TECHNICAL REPORT

CISPR 16-3

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AMENDMENT 1
2005-07

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Amendment 1

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 3: CISPR technical reports

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FOREWORD

This amendment has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

The text of this amendment is based on the following documents:

DTR	Report on voting
CISPR/A/572/DTR	CISPR/A/586/RVC

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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4 Technical reports

Add, on page 186, after the existing subclause 4.6, the following new subclause:

4.7 Correlation between amplitude probability distribution (APD) characteristics of disturbance and performance of digital communication systems

4.7.1 Introduction

The relationship between the degradation in quality of digital communication systems and APD of disturbance is shown in the following experimental results. Actual microwave ovens (MWO), such as the transformer and the inverter types, and a noise simulator, were used as a noise source in the following experiment. Bit Error Rate without error correction was basically used as a parameter of communication system performance (e.g., W-CDMA and PHS). Throughput is used if error correction could not be removed (e.g., W-LAN, Bluetooth and PHS).

Quantitative correlation between noise parameters and system performance is shown in 4.7.6 and 4.7.7 by using measured and simulated results.

These results show that APD measurement of disturbance is suitable for evaluating its interference potential on digital communication systems. Therefore APD measurement may be applicable to the compliance test of some products or product families, such as microwave ovens.

4.7.2 Influence on a wireless LAN system

The set-up for measuring communication quality degradation is shown in Figure 4.7.1, and measurement conditions are shown in Table 4.7.1. Throughput was chosen as a measure for communication quality evaluation. It was calculated from the time taken to transmit and time to receive data of a fixed size.

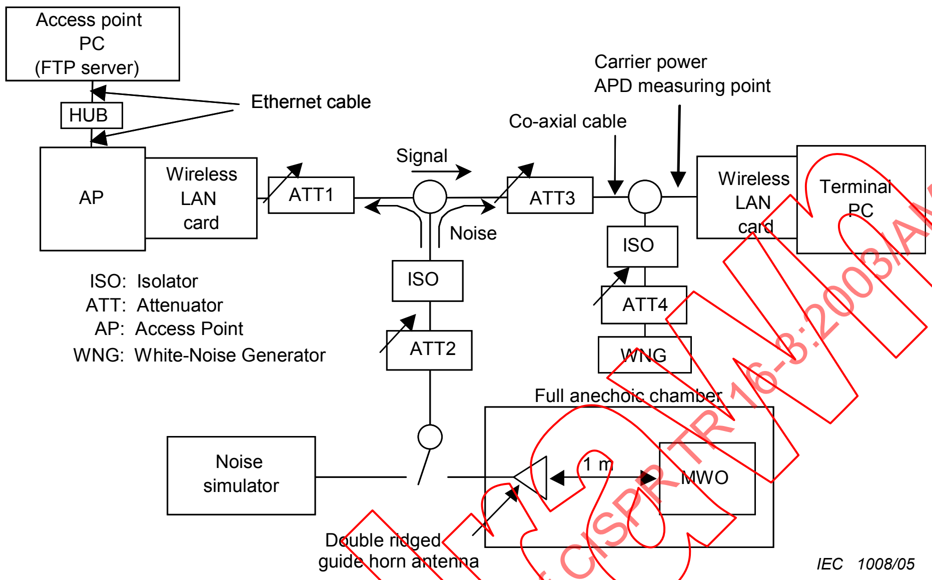


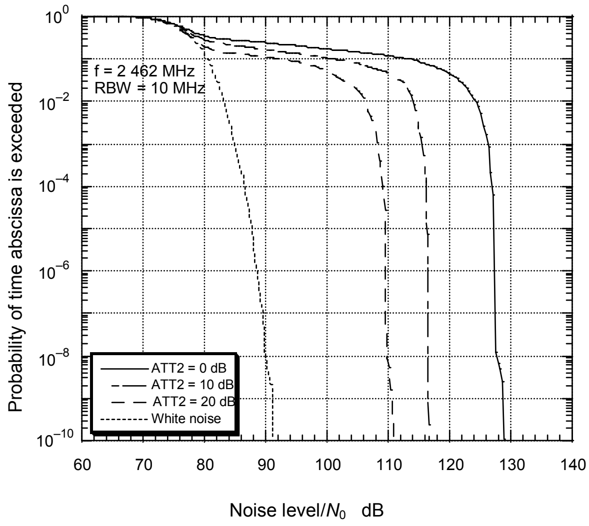
Figure 4.7.1 – Set-up for measuring communication quality degradation of a wireless LAN

Table 4.7.1 – Conditions for measuring communication quality degradation

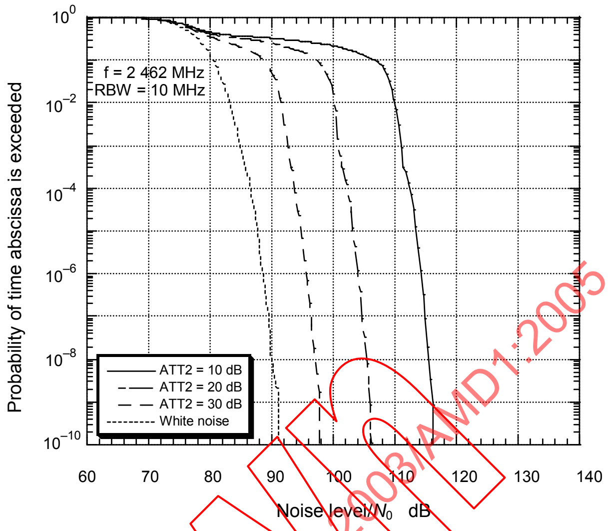
Wireless LAN	Frequency (channel)	2 462 MHz (11ch)
	Transmission data	20 Mbyte
	Protocol	FTP (GET command from terminal PC)
	Transmission mode	Packet transmission
Others	Noise power density N_0 (dBm/Hz)	–154 dBm/Hz (set by ATT4)

The APDs of disturbance are shown in Figure 4.7.2. The horizontal axis shows the level of radiated noise normalized by N_0, which has been approximated as the noise level from the white noise generator. The main frequency for measuring APD was 2462 MHz. The average and root-mean-square (RMS) values of the noise level normalized by N_0 derived from APD of the MWO noise and noise simulator noise are shown in Table 4.7.2.

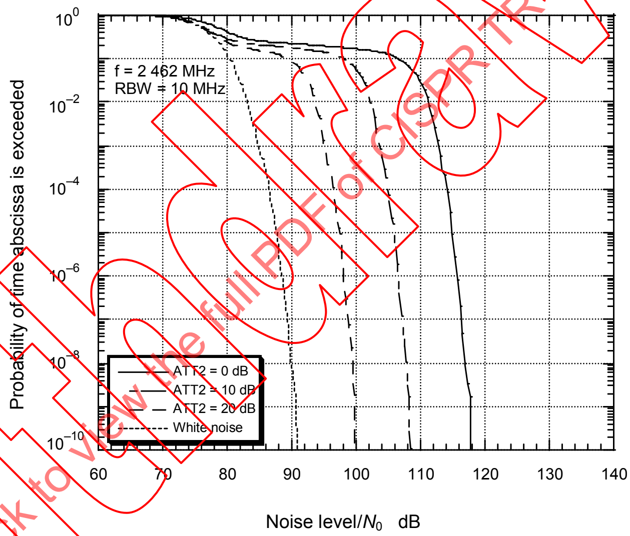
APD of the noise simulator at *ATT2* = 0 dB was in good agreement with APD of the inverter type MWO at *ATT2* = 10 dB.



a) Transformer type MWO



b) Inverter type MWO



c) Noise simulator (adjusted with inverter type MWO)

