



STUDY OF CONDUCTED EMISSION CHARACTERISTICS INDUCTION STOVES ON 9 KHZ-30 MHZ FREQUENCY

Henny Tri Kurniawati, Budi Sudiarto

Faculty of Engineering, Universitas Indonesia, Indonesia

Email: henny.tri@ui.ac.id, budi.sudiarto@ui.ac.id

ABSTRACT

The presence of increasingly sophisticated and innovative cooking utensils such as induction cookers has changed the way of cooking by providing a high level of efficiency. Induction cookers are also a breakthrough in reducing carbon emissions and making them an important choice in energy conservation efforts. The use of induction stoves in the community still faces several obstacles such as relatively high prices, significant power consumption, and the need for special cooking containers. In addition, the development of induction stove technology can produce electromagnetic emissions in the form of conduction emissions. Conducted emission is electromagnetic interference caused by electronic devices through conductors which can be interpreted as noise currents that propagate on the conduction path and have the potential to interfere with other electronic equipment through voltage sources. In the same power grid, conducted emissions caused by induction stoves can also interfere with data signals using Power Line Carrier (PLC) at a frequency of 30-500 kHz. This study aims to understand and identify patterns of electromagnetic wave emission, namely conduction emissions produced by induction stoves. The main focus is on conducted emissions, which can affect the performance of such electronic devices. The results of research related to the characteristics of the conducted emission value of this induction stove are expected so that this household device is safer and more comfortable to use by the community and can provide a reference for the further development of induction stove technology. The test method was carried out on 4 (four) brands of induction stoves C, A, M and P under various operating conditions and cooking modes both individually and simultaneously in the frequency range of 9 KHz-30 MHz through Electromagnetic Compatibility (EMC) testing. The measured parameter is a Quasi Peak (QP) value, in accordance with CISPR standard 14.1:2020. Based on measurements in the frequency range of 9 kHz-30 MHz, individual conditions were obtained that some of the induction stoves used in this study were above the threshold values required in CISPR 14.1:2020. Based on measurements with the condition that the induction stove is operated simultaneously, the level of conducted emission decreases and there is a disturbance at a new frequency beyond the disturbance frequency at individual conditions.

Keywords: Induction cooker, conducted emission, electromagnetic compatibility

INTRODUCTION

Household appliances have undergone a significant transformation along with continued technological

developments, making it easier for people to carry out daily activities such as cooking using an induction stove. Induction stoves make cooking activities quick, easy and safe, considering that gas stoves and other types

of conventional stoves have a risk of causing accidents when used (Gill-Wiehl et al., 2021). Induction stoves are household devices that offer convenience, safety and high efficiency in their use (Topuz et al., 2019).

An induction stove is a non-linear electronic equipment that works using the working principle of electromagnetic induction by using a coil as a magnetic field generator that is used for cooking. An electrical network with a frequency of 50 Hz is applied to the induction coil and current will flow through the coil. Alternating current (AC) will generate magnetic field lines that change according to changes in the current. This magnetic field will penetrate the cooking place made of metal, causing what is called an induced electromotive force to arise. Cooking tools made from ferromagnetic metals will transfer heat energy better (Tiandho et al., 2021).

In the future, it is predicted that induction stoves will be one of the cooking devices that will be able to replace previous conventional stoves due to the advantages of efficiency and energy security (Plumed et al., 2022). In overcoming conditions of energy security and economic subsidies, the Indonesian Government needs to implement the use of induction stoves among the public as an alternative form. This is the Government's effort to conserve energy by replacing the use of gas stoves and other conventional stoves with induction stoves which can reduce the energy crisis in Indonesia, namely state subsidies related to the supply of liquified petroleum gas (LPG) (Hakam et al., 2022; Tama, 2022). So that a lot of research has been carried out to support these energy conservation efforts. Previous research also stated that induction stoves are a form of

contribution to reducing the footprint of carbon emissions released into the atmosphere (Chacón-Troya et al., 2017).

On the other hand, there are concerns about the risks of using an induction stove. Apart from the fact that the price of induction stoves is still expensive, the electricity used is high, and the cooking utensils used must be made from special materials, previous research explains that the presence of induction stoves causes electromagnetic interference (EMI) which can interfere with the function and performance of the device itself and performance of other electronic devices in the vicinity. (Rickli et al., 2003) because, even though they are not able to arise EMI issues directly, they may cause much more significant radiated emissions that may interfere with device operations, such as AM radio systems and telecommunication (Spano, 2014). In the same electrical network, conducted emissions caused by induction stoves can also interfere with data signals using Power Line Carriers (PLC) at frequencies of 30-500 kHz (643-2004 - IEEE Guide for Power-Line Carrier Applications, 2005; IEEE Standard for Power-Line Carrier Line-Tuning Equipment (30 KHz to 500 KHz) Associated with Power Transmission Lines Sponsored by the Power System Communications Committee IEEE Power and Energy Society, 2013). Therefore, research is needed regarding the characteristics of the conducted emission values of induction stoves so that this household device has an optimal design and working system so that it is safer and more comfortable to use by the public and it is hoped that it can provide a reference for further development of induction stove technology.

The research is focused on understanding and identifying

electromagnetic wave emission patterns, namely conducted emissions (conducted emissions) produced by induction stoves in the frequency range 9 KHz-30 MHz because this frequency is also used as a Power Line Carrier (PLC) communication signal and as the types of devices increase which causes interference in that frequency range (Sudiarto, 2017). Conducted emissions refer to electromagnetic interference generated by electronic or electrical devices and propagated through power cables or other conductive pathways. Conducted emission characteristics at 9 KHz-30 MHz will be observed by varying the power consumption level of the induction stove with various operating loads. The parameter used is the quasipeak (QP) value to detect temporary spikes or peaks in the noise. The higher the quasipeak value, the higher the conduction emission value produced by the induction stove (Kharanaq et al., 2020).

RESEARCH METHODS

Research Flow Chart

Figure 1 shows a research flow diagram for analyzing the characteristics of conducted emissions on induction stoves.

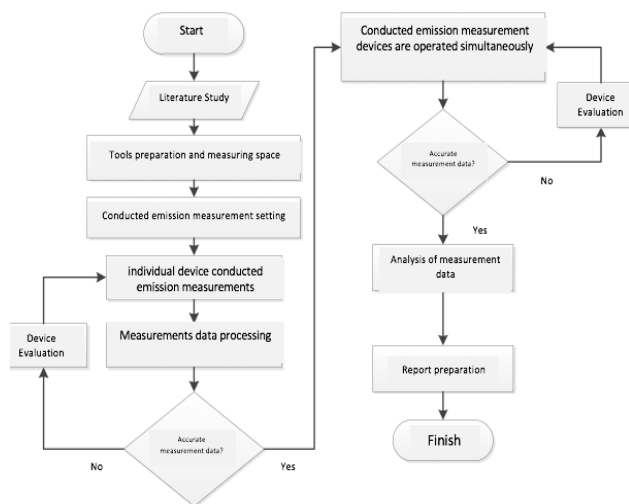


Figure 1. Research Flow Diagram

The research will be carried out with various measurement stages as follows:

1. The first stage in this research is conducting a literature study and identifying problems
2. Preparation of equipment and space for measuring conduction emissions by providing four brands of induction stoves which will be tested as EUT (Equipment Under Test) to obtain conduction emission values that represent the condition of induction stoves generally circulating in Indonesia, namely induction stoves with the letter notation C, A, M and P.
3. Prepare conducted emission measurement tools, such as Line Impedance Stabilization Network (LISN) devices and EMI Receivers to read measurement results with frequency capabilities from 9 kHz – 30 MHz as well as laptop or personal computer devices to display measurement results.
4. Measurements of induction stove conduction emissions were carried out with 10 measurements by taking the first 6 frequency points and using the Quasi Peak value parameters. Quasi Peak (QP) values are used to detect spikes or temporary peaks in noise. The noise or spikes have a detrimental effect on other devices on the network or in the electronic environment. Measurement of induction stove conduction emissions has the following stages:
 - a. Individual induction stove conduction emission measurements
 - 1) Position each of the four brands of induction stoves in stand-by condition and then measure the conduction emission values.
 - 2) Position the four stoves to operate at power settings operating at power levels of 200 Watts, 800

- Watts and 1000 Watts and above which will be adjusted to the capabilities of each induction stove with a frequency range of 9-150 kHz and 150 kHz-30 Mhz.
- 3) Analyze measurement data to see the characteristics of conducted emissions produced by induction stoves.
 - b. Measurement of conduction emissions from induction stoves that are operated simultaneously. At this stage, 2 (two) brands of induction stoves were selected which had the highest conducted emission values to be operated simultaneously with various cooking modes in the frequency range of 150 kHz-30 MHz and then the impact on the resulting level of conducted emissions was seen.
 - 1) Induction stoves that have the highest conduct emission values in individual conditions (certain brands of induction stoves and power levels) are operated in conjunction with other brands of induction stoves at power levels according to the capabilities of the induction stove.
 - 2) Analyze measurement data to see the characteristics of conducted emissions produced by induction stoves.
5. Data analysis
- a. Analyze the data produced by the measurement tool and conduction emission levels at the relevant frequencies for each induction stove.
 - b. Analyze the measurement results with the lowest conduction emission values and compare the measurement results between the four brands of induction stoves to see the

characteristics of the conduction emissions produced and the impacts caused when operated close to and at the same time as other induction stoves.

