Radiated electric field characteristics of a monopole antenna using the optical feeding method

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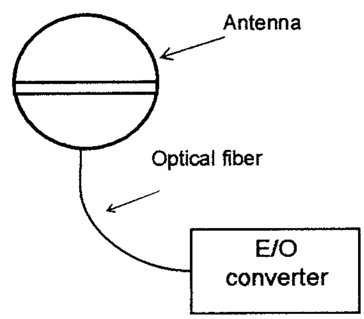
Abstract: In order to realize a spherical dipole antenna with wideband characteristics up to several GHz, the basic examination of the optical feeding antenna using UTC-PD was performed for a monopole antenna. As a result, the maximum electric field of about 86 dB μ V/m can be obtained corresponding to input optical power of 10 dBm, which is allowable maximum optical power for our measurement system. In addition, the calculated values of the electric field for the radiation directivity and frequency characteristics of monopole antenna are agreed very much with the measured values.

Key words: monopole antenna, spherical dipole antenna, optical feeding method, UTC-PD, EMC

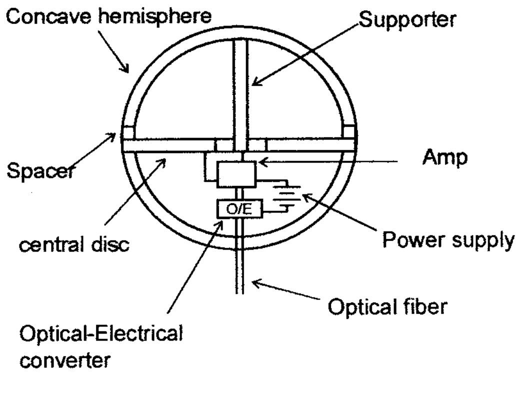
1. Introduction

Recently, the frequency bandwidth and the level of the electromagnetic interference increase by digitalizing the ISM (Industry, Scientific and Medical) equipment and ITE (Information Technology Equipment). In CISPR, international standardization to the electromagnetic interference at 1GHz or more has been being studied. Therefore, the antenna and the measurement tool, which evaluates the electromagnetic interference level, should be made to the high frequency and be made broadband. The spherical dipole antenna is convenient as the antenna for the electromagnetic interference evaluation [1] [2].

The structure of conventional spherical dipole antenna is shown in Fig.1. There is spherical dipole antenna, which can be used within the frequency range from 30 MHz to 1GHz. The antenna shown in Fig. 1 is composed of O/E conversion equipment, amplifier, stabilization circuit, and power supply, etc. Thus, since the inside of an antenna is complicated, it is difficult to make an antenna element small that is required to be higher-frequency. In order to solve such a problem, there is the optical feeding method that can transmit not only an optical information signal but also optical power possible to convert electric power by using an O/E conversion element and an optical fiber. Concretely, the device in the antenna becomes only O/E conversion element as the optical signal and the optical power conversions. Therefore, the inside of the antenna is greatly simplified, and the antenna miniaturization becomes possible.



(a) Aspect of antenna



(b) Sectional view of the antenna

Fig.1 Conventional spherical dipole antenna

This paper is described about the practical use of optical feeding method when UTC-PD (Uni-Traveling-Carrier Photodiode) [2] is used as O/E conversion element. However, it was assumed to be simple monopole antenna on a metal box to optical feed because optical feeding method by UTC-PD was a center topic in this paper. The result of measuring the frequency and input optical power dependencies of the UTC-PD output are described first. Secondly, radiation field of monopole antenna on a metal box including the UTC-PD is actually driven by the method of moment and the result of measuring radiation field is described. Finally, the comparison result with the measurement and the calculation is shown.

2. Characteristics of PD

2.1 Measurement method of PD output characteristics

UTC-PD is superior to pin-PD for the saturation level and the response. Furthermore, it is known that UTC-PD will operate on non-Bias.

Measurement system of PD output characteristics is shown in Fig.2. Optical modulator is put between semiconductor laser equipment and PD. The semiconductor laser output is impressed to optical modulator as a carrier wave. Optical modulator modulates strength of carrier wave by the RF signal. The modulated optical signal is amplified by an optical amplifier, and impressed to PD. A spectrum analyzer measures PD output electrical level.

