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AND9019/D

Consideration of Self-Pollution Reduction for Electronic Systems

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APPLICATION NOTE

Introduction

This application note will address the problem of Electro Magnetic Interference (EMI) self pollution in which one part of an electrical systems such as cell phones and consumer electrical products emit radiation that interferes with the operation of other parts of the system. After a discussion of the causes of EMI self pollution and how systems are tested for EMI it will be demonstrated that the choice of ON Semiconductor EMI Filters with integrated ESD protection provide better immunity from EMI self pollution than competing ceramic products.

A high-speed digital lifestyle (digital radio, TV, internet, new appliance and services) is emerging with digital components incorporated into all products. Multimedia products also combine radio, TV, PC and telephone functions. This richness in functionality increases the risk of self-pollution, with multiple transmit protocols operating simultaneously. In addition, due to the increased use of the radio spectrum and proliferation in antennas, conventional antennas will be replaced by smart array antennas and wideband antennas which are more susceptible to EMI.

The more complex electronic products use flexible PCBs which further increase the likelihood of EMI. A flexible PCB connects the main system board to the LCD PCB. When signals are transmitted through the flexible PCB at high frequency, the signal lines on the flexible PCB behave as antennas and radiate EMI to the environment internal to the phone. High performance EMI filters, combined with a high level of ESD protection, are required to eliminate the conducted and radiated frequencies and preserve the best signal integrity possible on high-speed data lines.

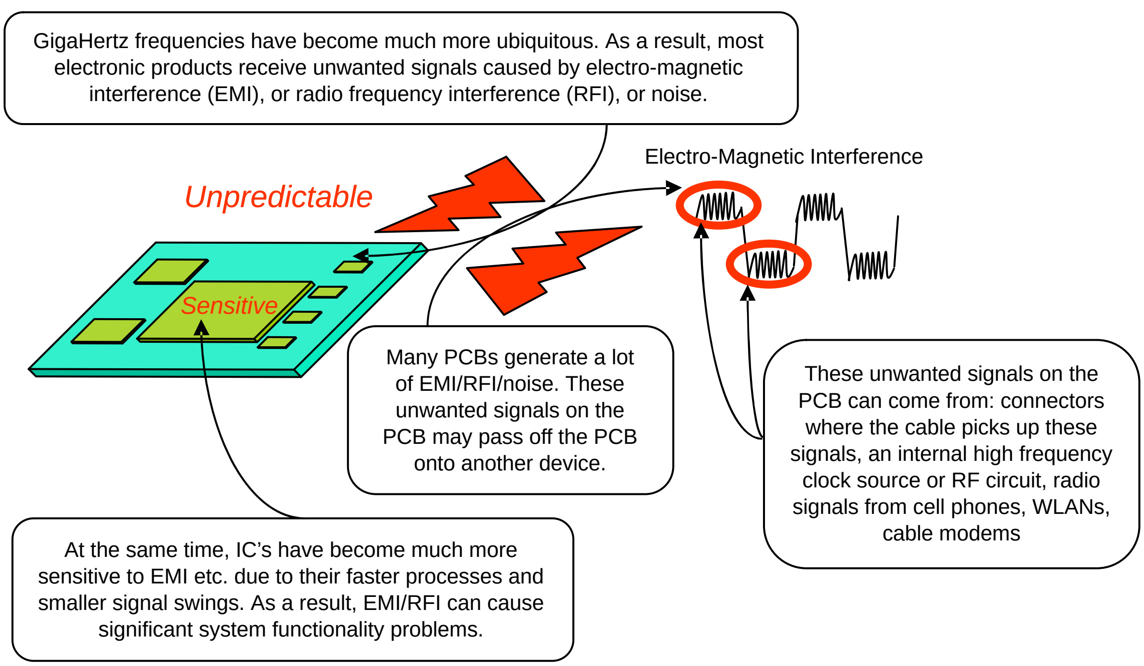

Figure 1. EMI/RFI/Noise Problems

NOISE SOURCES AND EMI NOISE

Noise Sources

Noise can come from a variety of sources including clock signals, bus lines, power supply noise and noise generated by ICs.

