The Analysis of Receiving Sensitivity Degradation of WLAN Performance due to EMI Noise from SSD Module

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Abstract— The Solid State Drive (SSD) is nowadays commonly installed in mobile devices or Ultrabook owing to its compact size and fast processing speed. However, due to ever shrinking space on edge of lid, the WLAN antennas are now usually located at base of Ultrabook computer and thus suffers EMI noise power generated from high speed SSD. Therefore the broadband EMI noise resulted from SSD operation would usually invade the RF communication channel, and thus degrades the receiving sensitivity of the system. In addition, when WiFi tethering is used for cloud applications with the 3G/4G WWAN network through smart phone, the EMI noise from SSD would also affect the file down-loading of mobile phone. Because when Internet accesses with WWAN network, the users always place the mobile phones by side of notebook computer with built-in EMI aggressive SSD. Since the receiving sensitivity of wireless system is the key issue for cloud applications as required by CTIA and related organization, this study investigates the EMI noise coupling mechanism from SSD to antenna and also analyzes the effect on WLAN performance. The coupling mechanism of EMI noise between SSD and RF modules can be categorized as antenna coupling, circuitry coupling, and cavity coupling. With the help of near-field EMC analysis for closely located RF and digital modules in this study, we can identify the root cause of receiving sensitivity degradation and benefit the manufacturers for proper SSD integration with mobile device or Ultrabook computer from compact form design limitation. We also evaluated the noise limit and frequency range for platform noise of wireless communications, and hope to apply the noise budget concept and IC-EMI measurement techniques on the component level to help SSD-related manufacturers and wireless communications system manufacturers to improve the integrating design to meet the performance and EMC requirement in the future study.

1. INTRODUCTION

Owing to its compact size and fast processing speed, the Solid State Drive (SSD) is commonly found been installed in Ultrabook and similar devices. However, such high speed digital module has malignant impact on RF performance of wireless communications. For instance, the SSD usually radiates RF noise power which affects the receiving performance of the WLAN antennas located at base of Ultrabook PC. In addition, when using the WiFi tethering, that is, the users can use the Ultrabook to surf the Internet by the 3G/4G WWAN network via mobile phone, the SSD also radiates the RF noise power which has degraded the reception of mobile phone placed beside the notebook with built-in SSD. When mobile phone is put beside the SSD for WiFi connection as shown in Fig. 1, the EMI signal of another externally connected SSD might also cause the interference on wireless communications.

Figure 1: Scenario of WiFi tethering with mobile phone and external SSD.

2. EMI NOISE EFFECT AND COUPLING MECHANISM ANALYSIS

To quantify the impact of SSD noise power on WLAN performance via embedded antennas, which usually located on the upper left and right corners of the LCD panel for traditional notebook PC as an example, we conduct the throughput rate measurement inside anechoic chamber and show the results with the test setup below in Fig. 2.

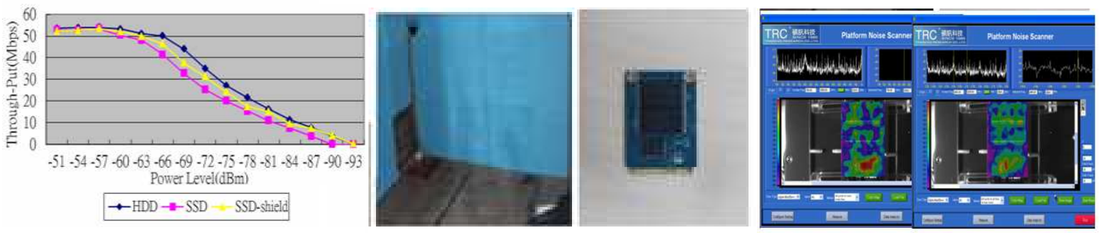

Figure 2: Impact of SSD on throughput rate measurement and results.

From the Fig. 2 shown above for the throughput rate measurement, the blue, yellow, and pink lines represent the WLAN throughput rate when the notebook PC is equipped with HDD, shielded SSD, and SSD, respectively. We here also show in Fig. 3 the possible noise coupling configurations and reason for the degradation of WLAN throughput rate. Compared to HDD case, it is found that the SSD noise power dominates the effect. In addition, it also shows the relative position for WLAN antennas with their cable routing, SSD, and WLAN/WWAN module for this throughput rate measurement.

