 1.8 dB and the average across all 121 points by 1.3 dB. The reduction could actually be less significant if the actual phone were simply made thicker with everything else held constant. However, in 2007, the market difference in thickness between an ultra-thin phone versus a more typical phone can easily approach an additional 10 mm as opposed

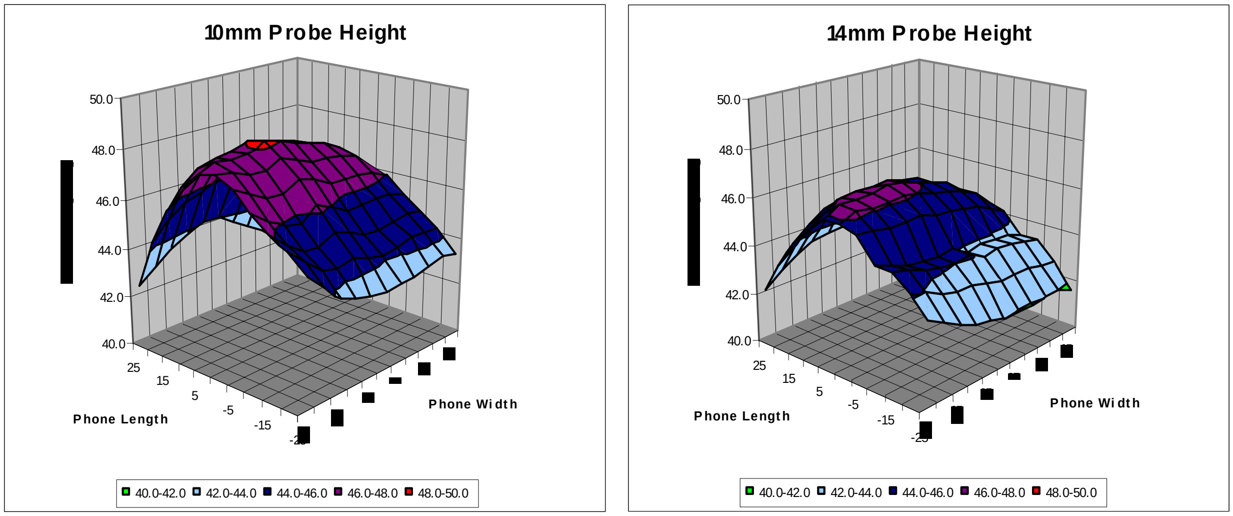

Figure 3: Phone Thickness Simulation Using Different Probe Heights

to the 4 mm simulated under these conditions. This data therefore demonstrate that typical phones (20 to 30 mm thick) can more readily meet the M3 or M4 performance than ultra-thin phones.

G. Metal vs. Plastic Cases

As marketing of wireless handsets has evolved dramatically in the past three to four years, another key product differentiator is the growing use of metal housings over plastic housings. Metal housings are more durable, have a more rugged and robust feel to consumers and, in some instances, are seen as having a more distinctive look and design. This market response, however, has hindered HAC compliance efforts. By definition, metal housings are conductive and, as such, give rise to currents in the housing that did not exist in plastic housings. These currents cause electric and magnetic fields outside the phone that can cause deleterious effects to hearing aids by bringing currents closer to the hearing aid and by increasing the coupling of interfering signals. Moreover, HAC-improvement design elements must be physically located inside the phone near the earpiece (acoustic output port) to reduce the electric and magnetic fields. Phones with metal housings greatly reduce, if not eliminate, the effectiveness of these techniques, which have been identified to improve HAC performance by locally attempting to steer interfering RF signals away from the hearing aid..

H. <u>"Candy Bar" Phones</u>

Monolithic "candy bar" designs present another unique challenge to HAC compliance. Candy bar phones represent a simple continuous resonant structure with little opportunity for near field manipulation. The figure below shows a simulation of 835 MHz electric field performance for a simulated rectangular printed circuit board with a typical "monopole" style antenna at the bottom of the phone (the image is inverted). The phone's radiating structure is comprised of the monopole antenna and the entire printed circuit board of the phone itself. Because the dimension of this overall structure is comparable to a half-wavelength at 835 MHz, it tends to support the simple sinusoidal current distribution of a half-wave dipole, regardless of the feed location or antenna element design. The half-wave dipole current distribution corresponds to a charge distribution with approximately equal high-charge areas at each end of the phone, so this common design will by definition concentrate the peak electric fields at the ends of the phone (in particular under the HAC measurement plane). Thus, the entire phone structure radiates as a typical dipole antenna. This behavior is very typical of low band performance for candy bar style phones across the industry and continues to be an industry design challenge for HAC.

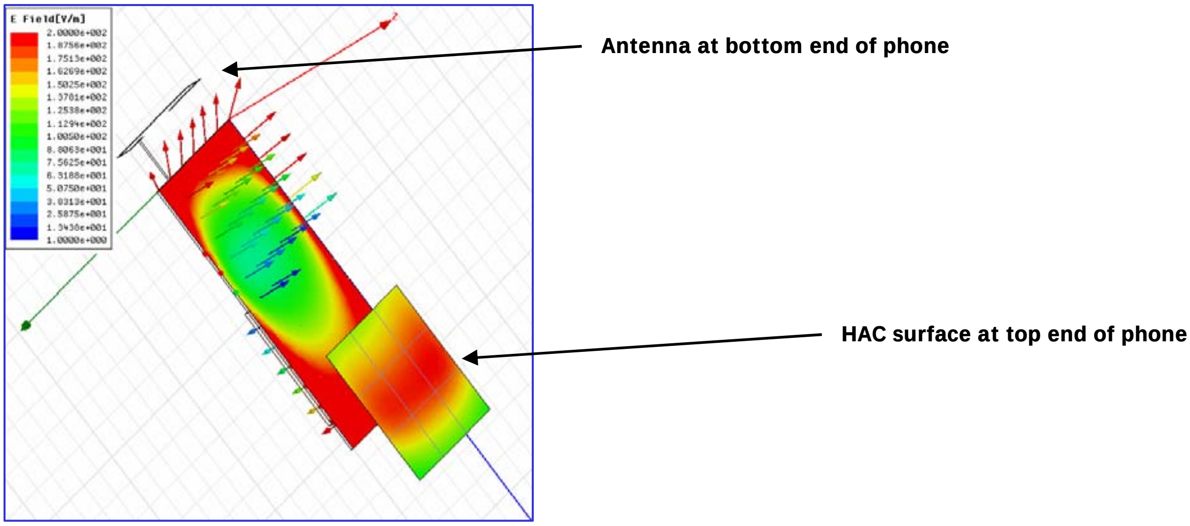

Figure 4

In sum, device form factors evolving toward being much smaller, thinner, metallic as a result of consumer demands have greatly complicated HAC compliance. As customer appetite for such devices continues to expand, whether due to visual attractiveness or otherwise, the technical challenges to provide HAC compliant devices will increase and become more and more difficult. At this time, there are no known technical solutions for producing the small, thin, metallic, candy bar-style phones increasingly in high customer demand HAC compliant for the GSM air interface.

I. <u>Swivel and Slider Phones</u>

Two additional form factors have been introduced into the handset market: swivel (or jackknife) and slider. Neither of these form factors have demonstrated a significant HAC performance improvement over the “candy bar” or clamshell styles.

In the closed configuration, both the swivel and slider are very similar to the candy bar configuration. As a result, the HAC performance in the closed state is typically similar to the candy bar with the same performance limitations.

In the open state, both form factors may be more similar to the clamshell configuration. As a result, there may be a slight improvement in HAC performance over a candy bar configuration (mainly in the PCS-1900 MHz band). However, the HAC performance is typically below that of a clamshell configuration of a comparable size.

VII. OTHER FACTORS NOT CONSIDERED BY ANSI C63.19

In developing the ANSI C63.19 standard, a number of factors were considered, including the hearing aid radiofrequency immunity and wireless device emissions. However, one other factor was not considered by the standard that affect hearing aid and wireless device usability/compatibility – the consumer's hearing profile.

Hearing-impaired consumers have ranges of auditory impairment; some may require extensive amplification in order to hear while others may have only slight hearing loss requiring relatively minor amplification. As described previously herein, individuals with hearing disabilities that use hearing aids can encounter interference when attempting to use a digital wireless phone. The electromagnetic interference produced will typically generate noise in a hearing aid, including distracting and sometimes painful buzzing noises. Depending on the consumer's individual hearing profile, however, this noise or buzzing may or may not inhibit or disrupt their attempts to use a digital wireless phone. For example, if a person is less susceptible to such interference (or otherwise resistant to such noise), his or her tolerance for such interference may be higher than that of other hearing aid users. Moreover, if less amplification of external signals is all that is required, the unwanted energy that is amplified may not rise to the level that the interference is disruptive.

VIII. FACTORS NOT CONSIDERED IN THE FCC RULES

The HAC rules require that wireless service providers and manufacturers provide the M and T ratings for HAC compliance in their device literature[42] and on labels on the exterior of the wireless telephone's box.[43] However, hearing aid manufacturers were encouraged but not required to provide such information for hearing aids, a factor that is a critical component to the effectiveness of the ANSI C63.19 standard. Further, improvements to hearing aid immunity have occurred in the intervening three years that make hearing aids more resistant to interference from wireless devices.

