A PRACTICAL ANTENNA CALIBRATION METHOD IN QUASI-FREE SPACE

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Abstract: As we mentioned in our previous paper[1][2], we found that the factor of the antenna under calibration (AUC) is shown the same value as in the free space at the specific antenna height. And we defined the specific antenna height as “quasi-free space” (QFS). This paper presents detailed QFS description and a practical calibration method of dipole antennas in QFS.
Key words: free space, quasi-free space, electric field, antenna factor, calibration, antenna impedance

1. Introduction

There is no specification for determination of antenna factor to use for EMI electric field disturbance measurements. Consequently, any antenna calibration is valid for EMI measurement antennas. We can use any antenna factor that was calibrated in any condition. Therefore, Antenna factor variation causes the EMI test result variation. In addition, even the national standards laboratory may gives different calibration result for an antenna depends on their different calibration methods or calibration configurations.

It is understandable that an unchangeable antenna factor shall be determined for one antenna. Determination of the antenna factor in free space (free space antenna factor) is the essential subject to solve the problem. However, the normally calibrated antenna factor by a calibration laboratory includes the ground effects. Generally we think that the standard site method described in ANSI C63.5 brings the free space antenna factor. However, the antenna factor obtained using this method contains ground effects that complicatedly varied depending on frequencies. Although, antenna factor calculation from the wave propagation does not perform actually measurement of the electric field strength (V/m). The calculated antenna factor depends on the validity and accuracy of the wave propagation equation. Moreover, antenna factor obtained by this calculation contains the ground effects. On the other hand, electric field being measured at a space can be determined using NIST Standard Dipole. The NIST Standard dipole method is superior to other calibration methods because of the NIST standard dipole provides physical value of the electric field according to the definition of the electric field strength. However, the antenna factor of the antenna to be calibrated contains the ground effect even used the NIST Standard Dipole. [1]

We have improved the calibration method using NIST Standard Dipole, and we developed calibration method to obtain antenna factor in free-space.
We propose a practical free-space antenna factor calibration method based on our study and consideration, and show the diagrams the antenna height indicating the quasi free-space condition.

2. What is the Quasi-Free Space

As shown in Figure 1, antenna factor swings side to side from the center where indicates the free space factor when antenna towards higher position. Finally, antenna factor reaches the value in free space at the height leads infinity. Figure 1 also shows that we can obtain the free space antenna factor at the specific antenna height as indicated ha_1, ha_2, ha_3, ---. Though the antenna factor shows as same value in free space at those indicated points, however the antenna impedance has different value as in the free space. Namely, the space property at the specific height is not same as the real free space.

The meaning of the QFS, quasi-free space, will be considered as follows;

> The current flow on the antenna element causes re-radiation. The re-radiated wave reflects on the ground plane right under the antenna. The phase relation between radiated- and reflected waves is changed in-phase or out-of-phase by depending on antenna height. The antenna height becomes higher, consequently the reflected wave phase delays and the amplitude goes smaller.

Figure 2 shows the manner of the phenomenon.

