EXPERIMENTAL IMPACT ANALYSIS OF THE REFRIGERATOR CABLE DESIGN ON DISTURBANCE POWER TEST

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ABSTRACT

The ever-increasing variety of electronic products brings with it many tests and controls. Especially for a product such as a refrigerator, which has an important place in the lives of users and works non-stop for almost its entire life, all compatibility tests that may affect the end-user must be carried out. Electromagnetic compatibility (EMC) tests are the most critical of these tests. In this study, the effect of the disturbance power test, one of the EMC tests, on the changing properties of the product was investigated. The effect of three different cable structures used in the refrigerator on the disturbance power test was investigated. These tests are carried out to cover 10 different frequencies in three products using different cable structures. Tables containing the oscilloscope results of these tests and the margin values corresponding to the frequencies are included in the document. In addition, visuals containing the differences between each cable structure and cable have been added. The results and analyzes of these tests are included in this thesis.

ÖZETÇE

Her geçen gün artan elektronik ürün çeşitliliği birçok test ve kontrolü de beraberinde getirmektedir. Özellikle buzdolabı gibi kullanıcıların hayatında büyük bir yeri olan ve neredeyse tüm ömrü boyunca hiç durmadan çalışan bir ürün için son kullanıcıyı etkileyebilecek tüm uyumluluk testleri yapılmalıdır. Elektromanyetik uyumluluk (EMC) testleri bu testlerin en kritik olanıdır. Bu çalışmada, EMC testlerinden biri olan bozucu güç testinin ürünün değişen özelliklerine etkisi araştırılmıştır. Buzdolabında kullanılan üç farklı kablo yapısının bozucu güç testine etkisi araştırılmıştır. Bu testler, farklı kablo yapıları kullanılarak üç üründe 10 farklı frekansı kapsayacak şekilde gerçekleştirilmektedir. Bu testlerin osiloskop sonuçlarını ve frekanslara karşılık gelen marjin değerlerini içeren tablolar doküman içerisinde yer almaktadır. Ayrıca her bir kablo yapısı ve kablolar arasındaki farkları içeren görseller eklenmiştir. Bu testlerin sonuçları ve analizleri tezde yer almaktadır.

ACKNOWLEDGEMENTS

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I would like to thank my dear wife, who never stopped supporting me during this process, my children who study with me, Vestel Beyaz Eşya who was the supporter of the whole process, and to my esteemed advisor, Göktürk Poyrazoğlu, who carefully followed all my processes and guided me to success.

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CHAPTER I

INTRODUCTION

The place of electronic products in our lives is inevitable. Every day, many different designs are made in more and more products [4]. The products that take up the most space in our daily life are white goods [5]. Refrigerators have a special place among white goods. Unlike others, these products work 24 hours a day, 7 days a week, from the first day to the last. All necessary tests must be carried out with appropriate methods so that refrigerators that operate continuously do not adversely affect the lives of users. EMC tests are the most critical among these tests [6]. Among the EMC tests, the effect of the Disturbance Power test on the changing properties of the product is examined [7].

Distortion power is the electromagnetic disturbance power measured under specified conditions. It is generally believed that audio power amplifiers, audio/video discs, tape recorders [8] and other equipments are connected by outward radiation with power lines and other connecting lines of radiation transmission of more than 30 MHz [9]. Thus, you can use the power line and other connections in the harassment power to describe the radiation harassment performance. Rigorous measurement procedures and their scope of application are specified in some relevant EMC standards [10]. With this test, the possible effects of High-frequency noises [11] on white goods can be tested, and improvements and developments can be made to the products according to the results that may emerge from these tests. Electromagnetic compatibility tests, including the disturbance power test, are carried out according to the IEC 55014-1 standard [12]. This standard specifies the requirements applicable to the emission of radiofrequency disturbances [13] in the frequency range of 9 kHz to 400 GHz from appliances, electrical appliances, and similar equipment, whether powered by AC or DC.

This study will try to reveal the purpose of this test, its effect on product approvals, how it affects designs, which situations trigger the product, and which methods can be used to solve the problems that may occur.

CHAPTER II

LITERATURE REVIEW

In this thesis, first of all, basic electromagnetic information will be shared and magnetic field, electromagnetic compatibility and emission, the history of EMC foundations, electromagnetic interferences, their sources and the effects of these sources and disturbance power testing will be mentioned. The information to be shared in this section are the basic technical details required to explain the foundations of the thesis work.

2.1 Basic Concepts in Electromagnetics

Electromagnetism is the physical force that causes the interaction between electrically charged particles. The fields where this interaction takes place are defined as electromagnetic fields.

Electromagnetism occurs in both electric and magnetic fields. Both fields are different consequences of electromagnetism; however, they are intrinsically related to each other. Therefore, a changing electric field produces a magnetic field; A changing magnetic field creates an electric field.

2.1.1 Electrical Field

It is the physical field that surrounds the electrically charged particles, where attractive and repulsive forces are applied to all charged particles in the area. The electric field is mathematically defined as the force applied to a point charge at rest at a certain point in space. It is expressed mathematically by the following formula.

$$E = F/q \tag{1}$$

F is the force exerted on the particle (newtons) q is the charge of the particle (coulomb) E is the electric field at the particle's position

The electric field lines of the "+" charge tend to exit the charge and the electric field lines of the "-" charge point towards the charge. When opposite charges are brought close to each other, the electric field lines from the "+" charge tend towards the "-" charges.

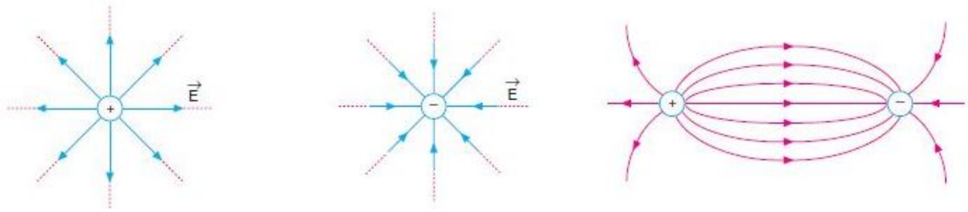

Figure 1: Electric field lines

2.1.2 Magnetic Field

While the electric field is a type of field created by stationary charges, the magnetic field is a type of field created by charges that move in a straight line without acceleration. The magnetic field is a vector quantity like the electric field, and In the International System of Units, H, magnetic field strength, is measured in the SI base units of an ampere per meter (A/m) [14].

The magnetic field arises when electric charges are displaced, that is when there is a circulation of electric current. When the lamp is lit, besides the electric field, there is also a magnetic field caused by the passage of current from the supply cable to the lamp. In the magnetic field, the unit of magnetic flux density tesla (T) is used as the international unit. It is often expressed as microtesla (T). Gauss (G) unit is also used as a magnetic field measurement unit. The higher the current, the higher the resulting magnetic field. As with the electric field, the magnetic field strength decreases rapidly with distance. In contrast, the magnetic field is rarely blocked by obstructing objects, as is the case with the electric field.

The electromagnetic force is the force acting on an electrically charged particle as it passes through a magnetic field.

2.1.3 Electromagnetic Field

Electromagnetic fields are combinations of invisible electric and magnetic force fields. They are produced not only by natural phenomena but also by human activities, mainly through the use of electricity.

Most man-made electromagnetic fields reverse direction over time at a given frequency, ranging from high radio frequencies (RF) such as those used by cell phones - to intermediate frequencies (IF) - extremely low frequencies such as those produced by computer screens. (ELF) – those generated by power lines, for example.

Table 1: Typical sources of electromagnetic fields

Frequency range	*Frequencies*	*Examples of exposure sources*
Static	0 Hz	Video display units MRI (medical imaging) and other diagnostic or scientific instrumentation industrial electrolysis welding devices
ELF (Extremely Low Frequencies)	0 - 300 Hz	Power lines; domestic distribution lines domestic appliances electric engines in cars trains and tramways; welding devices
IF (Intermediate Frequencies)	300 Hz - 100 kHz	Video display units anti-theft devices in shops hands-free access control systems card readers and metal detectors MRI, welding devices
RF (Radio Frequencies)	100 kHz - 300 GHz	Mobile telephones broadcasting and TV microwave ovens, radar and radio transceivers portable radio, MRI

2.2 Electromagnetic Compatibility

It is the ability of electrical equipment and systems to maintain acceptable operation in their electromagnetic environment by limiting the generation and emission of electromagnetic energy that can cause physical damage and undesirable effects such as electromagnetic interference. The main purpose of EMC is to ensure the correct operation of different equipment in a common electromagnetic environment [15]. There are 3 conditions for a device to be considered electromagnetic compatible Not causing interference in itself (Emission). Not interfering with other devices (susceptibility). Being immune to interference from other devices (Immunity).

Emission is the production and emission of electromagnetic energy directly or indirectly by a source into the environment. In EMC, the measures to be taken to prevent and reduce these emissions are examined.

Susceptibility is the tendency of electrical equipment to malfunction and deteriorates due to the presence of unwanted emissions.

Immunity, in contrast to susceptibility, is the ability of equipment to function correctly despite emissions.

EMC can be achieved by silencing sources of interference, blocking connection paths, and/or amplifying potential elements to be affected. EMC ensures that different items of equipment that use or respond to electromagnetic events operate correctly in the same electromagnetic environment and prevent any interference effects. Another way to say it is that EMC is the control of Radio frequency interference (RFI) so that unwanted effects are avoided. Electromagnetic interference can be defined as any natural or human-induced disturbance or sign in radio frequencies that cause reductions in the performance of electrical and electronic devices, deterioration, or malfunction. Electromagnetic interference is observed as a result of the electromagnetic environment in which the device is affected. All electromagnetic events occurring in a particular region constitute the electromagnetic environment of that region. The main effects of this electromagnetic environment can be said as EMI and EMC.

There are many measurement and test methods related to the electromagnetic field. Their validity is ensured by international standards. These standards have been put forward by the committees as a result of the ongoing studies and have been accepted by the manufacturers. EMC standards determine the standard of the test, the test method, the test equipment and the appropriate environments where the test will be performed. Each country or region has national and international organizations and committees that implement and develop EMC standards. The names of these organizations and the information of the countries they are located in are detailed in Appendix A.

The shaping of EMC actually started when electronic devices entered our fault. Electromagnetic effects, especially lightning and lightning, which are seen with the effect of natural life, have gained more importance with the increase in the number of electrical appliances. The interaction of these instruments with each other over time, the effect of the human factor on these instruments, and the emergence of the need to scientifically determine the suitability of these structures have affected the historical development of EMC. Details on EMC studies and historical development are available under the title of Appendix B.

2.2.1 EMI

Electromagnetic interference (abbreviated as EMI - electromagnetic interference) is the interference phenomenon between electromagnetic waves [16]. This interference may cause an EM wave not to reach the desired location, as well as cause EM waves emitted from a source to induce unwanted currents in another device. Electromagnetic interference can be encountered in daily life, in the form of the loudspeaker nearby when a message is sent to the mobile phone.

Electromagnetic Interference (EMI) occurs when there is no Electromagnetic Compatibility (EMC). Electromagnetic Interference can be considered if electrical and electronic devices emit more than the limits determined by the standards to the environment during their operation or show more susceptibility to this emission than they should be [17].

2.2.2 EMI Sources and Most Significant Effects

Electromagnetic interference (or EMI) is a disturbance that affects an electrical circuit due to either electromagnetic induction or radiation emitted from an external source The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. These effects can range from a simple degradation of data to a total loss of data. The source may be any object, natural or artificial, that carries rapidly changing electrical currents.

EMI can be intentionally used for radio jamming, as in some forms of electronic warfare, or can occur unintentionally, as a result of spurious emissions for example through intermodulation products. Here are some of the more common sources of EMI and EMP:

As the density of the electromagnetic environment continues to increase, the concern about its effects from sources producing EMI also increases. Advances in technology and the number of products produced are having a significant effect on the efforts aimed at maintaining the required operation and interoperability of products and systems used in our society. These events had added challenges for those who are responsible for keeping pace with the effort needed to maintain the required level of electromagnetic compatibility (EMC) in these products and systems.

Electromagnetic sources (EMI), both natural and man-made, that generate electromagnetic effects (EME) can be divided into several main categories. Some of these resource classifications are listed below [18].

1. Electromagnetic effects (EME) with external influences (ambient) from many sources, the most important of which are:
   - Analogue and digital Television broadcasts
   - Satellite and AM/FM Radio broadcasts

- Solar Magnetic Storms
- Lightning that occurs as a high voltage and high current event
- Power transmission lines with high voltage, low current and low frequency characteristics.
- Apart from these, there are airport port radar, telecom broadcasts, electrostatic discharge (ESD) and white noise. Also included in this category is the earth's magnetic field flux.
- Some other important sources of product and system emissions include switching power supplies, arc welders and electrical contacts.