IEC 1009/05

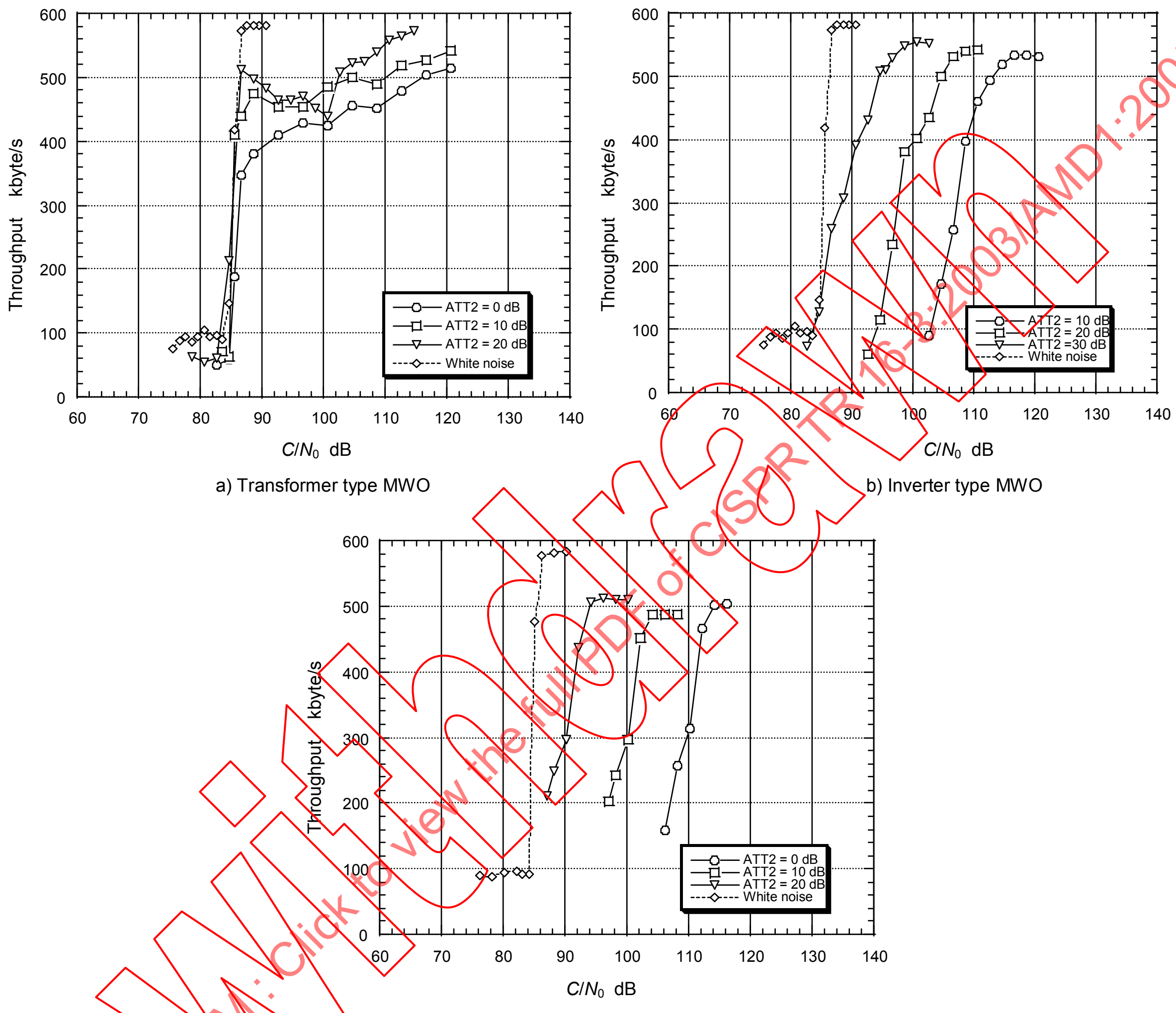
Figure 4.7.2 – APD characteristics of disturbance

Table 4.7.2 – Average and RMS values of noise level normalized by N_0

		ATT2				White noise
		0 dB	10 dB	20 dB	30 dB	
Transformer type MWO	Average (dB)	111,2	101,0	92,6		77,6
	RMS (dB)	117,1	107,0	98,8		78,7
Inverter type MWO	Average (dB)		100,6	91,4	83,4	77,6
	RMS (dB)		104,4	94,8	86,2	78,7
Noise simulator	Average (dB)	100,6	91,9	83,8		77,5
	RMS (dB)	105,1	96,2	87,6		78,6

The measured communication quality degradation for various amounts of attenuation of injected noise is shown in Figure 4.7.3.

The horizontal axis shows C/N_0, where C is the sub-carrier power and N_0 is the noise power density.



a) Transformer type MWO

b) Inverter type MWO

c) Noise simulator (adjusted with inverter type MWO)

IEC 1010/05

Figure 4.7.3 – Wireless LAN throughput influenced by noise

The throughput influenced by a transformer type MWO is 400 kbytes/s or more when C/N_0 is 90 dB or more, and decreases rapidly when C/N_0 is below 90 dB. This tendency is almost the same irrespective of the noise level. On the other hand, the throughput influenced by an inverter type MWO decreases almost in proportion to the noise level. The throughput influenced by a noise simulator has almost the same degradation characteristics as that for an inverter type MWO.

4.7.3 Influence on a Bluetooth system

The setup for measuring communication quality degradation is shown in Figure 4.7.4, and measurement conditions are shown in Table 4.7.3.

Throughput was chosen as the measure for communication quality evaluation.

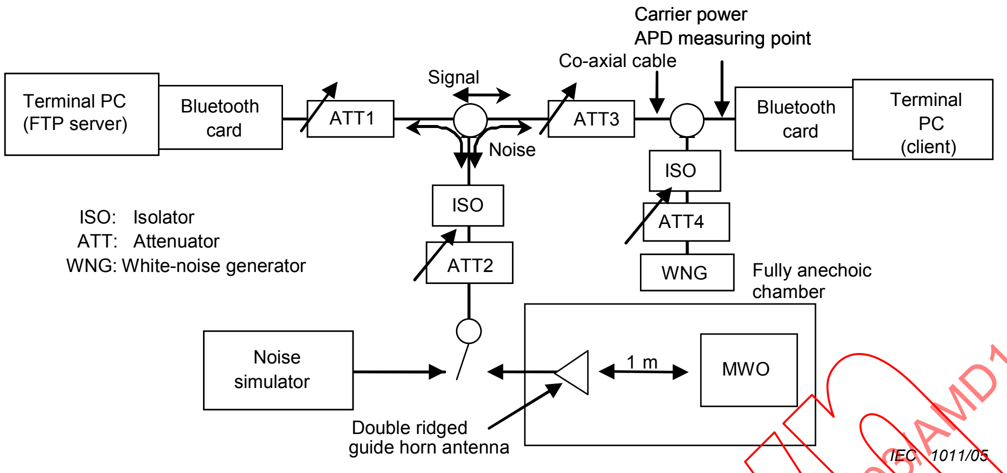
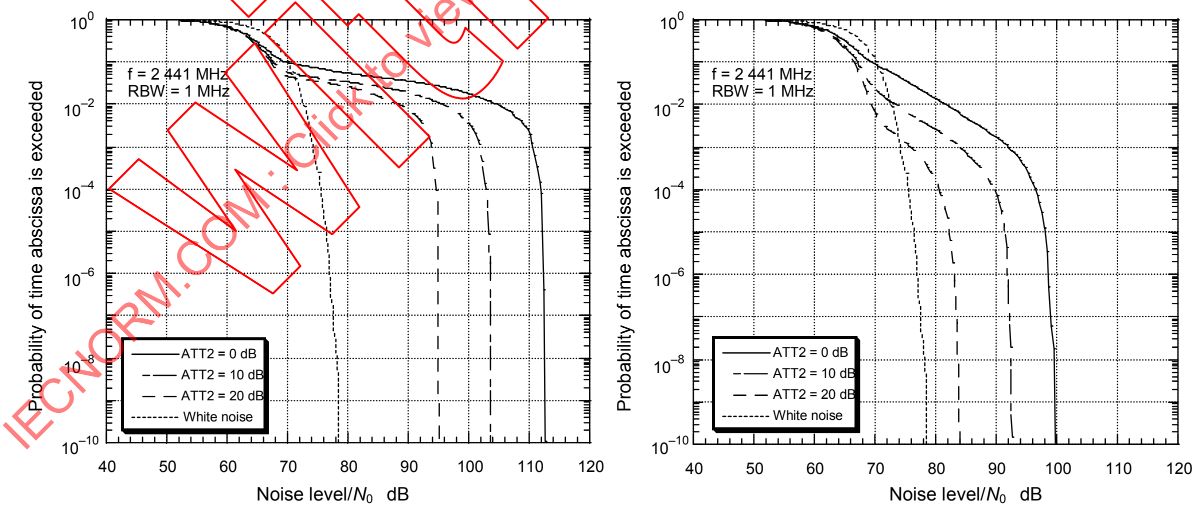


