In addition, to properly judge the interference potential of these various sources, the probability of interference must also be taken into account. A comparison was made between EMC, UWB and thermal noise. It could be seen that, for a 1 MHz receiver bandwidth, the probability of the aggregate interference levels from three UWB devices being higher than thermal noise was less than 0.1%. In the case of EMC emissions, this probability was up to 1%.

6 Validation Measurements

Validation measurements were performed in the anechoic chamber in order to obtain fundamental information on the ability of EMC emissions to cause an upset to radio services.

The following measurements were made:

1. The effect of EMC emissions from a single electronic product (laptop and desktop) to GSM.
2. The effect of accumulative EMC emissions from various electronic products (operating at the same time) to GSM.
3. The effect of AWGN and UWB interference (at FCC limits) to GSM.
4. The effect of EMC interference to WLAN
5. The effect of accumulative EMC emissions from various electronic products (operating at the same time) to WLAN
6. The effect of AWGN and UWB interference to WLAN

6.1 GSM Validation Results

Figure 32 shows the set-up for in the anechoic chamber used for measuring the interference from a desktop PC to a GSM mobile phone. A GSM simulator was used to produce a controlled link with the mobile phone, allowing complete control of channel selection, and transmitted base-station and mobile phone output power levels.

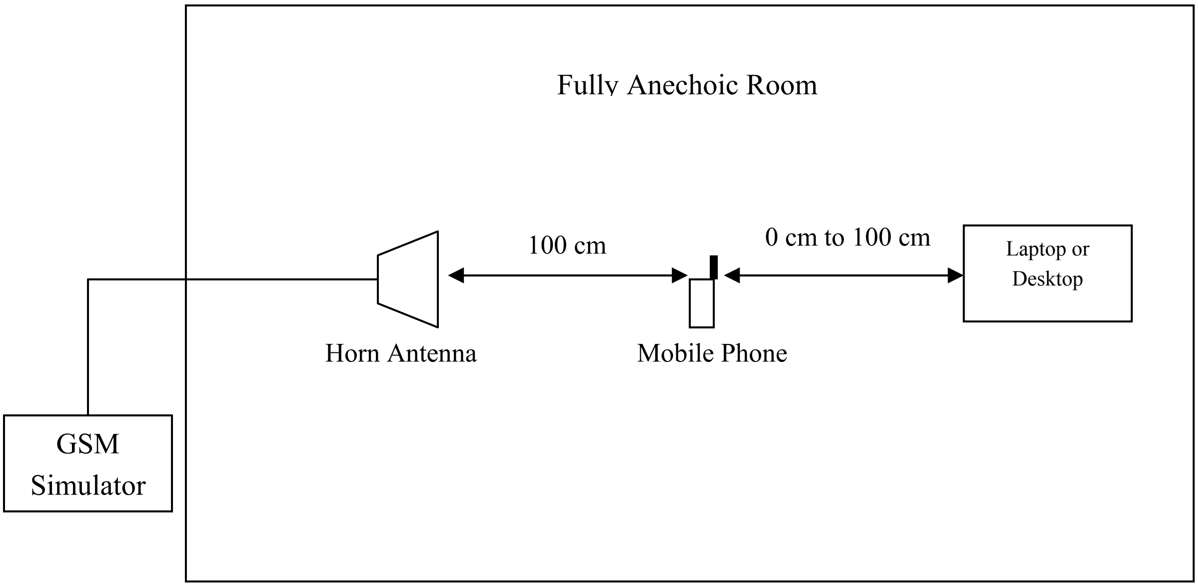

Figure 32: Test set-up for laptop/desktop vs. GSM

Figure 33 shows a photograph of the anechoic chamber set-up for measuring the effect of EMC interference from multiple electronic equipment to a GSM phone.