2. High Powered Electromagnetic Pulse (HEMP) threats which are intended to disable electrical and electronic equipment [19]. These sources are designed to be utilized by military organizations. Currently existing HEMP devices include the following:
   - Intentional Electromagnetic Interference (IEMI) source – a high powered pulse device utilized by combat, sabotage and terrorist organizations
   - High Altitude Nuclear Electromagnetic Pulse (HNEMP) – produced by the detonation of a nuclear device high above the earth's atmosphere
   - High Powered Microwave Weapon (HPM) – a device utilized by the military as a combat weapon
   - E-Bomb – a HEMP weapon employed by the military to disrupt an enemy's intra structure that is delivered by an aircraft.
   - EMP Cannon – a military tactical weapon
3. Power Quality degradation factors can affect the operation of equipment powered by a source [20]. These network disruption factors may include, in order:

- Voltage surges, sages, dips, spikes, and high and low voltage
- Blackouts
- Power line faults
- Electrical Fast Transitions (EFT)
- Electrical noise

4. Mass Transit Systems and railways have types of EMI source problems [21]. These are as follows, respectively.

    - High voltage and high current operating mode emissions of the propulsion system
    - Train signaling systems
    - Third rail shoes that increase broadband emissions
    - High voltage contact switches
    - Emissions of the train control system

5. Medical equipment utilized in medical facilities has numerous EMI sources. Some of the more prominent of these are listed below [22]:

    - Life support equipment such as ventilators, cardiac defibrillators, infusion pumps, etc.
    - Patient telemetry and assistance equipment which includes electrocardiographs and motorized wheelchairs
    - Electrical surgical units and their associated support equipment
    - Magnetic Resonance Imagine (MRIs) systems
    - X-ray units, both therapeutic and diagnostic
    - Gamma Beam Electron Accelerators and Therapeutic equipment

The effects of both natural and man-made electromagnetic sources that produce electromagnetic effects are listed below.

1. Ambient (EME) The effects of environmental conditions are listed below.

    - May affect sensitive electronic equipment near EMI sources. The closer electronic equipment is to the source, the more likely EMI is to cause an interference problem.
    - The effects of ESD on sensitive electronic systems can cause these units to malfunction, burn and lock up.

2. High Power Electromagnetic Pulse effects

    - High-power electromagnetic sources can completely destroy the function of an electrical and electronic equipment.

3. Power Quality degradation

    - Power Quality disturbances and transients found in power hosts can affect the normal operation of the equipment it powers. Transients such as power surges can destroy interface electronics.

4. Railway and Mass Transportation Systems

    - Rail and Mass Transit Systems have one primary source of EMI, and that is transit and rail motor propulsion systems operating with high voltages, currents and magnetic field levels. It is known to immediately affect other facilities containing sensitive electrical equipment located near rail or public transport systems.

5. Medical equipment and facility resources include patient monitoring systems.

    - These are very sensitive to EMI interactions. The human body, the signals they track are very weak. They are measured in units of microvolts and microamperes. Other devices susceptible to EMI include hearing aids, wireless patient monitoring systems, magnetic resonance imaging systems, implantable cardiovascular devices, drug pumps, and portable diagnostic meters.

2.2.3 Disturbance Power

The disturbance power is the electromagnetic disturbance power measured under specified conditions. It is generally believed that audio power amplifiers, audio /videos, tape recorders, and other equipment, that is more than 30MHz radiation transmission is connected with its power lines and other connecting lines outward radiation. So you can use the power line and other connections on the harassment power to define its radiation harassment performance. The rigorous measurement procedures and their scope of application are set foutlinedin the relevant EMC standards.

Measurement of disturbance power is carried out with an absorbing clamp in the frequency range of 30 MHz to 300 MHz [23]. It is an alternative test method to radiate emission measurements. Therefore, the maximum emission has to be found and recorded, which is received by the absorbing clamp moved along the slideway.

Usually, a frequency search is done in the first step. The measurement of the maximum is performed with a Quasi-peak detector at single frequency points. The test receiver is then tuned to a frequency and the absorber clamp is shifted until maximum emission is found.

Compared to this time-consuming test procedure, maximization at all frequency points above 30 MHz to 300 MHz bandwidth can be achieved instantly with real-time bandwidth.

The CISPR-Average detector and the Quasi-peak detector work in parallel and are simultaneously measured across the entire frequency range and displayed in real-time during measurement. The absorber clamp is moved continuously along the entire length of the slide, completing the measurement of the distortion force.

CHAPTER III

REFRIGERATOR

In every period of history, people have found various methods to continue their vital activities. The most important of these methods is to store foods correctly and for a long time. Mankind has tried many methods to find the most suitable method for storing food until the invention of the refrigerator. The oldest known cold storage method is ice houses, which were used 2000 years before Christ. In these houses, the ice collected from the lakes during the winter was stored and the food was preserved during the summer months. This method, which was used until modern times, has now left its place in refrigerators. The principle of keeping food for a long time by creating cold with ice has hardly changed. Instead of waiting for lakes to freeze to get ice, humanity invented its cooling system. With this invention, first mechanically controlled and then electronically controlled refrigerators entered our lives.

In mechanically controlled refrigerators, the control is controlled by electromechanical thermostats. There are bulbsSome bulbs act as the thermostat and contain gas, terminals for electrical connections, and mechanical contacts to provide transmission. The thermostat bulb is positioned in a suitable place in the section where it is desired to be cooled. The temperature changes in the chamber allow the gas in the bulb to expand, this allows the contacts on the thermostat to move to electrical conduction, so the compressor starts to work. The contacts are opened and closed according to the expansion state of the gas. Although this structure is a cheap and effective method, it has disadvantages in terms of frost, icing, sensor sensitivity, and correct operating conditions.

In electronically controlled products, control is provided with an electronic board, which contains an algorithm that includes how the product should work.

Control boards working with voltage coming from AC input ensure that compressor, fan, resistor, and LEDs on AC and DC outputs start and stop at the right time by using the data coming from sensor inputs. In addition, with the display connected to the user interface input, the products can be adjusted to the desired temperature, and any error status can be followed by the user.

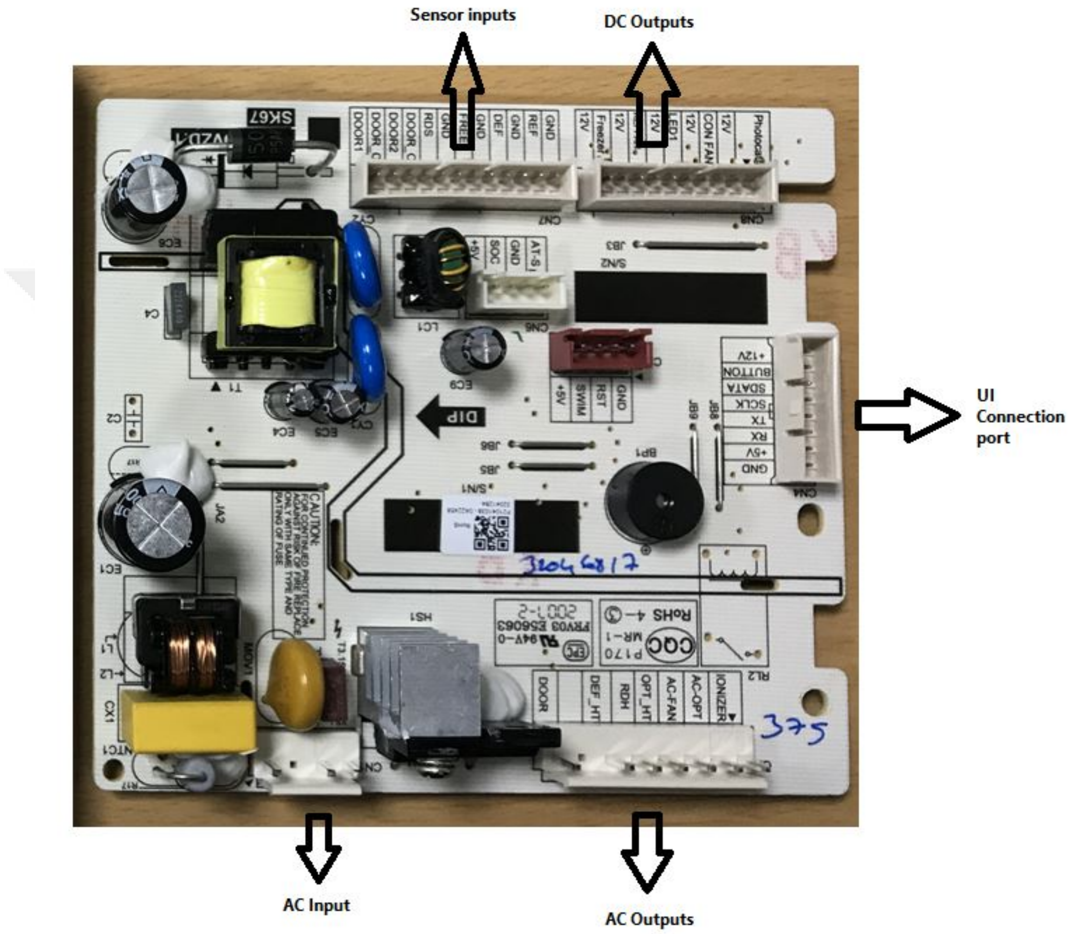

Figure 2: Electronic control board

Regardless of electronic or mechanical control, the whole structure is based on the principle of providing a refrigeration cycle. We can examine the principle of cooling under two headings. Basic cooling cycle and Refrigerator cooling cycle.

3.1 Basic Cooling Cycle

The basic refrigeration cycle is completed in four steps. In the first step, the compressor increases the pressure of the gaseous refrigerant and directs it to the condenser. In the meantime, the temperature of the fluid, whose pressure increases, also increases. The gas-phase fluid, whose pressure and the temperature rise, comes to the condenser, which is the second part of the cycle. As the fluid passes over the condenser, it gives heat to the environment and changes phase to the liquid phase. It is expected that the fluid temperature will not change at the condenser outlet. The refrigerant, which condenses in the condenser and passes into the liquid phase, comes to the expansion valve, which is the third part of the cycle. As a result of a sudden expansion in the expansion valve, the fluid pressure drops and a very rapid temperature drop occurs. The refrigerant, whose temperature decreases, comes to the evaporator, which is the fourth and last part of the cycle. In the evaporator, the refrigerant draws heat from the environment and lowers the ambient temperature. The refrigerant changes phase with the heat it absorbs from the environment and comes back to the compressor in the gas phase.

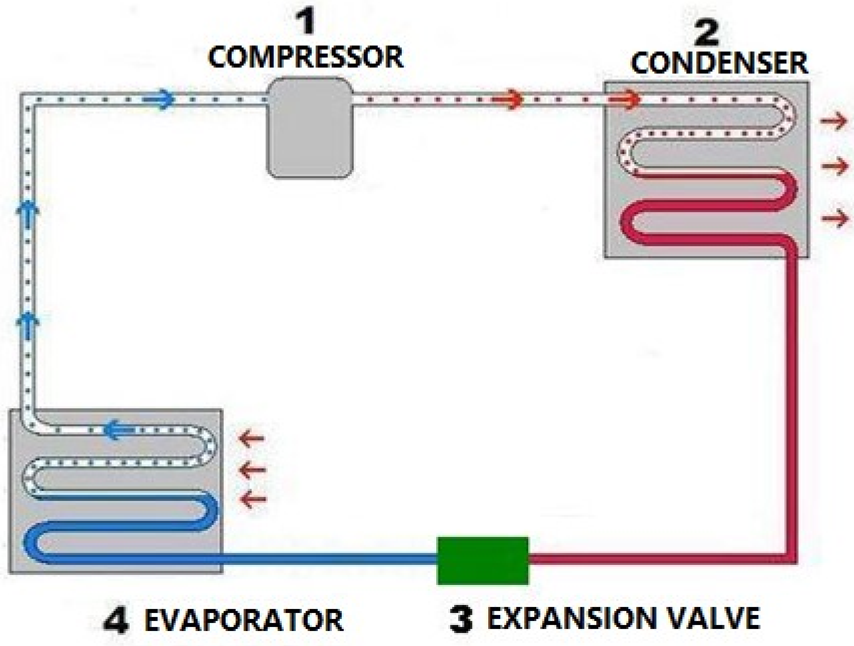

Figure 3: Basic cooling system

3.2 Refrigerator Cooling Cycle

The point on which the refrigerator refrigeration cycle is based in the basic refrigeration cycle. Some components have been added to the basic cycle to increase efficiency and improve the cycle. A simple refrigerator cycle is des described below.

The refrigerator refrigeration cycle also starts at the compressor. The compressor sends the gas-phase refrigerant, which it absorbs from the return pipe to the condenser. Here, in addition to the basic cooling cycle, the "hot gas" part has also entered the cycle. In fact, in the "Hot Gas" cooling cycle, the condenser performs the task, but the purpose of use in the refrigerator is not to extend the length of the condenser. The purpose of the use is to prevent the seals in the freezer section door from sticking to the body. For this purpose, according to the design, the fluid coming out of the compressor is passed first or after the condenser through the area where the door seal of the freezer section is pressed, and that section is heated. Thus, the door seals are prevented from sticking to the body and tearing.

The fluid coming out of the "Hot Gas" comes to the "Dryer" component. The "Dryer" component also has no place in the basic refrigeration cycle. The purpose of the use is to keep the moisture and pollution in the refrigerant and clean the fluid when the refrigerator is first started. It acts as a kind of filter. The fluid coming out of the "Dryer" comes to the capillary tube. The capillary tube carries the fluid to the section where expansion will take place. However, in a part of this path, a heat exchanger is created by bringing the capillary tube and return tube side by side. We will talk about the purpose of the use of the heat exchanger shortly. The refrigerant carried by the capillary tube comes to the explosion (blast) in the third step in the basic refrigeration cycle, where expansion will occur. The pressure of the suddenly expanding fluid in the blast pipe drops and a very rapid drop in temperature occurs.

