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CHALLENGES IN THE EMC STANDARDIZATION OF WIRELESS POWER TRANSFER SYSTEMS

IZZIVI V EMC STANDARDIZACIJI SISTEMOV BREZŽIČNEGA PRENOSA ENERGIJE

Bernd Jaekel ℜ

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Abstract

Charging of electrical and electronic equipment is currently mostly done via conducted connection to an AC/DC power supply unit. However, trends in technology, also driven by issues of convenience for the user, are moving towards wireless power transfer (WPT). A wireless process, in which most of the power is just used for the transfer of energy, includes the usage of a frequency for the power transfer, hence needing resources in the frequency spectrum. As the frequency spectrum is more or less completely assigned to the usage of radio or other services, such as industrial, scientific or medical (ISM) applications, it turns out to be a relatively complex task to actually decide on which frequencies can be used for WPT technology. This paper describes the challenges in the determination of such frequencies in terms of standardization and presents the related consequences.

Povzetek

Polnjenje električne in elektronske opreme je večinoma izvedeno preko povezave naprave z izmenično ali enosmerno napajalno enoto. Trendi v tehnologiji, ki jih narekuje vprašanje priročnosti za uporabnika, se premikajo proti brezžičnemu prenosu energije (WPT). Brezžični proces, pri katerem se

ℜ Corresponding author: Dr Bernd Jaekel, Siemens AG, Digital Industry, D-91058 Erlangen, Germany, E-mail address: bernd.jaekel@siemens.com;

večina moči porabi le za prenos energije, uporablja frekvenco za prenos energije, zato potrebuje vire v frekvenčnem spektru. Odločitev na katerih frekvencah se bo uporabljala tehnologija WPT, se je izkazala za kompleksno, saj je frekvenčni spekter bolj kot ne dodeljen v uporabo radiju in drugim storitvam, kot so recimo ISM frekvenčni pasovi. Članek opisuje izzive v določitvi omenjenih frekvenc v smislu standardizacije in predstavlja s tem povezane posledice.

1 INTRODUCTION

The increasing spread of electrical mobile devices and equipment requires new concepts for charging them in a convenient way. Currently, most devices and equipment are conductively charged by means of an AC/DC power supply. However, an approach that supports wireless charging (i.e., charging without galvanic connection between the device to be charged and the power supply system) has recently been becoming relevant.

This wireless technology is not that entirely new as it has been used for some applications for decades, with the prominent example of induction cooking appliances. The fundamental frequency being used for them is in the range of a few tens of kHz. Though there is the potential of causing interference with radio and broadcast reception or with other systems using those frequency ranges for wireless communication, the number of interference cases has shown to be very limited, as those appliances have to comply with emission limits. These limits were derived a long time ago, based on some unknown investigations and arguments, but the limits have been shown to be sufficient. The main reason for both the relatively low limits and the readiness of manufacturers to have accepted them is a technical one: the stray fields of such a wireless power transfer depend mostly on the air gap between the primary and secondary coils. This air gap is very small in the case of placing pots on an induction cooking surface.

Recently, WPT technology has also been introduced to other types of equipment, for example, the charging of mobile devices. However, the biggest issues are currently connected to a new area related to the prominent and promoted topic of electric vehicles. Most of them are currently charged by means of conductive charging, but charging in a wireless power transfer is expected.

This results in several issues to be considered and solved: as it is not convenient and practical to have different charging systems and requirements for different types and brands of vehicles, the need for standardization arises. In terms of compatibility, this means that there should be an agreement on the topology of the coils involved, and on the frequencies used for the wireless process.

In terms of electromagnetic compatibility (EMC), those issues cause further problems. The wireless charging process needs a system of primary and secondary coils that are separated by a more or less large air gap, with stray fields leaving the coil systems. The transfer power under discussion reaches up to several hundred kW and, consequently, the stray fields represent a potential threat to the immunity of other equipment not involved in the transfer process, and also represent a potential issue for personal safety.

2 FREQUENCIES USED FOR WPT

With regard to selecting a suitable frequency for the wireless process, the fact that nearly all frequencies are assigned to the usage of radio communication or other types of services has to be taken into account. There are a few ISM (industrial/scientific/medical) frequencies identified by the ITU (International Telecommunication Union) for the usage of services with nearly unlimited power, but those frequencies are not suitable for the systems used for electric vehicle charging from a technical point of view.

Therefore, only two possibilities exist: to identify frequencies for which there is only a low probability of interfering with radio services or to use arbitrary frequencies but apply the established limits that were introduced long ago for protecting radio services. As the latter possibility can hardly be followed because of the relatively huge power involved in the power transfer, the first possibility is currently investigated in the standardization groups.

IEC CISPR B is the relevant international standardization committee for this topic; the technical specifications taking into account frequency ranges, limits and measurement procedures are expected to become part of a future edition of the standard CISPR 11. Hence in a certain respect, the following information reflects the discussion and development currently underway in the committee CISPR B (in detail, see the recent IEC publications, *[1]*, *[2]*).