6. Reporting of measurement results is carried out by compiling a report that includes measurement results, data analysis, comparison of conduction emission values, characteristics and impacts caused.

Test Method

The research was carried out by observing the conduction emission values produced by 4 (four) brands of induction stoves. Measurements are carried out using devices that are adapted to the Electromagnetic Compatibility (EMC) testing standards contained in the CISPR 32:2015 standard concerning Electromagnetic compatibility of multimedia equipment – Emission requirements (Electromagnetic compatibility of multimedia devices – Emission Measurements) as follow:

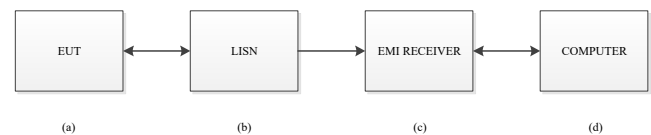


Figure 2. Conducted Emission Test Series

Electromagnetic Compatibility (EMC) testing is carried out by connecting the test item (Equipment Under Test) (a) with the Line Impedance Stabilization Network-LISN device (b) using the power cable from the EUT-test item (a). The LISN device (b) is connected to the EMI Receiver (c) using a BNC cable. Connection between EMI Receiver (c) and Personal Computer or laptop (d) to display measurement results using a USB cable.

Induction hobs are tested individually and operated simultaneously to obtain the conducted emission characteristics of each brand of induction stove by referring to the

CISPR 14.1:2020 standard concerning Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission. When testing, the induction stove was loaded with a ferromagnetic pan filled with water to around 50% of its maximum capacity. Standard cooking containers or pans (contact surface dimensions) are: 110 mm, 145 mm, 180 mm, 210 mm, 300 mm (CISPR 14-1: Electromagnetic Compatibility-Requirements For Household Appliances, Electric Tools and Similar Apparatus-Part 1: Emission, 2020). The data obtained from the conducted emission measurements were then processed using Microsoft Excel

Test Configuration

The conduction emission measurement room was carried out in the Electromagnetic Compatibility (EMC) laboratory room with a room temperature of 21.8 °C, air humidity of 55.8% RH and air pressure of 1003.2 mbar which refers to the International Electrotechnical Commission (IEC) standards. Measurement of conduction emissions with a test configuration on a table using a vertical ground plan as shown in Figure 3 below.

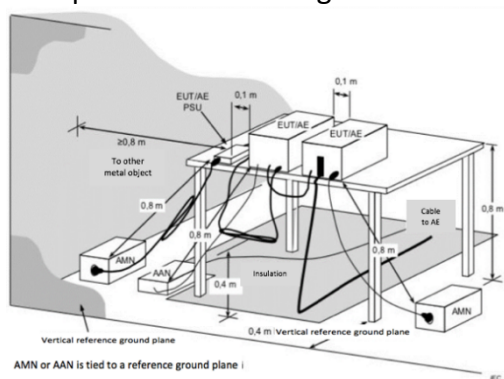


Figure 3. EMC Test Configuration on a Table Using a Vertical Ground Plan (CISPR 32-2015: Electromagnetic Compatibility of Multimedia Equipment-Emission Requirements, 2015)

The EMC test configuration on a table with a vertical ground plan refers to the CISPR

32:2015 (CISPR 32-2015: Electromagnetic Compatibility of Multimedia Equipment-Emission Requirements, 2015) similar with CISPR 14-1:2020 (CISPR 14-1:Electromagnetic Compatibility-Requirements For Household Appliances, Electric Tools and Similar Apparatus-Part 1: Emission, 2020) and as follows:

- The test items are on a table with a table height of 80 cm.
- The table with the ground plan is 40 cm apart.
- Tables with other metal objects must be more than 80 cm high.
- The distance between test items is 10 cm.
- The LISN is on the floor connected to the test item at a distance of 80 cm.
- Connecting cables between test items or test items – LISN must not touch the ground floor.

Conduction emission measurements were carried out with 10 measurements for each stage and 6 peak points were taken in the frequency range 150 kHz-30 MHz at a PLN electricity voltage of 220 Volts and a frequency of 50 Hz. The impedance and frequency characteristics of the LISN device in the measurement process meet the referenced standards. The L1 and N lines of the LISN were monitored for conduction interference values using an EMI test receiver via a coaxial type interface cable with a termination impedance of 50 Ohm. The standard that regulates the impedance and frequency that LISN must have is IEC 61000-4-6. This standard regulates electromagnetic interference (EMC) testing for electronic and electrical equipment. IEC 61000-4-6 specifies technical requirements for devices used in EMC testing, including Line Impedance Stabilization Networks (LISN) at various frequencies, connection configurations and other test requirements. This standard is

important to ensure that LISNs used in EMC testing meet appropriate specifications for accurate conductive interference measurements. The parameters used in measuring the conducted emissions of induction stoves are the Quasi Peak (QP). The higher the Quasi Peak values produced, the higher the conducted emissions produced by the induction stove.

RESULTS AND DISCUSSION

A. Measurement of Conducted Emissions for Individual Brand C, A, M and P Induction Stoves

Conducted emission (CE) measurements were carried out on 4 (four) brands of induction cookers, namely brands C, A, M and P in various cooking modes and individual power levels. The main objective of this analysis is to identify potential electromagnetic interference produced by each brand of induction cooker.

1) Induction Stove Conditions C, A, M and P Standby

a) Frequency Range 9-150 kHz

The results of conducted emission (CE) measurements carried out on induction cooker brands C, A, M and P in standby conditions in the frequency range 9-150 kHz are as follows:

Table 1. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Standby Position in the Frequency Range 9-150 kHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)
9.24	84.46	9.24	85.72	9.14	85.96	9.00	86.47	9.34	79.75	9.34	84.78	9.00	83.13	9.04	80.55
9.34	84.45	9.54	83.74	9.34	85.42	9.14	85.86	9.54	78.47	10.00	81.18	9.24	83.36	9.54	79.00
9.54	83.90	9.83	82.73	9.54	84.80	9.34	85.22	10.00	76.28	10.43	79.89	9.44	82.47	10.63	76.22
9.83	83.44	10.13	82.19	9.83	83.14	10.53	81.21	10.33	75.44	10.73	78.18	9.64	81.58	10.83	76.11
10.13	82.88	10.43	80.97	10.13	82.72	11.03	80.94	10.83	72.64	10.93	77.97	9.83	80.38	11.00	75.23
10.53	81.38	10.83	80.16	10.73	80.44	11.32	79.48	11.13	71.36	11.13	77.61	10.73	78.01	11.19	75.73

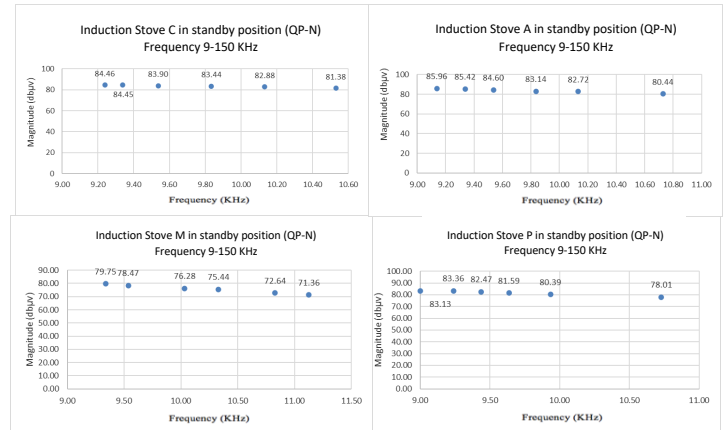


Figure 4. Graph of Conducted Emission (QP-N) Induction Stove C, A, M and P Characteristics in Standby Condition in the Frequency Range 9-150 kHz