The fluid whose temperature drops in the blast pipe comes to the evaporator, which is the fourth step in the basic refrigeration cycle. The refrigerant, which absorbs heat from the environment in the evaporator, cools the inside of the refrigerator. As a result of the heat absorbed by the fluid, it changes phase and passes into the gas phase.

The fluid leaving the evaporator comes to the return pipe to complete the cycle. It completes the cycle by connecting to the compressor in the return pipe.

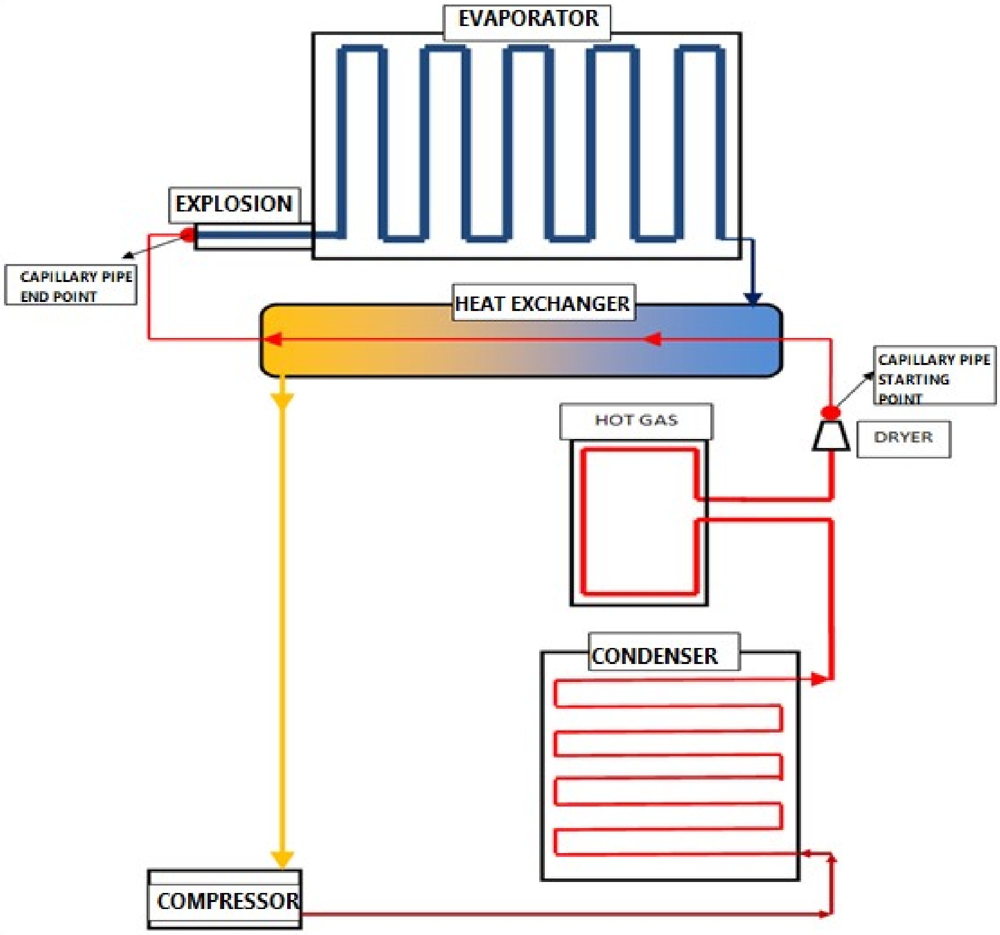

Figure 4: Refrigerator Cooling system

Now let's talk about the purpose of the use of the heat exchanger. The temperature of the fluid leaving the evaporator is low and the point where it connects to the compressor with the return pipe is in an environment open to the atmosphere. If the refrigerant enters the atmosphere at this low temperature, icing occurs on the return pipe. To prevent this icing, it is necessary to raise the temperature of the fluid flowing in the return pipe. This is done with the help of a heat exchanger. The cold fluid coming out of the evaporator comes into contact with the hot capillary tube and the temperature of the returning fluid is increased. In this part, the fluids do not mix in any way. Only the pipes carrying the fluids come into contact with each other and perform the heat transfer.

Another benefit of the heat exchanger is that it ensures that all of the fluid coming to the compressor is in the gas phase. Not all of the fluid coming out of the evaporator is in the gas phase. However, the compressor can only compress the gas phase fluid. Thanks to the heat transfer in the heat exchanger, all of the refrigerant passes into the gas phase and reaches the compressor.

There are many components used in a refrigerator. used of these components are used just for cooling but some of them are critical for electrical control.

3.3 Electrical and Electronic Components

We can consider electrical components in two parts. In the first part, they are used only for electrical connection and control, and in the other part, those that directly contribute to the cooling cycle. Used for electrical connection and control:

- Cable Groups
- Door switches
- Lighting Leds

3.3.1 Cable Groups

It is the structure that provides the electrical connections of all the components controlled in the refrigerator with each other. This structure is a wide connection structure that includes all components starting from the plug where the product is connected to the mains. It consists of two structures that we call AC and DC. The AC part contains the electrical connections of the components of the product working with alternating current. These connections are compressor, resistor, some fans, and mainboard connections. DC connections include the connections of the product with the components working with direct current. These are lighting LEDs, fans, and displays.

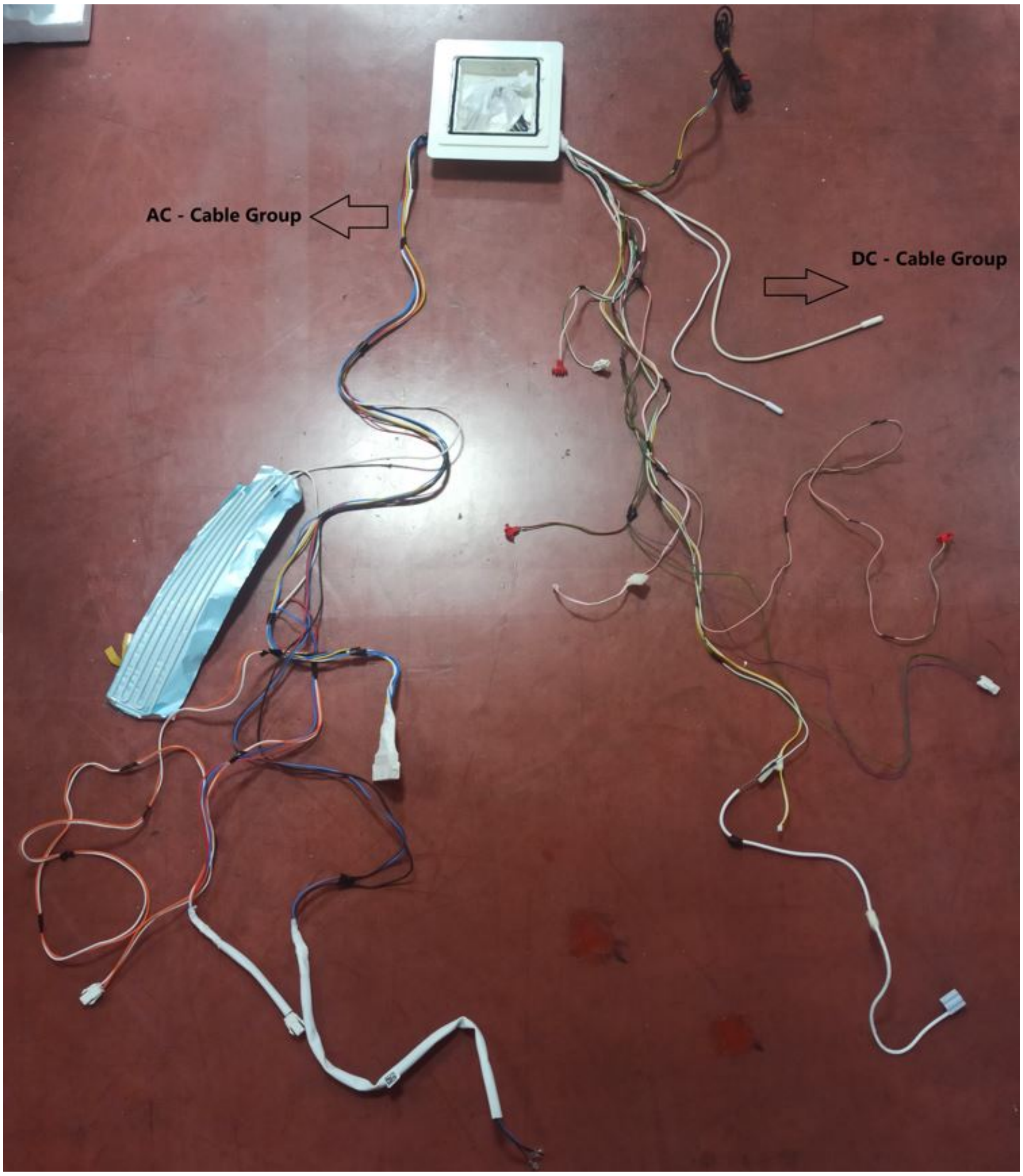

Figure 5: Cable Group

3.3.2 Door Switches

It is the component that provides door opening and closing information to be used in the cooling algorithm or for interior LED lighting. There are 3 types of switches preferred in household refrigerators. These are the Mechanical switch, Reed switch, and hall effect switch. Mechanical switches, as the name suggests, are switches that convert the contacts inside them into conduction and cut-off status with a mechanical structure. Reed switches are glass tubes with metal contacts inside. These are materials that provide transmission with magnets depending on the contact or separation of the contacts in them. Hall effect switches, on the other hand, are a component on which there is a constant voltage, detecting the presence and magnitude of the magnetic field and providing transmission accordingly.

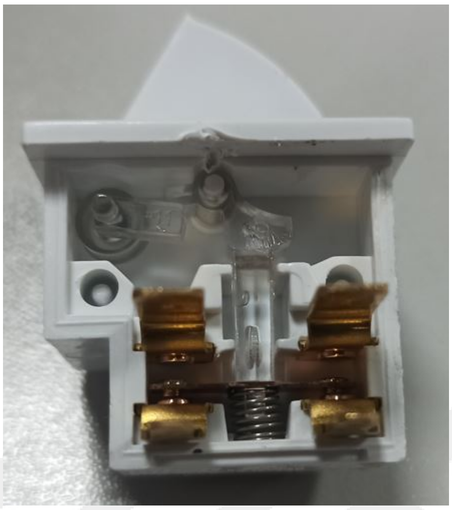

Figure 6: Door Switch

3.3.3 Lighting LEDs

It is a semiconductor, diode-based, light-emitting electronic circuit element. It has several advantages over traditional light sources such as low energy consumption, long life, robustness, small size, and fast switching on and off. Two types are used in refrigerators. One of them is the LED bulb. E14 type led bulbs to work with AC 220-230V. It consists of one or several rows of LEDs and circuit boards placed in the LED lamp. Another is sequential LEDs, which are expressed as strip LEDs. These are LEDs that work with DC 12V, which are arranged on a single PCB. They are the components used in the interior lighting of the product. It consists of LEDs arrayed on a single piece of PCB. They are operated with 12V DC voltage. There is no effect on the operation of the product.

Figure 7: LED Strip

In addition to these components, there are also components that directly affect the refrigeration cycle. These:

- Compressor
- Mainboards and UI Boards(displays)
- Fan Motors

3.3.4 Compressor

It is a mechanical device that increases the pressure of the gas by reducing (compressing) the volume of the gas. The compressor is the main cooling component and also it is an electrical control mechanical device.

The compressor used for the refrigerator should be well isolated since it provides the pressure of the gas. It is preferred to use Hermetically Sealed Refrigeration Compressors in today's refrigerators.

In the hermetically sealed compressor, the compressor, and the motor are enclosed in the welded steel casing and the two are connected by a common shaft. This makes the whole compressor and the motor a single compact and portable unit that can be handled easily. The hermetically sealed compressor is very different from the traditional open type of compressors in which the compressor and the motor are different entities and the compressor is connected to the motor by coupling or belt.

This structure contains oil, engine, piston, and connecting pipes. With the rotation of the engine in the compressor, the piston moves and draws the gas into the system thanks to the suction pipe, and the gas drawn into the cylinder is given back to the system by the discharge pipe. In addition, there is oil in the metal body, the purpose of the oil is to lubricate and cool the moving parts of the compressor. The oil also protects the rubber seals in the cooling line and connections, reducing the amount of refrigerant leaking out.

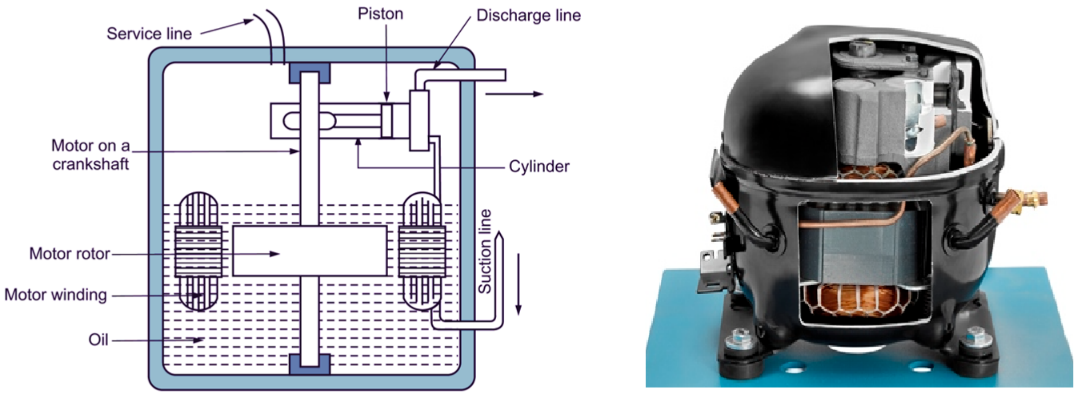

Figure 8: Compressor

3.3.5 Main Board and Display

Today, mainboards have replaced mechanical thermostats. With the use of mainboards, necessary algorithms for cooling cycles can be created and appropriate cooling scenarios can be developed. Due to the sensors, the internal temperatures of the product, the ambient temperatures of the product, the evaporator temperatures, and the temperatures of any region or compartment that are specifically desired to be monitored can be measured. In this way, all-temperature changes in the product are monitored instantly and suitable working conditions are provided.