Clock Signal

When the signal line is long, the clock signal may emit strong noise. Since the signal frequency is close to the noise frequency, it is difficult to eliminate noise from a clock signal line while maintaining the signal waveform. Furthermore, the clock signal is comprised of tons of higher harmonics to reach up to GHz bands. The harmonics are considered a principal cause of EMI noise emission from the electronic circuit. Because of the high frequencies, harmonics radiate easily causing receiving sensitivity.

Bus Lines

Since many signals are simultaneously turned ON/OFF in a bus line, large current flows through the power supply line and GND line instantaneously, causing noise interference.

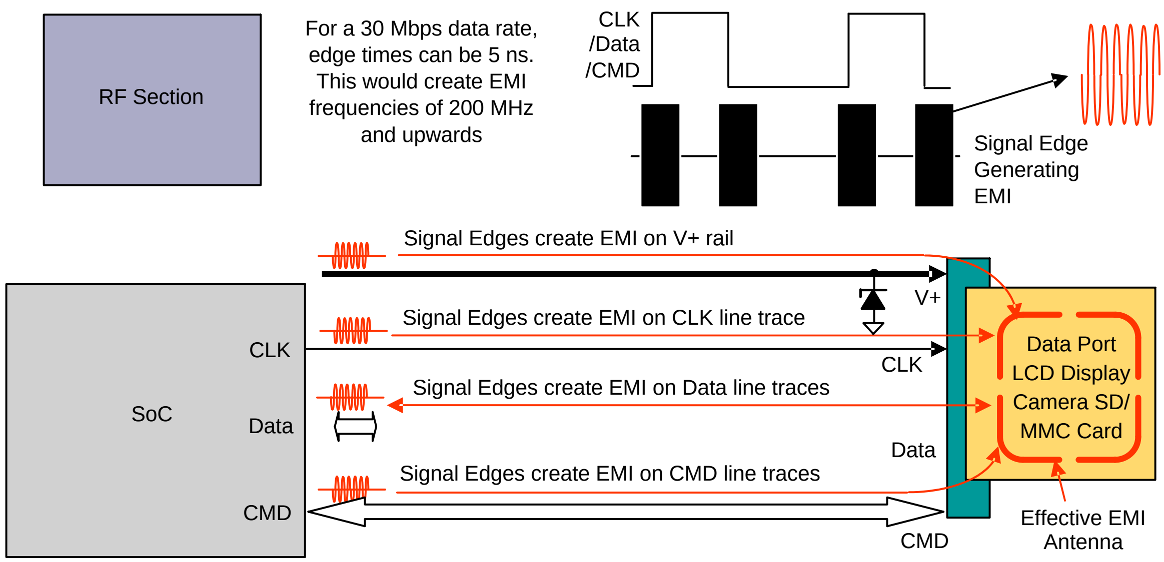

Figure 2. Faster CPU Signals Cause EMI

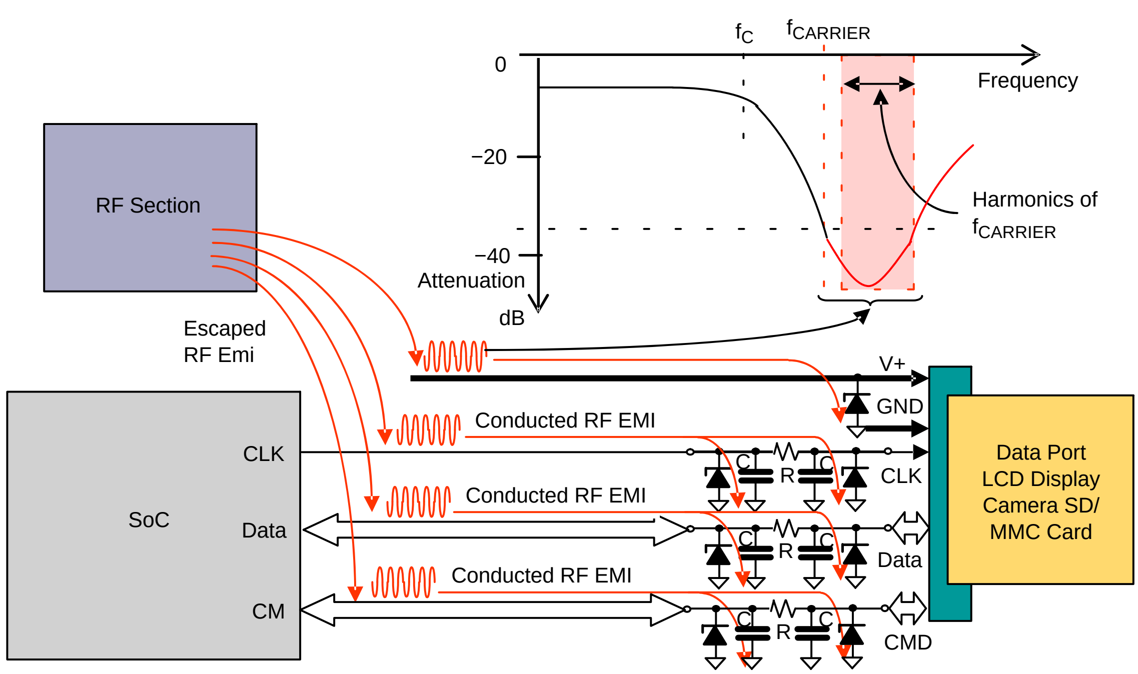

Figure 3. EMI Filters Attenuate RF EMI

Power Supply Noise

Power supply noise is another cause of EMI noise emission from electronic circuits. Digital IC's use DC power supplies, and the DC current on the digital IC's power supply terminal will be disturbed according to the IC operation. Such a sporadic change in current causes EMI noise. This EMI noise will be in sync with the IC timing.

Noise Generated by IC

With some of the recently used large ICs, their package itself may generate as a noise antenna.

EMI Noise

EMI noises are classified into two categories – radiated EMI noise and conductive EMI noise.

Radiated EMI noise usually arises from intentional transmissions such as radio and TV stations, cell phones or comes from incidental radio frequency emitters such as power transmission lines. This radiated interference can be effectively suppressed after the EMI filter with deep attenuation at wireless frequencies.