Figure 4.7.4 – Set-up for measuring the communication quality degradation of Bluetooth

Table 4.7.3 – Conditions for measuring communication quality degradation of Bluetooth

Bluetooth	Frequency	2 400 – 2 483,5 MHz
	Transmission data	2,5 Mbyte
	Protocol	FTP (GET command from terminal PC)
	Transmission mode	Packet exchange data transmission mode
Others	Noise power density N_0 (dBm/Hz)	-148 dBm/Hz (set by ATT4)

The APDs at a frequency of 2 441 MHz are shown in Fig. 4.7.5, and the average and RMS values of noise level normalized by N_0 are shown in Table 4.7.4.



a) Transformer type MWO

b) Inverter type MWO

IEC 1012/05

Figure 4.7.5 – APD of disturbance of actual MWO (2 441MHz)

Table 4.7.4 – Average and RMS values of noise level normalized by N_0

		ATT2				White noise
		0 dB	10 dB	20 dB	30 dB	
Transformer type MWO	Average (dB)	89,8	80,8	73,7		67,1
	RMS (dB)	99,2	90,2	82,5		68,3
Inverter type MWO	Average (dB)	70,7	65,4	63,5		67,1
	RMS (dB)	80,6	73,3	66,0		68,3

The APDs measured at 2 460 MHz, where the noise level of an MWO is at maximum, are shown in Figure 4.7.6, and the average and RMS values of noise normalized by N_0 are shown in Table 4.7.5. The noise level is about 10 dB larger than that at the frequency of 2 441 MHz. The APD of the noise simulator at *ATT2* = 0 dB is in good agreement with that of the inverter type MWO at *ATT2* = 10 dB.

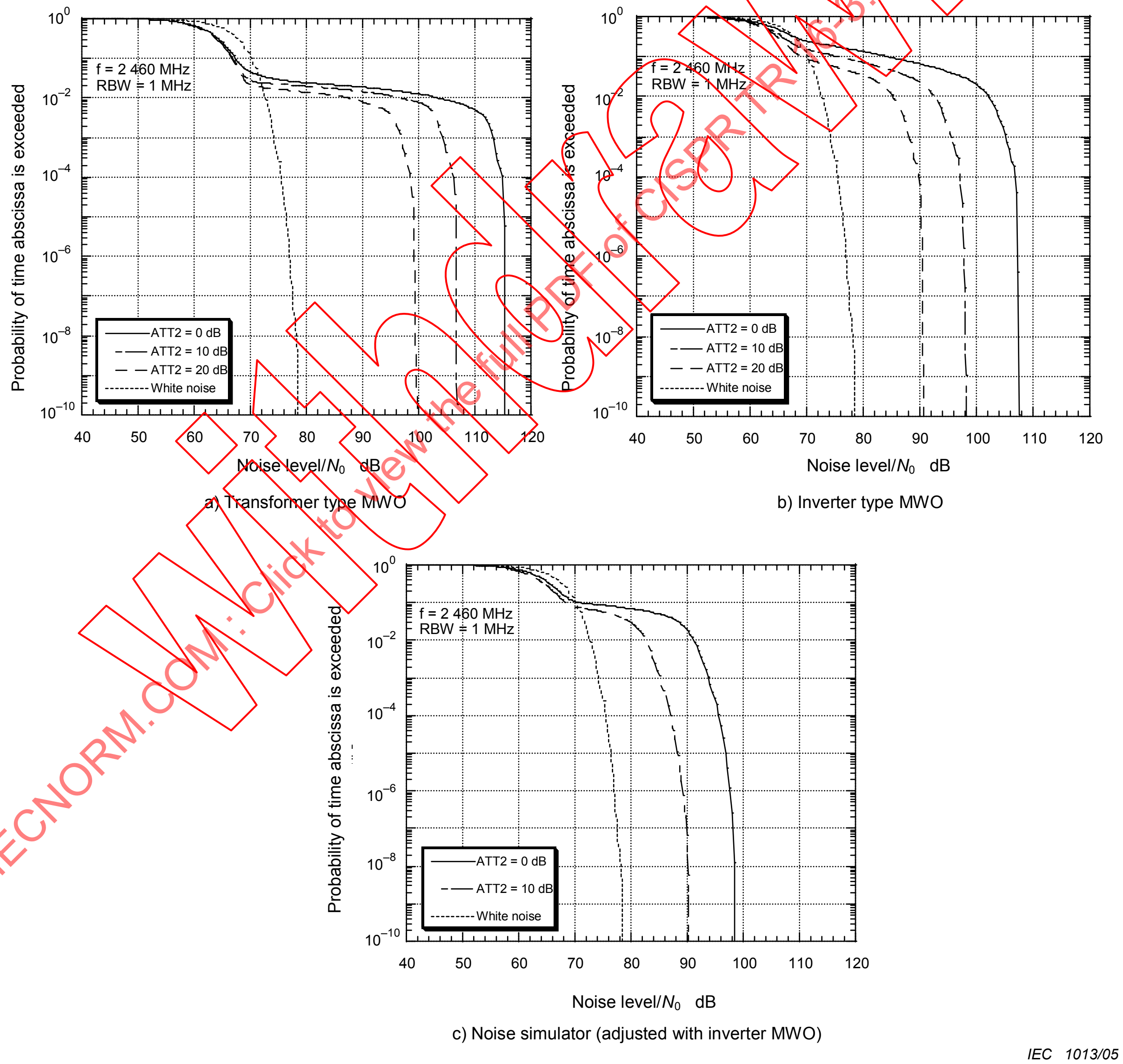


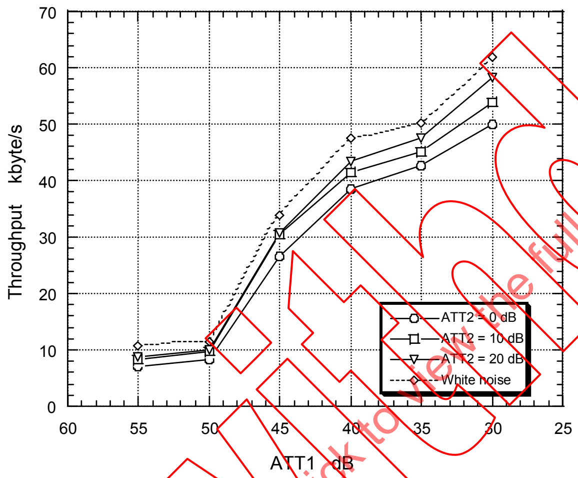
Figure 4.7.6 – APD characteristics of disturbance (2 460 MHz)

Table 4.7.5 – Average and RMS values of noise level normalized by N_0

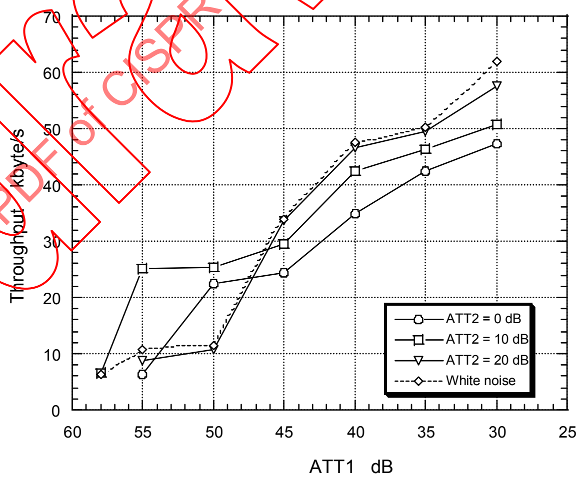
		ATT2				White noise
		0 dB	10 dB	20 dB	30 dB	
Transformer type MWO	Average (dB)	87,8	78,4	71,4		67,1
	RMS (dB)	94,9	85,4	78,0		68,3
Inverter type MWO	Average (dB)	70,7	65,4	63,5		67,1
	RMS (dB)	80,6	73,3	66,0		68,3
Noise simulator	Average (dB)	77,6	69,8			67,1
	RMS (dB)	84,1	75,5			68,3

The measured communication quality degradation for various amounts of attenuation of injected noise is shown in Figure 4.7.7.

