Translation of article 10.22146/jnteti.v13i3.11174

Conducted Emission Analysis of Induction Cooker at Frequencies of 150 kHz–30 MHz

Budi Sudiarto[1], Henny Tri Kurniawati[1]

[1] Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Depok, Jawa Barat 16424, Indonesia

[Submitted: 12 January 2024, Revised: 26 February 2024, Accepted: 5 July 2024]
Corresponding Author: Henny Tri Kurniawati (email: henny.tri@ui.ac.id)

ABSTRACT — Induction cooker usage is predicted to replace conventional cookers due to efficiency and energy resilience advantages. These energy conservation efforts are also the government efforts in reducing the energy crisis related to the liquified petroleum gas (LPG) supply. However, household appliances, including induction cooker using inverter technology, have the potential to cause electromagnetic interference (EMI) in the form of conducted emissions, which can be interpreted as noise currents propagating along conduction paths and potentially disrupting other electronic equipments through the voltage source. Regulations related to electromagnetic interference from induction cookers are listed in the Comité International Spécial des Perturbations Radioélectriques (CISPR) 14-1:2020. This research aimed to identify the induction cooker distribution with regard to electromagnetic interference requirements, namely conducted emissions, according to CISPR 14-1:2020. The conduction emission measurement was conducted on four induction cooker brands circulating in the community (A, C, M, and P) in various cooking modes and power levels in the frequency range of 150 kHz–30 MHz, with PLN electric voltage of 220 V and frequency of 50 Hz. Measurements were performed ten times for each stage, and the six highest conduction emission values were obtained. Based on measurements in the frequency range of 150 kHz–30 MHz, it was found that the conducted emission levels in most induction cookers exceeded the CISPR 14-1:2020 standard. In the future, induction cooker components must pay more attention to regulations regarding conducted emissions to ensure that these household appliances are increasingly safe and environmentally comfortable in the electromagnetic environment.

KEYWORDS — Induction Cooker, Conducted Emission, Electromagnetic Interferences (EMI), CISPR 14-1:2020 Standard.

I. INTRODUCTION

In the future, it is estimated that induction cookers will become one of the cooking appliances that can replace previous conventional cookers due to their beneficial energy efficiency and resilience [1], [2]. This step is part of the government's efforts for energy conservation by replacing the use of gas cookers and other conventional cookers with induction cookers, which can help address the energy crisis in Indonesia, including state subsidies related to the supply of liquified petroleum gas (LPG) [1], [3], [4]. Therefore, many studies have been conducted to support these energy conservation efforts. Previous research also indicates that using induction cookers can reduce carbon emissions released into the atmosphere [5].

On the other hand, there are concerns about the potential risks associated with the use of induction cookers. Apart from the fact that induction cookers are still relatively expensive, consume high electrical power, and require cookware made of specific materials, previous research has explained that the introduction of inverter technology in household appliances also poses risks of interference within the frequency range of 9-150 kHz [6]. Other studies have indicated that the inverter technology in household appliances can generate electromagnetic interference (EMI), which may disrupt the function and performance of the device itself and other electronic devices in its vicinity [7], [8]. The EMI in question consists of conducted emissions, which should be kept at very low levels because, although they may not directly cause EMI issues, these emissions can lead to much more significant radiation emissions that can disrupt the operation of devices such as AM radio systems and telecommunications [9]. Within the same power grid, the conducted emissions generated by induction cookers can also interfere with data signals that use power line carrier (PLC) technology at frequencies of 30 kHz until 500 kHz [10]–[12]. Therefore, research on the value of conducted emissions from induction cookers is needed to ensure that these household appliances have optimal design and operation systems, making them safer and more comfortable to use.

This research aimed to identify the distribution of induction cooker devices circulating in society related to electromagnetic interference requirements, namely conducted emissions according to Comité International Spécial des Perturbations Radioélectriques (CISPR) 14.1:2020. Testing was conducted on four brands of induction cookers circulating in society. The parameter used to detect spikes or temporary peaks in noise was the quasi-peak value. The higher the QP value generated, the higher the conducted emissions produced by the induction cookers [13].

II. CONDUCTED EMISSIONS OF INDUCTION COOKERS

A. INDUCTION COOKER

Induction cookers consist of a coil placed beneath the cooking utensil. Figure 1 displays a visual representation of components that make up an induction cooker. The followings are the further explanation of each component.

1) INDUCTOR

The coil operates at high frequency and experiences uneven current density distribution due to the skin effect and proximity effect. Skin effect occurs in conductors due to the sinusoidal excitation current flowing within them. According to the right-hand rule, this current creates a magnetic flux. According to Lenz's law, this magnetic flux induces opposing Eddy currents through the conductor. As a result, the current density is lower

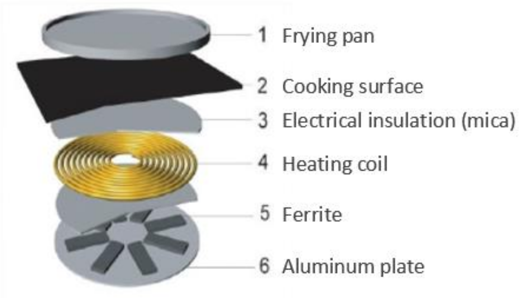


Figure 1. Induction cooker component.

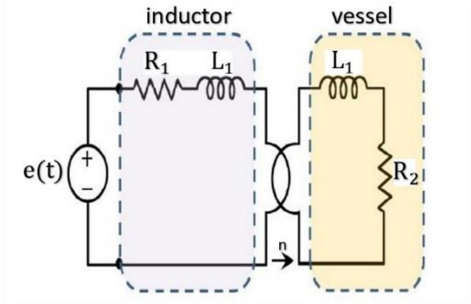


Figure 2. Equivalent circuit of induction cooker.

in the center of the conductor, and the current tends to flow closer to the conductor's surface, known as the skin effect [14].