A. Lack of Immunity Labeling for Hearing Aids

Currently, the C63.19 standard only addresses hearing aid radiofrequency immunity and the power levels of wireless device emissions. While by rule wireless service providers and manufacturers have publicized and made clear the M and T ratings for their devices, hearing aid manufacturers have not labeled hearing aids with their immunity rating. Accordingly, consumers cannot consider the hearing aid immunity and add that to the radiofrequency emissions rating (per the ANSI C63.19 standard) to predict performance. As one of the fundamental assumptions of the Commission was that consumers would be better informed of the compatibility of wireless phones and hearing aids, the absence of public information on radiofrequency immunity of hearing aids greatly diminishes the ability of the public to make an informed purchasing decision of either a wireless device or a hearing aid.

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[42] *See* R&O at ¶ 86.

[43] *Id.* at ¶ 85.

B. Improvement in Hearing Aid Immunity

While failing to label hearing aids with their immunity ratings, hearing aid manufacturers have been successful in improving their radiofrequency immunity. Indeed, these improvements have far exceeded the improvement expectations from 2001. Clearly, improved immunity of hearing aids would allow for lower M and T rated wireless devices to be completely acceptable to hearing aid users and consistent with the ANSI C63.19 standard.

C. Varying Levels of Predictability of Compatibility

Over the past several years, ATIS and Incubator participants have attempted to gauge and measure the usability and acceptability of wireless devices to hearing aid using customers. A rather surprising finding is that radiofrequency immunity improvement does not necessarily predict usability. Several years of consumer testing has shown some hearing aid wearers having hearing aids rated M1 per the C63.19 standard are able to use wireless devices rated M2. Some other hearing aid wearers having hearing aids rated M4 were unable to use wireless devices rated M4. The original assumption that making hearing aids immune to radiofrequency and having wireless devices that emit less radiofrequency energy would clearly predict usability has proven to be incorrect. Some consumers, with newer hearing aids, may benefit greatly from an M2 or greater rated phone.

IX. IMPACT ON CONSUMERS

The HAC regulations were adopted in an effort to implement a statutory mandate designed to assist the hearing impaired in efforts to integrate better into a world that relies greatly on speech transmitted electronically. Ideally, these regulations would foster the development of a wide variety of equipment that would offer the hearing impaired an array of choices. The promise of this regulatory scheme, however, has fallen short because of technical issues that have proven to be far more intractable than the Commission contemplated. In part because it recognized that there were technical challenges to be overcome, the Commission wisely included the opportunity for an assessment a few years out from the wireless HAC starting gate.

Left unchanged, the fifty percent requirement of Section 20.19(c)(1)(ii) and (2)(ii) of the Commission's Rules will have the effect of impeding the development of wireless handset technology in the face of evolving market demand. For people who have a hearing loss, this will likely mean fewer of the designs that are attractive to consumers will be hearing aid compatible. The choice of form factors for HAC compliant phones, especially those that employ the GSM air interface, will also be more restricted with clamshell designs being the overwhelming choice of manufacturers faced with the requirement to ensure that every other model is HAC compliant. Instead, GSM HAC phones will be more likely to use plastic instead of metal cases, be larger and feature smaller displays. Thus, the Commissions intent to remain technology neutral will result in a competitive disadvantage for GSM manufacturers and service providers.

The impact of the current regulations, however, extends well beyond the availability of HAC compliant handsets for the hearing impaired, and long before February 18, 2008. The need to balance product portfolios to ensure that by that date half of the models are HAC complaint will also affect the availability of innovative designs for use by all, including people who use hearing aids. For example, as discussed above, so-called "candy bar" style handsets now increasingly popular with consumers who make extensive use of non-voice data services present significant compliance challenges because of the inclusion of voice capabilities. Many of these devices are used by the profoundly hard of hearing as text messaging devices. As the experience of the last two years has shown, few handsets in this form are HAC compliant, especially in the GSM air interface. Even with respect to CDMA, the challenges are significant in this form factor. Other forms such as "sliders" and "swivel" phones pose an even greater obstacle.

The likely result is that manufacturers will increasingly be pressured to offer HAC compliant models that do not respond well to market demands for lighter, metallic phones with larger displays. Instead, the market can expect to find phones that are larger and feature smaller displays as innovative designs effectively carry the economic burden of supporting parallel HAC compliant designs for which demand may be far more limited. Thus, increasing the number of required HAC-compliant handsets will likely not only reduce the total number of phones being offered on the market, but also will disproportionately result in a prevalence of certain forms over others.

In short, the fifty percent rule raises the prospect of serious discontinuities in product offerings in much of the wireless marketplace, yet it is difficult to ascribe significant sales of handsets based on HAC ratings. Most severely hard of hearing consumers own cell phones, but the majority of these users have devices that are better capable for text messaging.[44] Moderately hearing impaired individuals are generally

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[44] *See e.g.*, Power, Mary R. and Des Power, Everyone here speaks TXT: Deaf people using SMS in Australia and the rest of the world, *Journal of Deaf Studies and Deaf Education* **9:**350–360 (2004); Pilling, Doria, Text communication survey (City University, London) (2004), News Release available at www.city.ac.uk/sonm/dps/news/07_09_04.pdf (finding that 65 percent of deaf respondents use SMS and that 35 percent of deaf respondents would use SMS if they could only have one form of text communication); Glaser, Meryl and William D. Tucker, Telecommunications Bridging Between Deaf and Hearing Users in South Africa, at http://people.cs.uct.ac.za/~btucker/publications/2004/GlaserTucker-CVHI2004.pdf ("Pager and cell phone Short Message Service (SMS) are becoming prevalent for Deaf users because of their wireless mobile nature"); Power, Mary R., Des Power, and Louise Horstmanshof, Deaf People Communicating via SMS, TTY, Relay Service, Fax, and Computers in Australia, Journal of Deaf Studies and Deaf Education, Oxford University

using digital wireless phones. At the last Hearing Loss Association of America convention, some eighty percent of the consumers tested were already digital cell phone users. Many of these devices rated lower than M3, yet were found usable by consumers. Accordingly, if the needs of both the hearing impaired and other consumers are to be served, the Commission should make a mid-course correction that will lead to greater certainty in the provision of hearing aid compatible digital wireless handsets and less distortion in the overall marketplace.

X. CONCLUSION

In furtherance of the goal of affording hearing impaired Americans with the means for achieving fuller use of electronic voice communications, Congress charged the Commission with adopting regulations that would yield a high measure of compatibility between hearing aids and telephones. As noted in these comments, however, the so-called fifty percent rule poses technical challenges that were not adequately appreciated at the time the rule was adopted and which, if left in their current form, will have the unfortunate and ironic effect of limiting choices in wireless telephony for both hearing and hearing-impaired consumers. Accordingly, the AISP.4-HAC members urge the Commission to consider the extent to which the fifty percent rule works against the goals and underlying assumptions of the R&O. To facilitate this effort, the Commission should encourage further dialog among wireless industry members and representatives of the hearing impaired community in an effort to reach a consensus proposal that will serve the needs of all consumers while yielding hearing aid compatible wireless handsets in

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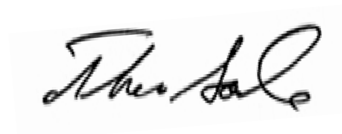
Press (2006) available at http://jdsde.oxfordjournals.org/cgi/content/full/12/1/80 (noting the prevalence of text messaging among the Deaf).

sufficient variety to meet the needs of those who must rely on compatibility between such handsets and hearing aids.

Respectfully submitted,

Alliance for Telecommunications
Industry Solutions on behalf of
its AISP.4-HAC



Thomas Goode
General Counsel
ATIS 1200 G Street, NW Suite 500
Washington, DC 20005

January 12, 2007

Appendix A – Square Law Detection of RF Signals in Hearing Aids

Source: [2]

TRANSISTOR CHARACTERISTICS

Transistor amplifiers designed for amplification of audio frequency signals respond to amplitude modulation of radio frequency signals applied to the input. The nonlinear characteristic of the input transistor causes square law detection of the amplitude modulation.

Bipolar Transistor:

In the normal active region at low currents, the instantaneous collector current *I* is, with sufficient accuracy:

$$I(V) = I_0 e^{\left(\frac{V}{v_T}\right)} \quad \ldots..\ (1)$$

where

$$v_T = \frac{kT}{q}$$

v_T is approximately 26mV

k is Boltzmann's Constant

T is absolute temperature,

q is the charge on an electron

V is the voltage across the diode.

The small signal gain is found by expanding *I(V)* in Equation (1) as a Taylor series about the quiescent bias (V_q, I_q). The small signal collector current i_C as a function of small signal base voltage v_B is:

$$i_C = I(V_q - v_B) - I_q = I_q \left[\frac{v_B}{v_T} + \frac{1}{2}\left(\frac{v_B}{v_T}\right)^2 + \frac{1}{6}\left(\frac{v_B}{v_T}\right)^3 + \ldots \right] \quad \ldots.\ (2)$$

where

$$I_q = I(V_q)$$

i_C is the sum of the desired linear term in v_B, plus the quadratic term in $v_B^{\ 2}$ which causes "detection" of the amplitude variations of RF signal voltages, plus third and higher order terms that are normally negligible, since $\frac{v_B}{v_T} << 1$. To allow direct comparison between the desired signal being amplified and the detected interference signal, Equation (2) may be written in the form as (ignoring the third and higher order terms):

$$\frac{i_c}{g_m} = v_B + \Delta v_B^{\ 2} \quad \ldots(3)$$

where $g_m = \frac{I_q}{v_T}$

And $\Delta = \frac{1}{2v_T}$

g_m is the small signal transconductance term (for linear amplification) and

Δ is the small signal input referred square law coefficient

<u>DETECTION OF AMPLITUDE MODULATION</u>:

Sinusoidal Amplitude Modulation:

Let an amplitude modulated carrier voltage be applied to the base of the input transistor of the amplifier. The input referred component of the input voltage causing detection is

$$\Delta v_B^{\ 2} = \Delta\left[\sqrt{2}V_c\left[1 + m\cos(w_m t)\right]\cos(w_c)t\right]^2 \quad (4)$$

where:

w_m = sinusoidal modulation frequency

w_c= carrier (radio) frequency,

m= modulation index

V_c =RMS radio frequency carrier voltage

Expand Equation (4) by substituting for cosine squared terms and discard the DC and $\cos(2w_c t)$ terms that are filtered out and not amplified. This leaves first and second harmonic terms in w_m :

$$2\Delta V_c^{\ 2} m\left[\cos(w_m t) + \frac{m}{4}\cos(2w_m t)\right]$$

which appear in the output of the hearing aid. These terms are the input referred detected amplitude modulation. The magnitude of the detected signal is proportional to the square of the magnitude of the RF carrier signal.