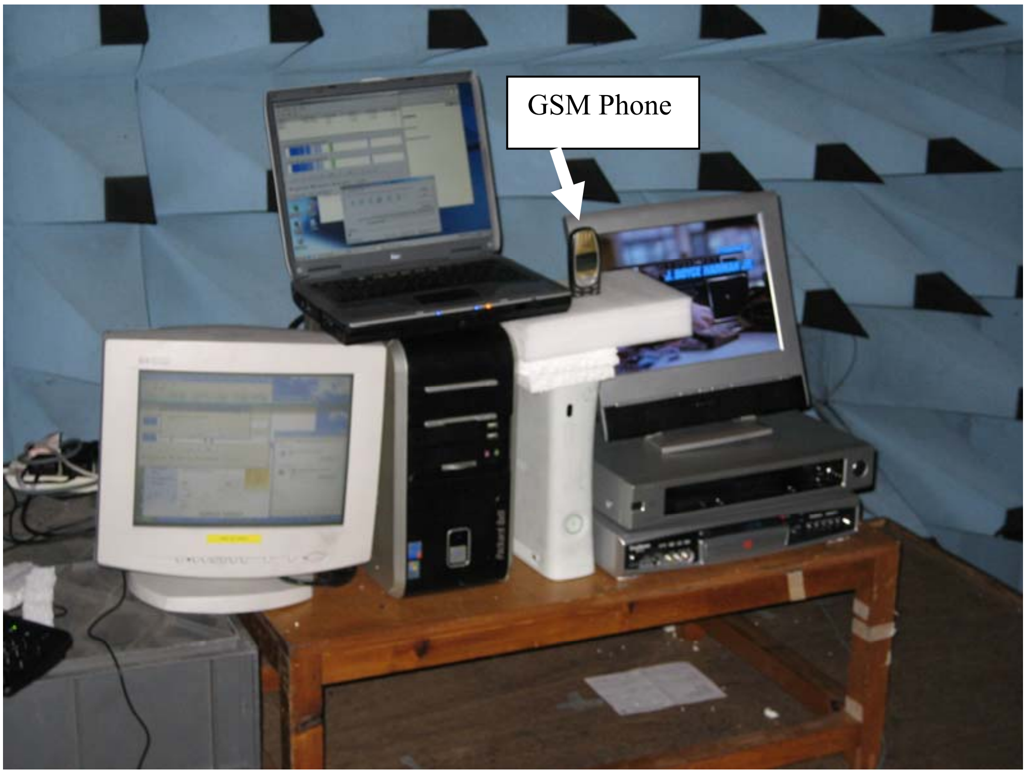

Figure 33: Photograph of set-up for multiple equipment EMC interference to GSM

The GSM channel was selected to coincide with the maximum EMC emissions from the equipment under test. The GSM simulator was used to monitor the quality of the GSM received signal in the presence of interference. The level of the GSM signal received at the phone required to maintain a certain quality level was recorded. The receive quality (RxQ) is compared to the bit error rate (BERR) in Table 13.

Table 13: Comparison of receive quality (RxQ) and Bit Error Rate (BERR) for GSM

RxQ	BERR
1	0.2 – 0.4%
2	0.4 – 0.8%
3	0.8 – 1.6%
4	1.6 – 3.2%
5	3.2 – 6.4%
6	6.4 – 12.8%
7	>12.8%
8	Lost signal

Two mobile phones were tested, a Nokia 6110 and a Motorola V3. Each phone was separately placed at a constant distance of 1 m away from the horn antenna connected to the GSM simulator. The source of EMC emissions (laptop or desktop) was placed at variable distances from 100 cm, 50 cm, 25 cm, 10 cm and 0 cm from the phone. Once the mobile phone was active i.e. linked to simulator, the receive quality and power were monitored and recorded for the different distances between the laptop/desktop and the mobile phone.

The results using the Nokia 6110 phone on channel 786 are shown in Figures 34 and 35. The Figure 34 results used the laptop as the interference source and the Figure 35 results used the desktop PC as the interference source. These graphs show the required carrier field strengths in the absence of interference and in the presence of interference. In the absence of interference the required carrier field strength required to achieve a receive quality (RxQ) of zero was 55 dBμV/m. With the interfering sources at 25 cm from the mobile phone the additional carrier level required to maintain an RxQ of zero was about 15 dB for the laptop and 25 dB for the desktop. This is what would be expected as the emission level from the laptop in channel 786 was 11 dB below that for the desktop PC.