2) FERRITE BARS

Several ferrite bars are placed beneath the coil. The mica is placed beneath the coil, then the ferrite bars are stacked on top of it. The mica functions as an insulating material, and the ferrite bars reduce the inductor's reluctance or magnetic resistance. In principle, ferrite bars have two main roles: increasing magnetic flux and acting as a shield. Ferrite bars should be as wide as possible to achieve lower reluctance.

3) ALUMINUM PLATE

The bottommost part is aluminum. This plate functions as a shield and holds the coil and ferrite bars.

4) FERROMAGNETIC POT

Pots made of ferromagnetic materials are the most suitable for cooking with induction methods. These pots are heated more efficiently by the magnetic field because they have high surface resistance. Each pot has different characteristics due to its properties. The cooking surface, made of vitro-ceramic glass, serves as an insulating layer between the coil and the pot. This ceramic glass forms an air gap between the pot and the heating coil. This characteristic affects the coil's inductance and the pot's resistance. Non-ferromagnetic materials decrease the coil's inductance value more rapidly than ferromagnetic materials.

The principle of induction cookers is based on Faraday's law. Faraday's law states that an alternating magnetic field induces Eddy currents. Due to the alternating power source, alternating magnetic fields occur and induce Eddy currents in the ferromagnetic pot, resulting in magnetic hysteresis. Both of these effects function to heat the pot [5].

Figure 2 depicts the topology of the induction cooker resembling that of a transformer. The primary side of the transformer corresponds to the inductor of the induction cooker, and the secondary side corresponds to the pot of the induction cooker [14]. In an induction cooker, most of the magnetic flux passes through the winding, whereas in a transformer, most of the flux passes through the core. Electromagnetic induction occurs when an alternating current flows through the primary circuit, resulting in a current being induced in the secondary circuit due to the alternating magnetic field [15].

B. ELEKTROMAGNETIC WAVES

Electromagnetic waves are waves that can propagate without the need for a medium, thus they can propagate in a vacuum. Electric and magnetic fields form electromagnetic waves as a result of the acceleration of electric charges [16]. Electromagnetic energy propagates in waves with several measurable parameters: amplitude, frequency, wave propagation velocity, and wavelength. Amplitude represents the height of the wave, frequency is the number of waves passing through a point in a specified unit of time determined by the wave propagation speed, and wavelength is the distance between two peaks. Electromagnetic energy has a constant velocity. Wavelength and frequency are inversely related; the longer a wave, the lower its frequency, and the shorter a wave, the higher its frequency. Electromagnetic energy is emitted or released at different levels. The higher the energy level in an energy source, the lower the wavelength of the produced energy, but the higher its frequency. Magnetic and electric fields, as the formers of electromagnetic waves, have varying values depending on their source [17]. When an electronic device receives unwanted electromagnetic waves from its surrounding environment, the device will be induced with electric current or voltage. Induced electronic devices will experience interference, thus they cannot operate properly. If the interfering electromagnetic wave energy to the device is too high, it will cause damage to the device [16].

An object entering a magnetic field causes a change in the speed of the magnetic motion [18]. The speed of magnetic motion can be calculated using the Ampere's law (1).

$$\oint H \,.\, dI = \sum i. \tag{1}$$

When the distance of an object from the surface gets closer to the center, the magnetic field density will decrease. Electromagnetic induction follows Faraday's principles, which state that the electromotive force generated in a closed circuit is equal to the negative value of the rate of change of magnetic flux passing through it over time [1]. Electromagnetic induction occurs when an alternating current flows through the primary circuit, resulting in current in the secondary circuit due to the alternating magnetic field flux [15]. The current present on the object's surface will generate Eddy currents (2)–(5).

$$\Phi = \iint_A B.dA \tag{2}$$

$$B = \mu\,.\,H \tag{3}$$

$$\mu = \mu_{0.}\,\mu_r \tag{4}$$

$$e = -N\frac{d\Phi}{dt}\,. \tag{5}$$

Then, the electrical energy arising from the induction current and Eddy currents will be converted into heat energy, according (6):

$$P = \frac{E^2}{R} = i^2.R \tag{6}$$

where e is the electromotive force (EMF) of induction, H is the electric field, A is the cross-sectional area, i is the current flowing, and Φ is the electric flux.

 p-ISSN 2301–4156 | e-ISSN 2460–5719

C. ELECTROMAGNETIC COMPATIBILITY (EMC)

Electromagnetic compatibility (EMC) refers to the ability of an electronic device to operate without generating unwanted electromagnetic interference and without being susceptible to interference from its surrounding environment. [19]. According to National Standard of Indonesia (Standar Nasional Indonesia, SNI), the EMC threshold limits in Indonesia are based on SNI referencing IEC (International Electrotechnical Commission), and its electromagnetic compatibility level is the maximum electromagnetic interference tolerated by equipment or systems operated under specific conditions. EMC testing for electronic devices, including household appliances, is one of the requirements outlined in the National Standard of Indonesia (SNI). EMC is related to the quality and reliability of a product, as well as the safety and security levels for its users.

EMC is divided into electromagnetic interference (EMI) and electromagnetic susceptibility (EMS). EMI is the release of electric or magnetic signals from a device or system that can disrupt the performance of other devices or systems [20]. EMS is the ability of equipment to operate normally when exposed to EMI from the environment. In other words, EMC is an effort to control EMI [20]. Three categories of factors influence EMI: the characteristics of electronic devices generating interference, the distance between these electronic devices, and the vulnerability level of exposed devices to electromagnetic signals [19]. EMI can occur due to the following reasons [21]: natural sources such as cosmic events, lightning, and static electric discharge (electrostatic discharge or ESD); and artificial sources arising from disturbances from electrical devices used for industrial and household power supplies, communication and control applications. EMI comprises the following groups: low-frequency conducted disturbances (up to 10 kHz) and high-frequency conducted disturbances (from 10 kHz to 1 GHz). Three elements must be present in every interference problem: a source causing interference, a receptor or victim disturbed by the interference, and a coupling path between the source and the receiver of the interference. Commonly affected objects by EMC disturbances include radio frequency (RF) Receivers, integrated circuits (IC), telephones, high-speed data traces, video displays, audio-video devices, and electronic controls. EMC is crucial because it compels systems or devices to handle electromagnetic disturbances that may interfere with their performance and functions. The increased usage of electronic devices also has the potential to raise electromagnetic emissions that can disrupt other systems nearby. To mitigate the impact of electromagnetic emissions produced by electronic devices, regulations or policies are needed to limit the electromagnetic waves generated or emitted by these devices. The Comité International Spécial des Perturbations Radioélectriques (CISPR), or International Special Committee on Radio Interference, is the standard body for EMC referenced by the international community.