Conductive EMI noise originates in power lines supplying the equipment and is conducted to the equipment and coupled through the power supply transformer.

This conductive interference also can be suppressed by the EMI filter with deep attenuation at wireless frequencies.

TESTING MOBILE PHONE PERFORMANCE

To meet the demand for higher data rates and better coverage of wireless networks, today's smart phones use a multiband environment including 850/900/1800/1900 MHz GSM, 1.6 GHz GPS, 1.7~2.2 GHz UMTS multiple band and 2.4 GHz Bluetooth/WLAN functionality with emerging technology called multiple input, multiple output (MIMO).

Current smart phones also use highest performance cameras and displays, which run at high clock speeds and use high capacity on board and removable memory, running at high data rates. Smart phones also use stereo speakers, and noise cancellation microphones. These advanced technologies eventually generate high frequency noise and self-pollution that are extremely sensitive to skew and pose inherent EMI challenges.

As the complexity of mobile phones increases and EMI challenges also increase, the ability to pass the certification of wireless association CTIA certification becomes an increasing challenge.

Mobile Station (MS) Performance Test Plan

The MS test plans by CTIA define tests for radiated RF power and receiver performance.

Test Requirements

Measurement of the basic performance of the test chamber includes a site validation method used to determine the uncertainty contribution of the test system.