Pulsed Modulation:

Let periodic pulses of RF signal voltage be applied to the input transistor. During each pulse of the input referred component of the input voltage causing detection is:

$$\Delta v_B^{\ 2} = \Delta\left[\sqrt{2}V_c \cos(w_c)t\right]^2$$

Expanding this term by substituting the cosine squared term and discarding the $\cos(2w_c t)$ term that is no amplified. This leaves the DC shift: ΔV_c^2 , which is the peak to peak amplitude of the input referred detected pulse train. If the duty cycle of the pulse is *d*, the average of the pulse is d times its magnitude. The RMS value of the pulse train obtained by evaluating the integrals:

$$\Delta \frac{V_c}{T}^{2} \sqrt{\left[\int_0^{Td} (1-d)^2\, dt + \int_{Td}^{T} (-d)^2\, dt\right]} = \Delta V_c^{\ 2}\sqrt{d-d^2}$$

Therefore, RMS value of the low-frequency (audible) term is obtained as $\Delta V_c^{\ 2}\sqrt{d-d^2}$

Appendix B – Frequency Distortion Caused by a Digital Cellular Phone

Many standards use the TDMA technique such as GSM, iDEN, D-AMPS. GSM has a pulse frequency of 217 Hz. Hence, the output spectrum of the hearing aid will contain the dominant frequency, 217 Hz and the various harmonics of the pulse frequency, as shown in Figure B.1.

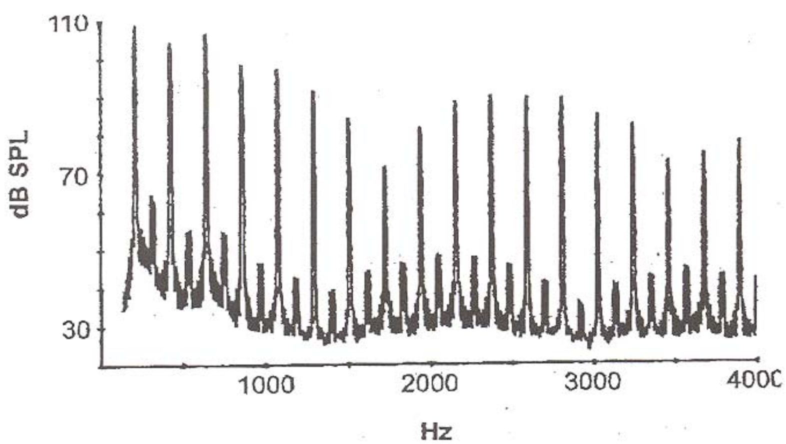


Figure B.1: Output spectrum from a conventional analog hearing aid (Widex Model ES8 without GSM protection means) with a GSM phone placed at ear level.

Note in Fig. B.1 the dominant output at 217 Hz. The spikes are the harmonics of the modulation frequency with an input related interference level (IRIL) > 55 dB sound pressure level (SPL) [3].

The spectrum for the hearing aid output is illustrated below when the hearing aid is placed near the antenna of a CDMA phone. In Figure B.2 the background spectrum is shown when the CDMA phone is switched "off".

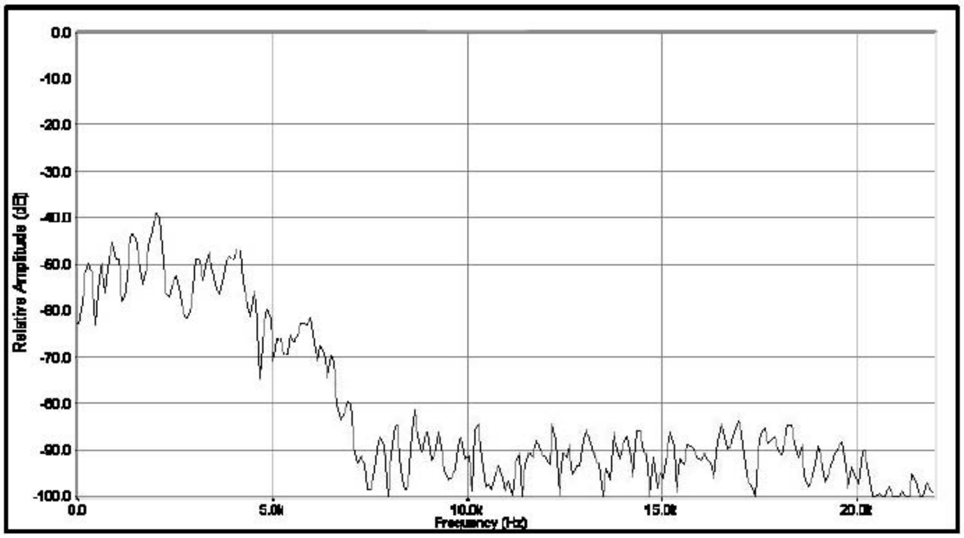


Figure B.2: Background Spectrum for hearing aid with no CDMA Interference.

Figures B.3 to B.6 depict the spectral response for full, 1/8, ¼ and ½ vocoder rates.

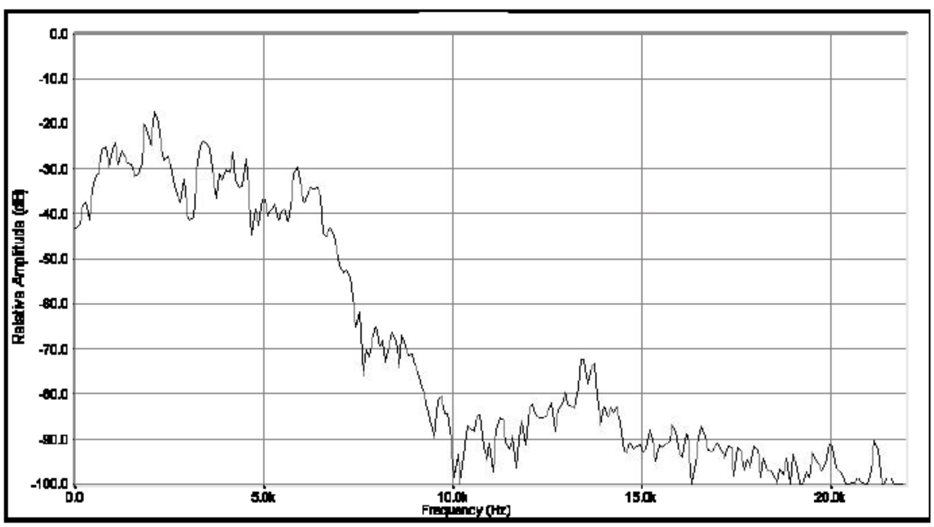


Figure B.3: Spectrum of Hearing Aid Output for Interference by CDMA at Full Vocoder Rate.

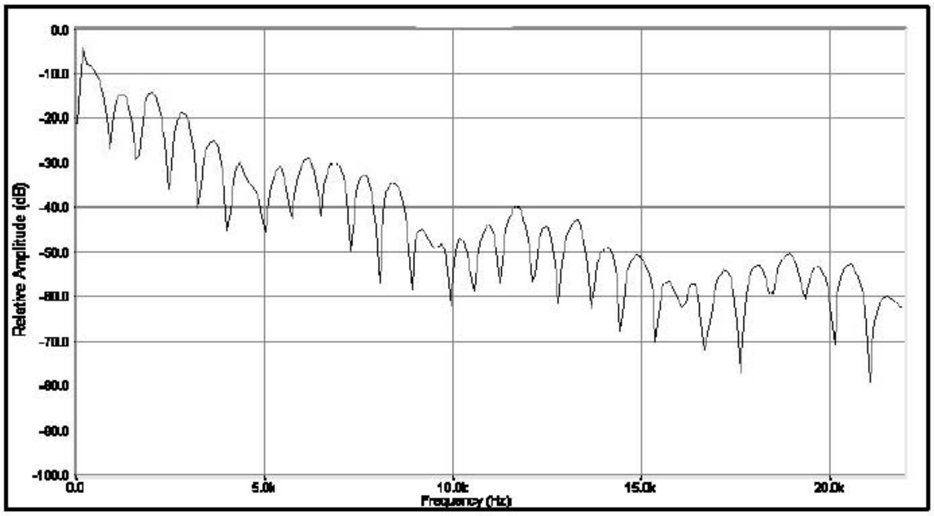


Figure B.4: Spectrum of Hearing Aid Output for Interference by CDMA at 1/8 Vocoder Rate.