Rapid changes in voltage and current during a switching process in power electronic equipment are sources of EMI for the device itself or other electronic devices nearby. EMI is transmitted in two forms [21]: radiation emitted as electric or magnetic fields from one circuit, which serves as a source of interference and combined into another circuit as a victim; and conduction, which is an electromagnetic interference caused by electronic devices through conductors interpreted as noise currents propagating through conducting paths (via power cables or signal cables) and potentially disrupting other electronic equipment through voltage sources [22].

D. CONDUCTED EMISSION

Conducted emissions occur through power cables or signal cables. Conducted interference (conducted noises) consist of two categories commonly known as differential and common modes. Differential mode interference are currents or voltages measured between source lines, namely voltage line to line or current line (i_{dm}) in the diagram. Common mode interference are voltages or currents measured between the power line and ground, such as i_{cm} in the diagram. Both types of interferences are generally present on input and output lines. Every filter design must consider both of these interference modes [23].

Common mode interference noise moves in the same direction through the power conductor and then return through the ground conductor. Inductors in EMI filters placed in series or sequentially with each power channel can be used to control them. Another alternative method involves connecting capacitors from both power channel conductors to the ground. Differential mode interference noise flows through one alternating current conductor and return through the other conductor. Filters containing inductor components connected in series or sequentially and capacitors connected in parallel between the two current-carrying conductors can be utilized to reduce this interference [24].

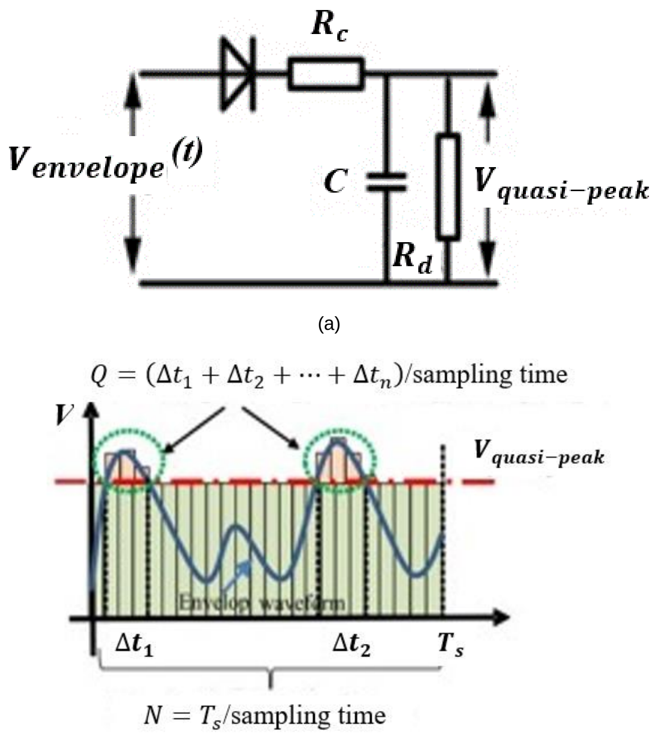
E. MEASUREMENT PARAMETERS

EMI can compromise the reliability of power electronic systems and shorten component lifespan [25]. The fast Fourier transform (FFT) can be utilized to measure the magnitude of EMI, which is a computational algorithm used to convert signals from the time domain to the frequency domain, generating voltage waveforms on the line impedance stabilization network (LISN) to extract the EMI spectrum for prediction, analysis, and reduction of EMI. In addition to the FFT algorithm, EMC measurements can utilize an EMC spectrum analyzer. Calculations on the EMC spectrum analyzer differ from FFT calculations because EMI standards have specific requirements for resolution bandwidth (RBW), envelope detector, peak detector, quasi-peak detector, and average detector for spectrum analysis. Figure 3 illustrates the operating principle of peak, quasi-peak, and average measurements on the spectrum analyzer (150 kHz–30 MHz). Based on the envelope waveform, peak, quasi-peak, and average values can be determined by detector circuits with different charging and discharging time constants, similar to FFT calculations.

Digital sampling is performed (Figure 3) to obtain peak and average values from the envelope waveform within one period. If N data samples are taken evenly within one period (Figure 3), the peak value (V_{peak}) of the envelope waveform is the maximum value of the sampled data V_i [25]. One period of the waveform is used to detect peak, quasi-peak, and average measurements. For quasi-peak value detection, the CISPR 16-1-1 standard specifies charging and discharging time constants (Figure 3(a) and Figure 3(b)) for the R_c quasi-peak detector circuit (charging resistance), R_d (discharging resistance), (charging capacitor), $V_{envelope}$ (input envelope voltage), and $V_{quasi-peak}$ (output quasi-peak voltage) from the quasi-peak detector [25].

$$V_{peak} = max(V_i) \tag{7}$$

$$V_{average} = \frac{\sum_{i=1}^{N} V_i}{N}. \tag{8}$$



(a)

(b)

Figure 3. Figures of (a) detector circuit of quasi peak and (b) quasi peak value based on capacitor charge balance [25].

By neglecting small ripples, the steady-state quasi-peak ($V_{quasi-peak}$) can be obtained based on the charge balance on capacitor *C*. Based on the sample data in Figure 3, the equation used to calculate the quasi-peak value is elaborated in (9). Δt_i is the time interval at the *i*-time instance when the envelope waveform $V_{envelope}$ is greater than $V_{quasi-peak}$. The notation Q represents the number of sample data points greater than $V_{quasi-peak}$.

$$\frac{\sum_{i=1}^{Q}(V_i - V_{quasi\,peak})}{R_c} = \frac{V_{quasi\,peak}\ x\ N}{R_d}. \qquad (9)$$

From (7)–(9), it can be concluded that the value of $V_{peak} \geq V_{quasi-peak} \geq V_{average}$.

