Generation of Homogeneous EM Field for EMC Test Purposes

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***Abstract**. This paper describes the problem of homogeneous electromagnetic field generation in consideration of an understanding of non-homogeneous performance creation of electromagnetic field propagation in real environment. One of the possible solutions how to get a homogeneous field is using of a stripline. The properties of stripline are numerically modeled and consequently measured in dependence of its input and output impedance. Based on obtained results a recommendation, which load impedances should be used to get the largest frequency range of the stripline and also the best field homogeneity in it, is prepared.*

Keywords: Homogeneous Field, Electromagnetic Compatibility, Stripline

1. Introduction

In EMC area it is necessary to generate electromagnetic (EM) field with given intensity and in given volume [1]. This requirement is known as the homogeneity of the EM field. If EM filed is obtained by radiation of the elementary radiator, the field distribution and also its homogeneity depends on many factors, for example a frequency of radiation, a distance from the radiation source, homogeneity of the environment etc. It means that we can ensure homogeneity of the field only if EM field propagates in homogeneous isotropic and infinite environment [2].

Two possible solutions exist to generate the field with necessary requirements. Electromagnetic wave may be excited and propagated in the environment, which properties are similar to the infinite area. It is possible to ensure only in homogeneous environment without any reflections. Next, we may use special elements – equipment in which traveling wave is excited. The wave propagates in a special line, where no reflection creates and geometry is arranged to get the field with known value and distribution in every point of it. Such a special line is stripline, on which this paper is focused.

2. Infinite area with conducting floor

A behavior of the wave in infinite area with conductive plane is analyzed. Consider elementary source of EM field situated over the conductive floor in point O, as it shown in Fig. 1. The EM wave propagates to every point of the analyzed area directly and also by reflection from the conductive plane. Intensity of the direct wave may be obtained [3]:

$$E(r) = \frac{ILk^2 \sin\Theta}{8\pi^2 f\varepsilon r} e^{-jkr} \qquad (1)$$

where I is a feeding current of the elementary radiator, L its length, k is a wave number, f frequency of the current and ε permittivity of the environment. The length of direct wave trajectory in dependence of deflection x' is given by equation:

$$Z_a = \sqrt{(Z_P)^2 + (x')^2} \qquad (2)$$

and length of reflected wave trajectory is given by sum of two components Z_{b1} and Z_{b2}, given by:

$$Z_{b1} = \frac{X_R}{(2X_R + x')}\sqrt{(Z_P)^2 + (2.X_R + x')^2} \qquad (3)$$

$$Z_{b2} = \frac{(X_R + x')}{(2X_R + x')}\sqrt{(Z_P)^2 + (2X_R + x')^2} \qquad (4)$$

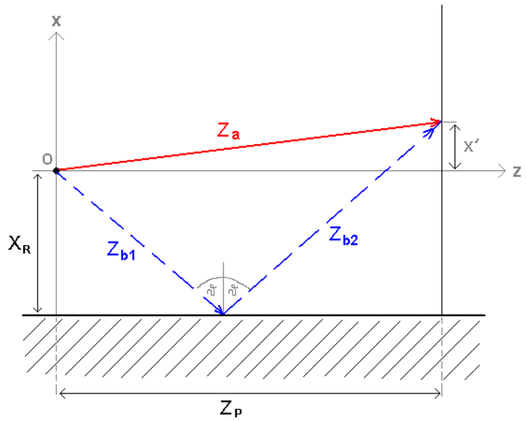

Fig. 1. Propagation of direct and reflected wave

Calculation of intensity of electric component of EM field in an observation point (distance from the radiator 10 m and 1.5 m over the ground plane) was performed at frequency 1GHz. According to (1), (2), (3), (4) a distribution of the intensity of electric field in dependence on deflection x' is calculated. Obtained distribution of the field, if only direct wave is considered, in proportion to its maximal value is shown in Fig. 2. The situation is completely different if also reflected wave is considered. Such a situation is shown in Fig. 3, where the distribution of electric component of the EM field is displayed in percents of the maximal value. As it can be seen in Fig. 3, the intensity of electric field varies from 1% to 100 % of maximal value. Such a distribution is inconvenient in term of field homogeneity. It means that only one reflection from the conductive plane (floor) can decline an experiment and disable to get homogeneous field. It is necessary to reduce possible reflections from the conductive plane using absorber materials to achieve proper field homogeneity [4].