In addition, with the use of mainboards many different components such as variable speed fans, variable speed compressors, and valves can be used that contribute to the product cooling cycle.

Displays are used to provide many features such as users following the temperatures of their products, changing these temperatures at any time, to be aware of this situation in case of a possible error. The use of display also increases the prestige of the product visually. In today's products, there are many types such as small screen led displays, seven-segment led displays, LCDs, and large size android based displays.

Electrically, the mainboard and displays constitute the most important parts in terms of EMC. Since they are the components that can be affected first in a possible operating error, they also have a very critical place in terms of maintaining the operation of the user's product.

Figure 9: Display

3.3.6 Fan

A fan is a machine used to create airflow. Fans, which are an important part of refrigerators, are used to transfer the air coming from the evaporator to the compartments of No-Frost models. They circulate air for distribution in the chambers of static models and increase convection on the evaporator surface.

Mechanical rotary vane fans are made in a wide variety of designs. There are three main types of fans used to move air, axial, centrifugal (also called radial), and cross-flow (also called tangential).

Axial flow fans have blades that force air to move parallel to the shaft around which the blades rotate. This type of fan is used in a wide variety of applications, from small cooling fans for electronics to huge fans used in cooling towers. Axial flow fans are applied in air conditioning and industrial process applications. Standard axial flow fans have diameters of 300–400 mm or 1,800–2,000 mm and operate at pressures up to 800 Pa.

Figure 10: Axial flow fans

The centrifugal fan has a moving component (called an impeller) consisting of a central shaft with a set around it. positioning of the blades forming a spiral or rib. Centrifugal fans blow air at right angles to the fan inlet and rotate the air towards the outlet (by deflection and centrifugal force). The impeller rotates, causing air to enter the fan from the side of the shaft and travel perpendicularly from the shaft to the opening in the helical fan guard. A centrifugal fan produces more pressure for a given air volume and is used when this is desired.

The cross-flow of the tangential fan, sometimes known as the tube fan, was patented by Paul Mortier in 1893 [24] and is widely used in heating, ventilation, and air conditioning (HVAC), especially in ductless split air conditioners. The fan is usually long relative to the diameter, so the flow remains approximately two-dimensional from the ends. The cross-flow fan uses a forward-curved blade impeller housed in a housing consisting of a rear wall and a swirling wall. Unlike radial machines, the main flow passes twice through the vane and moves transversely along the impeller.

CHAPTER IV

DISTURBANCE POWER TEST

The setup of EUT is according with Comité International Spécial des Perturbations Radioélectriques (CISPR) 16-1:2002, CISPR 16-2:2002 measurement procedure. See the following test setup figure 11. The specification used was EN 55014-1 limits. The EUT was placed at the edge of the test table to make the end of the lead close to the EUT as short as possible between the power clamp and the EUT. The spacing between the peripherals was 10 cm.

Maximum emission emitted from EUT was determined by manipulating the EUT, support equipment, interconnecting cables, and varying the mode of operation, and the levels in the final result of the test were recorded with EUT running in the operating mode that maximum emission was emitted.

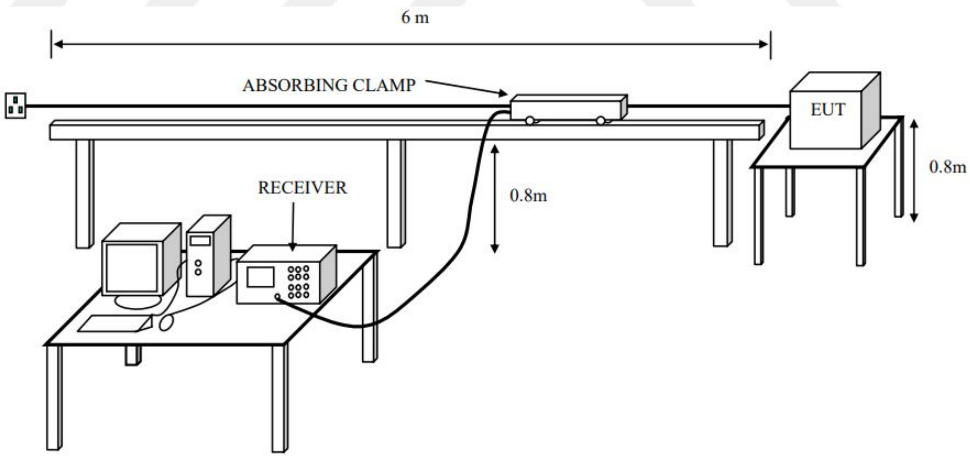

Figure 11: DP test setup [1]

4.1 Disturbance Power Test Procedure

The principle is that for a small EUT, the radiation emitted by the common-mode current on the lead is much larger than the outward radiation on the surface of the test object. The power cord of the EUT can be considered as a radiating antenna where the disturbance power is approximately equal to the power at the measured EUT provided to the test line at the position where the clamp is at the common mode current maximum. To find a ”common-mode current maximum,” the absorption forceps need to be able to move, so an absorber clamp rail length of 6 meters is required in the test system. Absorption clamp measurement (ACMM) is an alternative to the method of measurement of radiation emission for small test objects, such as household appliances and power tools, where only one power lead is connected [1]. ACMM with absorbing clamp to determine the disturbance power. The advantages of ACMM's radiated emission measurements are the reduction of testing time and cost savings.

4.2 Test Equipments

2 basic test equipments are used in the disturbance power test. These are respectively

- EMI Test Receiver

  To accurately calculate EMC tests, the characteristics of the meter must be modeled. The EMI receiver has defined frequency ranges and settings for each frequency band as specified in the CISPR 16 standard [25]. Figure 12 shows a simplified block diagram of an EMI receiver.

  Here, the measuring signal means is first filtered by an adjustable bandpass filter with adjustable center frequency and bandwidth. A heterodyne receiver creates an envelope from the filtered measurement signal. Finally, the detector detects EMI from the envelope.

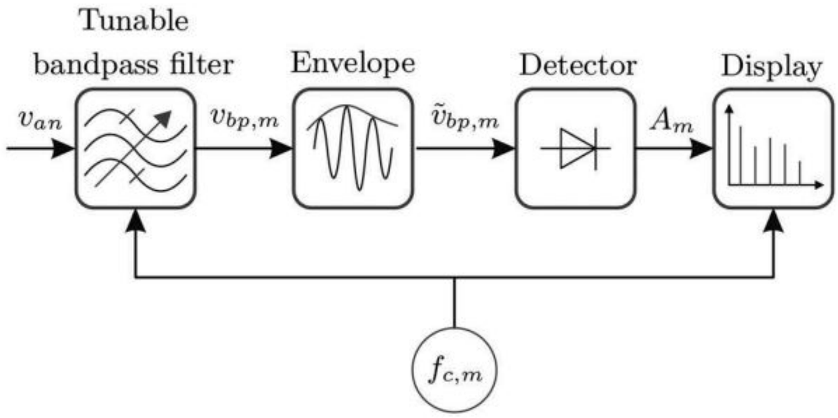

Figure 12: Block diagram of the EMI receiver function principle [2]

- Absorbing Clamp

The absorber clamp meets the requirements of CISPR 16-1-3/EN 55016-1-3 for interference power measurements in the frequency range 30 MHz to 1000 MHz and is applicable for scanning efficiency measurements [26].

In the frequency range below 30 MHz, the interference required by many standards is defined by measuring the breakdown voltage produced by the equipment under test (EUT). This is important because distortion in this frequency range is mainly propagated through cables.

Above 30 MHz, where radiated distortion predominates, interference is defined by the distortion field strength at a distance. Small EUTs emit interference mainly through connected cables. Therefore, to minimize field strength measurements, many standards require the absorber clamp to measure the disturbance strength.

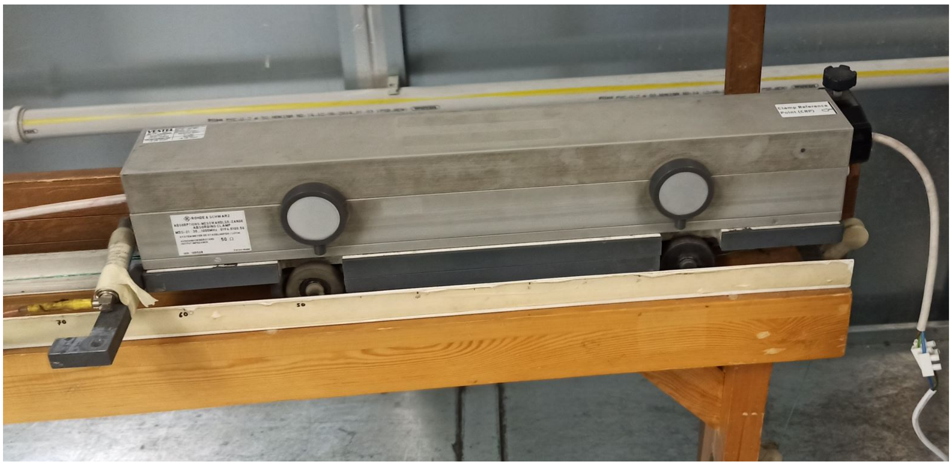

Figure 13: The Absorbing clamp

CHAPTER V

EXPERIMENTAL ANALYSIS REFRIGERATOR

In this section, the effect of all changes made on the product on the test results will be checked. The effects of all planned changes will be revealed with test reports and the data will be compared. The main purpose of this study will be to reveal the differences that will arise in the Disturbance Power test, which is a special EMC test, in the face of electrical changes in the refrigerator product.

These tests will begin by considering a reference product produced in production. then, based on this product, various changes will be revealed and test changes that may arise with these changes will be interpreted. Changes in the two main topics will be tested and compared. In the first part, the effect of cable changes will be checked. Cable replacement will be examined under three subheadings.

The first is the structure in which the cables are contained in the product as a whole and also come out of the card box. The second is the structure where the cables come as a single whole and the parts feeding the AC and DC loads are separated by entering the card box from different inputs. Thirdly, the structure in which the AC and DC cables are completely separated from both the parts on the product body and the parts entering the card box will be tested.

In the second main topic, the effect of ferrites will be controlled. According to the test result in which the cable differences are checked, it will be checked whether the ferrite position provides an improvement in the test result in the product with the worst result. ferrite position will be tested in two sub-titles. In the first case, the structure in which the ferrite is wound on the supply cable will be checked. In the second case, the case where the ferrite is connected to the phase, neutral and compressor wiring in the mainboard box will be tested.

5.1 Impact Of Cable Alignment

The cable structures used in the refrigerator include many variations according to the characteristics of the product. Cable structures are affected by many changes, such as the electrical properties of the component used, its location, the distance from the cable's first exit point, and the body dimensions.

The product that we will refer to in our tests and other products to be produced based on this product will contain the same components. In the products, there will be variations in only the components that are planned to be tested, which will enable us to see whether only the tested variable affects the test result.

The first of these variables, the cable structure, will be tested in three different ways, respectively. First of all, it will be the structure where the whole cable, which is the standard production method, is produced as a single piece and used on the product.

Then, secondly, the test will be carried out with the structure in which the cables are combined over the refrigerator body and separated from each other only in the mainboard housing.

Finally, the cable structure in which both the part of the cable on the refrigerator body and the part in the mainboard housing are separate from each other will be tested.

5.1.1 Aligned Entangled AC - DC Cables

As you can see in the cable photo below, the cables we refer to as AC and DC in the structure where we performed the first test are completely together and in the form of a single line.

DC cables are marked with the number 1. Number 1 cables are display connection cables, fan cables, sensors, door switch cables, and led lighting cables, respectively, from top to bottom.

AC wires are marked with the number 2. Cables number 2 are, respectively, resistance cable, multi-socket connection, cabinet bottom fan cables, and compressor cable.