The peak detector measures the peak amplitude of the signal (noise). Peak can be achieved with a short power charging time constant and a very long discharge time constant. The quasi peak (QPK) detector measures the signal based on its repetition rate pulse repetition frequency (PRF) and has a short charging time constant (45 ms in band A, 1 ms in band B/C/D) and a relatively long discharge time constant (500 ms in band A, 160 ms in band B, and 550 ms in band C/D). The average (AVG) detector indicates the signal repetition frequency (pulse) [26].

Regulations regarding the magnitude of quasi peak and average conducted emission values for household appliances are calculated based on the CISPR 14.1:2020 standard as in Table I. In accordance with CISPR 14.1:2020 standard clause 4.3, the measurement frequency ranges from 150 kHz to 30 MHz. For each frequency range, there are maximum limits for quasi peak and average levels as stated in Table I.

F. DESIBEL (dB) UNITS IN MEASUREMENT

The unit dB, or decibel, is a relative unit commonly used in electronic communication measurement processes to depict

TABLE I
TEST LIMIT

Frequency Range (MHz)	Limit (dbμV)	
	Quasi Peak	*Average*
0.15 to 0.50	66 to 56	56 to 46
0.50 to 5	56	46
5 to 30	60	50

Notes:
1. The lower limit applies at the transition frequency.
2. Decreasing linearly with the logarithm of the frequency from 0.15 MHz to 0.50 MHz.

power gain or loss. Decibels are used to determine the size and value calculated in audio systems, microwave wave system gain calculations, satellite link budget analysis, antenna power gain, and measurement of other communication systems. dB values are calculated based on specific references or standards. The dB value is calculated by taking the logarithm of the ratio of the measured power (P_2) or calculated to a reference power (P_1). The result obtained is then multiplied by 10 to obtain the value in dB. The formula for calculating the dB value as a power ratio (10).

$$dB = 10\ log_{10} \frac{P_2}{P_1}. \qquad (10)$$

The above equation can be modified to provide a dB value based on the comparison of two voltages. By using the formula relationship $P = \frac{V^2}{R}$ the following equation relationship (11), (12).

$$dB = 10\ log_{10} \frac{V_2^2/R_2}{V_1^2/R_1}\ ;\ (R_1 = R_2) \qquad (11)$$

$$\therefore dB = 10\ log_{10} \frac{V_2^2}{V_1^2}. \qquad (12)$$

From the simplifications results, the calculation of voltage gain in dB units is as follows:

$$dB = 10\ log_{10} \frac{V_2}{V_1}. \qquad (13)$$

The dB unit is frequently used to determine the input and output signal level requirements of different communication systems. For example, specific audio levels can be found in microwave transmitters, with an input level of +8dBm specified. It can be seen that a lowercase "m" has been appended to the dB value, indicating that the specified dB level is relative to a reference of 1 mW. Parameters using dB are also commonly used to express measurement voltage such as dBμV following (14), with 1 μV determined as the reference (V_1):

$$dB\mu V = \pi r^2\ = 20\ log\ \frac{V_2}{1\ \mu V}. \qquad (14)$$

There are many uses of dB for calculations involving relative values. Parameter dBμV is a generalized form of specifying the radio frequency (RF) input level to a communications receiver [27].

III. RESEARCH METHODS

A. RESEARCH FLOWCHART

The analysis of conducted emission in induction cookers has a research flowchart as shown in Figure 4. The research was conducted with various testing steps. The first stage in this research was to conduct a literature review and problem

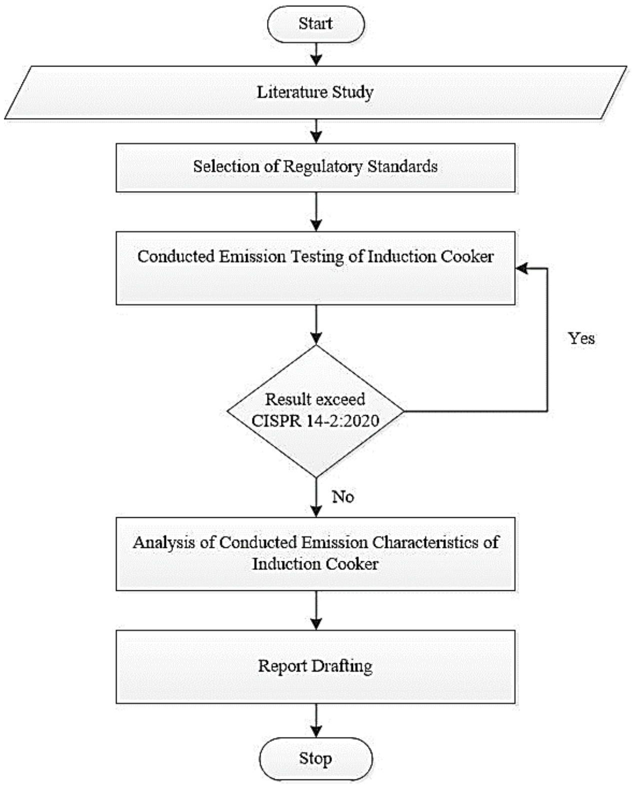


Figure 4. Research flowchart.

identification and prepare equipment and space by setting up four units of induction cookers to be tested and ensuring all of them were in normal operational condition with notations A, C, M, and P. Conducted emission measurement equipment were then prepared, such as a spectrum analyzer or conducted emission monitoring device. The equipment was ensured to be calibrated correctly. After that, testing location with minimal electromagnetic interference was chosen, for example, in a well-isolated enclosed space away from other devices that might interfere with measurements. Testing setup was done by positioning each of the four induction cookers according to the CISPR 14-1:2020 standard and ensuring all components and cables were properly connected to each cooker and operating at power settings according to their respective capabilities. Subsequently, conducted emission was measured using the EMI measurement equipment to determine the electromagnetic emissions produced by each induction cooker. Data processing was done by analyzing the data generated by the measurement equipment and the level of electromagnetic emissions at relevant frequencies for each cooker and analyzing the measurement results of induction cookers with the lowest conducted emission values, then operated simultaneously to observe the level of conducted emissions produced and adjust them to the standard. Results were reported by compiling a report including measurement results and data analysis.