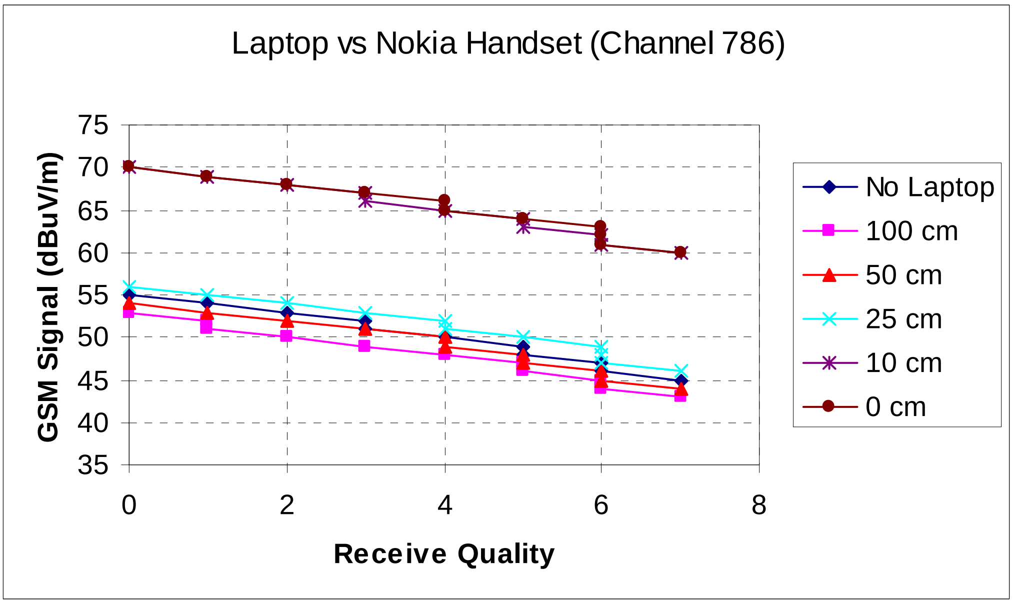

Figure 34: Electric field strength of the received GSM signal vs. receive quality as a function of laptop separation distance for a Nokia handset

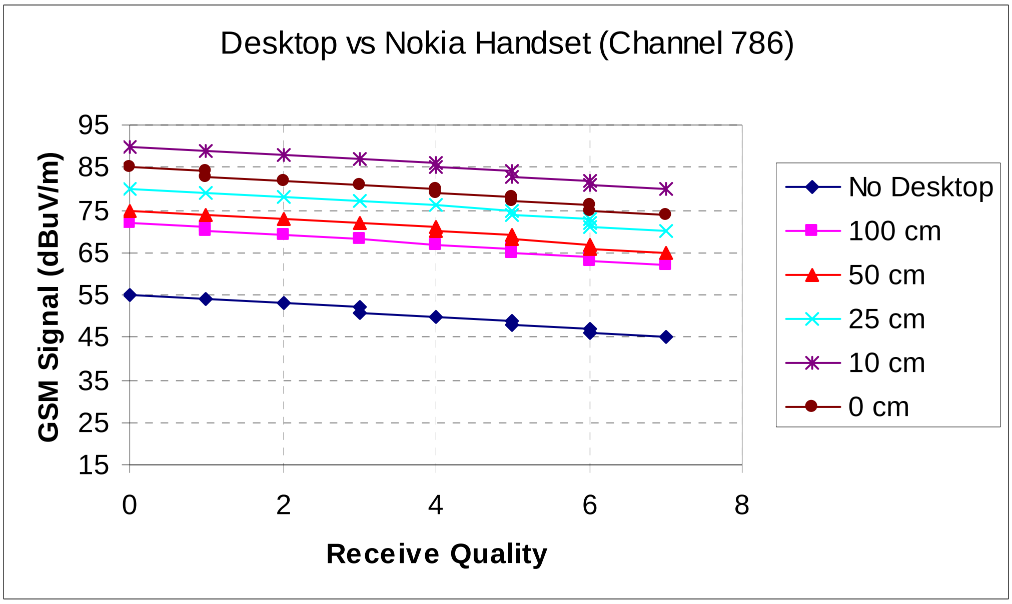

Figure 35: Electric field strength of the received GSM signal vs. receive quality as a function of desktop separation distance for a Nokia handset

Figure 36 shows a comparison of the effect of interference from a single piece of equipment, in this case the desktop, and accumulative interference from five pieces of equipment.