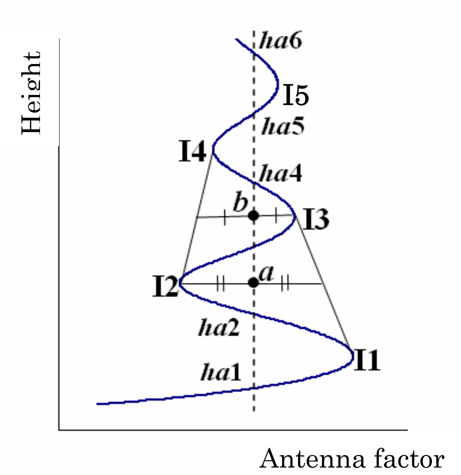

Figure 1 Antenna Height and Factor variation

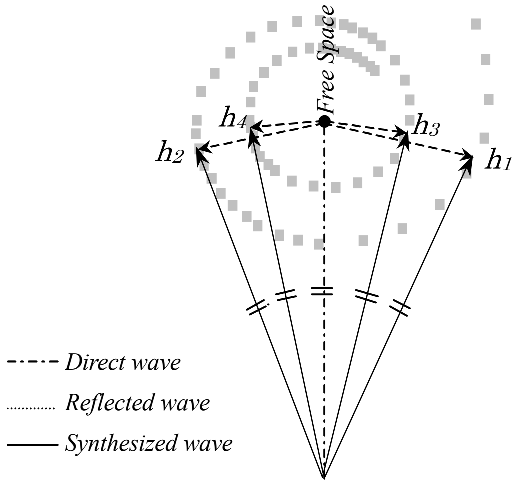

Figure 2 Meaning of Quasi-Free Space

Figure 2 shows a synthesis for direct- and reflect waves, i.e., induced voltages by adding up vector components of two waves. When the amplitude of the synthesized waves is as same value of direct wave at the specific antenna height, the antenna factor also shows the same value as in the free space. In that case, though the antenna output voltage has same amplitude as in the free space, however, phase is not same as in the free space. This means antenna impedance in the free space and the impedance at specific height are quite different. So we defined the property at the specific antenna height as Quasi-Free Space.

3. Specific antenna height (Quasi-Free Space)

The specific antenna height for tuned- and half-wave dipoles in horizontal polarization is shown in Figures 3-1, and 3-2. The antenna factor leads the same value in the free space at the heights ha_1, ha_2, --- correspond to the same symbols in Figure 1.

Also the calculated relative antenna factor variations referred to the free space factor for tuned- and half-wave dipoles are shown in Figures 4-1 and 4-2.

4. Calibration method in quasi-free space

4.1 Condition

- Why Vertical polarization should not be adopted?

It seems that vertical polarization is advisable because of the ground plane influence is smaller than horizontal polarization. However, interfere between antenna element and cable increases uncertainty in vertical polarization.

- Ground Plane

A wide and flat ground plane is necessary for antenna factor determination by using wave propagations calculation such as the standard site method. However, the method described in this paper needs a flat ground plane only around right under the AUC.

- Distance between the transmitting antenna and AUC

At least 5λ spacing should be necessary to reduce the influences caused by mutual coupling less than 0.1dB.[1]

- Transmitting antenna

Any type of antennas can be used for this method. Broadband antennas are convenient. A biconical antenna having large mismatch loss in lower frequency band reduces mutual coupling with AUC, therefore shorter antenna distances can be used.

5. Practical calibration procedure

5.1 Simple and easy method

This method should be used for an antenna which is not used as a reference antenna for determination of antenna factor for other EMI measurement antennas. Calibration is carried out at one of the appropriate specific heights indicating ha_1, ha_2, ---. Please note that the difference of the antenna factor with the height change is larger at those specific heights.