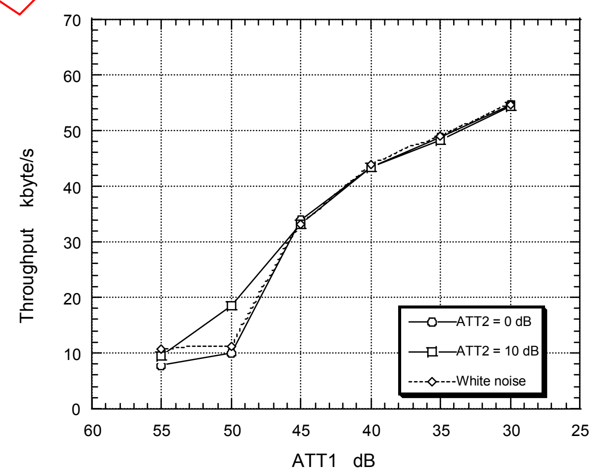
There is only a minor difference in degradation caused by the level of noise between a transformer and an inverter type MWO. This is because Bluetooth performs frequency hopping, and is hard to be influenced by noise continuously. Furthermore, there is almost no difference in communication quality degradation for a noise simulator.



a) Transformer type MWO



b) Inverter type MWO



c) Noise simulator (adjusted with inverter type MWO)

IEC 1014/05

Figure 4.7.7 – Throughput of Bluetooth influenced by noise

According to the specifications, Bluetooth controls the transmission power automatically depending on the communication situation. The sub-carrier power at the reception point cannot be obtained uniquely since transmission power may change when ATT1 is changed. The horizontal axis in this figure shows the attenuation of signal power.

4.7.4 Influence on a W-CDMA system

The set-up for measuring communication quality degradation is shown in Figure 4.7.8, and measurement conditions are shown in Table 4.7.6.

Bit error rate (BER) was chosen as the measure for communication quality evaluation.

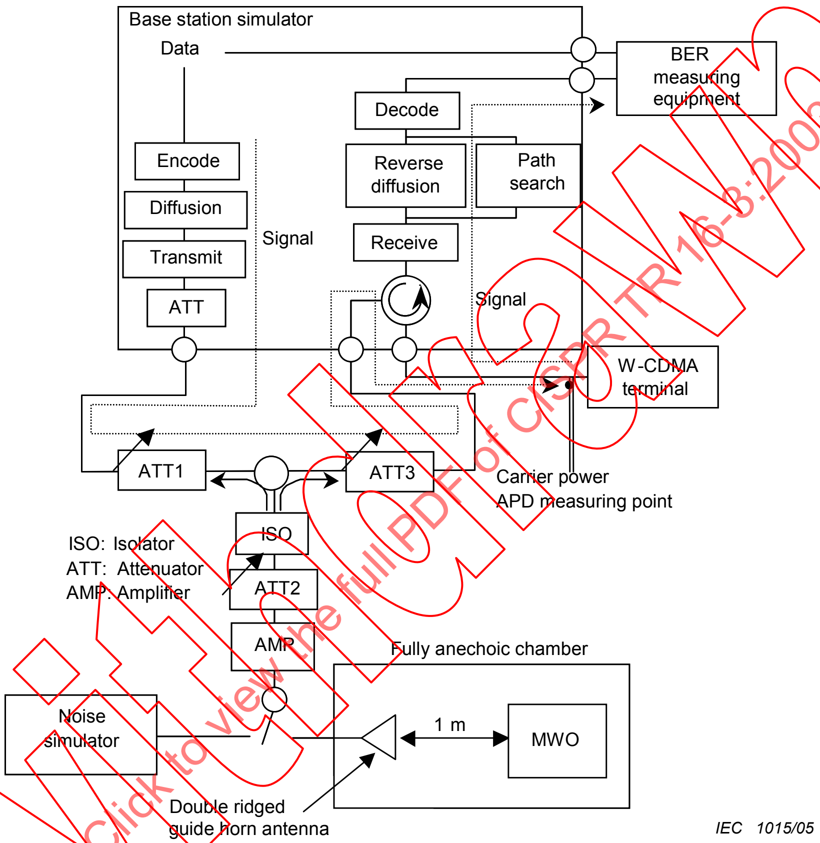
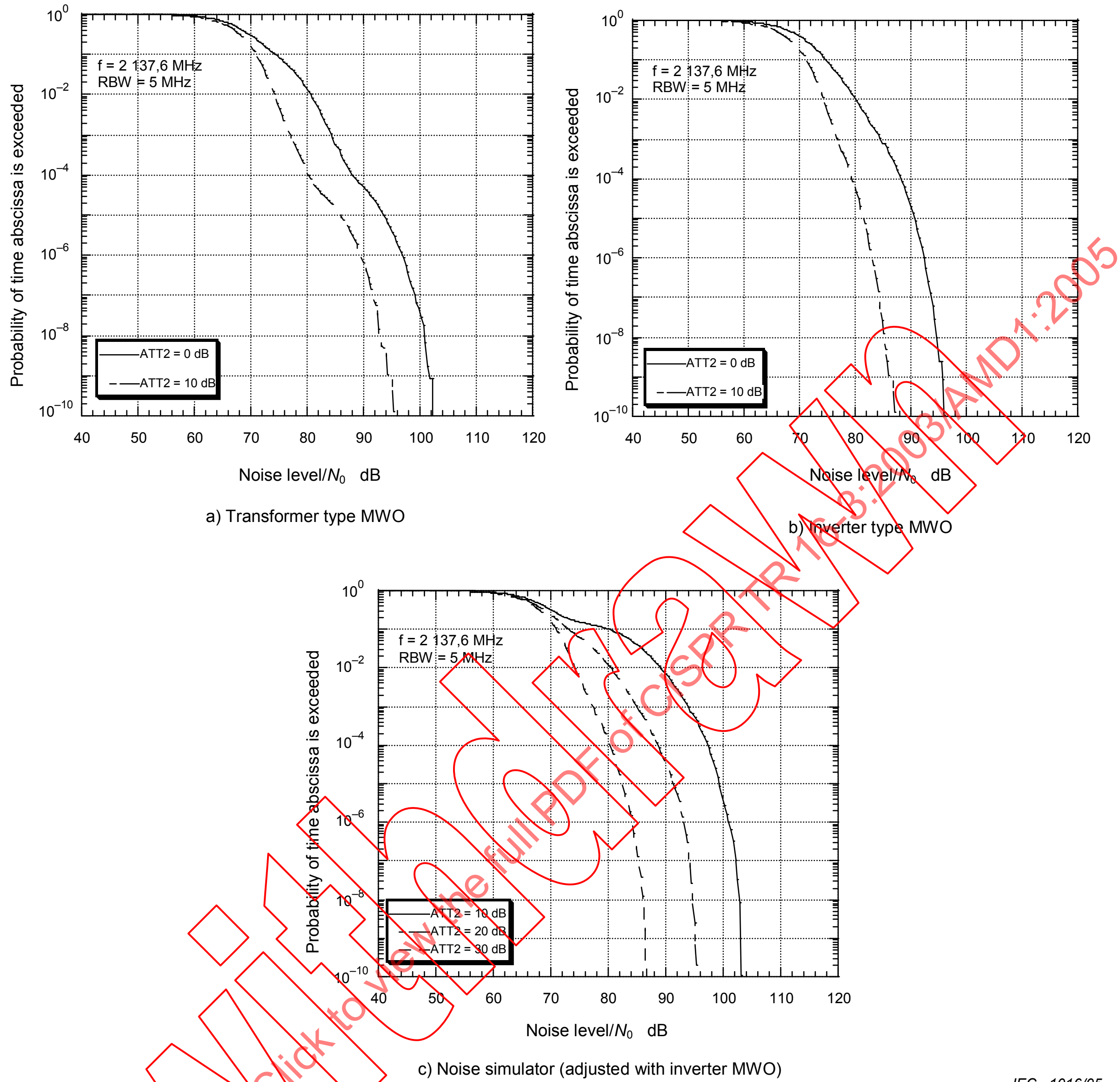


Figure 4.7.8 – Setup for measuring the BER of W-CDMA

Table 4.7.6 – Conditions for measuring communication quality degradation of W-CDMA

Base band simulator	Frequency	2 137,6 MHz (downlink)
	Chip rate	3,84 Mcps
	Spread rate	Uplink: DPDCH 64 / downlink: DPCH 128
	Data rate	12,2 kbps (acoustic)
	Transmission data	6 Mbit
	Transmission mode	RMC communication test (UE turn) 3GPP TS34.121

The measured APDs of the noise are shown in Figure 4.7.9, and the average and RMS values of the noise level normalized by N_0 are shown in Table 4.7.7. The APD of the noise simulator at *ATT2* = 0 dB is in good agreement with the APD of the inverter type MWO at *ATT2* = 10 dB.