Measurements are taken at 6 (six) equal and/or adjacent frequency points on all brands of induction stoves. In standby state, the induction stove still produces conducted emissions. This happened to all brands of induction stoves used in this study. From the graphic data above, it can be seen that the highest level of conducted emissions is at the dominant frequency of 9 – 9.34 kHz.

b) Frequency Range 150 kHz-30 MHz

The results of conducted emission (CE) measurements carried out on induction stove brands C, A, M and P in standby conditions in the frequency range 150 kHz-30 MHz are as follows:

Table 2. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Standby Position in the Frequency Range 150 kHz-30 MHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)	Frequency (kHz)	Average (dBuV)
150.00	61.81	150.00	61.74	159.74	56.29	159.74	58.42	2.58	37.33	2.58	37.40	154.97	61.89	154.97	61.97
183.58	59.72	159.74	60.93	188.35	64.08	178.81	65.96	2.69	37.12	2.87	37.32	193.12	61.97	193.12	61.85
531.67	39.53	174.05	60.05	207.42	54.64	188.35	66.48	2.87	37.32	2.93	37.24	240.80	62.12	240.80	62.04
545.98	38.13	183.58	59.71	236.03	59.51	216.96	54.03	2.93	37.22	2.98	37.30	264.64	62.41	264.64	62.45
669.96	39.32	216.96	57.72	250.34	61.21	236.03	61.82	2.98	37.28	3.11	38.38	298.02	62.00	298.02	61.87
684.26	38.37	231.27	56.95	283.25	56.44	245.57	62.61	3.11	38.33	3.82	37.18	331.40	62.55	331.40	62.48

Study of Conducted Emission Characteristics Induction Stoves on 9 kHz-30 MHz Frequency

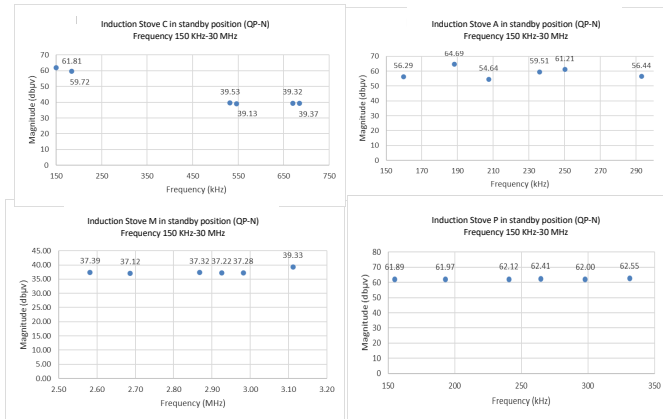


Figure 5. Graph of Conducted Emission (QP-N) Induction Stove C, A, M and P Characteristics in Standby Condition in the Frequency Range 150 kHz-30 MHz

The CE value for stove M starts at a frequency of 2.58 MHz with a value of 37.39 dBμV, for stoves C, A and P the CE value starts at a frequency of 150 kHz. In standby state, the induction stove still produces conducted emissions. Based on table 2 and graph 5 above, the highest conducted emissions are at different frequencies in each stove brand.

2) Conditions for Stoves C, A, M and P Operating at Low Power Levels

a) Frequency Range 9-150 kHz

The results of conducted emission (CE) measurements carried out on induction cooker brands C, A, M and P operating conditions at power levels of 200 Watt and 400 Watt with a frequency range of 9-150 kHz are as follows:

Table 3. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Power Level Position 200 W and 400 W in the Frequency Range 9-150 kHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average
cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)
27.32	92.76	9.24	66.04	-	-	-	-	9.44	80.13	9.44	84.95	25.23	89.06	25.23	97.03
27.52	95.74	9.34	65.38	-	-	-	-	9.54	80.20	9.83	81.74	25.53	95.19	25.83	112.95
27.82	97.86	9.54	64.03	-	-	-	-	9.74	79.03	31.19	73.96	25.83	100.24	26.23	94.00
28.21	104.77	9.83	62.88	-	-	-	-	9.93	78.17	31.49	79.45	26.03	98.55	26.52	87.62
28.41	101.60	10.23	61.63	-	-	-	-	10.43	77.38	31.69	75.66	26.33	91.83	26.82	83.95
54.74	81.89	10.83	60.19	-	-	-	-	10.73	76.18	31.99	67.25	26.62	87.73	27.12	83.95

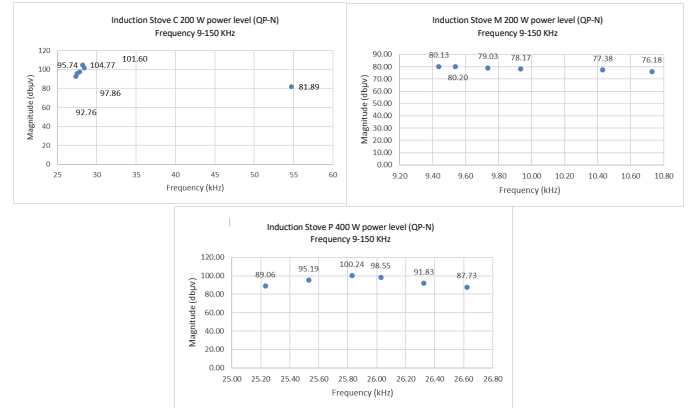


Figure 6. Chart of Conducted Emission (QP-N) Induction Stove C, A, M and P Power Levels 200 W, 400 W in the Frequency Range 9-150 kHz

CE measurements for stove A at a power level of 200 Watts at a frequency of 9-150 kHz cannot be carried out because the CE value exceeds the measurement tool's limit. For stove M the CE value starts at a frequency of 9.44 kHz with a value of 80.13 dBμV and stoves C and P start at a frequency of 25.23 kHz. The CE value in measurements fluctuates up and down in all brands of induction stoves.

b) Frequency Range 150 kHz-30 MHz

The results of conducted emission (CE) measurements carried out on induction cooker brands C, A, M and P operating conditions at power levels of 200 Watt and 400 Watt with a frequency range of 150 kHz-30 MHz are as follows

Table 4. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Power Level Position 200 W and 400 W in the Frequency Range 150 kHz-30 MHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average
cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)
1.09	90.96	150.20	83.99	164.51	88.33	150.00	81.55	159.74	58.36	154.97	59.22	159.74	76.51	154.97	86.63
1.12	89.37	164.51	83.79	178.81	83.49	169.28	94.23	174.05	54.81	174.05	54.77	183.58	89.50	188.35	90.56
1.14	96.24	197.89	88.76	197.89	89.33	197.89	83.21	183.58	53.95	188.35	56.75	212.19	86.59	212.19	85.51
1.15	92.38	207.42	79.03	221.73	80.45	226.50	83.72	193.12	53.67	216.96	52.68	236.03	86.38	231.27	88.77
1.18	89.04	236.03	77.47	236.03	78.66	255.11	81.75	221.73	52.65	231.27	51.07	264.64	90.70	264.64	89.31
1.21	92.44	264.64	75.84	255.11	83.71	283.72	76.56	231.27	51.05	250.34	52.08	288.49	91.45	288.49	88.76

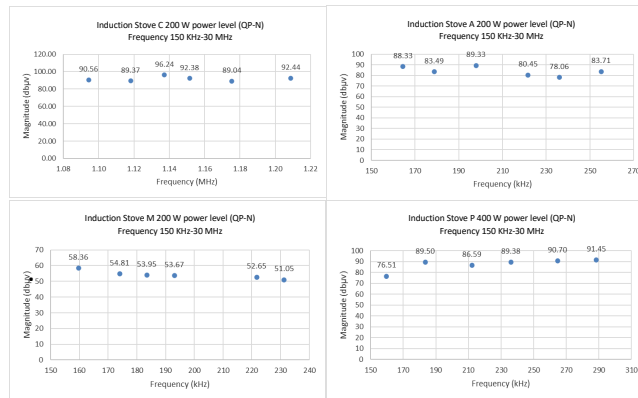


Figure 7. Chart of Conducted Emission (QP-N) Induction Stove C, A, M and P Power Levels 200 W, 400 W in the Frequency Range 150 kHz-30 MHz

The CE value for stove C starts at a frequency of 1.09 MHz with a value of 90.56 dBμV and stoves A, M and P start at a frequency of 150 kHz. The CE value in the measurement fluctuates up and down.