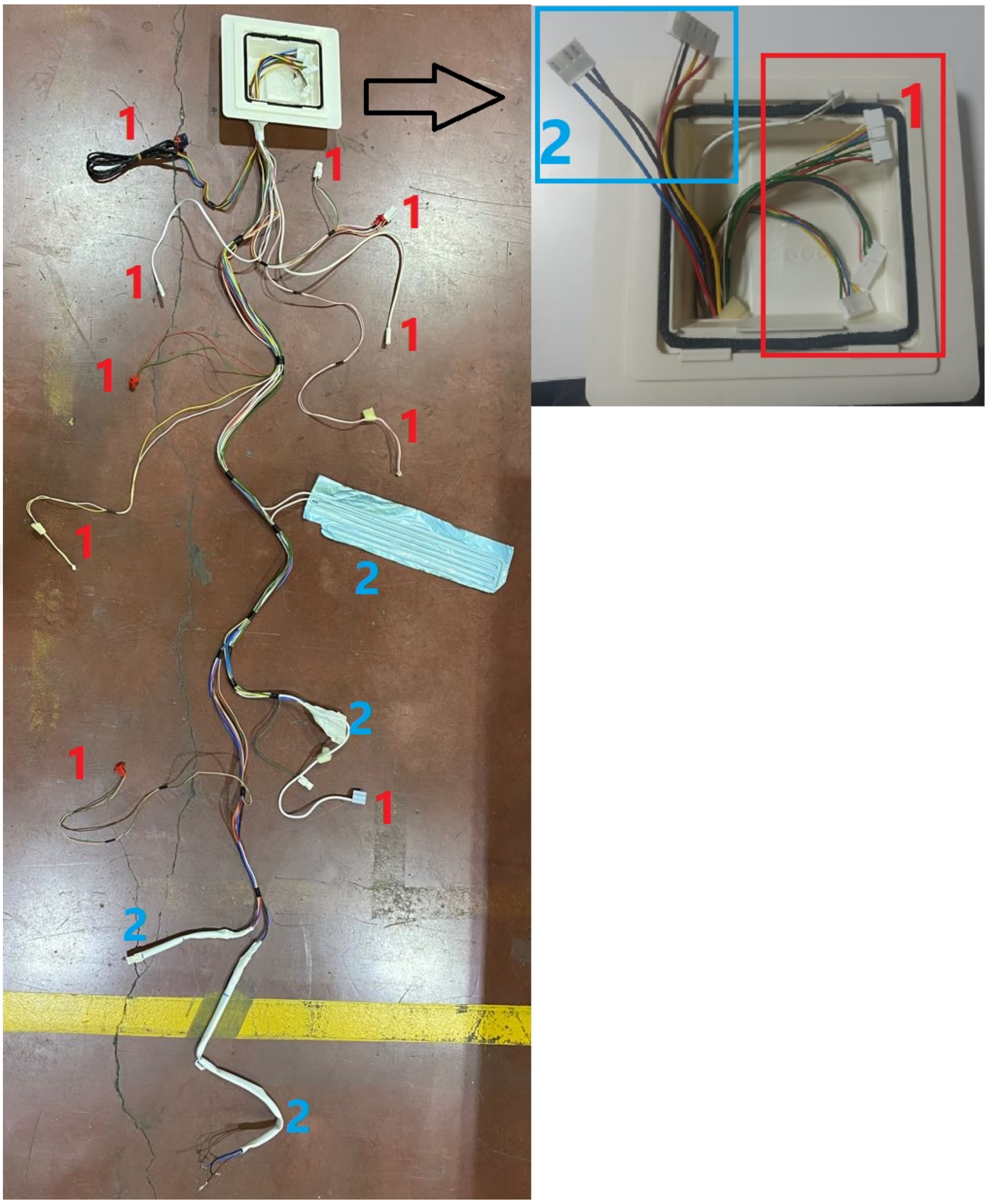

Figure 14: Test image of aligned entangled AC - DC

The first test result of the structure where the cables are common is as follows. During this test, a one-piece cable structure was chosen as a reference. In the test performed on this reference product, the regions with the largest peaks in the test graph were taken as references. In the controls in these regions, the maximum noise levels of the regions were determined by moving the clamp.

As can be seen in the table below, measurement results were taken at 10 different frequencies, with peak values on the graph, during the test. According to the test results, the product passed the test as the values were within the limit. In the table, the validity of the test result is determined according to the value in the Margin column. If this value is greater than "0", the test result is positive. In the next process, the tests will continue concerning the frequencies corresponding to these peak points.

In a pre-compliance test, you scan your product for noise and compare it to limit lines described in various standards based on region and class of equipment under test. Most commercial standards use three major detection methods defined by CISPR 16-1: peak, quasi-peak, and average.

Peak detection, as its name implies, retains the peak value of each harmonic in an emitted signal, indicating the worst-case scenario. Average detection provides the average amplitude of each signal component across its period. Quasi-peak detection weighs each component based on its repetition rate: the faster the repetition rate, the higher the weight given to that component.

To quickly perform EMI scans, you should start with peak detection for pre-compliance testing. Compare the results against the published quasi-peak limits. If the design meets the quasi-peak limits, with lots of margins to spare (say 6 dB or more), the product is likely to pass compliance testing. Thus, quasi-peak testing may not be necessary. If, however, the product marginally passes peak detection, quasi-peak testing is recommended. This is the same approach used in compliance testing and will assist in identifying potential areas of concern.

Table 2: Limit and Margin AV of Aligned Entangled AC-DC Cables

$Frequency$ (MHz)	$QuasiPeak$ $(dBpW)$	$Average$ $(dBpW)$	$Corr.$ (dB)	$Margin - AVG$ (dB)	$Limit - AVG$ $(dBpW)$
32.52	38.1	29.7	9.5	5.4	35.1
35.56	37.1	27.9	8.6	7.3	35.2
43.28	35.4	27.5	6.9	8	35.5
54.96	36.0	28.2	6.1	7.7	35.9
66.40	32.2	23.4	5.7	12.9	36.3
67.96	32.7	23.5	5.6	12.9	36.4
91.12	26.3	17.3	5.5	20.0	37.3
124.92	16.4	8.3	5.1	30.2	38.5
176.84	19.1	10.0	4.1	30.5	40.4
254.72	17.0	9.1	4.5	34.3	43.3

The chart automatically shows the limits set by the test standard. The limits set here consist of two parts as Quasi-peak and Average. The test result refers to the Average limits. The test results are accepted if the graphic values are below the average limit. Under normal conditions, products that meet these limits, that is, devices with a "0" dB difference can pass the test. However, these values are determined as "3" dB, taking into account the differences between products, possible sudden changes, and calibration deviations of the devices. If there is a difference of "3" dB or more, the product is considered to have passed the test. The figure 15 shows the results for quasi-peak (blue trace) and average (green trace) versus the limit line. To account for inaccuracies in the pre-compliance test setup, it is best to have more margin. Ideally, at least 3 dB of margin, if achievable. In this example, the device is now passing with a margin of 5.4 dB. This is enough to ensure passing at the test house.

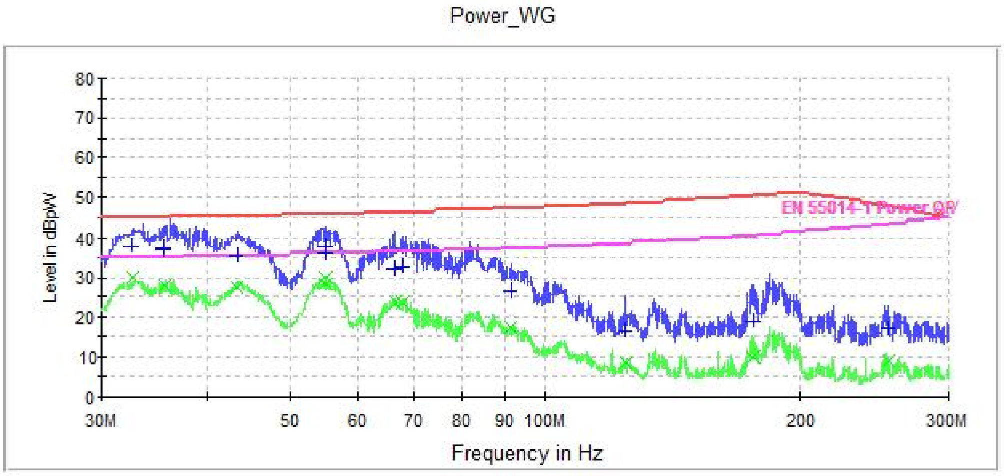

Figure 15: Oscilloscope image of aligned entangled AC - DC cables

5.1.2 Seperated AC - DC Cables at the Control Board Box

As can be seen in figure 16, most of the cable tree on the product body is in a single line, as a whole. they are separated from each other only in the card slot part. This structure ensures that the cables remain separate from each other in the card slot. This structure is suitable for production, but production costs increase due to changes in cable distances and grouping changes.

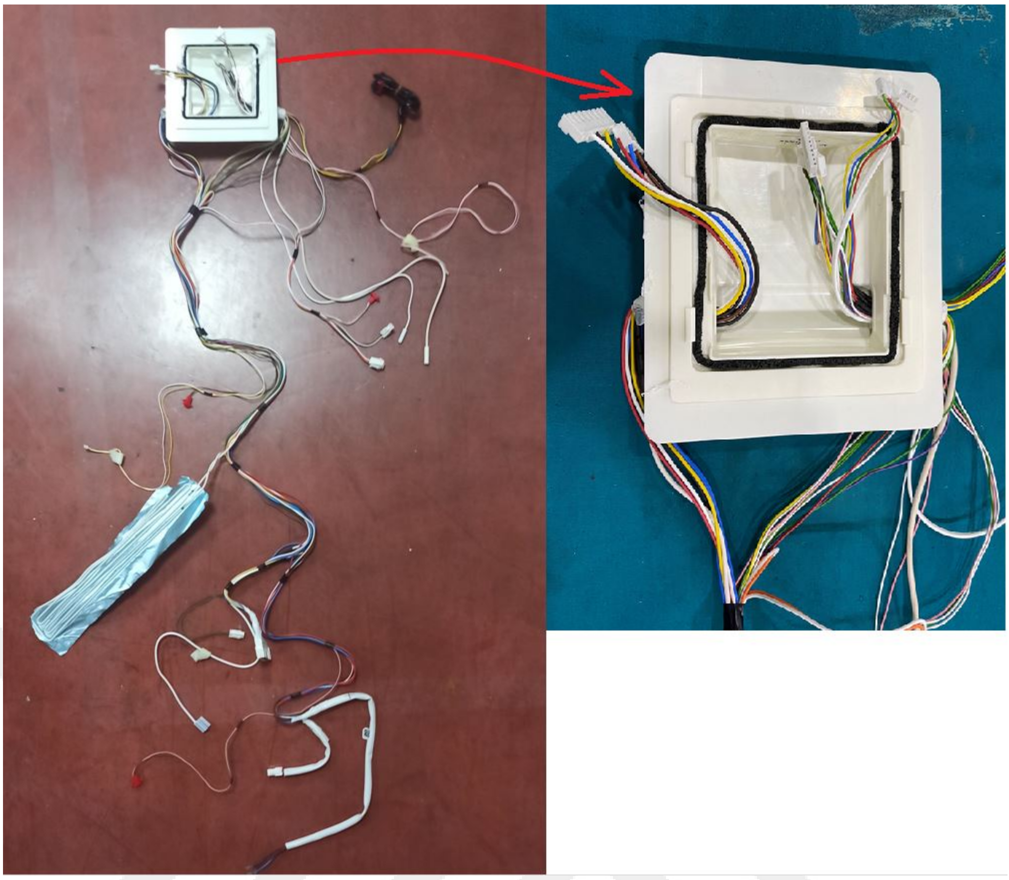

Figure 16: Test Image of Separated AC-DC Cables at the Control Board Box

As mentioned before, the chart automatically shows the limits set by the test standard. The limits set here consist of two parts Quasi peak and Average. The test result refers to the Average limits. The test results are accepted if the graphic values are below the average limit. Under normal conditions, products that meet these limits, that is, devices with a "0" dB difference can pass the test. However, these values are determined as "3" dB, taking into account the differences between products, possible sudden changes, and calibration deviations of the devices. If there is a difference of "3" dB or more, the product is considered to have passed the test.

Figure 17 shows the results for quasi-peak (blue trace) and an average (green trace) versus the limit line. Ideally, at least at 3 dB of margin, if achievable. In this example, the device is now passing with a margin of 10.5 dB. This is enough to ensure passing at the test house.

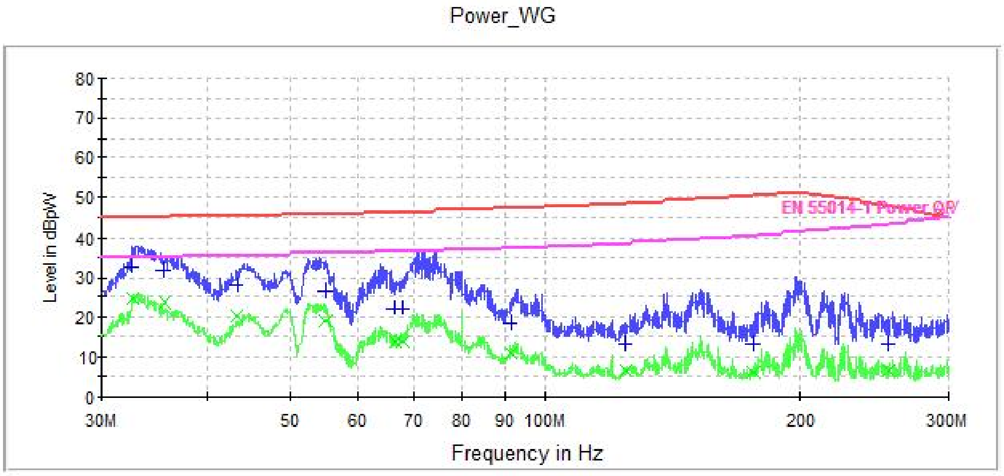

Figure 17: Oscilloscope image of Separated AC-DC Cables at the Control Board Box

As can be seen in Table 3, the test was repeated with the new cable product, concerning the frequency limits of the previous test. According to this test result, it was below the specified limits. passed the test in this context. According to the 10 frequencies determined in the table, it is seen that the test results are better than the previous cable structure. The lowest margin value is 10.5 dB. The lowest margin value is 10.5 dB. The lowest value is taken as a reference when interpreting the test result. This value is better than the determined 3 dB value.