IEC 1016/05

Figure 4.7.9 – APD characteristics of disturbance

Table 4.7.7 – Average and RMS values of noise level normalized by N_0

		ATT2				Receiver noise
		0 dB	10 dB	20 dB	30 dB	
Transformer type MWO	Average (dB)	71,1	67,7			67,2
	RMS (dB)	75,1	69,4			68,6
Inverter type MWO	Average (dB)	71,6	68,0			67,2
	RMS (dB)	74,7	69,4			68,6
Noise simulator	Average (dB)		77,1	70,4	67,7	67,2
	RMS (dB)		83,3	74,7	69,3	68,6

The measured communication quality degradation for various amounts of attenuation of injected noise is shown in Figure 4.7.10.

For both types of MWO, the BER was degraded by several dB after a 10 dB change in noise level. Moreover, BER characteristics influenced by the noise simulator are in good agreement in these measurement results.

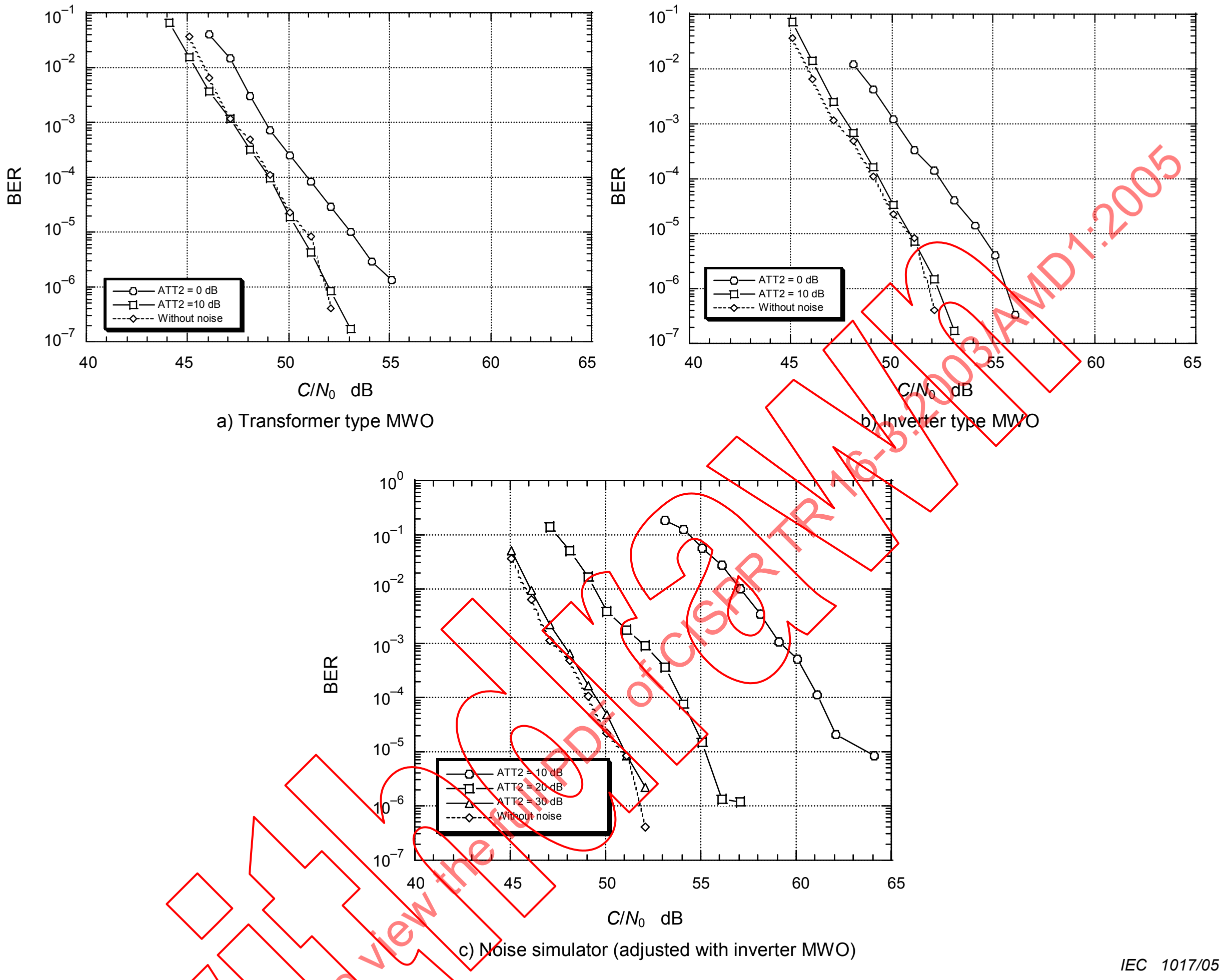


Figure 4.7.10 – BER of W-CDMA caused by radiation noise

4.7.5 Influence on Personal Handy Phone System (PHS)

The set-ups for measuring communication quality degradation are shown in Figures 4.7.11 and 4.7.12, and conditions for measuring throughput and BER are shown in Tables 4.7.8 and 4.7.9.

Throughput and BER were chosen as measures for evaluating the communication quality of PHS.

The measured APDs are shown in Figure 4.7.13, and the average and RMS values of noise normalized by N_0 are shown in Table 4.7.10.

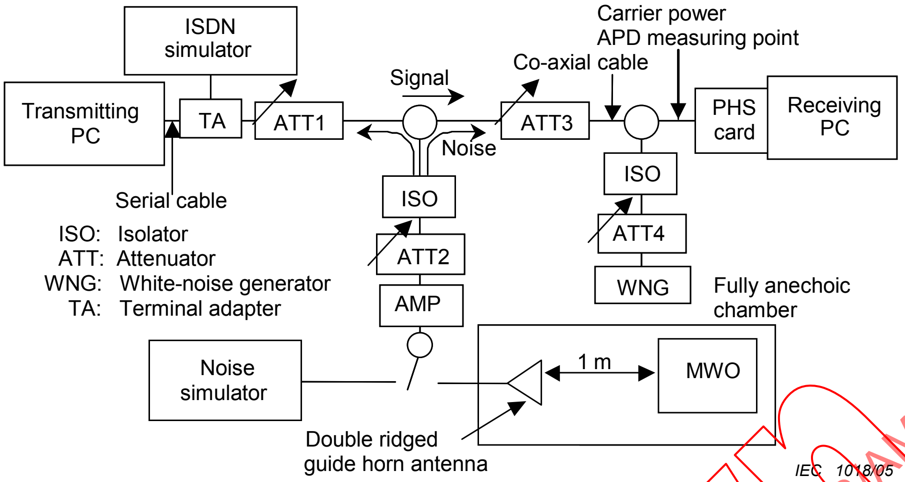


Figure 4.7.11 – Set-up for measuring the PHS throughput

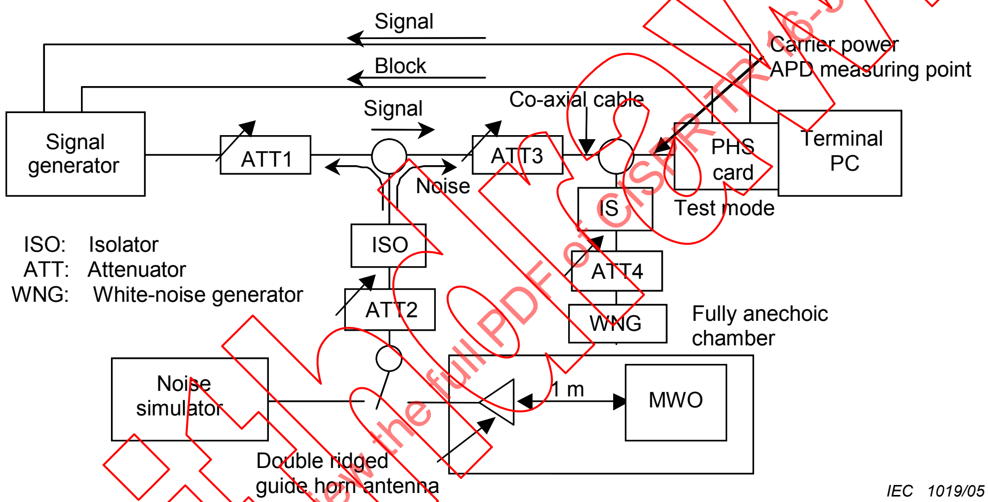


Figure 4.7.12 – Set-up for measuring the BER of PHS

Table 4.7.8 – Conditions for measuring the PHS throughput

PHS	Transmission data	About 376 kbytes data
	Transmission system	Non protocol
	Transmission mode	32 kbps real time data transmission
Others	Noise power density N_0 (dBm/Hz)	–160 dBm/Hz (set by ATT4)