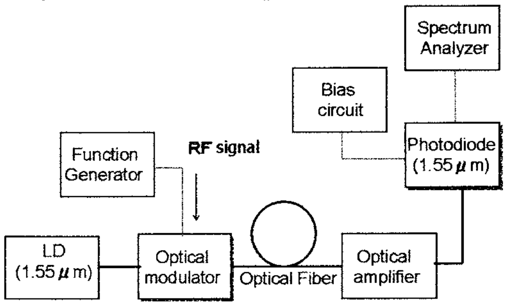
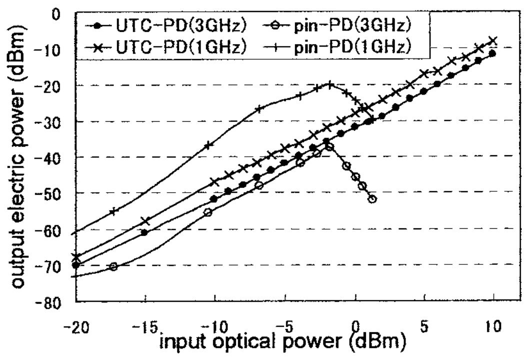


Fig.2 Measurement system of PD output characteristics

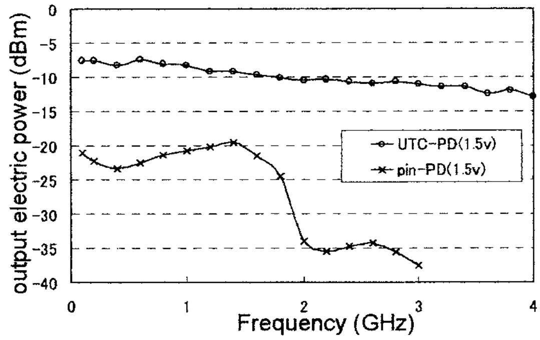
2.2 Output electrical power from UTC-PD

Figure 3(a) shows the relation between output electrical power and input optical power for the UTC-PD and pin-PD. It was seen from Fig. 3 (a) that the relation for UTC-PD has linear, but the output electrical power for pin-PD is saturated to the input optical power. ; The average output electrical power for the UTC-PD reach up to -12dBm corresponding to input optical power of 10 dBm, though the maximum value slightly changes according to the RF modulation frequency. The input optical power of 10 dBm is maximum power possible to realize on optical source having our measurement system. If we could have a powerful input optical source, it is considered to be able to have more powerful output electrical power than that of -12dBm.

The result of measuring the dependency of the PD output to RF modulation frequency (0.1 – 4 GHz) is shown in Fig. 3(b) for constant input optical power of 10dBm. There is a small difference of about 6dB in the case of UTC-PD output when RF modulation frequency is 0.1GHz and 4GHz, but in the case of pin-PD the difference is about 20 dB at the RF modulation frequency from 0.1GHz to 3GHz.



(a) The output signal level to input optical power



(b) The frequency characteristic of output electric power

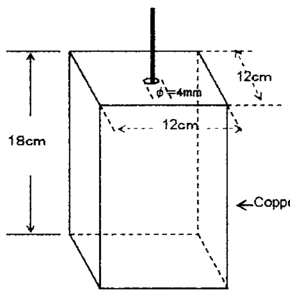
Fig.3 The output characteristic of UTC-PD

3. Antenna structure and Measurement system

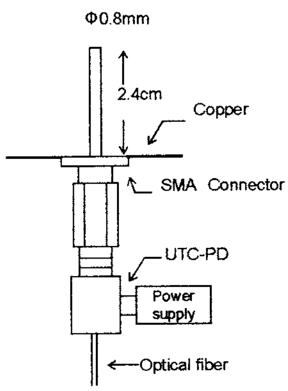
3.1 Structure of λ/4 monopole antenna on a box

The structure of λ/4 monopole antenna on a metal box is shown in Fig. 4. The size of the metal box is 120mm in width, 120mm in depth, and 180mm in height because of building in as for UTC-PD and battery, and it is constructed with the sheet copper (0.2mm in thickness).