Table 3: Limit and Margin AV of Separated AC-DC Cables at the Control Board Box

$Frequency$ (MHz)	$QuasiPeak$ $(dBpW)$	$Average$ $(dBpW)$	$Corr.$ (dB)	$Margin - AVG$ (dB)	$Limit - AVG$ $(dBpW)$
32.52	24.6	24.6	9.5	10.5	35.1
35.56	31.8	23.6	8.6	11.6	35.2
43.28	28.1	20.2	6.9	15.3	35.5
54.96	26.6	18.9	6.1	17	35.9
66.40	22.1	13.8	5.7	22.5	36.3
67.96	22.1	13.6	5.6	22.8	36.4
91.12	18.5	11.1	5.5	26.2	37.3
124.92	13.5	6.4	5.1	32.1	38.5
176.84	13.4	6.1	4.1	34.4	40.4
254.72	13.4	6.5	4.5	36.8	43.3

5.1.3 Separated AC-DC Cables During the Whole Path

As can be seen in Figure 18, the cable groups that we classify as AC and DC in this structure proceed completely separately from each other. Cable lines are planned to pass separately from the line on the body of the product. Since this cable structure is like two independent cable groups, it is less advantageous in terms of production costs compared to other cable groups. Although these structures seem like two independent groups, during production, there may be situations where the component groups of the product interlock with each other due to their positions.

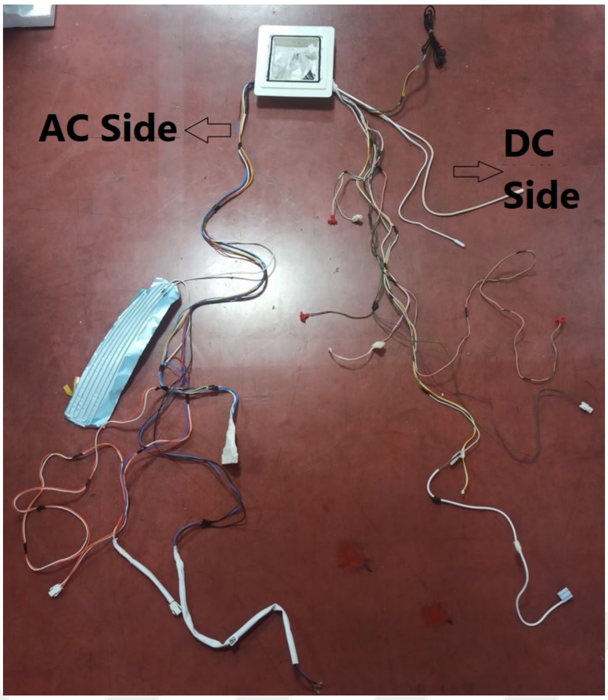

Figure 18: Test Image of AC-DC Cable Separation

Figure 19 shows the results for quasi-peak (blue trace) and average (green trace) versus the limit line. As can be seen in the chart below, there are differences in the test results compared to the previous results. There are changes in peak points. As can be seen from the graph, the results are close to the limit values. There are peaks in the 50-60 Mhz range and around 70 Mhz. It should be examined separately what differences arise from these elevation points in the product.

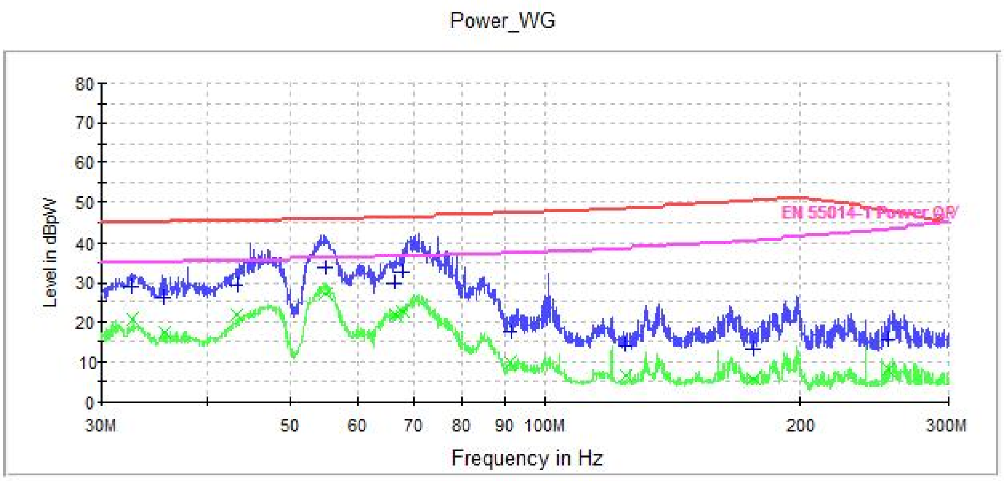

Figure 19: AC-DC Cable Seperated Test Result

As can be seen in table 4, only margin differences were checked without changing the limit values at the fixed frequencies determined. According to the results of the table, the product passes the test with the lowest 9.1 dB and the highest 35.4 dB. Although we have achieved much better results than the 3 dB limiter we have determined, the rise and fall of these values at some points should be examined in terms of the product.

Table 4: Limit and Margin AV of AC-DC Cable Seperation

$Frequency$ (MHz)	$QuasiPeak$ $(dBpW)$	$Average$ $(dBpW)$	$Corr.$ (dB)	$Margin-AVG$ (dB)	$Limit-AVG$ $(dBpW)$
32.52	29.1	20.7	9.5	14.4	35.1
35.56	25.9	17.4	8.6	17.8	35.2
43.28	29.3	21.8	6.9	13.7	35.5
54.96	33.8	26.9	6.1	9.1	35.9
66.40	29.9	21.7	5.7	14.6	36.3
67.96	32.5	22.9	5.6	13.5	36.4
91.12	17.7	10.1	5.5	27.2	37.3
124.92	14.0	6.7	5.1	31.8	38.5
176.84	13.1	5.7	4.1	34.7	40.4
254.72	15.5	7.9	4.5	35.4	43.3

5.1.4 Comparison of The Result

In the figure 20 below, the test results of 3 different cable structures are compared. The part expressed as Peak1 shows the peak of the Decibel Number for One Picowatt (dBpW) of the cable structure that is closest to the maximum limits within 3 tests. Peak2 represents the peak of the Decibel Number Per Picowatt (dBpW) of the cable structure that is closest to the average limits within 3 tests. Concerning these upper limits, we will check whether the 3 test results are making good progress. Contrary to the tables, in these images, besides the test results of certain points, we can reach the correlation of each desired point from the whole graph.

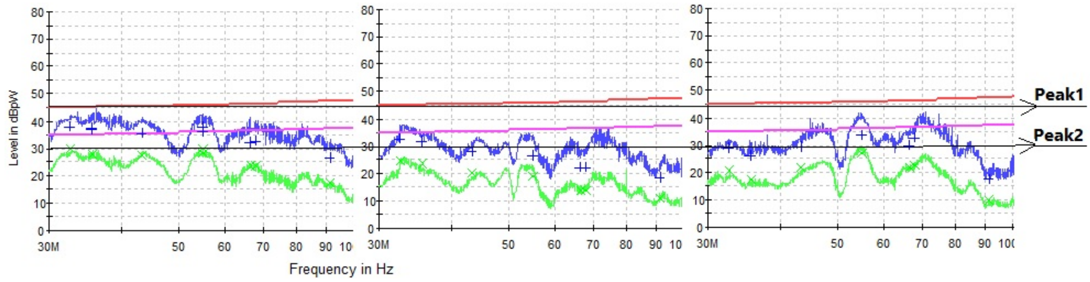

Figure 20: Comparison of 3 test results

As can be seen in the Test Chart, the first test result (Graph A) belongs to the structure in which the cables run as a single line. Here (the part marked with number 1), it is seen that the peak reaches around 45 dBpW values in the 35-40 MHz range. On the other hand, in the structure where the cables are separated only in the card box (B graphic), the value in this range is approximately 35dBpW. In the third graphic (Graph C), the test result of the structure where the cables are separate from each other on the whole body and also in the card box is seen. The value here is approximately in the range of 30-35 dBpW. In the A graph we look at the peak marked with the number 2, values are approximately 42 dBpW in the 50-60 MHz range. On the B graph, it is below 35 dBpW. In the C graph, the value at this point is approximately the same as the A graph and is approximately 42 dBpW. When we check the peaks marked with the number 3, it is seen that the peak value is approximately 40 dBpw in the 60-70 MHz range in the A graph. In the B graph, the peak value in this range is lower than 35 dBpW. In the C graph, unlike the A and B graphs, the peak values in this range started from 30 dBpW and went up to 45 dBpW. Since all test results were below the limit values after 100 MHz in the graphics, they were not included in the comparison criteria.

When the test results are examined through graphics, it is seen that all three cable structures have great effects on the test results. Based on these results, making the AC and DC cable groups completely independent shows positive results in the input frequencies, that is, in the range of 30 to 50 MHz, but the results of the completely separated cable and the cable structure in the form of a single line after 50 MHz are similar. This shows that it may be beneficial for the cables to be separated from each other, as well as for the cables to be properly intertwined with each other [27]. Properly twisted shaped cables reduce incoming electromagnetic radiation and cross talk between neighboring pairs and improve rejection of external electromagnetic interference [28]. A twisted pair cable can be used as a balanced line, which can greatly reduce the effect of noise currents induced on the line. The idea is that the currents induced in each of the two wires are almost equal. In this structure, the effects of cables on each other can reveal positive results at certain signal levels.

The peaks 4-5-6 and 7, marked with the green box, are also the peaks of the average value. The same results emerge when the points in the specified range are examined. Based on these results, the following inference can be made. Cable separation in the card box positively high-frequency measurement results such the has Disturbance power test. On the other hand, instead of separating the cables on the body, suitable cable structures, that is, the cables of the same length and under similar loads, are twisted in pairs, which can be beneficial at certain frequencies.

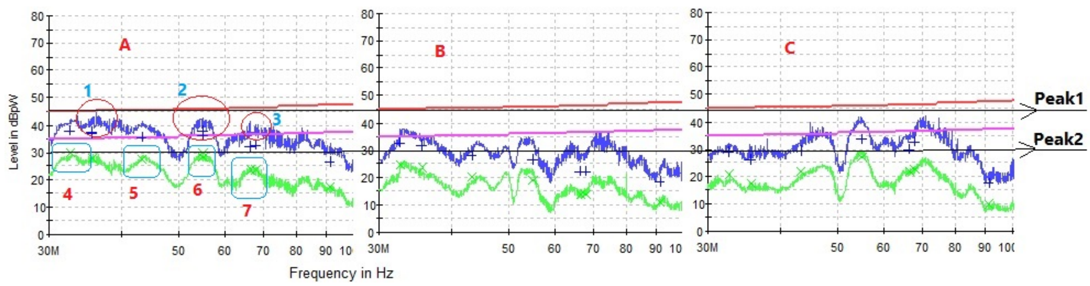

Figure 21: Comparative graph of 3 test results

5.2 Impact Of Ferrite Type and Position

Ferrite is a ceramic material made by mixing one or more additional metallic elements such as strontium, barium, manganese, nickel, and zinc in low proportions with a high proportion of iron(III) oxide ($Fe2O3$, rust) and firing [29]. Most ferrites are electrical and are not conductive, making them useful as magnetic cores to suppress currents of transformers [30]. Ferrites can be divided into two families based on their resistance to magnetic forcing. Hard ferrites have high coercivity, so they are difficult to demagnetize. They are used to make permanent magnets for applications such as refrigerator magnets. Soft ferrites have low coercivity, so they act as conductors of magnetic fields [31]. They are used in the electronics industry to make magnetic cores for transformers and antennas. In addition to these, there are also special ferrite structures consisting of amorphous strips that are used as ferrite. These are alloys obtained from rapid solidification techniques as thin strips (characterized thickness below 30 microns and variable lengths) and fine wires (typical diameters less than 120 microns and variable lengths). Very soft near-zero magnetostriction amorphous and nanocrystalline strips are also contemplated as alternative materials for applications up to the MHz range. In this study, the effects of soft ferrites and amorphous ferrite structures on the test results will be checked with the interaction of both the supply cable (main supply line) at the entrance of the product and the phase and neutral lines in the mainboard box.

5.2.1 Ferrite Ring (Soft Ferrite) on the Main Cable

The product chosen for this test is the product with the worst test result among the products with 3 different cable structures used in the previous tests, where the entire cable is used in a single line. The main reason for choosing this product is to see how much a structure that is in the worst condition and which has been tested before, will change with the application to be made. In this product, as seen in figure 23, the supply cable of the product is wrapped in soft ferrite for 2 turns. Increasing the number of turns increases the maximum impedance and decreases the maximum frequency. As can be seen in the graphic below (figure 22), the effect of the increase in the number of turns in certain frequency ranges is shown. From this point of view, tests were carried out with 2 turns, which is ideal for 100 MHz and also suitable for use in terms of core inner diameter [3].