Table 4.7.9 – Conditions for measuring the BER of PHS

PHS	Frequency (channel)	1 907,15 MHz (41ch)
	Transmission data	5 Mbit PN9
	Data rate	32 kbps
Others	Noise power density N0 (dBm/Hz)	–160 dBm/Hz (set by ATT4)

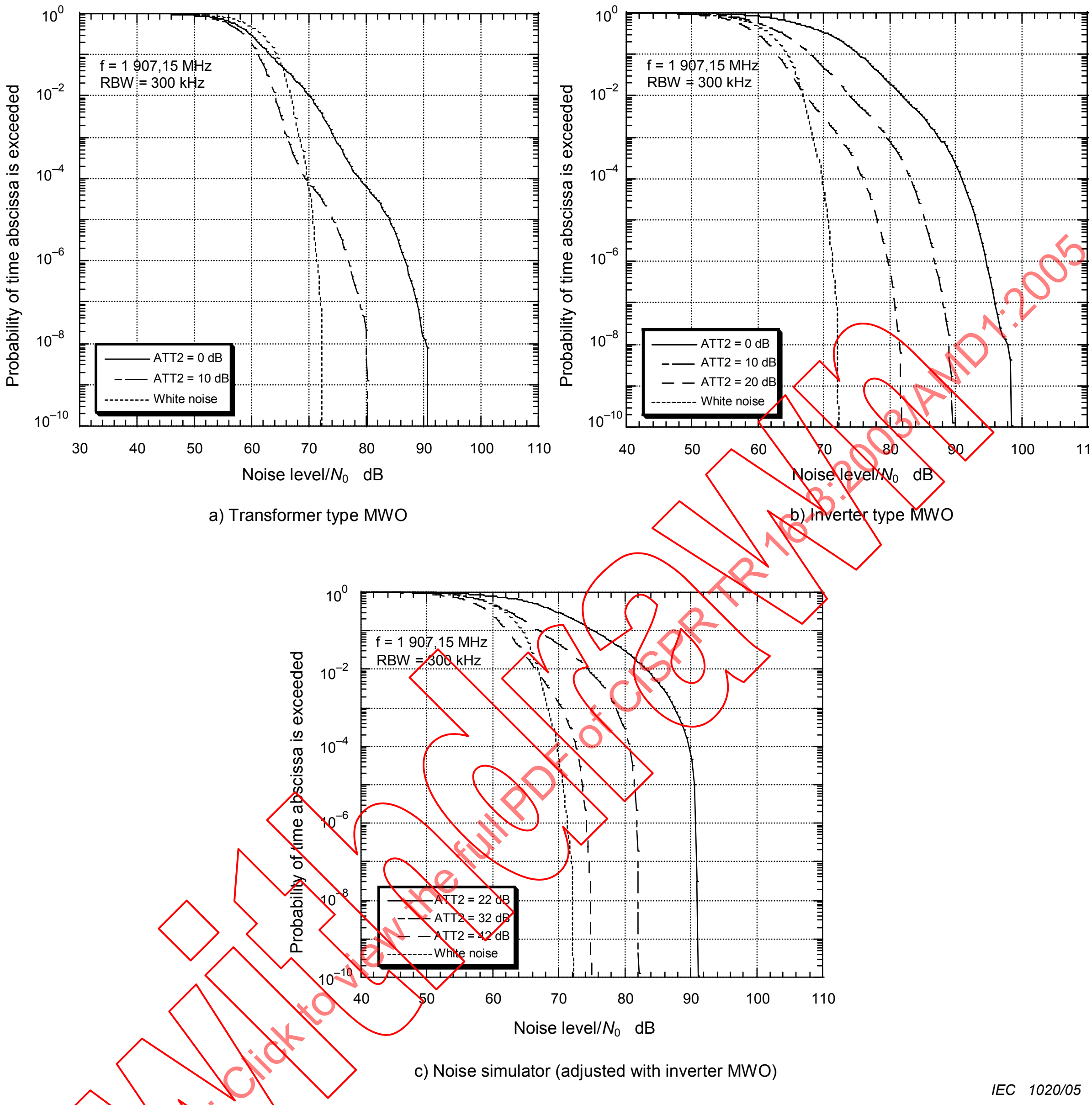


Figure 4.7.13 – APD characteristics of disturbance

Table 4.7.10 – Average and RMS values of noise level normalized by N_0

		ATT2				**White noise**
		0 dB	10 dB	20 dB	30 dB	
Transformer type MWO	Average (dB)	60,6	58,1			61,2
	RMS (dB)	64,9	59,4			62,4
Inverter type MWO	Average (dB)	72,6	64,9	59,9	58,0	61,2
	RMS (dB)	76,7	68,9	62,5	59,3	62,4
Noise simulator	Average (dB)	72,3	64,2	59,1	57,8	61,2
	RMS (dB)	77,0	68,2	61,1	59,0	62,4
NOTE The values of *ATT2* are 22, 32, 42 and 52 dB, respectively for the noise simulator.						

The measured throughput for various amounts of attenuation of injected noise is shown in Figure 4.7.14.