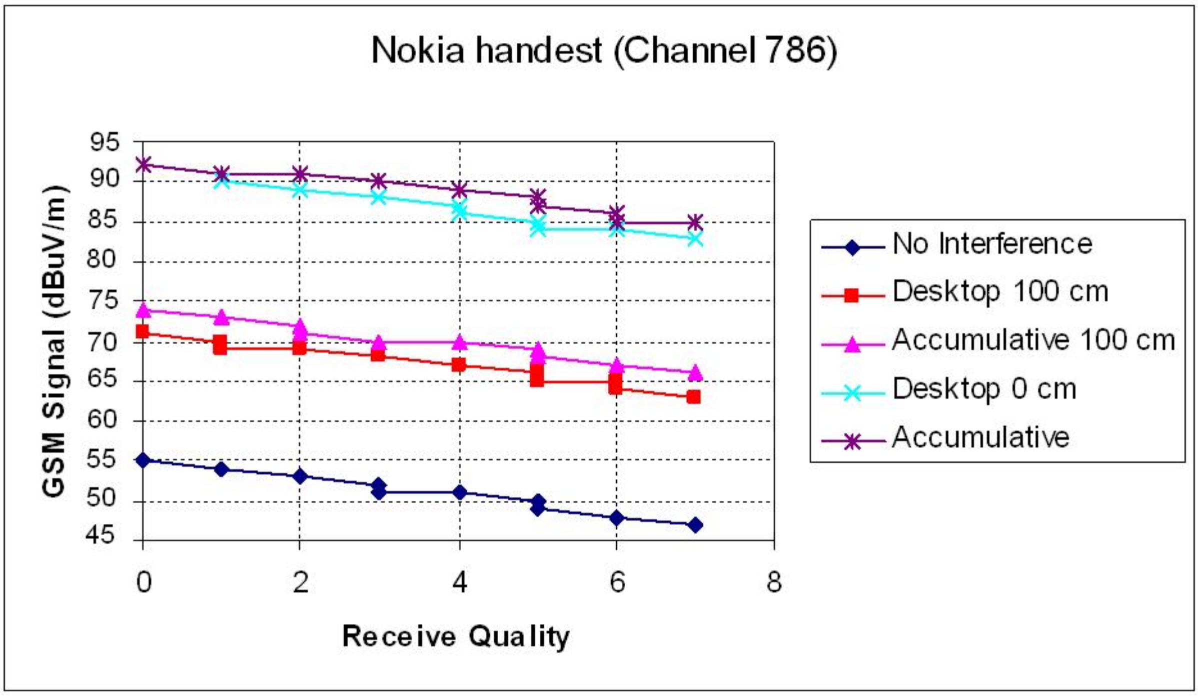

Figure 36: Electric field strength of received GSM signal vs. receive quality for accumulative interference (channel 786)

It should be noted that the emissions from the desktop PC in channel 786 were higher than for the other items of equipment, and therefore it would be expected that the emissions from the desktop PC would dominate. The required carrier field strength for the aggregate emissions were a few dBs higher for an interferer distance of 100cm. For the 0cm separation distance, that is with the mobile phone 0cm from the desktop PC but 10cm to 30cm further from the other items of equipment, the accumulative emissions were perhaps marginally higher.

These results demonstrate that it is possible to cause interference to a GSM phone with EMC emissions from typical electronic equipment but only under fairly worst-case conditions with either the phone operating at around its minimum usable signal level or with the interferer very close to the phone.

It was possible to estimate the effective C/I for the mobile phones experiencing interference from EMC emissions. For a range of measurements carried out on several mobile phones the effective C/I was between 3 and 16 dB, which was quite a wide range. This compares to the target C/I of 9 dB used for the Monte-Carlo modelling.