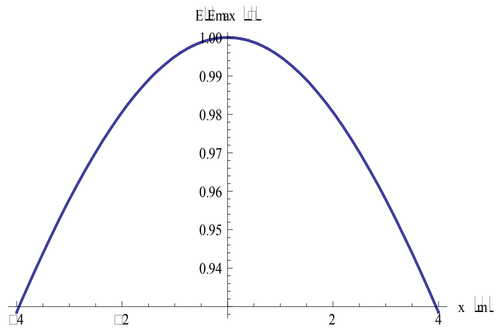

Fig. 2. Distribution of E for direct wave

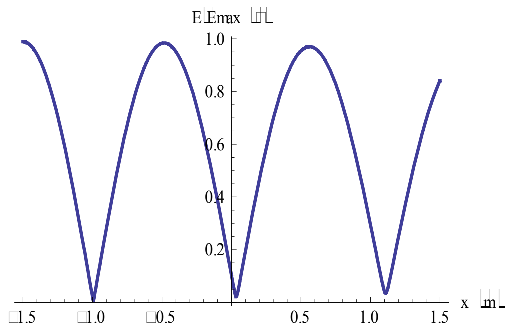

Fig. 3. Distribution of E for direct and reflected wave

3. Use of special elements to obtain homogeneous field – stripline

Another possibility how to obtain a homogeneous field for EMC purposes is using of a stripline. It consists of two strips with constant wave impedance. A traveling wave propagates through these strips. Electric field between the strips is homogenous and depends only on the distance between the strips and amplitude of the exciting rf voltage [5]. Mechanical arrangement of the stripline is shown in Fig. 4. The size of its parallel sheets is 30 x 30 cm and a distance between these strips also 30 cm. It is easy to determine characteristics of stripline in term of its field homogeneity or amplitude-frequency characteristics because it represents just a modification of two parallel plates. According to [6] the field homogeneity shell be fulfilled in 50 % of the stripline cross-section minimally. To use stripline for EMC purposes it is necessary to examine this fact for given stripline. A geometric arrangement of the stripline was modeled in FEKO, which is based on method of moments. Hence, it can calculate a current distribution along the strips and also the electric field distribution consequently. The result of the numerical simulation for frequency 50 MHz is shown in Fig. 5, where electric field is expressed in dB units. As it can be seen the entire area is practically homogenous except for marginal parts of the examined area.

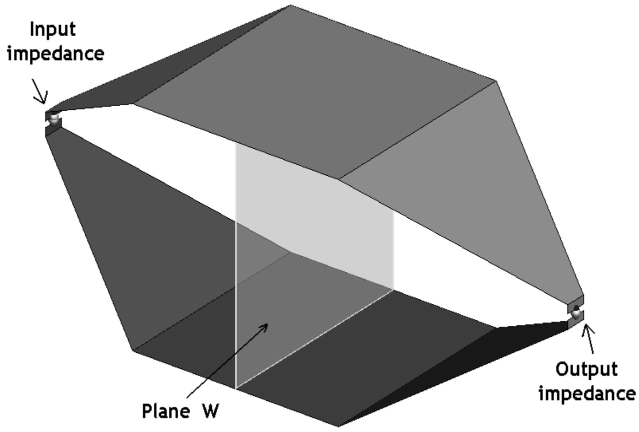

Fig. 4. Arrangement of stripline

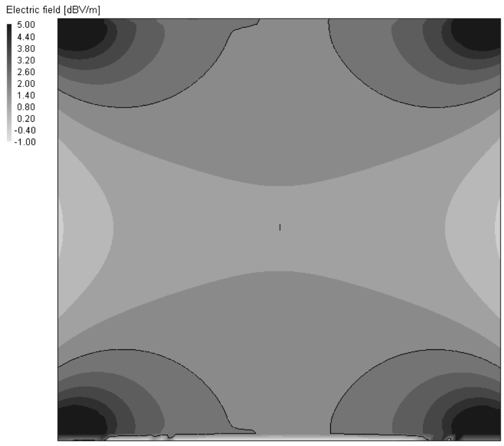

Fig. 5. Distribution of EM field in plane *W*

Another results shows in Fig. 6 the dependence of homogeneity rate on frequency for three parameters of a tolerance (±3 dB, ±2 dB and ±1 dB) and terminal impedances of stripline 200Ω. If a ±3dB tolerance were chosen (common tolerance for EMC measurements [1] the homogeneity is ensured for 94 % of area minimally. Also if more strict tolerance is chosen, for example at ± 1dB tolerance it is possible to use more than 71 % of area. Such results confirm the possibility of the stripline use in EMC area [6].