This research aimed to measure the level of conducted emissions generated by induction cookers at each power level, from various brands of induction cookers commonly available in the market. Conducted emission testing on electronic equipment referred to the CISPR 14-1:2020 standard. This standard regulates the limits of conducted emissions from household appliances and similar equipment.

B. TESTING CIRCUIT

The research was conducted by observing the conducted emission values produced by four brands of induction cookers.

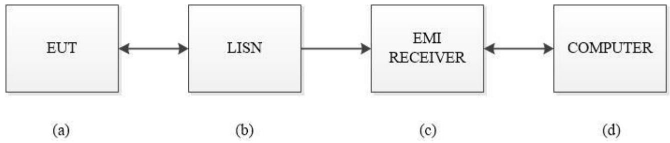


Figure 5. Conducted emission testing circuit.

TABLE II
INDUCTION COOKER SPECIFICATIONS

Specification	Brand A	Brand C	Brand M	Brand P
Input voltage	200-240 V	200 V	200-240 V	220-240 V
Frequency	50 Hz	50 Hz	50 Hz	50/60 Hz
Output power	200 W, 800 W, 1,200 W	200 W, 400 W, 800 W	200 W, 800 W, 1,000 W	400 W, 800 W, 2,000 W
Cooktop dimensions	36 cm × 29 cm × 6.5 cm	34 cm × 28 cm × 6 cm	28 × 36 × 3.6 cm	28 × 35 × 6.5 cm
Pot diameter	10-23 cm	12- 20 cm	12- 20 cm	12- 20 cm
Weight	5,000 gr	2,250 gr	2,100 gr	4,000 gr

Measurements were carried out using devices adapted to the EMC testing standards specified in the CISPR 14.1:2020 standard.

Figure 5 shows the EMC testing setup for conducted emission, which was conducted by connecting the equipment under test (EUT) with the LISN device using the power cable from the EUT. The LISN device was connected to the EMI receiver using a BNC cable. The connection between the EMI receiver and the personal computer or laptop was used to display measurement results using a USB cable [28], [29]. The induction cookers were tested individually and operated simultaneously to obtain the level of conducted emission for each brand of induction cooker, referring to the CISPR 14.1:2020 standard.

The test samples in this study used four brands of induction cookers commonly available in the community through e-commerce sales or government subsidies. These brands were then denoted by the initials A, C, M, and P. Brand A was chosen for its low pricing in the market, brand C was chosen for its relatively higher price compared to brand A, and brand P was chosen for its even higher price compared to both brand C and A. Brand M was selected as a test sample because it was included in the government's LPG conversion subsidy program [30]. Specifications of the tested induction cooker are as presented in Table II.

The conducted emission measurement room was located in the EMC laboratory with a room temperature of 21.8 °C, air humidity of 55.8% RH, and air pressure of 1,003.2 mbar, referring to the IEC standard. The conducted emission measurement settings with the testing configuration were conducted on the table using a vertical ground plan. It refers to the CISPR 14.1:2020 standard which is similar to the CISPR 32:2015 standard on the electromagnetic compatibility of multimedia equipment - emission requirements. The details are follows.

a. The test item is placed on the table with a table height of 80 cm.
b. The table with the ground plan is spaced 40 cm apart.

TABLE III
CONDUCTED EMISSION RATES OF INDUCTION COOKERS A, C, M, AND P (QP-N AND QP-L1) IN THE FREQUENCY RANGE OF 150 KHZ-30 MHZ

Induction Cooker	Frequency	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 A	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
		1,200	158.18	101.89	158.18	101.83	66.00	-35.89	-35.83
Brand C	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 M	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
		1,000	166.36	61.59	166.36	58.58	66.00	4.41	7.43
Brand P	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
		2,000	150.00	102.96	150.00	103.11	66.00	-36.96	-37.11

TABLE IV
CONDUCTED EMISSIONS OF INDUCTION COOKERS CONDITIONS OF M STANDBY AND C STANDBY (QP-N AND QP-L1) OPERATING SIMULTANEOUSLY AT 150 KHZ-30 MHZ

M Standby and C Standby	QP-N	Limit QP	Margin	QP-L1	Limit QP	Margin
Frequency (kHz)	*Mag [dBμV]*	*dBμV*	*dBμV*	*Mag [dBμV]*	*dBμV*	*dBμV*
2.58	36.62	56.00	19.38	36.58	56.00	19.42
2.68	36.12	56.00	19.88	36.12	56.00	19.88
2.76	36.31	56.00	19.69	36.27	56.00	19.73
2.86	36.34	56.00	19.66	36.06	56.00	19.94
2.92	36.35	56.00	19.66	36.31	56.00	19.69
2.98	36.35	56.00	19.65	36.28	56.00	19.72

TABLE V
CONDUCTED EMISSIONS OF INDUCTION COOKERS CONDITIONS OF M 800 W AND C STANDBY (QP-N AND QP-L1) OPERATING SIMULTANEOUSLY AT 150 KHZ-30 MHZ

M 800 W and C Standby	QP-N	Limit QP	Margin	QP-L1	Limit QP	Margin
Frequency (kHz)	*Mag [dBμV]*	*dBμV*	*dBμV*	*Mag [dBμV]*	*dBμV*	*dBμV*
150.00	66.17	66.00	-0.17	67.72	66.00	-1.72
154.09	59.20	66.00	6.80	59.36	66.00	6.64
180.68	65.96	66.00	0.04	65.73	66.00	0.27
211.35	67.67	66.00	-1.67	66.33	66.00	-0.33
239.98	66.54	66.00	-0.54	65.81	66.00	0.19
270.66	66.31	66.00	-0.31	67.16	66.00	-1.16

c. The distance between the table with other metal objects must be more than 80 cm.
d. The distance between test items is 10 cm.
e. The LISN is placed on the floor connected to the test item with a distance of 80 cm.
f. The connection cable between test items or test items - LISN must not touch the ground.