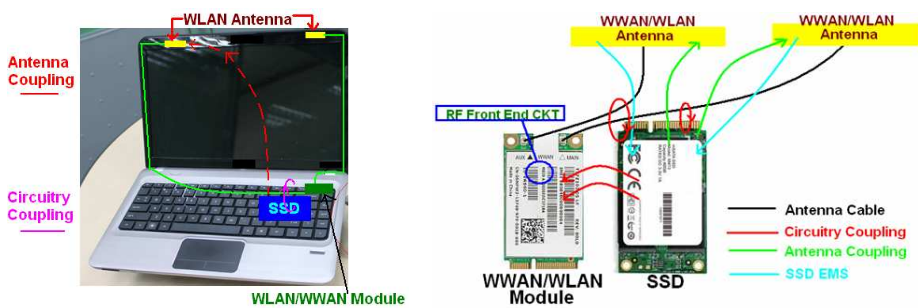

Figure 3: WLAN antennas and cabling configuration with SSD module.

From the analysis of measurement results, the main reason for the degradation of receiving sensitivity is circuitry coupling. The circuitry coupling here means that the SSD noise couples to the mini-coaxial cable connecting WLAN antennas and WLAN module. If the WLAN antennas are further moved down to PC base due to the shrinking lid form limitation of the Ultrabook design, then the SSD EMI noise will even couple directly to the WLAN antennas which is so-called "Antenna Coupling." The coupling mechanism between WLAN antenna and SSD module is illustrated in Fig. 4 for detail.

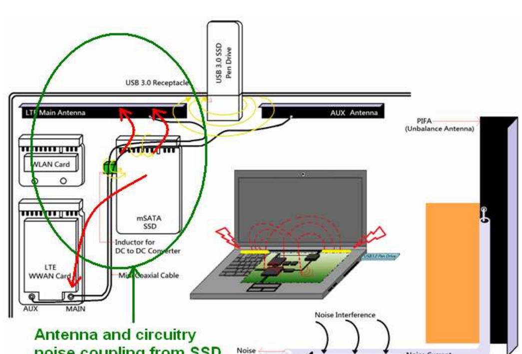

Figure 4: Detailed coupling mechanism between WLAN antenna and SSD module.

We also found out that even the SSD is moved far away from the wireless antenna, as shown below in Fig. 5, RF noise power still couples to antenna from SSD module. Since the chassis of Ultrabook is made of Al-Mg alloy, we therefore call such phenomenon as "cavity resonance" [2] coupling. From the possible coupling mechanism mentioned above, it would be the optimal solution for RFI problems by modifying the components placement layout for better isolation and improving SSD design to mitigate the radiated noise power.

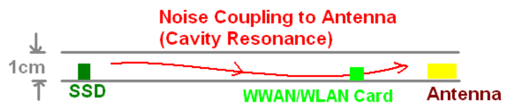

Figure 5: Cavity resonance coupling between WLAN antenna and SSD module.

3. MEASUREMENT SETUP AND PROCEDURES

To help the wireless communications manufacturers and SSD manufacturers identify the root cause of SSD EMI problems on RF receiving performance, we here provide the SSD EMI diagnosis procedures for RF design solutions.

a. Measure the SSD noise power received by the embedded WLAN antennas using the SSD test fixture (Antenna Coupling) as shown in Fig. 6. From the setup shown, the SSD module can be placed in the yellow area of the text fixture and then measure the noise power (generated from SSD) received by WLAN antennas.

   The measurement result is shown in Fig. 7, which shows the noise map in WLAN band (2.4 GHz$\sim$2.5 GHz) and the corresponding noise level of the whole SSD. The corresponding spectrum (from 2415.5 MHz to 2474.4 MHz) for the noise map is shown in the left figure, and the spectrum for the point with the highest noise level in noise map is shown in the right figure. In the Fig. 7, the left one also represents the highest noise level at each frequency point in WLAN band of scanned area.

b. For some critical WLAN channels interfered by SSD found in step 1, we then utilize the PNS [1] (Platform Noise Scanner) for near field noise scanning to locate the EMI noise distribution generated from SSD (Circuitry Coupling & Cavity Resonance [2]) as shown in Fig. 8.