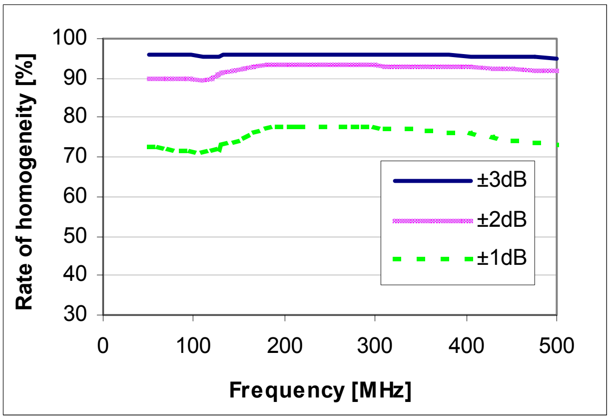

Fig. 6. Dependency of homogeneity rate in stripline on frequency

As it was mentioned the stripline consists of two parallel plates. Hence, aligned amplitude-frequency characteristic may be assumed according to [5]. The real characteristic was analyzed as a dependence of input as well as output impedance. This was expressed as a dependence of a variation of average value of the electric field E_{AVG} on frequency, shown in Fig. 7. Value of E_{AVG} was calculated as an arithmetic mean of electric field intensity values in $X \times Y$ points of cross-section W (see Fig. 4):

$$E_{AVG}(dB) = 20.\log\left(\frac{\frac{1}{X \cdot Y}\sum_{i=1}^{X}\sum_{j=1}^{Y} E_{ij}(V/m)}{1V/m}\right) \qquad (5)$$

As it can be seen in Fig. 7 the amplitude-frequency characteristic of the stripline is evidently dependent on frequency. In analyzed frequency range 50 MHz to 500 MHz an undulation of the characteristics are until 15 dB. Such an undulation is unexpected in regard to [5]. Therefore we tried to minimize the undulation of the characteristic by change of the input Z_{IN} and load (output) Z_{OUT} impedance. A dispersion of standard deviation of E_{AVG} is examined in dependence of various combinations of the impedances. This dependence is shown in Fig. 8

for some of impedance combinations. A goal of this analysis was to find such a values of Z_{IN} a Z_{OUT} that value of the standard deviation is minimal. There are suitable values of impedances that can minimize the undulation of amplitude-frequency characteristic, as it is shown in Fig. 8. In our case of Z_{IN} = 200Ω, if Z_{OUT} = 110Ω the minimal standard deviation of E_{AVG} is only 5 dB.

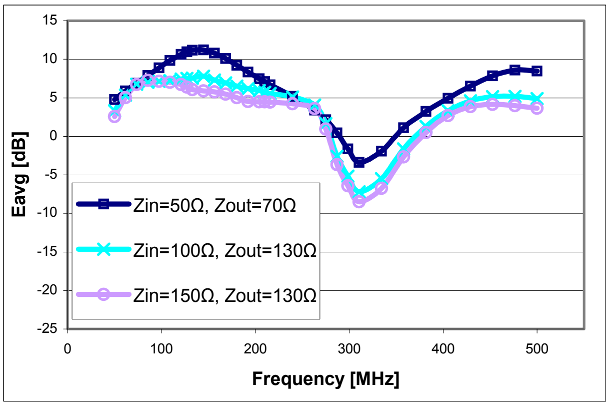

Fig. 7. Dependence of E_{AVG} on frequency with parameters Z_{IN} and Z_{OUT}

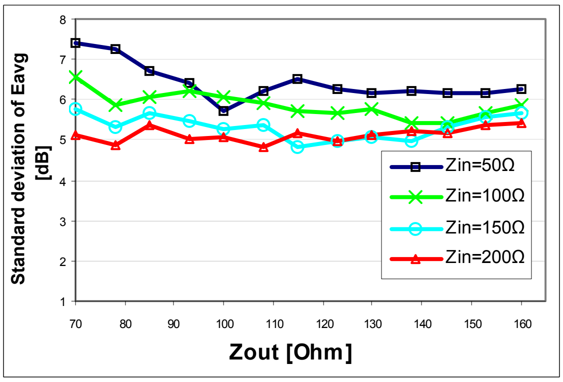

Fig. 8. Dependence of standard deviation of E_{AVG} on Z_{OUT} with parameter Z_{IN}

4. Conclusion

In this paper the problem of homogenous EM field generation for EMC purposes was analyzed. Obtained results concerning to field homogeneity in the stripline are evidently better than it is published in available EMC standards [6]. However, the amplitude-frequency characteristics of the stripline are not so straight as it was expected [5]. Using various combinations of input and output impedances, the undulation can be minimized only to 5dB in frequency range from 50 MHz to 500 MHz using input impedance Z_{IN} = 200Ω and output impedance Z_{OUT} = 110Ω.

Acknowledgement

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