Interference measurements were also made using UWB and AWGN as interference sources. A single channel of a Multi-band (MB) Orthogonal Frequency Division Multiplex (OFDM) UWB source was created using a R&S AMIQ box connected to the external I/Q ports of an Agilent E4438C signal generator. The power from the AWGN and UWB signals were set to the FCC UWB limit of –53.3 dBm/MHz for indoor devices below 1.99 GHz and the results were corrected for a distance of 1 m for a direct comparison of the EMC emission results from the laptop and desktop devices described previously. There was no activity factor used for the UWB interference source. The results are shown in Figure 37, which compares the UWB and AWGN results with the laptop and desktop PC results, all at 100cm.

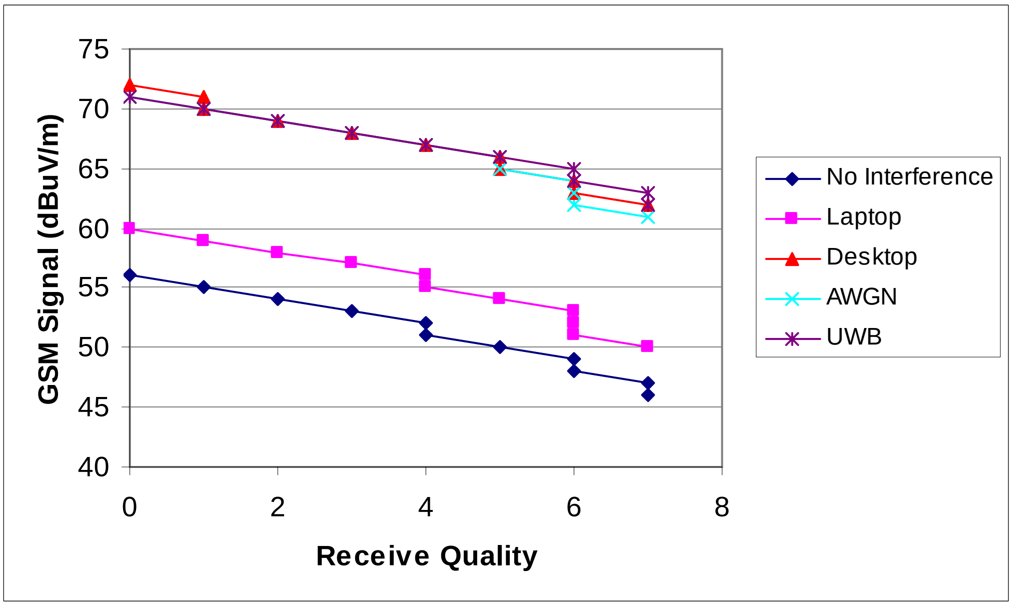

Figure 37: Electric field strength of received GSM signal for AWGN, UWB and EMC interference measured at 1 m respectively vs. receive quality for a GSM phone

It can be seen that the interference from the AWGN and UWB at the FCC level is similar to that from the desktop PC, when using no UWB activity factor.

6.2 Interference results for WLAN

The test set-up for EMC emissions interference to a wireless router used to communicate between two laptops is shown in Figure 38. The throughput measurement tests were carried for the router inside a FAR. Laptop A was connected to the router using Ethernet cable. Laptop B was placed inside the FAR and a link between the router was established via a wireless connection. Data was then transmitted from laptop A to Laptop B and the data rate was monitored on laptop B for any degradation during the testing. The WLAN Router was set to channel 6 (2.437 GHz). This channel was chosen to coincide with the maximum EMC emission from the desktop. The received Wi-Fi wanted signal on the laptop was set to a minimum usable signal of 15 % using the attenuator connected to the router as shown in Figure 38.

The throughput was measured for no interference and for the desktop placed at 100 cm, 50 cm, 25 cm, 10 cm and 0 cm from the router.