Conducted emission measurements were performed with ten measurements for each stage and six conducted emission values were taken in the frequency range of 150 kHz-30 MHz at a PLN voltage of 220 V and a frequency of 50 Hz. The impedance and frequency characteristics of the LISN device during the measurement process met the referenced standard. The L1 and N lines of the LISN monitored the conducted interference values using an EMI test receiver via coaxial interface cables with a termination impedance of 50 Ω. The parameters used in the conducted emission measurement of the induction cooker are quasi peak and average values. The higher the quasi peak and average values produced, the higher the conducted emission generated by the induction cooker.

During testing, the induction cooker was loaded with a pot made of ferromagnetic material filled with water to about 50% of its maximum capacity. An induction cooker is a type of cooker that utilizes the principle of induction to generate heat. It is achieved by placing a copper wire coil under a pot made of ferromagnetic material with a high magnetic permeability. When an alternating electric current flows through the coil, it creates a fluctuating magnetic field. This magnetic field induces electric currents in the ferromagnetic pot, which flow with high values and cause resistive heating. This resistive

Jurnal Nasional Teknik Elektro dan Teknologi Informasi
Volume 13 Number 3 August 2024

TABLE VI
CONDUCTED EMISSIONS OF INDUCTION COOKERS CONDITIONS OF M STANDBY AND C 800 W (QP-N DAN QP-L1) OPERATING SIMULTANEOUSLY AT 150 KHZ-30 MHZ

M Standby and C 800 W	QP-N	Limit QP	Margin	QP-L1	Limit QP	Margin
Frequency (kHz)	*Mag [dBμV]*	*dBμV*	*dBμV*	*Mag [dBμV]*	*dBμV*	*dBμV*
152.05	65.50	66.00	0.50	65.26	66.00	0.74
160.23	70.77	66.00	-4.77	70.23	66.00	-4.23
182.72	73.09	66.00	-7.09	73.61	66.00	-7.61
205.22	71.07	66.00	-5.07	70.65	66.00	-4.65
229.76	72.64	66.00	-6.64	72.95	66.00	-6.95
252.25	71.32	66.00	-5.32	70.34	66.00	-4.34

TABLE VII
CONDUCTED EMISSIONS OF INDUCTION COOKERS CONDITIONS OF M 800 W AND C 800 W (QP-N DAN QP-L1) OPERATING SIMULTANEOUSLY AT 150 KHZ-30 MHZ

M 800 W and C 800 W	QP-N	Limit QP	Margin	QP-L1	Limit QP	Margin
Frequency (kHz)	*Mag [dBμV]*	*dBμV*	*dBμV*	*Mag [dBμV]*	*dBμV*	*dBμV*
152.05	75.52	66.00	-9.52	78.74	66.00	-12.74
158.18	74.98	66.00	-8.98	80.49	66.00	-14.49
180.68	79.80	66.00	-13.80	85.13	66.00	-19.13
203.17	74.22	66.00	-8.22	77.73	66.00	-11.73
227.71	75.63	66.00	-9.63	80.97	66.00	-14.97
250.21	71.95	66.00	-5.95	74.94	66.00	-8.94

heating process is used to heat foods. Thus, the induction cooker operates efficiently and effectively for cooking. Eddy currents on the bottom layer of the pot and hysteresis losses of the magnetic material inside the pot cause heat on the induction cooker [31]. The standard cooking container or pot (contact surface dimensions) is 110 mm, 145 mm, 180 mm, 210 mm, and 300 mm [28].

IV. RESULTS AND ANALYSIS

A. CONDUCTED EMISSION ANALYSIS OF A, C, M, AND P INDUCTION COOKER

Conducted emission analysis was conducted on four brands of induction cookers (brands A, C, M, and P) in various cooking modes and power levels in the frequency range of 150 kHz to 30 MHz. The research encompasses not only several cooker brands but also the analysis of differences in power usage among each cooker. The use of different power levels reflects the variation in cooker usage in society depending on cooking needs and the types of dishes being cooked. Testing with power variations provides a more accurate picture of conducted emissions in various usage scenarios. By testing at various power levels, the research can provide a more comprehensive understanding of how conducted emissions are influenced by various factors, thereby enabling the evaluation of cooker performance in various usage scenarios.

Table III represents the levels of conducted emissions for each induction cooker compared to the measurement limits according to the CISPR 14.1:2020 standard. Measurements were taken for the six highest emissions with ten measurements each. In standby mode, induction cookers still produced conducted emissions, which occurred in all brands of induction cookers used in this study. Based on measurements in the frequency range of 150 kHz to 30 MHz, it was found that the level of conducted emissions from induction cookers in this study exceeded the specified limits in CISPR 14.1:2020, except for brand M.

B. CONDUCTED EMISSION ANALYSIS OF SIMULTANEOUS OPERATED M AND C INDUCTION COOKER

Next, conducted emission measurements were performed on induction cookers of brands M and C operated simultaneously to measure the magnitude of the conducted emissions generated, which were then analyzed for compliance with the threshold values required in CISPR 14.1:2020. Cookers M and C were selected for simultaneous measurement because they had lower levels of conducted emissions compared to other induction cookers used in this study.

1) M STANDBY AND C STANDBY INDUCTION COOKER CONDITIONS

Table IV shows the results of conducted emission measurements on induction cookers of brands M and C operated simultaneously, with cooker M in standby condition and cooker C in standby condition. Based on the measurement results, the level of conducted emissions generated by the induction cookers still complied with the CISPR 14.1:2020 standard.

2) CONDITIONS OF M 800 WATT AND C STANDBY INDUCTION COOKER

Table V shows the results of conducted emission measurements on induction cookers of brands M and C operated simultaneously, with cooker M operating at 800 W power level and cooker C in standby position. Based on the measurement results, the level of conducted emissions from the induction cookers at some frequency points exceeded the values required in CISPR 14.1:2020 with a low margin.