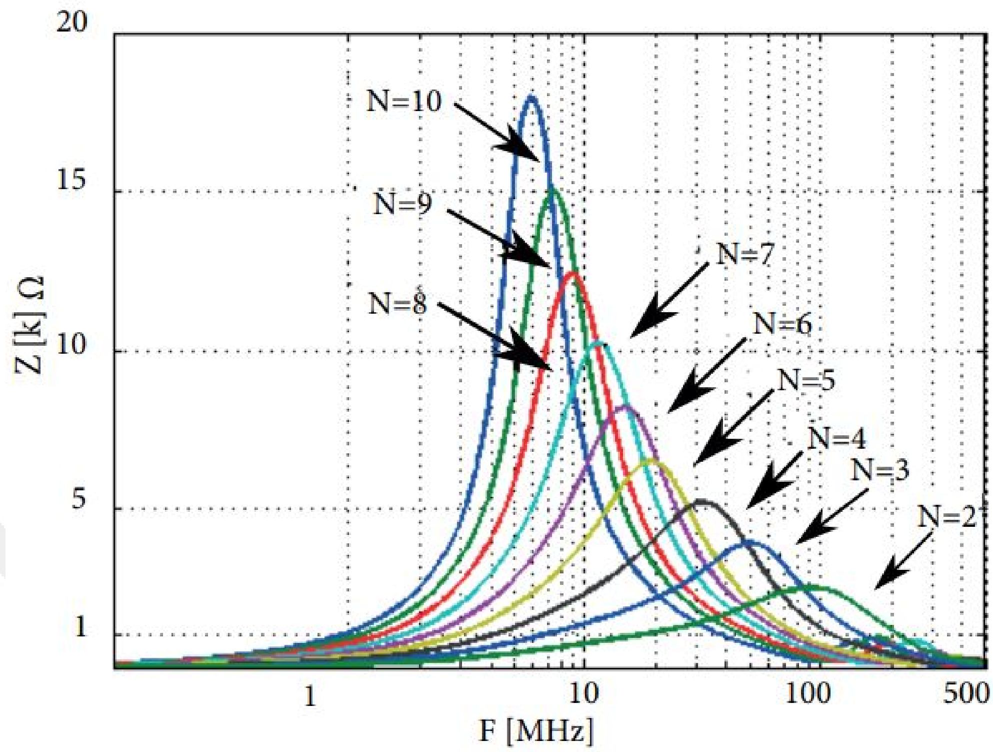

Figure 22: Impedance of a ferrite round cable core ferrite vs. frequency [3]

The material used is soft ferrite. It is ring-shaped and has high permeability. This structure is referred to as F10. The material type is Manganese-Zinc. It has an effective structure in the range of 25-100 MHz. The outer diameter of the core is 31 mm, the inner diameter is 19 mm and its height is 16 mm.

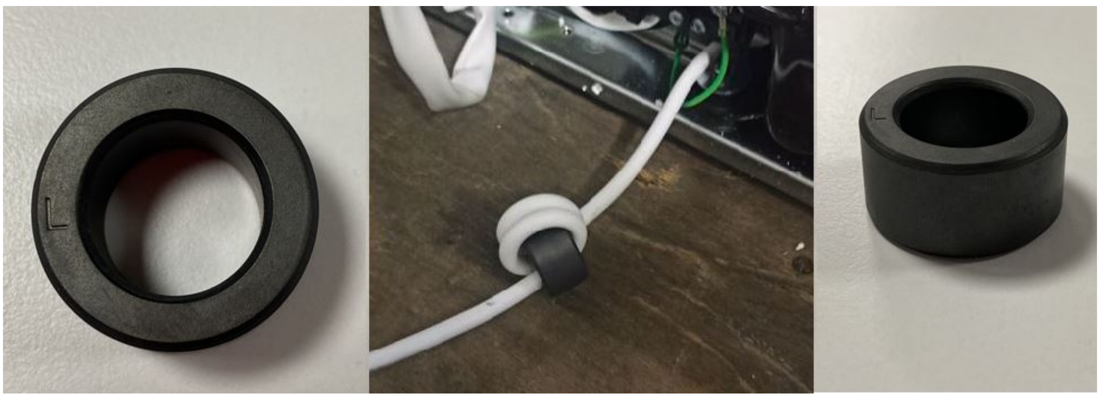

Figure 23: Ferrite Ring (Soft Ferrite) on the Main Cable

As seen in Figure 24, it is seen that ferrite dampens all the noise in the range of 25-100 MHz and reduces it below the critical limits. It was observed that the peak decibel values were damped in the part marked with the red line. At the point marked with orange color, it is seen that the average values are close to each other and even there is no change. Even though the average values have increased and decreased in places, it is seen that the ferrite application is successful since it is observed that they are below the limits and the peak values are damped. It is seen that there is a decrease of approximately 10 dBpW in the 30 - 50 MHz range, 15 dBpW in the 50 - 60 MHz range, and 5 dBpW in the 60 - 90 MHz range.

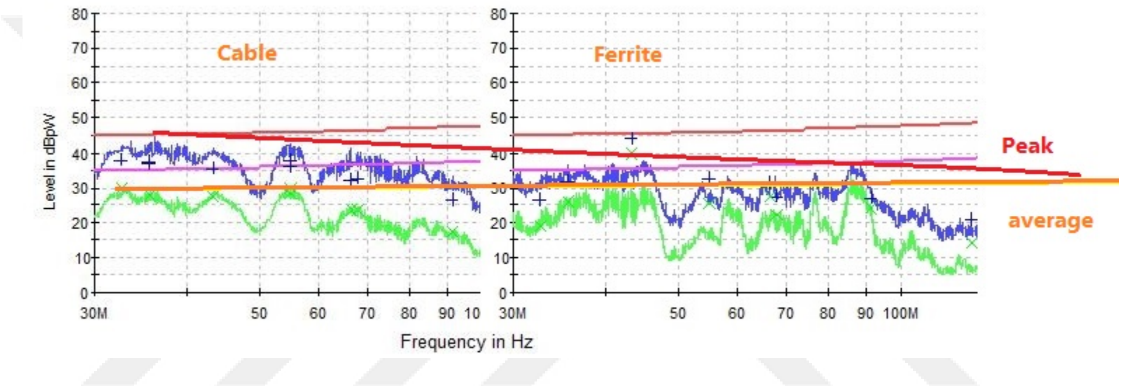

Figure 24: Ferrite Ring (Soft Ferrite) on the Main Cable test result

5.2.2 Ferrite Ring (Soft Ferrite) On The Cables in The Control Box

The product selected for this test is the product with the worst test result among the products with 3 different cable structures used in the previous tests where the entire cable was used in a single line. In this product, as seen in figure 25, the phase and neutral cables, which are the input of the mainboard, and the cable with the compressor output, are wrapped with soft ferrite for 2 turns in the mainboard box of the product. This structure is difficult in terms of applicability. In addition, the card box of the product in which the test was carried out was not suitable in size. But the result to be obtained from this is important as it will contribute to the development of designs that will allow a new design to be made and, if necessary, ferrite and similar applications in card boxes.

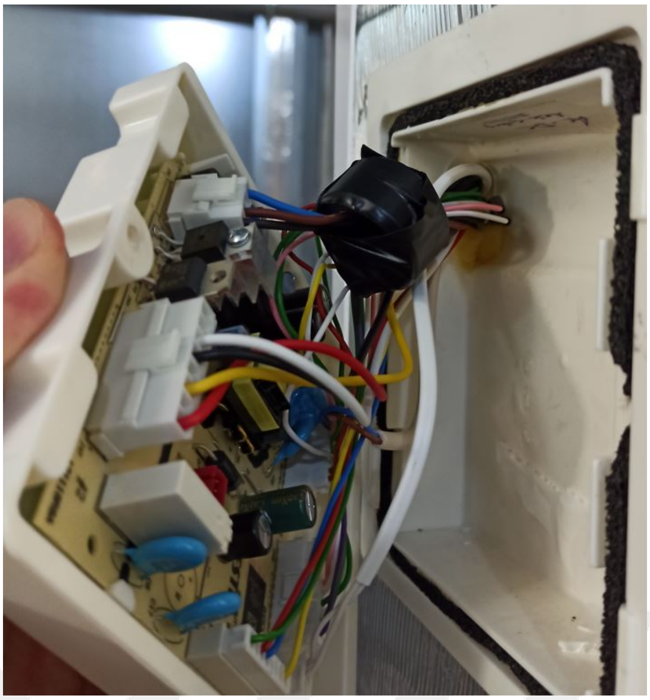

Figure 25: Ferrite Ring (Soft Ferrite) On The Cables in The Control Box

As can be seen in Figure 26, it is seen that ferrite cannot dampen the noise in the range of 25-100 MHz, and even affects it negatively at some points. In the part marked with the red line, it is seen that the part of the peak decibel values up to 45 MHz is damped, but the peak values in the 45 - 50 MHz range increase up to the limits. At the point marked with orange color, it was determined that the mean values increased throughout the entire range and even approached the peak values. The main reason for this is that the disturbance power test measures the noise on the cable on the input line of the product. Therefore, the ferrite solution may not be efficient when applied to a location other than this cable. In addition, the semiconductor materials on the PCB in the card box, the X caps at the PBC entrance, may have experienced a decrease in the impedance values with the effect of ferrite and may have affected the damping negatively instead of contributing to it. Since the average values are constantly increasing, it can be said that the ferrite application is not successful in this position. It is seen that there is an increase of approximately 10 dBpW in the 30 - 50 MHz range, and 20 dBpW in the 50 - 100 MHz range.

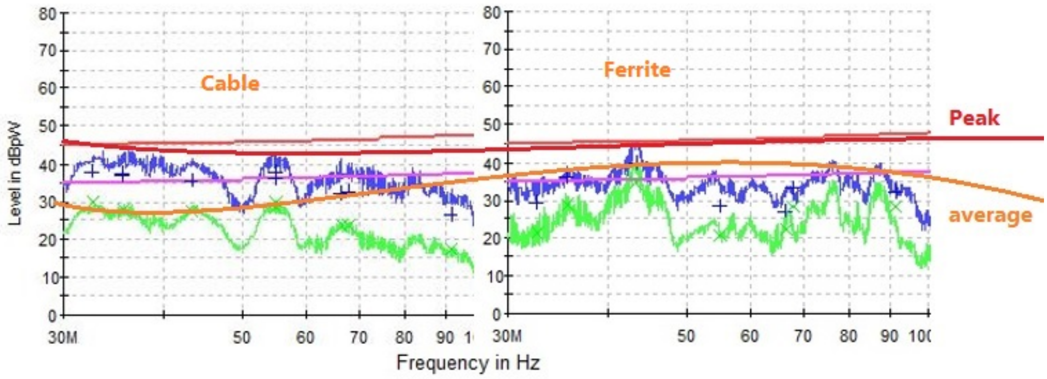

Figure 26: Ferrite Ring (Soft Ferrite) On The Cables in The Control Box test results

5.2.3 Ferrite Ring (amorphous) on the Main Cable

Amorphous ferrites, unlike other ferrites, are not in a single whole. Amorphous cut cores are made of non-crystalline metallic glass materials. The amorphous atomic structure exhibits much higher resistivity than crystalline alloys, so amorphous cut cores offer efficiency with optimal response to frequencies. Amorphous truncated cores are the preferred solution for high-frequency [32], low-loss applications such as uninterruptible power supplies, SMPS power factor correction chokes, and high-frequency power transformers and inductors. Compared to ferrite cores, amorphous cores provide much higher flux capacity and significantly higher impedance at high frequencies [33]. Amorphous cut cores are strong in compression and tension, so they are resistant to fracture and corrosion. Since it provides more efficient results at high frequencies, it will give more ideal and appropriate results in High-frequency tests such as the Disturbance power test compared to existing structures.

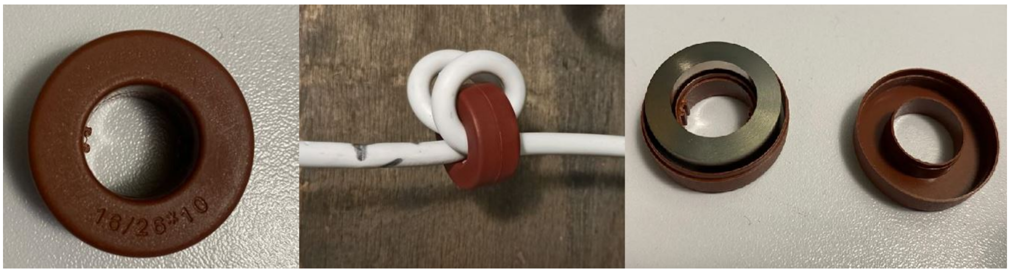

Figure 27: Ferrite Ring (amorphous) on the Main Cable

As can be seen in Figure 28, Amorphous works effectively across the entire frequency band and attenuates noise at all peaks. In the part marked with the red line, it is seen that the peak decibel values increase only at 55 MHz. At the point marked with orange color, it can be seen that the average values decrease over the entire range. This is mainly because it is ideal for high frequency and low loss tests such as disturbance power. It can be said that the Amorphous application was successful in this position since the average values continuously decreased. It is seen that there is an improvement of approximately 20 dBpW in the 30 - 50 MHz range, and 10 dBpW in the 50 - 100 MHz range.