The peak and RMS electric field strength of the router was measured as 101.14 dBuV/m and 94.50 dBuV/m, respectively, at a distance of 100 cm using a 20 MHz RBW, for a low received laptop signal level of 15 %

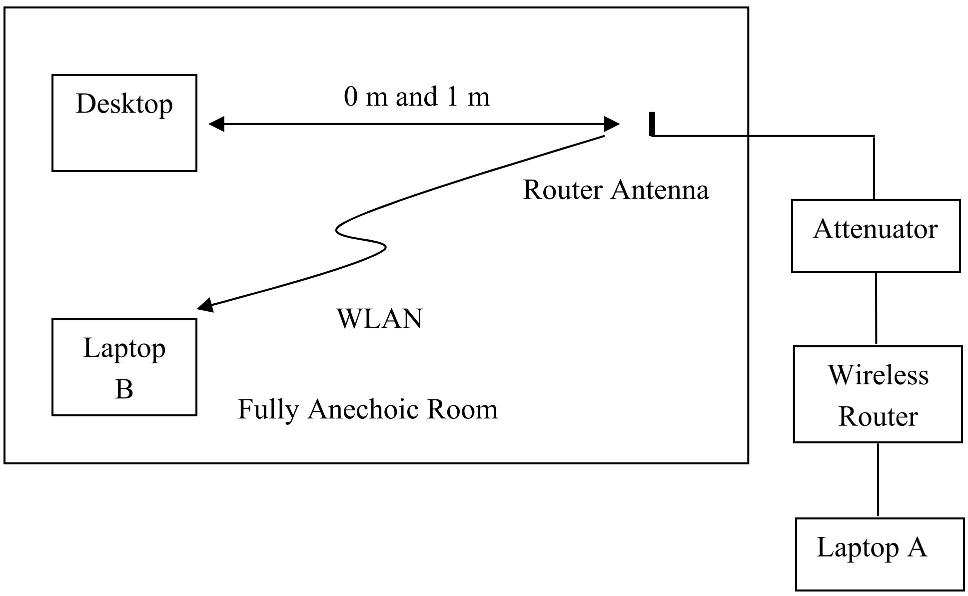

Figure 38: Measurement set-up for EMC interference to WLAN

The results are shown in Figure 39 using just the desktop PC as a source of interference, and also using five items of equipment to give accumulative EMC emissions. It can be seen that for both the single desktop and for accumulative EMC emissions, the throughput starts to drop significantly at about 10cm or less. The accumulative emissions had less of an effect and this was probably due to the Wi-Fi not being as near to the desktop PC during the accumulative measurements than for the desktop on its own, due to the other 4 items of equipment being used.

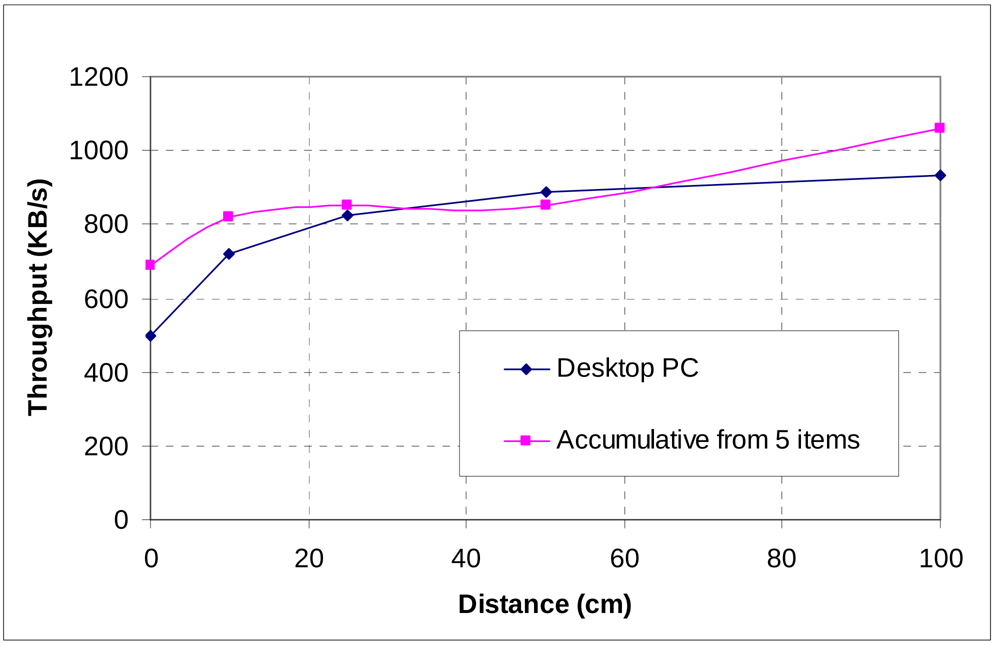

Figure 39: Effect of throughput due to EMC emissions from desktop PC interfering with WLAN

The throughput versus time is plotted in Figures 40 and 41 for the desktop PC being 100cm and 0cm separation distances from the Wi-Fi, respectively. It can clearly be seen how the Wi-Fi throughput is more severely affected with the desktop PC closer to the Wi-Fi system.