3) Conditions for Stoves C, A, M and P Operating at Medium Power Level

a) Frequency Range 9-150 kHz

The results of conducted emission (CE) measurements carried out on induction cooker brands C, A, M and P operating conditions at power levels of 400 Watt and 800 Watt with a frequency range of 9-150 kHz are as follows:

Table 5. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Power Level Position 400 W and 800 W in the Frequency Range 9-150 kHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average
cy (kHz)	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)
26.42	93.37	26.42	92.51	-	-	-	-	14.21	78.48	9.04	84.21	25.23	99.99	25.83	114.83
26.72	99.48	26.72	99.41	-	-	-	-	14.70	80.71	9.64	82.34	25.53	108.50	50.76	93.54
27.12	91.71	26.92	96.80	-	-	-	-	14.90	80.57	10.13	80.84	25.83	115.13	51.06	95.22
27.42	88.67	27.22	88.75	-	-	-	-	29.60	108.49	10.43	80.47	50.86	92.87	51.36	97.59
27.72	82.76	27.52	86.23	-	-	-	-	58.71	78.45	10.83	79.53	51.16	95.01	51.66	103.34
53.25	89.18	53.25	89.01	-	-	-	-	58.90	79.33	11.03	79.36	51.36	97.74	76.10	84.69

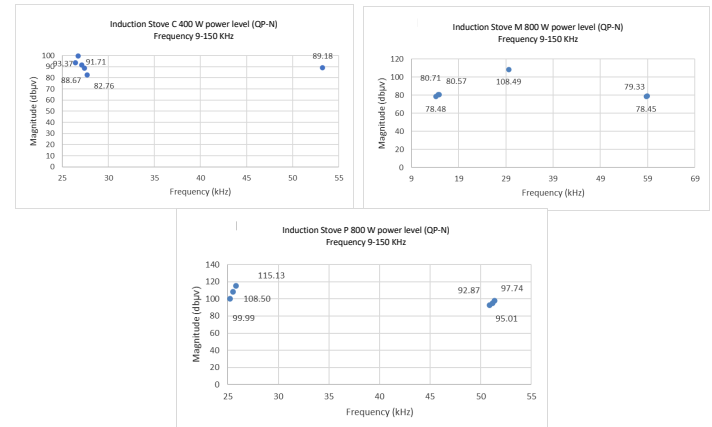


Figure 8. Chart of Conducted Emission (QP-N) Induction Stove C, A, M and P Power Levels 400 W, 800 W in the Frequency Range 9-150 kHz

CE measurements for stove A at a power level of 800 Watts at a frequency of 9-150 kHz cannot be carried out because the CE value exceeds the measurement tool's limit. From the graphic data above, it can be seen that the highest level of conducted emissions is at the dominant frequency of 25.53 – 29.60 kHz for all brands of induction stoves.

b) Frequency Range 150 kHz-30 MHz

The results of conducted emission (CE) measurements carried out on induction cooker brands C, A, M and P operating conditions at power levels of 400 Watt and 800 Watt with a frequency range of 150 kHz-30 MHz are as follows:

Table 6. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Power Level Position 400 W and 800 W in the Frequency Range 150 kHz-30 MHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average	Frequen	Average
cy (kHz)	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)	cy (kHz)	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)
1.08	71.40	150.00	75.85	150.00	78.69	150.00	78.69	150.00	63.42	150.00	65.25	154.97	98.72	154.97	98.56
1.11	71.48	159.74	87.51	164.51	101.31	164.51	101.23	164.51	52.43	178.81	57.29	183.58	95.48	183.58	95.30
1.12	73.55	197.88	77.84	193.12	94.42	193.12	94.42	178.81	55.14	193.12	51.24	207.42	94.88	207.42	94.66
1.15	91.62	212.16	76.79	221.73	91.31	221.73	91.29	193.12	51.36	207.42	58.59	236.03	95.70	236.03	95.56
1.17	71.52	240.80	81.52	250.34	85.97	250.34	85.97	207.42	54.07	236.03	53.77	259.88	93.92	259.88	93.87
1.21	90.81	250.34	74.16	278.95	83.36	278.95	83.30	236.03	53.00	298.02	53.46	283.72	94.78	283.72	94.49

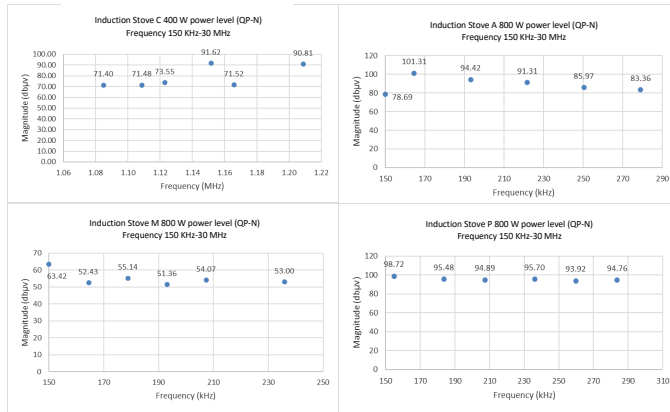


Figure 9. Chart of Conducted Emission (QP-N) Induction Stoves C, A, M and P Power Levels 400 W, 800 W in the Frequency Range 150 kHz-30 MHz

The CE value for stove C starts at a frequency of 1.08 MHz with a value of 71.40 dBμV and stoves A, M and P start at a frequency of 150 kHz. The CE value in the measurement fluctuates up and down. From the graphic data above, it can be seen that the highest levels of conducted emissions for stove brands A, M and P are at the dominant frequency of 150 – 164.51 kHz.

4) Conditions for Stoves C, A, M and P Operating at High Power Levels

a) Frequency Range 9-150 kHz

The results of conducted emission (CE) measurements carried out on induction stove brands C, A, M and P operating conditions at power levels of 800 Watt, 1000 Watt, 1200 Watt and 2000 Watt frequency range 9-150 kHz are as follows:

Table 7. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Position Power Levels 800 Watts, 1000 Watts, 1200 Watts and 2000 Watts in the Frequency Range 9-150 kHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average
cy (kHz)	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)
21.95	100.51	21.95	103.73	-	-	-	-	9.00	90.59	11.05	90.80	-	-	-	-
22.25	106.07	22.25	112.83	-	-	-	-	25.36	113.12	25.36	113.33	-	-	-	-
22.85	108.37	22.45	112.36	-	-	-	-	35.59	84.54	53.99	89.51	-	-	-	-
22.95	103.11	22.75	104.87	-	-	-	-	53.99	89.47	82.62	70.91	-	-	-	-
23.25	96.21	23.05	99.99	-	-	-	-	80.59	71.10	96.94	38.71	-	-	-	-
44.60	90.57	44.31	91.48	-	-	-	-	107.16	65.01	109.21	66.17	-	-	-	-

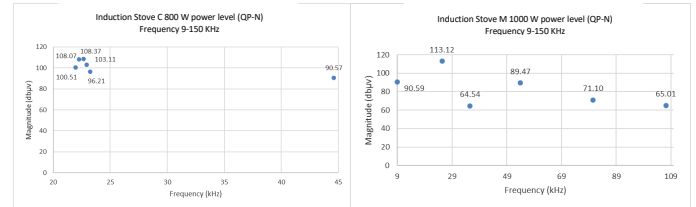


Figure 10. Chart of Conducted Emission Characteristics of C, A, M and P Induction Stoves (QP-N and QP-L1) Position of Power Levels 800 Watt, 1000 Watt, 1200 Watt and 2000 Watt in the Frequency Range 9-150 kHz

CE measurements for stoves A and P at power levels of 1200 Watt and above at a frequency of 9-150 kHz cannot be carried out because the CE value exceeds the measurement tool's limit. For stove M the CE value starts at a frequency of 9.0 kHz with a value of 90.59 dBμV and stove C starts at a frequency of 21.95 kHz with a value of 100.51 dBμV. The CE value in the measurement fluctuates up and down. From the graphic data above, it can be seen that the highest level of conducted emissions is at the dominant frequency of 22.25 – 25.36 kHz.

b) Frequency Range 150 kHz-30 MHz

The results of conducted emission (CE) measurements carried out on induction stove brands C, A, M and P operating conditions at power levels of 800 Watt, 1000 Watt, 1200 Watt and 2000 Watt frequency range 150 kHz-30 MHz are as follows:

Table 8. Conducted Emission Levels of C, A, M and P Induction Stoves (QP-N and QP-L1) Position Power Levels 800 Watt, 1000 Watt, 1200 Watt and 2000 Watt in the Frequency Range 150 kHz-30 MHz

Induction Stove C				Induction Stove A				Induction Stove M				Induction Stove P			
QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1		QP-N		QP-L1	
Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average	Frequency	Average
cy (kHz)	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)	ncy	Mag (dBμV)	y (kHz)	Mag (dBμV)
1.08	92.87	150.00	91.30	152.05	83.87	152.05	83.75	152.05	51.86	152.05	51.82	150.00	102.96	150.00	103.11
1.13	93.54	197.89	86.72	158.18	101.89	158.18	101.83	154.09	52.38	154.09	52.30	154.09	97.91	154.09	97.89
1.15	88.05	240.80	78.90	184.77	94.36	184.77	94.34	166.36	61.59	166.36	59.58	166.36	94.19	166.36	94.19
1.16	97.36	264.64	84.68	211.35	89.99	211.35	89.92	192.95	59.25	270.84	50.80	188.86	96.26	188.86	96.27
1.18	92.27	288.02	72.64	237.94	83.94	237.94	83.84	223.62	57.77	305.42	50.43	209.31	94.37	209.31	94.29
1.20	96.16	317.10	62.78	264.52	81.01	264.52	80.89	250.21	54.28	362.69	47.68	229.76	95.28	231.80	94.70

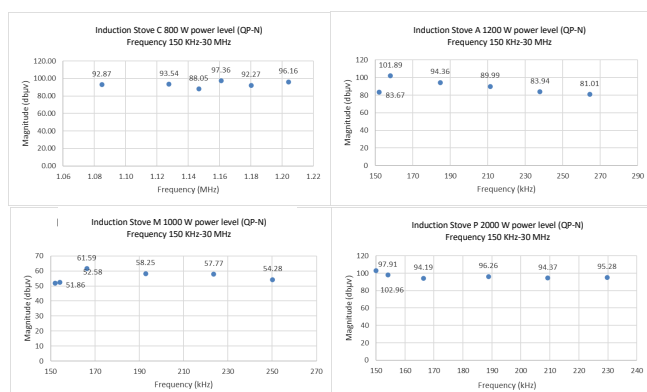


Figure 11. Chart of Conducted Emission Characteristics of C, A, M and P Induction Stoves (QP-N and QP-L1) Position of Power Levels 800 Watt, 1000 Watt, 1200 Watt and 2000 Watt in the Frequency Range 150 kHz-30 MHz

At the maximum power level of each induction stove, the level of conducted emissions produced is higher except for stove M. In measurements in the frequency range 9-150 kHz, the CE value of the induction stove is higher when compared to measurements in the frequency range 150-30 MHz.

The highest CE values for each power variation and cooking mode in the frequency ranges 9-150 kHz and 150 kHz-30 MHz when compared with the measurement limits according to CISPR 14.1:2020 are as follows:

Table 9. Highest Conducted Emission Levels for C, A, M and P Induction Stoves (QP-N and QP-L1) in the Frequency Range 9 kHz-30 MHz

Stove Brand	Frequency	Operating power (W)	QP-N		QP-L1		Limit	Margin	
			Frequency (kHz)	Average Mag (dBμV)	Frequency (kHz)	Average Mag (dBμV)	Quasi-peak dBμV	QP-N dBμV	QP-L1 dBμV
Brand C	9-150 KHz	Standby	9.24	84.46	9.24	85.72	110.00	25.55	24.28
		200	28.21	104.77	23.05	76.46	110.00	5.23	33.54
		400	26.72	99.48	26.72	99.41	110.00	10.52	10.59
		800	22.65	108.37	22.25	112.63	110.00	1.63	-2.63
	150 KHz-30 MHz	Standby	150.00	61.81	150.00	61.74	66.00	4.20	4.26
		200	1.14 MHz	96.24	197.89	88.76	66.00	-30.24	-22.76
		400	1.15 MHz	91.62	159.74	87.51	66.00	-25.62	-21.51
		800	1.16 MHz	97.36	150.00	91.30	66.00	-31.36	-25.30
Brand A	9-150 KHz	Standby	9.14	85.96	9.14	85.86	110.00	24.04	24.14
		200	NA	NA	NA	NA	110.00	NA	NA
		800	NA	NA	NA	NA	110.00	NA	NA
		1200	NA	NA	NA	NA	110.00	NA	NA
	150 KHz-30 MHz	Standby	188.35	64.69	188.35	66.49	66.00	1.31	-0.49
		200	197.89	89.33	197.89	83.21	66.00	-23.33	-17.21
		800	164.51	101.31	164.51	101.23	66.00	-35.31	-35.23
		1200	158.18	101.89	158.18	101.83	66.00	-35.89	-35.83
Brand M	9-150 KHz	Standby	9.34	79.75	9.34	84.78	110.00	30.25	25.22
		200	9.54	80.20	9.44	84.95	110.00	29.80	25.05
		800	9.34	82.70	9.04	84.21	110.00	27.30	25.79
		1000	25.36	113.12	25.36	113.33	110.00	-3.12	-3.33
	150 KHz-30 MHz	Standby	3.1 MHz	39.33	3.1 MHz	39.38	66.00	26.67	26.62
		200	159.74	58.36	154.97	59.22	66.00	7.64	6.78
		800	150.00	63.42	150.00	65.25	66.00	2.58	0.75
		1000	166.36	61.59	166.36	58.58	66.00	4.41	7.43
Brand P	9-150 KHz	Standby	9.00	83.13	9.04	80.55	110.00	26.87	29.45
		400	25.83	100.24	25.83	112.95	110.00	9.76	-2.95
		800	25.83	115.13	25.83	114.93	110.00	-5.13	-4.93
		2000	NA	NA	NA	NA	110.00	NA	NA
	150 KHz-30 MHz	Standby	331.40	62.55	331.40	62.48	66.00	3.46	3.53
		400	288.49	91.45	288.49	88.76	66.00	-25.45	-22.76
		800	154.97	98.72	154.97	98.56	66.00	-32.72	-32.56
		2000	150.00	102.96	150.00	103.11	66.00	-36.96	-37.11

The measurement results show fluctuating results up and down. In the frequency range 9-150 KHz in standby position, the M brand induction stove has a lower conducted emission level, namely 79.75 dBμV (N line) and 84.78 dBμV (L1 line) at a frequency of 9.34 kHz, followed by P stove which is 83, 13 dBμV (N line) and 80.55 dBμV (L1 line) at a frequency of 9 kHz, followed by stove C which is 84.46 dBμV (N line) and 85.72 dBμV (L1 line) at a frequency of 9.24 kHz and stove A which is 85.96 dBμV (N line) and 85.86 dBμV (L1 line) at a frequency of 9.14 kHz.

Based on measurement results in two frequency ranges, namely 9-150 kHz and 150 kHz-30 MHz, the conducted emission (CE) level of some induction stoves is above the threshold value required in CISPR 14.1:2020, this happened in 4 (four) induction cooker brand. Stoves P and A have CE values that exceed the measurement tool limit, namely above 120 dBμV (Not Applicable). The next scenario will be testing 2 (two) induction stove units if they are operated simultaneously in the frequency range 150 KHz-30 MHz. The induction stoves Based on measurement results in two frequency ranges, namely 9-150 kHz and 150 kHz-30 MHz, the conducted emission (CE) level of some induction stoves is above the threshold value required in CISPR 14.1:2020, this happened in 4 (four) induction cooker brand. Stoves P and A have CE values that exceed the measurement tool limit, namely above 120 dBμV (Not Applicable). The next scenario will be testing 2 (two) induction stove units if they are operated simultaneously in the frequency range 150 KHz-30 MHz. The induction stoves that will be used as measurements are 2 brands of stoves, namely P and A stoves, to see their impact on the level of conducted emissions produced.