Frequency ranges suitable for WPT charging of electric vehicles are listed in Table 1, together with some information regarding their usage.

Table 1: *Candidate frequency bands considered for wireless power transfer in the frequency range below 150 kHz*

Frequency range (kHz)	**Typical WPT use [c]**
19 to 25	Local WPT via an air gap in cm range, throughput power up to 200 kW – automated in-plant transportation systems, trams and electric buses
36 to 40	Local WPT via an air gap in cm range, throughput power up to 200 kW – automated in-plant transportation systems, trams, and electric buses
55 to 65 [a]	Local WPT via an air gap in cm range, throughput power up to 200 kW – automated in-plant transportation systems, trams and electric buses
79 to 90 [b]	Local WPT via an air gap in cm range, throughput power in the range up to 22 kW – electric personal passenger vehicles (e.g., automobiles) and automated in-plant transportation systems
130 to 135	Local WPT via an air gap in cm range, throughput power up to 90 kW – automated in-plant transportation systems

[a] It should be noted that 60 kHz is used as a standard frequency and time signal service.

[b] Candidate WPT frequency range for global harmonization.
The frequency range of 79 kHz to 90 kHz is being considered for electric vehicles.

[c] The power for WPT systems is given for information only.

3 ASSIGNMENT OF WPT SYSTEMS

The CISPR 11 standard applies to industrial, scientific, and medical electrical equipment operating in the frequency range 0 Hz to 400 GHz and to domestic and similar appliances. WPT systems used for the charging of electric vehicles are assigned to it. With respect to the application of appropriate limits for conducted and radiated disturbances for the various types of equipment, CISPR 11 uses a classification scheme according to which WPT systems are categorized as Group 2 equipment. Such equipment contains all ISM (Industrial/Scientific/Medical) RF (radio frequency) equipment in which radio-frequency energy in the frequency range 9 kHz to 40 GHz is intentionally generated and used or only used locally, in the form of electromagnetic radiation, inductive and/or capacitive coupling, for the treatment of material, for inspection/analysis purposes, or for transfer of electromagnetic energy.

In essence, CISPR 11 already contains disturbance limits for Group 2 equipment, for Class A type equipment intended to be used in the industrial environment as well as for Class B type equipment which is intended for the residential area. Consequently, this standard can already be used for measuring WPT systems, for example, to demonstrate compliance with an international specification.

However, the physical parameters and their future use case could imply that the existing limits might have to be amended in order to take into account the interference situation, which could occur if many WPT systems are installed.

4 LIMITS FOR WPT SYSTEMS

There are more or less three aspects which need to be considered when discussing limits (including appropriate measurement methods) for the WPT systems intended to be used for the charging of electric vehicles.

(1) radiated disturbances in the frequency range below 150 kHz,

(2) disturbances produced by the wireless power port, i.e., the cabling arrangement between the secondary terminal of the power electronics and the primary coil, and

(3) consideration of whether the limits above 150 kHz are appropriate for this kind of equipment, also in the light of the expected spreading of its usage.

To date, limits in the frequency range below 150 kHz have been applied relatively seldom and only for special types of equipment, such as induction cooking appliances. The main reason for not having commonly used limits is because there are only a few types of equipment producing intentional disturbances in that frequency range and that there are not that many radio services that could be disturbed. However, aspect (1) is expected to become more and more important because the use cases connected to WPT are expected to have widespread usage and hence a high number of interference sources.

When discussing limits in the frequency range, a closer look has to be taken to identify the radio services to be protected. The investigations showed that typically time signals use this frequency range. Therefore, in a first step, limits have to be derived in such a way that the reception of time signals should continue without being disturbed. The implementation of this requirement, together with the fact that WPT systems produce relatively strong electromagnetic fields at their fundamental frequencies, has led to a concept that can be called the “chimney approach”. This means that a certain relaxation is allowed only for those frequency bands in which the fundamental WPT frequency is located, and relatively tight limits will be required outside of these bands. Of course, it has to be ensured that the frequency bands actually used for WPT do not clash with frequencies used for time signals, for example.

A proposal for limits for the H-field in the frequency range from 9 kHz to 150 kHz is shown in Fig. 1, *[2]*. It has to be noted that the limits shown apply to Class B WPT systems with rated power between 1 kW and 7.7 kW, and measured at a measurement distance of 10 m. For WPT systems with higher power, the limits in the “chimney frequency bands” are relaxed by 15 dB.