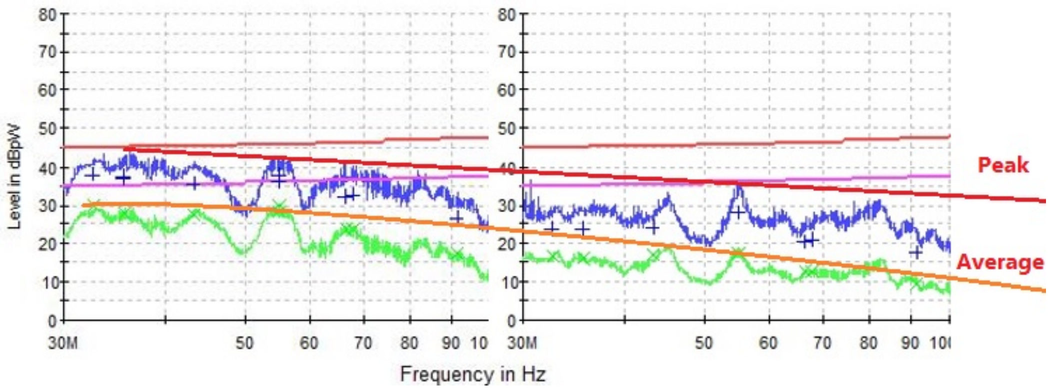

Figure 28: Ferrite Ring (amorphous) on the Main Cable test results

5.2.4 Ferrite Ring (amorphous) On The Cables in The Control Box

In this test, as seen in Figure 29, the phase and neutral cables of the motherboard and the cable with the compressor output were wrapped in amorphous ferrite for 2 turns in the motherboard box of the product. In this test, the location where the application is made is not suitable as desired, considering the current structure and manufacturability of the product. Here, the goal is to see the results that will be obtained when the cable coming from the main supply line to the product is bypassed and applied only in the part inside the box, and if it is beneficial, to obtain the arguments that will provide the necessary design studies for the positioning of the ferrite structure on the product.

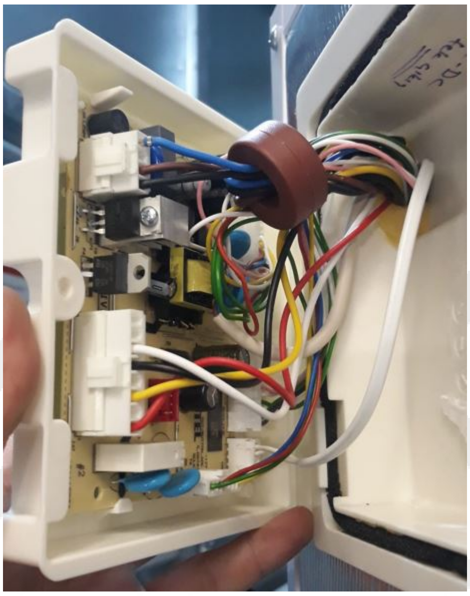

Figure 29: Ferrite Ring (amorphous) On The Cables in The Control Box

As can be seen in Figure 34, Amorphous works effectively across the entire frequency band and dampens noise at all peaks. In the part marked with red and orange lines, it can be seen that the peak decibel values increase only at 55 MHz. At all points other than this, it can be seen that the average values decrease over the entire range. This is mainly because it is ideal for high frequency and low loss tests such as disturbance power. It can be said that the Amorphous application was successful in this position since the average values continuously decreased. It is seen that there is an improvement of approximately 15 dBpW in the 30 - 50 MHz range, and 10 dBpW in the 50 - 100 MHz range.

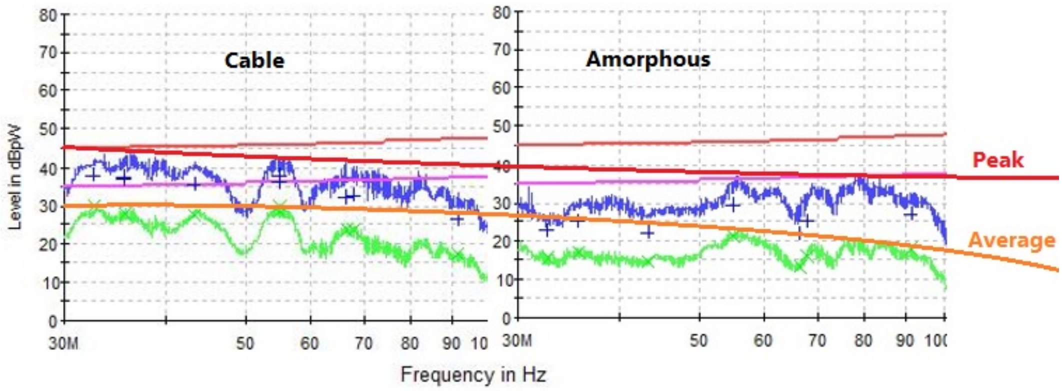

Figure 30: Amorphous On The Cables in The Control Box test results

5.2.5 Comparison Of The Results

As seen in Figure 31, all test results were compared. The first graph shows the test results where Soft ferrite is connected to the input cable (supply cable) of the product, the second graph is used in the graphics card box, and the third graph shows the test results where the amorphous ferrite is connected in the supply cable and the fourth graph is in the card box. When the path marked with red and orange colors on the graph is followed, it is seen that the most ideal region for the use of both ferrite and amorphous is the supply cable. Although the results in the card box are positive, this region has more disadvantages due to the difficulty of use and its proximity to the electrical components on the card. When the situation between these two materials is compared, it is seen that the use of amorphous is more efficient in terms of noise damping at peak values, at graphic values. When we compare the 1st and 3rd graphs; The noise level, which is 40 dBpW in the 30-50 MHz range in the 1st graph, decreases to 30 dBpW as can be seen in the 3rd graph with the use of amorphous.

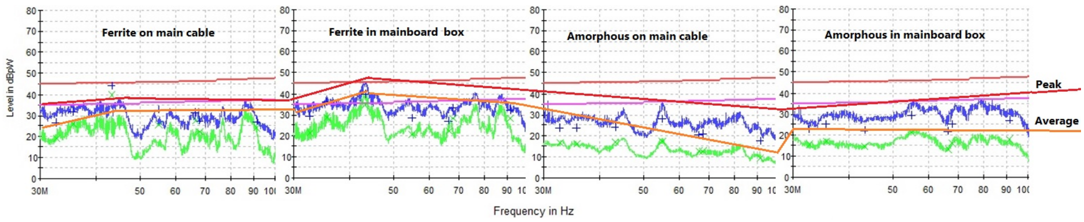

Figure 31: All test result comparison

CHAPTER VI

CONCLUSION

The purpose of this research is to investigate the effect of the components used in the refrigerator on the disturbance power test, which is one of the critical EMC factory tests of a refrigerator. This test is especially important for studying the effect of High-frequency interactions on the refrigerator. The main purpose of choosing this study is that the effect of conventional designs on EMC tests in white goods products has not been revealed by test results, and the performance of the products in these tests is very variable according to design changes, based on experience. To investigate the most fundamental root causes of this variability and to investigate whether adding or removing components affects the product's EMC test results. In the first place, how the cable structure, which is one of the most basic components, affects the tests, was examined and these test results were shared for the first time in this report. According to these test results, changes in the product cable affect the test results. It has been revealed with which changes these effects occur in cable structures and whether they affect them positively or negatively. It has been clarified by these test results that the effect of cabling, which is the most basic component used during product designs, on the production of products suitable for EMC designs cannot be ignored. In addition, it has been supported by the test results that various studies can be done to improve existing designs without making changes in cable designs, and the most easily applicable of them is the addition of ferrite to cable assemblies. Thanks to one-to-one comparative tests, results have been obtained that will contribute to the production of correct designs for productively correct and effective product production. According to the data obtained from these test results, it has been observed that while wiring the products, separating the cable structures as much as possible in the parts close to the electronic board group and ensuring appropriate distances between the cables carrying different electrical loads and cables of different lengths have a positive effect on the results. In addition, the proper alignment of the cable parts within the polyurethane foam structure of the product can provide benefits without the need for complete separation from each other. Ferrite application is applied to the cable group as an alternative solution to improve a possible negative test result because the cable structure in the refrigerator remains in the polyurethane foam. According to the information obtained in these test studies, the types and locations of Ferrite applications positively affect the current test results. Test results show that ferrite applications can be presented as a solution to the problem since no changes can be made in the cable structure when situations requiring intervention occur after mass production.

APPENDIX A

EMC STANDARTS AND NORMS

EMC standards and norms define terms, rules, and test methods for EMC. They also specify limits and minimum test levels for electrical and electromagnetic emissions and immunity of electromechanical and electronic products.

EMC standards help make measurements comparable and repeatable by defining test methods, test equipment, and test environment. And an important point about EMC standards: At best, they have the purpose of bringing compliance to EMC testing: global compliance.

Standards in EMC are defined and expressed by international and national or regional organizations and committees on behalf of governing bodies, or administrative and/or regulatory bodies refer to EMC Standards and regulations.

Here is an overview of the international and national organizations and committees that have developed and/or defined applicable EMC standards [34]:

1. International Electrotechnical Commission (IEC)
    (a) Committees within IEC for Basic and Generic EMC Standards
        i. Technical Committee 77, Electromagnetic Compatibility (TC 77)
        ii. International Special Committee on Radio Interference (CISPR)
    (b) Committees within IEC for Product and Product Family EMC Standards
        i. Plenty of committees
    (c) Liaison partners of IEC
        i. International Organization for Standardization (ISO)
        ii. ITU Telecommunication Standardization Sector (ITU-T)

   iii. International Council on Large Electric Systems (CIGRE)
   iv. The Union of the Electricity Industry (Eurelectric)
   v. International Organization of Legal Metrology (OIML)

2. Australia / New Zealand
   (a) Standards Australia (AS)
   (b) Standards New Zealand (NZS)
3. Canada
   (a) Canadian Standards Association (CSA)
4. China
   (a) Standardization Administration of China (SAC, representing China in National in ISO and IEC committees)
      i. SAC/TC79: National Radio Interference Standardization Technical Committee (the corresponding Chinese committee to IEC/CISPR)
      ii. SAC/TC246: National Electromagnetic Compatibility Standardization Technical Committee (the corresponding Chinese committee to IEC/TC77)
5. Europe (EU)
   (a) Comité Européen de Normalisation Electrotechniques (CENELEC)
   (b) European Telecommunications Standards Institute (ETSI)
   (c) European Committee for Standardization (CEN)
6. Germany
   (a) Verband der Elektrotechnik, Elektronik und Informationstechnik(VDE)
7. India

(a) Bureau of Indian Standards (BIS)

8. Japan

    (a) Japanese Industrial Standards Committee (JISC)

    (b) Japanese Standards Association (JAS)

9. Korea

    (a) Korean Standards Association (KSA)

10. Russia

    (a) Federal Agency for Technical Regulation and Metrology (GOST R)

11. Russia,Azerbaijan, Armenia,Belarus,Georgia, Kazakhstan,Kyrgyzstan, Moldova, Tajikistan,Turkmenistan,Uzbekistan,Ukraine:

    (a) Euro Asian Council for Standardization, Metrology and Certification (EASC)

12. Singapore

    (a) Info-Communications Media Development Authority (IMDA)

13. Turkey

    (a) Turkish Standards Institution (TSE)

14. United Kingdom (UK)

    (a) British Standards Institution (BSI)

15. United States (USA)

    (a) Association for the Advancement of Medical Instrumentation (AAMI)

    (b) American National Standards Institute (ANSI)

    (c) Department of Defense (DoD)

(d) Federal Communications Commission (FCC)

(e) Radio Technical Commission for Aeronautics (RTCA)

(f) Society of Automotive Engineers (SAE)

APPENDIX B

HISTORY OF EMC

Since we began to understand and use electricity, the effects of electronic interference have been observed, documented, and regulated. Although the extensive presence of electronic devices in our lives and the potential for the conflict they create may seem like a modern phenomenon, primitive forms of EMC compatibility testing date back to the late 19th century.

The oldest EMC problem was lightning strikes on ships and buildings. Lightning rods began to appear in the middle of the 18th century [35]. With the emergence of widespread electricity generation and power supply lines from the late 19th century, problems also arose with equipment short-circuit failure affecting the power supply and local fire and shock hazards when the power line was struck by lightning. Output circuit breakers were provided to the power stations. Buildings and appliances would soon be equipped with input fuses, and later in the 20th-century miniature circuit breakers (MCBs) would come into use.

From the late 1970s, the popularity of modern digital circuits grew rapidly. As technology improved, with ever-faster switching speeds (increased emissions) and lower circuit voltages (increased sensitivity), EMC became more and more of a concern. Many more countries have recognized that EMC is a growing problem and has issued guidelines to digital electronic equipment manufacturers outlining key manufacturer requirements before their equipment is marketed or sold. Organizations in individual countries have been set up throughout Europe and around the world to maintain these directives and related standards. In 1979, the American FCC issued a regulation requiring that the electromagnetic emissions of all "digital devices" be below certain limits [35]. This regulatory environment has led to sharp growth in the EMC industry, which provides specialist devices and equipment, analysis and design software, and testing and certification services. Low-voltage digital circuits, especially CMOS transistors, became more susceptible to ESD damage as they were miniaturized, and despite the improvement of on-chip hardening techniques, a new ESD regulatory regime had to be developed.

The explosive growth in mobile communications and broadcast media channels from the 1980s put a huge strain on existing airspace. Regulators have begun to bring band allocations closer together, relying on increasingly sophisticated EMC control methods, particularly in the digital communications field, to keep inter-channel interference at acceptable levels. Digital systems are inherently less sensitive than analog systems and also offer much easier ways (such as software) to implement highly complex protection and error correction measures.

In 1985, the US introduced ISM bands for low-power mobile digital communications, leading to the development of Wi-Fi and remote car door switches. This approach relies on the intermittent nature of ISM interference and the use of sophisticated error correction methods to provide lossless reception during silent gaps between any interference bursts.

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