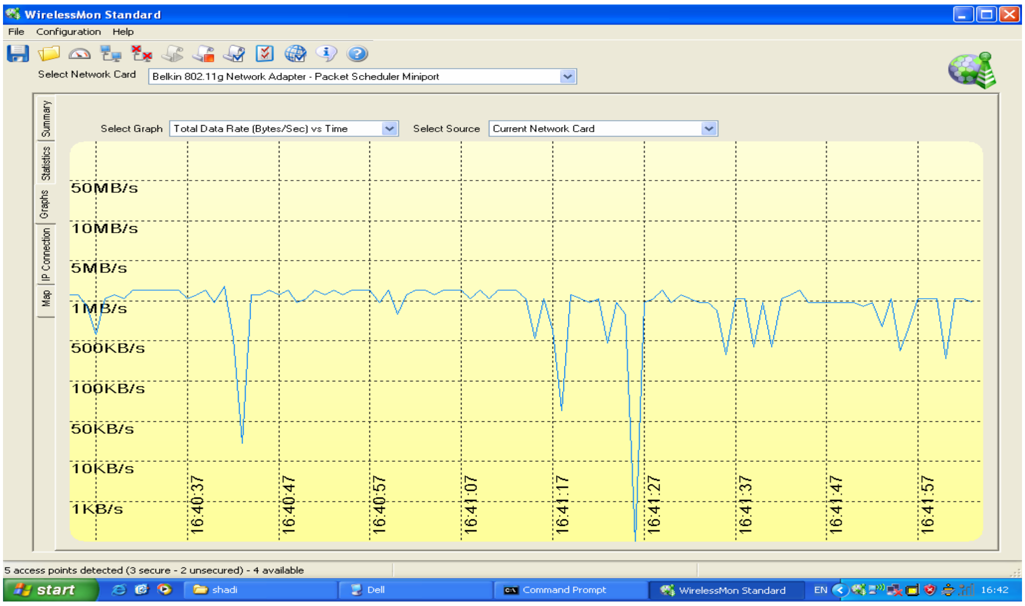

Figure 40: WLAN throughput with a desktop PC at a separation distance of 100 cm

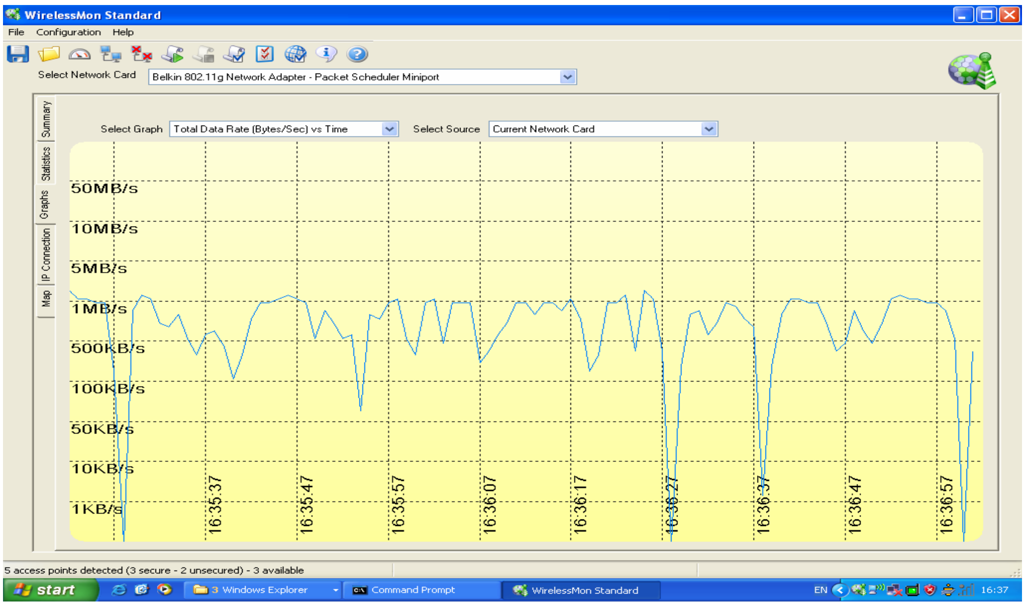

Figure 41: WLAN throughput with a desktop PC at a separation distance of 0 cm

UWB and AWGN were also used as interference sources for the Wi-Fi receiver. Once again, there was no activity factor associated with the UWB source and this would in reality be typically less than about 5%. Although accumulative UWB emissions from a number of UWB devices would tend to increase the effective activity factor, as each UWB device filled in more of the time period, using a single device with a 100% activity rate is likely be too worst-case for most radio-communications systems.

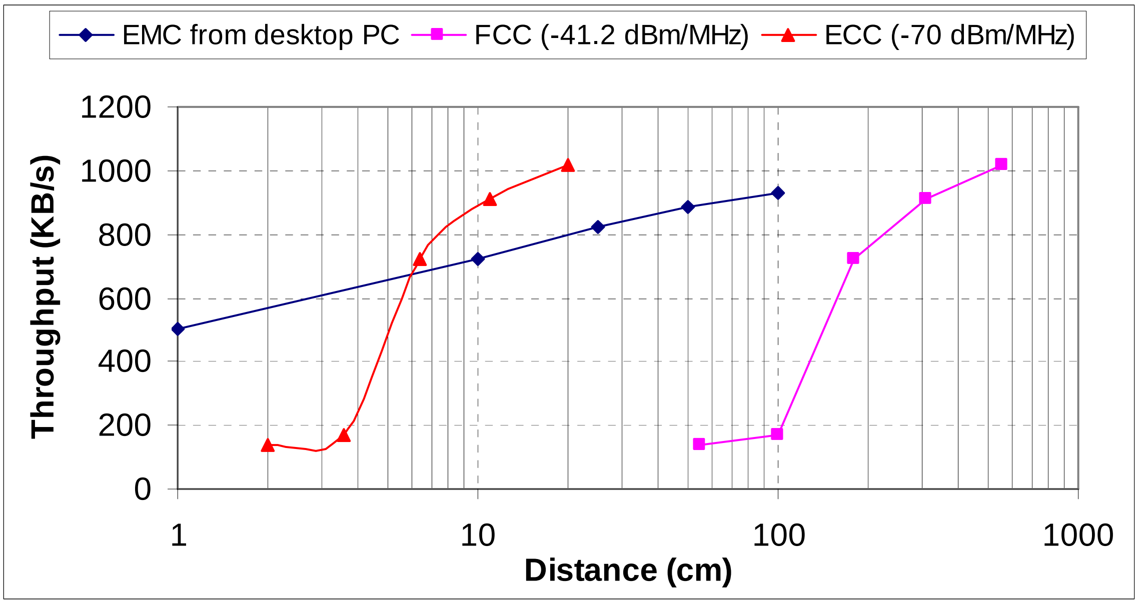

Figure 42: Interference to WLAN from AWGN and OFDM at 1m

With these caveats in mind, Figure 42 shows that the EMC emissions were similar to the ECC UWB emissions. For the EMC emissions, the interferer needed to be 10cm or so from the Wi-Fi system to avoid significant interference. For the ECC UWB emissions, the required separation distance is of the same order, but the throughput falls off more rapidly for ECC UWB emissions at distances of a few cms, than for EMC emissions. With FCC UWB emission levels, the required separation distances are typically a few metres. Once again, it must be stressed that the UWB source had a 100% activity factor and the effect of more realistic activity factors should be investigated.

7 Analysis of Results

This main issues that are important in order to answer the question whether future unwanted emissions are a threat to radio services and how any risk should be controlled are:

- EMC Emissions
    - o Current and future EMC levels from single items of equipment