Measurement of the path loss of the test system includes contributions from range length, measurement antenna, cables, amplifiers, etc. and are determined using the range reference measurement. This measurement uses a calibrated reference antenna to determine a relative correction value that can then be applied to measurement instrument readings in order to determine the performance of the MS related to a theoretical isotropic radiator or receiver.

Performance of the MS is evaluated in two categories.

1. For radiated power measurements (Total Radiated Power, TRP)
2. For sensitivity measurement (Total Isotropic Sensitivity, TIS)

The total radiated power (TRP) is the representation of the ability to transmit signal power, while, total isotropic sensitivity (TIS) is described as the ability to receive signal power of mobile phones. In reality, unknown noise guiding through the antenna as well as transmitted and received signals can be detected in the antenna port. Due to electromagnetic interferences of various active devices such as modem, memories, RF Front-end Module and transceiver, they can make serious noise and reduce TRP and TIS performance. The digital harmonic noise from a baseband is a dominant factor to reduce the TIS performance of a mobile phone, therefore the TIS level is very small signal.

Isotropic Radiated Power (Total Radiated Power, TRP)

This test is to maximize the spatial coverage of the antenna system so that the user does not have to point the antenna in one particular direction to get good call performance.

The human head can alter the shape and peak value of the Equipment Under Test (EUT) radiation pattern. Losses due to the head can vary significantly with frequency, device size, and the antenna design implemented. From a field performance perspective, measurement of the average and peak effective isotropic radiated power (EIRP) on a head model is more meaningful than measurement of peak EIRP in free-space conditions.

Figure 4 shows simplified block diagram of a common configuration for the use of a Base Station for TRP measurement. The forward link communication is transmitted through the communication line antenna and the reverse link is received through the measurement antenna.

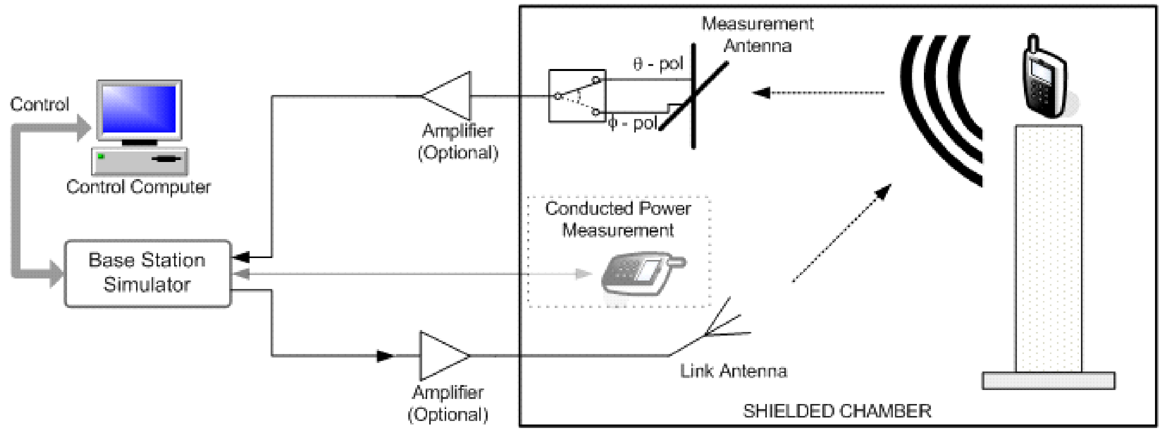

Figure 4. Simplified Block Diagram for TRP Measurement

Receiver Sensitivity (Total Isotropic Sensitivity, TIS)

A frequent cause of poor sensitivity on a single wireless channel, or a small number of wireless channels, is due to receiver in-band noise, or spurious signals from the transmitter itself being radiated back into the receiver. The receiver sensitivity is measured with the transmitter set to the maximum power output allowed by the particular EUT and technology combination.

