Introduction of the amplitude probability distribution (APD) measurement in CISPR 32

Toshio Chiyojima
Certification Center.
PFU Techno consul Limited
Yokohama, JAPAN
chiyojima.pfu@fujitsu.com

***Abstract*— CISPR 32 emission requirements for multimedia equipment (MME) describes that "The peak detector limits for radiated emissions requirements above 1 GHz shall not be applied to emissions produced by arcs or sparks that are high voltage breakdown events." In order to verify this exclusion of limits, we investigated impacts of impulsive disturbances from printer on Wi-Fi communications that were generated by feeding papers especially in low humid winter season, concluding no remarkable impact observed. We have therefore extended our investigations to cover most of all wireless communication systems above 1 GHz such as LTE, WCDMA, GSM, DAB and DECT. Measurements have been made of the APD of disturbances and the communication qualities. As a result, it is found that GSM and Wi-Fi have the lowest immunity. Finally we propose addition of the APD limits to CISPR 32 based on the immunity level of GSM and Wi-Fi so as to keep current spectrum protection level. The introduction of the APD measurement and the proposal of the limits in CISPR 32 has currently been discussed in CISPR.**

Keywords—impulsive noise, amplitude probability distribution, APD, multimedia equipment, MME, CISPR, BER, wireless communications

I. INTRODUCTION

CISPR 32 Ed.2.0[1] describe that "The peak detector limits for radiated emissions requirements above 1GHz shall not be applied to emissions produced by arcs or sparks that are high voltage breakdown events. " In order to verify this exclusion of limits, we investigated impacts of impulsive printer disturbances on Wi-Fi communication that were generated by feeding papers especially in low humid winter season. The results were concluded no remarkable impact observed. It is reported that APD is proper way to evaluate impact on digital communications of disturbance [2] [3]. As a proper evaluation method we propose to start study on introducing APD for MME in CISPR. This item was listed in CISPR/I/524/INF [4] long term work in CISPR SC-I MT7 as a next amendment of CISPR 32 Ed.2.0.

As a next step, we decided to investigate all wireless services currently in use. Firstly, impact on wireless communication system such as LTE, WCDMA, and GSM using pulse modulated signal which represent the emission due to high voltage discharging was investigated. Several duty cycle pulse modulated signals were used and we found each wireless communication system's immunity characteristics against such disturbances. It was found that GSM had the lowest immunity. Therefore we proposed limits for APD measurements based on GSM immunity level.

After that, another communication technologies such as DAB, DECT, Wi-Fi 11b and 11g were investigated. As far as our series investigation wireless communication systems with the lowest immunity against disturbances were GSM and Wi-Fi.

This paper summarize these test results and provide justification for introducing APD measurement to radiated emission measurement above 1 GHz in CISPR 32.

II. EVALUATION METHOD

A. *printer with paper feeding*

The method to evaluate the impact on Wi-Fi communication (11bg) of a printer with high voltage breakdown event while paper feeding is following.

Figure 1 shows the configuration to evaluate this impact. It is important for electrostatic discharging phenomenon to control humidity. So, this experiment was performed in winter very low humid season in Yokohama. Recorded humidity was 28%. PC1 and PC2 are lap top PC with Wi-Fi dongle. Wi-Fi protocol used was 11bg which had several digital modulation such as 64QAM 16QAM OFDM and DSSS automatically selected. Throughput of Wi-Fi communication and APD were measured at the distance 3 meter from printer. APD receiver meets the requirements defined CISPR 16-1-1[5].

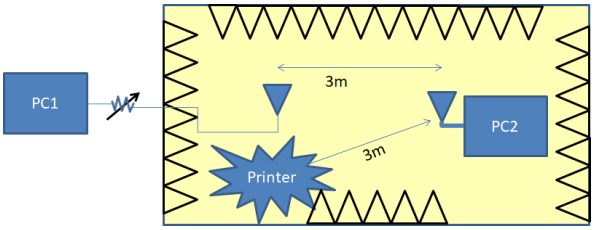

Fig. 1. Test configuration for printer

B. *Wireless communications*

The method to evaluate the impact on several wireless communication systems of impulsive disturbances is following.

Pulse modulated sine wave with 20 ns pulse width was used as representative of emissions produced by arcs or sparks that are high voltage breakdown events. Its calculated spectrum is shown in Fig. 2 and its period and duty are shown in Table I. Peak level was adjusted 70 dBμV/m at smartphone position which is current peak limits in the frequency range from 1 GHz to 3 GHz in CISPR 32 Ed.2.0. Fig.3 shows test configuration in FSOATS defined in CISPR 16-1-4[6]. Fig.4 shows APD measurement results for 10^{-5} duty pulse modulated disturbance. Test conditions and setting are shown in Table II.