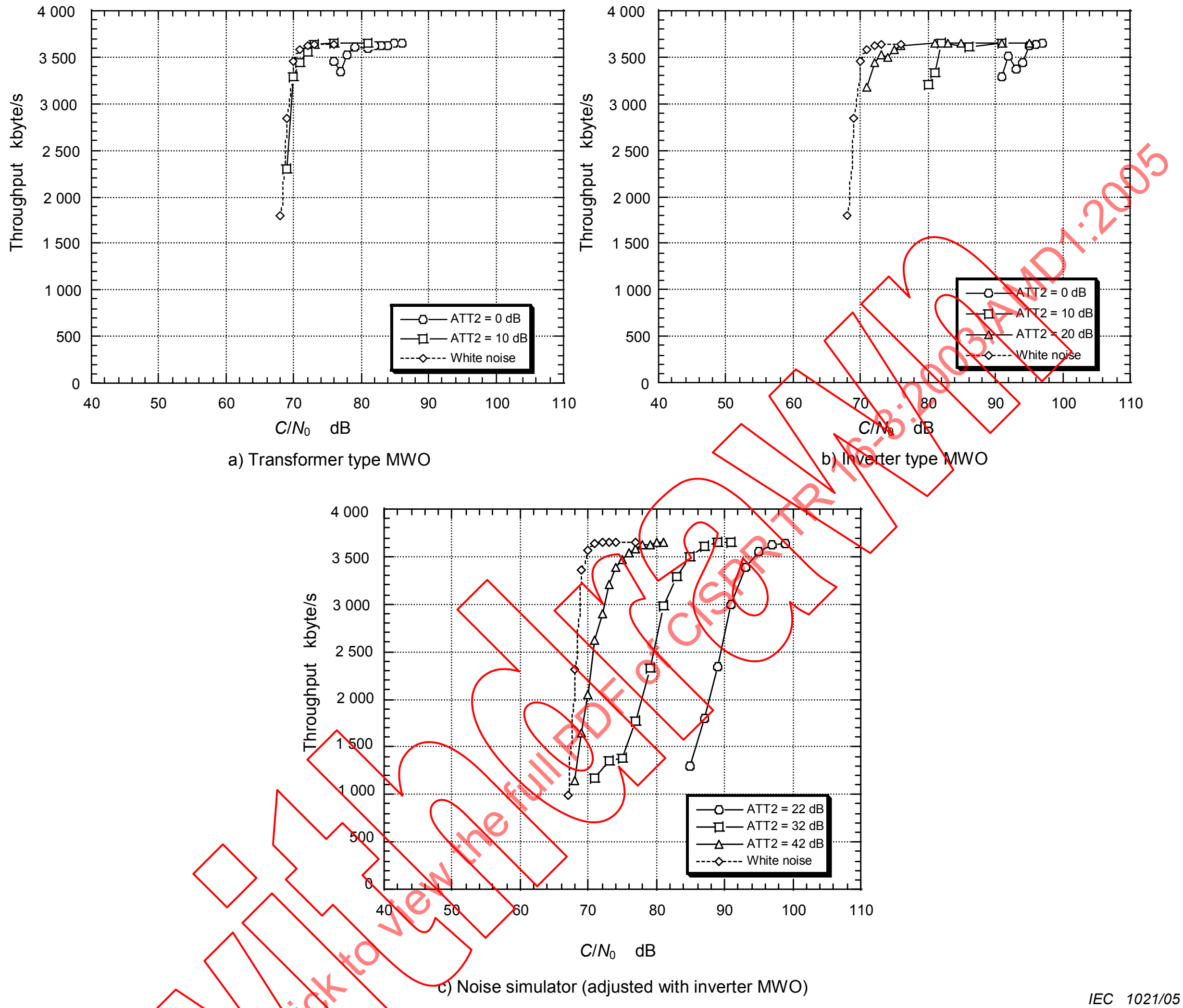


Figure 4.7.14 – PHS Throughput caused by radiation

Similarly, the measured BER is shown in Figure 4.7.15. The BER characteristics caused by the noise simulator were in good agreement in the measurement results of the inverter type MWO.

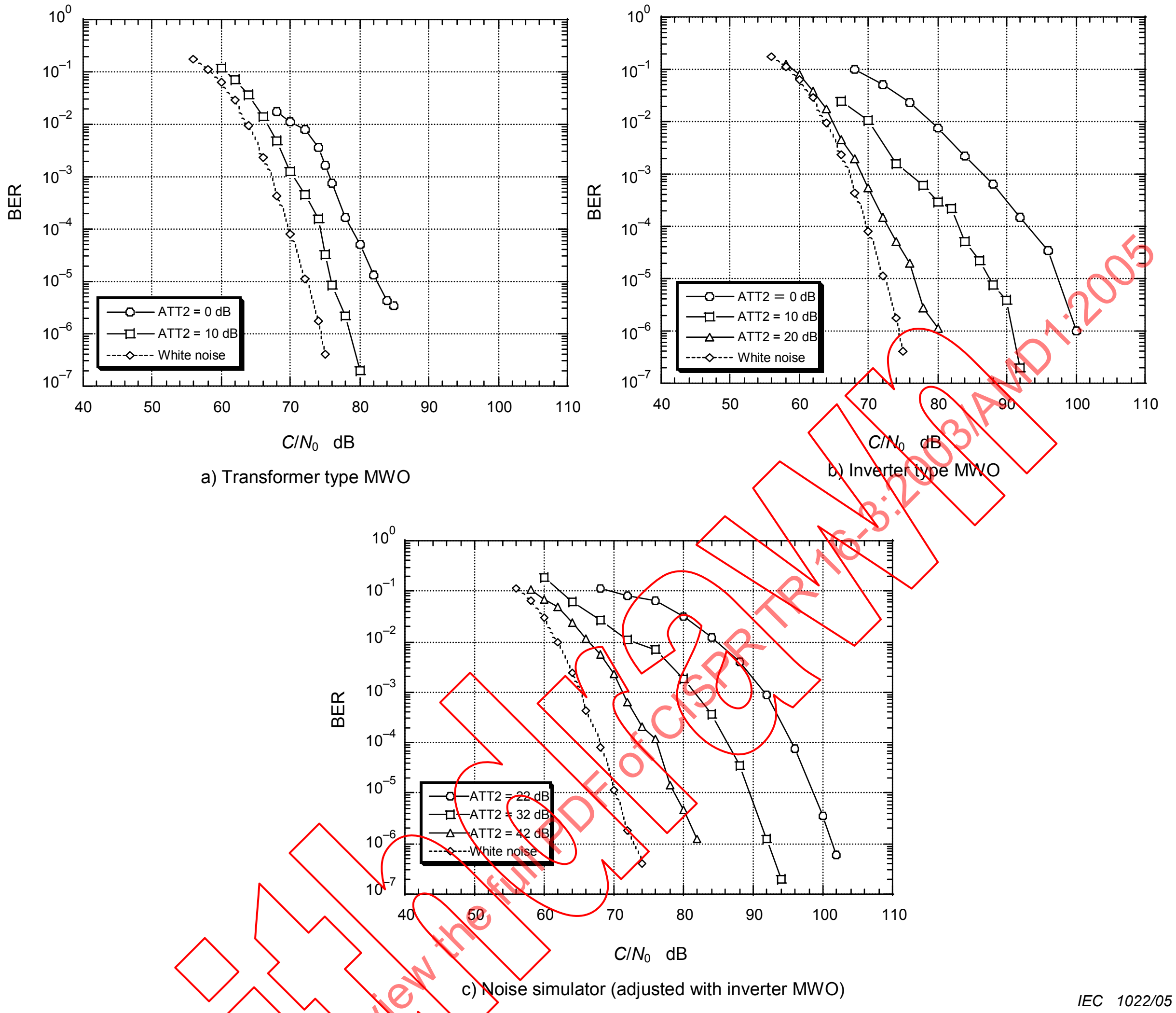


Figure 4.7.15 – BER of PHS caused by radiation noise

4.7.6 Quantitative correlation between noise parameters and system performance

Correlations between the noise parameter of the disturbance (levels of disturbance correspond to certain probability that is derived from APD) and degradation of system performance (throughput and/or Bit Error Rate) are evaluated for the communication systems described in 4.7.2 to 4.7.5.

4.7.6.1 Wireless LAN (throughput)

From Figures 4.7.2(a) and (b), the disturbance voltage for each probability, e.g., 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, was read. C/N_0 values that are necessary to assure the throughput of 500 kByte/s under microwave oven disturbance were obtained from Figures 4.7.3(a) and (b). The correlation between the disturbance voltages and the C/N_0 values is plotted in Figures 4.7.16(a) and (b) for a transformer type oven and inverter type oven, respectively.

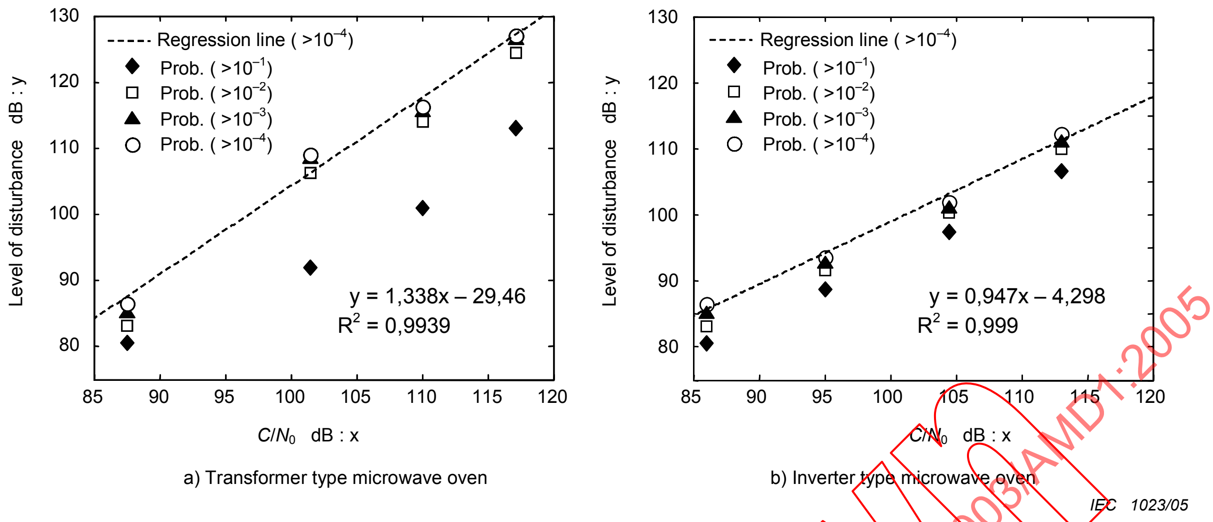


Figure 4.7.16 – Correlation of the disturbance voltages with the system performance(C/N_0)

In Figure 4.7.16, the linear regression line by using the values for 10^{-4} probability is also plotted with the equation and correlation coefficients *R*. It is found that 10^{-4} probability values are well correlated to the C/N_0 and thus these values are suitable for the noise parameters to estimate the degradation of the system performance.