3) CONDITIONS OF M STANDBY AND C 800-WATT INDUCTION COOKER

Table VI shows the results of conducted emission measurements on induction cookers of brands M and C operated simultaneously, with cooker M in standby position and cooker C operating at 800 W power level. Based on the measurement results, the level of conducted emissions from the induction cookers at some frequency points exceeded the values required in CISPR 14.1:2020 with a higher margin than the condition of cooker M at 800 W and C in Standby.

4) M 800 WATT AND C 800-WATT INDUCTION COOKER CONDITIONS

Table VII shows the results of conducted emission measurements on induction cookers of brands M and C operated simultaneously, with both cookers M and C operating at the same 800 W power level. Based on the measurement results, the level of conducted emissions from the induction cookers at some frequency points exceeded the values required in CISPR 14.1:2020 with a high margin.

V. CONCLUSION

Based on the data from the conducted measurements, it can be concluded that the level of conducted emissions from the four brands of induction cookers used in this study exceeded the specified values in CISPR 14.1:2020. Even in standby mode, induction cookers still emit conducted emissions. Induction cooker brand M had a lower level of conducted emissions compared to cookers branded C, P, and A under individual conditions. However, when induction cookers M and C were operated simultaneously with variations in power levels, the measurement results indicated that the level of conducted emissions exceeded the specified values in CISPR 14.1:2020 by a significant margin. It raises concerns because high conducted emissions can disrupt the functioning and performance of other electronic devices in the vicinity and may violate established EMC standards.

Moving forward, it is still necessary to conduct quasi-peak detection on several brands of induction cookers available in the market. This method will provide more quantitative results and allow for a broader depiction of the characteristics of conducted emissions generated by induction cookers. Consequently, it will enable the identification and more effective resolution of potential conducted emission issues, ensuring compliance with EMC standards and user comfort in the use of induction cookers.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest in the research and preparation of this report.

AUTHORS’ CONTRIBUTIONS

Conceptualization, Budi Sudiarto and Henny Tri Kurniawati; methodology, Henny Tri Kurniawati; software, Budi Sudiarto and Henny Tri Kurniawati; validation, Budi Sudiarto and Henny Tri Kurniawati; formal analysis, Budi Sudiarto and Henny Tri Kurniawati; investigation, Budi Sudiarto and Henny Tri Kurniawati; resources, Budi Sudiarto and Henny Tri Kurniawati; data curation, Budi Sudiarto and Henny Tri Kurniawati; writing—original draft preparation, Budi Sudiarto and Henny Tri Kurniawati; writing—review and editing, Budi Sudiarto and Henny Tri Kurniawati; visualization, Budi Sudiarto and Henny Tri Kurniawati; supervision, Budi Sudiarto; project administration, Budi Sudiarto and Henny Tri Kurniawati; funding acquisition, Henny Tri Kurniawati.

ACKNOWLEDGMENT

Thank you to the Electromagnetic Compatibility (EMC) Laboratory of the Telecommunication Device Testing Center (Balai Besar Pengujian Perangkat Telekomunikasi, BBPPT) of the Ministry of Communication and Information Technology for their full support in conducting conducted emission measurement activities and to the Ministry of Communications and Informatics for providing funding assistance through the Domestic Master’s Scholarship Program of the Ministry of Communications and Informatics.

REFERENCES

[1] B. Sudiarto *et al.*, “Pengaruh perubahan tegangan masukan terhadap efisiensi energi kompor induksi,” *J. Nas. Tek. Elekt. Teknol. Inf.*, vol. 12, no. 2, pp. 101–109, May 2023, doi: 10.22146/jnteti.v12i2.6784.

[2] E. Plumed, I. Lope, and J. Acero, “Modeling and design of cookware for induction heating technology with balanced electromagnetic and thermal characteristics,” *IEEE Access*, vol. 10, pp. 83793–83801, Aug. 2022, doi: 10.1109/ACCESS.2022.3197631.

[3] D.F. Hakam *et al.*, “Mega conversion from LPG to induction stove to achieve Indonesia’s clean energy transition,” *Energy Strategy Rev.*, vol. 41, pp. 1–12, May 2022, doi: 10.1016/j.esr.2022.100856.

[4] A. Tama, “Deployment of electric induction technologies into cooktops plates as a part of energy sustainability,” *Smart Grid Renew. Energy*, vol. 13, no. 3, pp. 55–74, Mar. 2022, doi: 10.4236/sgre.2022.133004.

[5] D.P. Chacon-Troya, J. Quezada, and C. Espinoza, “Development and implementation of a smart induction stove,” in *2017 Braz. Power Electron. Conf. (COBEP)*, 2017, pp. 1–5, doi: 10.1109/COBEP.2017.8257376.

[6] S.A. Kurniawan, “Karakteristik disturbance pada frekuensi 9-150 kHz yang dibangkitkan oleh kompor induksi pada jaringan PLN dan sistem PLTS fotovoltaik atap on-grid serta pengaruh akibat peralatan sekitar dan perbedaan titik pengukuran,” M.S. thesis, Universitas Indonesia, Depok, Indonesia, 2021.

[7] H.W. Nugroho, M.K. Anam, and Yudhistira, “Implementation of CISPR 14-2 standards on electrostatic discharge (ESD) immunity test for household appliances induction cooker,” *Int. J. Appl. Sci. Eng.*, vol. 15, no. 2, pp. 119–125, Oct. 2018, doi: 10.6703/IJASE.201810_15(2).119.

[8] H. Rickli *et al.*, “Induction ovens and electromagnetic interference: What is the risk for patients with implanted pacemakers?” *Pacing Clin. Electrophysiol.*, vol. 26, no. 7p1, pp. 1494–1497, Jun. 2003, doi: 10.1046/j.1460-9592.2003.t01-1-00216.x.

[9] I.L. Spano, “Electromagnetic compatibility issues of electrical and electronic devices,” Ph.D. dissertation, Università degli Studi di Cagliari, Cagliari, Italy, 2014.