Table III shows Base station simulator used and its settings. Typical smartphones were used for LTE, WCDMA and GSM. A receiver for DAB, a handset for DECT and, an access point for Wi-Fi were used. BER block error rate was provided by Base station simulator listed.

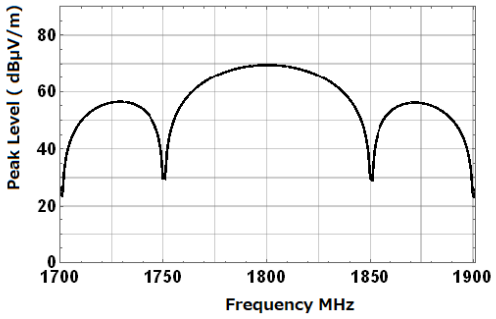

Fig. 2. Calculated spectrum of pulse modulated sine wave

TABLE I. THE PRIOD AND DUTY OF PULSE MODULATED SINE WAVE

Duty	10^{-6}	10^{-5}	10^{-4}	10^{-3}
Period	20 ms	2 ms	200 μs	20 μs

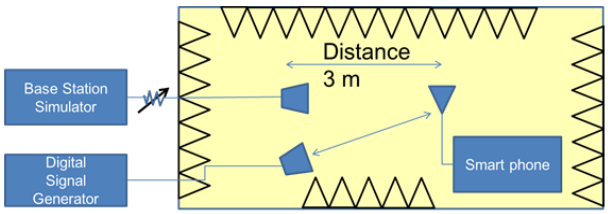

Fig. 3. Test configuration

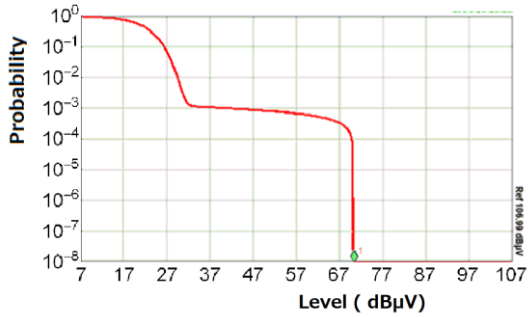

Fig. 4. APD of 10^{-5} duty pulse modulated sine wave

TABLE II. TEST CONDITIONS AND SETTING

Wireless communication	Primary Modulation	Secondary modulation	Sub-carrier band width	Band width	Maximum speed	Frequency (Down Link)
LTE	64QAM	OFDM	15 kHz	20MHz	75 Mbps	2140 MHz
WCDMA	16QAM	DSSS	-	5 MHz	7.2 Mbps	2140 MHz
GSM (GPRS)	GMSK	TDD 5 msec	-	200 kHz	85.6 kbps	1.8 GHz
DECT	GFSK, BPSK, 16QAM, 64QAM	TDD	-	2 MHz	6.912 kbps	1.9 GHz
DAB	1/4 π DQPSK	OFDM	1 kHz	1.536 MHz	1184 kbps	1.4 GHz (239.2 MHz) [a]
Wi-Fi 11b	CCK QPSK	DSSS	-	20 MHz	11 Mbps	2412 MHz
Wi-Fi 11g	QAM 16QAM 64QAM	OFDM	384 kHz	20 MHz	54 Mpbs	2412 MHz

[a.] Evaluation was performed at the frequency 239.2 MHz because of the receiver prepared.

TABLE III. BASE STATION SIMULATOR USED AND ITS SETTINGS

Wireless communication	Simulator	Settings
LTE-FDD	E7515A	MCS 28 (64QAM, code rate 0.8)
WCDMA/HSDPA	E7515A	UE Category 8, CQI=25
GSM/GPRS	E7515A	4 slots down , 1 slot up Coding Scheme : CS4 [b]
DAB	CMW 270	DAB Radio RF-D5
DECT	CTS 60	DECT handset: KX-TCA385
Wi-Fi 11b	MT8860C	AP: PA-WR8700N-HP
Wi-Fi 11g	MT8860C	AP: PA-WR8700N-HP

[b.] CS4 has no error correction.

III. EXPERIMENTAL RESULTS

A. Printer with paper feeding.

Fig.5 shows the impact on Wi-Fi communications. There is no difference between printer on and off (reference).

Fig.6 shows APD of emission from printer. The probability at the level 65 dBμV/m is less than 10^{-6}.

