Spread Spectrum Technology to Reduce the EMI from the Constant Voltage Source Type Wireless Power Transfer System

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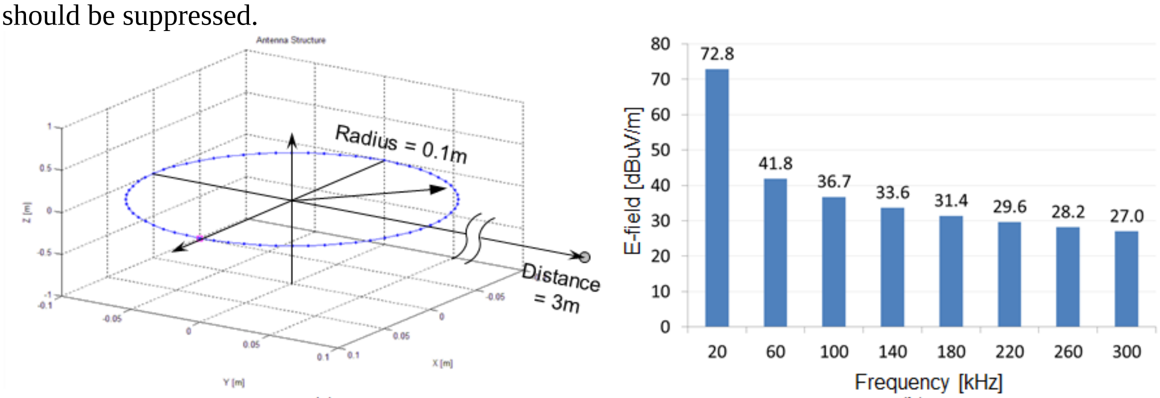
Abstract

The electromagnetic interference (EMI) from the coil system for the wireless power transfer (WPT) with the voltage source and series LC resonance type can be reduced by 20dB at the most by using the spread spectrum technology when operating frequency 20 kHz, peak deviation 1%, and modulation frequency 156.25Hz.

Keywords: Wireless Power Transfer (WPT), Electromagnetic Interference (EMI), Spread Spectrum

1. Introduction

Recently, the commercial products with the function of wireless power transfer (WPT) were introducing to provide convenience. [1] Most of the WPT system for the high power transmission transfers through the strong magnetic field caused by the current on coil structure as shown in Fig. 1(a). The electric field from the coil with 10A current and 10 turns is up to 72.8dBuV/m as shown in Fig. 1(b). Because the strong electric field can be interfered the other electronic equipment, it should be suppressed.



(a) (b)

Figure 1: Electromagnetic Interference (EMI) from the coil system for WPT
(a) Structure of a coil system (example) (b) Electric field from the coil system

To reduce the EMI from high-speed digital system, the spread spectrum clock technology can be adopted to lots of digital equipment's such as computer. [2] To generate the spread spectrum clock (SSC), the period should be changed like Fig. 2(a). The resultant bandwidth is much larger than that of the fixed period clock and the maximum EMI can be suppressed as shown in Fig. 2(b). When the triangular modulation profile is used, the attenuation by using the SSC can be estimated by equation (1). The attenuation is directly proportional to the peak deviation (δ) and the harmonic frequency ($n\cdot f_0$), and inversely proportional to the modulation frequency (f_m). [2]

$$\text{Attenuation} = A_{dB} \approx 10\cdot\log_{10}\left(\frac{\delta\cdot n\cdot f_0}{f_m}\right) \qquad (1)$$