[10] D.P. Apsari, “Pengaruh disturbansi frekuensi 9-150 kHz pada komunikasi data menggunakan teknologi power line carrier yang dihasilkan oleh peralatan rumah tangga,” Undergraduate thesis, Universitas Indonesia, Depok, Indonesia, 2020.

[11] *IEEE Guide for Power-Line Carrier Applications*, IEEE Standard 643-2004 (Revision of IEEE Standard 643-1980), Jun. 2005. [Online]. Available: https://standards.ieee.org/ieee/643/892/

[12] *IEEE Standard for Power-Line Carrier Line-Tuning Equipment (30 kHz to 500 kHz) Associated with Power Transmission Lines*, IEEE C93.4-2012, Feb. 2013. [Online]. Available: https://standards.ieee.org/ieee/C93.4/5340/

[13] F.A. Kharanaq, A. Emadi, and B. Bilgin, “Modeling of conducted emissions for EMI analysis of power converters: State-of-the-art review,” *IEEE Access*, vol. 8, pp. 189313–189325, Oct. 2020, doi: 10.1109/ACCESS.2020.3031693.

[14] N.E. Topuz *et al.*, “Electromagnetic and thermal analysis of a domestic induction cooker oil,” in *2019 4th Int. Conf. Power Electron. Their Appl. (ICPEA 2019)*, 2019, pp. 1–5, doi: 10.1109/ICPEA1.2019.8911134.

[15] J.D. Nugroho, “Analisis pengaruh variasi tegangan terhadap efisiensi energi pada kompor induksi,” Undergraduate thesis, Universitas Indonesia, Depok, Indonesia, 2020.

[16] A. Suntoro, R.N. Siregar, H. Nurcahyadi, and L. Yuniarsari, “Kajian operasional laboratorium pengujian electromagnetic compatibility (EMC) untuk perangkat nuklir,” *PRIMA, Aplikasi Rekayasa Bid. Iptek Nukl.*, vol. 18, no. 2, pp. 8–17, Nov. 2021.

[17] Jumingin *et al.*, “Radiasi gelombang elektromagnetik yang ditimbulkan peralatan listrik di lingkungan Universitas PGRI Palembang,” *JOP (J. Online Phys.)*, vol. 7, no. 2, pp. 48–53, Jun. 2022, doi: 10.22437/jop.v7i2.17267.

[18] N.S Aulia, “Analisis pengaruh setting daya terhadap efisiensi kompor induksi,” Undergraduate thesis, Universitas Indonesia, Depok, Indonesia, 2021.

[19] A.Y. Wirapraja and M.M. Ali, “Emisi radiasi speaker aktif pada frekuensi 30 Mhz - 1 GHz dan 1 - 6 GHz,” *JTPII (J. Teknol. Proses Inov. Ind.)*, vol. 4, no. 2, pp. 79–83, Nov. 2019, doi: 10.36048/jtpii.v4i2.5736.

[20] T. Akbar, M. Ramdhani, and E. Kurniawan, “Implementasi dan analisis insertion loss filter berbasis electromagnetic compatibility (EMC) pada light emitting diode (LED),” *Proc. Eng. (E-PROCEEDING)*, vol. 4, no. 3, pp. 3255–3262, Dec. 2017.

[21] M. Barnes, “Electromagnetic compatibility (EMC),” in *Practical Variable Speed Drives and Power Electronics*, 1st ed. Burlington, MA, USA: Newnes, 2003, ch. 4, pp. 114–139.

[22] Yudhistira *et al.*, “Karakterisasi conducted emission noise pada inverter di sistem photovoltaic off-grid,” *J. Nas. Tek. Elekt. Teknol. Inf.*, vol. 10, no. 1, pp. 100–109, Feb. 2021, doi: 10.22146/jnteti.v10i1.1066.

[23] N. Mohan, T.M. Undeland, and W.P. Robbins, *Power Electronics: Converters Applications and Design*, 2nd ed. Quebec, Canada: John Willey & Sons, Inc, 1995.

[24] H.T. Bangsawan and I.P. Wulandari, “Pengujian CISPR 32 pada mobile phone charger,” in *Pros. Pertem. Present. Ilm. Stand. 2020 (PPIS)*, 2020, pp. 89–96, doi: 10.31153/ppis.2020.61.

[25] L. Yang, S. Wang, H. Zhao, and Y. Zhi, “Prediction and analysis of EMI spectrum based on the operating principle of EMC spectrum analyzers,” *IEEE Trans. Power Electron.*, vol. 35, no. 1, pp. 263–275, Jan. 2020, doi: 10.1109/TPEL.2019.2914468.

[26] A. Singh. “Understanding EMI detectors.” Linkedin. Access date: 3-Jan-2024. [Online]. Available: https://www.linkedin.com/ pulse/understanding-emi-detectors-arminder-singh

[27] J. Beasley, “The dB in Communications,” *Technol. Int. J.*, vol. 1, no. 1, Fall 1996.

[28] *Electromagnetic Compatibility-Requirements for Household Appliances, Electric Tools and Similar Apparatus-Part 1: Emission*, CISPR 14.1:2020, International Electrotechnical Commission, Oct. 2020. [Online]. Available: https://webstore.iec.ch/publication/60734

[29] *Electromagnetic Compatibility of Multimedia Equipment-Emission Requirements*, CISPR 32:2015, International Electrotechnical Commission, Mar. 2015. [Online]. Available: https://webstore.iec.ch/en/publication/22046

[30] T. Purwanti. “5 perusahaan ini cuan dari kompor listrik, ada konglomerat.” CNBC Indonesia. Access date: 29-Dec-2023. [Online]. Available: https://www.cnbcindonesia.com/market/20220922081651-17-374047/5-perusahaan-ini-cuan-dari-kompor-listrik-ada-konglomerat#:~:text=Rinciannya%20adalah%20PT%20Rinnai%20Indonesia,International%2C%20dan%20PT%20Winn%20Appliance

[31] L. Subekti and M. Budiyanto, “Pengaruh perbaikan faktor daya pada kinerja kompor induksi,” in *Pros. Sem. Nas. Inform. 2012 (semnasIF 2012)*, 2012, pp. 59–66.