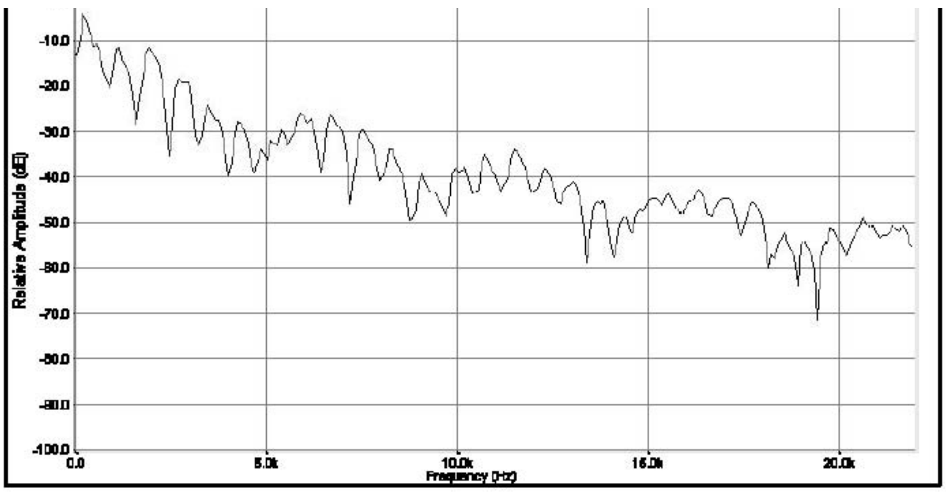


Figure B.5: Spectrum of Hearing Aid Output for Interference by CDMA at 1/4 Vocoder Rate.

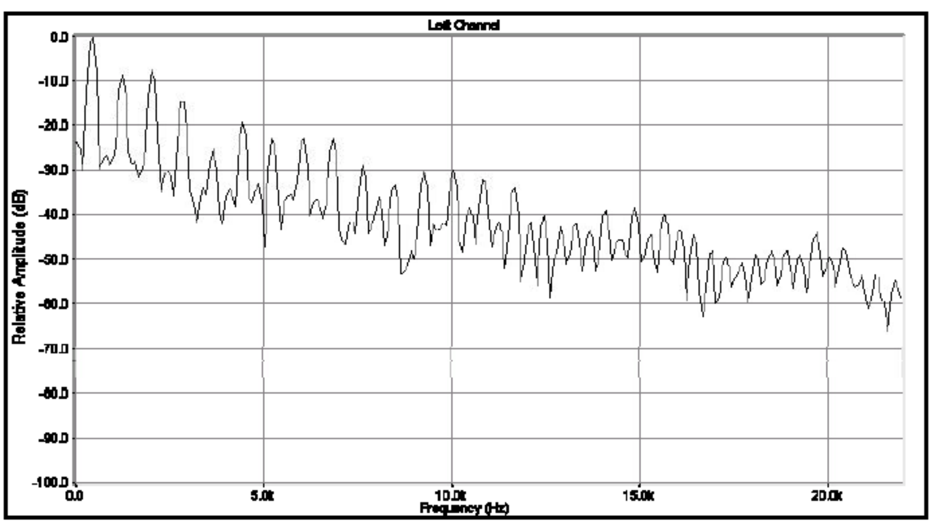


Figure B.6: Spectrum of Hearing Aid Output for Interference by CDMA at 1/2 Vocoder Rate.

The spectral results indicate that the interfering noise in the full vocoder rate is rather flat in response up to 5 kHz and sounds very much like white noise. For the same level of interference when operating in the full vocoder rate, the CDMA phone needs on the order of 6 to 12 dBm more power than when operating at the other three vocoder rates [4].

Subjective Comparison of Different Networks:

According to a study conducted by Linda Kozma-Spytek and Judith Harkins [5], GSM technology handsets received the worst annoyance ratings among CDMA and iDEN technologies. While the CDMA handsets were the most favorable among users: having the best annoyance rating. The comparison graph is shown in Figure B.7.

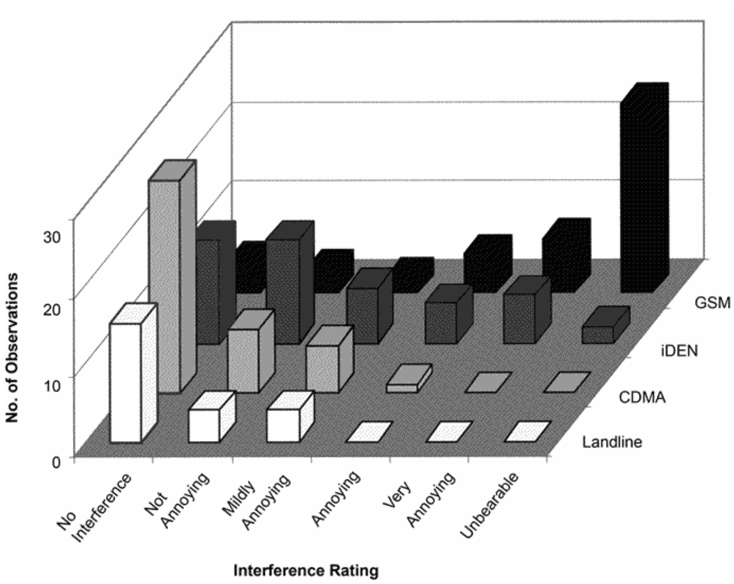


Figure B.7: Distribution of participants' annoyance rating of interference

Appendix C – Summary of HAC Compliant Models Offered by US Carriers

Data taken from AISP.4-HAC November 17, 2006 report

Carrier	Model	Technology	Form Factor	Packet Data Technology
Cellular One / Dobson	LG 2000	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola RAZR V3	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola V3i	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia 6061	GSM 850 / GSM 1900	Clamshell	GPRS
Cingular	LG C2000	**850/1800/1900MHz GSM/GPRS**	Clamshell	GPRS
	LG CG 300	**850/900/1800/1900MHz GSM/GPRS**	Clamshell	GPRS
	LG CU 400	GSM/GPRS/EDGE - **850/900/1800/1900 MHz** UMTS/HSDPA - **850/1900/2100 MHz**	Clamshell	GPRS
	Motorola V3i/V3r	**850/900/1800/1900MHZ GSM/GPRS**	Clamshell	GPRS
	Nokia 6061	**850/1900MHz GSM/GPRS**	Clamshell	GPRS
	Samsung A707	GSM/GPRS/EDGE - **850/900/1800/1900 MHz** UMTS/HSDPA - **850/1900/2100 MHz**	Clamshell	EDGE (EGPRS)
	Nokia 6102h	**850/1800/1900 MHz GSM/GPRS/EDGE**	Clamshell	EDGE (EGPRS)
	Samsung ZX20	GSM/GPRS/EDGE - **850/900/1800/1900 MHz** UMTS/HSDPA - **850/1900/2100 MHz**	Clamshell	HSDPA 1.8
Corr Wireless	6101h	?	?	
	6102h	?	?	
	Motorola Motorola V3i	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola V3C	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	LG1400	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
Epic Touch	Motorola Motorola V555	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia Nokia 6230	GSM/ 850/1800/1900 MHz	Bar	GPRS/EDGE
	Nokia Nokia 3100	GSM/ 850/1800/1900 MHz	Bar	GPRS
	Motorola V3	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia 6061	GSM 850 / GSM 1800 / GSM 1900	Clamshell	EDGE (EGPRS)
Leap Wireless	Motorola V3C	CDMA 800/ CDMA1900D	Clamshell	
	Nokia 6265i Phone		Slider	
	UTStarcom CDM7025		Clamshell	
	Kyocera KCX9e		Clamshell	
	Kyocera Slider Remix		Slider	
Qwest Wireless	Samsung SPH-A640	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom PPC-6700	AMPS 850 / CDMA 850 / CDMA 1900	Barl	1xRTT
	Samsung MM-A880	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-2400	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-3100	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6165i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-7025 / CDM-120	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-

Sprint	LG Fusic / LX-550	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	LG LX-350	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG PM-225	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola C290	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Research In Motion BlackBerry 7250	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 8703e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Samsung SPH-A420	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	Samsung Swamsung A580	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SPH-A640	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-2400	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-3100	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP 8400	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
Sprint (Nextel)	Motorola i450	iDEN 800/900	Clamshell	
	Motorola i560	iDEN 800/900	Clamshell	-
	Motorola i580	iDEN 800/900	Clamshell	WiDEN
	Motorola i670	iDEN 800/900	Clamshell	WiDEN
	Motorola i760	iDEN 800/900	Clamshell	-
	Motorola i830 / i833 / i835 / i836	iDEN 800/900	Clamshell	-
	Motorola i850	iDEN 800/900	Clamshell	-
	Motorola i855	iDEN 800/900	Clamshell	-
	Motorola i870 / i875	iDEN 800/900	Clamshell	WiDEN
SunCom	Motorola RAZR V3	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia 6061	GSM 850 / GSM 1900	Clamshell	GPRS
	LG 1400 i	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
T-Mobile	Motorola RAZR V3 Nokia 6133	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	RIM 8705 G	GSM 850 / 900 / GSM 1800 / GSM 1900	Bar	EDGE
	Samsung SGH-T209 / X495 / X497 / X496	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Samsung SGH-T309 / T319	GSM 850 / GSM 1800 / GSM 1900	Clamshell	
	Samsung SGH-T809 / SGH-D820	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Slider	EDGE (EGPRS)
Verizon Wireless	AUDIOVOX 180 VW	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Audiovox CDM8945	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX1000	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX 4700	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX 3400	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX- 3450	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX5200 & 5200pp	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-5300	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-8300	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0