B. Analysis of Conducted Emission Characteristics in Conditions of Brand P and A Induction Stoves Operated Simultaneously

1) Condition of P Standby and A Standby Stoves

The first research carried out measurements with the P and A stoves in standby position, the results of the conducted emission measurements were obtained as follows:

Table 10. Conducted Emission Level (QP-N) of Induction Stove Condition P Standby and A Standby Simultaneous and Individual Standby in the Frequency Range 150 kHz-30 MHz

P Standby and A Standby	QP-N	Limit QP	Margin	P Standby	QP-N	A Standby	QP-N
Frequency (KHz)	Mag [dBμV]	dBμV	dBμV	Frequency (KHz)	Mag [dBμV]	Frequency (KHz)	Mag [dBμV]
152.05	57.32	66	8.68	154.97	61.89	159.74	56.29
156.14	57.94	66	8.06	-	-	-	-
184.77	64.9	66	1.1	193.12	61.97	188.35	64.69
248.16	61.26	66	4.74	240.8	62.12	236.03	59.51
311.56	58.12	66	7.88	298.02	62	293.25	56.44
374.95	56.58	66	9.42	383.85	61.81	379.09	56.68

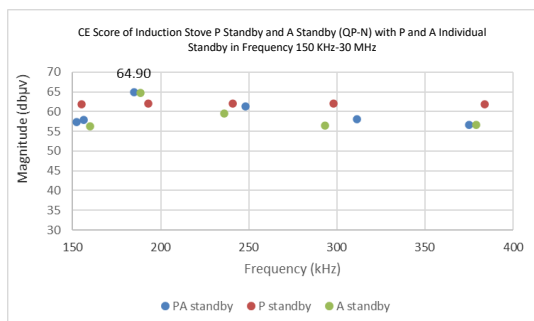


Figure 12. Graph of Conducted Emission (QP-N) Characteristics of an Induction Stove for P Standby-A Standby Simultaneous and Individual Conditions in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is disturbance at a new frequency outside the disturbance frequency during individual conditions with the highest disturbance level of 64.90 dBμV at the frequency 184.77 kHz. In this condition, the resulting conducted emissions initially increase and then decrease. Some CE values at frequency points belonging to A and P

when individually in standby do not appear when P and A are operated together in standby condition. At the same and/or adjacent frequencies, the CE values of PA stoves mostly do not exceed the CE values of P and A induction stoves when measured individually. The level of conducted emissions (CE) in the P standby and A standby stove conditions is below the threshold value required in CISPR 14.1:2020 with a small margin value.

Table 11. Conducted Emission Level (QP-L1) of Induction Stove Condition P Standby and A Standby Simultaneous and Individual Standby in the Frequency Range 150 kHz-30 MHz

P Standby and A Standby	QP-L1	Limit QP	Margin	P Standby	QP-L1	A Standby	QP-L1
Frequency (KHz)	Mag [dBμV]	dBμV	dBμV	Frequency (KHz)	Mag [dBμV]	Frequency (KHz)	Mag [dBμV]
152.05	57.51	66	8.49	154.97	61.97	159.74	58.42
158.18	57.76	66	8.24	-	-	-	-
184.77	64.98	66	1.02	193.12	61.85	188.35	66.49
235.89	60.1	66	5.9	240.8	62.04	236.03	61.82
295.2	56.79	66	9.21	298.02	61.87	298.02	59.34
374.95	56.32	66	9.68	383.85	61.84	379.09	58.4

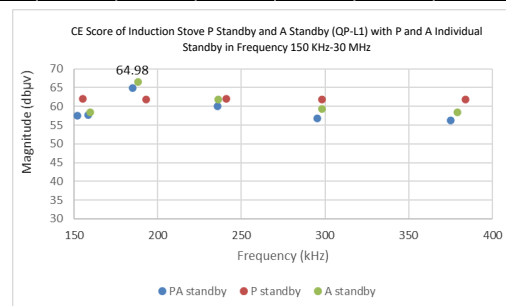


Figure 13. Graph of Conducted Emission Characteristics (QP-L1) of Induction Stove Condition P Standby-A Standby Simultaneous and Individual in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is disturbance at a new frequency outside the disturbance frequency during individual conditions with the highest disturbance level of 64.90 dBμV at the frequency 184.77 kHz. In this condition, the resulting conducted emissions initially increase and then decrease. Some CE values at certain frequency points belonging to A and P when individually standby do not appear

when P and A are operated together in both standby conditions. At the same and/or adjacent frequencies, the CE values of PA stoves mostly do not exceed the CE values of P and A induction stoves when measured individually. The level of conducted emissions (CE) in the P standby and A standby stove conditions is below the threshold value required in CISPR 14.1:2020 with a small margin value.

2) Condition of Stove P 1200 Watt and A Standby

The next research carried out measurements with stove P in the operating position at a power level of 1200 Watts and A in the standby position, the results of the conducted emission measurements were obtained as follows:

Table 12. Conducted Emission Level (QP-N) of Induction Stove Condition P 1200 Watt-A Standby Operates Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

P 1200 W and A Standby	QP-N	Limit QP	Margin	P 1200 W	QP-N	A Standby	QP-N
Frequency (KHz)	Mag [dBμV]	dBμV	dBμV	Frequency (KHz)	Mag [dBμV]	Frequency (KHz)	Mag [dBμV]
150	83.87	66	-17.87	150	91.96	159.74	56.29
154.09	76.99	66	-10.99	168.41	99.13	188.35	64.69
168.41	88.86	66	-22.86	192.95	99.37	207.42	54.64
192.95	88.04	66	-22.04	217.49	97.91	236.03	59.51
217.49	84.88	66	-18.88	242.03	98.31	250.34	61.21
242.03	82.89	66	-16.89	266.57	95.7	293.25	56.44
266.57	79.28	66	-13.28	289.06	96.3	312.33	57.69
289.06	77.61	66	-11.61	313.6	94.95	350.48	52.3

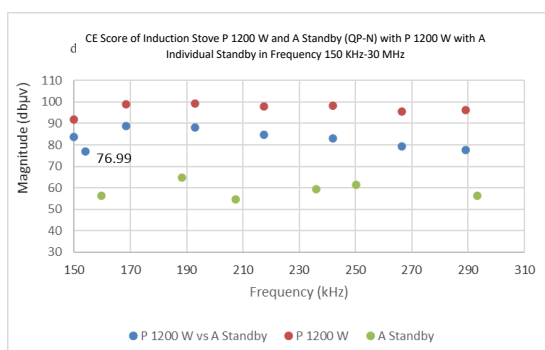


Figure 14. Chart of Conducted Emission (QP-N) Induction Stove Condition P 1200 Watt -A Standby Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz.

Based on the measurement results, there is disturbance at a new frequency outside the disturbance frequency during individual conditions of 76.99 dBμV at the frequency 154.09 kHz. In this condition, the resulting conducted emissions initially increase and then decrease. When one stove is on standby and one stove is operating and then operated simultaneously, it produces a conduct emission value and frequency that follows the conduct emission value and the frequency of the operating stove is not the standby one, but the resulting conducted emission value is below the CE value of the P stove (which is in operation). individual moments. The value of conducted emissions produced during simultaneous operation conditions does not exceed the P value of 1200 W individually. The conducted emission (CE) level for the P 1200 Watt induction stove and A standby is above the threshold value required in CISPR 14.1:2020, with a large margin value.

Table 13. Conducted Emission Level (QP-L1) Induction Stove Condition P 1200 Watt-A Standby Operates Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

P 1200 W and A Standby	QP-L1	Limit QP	Margin	P 1200 W	QP-L1	A Standby	QP-L1
Frequency (KHz)	Mag [dBμV]	dBμV	dBμV	Frequency (KHz)	Mag [dBμV]	Frequency (KHz)	Mag [dBμV]
150	85	66	-19	150	92.06	159.74	58.42
154.09	78.06	66	-12.06	168.41	99.07	178.81	65.96
168.41	89.67	66	-23.67	192.95	99.3	188.35	66.49
192.95	89.02	66	-23.02	217.49	97.86	216.96	54.03
217.49	85.93	66	-19.93	242.03	98.24	236.03	61.82
242.03	83.81	66	-17.81	266.57	95.74	245.57	62.61
266.57	80.3	66	-14.3	291.11	96.2	-	-
289.06	78.36	66	-12.36	313.6	94.94	-	-

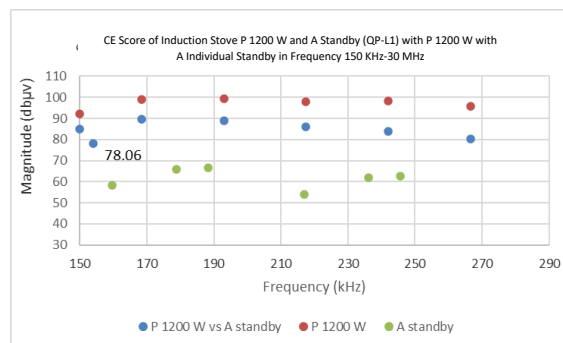


Figure 15. Graph of Conducted Emission Characteristics (QP-L1) Induction Stove Condition P 1200 Watt -A Standby Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is disturbance at a new frequency outside the disturbance frequency during individual conditions of 78.06 dB μ V at a frequency of 154.09 kHz. In this condition, the resulting conducted emissions initially increase and then decrease. When one standby stove and one operating stove are then operated together, it produces a CE value and frequency that follows the CE value and the frequency of the operating stove, not the standby one, but the resulting CE value is below the CE value of stove P (which is operating) when individually. The CE value produced under simultaneous operating conditions does not exceed the individual P value of 1200 W. The conducted emission (CE) level for the P 1200 Watt induction stove and A standby is above the threshold value required in CISPR 14.1:2020, with a large margin value.