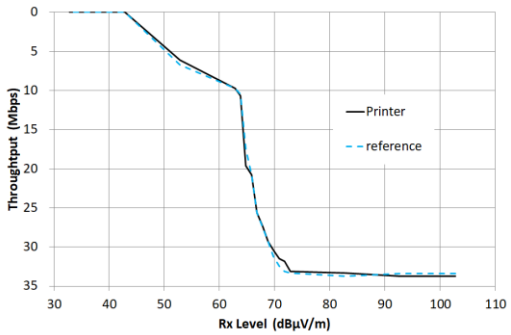

Fig. 5. The impact on Wi-Fi communications

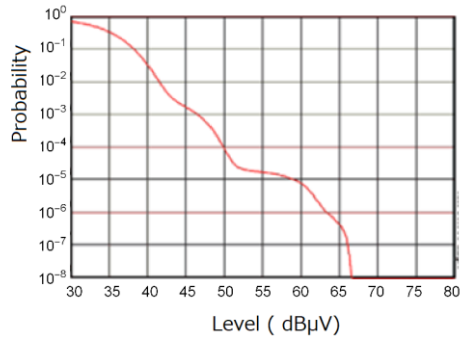

Fig. 6. APD of emission from printer

B. Wireless communications

Fig. 7 shows test results of LTE BER and field strength at receiver. And Fig. 8 shows test results of DAB BER. Fig. 9 shows test results of GSM BER. Fig. 10 shows test results of Wi-Fi 11b BER.

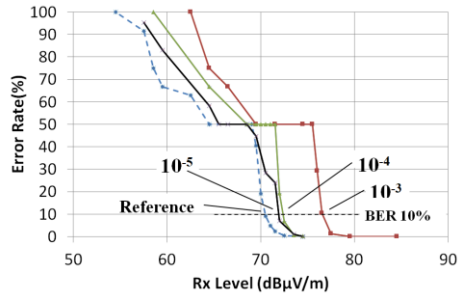

Fig. 7. Test result of LTE BER and field strength at receiver

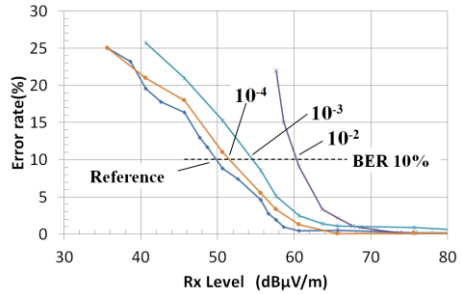

Fig. 8. Test results of DAB BER and field strength at receiver

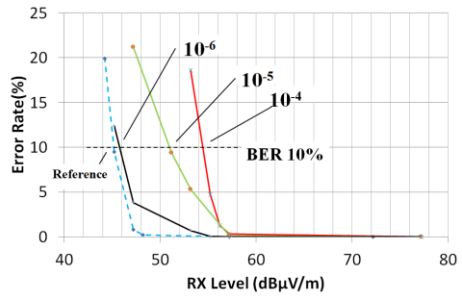

Fig. 9. Test results of GSM BER and field strength at receiver

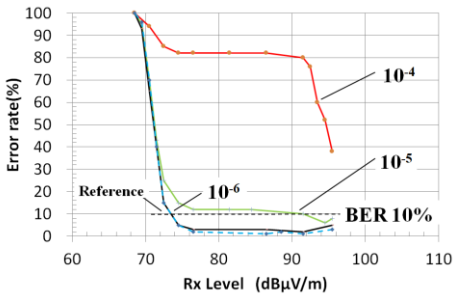

Fig. 10. Wi-Fi 11g BER and field strength at receiver

Fig. 11 shows *all* test results with parameter BER.

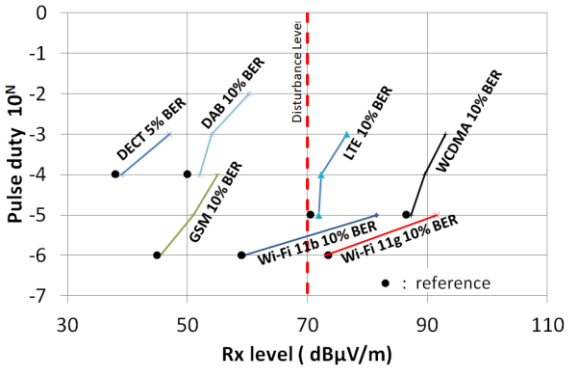

Fig. 11. Impact on wireless telecommunicaions

GSM and Wi-Fi are the lowest immunity against emissions due to high voltage discharging. The degradation of these wireless communication start between pulse duty 10^{-6} and 10^{-5}. The reason why GSM and Wi-Fi are the lowest immunity is as follows:

In this study coding scheme of GSM was CS-4 which has no error collecting function. While other wireless technology LTE, WCDMA, DECT and DAB have strong error collecting code.