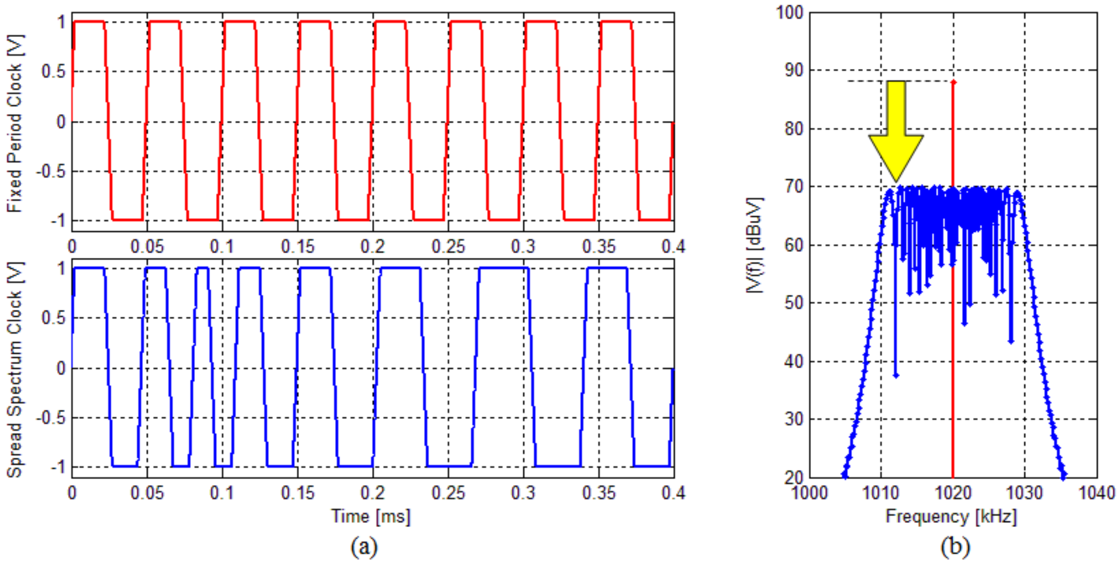


Figure 2: The principle of EMI reduction by using the SSC (a) Waveform in time domain (fixed period clock: upper, spread spectrum clock: lower) (b) Spectrum in frequency domain

The spread spectrum technology which is applied to the wireless power transfer system to reduce the EMI is studied in this paper.

2. Conventional Coil System with Fixed Period Clock for WPT

The power system for wireless power transfer can be divided into 3 parts as shown in Fig. 3. There is the power transmission part which may include rectifier, inverter, and control circuit. The power receiving part may include rectifier and voltage regulator. The coil system has more than two coils which are coupled by magnetic field for transmission and reception. To simplify the research, only the transmission coil will be focused in this paper.

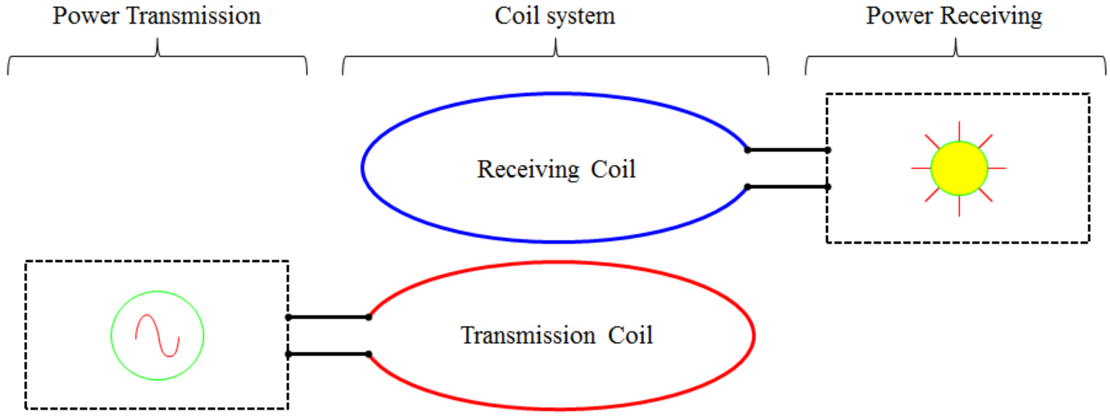


Figure 3: The configuration of the wireless high-power transfer system

So many kinds of architectures for the coil system are available. In this study, the architecture with the voltage source and LC series circuit was assumed as shown in Fig. 4(a). The coil has the inherent parasitic resistance which has been modelled as the series resistance, R_1. The waveform of voltage source is similar to the digital signal waveform like Fig. 2(a) because of the power electronic inverter circuit. The input impedance at the voltage source toward the coil is shown Fig. 4(b) and determines the current through the capacitor and the inductor. At the resonance frequency which is calculated by equation (2), maximum current could be flowed

$$\text{Resonance Frequency},\ f_r = \frac{1}{2\pi \cdot \sqrt{L \cdot C}} \tag{2}$$