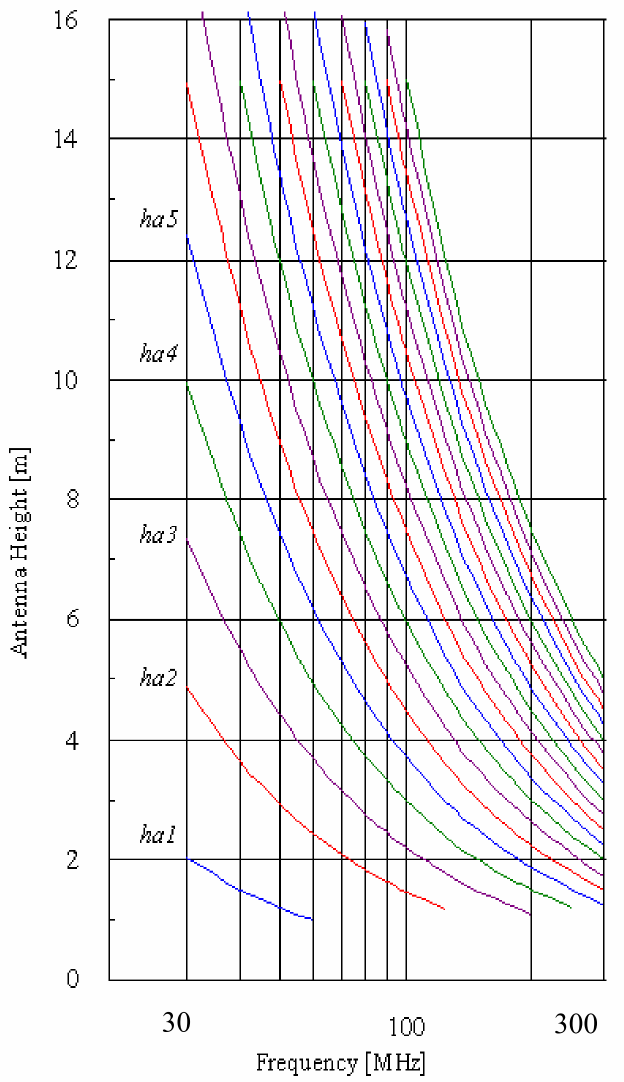

Figure 3-1 Specific Antenna Height showing Quasi-Free Space for Tuned Dipole, Horizontal Polarization

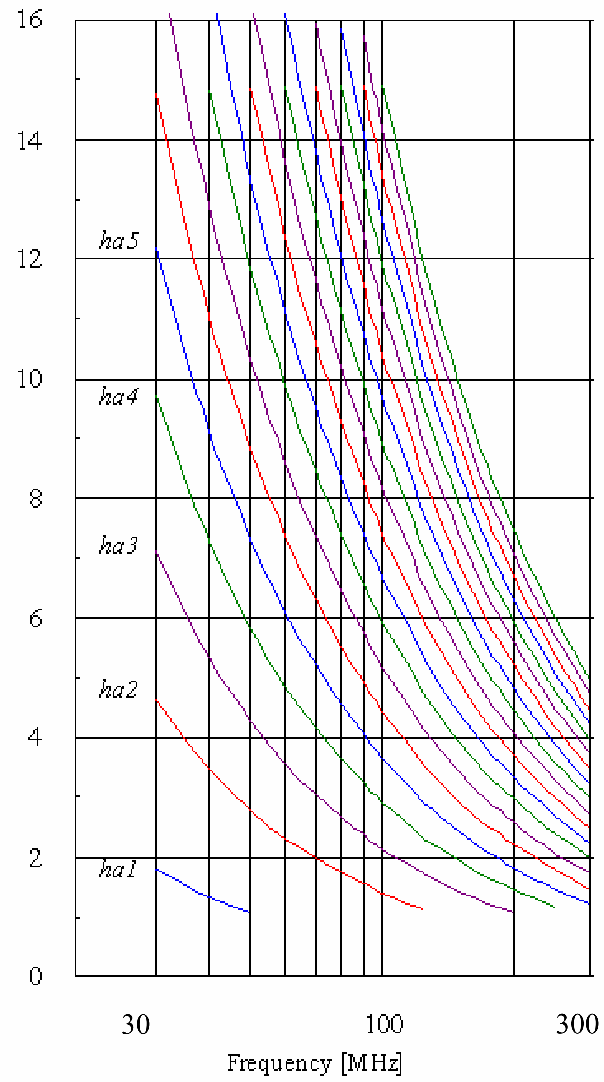

Figure 3-2 Specific Antenna Height showing Quasi-Free Space for Half-wave Dipole, Horizontal Polarization

The accurate antenna height setting is necessary for this method is used.

5.2 Accurate method

Figure 1 shows that the antenna factor varies sharply with the antenna height change at the near points to ha_1, ha_2, ---. On the other hand, antenna factor variation is gentle at the inflection points I_1, I_2, ---. Therefore, even if antenna height adjustment is not so precisely at the inflection point, the antenna factor is not changed so sharply. Therefore the accurate calibration will be carried out using the antenna factor at inflection points described as following operation.