4.7.6.2 Bluetooth (throughput)

From Figures 4.7.6(a) and (b), the disturbance voltage for each probability was read. As shown in Figure 4.7.4, not only MWO disturbance but also white noise was injected to the communication link. Then, disturbance voltages are meaningful only when MWO disturbance exceeds the white noise. Therefore, probability of 10^{-1} value was ignored and probability of 10^{-2}, 10^{-3} and 10^{-4} values were used in the evaluation below.

Relative C/N_0 values that are necessary to assure the throughput of 40 kByte/s under microwave oven disturbance were obtained from Figures 4.7.7(a) and (b) (Relative C/N_0 = 0 dB corresponds to ATT1= 43 dB). The correlation between the disturbance voltages and the relative C/N_0 values are plotted in Figures 4.7.17(a) and (b) for a transformer type oven and inverter type oven, respectively.

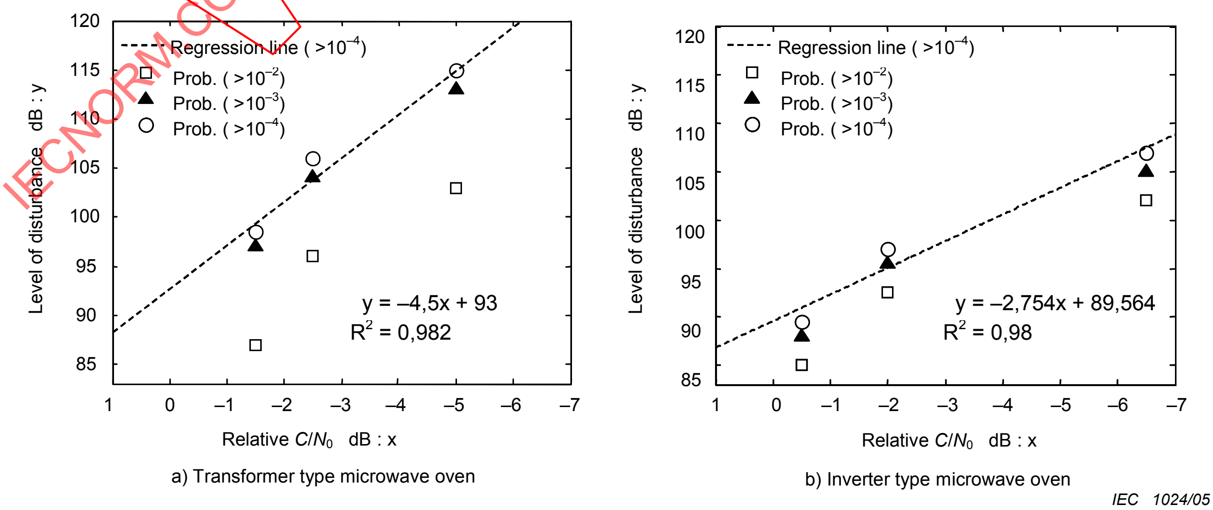
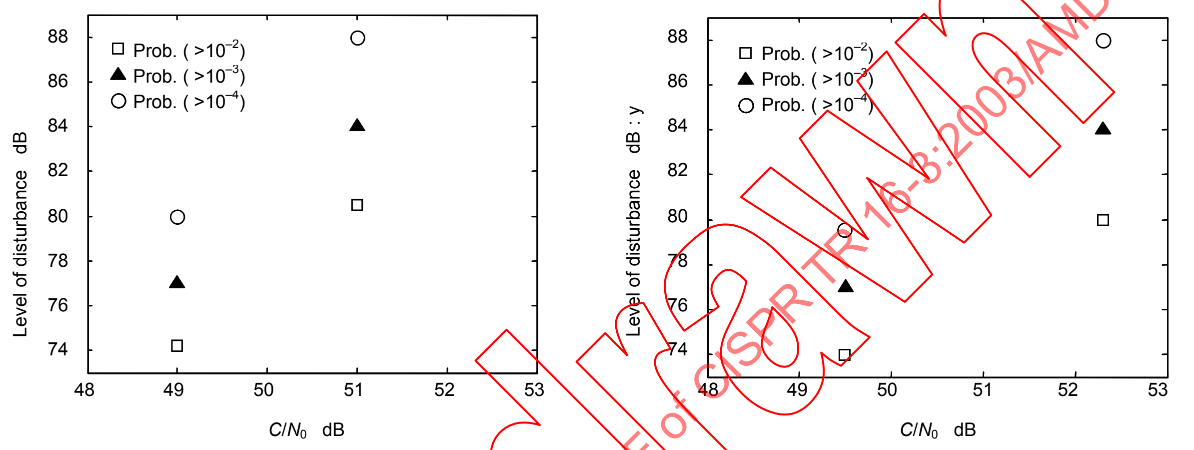


Figure 4.7.17 – Correlation of the disturbance voltages with the system performance

In Figure 4.7.17, the linear regression line by using the values for 10^{-4} probability is also plotted with the equations and correlation coefficients. The same results were obtained as in subclause 4.7.6.1.

4.7.6.3 W-CDMA (BER)

From Figures 4.7.9(a) and (b), disturbance voltages for each probability, e.g., 10^{-2}, 10^{-3}, 10^{-4}, were read. C/N_0 values that are necessary to assure the BER of 10^{-4} under microwave oven disturbance were obtained from Figures 10(a) and (b). Because only two curves available in the APD and BER, regression analyses were not performed.



a) Transformer type microwave oven b) Inverter type microwave oven

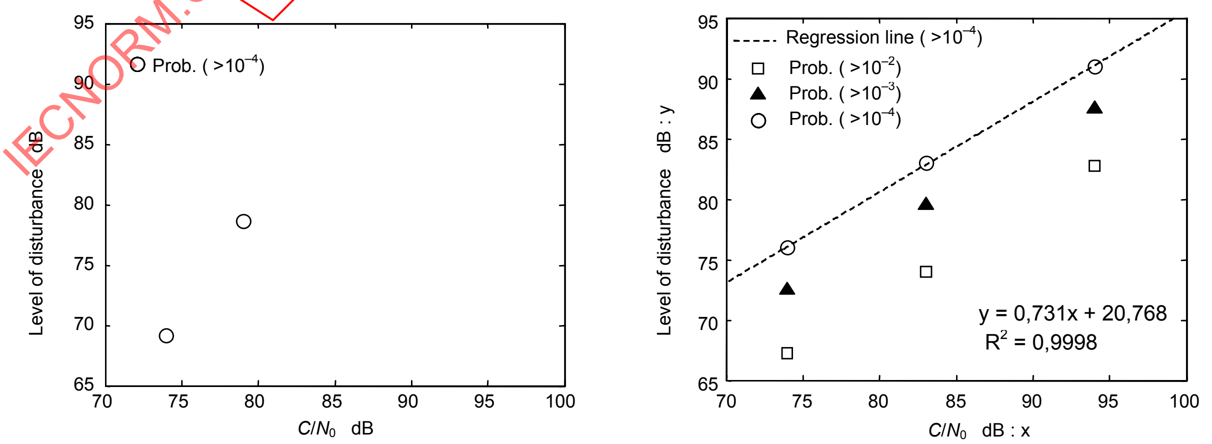
IEC 1025/05

Figure 4.7.18 – Correlation of the disturbance voltages with the system performance

4.7.6.4 PHS (BER and throughput)

Same analyses were performed on PHS data. C/N_0 values correspond to the signal input that is necessary to assure the BER of 10^{-4} under microwave oven disturbance. The correlation between the disturbance level and the C/N_0 values is plotted in Figures 4.7.19(a) and (b) for a transformer type oven and inverter type oven, respectively.

Because only one set of data was usable in the APD and BER for the transformer type oven, regression analysis was not performed. On the other hand, excellent correlation was confirmed in the case of inverter type oven.



a) Transformer type microwave oven b) Inverter type microwave oven

IEC 1026/05

Figure 4.7.19 – Correlation of the disturbance voltages with the system performance(C/N_0)