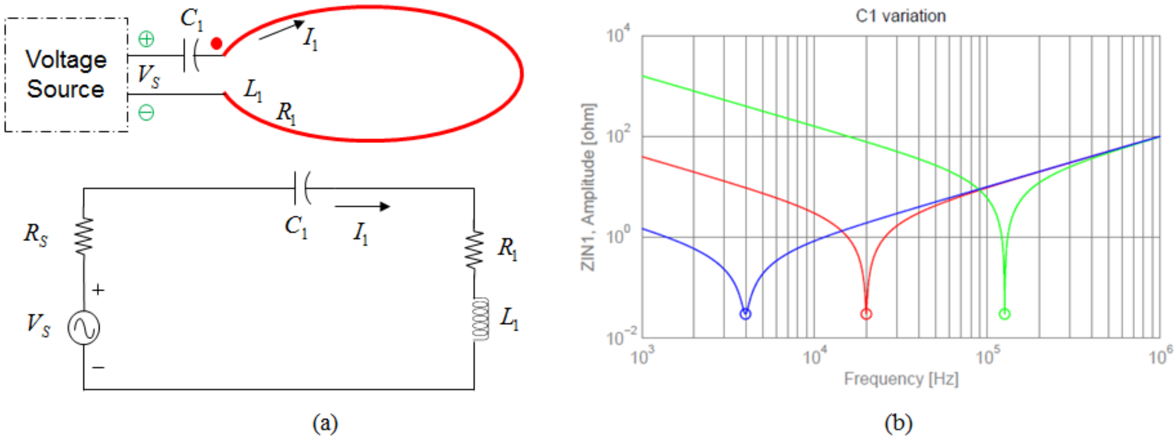


Figure 4: Transmission coil system (a) Block diagram and equivalent electrical circuit model (b) Input impedance at the voltage source toward the coil

Typically, because the efficiency of power transfer is highest at the resonance frequency, the operating frequency which is called fundamental frequency was tuned to 20 kHz. If the capacitance is varied, the resonance frequency will be changed as shown in Fig. 4(b). The voltage source is normalized from –1V to +1V and the rise time is assumed to be 100ns. The current can be determined by equation (3). Because the EMI is proportional to the current, if the current is reduced, the EMI will be suppressed.

$$\text{Current, } I_1 = \frac{V_S}{Z_{IN1}}, \qquad Z_{IN1} = R_S + R_1 + j\omega L_1 + \frac{1}{j\omega C_1} \tag{3}$$

3. Proposed Coil System with Spread Spectrum Technology

The spread spectrum technology was applied to the coil system as shown in Fig. 6(a). It has the triangular modulation profile, the peak deviation ±1%, and modulation frequency 156.25Hz. The voltage harmonics are reduced throughout the spectrum which is shown in Fig. 6(b).