Wi-Fi has error collecting function but has no time interleaving function only frequency interleaving (within symbol). Error collecting function does not work for impulsive disturbance because it has broadband spectrum which covers all sub-carriers.

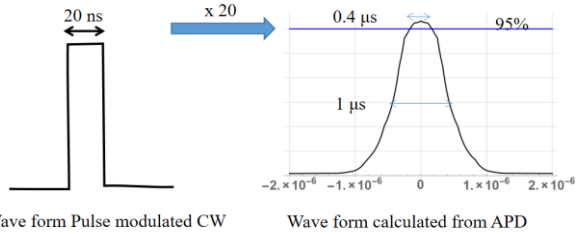

Fig. 12. Effect of BPF (1 MHz)

IV. CONSIDERATION AND PROPOSED LIMITS

A. Effect of BPF of APD receiver

Fig.12 shows wave form of pulse modulated CW with 20 ns width and band pass filtered wave form calculated from APD measured. APD receiver with 1MHz RBW increase probability 20 times as shown in Fig 12 focusing 95 % level.

B. Proposed limits

The degradation of these wireless communications started between pulse duty 10^{-6} and 10^{-5}. BPF makes its probability 20 times then 2 10^{-5} and 2 10^{-4}. We decided its threshold is 10 $^{-4}$. Proposed limits is 70 dBµV/m and probability 10^{-4} in the frequency range from 1 GHz to 3 GHz, and 74 dBµV/m from 3 GHz to 6 GHz for class B equipment.

Fig 13 shows proposed limits of APD: 10^{-4} @ 70 dBµV/m. According to APD nature APD curve cannot exist in right upper area. For example EUT ON; APD exceeds current peak limits but meets proposed APD limits.

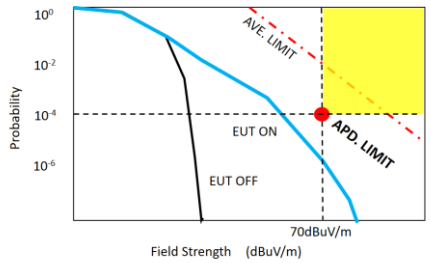

Fig. 13. Proposed limits of APD from 1 GHz to 3 GHz

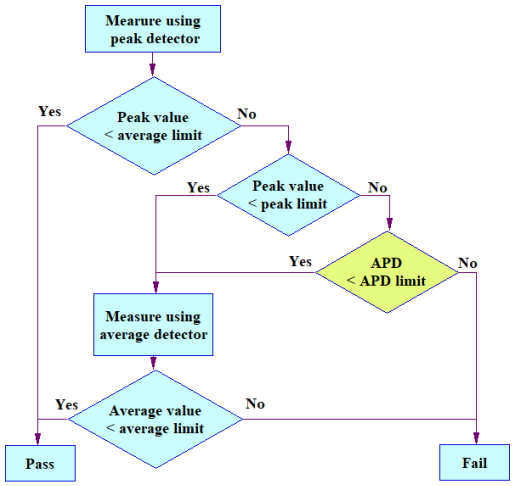

Fig. 14. Proposed decision tree

C. Decision tree

At the moment APD is time consuming measurement, so, firstly peak measurement was performed whole frequency band then spectrums exceed peak limits were APD measured. Fig.14 shows proposed decision tree using peak average and APD measurement.

For impulsive disturbance it shall be special care to perform peak measurement with sufficient peak hold duration.

D. Delete existing exemption of peak limits

For amendment of CISPR 32, 2nd. First sentence of A.1 3rd. paragraph should be replaced to the following;

Radiated emissions from MME devices shall satisfy both peak and average limits as specified in A.2. Peak limits is for narrowband emission and average limits is for broadband emission. However, the peak limits shall not be applied to impulsive emissions that exceed the relevant peak limit with a probability of time less than 10^{-4}.

V. CONCLUSION

Among wireless communications system we have tested LTE, WCDMA, GSM, DAB, and DECT, GSM and Wi-Fi had the lowest immunity against emissions due to high voltage discharging. So, we proposed APD limits and decision tree using Peak, APD, and Average for above 1GHz radiated emission measurement. This justification for introducing APD measurement to CISPR 32 will be submitted CISPR SC-I MT7 meeting in Singapore and discussed.

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