The TIS level is related to a bit error rate (BER) for GSM and WCDMA, frame error rate (FER) for CDMA2000. These parameters are equal to the receiver sensitivity of a phone considering the coupling noise through the antenna and the received signal degraded by the antenna efficiency. The equation for TIS calculation considering the digital coupling noise can be expressed,

TIS(dBm) = Total noise + RF path loss + NF + SNR – Antenna efficiency

Total noise = 10 log [KTB noise (mW) + Σ coupling noise (mW)]

Where: *Total noise* is the sum of *KTB noise* (thermal noise) and the digital coupling noise,

RF path loss presents the loss between the antenna port and the modem input of a phone,

NF and SNR mean a noise figure and signal to noise ratio of RF components such as RF Front-end Module and a transceiver of the phone.

In the equation, the coupling noise contained on Total noise is the most dominant factor of TIS calculation when the coupling noise is larger than the thermal noise of a phone.

Therefore, noise ecosystem of the mobile station itself, beam-forming antenna design/placement, wireless air standard and selection of digital filters are key consideration to improve the TIS performance.

Figure 5 shows simplified block diagram of a common configuration for TIS measurement. The forward link communication is transmitted through the measurement antenna and the reverse link is received through the communication link antenna.

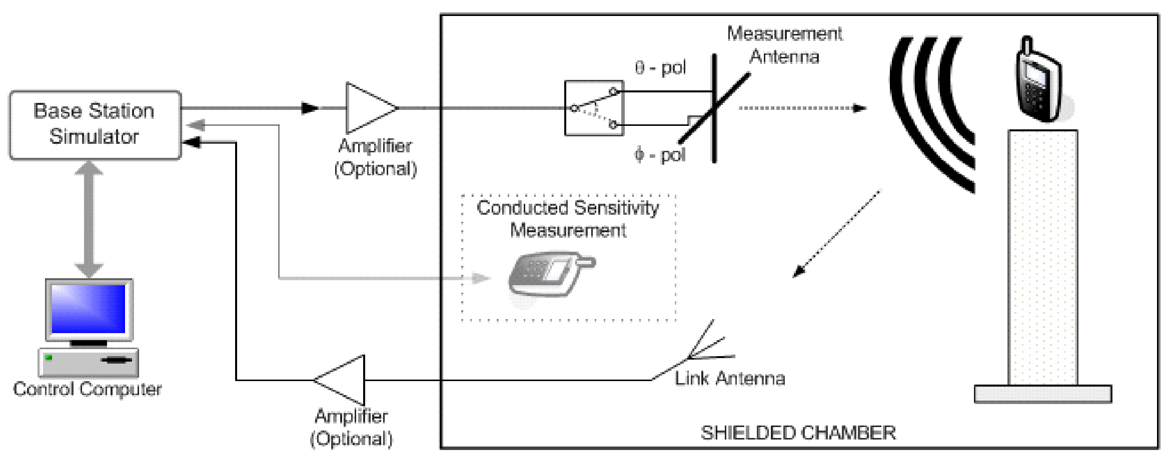

Figure 5. Simplified Block Diagram for TIS Measurement

TIS COMPARISON BETWEEN SILICON AND CERAMIC BASED FILTERS

We performed a study on identical phones, one using ceramics, one using silicon based filters.

All phones parameters were tested including TIS, which is the parameter most susceptible to self pollution and poor handset performance.

Test Setup

- Camera recording video, writing to internal memory or internal SD card
- Primary LCD on, playing recording from camera
- Tested in three axis, slider opened
- Tested middle channel of low and high band GSM

Test Environment

The TIS measurement was usually carried out in an anechoic chamber. The test was performed using the 'great circle' cut method as described in the CTIA certification program. The EUT is placed on a 3D rotator device. Before TIS is measured, the computer sends commands to the position controller which controls the 3D rotator device to a location with fixed θ and $\varnothing$ angle. Then the EUT calls the emulator by its connected horn antenna and maintains communication with it during the test. When the measurement starts, the computer set the parameters of the emulator, such as telecommunication channel, cell power (transmit power) and so on. Then, the computer carries out the BER measurement to obtain the value of BER at that time.