The antenna shown in Fig.4 (b) is designed so that the resonance frequency may become 3GHz (λ= 0.1m). Moreover, UTC-PD (50ohms) and SMA connector terminating the monopole antenna are connected by the K/V connector.



(a) The size of a cabinet



(b) Structure of monopole antenna

Fig.4 Structures of cabinet and monopole antenna

3.2 Measurement system of radiation electric field

The radiation field from monopole antenna was measured in the radio anechoic chamber. The measurement system is shown in Fig. 5. An optical input for driving the monopole antenna is impressed with the optical fiber cable, and horn antenna detects the radiation field from monopole antenna. Moreover, the monopole antenna was set up on the turntable, and the radiation pattern was measured (the distance between monopole antenna and horn antenna was set 1m.). In the radiation field evaluation from monopole antenna, it is necessary to measure the radiation field from a standard antenna as reference data. Actually, the radiation level of monopole antenna and a standard antenna (LPDA is used) were measured with spectrum analyzer, and the radiation electric field E_{DUT} from monopole antenna was evaluated according to the following expressions (1).

$$E_{DUT} = E_{Log} - P_{Log} + P_{DUT} \qquad (1)$$

E_{Log} : Electric field intensity from LPDA.

P_{Log} : Radiation power by LPDA (spectrum analyzer display value). Spectrum analyzer measured value at the time of LPDA antenna.

P_{DUT} : Radiation power by monopole antenna (spectrum analyzer display value). Spectrum analyzer measured value at the time of monopole antenna connection.

The Electric field intensity E_{Log} of a LPDA antenna is called for expressions (2).

$$E_{\log} = 139.6 + 10 \log P[W] - 20 \log D[m] \qquad (2)$$

P: Supplied electric power to an antenna
D: Distance from an antenna

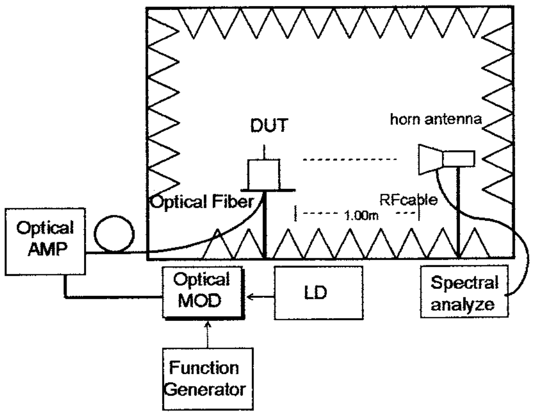


Fig.5 Measurement system of radiation electric field

The radiation field intensity of the monopole antenna can be obtained from the above-mentioned formula, where the influence of an antenna factor and a cable loss is removed.

4. Calculation model of the monopole antenna set on a metal box

The radiation field intensity from the monopole antenna was calculated by the moment of method. The calculation model is shown in Fig. 6. NEC (Numerical Electromagnetic Code)-Win pro was used for calculation software. Wire grid model approximates the metal box set on monopole antenna. . the resonance frequency and the input level are set to 3GHz and -12dBm respectively in calculation model.