	LG VX-9800			
	Motorola KRZR K1m	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola Q	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Motorola RAZR V3c	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola RAZR V3m	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola V325	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V325i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 2366i pp	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6215i	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6315i	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Palm Treo 700w Pantech PN-215 pp	CDMA 850 / CDMA 1900 CDMA 850 / CDMA 1900	Bar Clamshell	1xEV-DO r0 1xRTT
	Panteck 210	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Research In Motion BlackBerry 7130e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 7250	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 8703e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Samsung SCH-A870	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-A930	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Samsung SCH-A990	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	UTStarcom VX6700	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	UTStarcom G'zOne Type V	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0

Wireless Carriers – Oct. 04, 2006, gleaned from internet web site phonescoop.com

Carrier	Model	Technology	Form Factor	Packet Data Technology
Alltel	Kyocera Slider Remix KX5 / Slider Sonic	AMPS 850 / CDMA 850 / CDMA 1900	Slider	1xRTT
	Kyocera SoHo KX1	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-355 / UX-355	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-390 / UX-390	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-490	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-5000 / UX-5000	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-4700 / VX-4650 / AX-4750 / UX-4750	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola E815 / E816 Hollywood	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola KRZR K1m	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola RAZR V3c	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola V265 / V266 / V276	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V710	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6255i / 6256i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Pantech CDM-180 / PN-218	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	BlackBerry 7130e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	BlackBerry 7250	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Samsung SCH-A645	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT

	Samsung SCH-N330	CDMA 850 / CDMA 1900	Slider	1xRTT
Amp'd Mobile	Motorola E815 / E816 Hollywood	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
Boost Mobile	Motorola i450 / i455	iDEN 800	Clamshell	
	Motorola i730 / i733 / i710 / i720 / i740	iDEN 800	Clamshell	
	Motorola i830 / i833 / i835 / i836	iDEN 800	Clamshell	
	Motorola i850 / i855	iDEN 800	Clamshell	
	Motorola i870 / i875	iDEN 800	Clamshell	WiDEN
Cellular One / Dobson	LG L1400 / C1400	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola RAZR V3	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola V220	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia 6061	GSM 850 / GSM 1900	Clamshell	GPRS
	Samsung SGH-T209 / X495 / X497 / X496	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
Cellular One/ Western Wireless	Kyocera SoHo KX1	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-5000 / UX-5000	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V265 / V266 / V276	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6015i / 6016i / 6019i	AMPS 850 / CDMA 850 / CDMA 1900	Bar	1xRTT
	Nokia 6255i / 6256i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
Cingular	LG C2000	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	LG CE500	GSM 850 / GSM 1800 / GSM 1900	Clamshell	EDGE (EGPRS)
	LG CG300	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	LG L1400 / C1400	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola RAZR V3	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola RAZR V3i	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Motorola V220	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia 6061	GSM 850 / GSM 1900	Clamshell	GPRS
	Samsung SGH-D307	GSM 850 / GSM 1800 / GSM 1900	Clamshell	EDGE (EGPRS)
	Samsung SGH-D407 / D347	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	EDGE (EGPRS)
	Samsung SGH-P207	GSM 850 / GSM 1800 / GSM 1900	Clamshell	EDGE (EGPRS)
	Samsung SGH-T209 / X495 / X497 / X496	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Samsung SGH-ZX10	GSM 850 / GSM 900 / GSM 1800 / GSM 1900 / WCDMA 850 / WCDMA 1900	Clamshell	WCDMA (UMTS)
	Samsung SGH-ZX20	GSM 850 / GSM 900 / GSM 1800 / GSM 1900 / WCDMA 850 / WCDMA 1900	Clamshell	HSDPA 1.8
Cricket	Kyocera KX9A	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Kyocera Milan KX9B / KX9C	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Kyocera Oystr KX9d / KX9e	CDMA 1900	Clamshell	1xRTT

	Kyocera Slider Remix KX5 / Slider Sonic	AMPS 850 / CDMA 850 / CDMA 1900	Slider	1xRTT
	Motorola RAZR V3c	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola V265 / V266 / V276	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-105 / CDM-7000	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-7025 / CDM-120	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
Helio	Pantech Hero / PN-8300	CDMA 850 / CDMA 1900	Slider	1xEV-DO r0
	VK Mobile Kickflip	CDMA 850 / CDMA 1900	Swivel	1xEV-DO r0
MetroPCS	Motorola RAZR V3c	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola V265 / V266 / V276	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6015i / 6016i / 6019i	AMPS 850 / CDMA 850 / CDMA 1900	Bar	1xRTT
	Nokia 6255i / 6256i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-A645	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-A850	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-N330	CDMA 850 / CDMA 1900	Slider	1xRTT
	UTStarcom CDM-7075 / CDM-220	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
Qwest Wireless	Kyocera SoHo KX1	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V710	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung MM-A880	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-2400	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-3100	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo VI-2300	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-7025 / CDM-120	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
Southern Linc	Motorola i560	iDEN 800	Clamshell	-
	Motorola i580	iDEN 800	Clamshell	WiDEN
	Motorola i670	iDEN 800	Clamshell	WiDEN
	Motorola i730 / i733 / i710 / i720 / i740	iDEN 800	Clamshell	-
	Motorola i760	iDEN 800	Clamshell	-
	Motorola i830 / i833 / i835 / i836	iDEN 800	Clamshell	-
	Motorola i850 / i855	iDEN 800	Clamshell	-
	Motorola i870 / i875	iDEN 800	Clamshell	WiDEN
Sprint	LG Fusic / LX-550	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	LG LX-350	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VI-125	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola C290	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola KRZR K1m	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Nokia 3155i / VI-3155	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6015i / 6016i / 6019i	AMPS 850 / CDMA 850 / CDMA 1900	Bar	1xRTT
	Palm Treo 700p (CDMA)	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Palm Treo 700w / 700wx (CDMA)	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Pantech PN-210 / PN-205	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Research In Motion BlackBerry 7130e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 7250	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 8703e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0

	Samsung MM-A880	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung PM-A840	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SPH-A420	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	Samsung SPH-A640	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo MM-5600	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-200	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	Sanyo SCP-2400	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo SCP-3100	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Sanyo VI-2300	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-105 / CDM-7000	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-7025 / CDM-120	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	UTStarcom CDM-7075 / CDM-220	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
Sprint (Nextel)	Motorola i560	iDEN 800	Clamshell	-
	Motorola i580	iDEN 800	Clamshell	WiDEN
	Motorola i670	iDEN 800	Clamshell	WiDEN
	Motorola i730 / i733 / i710 / i720 / i740	iDEN 800	Clamshell	-
	Motorola i760	iDEN 800	Clamshell	-
	Motorola i830 / i833 / i835 / i836	iDEN 800	Clamshell	-
	Motorola i850 / i855	iDEN 800	Clamshell	-
	Motorola i870 / i875	iDEN 800	Clamshell	WiDEN
SunCom	Motorola RAZR V3	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Nokia 6061	GSM 850 / GSM 1900	Clamshell	GPRS
	Samsung SGH-T209 / X495 / X497 / X496	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
T-Mobile	Motorola RAZR V3	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Clamshell	GPRS
	BlackBerry 8705g	GSM 850 / 900 / GSM 1800 / GSM 1900	Bar	EDGE
	Samsung SGH-T209 / X495 / X497 / X496	GSM 850 / GSM 1800 / GSM 1900	Clamshell	GPRS
	Samsung SGH-T309 / T319	GSM 850 / GSM 1800 / GSM 1900	Clamshell	
	Samsung SGH-T809 / SGH-D820	GSM 850 / GSM 900 / GSM 1800 / GSM 1900	Slider	EDGE (EGPRS)
TracFone	LG VX-3300 / 3280	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
U.S. Cellular	Kyocera Milan KX9B / KX9C	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Kyocera Slider Remix KX5 / Slider Sonic	AMPS 850 / CDMA 850 / CDMA 1900	Slider	1xRTT
	Kyocera SoHo KX1	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-355 / UX-355	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-390 / UX-390	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG AX-5000 / UX-5000	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-3400 / 3450 / UX-210	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-4700 / VX-4650 / AX-4750 / UX-4750	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-8100	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0

	Motorola E815 / E816 Hollywood	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola RAZR V3c	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola V265 / V266 / V276	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V323 / V325 / V323i / V325i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V710	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 3155i / VI-3155	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6015i / 6016i / 6019i	AMPS 850 / CDMA 850 / CDMA 1900	Bar	1xRTT
	Nokia 6255i / 6256i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Research In Motion BlackBerry 7130e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 7250	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Samsung SCH-A850	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-7025 / CDM-120	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	UTStarcom CDM-7075 / CDM-220	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
Verizon Wireless	Kyocera KX9A	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Kyocera SoHo KX1	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG Migo VX-1000	CDMA 850 / CDMA 1900	Bar	-
	LG VX-3300 / 3280	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-3400 / 3450 / UX-210	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-4700 / VX-4650 / AX-4750 / UX-4750	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-5300 / AX-245	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	LG VX-8100	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	LG VX-8300	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	LG VX-8500 Chocolate	CDMA 850 / CDMA 1900	Slider	1xEV-DO r0
	LG VX-9800 / V	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola E815 / E816 Hollywood	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola KRZR K1m	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola Q	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Motorola RAZR V3c	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola RAZR V3m	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Motorola V265 / V266 / V276	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V323 / V325 / V323i / V325i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Motorola V710	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 2365i / 2366i	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6015i / 6016i / 6019i	AMPS 850 / CDMA 850 / CDMA 1900	Bar	1xRTT
	Nokia 6215i	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6255i / 6256i	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Nokia 6315i	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Palm Treo 700p (CDMA)	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Palm Treo 700w / 700wx (CDMA)	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Pantech CDM-180 / PN-218	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Pantech PN-210 / PN-205	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Pantech PN-215 / PN-212 / CDM-8915 / Snapper	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Research In Motion BlackBerry 7130e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 7250	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Research In Motion BlackBerry 8703e	CDMA 850 / CDMA 1900	Bar	1xEV-DO r0
	Samsung SCH-A630	CDMA 850 / CDMA 1900	Clamshell	1xRTT