Step 1
Measure the antenna factor at least 3 (odd) inflection points I_1, I_2, and I_3 by turns as shown in Figure 1.

Step 2
In case of the each three antenna factor AF_1, AF_2, and AF_3 at the inflection points I_1, I_2, and I_3 are measured, the antenna factor in free space $AFs(a)$ at the point a is obtained by the geometrical average calculation over three antenna factors as following equation;

$$AFs(a) = \frac{\frac{1}{2}\left(AF_1 + AF_3\right) + AF_2}{2} . \qquad (1)$$

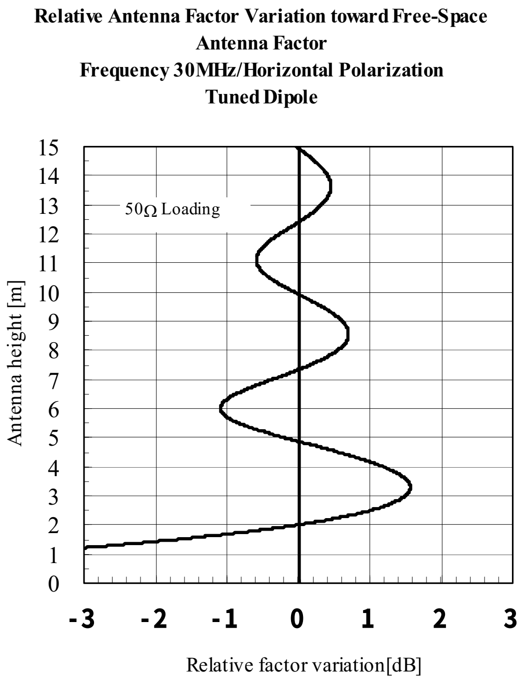

Figure 4-1
Relative Antenna Factor variation
Tuned Dipole

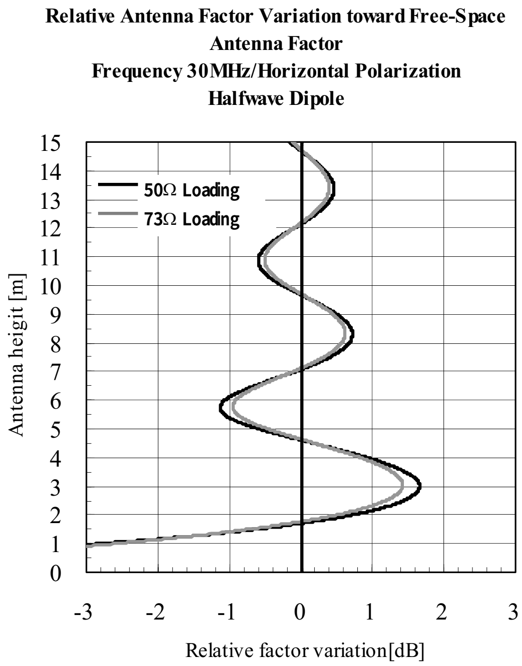

Figure 4-2
Relative Antenna Factor variation
Half-wave Dipole

We had confirmed that the tolerance between antenna factors obtained by above procedure and real free space factor is less than 0.1dB.

6. Conclusion

Our developed method could provide free space antenna factor for EMI measurement dipole antennas. Moreover we will verify the applicability of this method for biconical antennas in the near future.

References

[1] A. MAEDA, et al., “Development of Antenna Factor Calibration for EMI Testing in Quasi-Free Space,” 15th International Zurich Symposium on EMC, 127S4, pp.673-676, Feb.’03

[2] A. MAEDA, et al., “Development of Antenna Factor Calibration for EMI Testing in Quasi-Free Space (1),” Technical Report of IEICE EMCJ 2003-1 (2003/04)