- Measures 3-D sensitivity pattern of the handset's receiver
- Integrates the pattern to provide a figure of merit for the device
- TIS is influenced by EMI
  - The better the EMI filtering the higher the TIS sensitivity

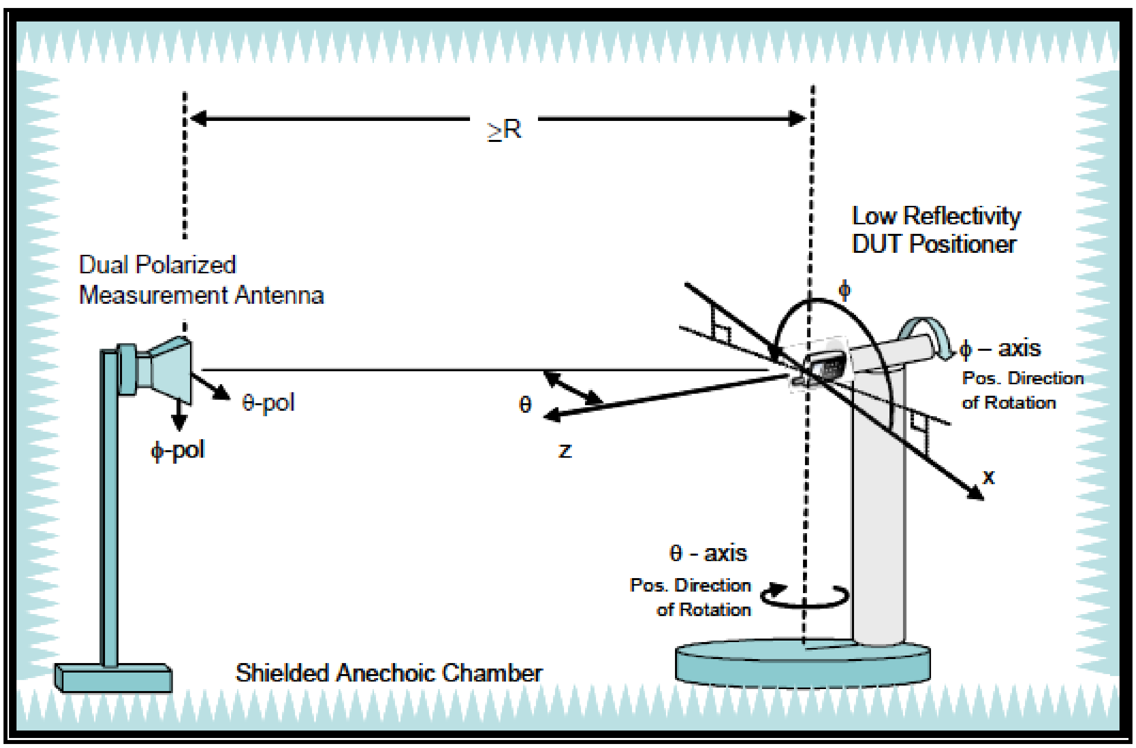

Figure 6. Typical TIS Test Environment

TIS Test Result: Test Data between Ceramic EMI and IC Type EMI Solutions

The TIS test performs three different directions of EUT such as up view, down view and front view. ON Semiconductor tested two mobile phones with same model name and only different EMI filters, one for ceramic based and the other silicon based filters. The test data shows that EUT using the silicon based EMI filters has more than 2 dB better TIS performance than the EUT with ceramic EMI filters (Figures 7, 8 and 9).