   The current distribution of EMI noise on the victim WLAN antenna from the PNS scanning is shown in Fig. 9 to verify the coupling effect.

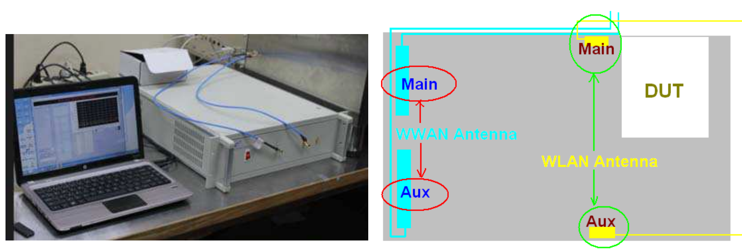

Figure 6: Antenna coupling measurement.

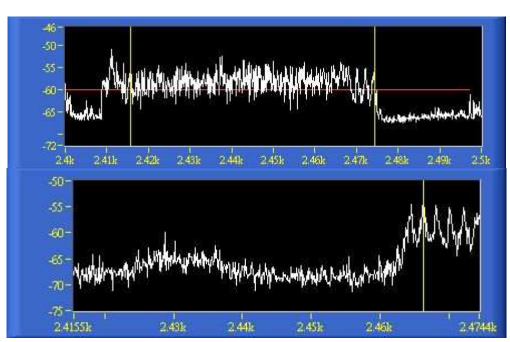

Figure 7: SSD noise map in WLAN band.

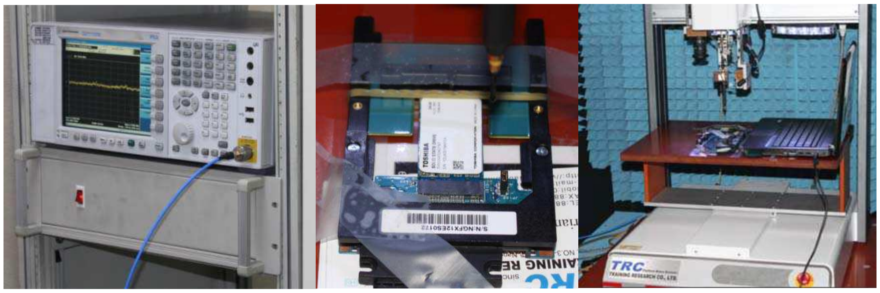

Figure 8: Circuitry and cavity resonance coupling measurement.

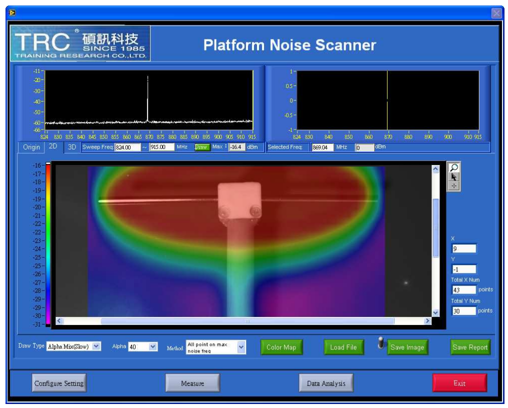

Figure 9: Current distribution on victim antenna.

4. NOISE LIMIT AND FREQUENCY RANGE PLANNING

From the measurement and test plan mentioned for RFI noise evaluation in the previous section, we here suggest that the noise limit of high speed digital component can be determined with the following formula.

$$\mathrm{NLimit}\,(\mathrm{dBm}) = \mathrm{SM}\,(\mathrm{dBm}) + \mathrm{GA}\,(\mathrm{dBi}) - \mathrm{SNR}\,(\mathrm{dB}) \tag{1}$$

For example, if a WLAN device requires -103 dBm receiving sensitivity with 2.14 dBi antenna gain, then the noise limit could be determined as follows.

$$\mathrm{NLimit} = -103\,(\mathrm{dBm}) + -2.14\,(\mathrm{dBi}) - 7\,(\mathrm{dB}) \approx -108(\mathrm{dBm}) \tag{2}$$

Since the coupling coefficient is a transfer function of distance, the separation between SSD module and WLAN antennas should also be taken into consideration when enacting the RF noise limit for each communication band.