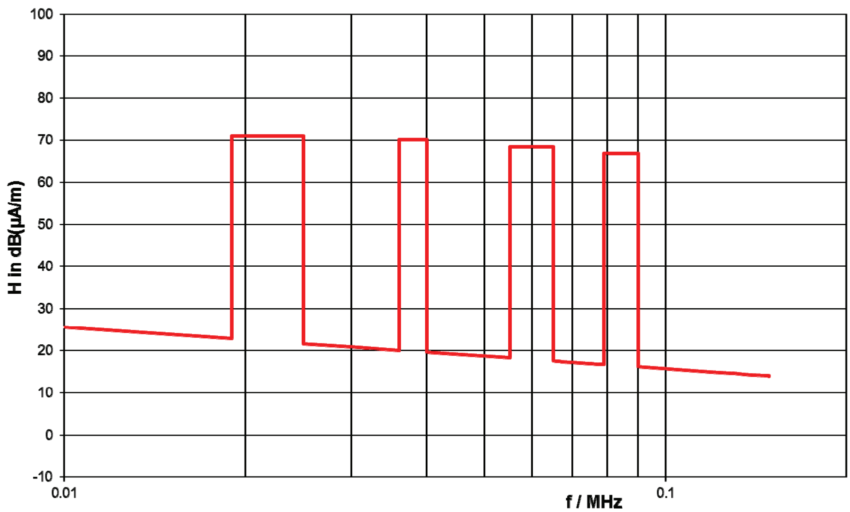

Figure 1: *Radiated limits currently under discussion*

Aspect (2) mentioned above considers the situation that the cable between the output of the power electronics and the coil could be relatively long, thus representing an efficient radiator. Therefore, limits for that interference situation have been discussed. One possibility would be to introduce limits for conducted disturbances on that port. In order to ensure a defined measurement setup, a kind of artificial network would be needed in this circuit. Investigations have shown that this would be very difficult to establish as this circuit is highly sensitive to any parasitic impedances (caused by the artificial network) because this would detune the resonance behaviour of the circuit needed for supplying the coil at discrete frequencies.

An alternative approach would consist of the performance of radiated measurements. There is currently a measurement setup under discussion for E-field measurements in the frequency range from 150 kHz to 30 MHz.

Regarding aspect (3), it should be noted that the current edition of CISPR 11 already specifies limits for the H-field in the frequency range from 150 kHz to 30 MHz. These limits were published a long time ago and apply to Group 2 equipment in general, meaning to equipment that intentionally produces electromagnetic fields, for example, for the treatment of the material. By default, they apply to WPT systems as well. However, it had been assumed that Group 2 equipment is not used that frequently and, therefore, the limits are relaxed compared to Group 1 equipment: this results from the fact that CISPR limits are derived on a statistical basis and, therefore, equipment with a relatively low number of installations could have relaxed limits compared to that with a high number of installations.

However, the business case for WPT systems expects a wide spreading of their usage; in the ideal case, nearly one system per household when mostly electric vehicles will be used in future. Hence, the statistical basis currently used for the derivation of Group 2 equipment might not be the correct one, and the limits for WPT systems as Group 2 equipment might have to be modified. Such amended limits are currently derived taking into account the interference model and its associated probabilistic factors of the publication CISPR 16-4-4, *[3].*

Fig. 2 shows the limits (Class B, measurement distance 10 m) derived from that interference model. This derivation results in a straight line starting with 15 dBµA/m at 150 kHz and ending with -22 dBµV/m at 30 MHz. However, due to limitations of the achievable signal to noise ratio for frequencies above 6 MHz, the limit line indicated as option 1 is proposed.

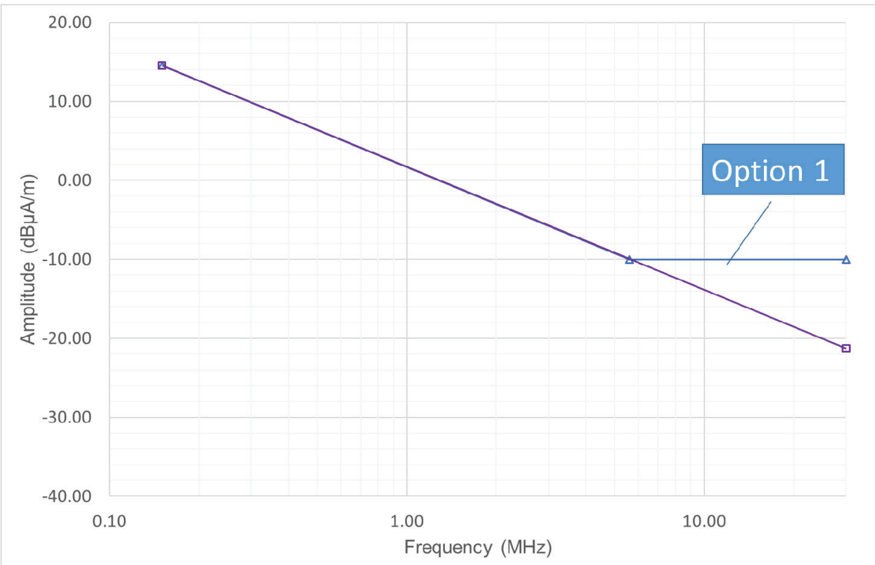

Figure 2: *Proposed H-field limits in the frequency range from 150 kHz to 30 MHz*

5 CONCLUSION

The evolving technology of WPT for charging of electric vehicles requires some attention with respect to the standardization of its emission characteristics. This paper described the challenges associated with it. The ideas and proposals given above are expected to be published in the near future as a document within the IEC CISPR B community for commenting by National Committees.

References

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