3) Condition of Stoves P Standby and A 1200 Watt

The next research carried out measurements with stove P in the standby position and A in the operating position at a power level of 1200 Watts. The results of the conducted emission measurements were obtained as follows:

Table 14. Conducted Emission Level (QP-N) of Induction Stove P Standby Condition-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

P Standby and A 1200 W	QP-N	Limit QP	Margin	P Standby	QP-N	A 1200 W	QP-N
Frequency (KHz)	Mag [dB μ V]	dB μ V	dB μ V	Frequency (KHz)	Mag [dB μ V]	Frequency (KHz)	Mag [dB μ V]
152.05	80.17	66	-14.17	154.97	61.89	152.05	83.67
162.27	103.37	66	-37.37	193.12	61.97	158.18	101.89
190.9	96.19	66	-30.19	240.8	62.12	184.77	94.36
217.49	92.84	66	-26.84	264.64	62.41	211.35	89.99
244.07	87.75	66	-21.75	298.02	62	237.94	83.94
272.7	85.74	66	-19.74	331.4	62.55	264.52	81.01
299.29	83.91	66	-17.91	360.01	62.27	293.16	81.56
325.87	77.48	66	-11.48	383.85	61.81	319.74	75.91

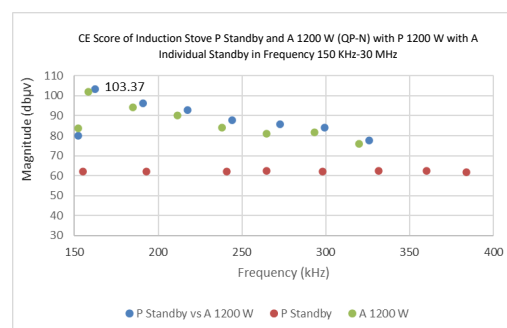


Figure 16. Chart of Conducted Emission (QP-N) Induction Stove Condition P Standby-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is disturbance at a new frequency outside the disturbance frequency during individual conditions with the highest disturbance level of 103.37 dB μ V at the frequency 162.27 kHz. So, when one stove is on standby and another is operating, the frequency produced when operated simultaneously follows the frequency of the stove that is operating and not the stove that is on standby. In this condition, the resulting conducted emissions initially increase and then decrease. The resulting CE value is above the CE value of stove A when individual standby. The level of conducted emissions (CE) on the P standby and A 1200 Watt induction stoves is above the threshold value required in CISPR 14.1:2020 with a large margin.

Table 15. Conducted Emission Level (QP-L1) of Induction Stove P Standby Condition-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

P Standby and A 1200 W	QP-L1	Limit QP	Margin	P Standby	QP-L1	A 1200 W	QP-L1
Frequency (KHz)	Mag [dB μ V]	dB μ V	dB μ V	Frequency (KHz)	Mag [dB μ V]	Frequency (KHz)	Mag [dB μ V]
152.05	80.36	66	-14.36	154.97	61.97	152.05	83.75
162.27	103.31	66	-37.31	193.12	61.85	158.18	101.83
190.9	96.17	66	-30.17	240.8	62.04	184.77	94.34
217.49	92.82	66	-26.82	264.64	62.45	211.35	89.92
244.07	87.81	66	-21.81	298.02	61.87	237.94	83.84
272.7	85.72	66	-19.72	331.4	62.48	264.52	80.89
299.29	83.94	66	-17.94	360.01	62.25	291.11	76.46
325.87	77.52	66	-11.52	383.85	61.84	319.74	75.88

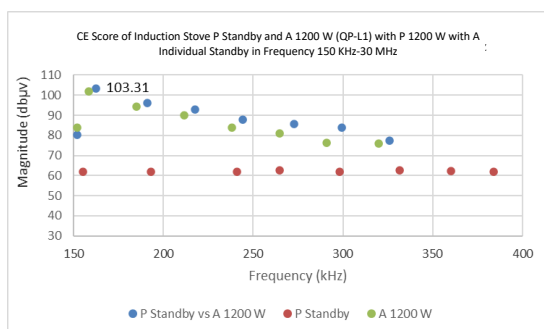


Figure 17. Graph of Conducted Emission Characteristics (QP-L1) Induction Stove Condition P Standby-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is disturbance at a new frequency outside the disturbance frequency during individual conditions with the highest disturbance level of 103.31 dB μ V at the frequency 162.27 kHz. So, when one stove is on standby and another is operating, the frequency produced when operated simultaneously follows the frequency of the stove that is operating and not the stove that is on standby. In this condition, the resulting conducted emissions initially increase and then decrease. The resulting CE value is above the CE value of stove A when individual standby. The level of conducted emissions (CE) on the P standby and A 1200 Watt induction stoves is above the threshold value required in CISPR 14.1:2020, with a large margin value.

4) Condition of the P 1200 W and A 1200 W Stoves

The next research carried out measurements with the P stove operating at a power level of 1200 Watts and A 1200 Watts, the results of the conducted emission measurements were obtained as follows:

Table 16. Conducted Emission Level (QP-N) Induction Stove Condition P 1200 Watt-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

P 1200 W and A 1200 W	QP-N	Limit QP	Margin	P 1200 W	QP-N	A 1200 W	QP-N
Frequency (KHz)	Mag [dB μ V]	dB μ V	dB μ V	Frequency (KHz)	Mag [dB μ V]	Frequency (KHz)	Mag [dB μ V]
152.05	93.4	66	-27.4	150	91.96	152.05	83.67
158.18	102.22	66	-36.22	168.41	99.13	158.18	101.89
184.77	100.41	66	-34.41	192.95	99.37	184.77	94.36
211.35	92.3	66	-26.3	217.49	97.91	211.35	89.99
237.94	89.8	66	-23.8	242.03	98.31	237.94	83.94
264.52	85.1	66	-19.1	266.57	95.7	264.52	81.01
152.05	93.4	66	-27.4	150	91.96	152.05	83.67
158.18	102.22	66	-36.22	168.41	99.13	158.18	101.89

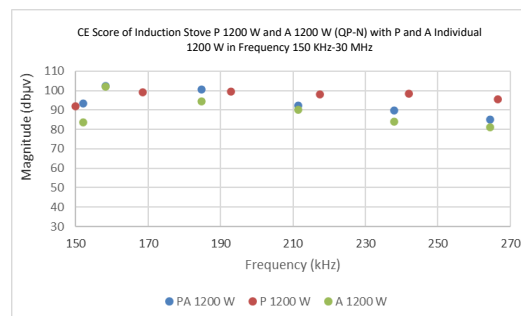


Figure 18. Chart of Conducted Emission (QP-N) Induction Stove Conditions P 1200 Watt-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is no disturbance at new frequencies outside the disturbance frequency during individual conditions. The CE value and PA frequency resemble the CE value and frequency of stove A. The first two PA frequencies are higher than P and A individually 1200 W, then the CE value decreases. The conducted emission (CE) level for the P 1200 Watt and A 1200 Watt induction stoves is above the threshold value required in CISPR 14.1:2020, with a large margin value.