Once the SSD RFI noise limit is determined for wireless communications manufacturers, they can control the noise budget for SSD together with the corresponding test fixture shown previously to improve RF receiving performance. With the designated noise limit, the SSD noise level in each band should be further suppressed and validated by IEC 61967 [3] IC-EMI measurement series. From the step 2 test item shown in previous section, the SSD noise level in hot spot image of surface scan is better not exceed -60 dBm/30 kHz in each communication band. Otherwise, the potential risk for RF de-sensitivity will increase if the antenna cable is routed across the SSD module.

5. NOISE RESULTS OF SSD NEAR FIELD EMI TEST

To illustrate the SSD EMI noise effect on WLAN receiving performance, we have shown in Fig. 10 for antenna receiving EMI power comparison of the SSDs from two different manufacturers S1 and S2. In the left hand side, it shows that the WLAN antennas (both main and auxiliary antenna) receive more noise power from S1 manufacturer's SDD than from S2's. When we utilized the platform noise scanner to scan the SSD's noise current distribution in WLAN band, the result is shown in the right hand side. It can thus be realized that the S1 SSD imposes greater potential risk than S2 SSD for those WLAN communication band.

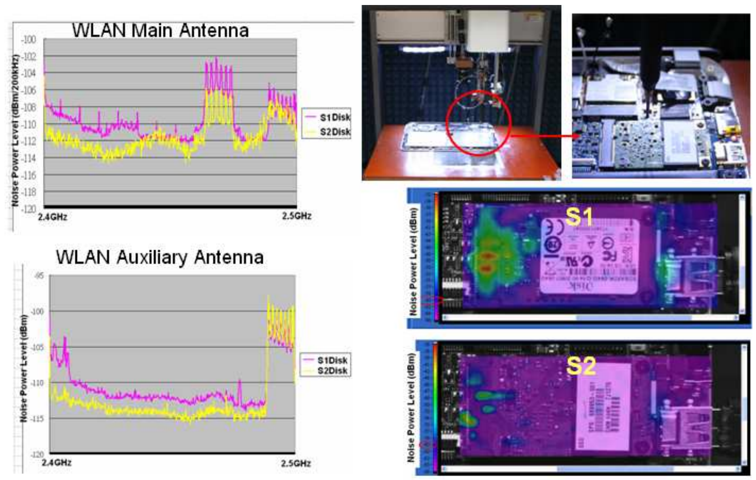

Figure 10: EMI comparison of the SSDs from two different manufacturers.

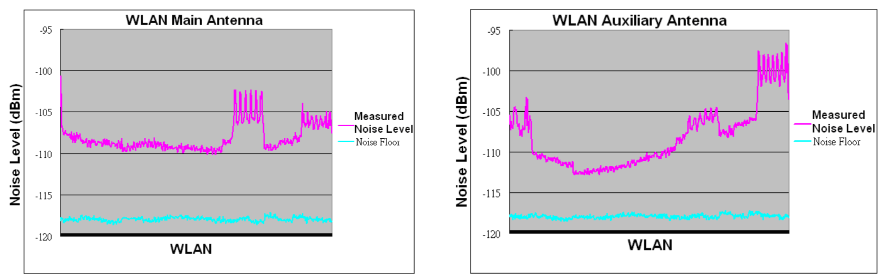

Figure 11: EMI noise power received by main and auxiliary antennas from S3's SSD.

Finally we implemented the SSD made by S3 manufacturer on Ultrabook PC, then we also measured the EMI noise power received by main and auxiliary antennas of WLAN respectively as shown below in Fig. 11. It obviously shows that the noise level of RF module raises drastically, and thus will inevitably degrade the RF receiving performance despite the good RF design practice.

6. CONCLUSION

The SSD EMI noise measurement is conducted to evaluate the noise level and isolation requirement needed for SSD integrated with RF module. For the Ultrabook and notebook PC manufacturers, they can benefit the SSD noise impact on WLAN system and further utilize the mitigation techniques to suppress the noise coupling with compact design limitation from this study. As to the SSD related manufacturers, they can also benefit from understanding the noise current distribution to improve their SSD design to meet the system manufacturers' requirement for platform noise consideration.

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