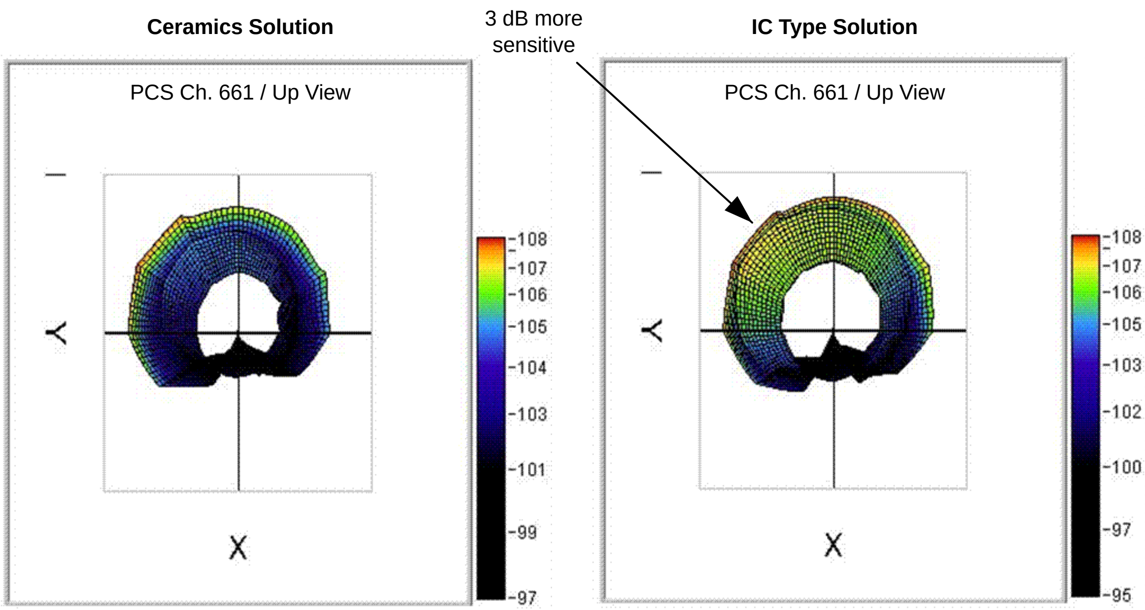

Figure 7. Up View Test Result

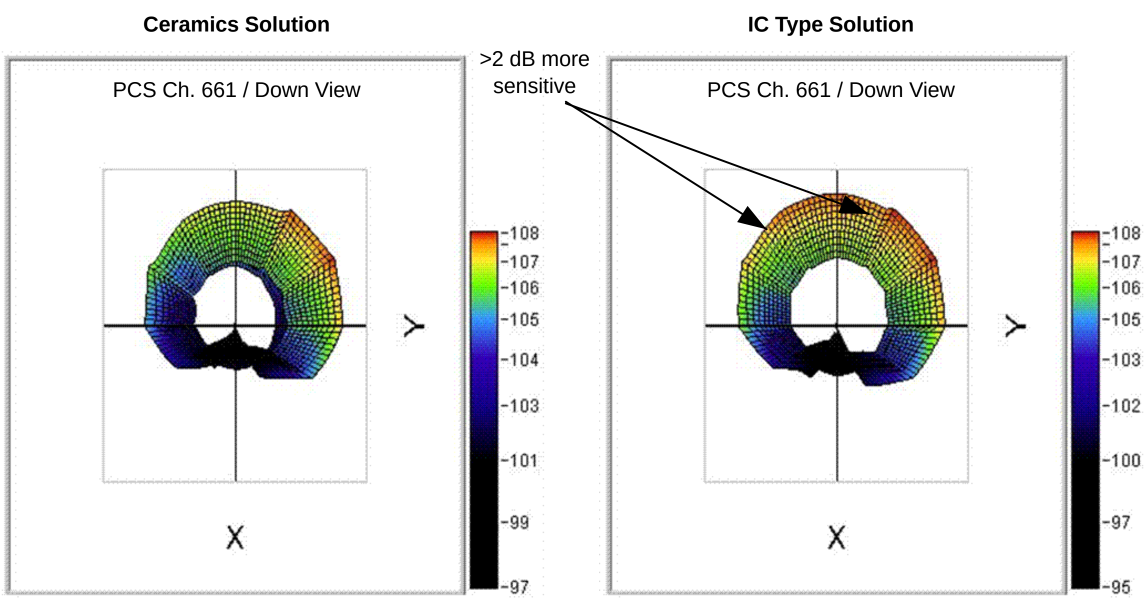

Figure 8. Down View Test Result

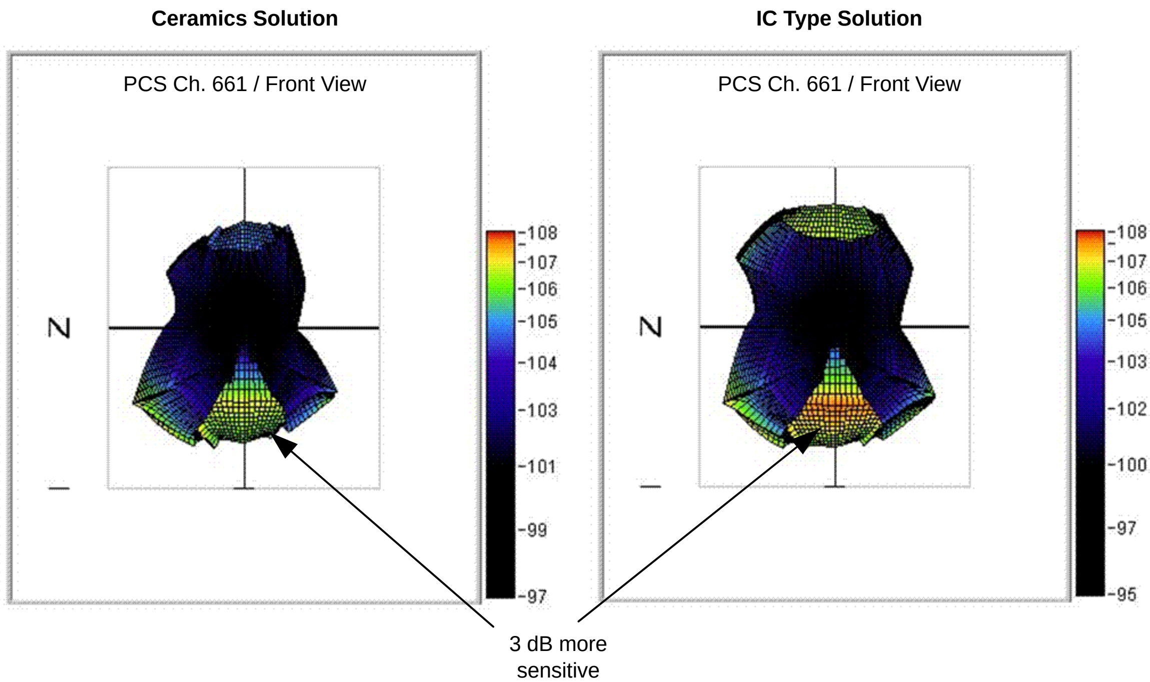

Figure 9. Front View Test Result

Conclusion

The tests performed on TIS clearly demonstrate that the IC-based EMI filter is better than the ceramic-based one.

Based on TIS test results, Low Pass Filter Selection is a more important element in overall phone performance than most engineers realize, and has a critical impact on handset performance with the added benefit of a lower Total Cost of Ownership (TCO).

Better TIS performance translates to:

- Better Reception in Marginal Wireless Areas
- Fewer Dropped Calls
- Better Signal Ranges (Greater Wireless Radius from Base Stations)
- Longer Battery Life, when Exploiting Lower Frequencies of Wireless Band

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