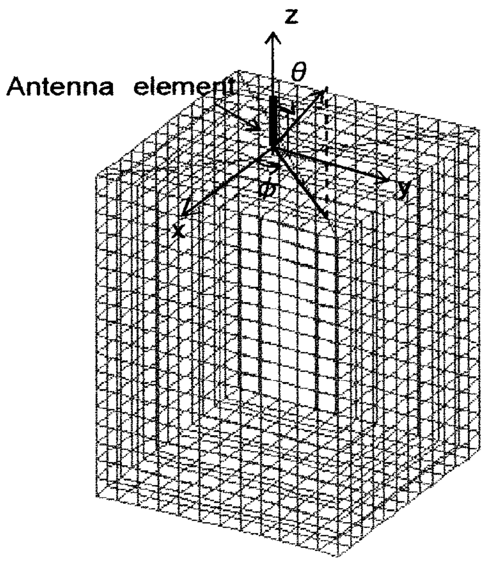


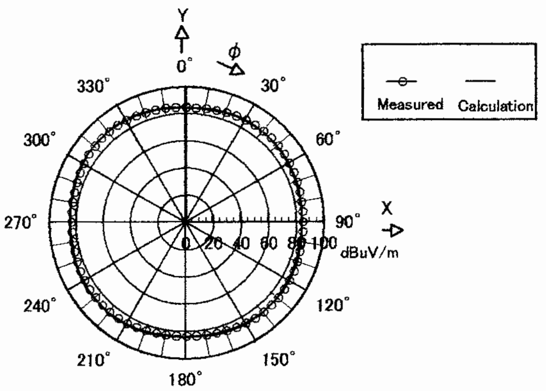
Fig.6 Calculation model for a monopole antenna set on a metal box

5. Measured and calculated results

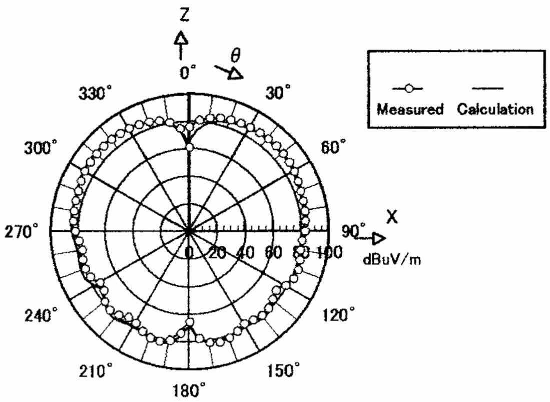
5.1 Directivity of radiation

The directivity of radiation with a resonance frequency of 3GHz is shown in Fig. 7. Figure 7 (a) shows the radiation pattern in the direction of φ (θ= 90 degrees). Figure7 (b) shows the radiation pattern in the direction of θ (φ= 0 degrees). The distance of a monopole antenna and a receiving antenna is 1m. A black dot is measured values and a solid line is calculated values.

The calculated and the measured values in Fig. 7 are good agreements. The maximum electric field is about 86 dB μ V/m.



(a) φ direction



(b) θ direction

Fig.7 Directivity of monopole antenna

5.2 Frequency characteristics

The frequency characteristics are shown in the Fig. 8. At the distance of the receiving antenna of 1m and the directivity angles with φ=0 and θ=90.
The calculated value agreed very well with the measured value, and their deviation is only 4dB in the frequency band from 1GHz to 5GHz. Their deviation below 1GHz is little bit large, and it is considered that the measured value below 1GHz is affected by the reflection from the wall of an anechoic chamber because an absorber of the anechoic chamber works only above 1GHz.

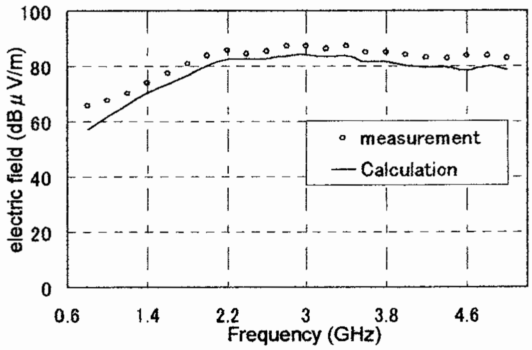


Fig.8 Frequency characteristics of monopole antenna

6. Conclusion

The basic examination of the optical feeding antenna using UTC-PD was performed for a monopole antenna, and following items are clear.
(1) The maximum electric field of about 86 dB μ V/m can be obtained corresponding to input optical power of 10 dBm, which is allowable maximum optical power for our measurement system.
(2) The calculated values of the electric field for the radiation directivity and frequency characteristics of monopole antenna are agreed very much with the measured values

Therefore, it is revealed that a spherical dipole antenna with wide band characteristics up to several GHz can be realized by using UTC-PD.

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