	Samsung SCH-A645	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-A850	CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-A870	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	Samsung SCH-A930	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Samsung SCH-A990	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
	Samsung SCH-N330	CDMA 850 / CDMA 1900	Slider	1xRTT
	UTStarcom CDM-7025 / CDM-120	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	-
	UTStarcom CDM-7075 / CDM-220	AMPS 850 / CDMA 850 / CDMA 1900	Clamshell	1xRTT
	UTStarcom CDM-8945 / PN-230	CDMA 850 / CDMA 1900	Clamshell	1xEV-DO r0
Virgin Mobile	Kyocera Oystr KX9d / KX9e	CDMA 1900	Clamshell	1xRTT
	Kyocera Slider Remix KX5 / Slider Sonic	AMPS 850 / CDMA 850 / CDMA 1900	Slider	1xRTT
	Pantech PN-215 / PN-212 / CDM-8915 / Snapper	CDMA 850 / CDMA 1900	Clamshell	1xRTT

Appendix D – Electric (E) & Magnetic (H) Field Scans

The following four devices are from a manufacturer that only offers bar and PDA style phones. These are the latest FCC approved devices. The only GSM bar/PDA HAC T-coil rated phone passing ANSI C63.19 on the market today is shown below.

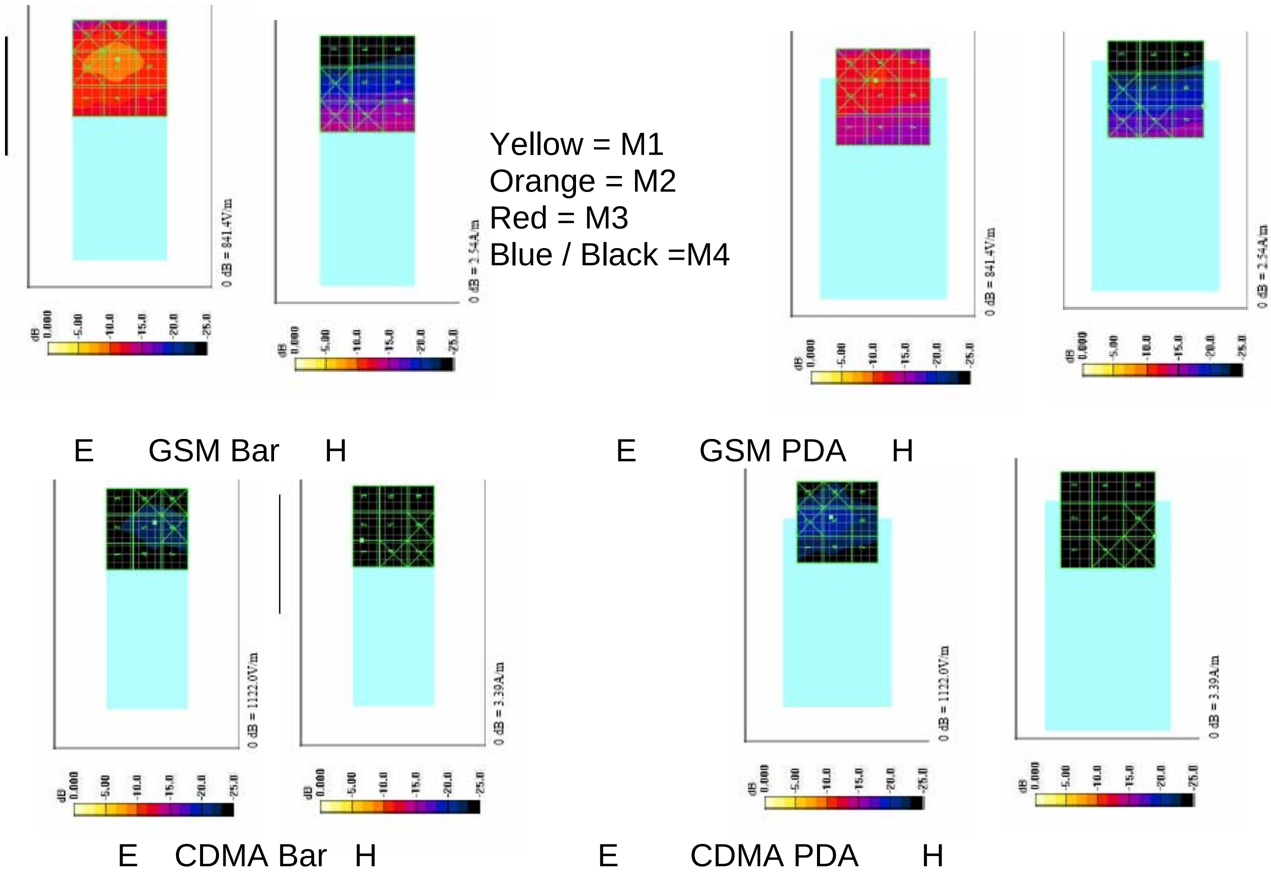
The first phone was referred to in the white paper as an ultra thin phone and is 14 mm thick. It is not HAC compliant. The second phone is the only CDMA bar phone in this manufacturer's inventory and is used for comparisons to the first phone later in this section. The last two phones have identical form factors: one for CDMA and one for GSM. Thus, the following comparisons eliminate the form factor from the comparison.

Dimensional Comparison of Bar and PDA Phones Scanned

GSM Bar	CDMA Bar	GSM PDA	CDMA PDA

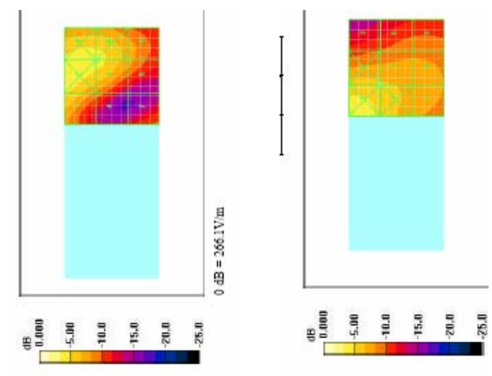
4.20" x 2.00" x 0.57"	4.60" x 2.20" x 0.90"	4.30" x 2.70" x 0.80"	4.30" x 2.70" x 0.80"

Scan Comparisons – 850 MHz

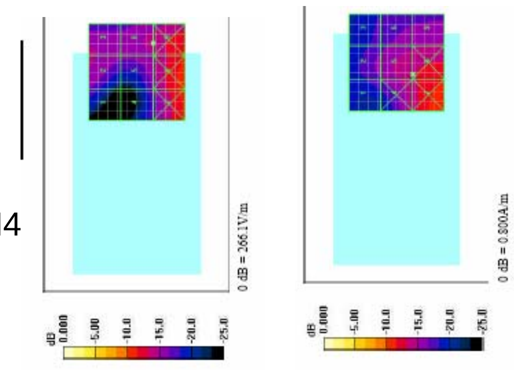


As discussed in the white paper, the GSM scans show a much higher field strength than the compatible CDMA scan. The left scans depict a two rating difference between GSM E and CDMA E field scans (i.e. orange M2 to blue M4). However, the H field is not an issue in either handset.

Scan Comparisons – 1900 MHz

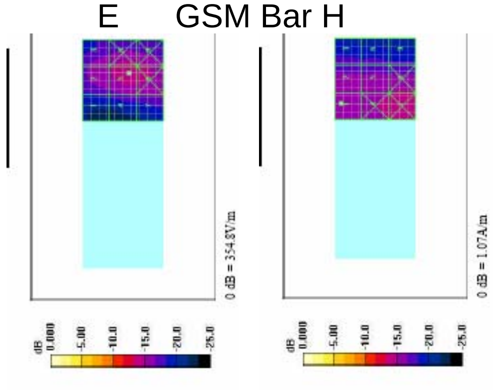


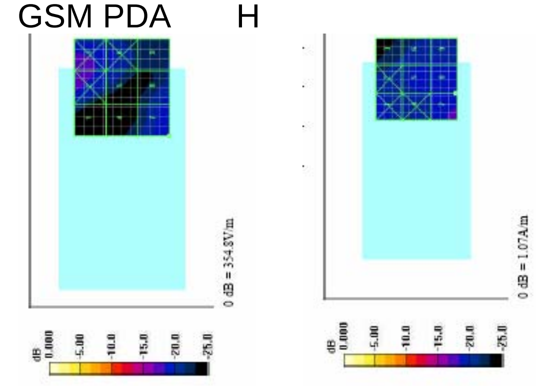
Yellow = M1
Orange = M2
Red = M3
Blue / Black =M4