Table 17. Conducted Emission Level (QP-L1) Induction Stove Condition P 1200 Watt-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

P 1200 W and A 1200 W	QP-L1	Limit QP	Margin	P 1200 W	QP-L1	A 1200 W	QP-L1
Frequency (KHz)	Mag [dB μ V]	dB μ V	dB μ V	Frequency (KHz)	Mag [dB μ V]	Frequency (KHz)	Mag [dB μ V]
152.05	93.35	66	-27.35	150	92.06	152.05	83.75
158.18	102.12	66	-36.12	168.41	99.07	158.18	101.83
184.77	100.35	66	-34.35	192.95	99.3	184.77	94.34
211.35	92.26	66	-26.26	217.49	97.86	211.35	89.92
237.94	89.77	66	-23.77	242.03	98.24	237.94	83.84
264.52	85.1	66	-19.1	266.57	95.74	264.52	80.89

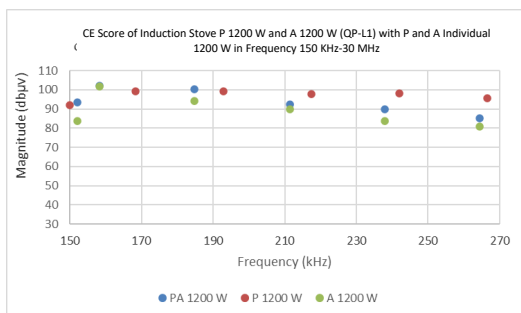


Figure 19. Graph of Conducted Emission Characteristics (QP-L1) Induction Stove Condition P 1200 Watt-A 1200 Watt Operating Simultaneously and Individually in the Frequency Range 150 kHz-30 MHz

Based on the measurement results, there is no disturbance at new frequencies outside the disturbance frequency during individual conditions. The CE value and PA frequency resemble the CE value and frequency of stove A. The first two PA frequencies are higher than P and A individually 1200 W, then the CE value decreases. The conducted emission (CE) level for the P 1200 Watt and A 1200 Watt induction stoves is above the threshold value required in CISPR 14.1:2020, with a large margin value.

CONCLUSION

Based on the measurement results in two frequency ranges, namely 9-150 kHz and 150 kHz-30 MHz for individual conditions, the following results were obtained: (1) conducted emission (CE) levels in the 4 (four) brands of induction stoves used in this study were partly above the threshold values required in CISPR 14.1:2020, (2) in standby condition, the induction stove still produces a level of controlled emissions. This condition occurs in all brands of induction stoves used in this research, (3) the conductive emission level of an induction stove when operating is

higher compared to when it is in standby position, (4) the M induction stove has a lower level of conducted emissions compared to C, P and A stoves in individual conditions, and (5) induction stoves C, A, M and P have conducted emission levels that fluctuate up and down at certain frequencies.

Based on the results of measurements in the frequency range 150 kHz-30 MHz when the P and A induction stoves were operated simultaneously, the following results were obtained: (1) when stoves P and A are operated simultaneously in various cooking modes, they have the same characteristic pattern, where the level of conducted emissions produced initially increases and then decreases, (2) in the condition that 2 (two) brands of induction stoves P and A were operated simultaneously at a power level of 1200 Watts, the result was that there was no disturbance at the new frequency outside the disturbance frequency during the individual conditions, (3) when the P and A stoves were operated simultaneously with the conditions of the P standby-A standby stove, the P 1200 Watt-A standby stove, the P standby-A 1200 Watt stove, the result was that there was disturbance at a new frequency outside the disturbance frequency during the individual conditions, (4) in the condition that 2 (two) brands of P and A induction stoves were operated simultaneously with the P standby stove and the A 1200 Watt stove, it was found that the resulting level of conducted emissions was higher than the value of the P individual standby stove and the A individual 1200 Watt stove, (5) in conditions where 2 (two) brands of induction stoves P and A are operated simultaneously with conditions P standby-A standby, stove P 1200 Watt-A standby, stove P 1200 Watt-A

1200 Watt, it is found that the level of conducted emissions produced is not higher from the CE values of individual P and individual A stove measurements, (6) when one stove is on standby and another stove is operating, it produces a conduct emission value at a frequency that is close to the conduct emission value at the frequency of the stove operating, not the standby one, (7) the level of conducted emissions (CE) in the P standby and A standby induction cooker conditions is below the threshold value required in CISPR 14.1:2020 with a small margin value, and (8) the level of conducted emissions (CE) in the P 1200 Watt-A standby induction stove, P standby-A 1200 Watt induction stove, P 1200 Watt-A 1200 Watt induction stove is above the threshold value required in CISPR 14.1:2020 with a value big margins.

ACKNOWLEDGMENT

The gratitude toward Electromagnetic Compatibility (EMC) Laboratory of the Telecommunication Equipment Testing Center (BBPPT) of the Ministry of Communication and Information Technology who has provided full support in the implementation of research activities and to the Ministry of Communication and Information Technology which has provided funding assistance through the Internal S2 Domestic Scholarship Program of the Ministry of Communication and Information Technology.

BIBLIOGRAPHY

Chacón-Troya, D. P., Quezada, J., & Espinoza, C. (2017). Development and implementation

of a smart induction stove. *2017 Brazilian Power Electronics Conference (COBEP)*, 1–5.

CISPR 14-1: Electromagnetic Compatibility-Requirements For Household Appliances, Electric Tools and Similar Apparatus-Part 1: Emission. No. CISPR 14-1, 1 (2020). www.iec.ch

Gill-Wiehl, A., Price, T., & Kammen, D. M. (2021). What's In A Stove? A Review Of The User Preferences In Improved Stove Designs. *Energy Research and Social Science*, 81. <https://doi.org/10.1016/j.erss.2021.102281>

Hakam, D. F., Nugraha, H., Wicaksono, A., Rahadi, R. A., & Kanugrahan, S. P. (2022). Mega Conversion From LPG to Induction Stove to Achieve Indonesia's Clean Energy Transition. *Energy Strategy Reviews*, 41. <https://doi.org/10.1016/j.esr.2022.100856>

CISPR 32-2015: Electromagnetic Compatibility of Multimedia Equipment-Emission Requirements. No. 32, 1 (2015). www.iec.ch

Kharanaq, F. A., Emadi, A., & Bilgin, B. (2020). Modeling Of Conducted Emissions For EMI Analysis Of Power Converters: State-Of-The-Art Review. *IEEE Access*, 8, 189313–189325. <https://doi.org/10.1109/ACCESS.2020.3031693>

Plumed, E., Lope, I., & Acero, J. (2022). Modeling and Design of Cookware for Induction Heating Technology With Balanced Electromagnetic and Thermal Characteristics. *IEEE Access*, 10, 83793–83801. <https://doi.org/10.1109/ACCESS.2022.3197631>

Rickli, H., Facchini, M., Brunner, H., Ammann, P., Sagmeister, M., Klaus, G., Angehrn, W., Luechinger, R., & Duru, F. (2003). Induction Ovens and Electromagnetic Interference: What is the Risk for Patients with Implanted Pacemakers? *PACE*, 26, 1494–1497.

Spano, I. L. (2014). Electromagnetic Compatibility Issues of Electrical and

- Electronic Devices [Tesi di Dottorato]. Università degli Studi di Cagliari.
- Sudiarto, B. (2017). *The properties and behavior of disturbances in the frequency range 9 kHz to 150 kHz produced by household appliances in a residential network environment*. Dissertation, Duisburg, Essen, Universität Duisburg-Essen, 2017.
- IEEE Standard 643-2004 - IEEE Guide for Power-Line Carrier Applications Sponsored by the Power System Communications Committee IEEE Power and Energy Society. (2005).
- IEEE Standard for Power-Line Carrier Line-Tuning Equipment (30 kHz to 500 kHz) Associated with Power Transmission Lines Sponsored by the Power System Communications Committee IEEE Power and Energy Society. (2013).
- Tama, A. (2022). Deployment of Electric Induction Technologies into Cooktops Plates as a Part of Energy Sustainability. *Smart Grid and Renewable Energy*, 13(03), 55–74.
<https://doi.org/10.4236/sgre.2022.133004>
- Tiandho, Y., Indriawati, A., Putri, A. K., & Afriani, F. (2021). Induction stoves: An option for clean and efficient cooking in Indonesia. *IOP Conference Series: Materials Science and Engineering*, 1034(1), 012068.
<https://doi.org/10.1088/1757-899x/1034/1/012068>
- Topuz, N. E., Dawood, K., Ünsal, K., Odabaş, G., & Kömürgöz, G. (2019). Electromagnetic and thermal analysis of a domestic induction cooker coil. *2019 4th International Conference on Power Electronics and Their Applications (ICPEA)*, 1–5.

Copyright holder:

Henny Tri Kurniawati, Budi Sudiarto (2023)

First publication right:

Asian Journal of Engineering, Social and Health (AJESH)

This article is licensed under:

