

Electromagnetic emission from domestic electric equipment of 20th and 21st centuries in the aspect of electromagnetic compatibility

Abstract. *The electromagnetic environment in the residential area is dominated by consumer electronics, household appliances and IT equipment. Many of the devices in use are products that were manufactured in the late 20th and early 21st centuries. The paper presents an analysis of how the electromagnetic emissions of such devices affect the environment. Tests were carried out in the area of radiated and conducted emissions, and the results were compared with current environmental limits.*

Streszczenie. Środowisko elektromagnetyczne w obszarze mieszkaniowym zdominowane jest przez urządzenia RTV, AGD i informatyczne. Wiele użytkowanych urządzeń to produkty, które wyprodukowane zostały na przełomie XX-XXI wieku. W pracy podjęto się analizy jak emisja elektromagnetyczna tego typu urządzeń wpływa na środowisko. Przeprowadzono testy w obszarze emisji promieniowanej i przewodzonej, a wyniki odniesiono do obowiązujących limitów środowiskowych. (Emisja elektromagnetyczna domowych urządzeń elektrycznych XX i XXI wieku w aspekcie kompatybilności elektromagnetycznej).

Keywords: electromagnetic compatibility, electromagnetic emission, power quality, electric devices

Słowa kluczowe: kompatybilność elektromagnetyczna, emisja elektromagnetyczna, jakość energii, urządzenia elektryczne

Introduction

The number of electrical devices used in industry and homes is constantly increasing. This creates the need to verify their impact on the environment, on the electrical objects coexisting in it. Issues of electromagnetic compatibility include quality and safety analyses and are now defined by appropriate legislation and research methodology. Unfortunately, many households and workplaces still actively operate equipment that was introduced to the market decades ago, when other standards were in force and compatibility issues were not applicable. This raises the need to monitor the impact of such devices on the electromagnetic environment.

Currently, in European countries, newly designed and manufactured electrical equipment and installations are subject to requirements regarding their quality and ensuring safety during their use. An important issue is the compliance of equipment with electromagnetic compatibility (emc) conditions. EMC is understood as the ability to operate in an electromagnetic environment without causing disturbances of a magnitude higher than the immunity of other systems or apparatus coexisting in a given operating environment. This is the basis for allowing the device to be placed on the market. On the basis of the conducted tests of emissivity and immunity, it is possible to determine the levels of electromagnetic compatibility. This makes it possible to market the device and operate it safely. [8-11]

Trends in the household - Poland

Households are among the smallest but most numerous economic entities. They play a very important economic role due to the fact that they dispose of a significant portion of the national income and purchase many goods and services. Meeting the needs of household members occurs through: producing goods, acquiring them through purchase, obtaining them from social funds and using public goods which is the realization of the production and supply function. Satisfaction of needs also includes the realization of the consumption function, understood as the use of goods and the use of services. [1-3]

In assessing the material development of the population, the housing stock and the stock of durable goods are taken

into account. Changes in household behavior in the market for durable goods are mainly determined by the amount of disposable income, the level of unemployment and the amount of inflation. An increase in employment and wage levels increases demand for durable goods while an economic slowdown reduces demand. [1-3]

Utility equipment is characterized by durability and significant purchase cost. The degree to which needs are satisfied depends on the quality and quantity of things in the household. This translates into the level of satisfaction of household members. This is mainly due to the fact that they make work easier and shorter. Home appliances optimize the amount of leisure time and create various opportunities for its use, which improves the quality of life. Durable goods are most often divided into [3]:

- kitchen: used for food preparation and storage (including refrigerators, freezers, stoves, food processors, microwaves)
- general household: used for cleaning and maintenance of clothes (among others, washing machines, dryers, vacuum cleaners, irons)
- electronic: used for entertainment and leisure (including televisions, consoles, computers, laptops).

In 1989, free market rules began to dominate in Poland. Households began to modify their consumption behavior. The initial years of transition were a time of low financial condition and most income was spent on basic needs. However, in the early 1990s. Poles were increasing spending and consumption behavior was on the rise. The level of supply had increased, the distribution network was being expanded, and goods were gaining in quality. People assessed that their basic needs were being met sufficiently, but home furnishings and household appliances were still in short supply. In Poland, between 2000 and 2012, there was an increase in the level of households equipped with audiovisual and household appliances. In 1997, only 65.4% of households had a washing machine and 92.3% of households were equipped with a television. By 2012, the level of equipment in these categories had steadily increased and they had become commonplace, as had cell phones, refrigerators and vacuum cleaners. In 2012, satellite TV reception devices, computers, food processors,

microwave ovens or digital cameras were estimated to be present in between 50 and 80 percent of households. The changes in equipment taking place concerned not only the number of devices, but also an increase in the quality and modernity of the equipment. There was a decrease in equipment with VCRs and video players in favor of an increase in equipment with DVD players and home theater sets. There was also a very significant increase in dishwashers and microwave ovens. In 2012, compared to 2010, there was a more than 3-fold increase in the number of computers, and a more than 10-fold increase in the number of computers with Internet access. [1,2,3]

According to the GUS's publication on household energy consumption [5], there were 14.4 million households in Poland in 2018. The average number of people per household was 2.6. Polish households consumed 18.2% of the national energy consumption. Electricity was used in households mainly to power household appliances and consumer electronics, as well as to light rooms. The use of electricity for space heating was low due to high costs and the existence of cheaper alternatives. In the period from 2002 to 2018, an increasing use of more energy-efficient technologies was observed. During this period, an increase in the average consumption of electricity by households was noted, which was a consequence of the increase in the number of electrical and electronic devices that equip homes. [4-6]

Table 1. Durable household items in 2021, in Poland [4]

Household appliances	Total	employees	farmers	self-employed		pensioners
					%	
CRT receiver	2.4	1.7	6.3	0.9	3.3	
Plasma or LCD TV receiver	94.1	93.6	94.1	92.6	95.6	
Satellite or cable TV receiving device	63.1	66.0	57.3	65.5	59.5	
Home theater set	10.1	13.4	3.6	18.6	3.9	
Audio recording and playback equipment	59.8	56.8	73.2	55.3	64.6	
Personal computer	75.4	90.5	89.2	94.1	46.9	
A device with Internet access	86.1	97.1	95.3	97.8	65.8	
Game console	13.9	20.0	14.6	25.3	1.9	
Printer	37.7	47.8	53.2	70.7	13.3	
Cell phone	98.6	99.7	99.5	99.2	96.6	
Smartphone	80.7	92.5	90.5	92.6	59.3	
Automatic washing machine	94.7	94.8	96.2	92.9	95.1	
Microwave oven	63.8	70.9	74.2	72.6	50.3	
Dishwasher	47.6	57.5	57.4	76.6	26.1	

Trends in the household - Ukraine

Similar parallels can also be observed in the neighboring country of Ukraine. Here, too, there has been a dynamic change in the level and quality of household furnishings with consumer electronics and appliances since the political transition. Statistics on the use of electrical and electronic appliances in households in Ukraine before 2000 and now, as in Poland, are conducted at the national level - by the State Statistics Service of Ukraine.

For more than 20 years, the situation regarding the use of various in-home and out-of-home devices has changed markedly. It should be noted that the use of many electrical and electronic devices has been influenced by their availability and cost, as well as by the emergence of completely new scientific and technological developments, such as the Internet and mobile communications. For

example, the number of home Internet users in Ukraine has increased in 20 years from a few percent in 2000 to more than 77 percent today, and the same is true of cell phone use.

The use of home appliances is related to norms and standards, which have changed a lot in more than 20 years. In the past, people mainly used refrigerators, non-automatic washing machines, vacuum cleaners and televisions in their homes. These power consumers needed a different load than today's appliances. Moreover, the average number of such appliances per 100 households has increased significantly. For example, before 2000 and in 2018 (shown with a "/"), respectively: refrigerators and freezers - 94 /124 units, washing machines - 74 /91 units, vacuum cleaners - 56 /81 units. At the same time, the level of use of some appliances remained unchanged, and some dropped or were not used at all, including: irons - 98 /99 units, CD players - 0 /5 units, video players and tape recorders - 13 /18 units. It is worth noting that modern households now use such appliances as televisions - 69 /116 pcs, PCs, laptops - 1 /90 pcs, microwaves - 1 /54 pcs, food processors - 3 /17 pcs, air conditioners 0 /12 pcs, satellite dishes - 0 /31 pcs. [7].

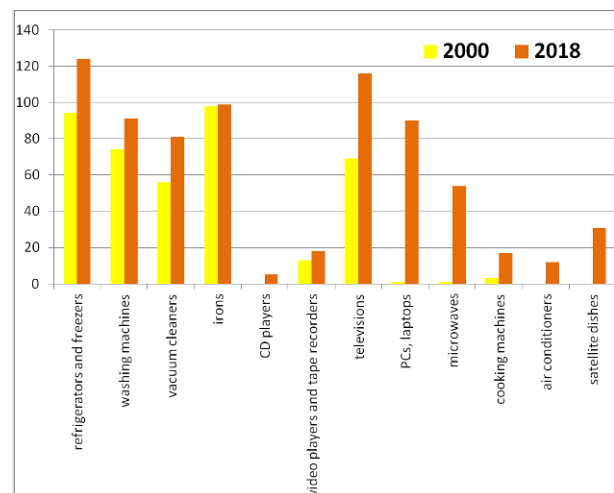


Fig. 1. Use of household appliances in Ukraine, number per 100 households [7]

Tested devices

The purpose of this work is to perform electromagnetic emission tests of selected electrical equipment in terms of electromagnetic compatibility. Dozens of single-phase devices that were manufactured in the period 1980-2018 were selected for testing.

The following devices from household appliances were subjected to measurements of conducted and radiated emissivity: mixers, grinders, coffee grinders, vacuum cleaners, hair dryers, radios, calculators and monitor, computer sets, laptop, curling iron, hair dryers. In selecting appliances for the survey, the focus was on small-sized appliances due to logistical and transportation difficulties. It was also guided by the criterion of the greatest popularity of occurrence in households. Products from both domestic manufacturers and multinationals were tested, and Figure 2 shows grouped photos of the tested appliances.

In the study, 32 devices were tested, for conducted emissions in the range of 150 kHz to 30 MHz and for radiated emissions in the range of 30 MHz to 1 GHz.

All products introduced to the market have always had to go through an appropriate procedure to ensure safe operation. Several decades ago, today's standards for electromagnetic compatibility did not apply, and many

devices manufactured at that time are still in use. There is no data in the literature showing the emissivity of devices from that period, so it was decided to conduct such a study.

All devices tested have been in service for several years to even several decades. Thus, it is possible to assess whether, with the passage of time and the wear and tear of components, their compatibility parameters do not deteriorate to levels that threaten other electrical and electronic equipment coexisting in the local environment. Valuable, therefore, are the results of tests of electromagnetic emissivity and their possible impact on the electromagnetic environment and also the impact of conducted interference on the quality of electricity in the power system.



Fig. 2. Photos of selected tested electrical devices

Measuring stations

Electromagnetic emission tests of selected electrical equipment were carried out in the university laboratory in two stages - analyzing radiated and conducted emissions.

The test stand for testing the electromagnetic emission of conducted disturbances in the power path consisted of a shielded cabin of EK-2 type, NNB 41 artificial network from Schaffner, HMS-X spectrum analyzer from Rohde&Schwarz. All measurement was managed from the HMEExplorer software. The idea of the bench is presented in Figure 3. Measurement settings were made in accordance with CISPR recommendations, and the permissible emission limit is derived from the PN-EN 61000-6-3 standard for residential, commercial and light industrial environments.

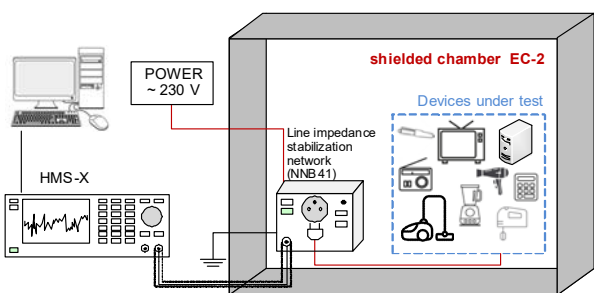


Fig. 3. Measuring station - conducted emissions

The next stage of the research required another measuring station. The tests were carried out using an ESCI 3 measurement receiver from Rohde&Schwarz and a set of antennas - biconical and logarithmic-periodic. The tests were carried out at a distance of 3 meters from the devices in vertical and vertical polarizations. The measurement parameters were set according to the CISPR standard, and the measurement was managed from the EMC32 software. Figure 4 shows the idea of this measurement.

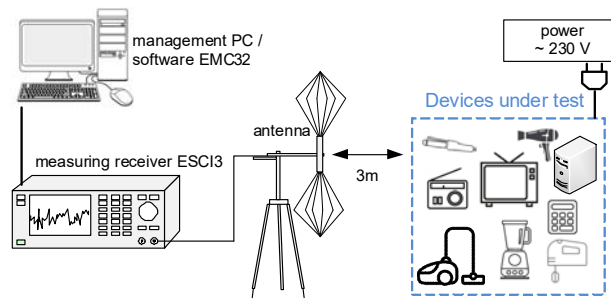


Fig. 4. Measuring station - radiated emissions

Results

The tests included measurement of conducted emissions in the power paths and radiated emissions. The obtained emission results, in the form of graphical charts, were compared to the limits of environmental standards - PN-EN 61000-6-3 for residential environments and, in the case of radiated emissions, also to PN-EN 61000-6-4 for industrial environments. The charts below present selected measured values for several devices.

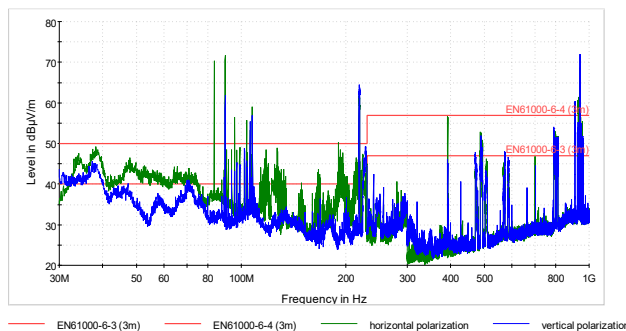


Fig. 5. Radiated emission - Philips radio receiver

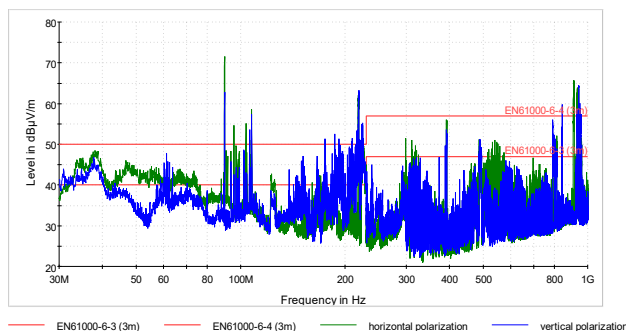


Fig. 6. Radiated emission - Zelmer mixer

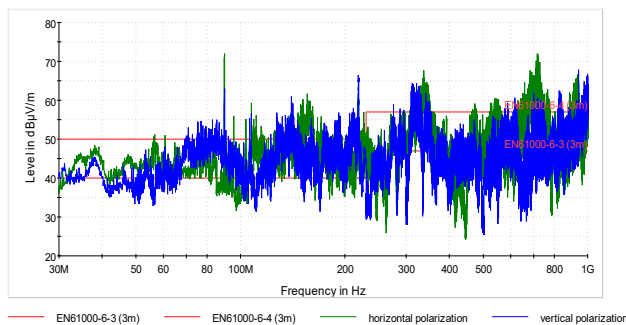


Fig. 7. Radiated emission - Zelmer mincer

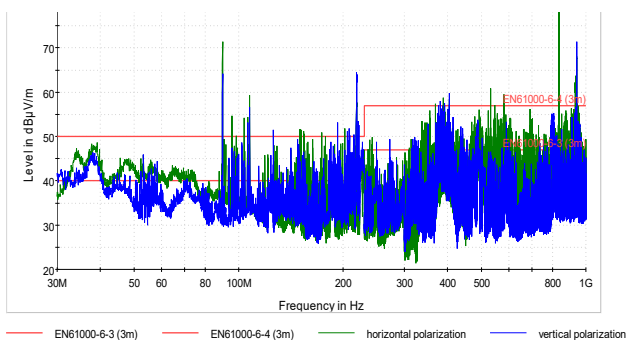


Fig. 8. Radiated emission - Zelmer vacuum cleaner

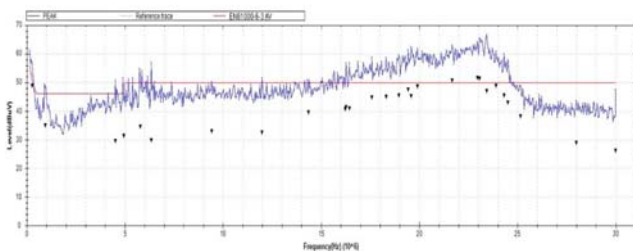


Fig. 9. Conducted emission - Zelmer mincer

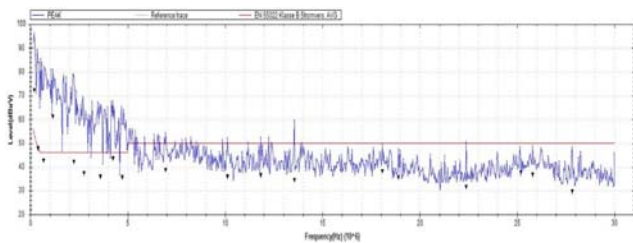


Fig. 10. Conducted emission - Zelmer coffee grinder

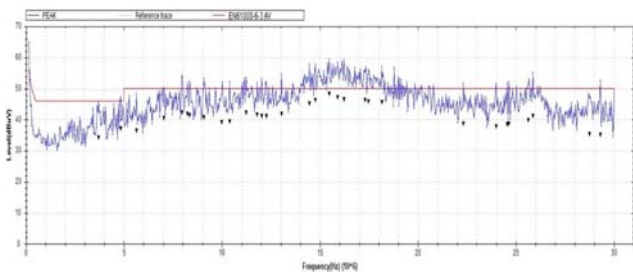


Fig. 11. Conducted emission - Niewiadów mixer

The radiated emission charts of Figure 5-8 show in blue the emission level with vertical polarization, and in green for horizontal polarization. The red lines are the limits of the standards. Recorded exceedances indicate over the limit indicate incompatibility and emission of electromagnetic disturbances into the environment. Part of the identified emission is of external origin (FM radio band, terrestrial TV, GSM) - this is the result of taking measurements in an unshielded space. With regard to conducted emissions, the blue graphs are the result of scanning a specific spectrum with a maximum detector. For selected points, a re-measurement was performed with a quasipeak detector with a longer sampling time, which finally verified whether the standard marked in red was exceeded.

Conclusions

Increasingly richer market offerings and steady growth in household incomes are positive developments that improve the quality of life. This translates, for example, into

the use of an increasing number of electrical, electronic devices and installations in households.

32 devices were subjected to emission testing, 8 devices did not pass verification - exceeded the permissible limits of the environmental standard, (including devices that had CE markings). Exceedances were detected for the following devices: mixers Niewiadów and Zelmer Robi mix, Zelmer 686.5A and Zelmer Diana mincers, Zelmer Predom coffee grinder, Bosch dryer, Zelmer Meteor vacuum cleaner and old PC.

The study shows that electrical appliances that convert electrical energy into mechanical energy (mixers, grinders, machines, vacuum cleaners, dryers) show higher levels of electromagnetic emissions than electronic devices.

It is difficult to generalize the results obtained for all household appliances. Over the years and with the rapid development of new technologies in households, older equipment will be displaced by new devices that are more energy-efficient and thoroughly tested to meet electromagnetic compatibility requirements. This is very important due to the fact that the number of different types of electrical and electronic devices and systems coexisting side by side is increasing, as their harmonious operation ensures stable and safe environmental parameters.

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