E GSM Bar H

E GSM PDA H

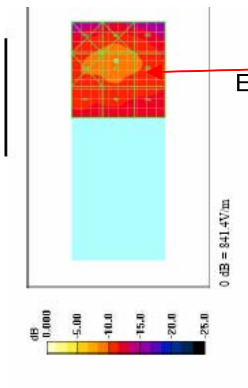


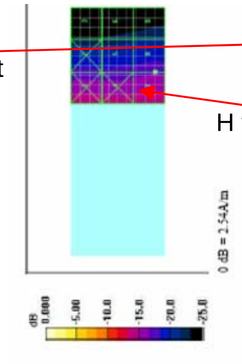


E CDMA Bar H

E CDMA PDA H

GSM Bar 850 MHz





Grid 1 252.4	Grid 2 283.7	Grid 3 279.0
Grid 4 261.8	Grid 5 297.3	Grid 6 291.5
Grid 7 244.0	Grid 8 275.7	Grid 9 269.8

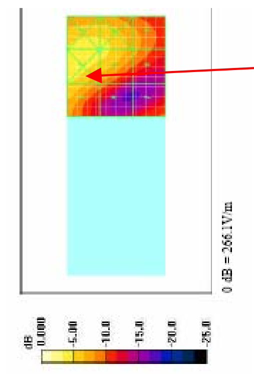
E Field

Grid 1 0.509	Grid 2 0.335	Grid 3 0.181
Grid 4 0.510	Grid 5 0.344	Grid 6 0.203
Grid 7 0.535	Grid 8 0.362	Grid 9 0.218

H Field

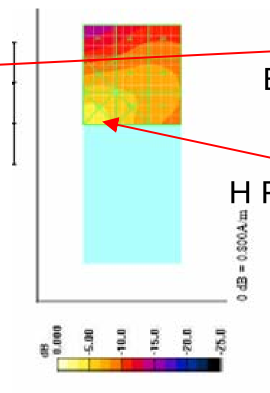
The lower the number, the better. C63.19 has 266.1 V/m Field and 0.8 A/m as the lower boundary for M 3 rating.

GSM Bar 1900 MHz



Grid 1 150.5	Grid 2 165.3	Grid 3 162.1
Grid 4 97.5	Grid 5 154.8	Grid 6 154.7
Grid 7 93.9	Grid 8 109.5	Grid 9 111.9

E Field

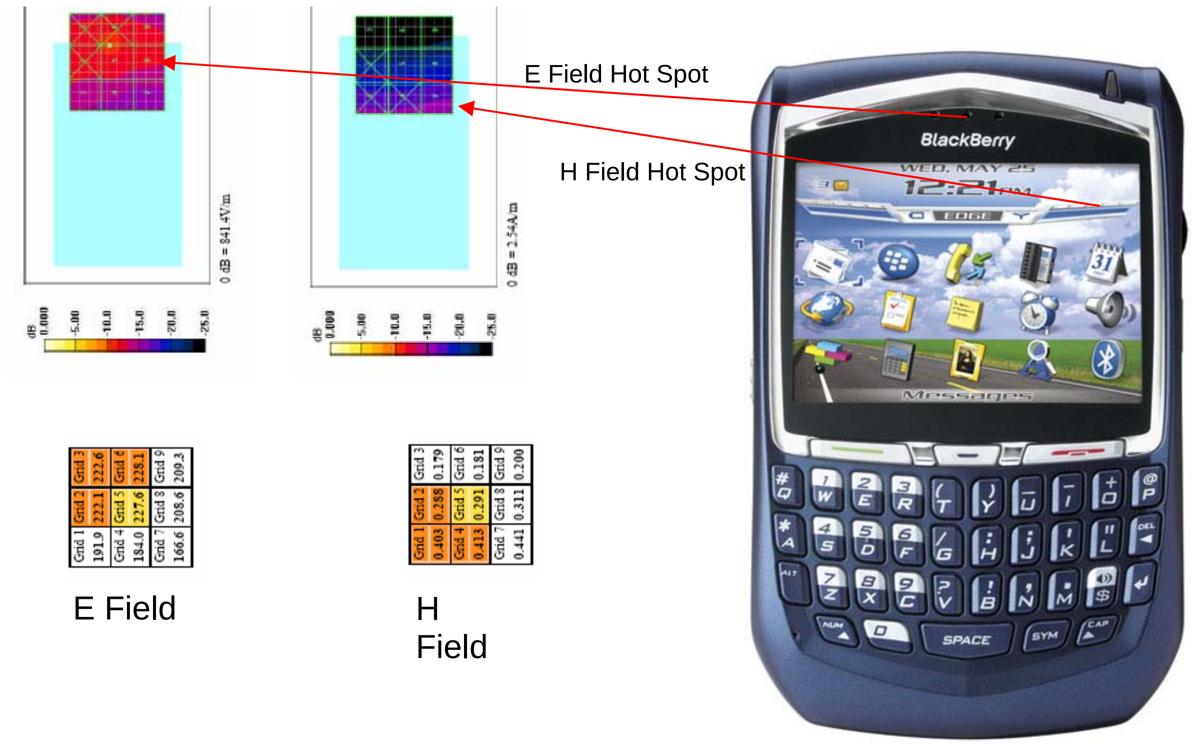


Grid 1 0.509	Grid 2 0.400	Grid 3 0.260
Grid 4 0.433	Grid 5 0.384	Grid 6 0.292
Grid 7 0.356	Grid 8 0.352	Grid 9 0.292

H Field

The lower the number, the better. C63.19 has 84.1 V/m E Field and 0.25 A/m as the lower boundary for M 3 rating.

GSM PDA 850 MHz



Grid 1 191.9	Grid 2 222.1	Grid 3 222.6
Grid 4 184.0	Grid 5 227.6	Grid 6 228.1
Grid 7 166.6	Grid 8 208.6	Grid 9 209.3

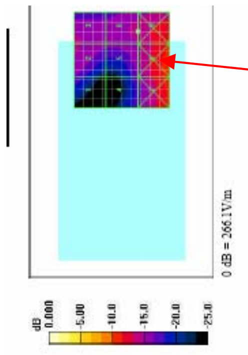
E Field

Grid 1 0.403	Grid 2 0.288	Grid 3 0.179
Grid 4 0.413	Grid 5 0.291	Grid 6 0.181
Grid 7 0.441	Grid 8 0.311	Grid 9 0.200

H Field

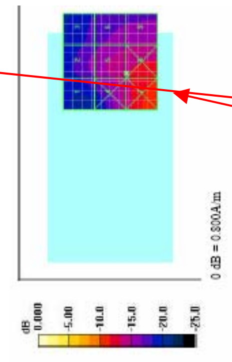
The lower the number, the better. C63.19 has 266.1 V/m E Field and 0.8 A/m as the lower boundary for M 3 rating.

GSM PDA 1900 MHz



Grid 1	Grid 2	Grid 3
39.0	49.1	49.1
Grid 4	Grid 5	Grid 6
40.4	47.9	51.1
Grid 7	Grid 8	Grid 9
77.1	77.7	72.2

E Field

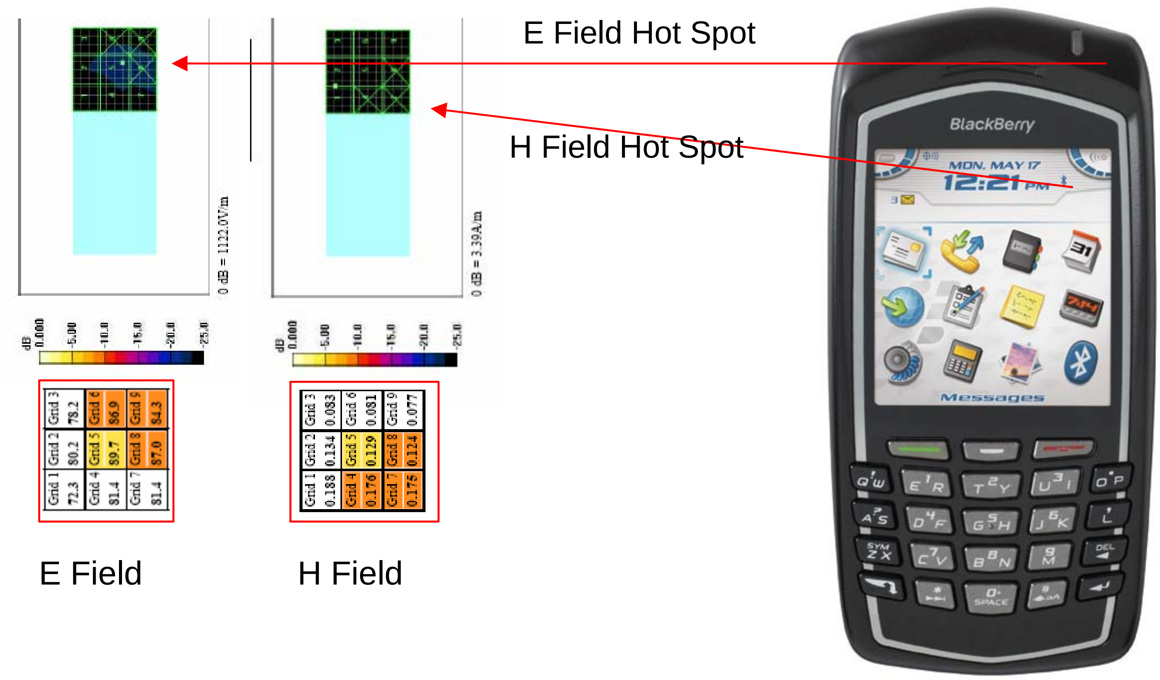


Grid 1	Grid 2	Grid 3
0.115	0.127	0.110
Grid 4	Grid 5	Grid 6
0.167	0.169	0.139
Grid 7	Grid 8	Grid 9
0.254	0.206	0.148

H Field

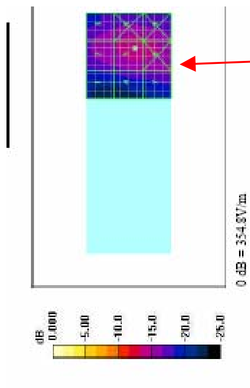
The lower the number, the better. C63.19 has 84.1 V/m E Field and 0.25 A/m as the lower boundary for M 3 rating.