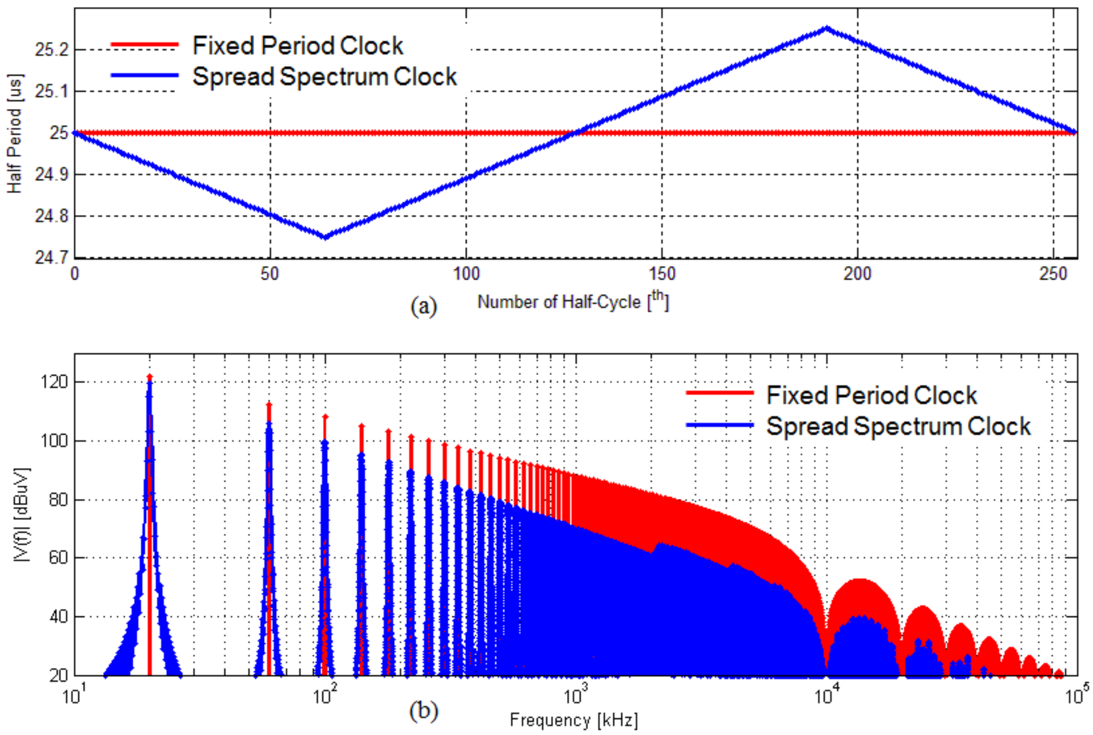


Figure 6: Proposed coil system with spread spectrum technology (a) Triangular modulation profile (b) Voltage spectrum in frequency domain

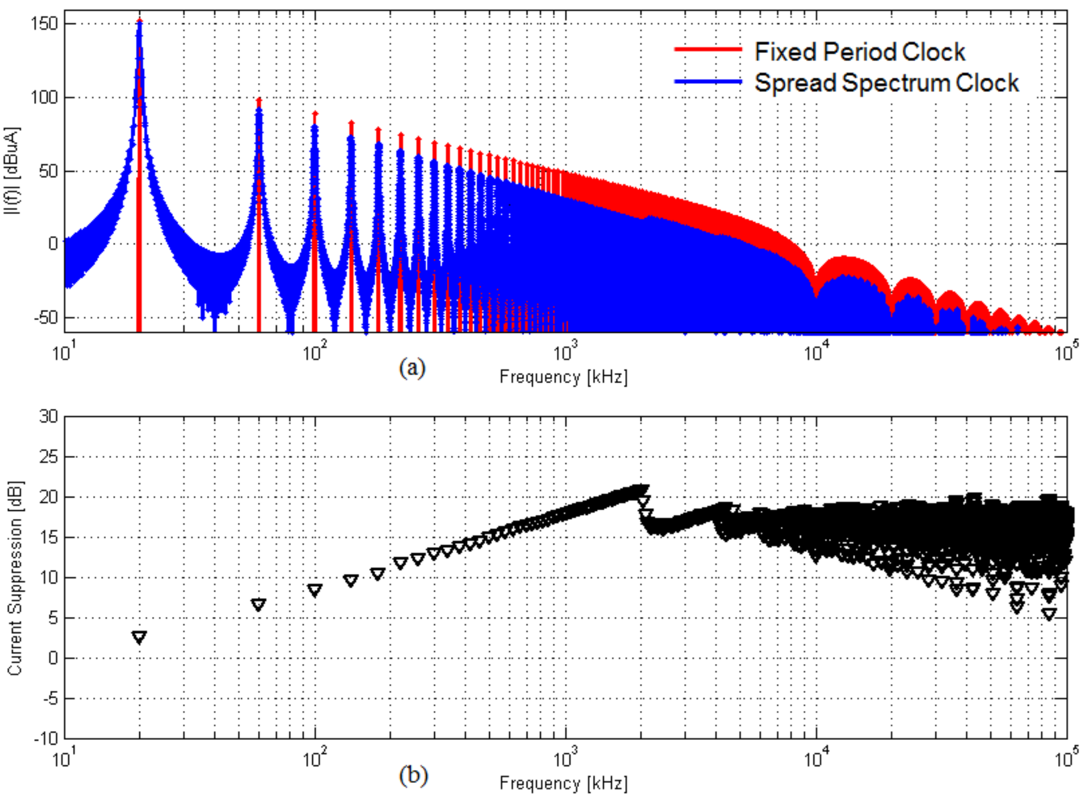


Figure 7: Suppression of the current spectrum caused by the proposed spread spectrum technology (a) Current spectrum in frequency domain (b) Suppression of the current spectrum at each harmonic

The resultant current spectrum is explained in Fig. 7(a). Current is much higher at the fundamental frequency than other harmonic frequencies. It can be found easily that the current spectrum is reduced by applying the spread spectrum technology to wireless power transfer system. The suppressed current spectrum by 20dB at the most is described in Fig. 7(b).

4. Conclusion

To reduce the electromagnetic interference (EMI), the spread spectrum technology was implemented to the wireless power transfer (WPT) system. Because the EMI is proportional to the current, if the current is reduced, the EMI will be suppressed. In this paper, it is verified that the proposed spread spectrum technology with peak deviation 1% can suppress the current spectrum by 20dB at the most at each harmonic.

References

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