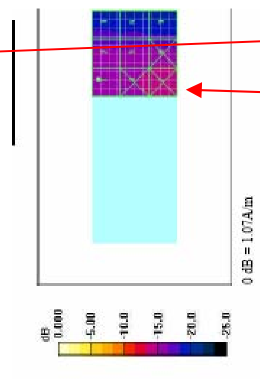
CDMA Bar 800 MHz



The lower the number, the better. C63.19 has 354.8 V/m E Field and 1.07 A/m as the lower boundary for M 3 rating.

CDMA Bar 1900 MHz





Grid 1 48.2	Grid 2 62.8	Grid 3 62.4
Grid 4 54.8	Grid 5 68.3	Grid 6 67.8
Grid 7 54.8	Grid 8 67.4	Grid 9 66.4

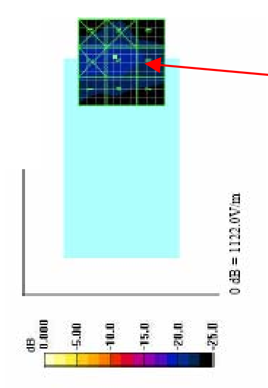
E Field

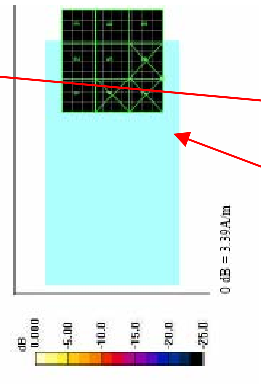
Grid 1 0.192	Grid 2 0.186	Grid 3 0.146
Grid 4 0.198	Grid 5 0.189	Grid 6 0.146
Grid 7 0.218	Grid 8 0.198	Grid 9 0.140

H Field

The lower the number, the better. C63.19 has 112.2 V/m E Field and 0.34 A/m as the lower boundary for M 3 rating.

CDMA PDA 800 MHz





Grid 1 96.4	Grid 2 102.9	Grid 3 98.9
Grid 4 95.6	Grid 5 105.0	Grid 6 100.9
Grid 7 86.8	Grid 8 95.9	Grid 9 92.3

E Field

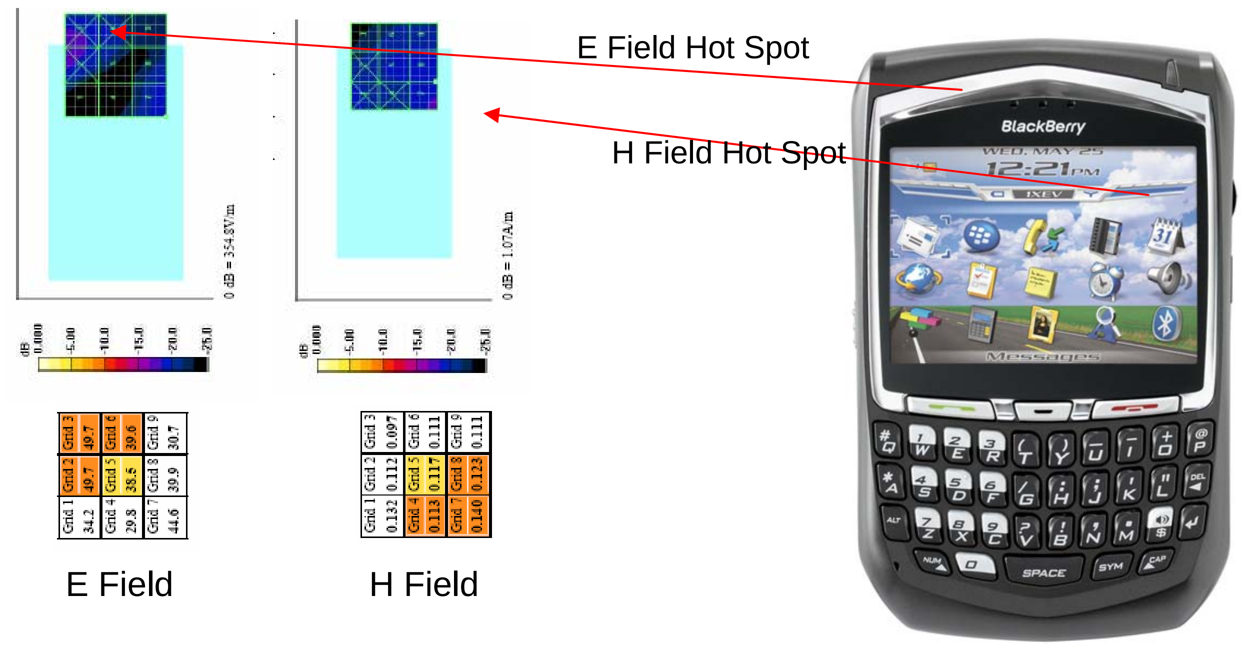
Grid 1 0.188	Grid 2 0.139	Grid 3 0.087
Grid 4 0.192	Grid 5 0.147	Grid 6 0.099
Grid 7 0.209	Grid 8 0.159	Grid 9 0.110

H Field

The lower the number, the better. C63.19 has 354.8 V/m E Field and 1.07 A/m as the lower boundary for M 3 rating.

Note: This GSM device use the same form factor as the CDMA device measured next, thus eliminating the difference in form factor from the two measurements.

CDMA PDA 1900 MHz



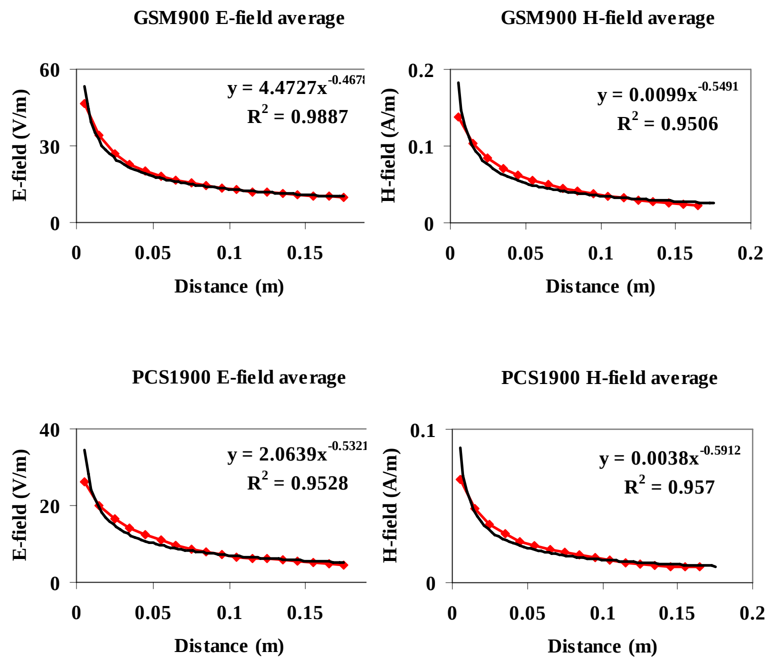
The lower the number, the better. C63.19 has 112.2 V/m E Field and 0.34 A/m as the lower boundary for M 3 rating.

Distance vs Field Strength

The measurements were made on a Monoblock-, Folded and Slider form factor phone, respectively.
It showed a decrease of

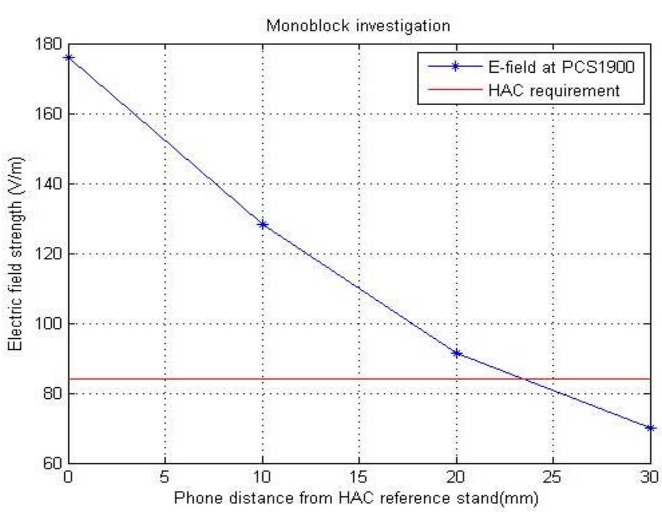
$$\frac{1}{\sqrt{r}}$$

where r is the distance. The monoblock device would have to be 23 mm thicker to meet the M3 rating



Monoblock investigation – Results (GSM 1900)

How thick should it be?
Original 26 mm + 23 mm!



Scaled
Normal Size
23 mm

Scaled
HAC Size
49 mm