Design of High Gain Wideband Quad-Ridged Horn Antenna for EMC Testing

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Abstract — This paper presents a design and simulation of high gain wideband quad-ridged horn antenna for Electromagnetic Compatibility (EMC) testing. The selected operating frequency range of the antenna is 1 GHz – 6 GHz, which is used for radiated emission and radiated immunity tests. The antenna is designed as a quad-ridged which is desired to be used in the horizontal and vertical polarization measurements simultaneously for emission testing. While determining the specification for the antenna gain, it has been considered requirements of test system in Vestel. The gain of the horn antenna currently used laboratories is not enough for the 3 meter testing. Therefore, 1 meter testing window method is used for radiated, radio-frequency, electromagnetic field immunity tests which are in the scope of EN61000-4-3 standard. Hence, the designed horn antenna gain is aimed to have approximately 14 dBi. CST Microwave Studio is used in the design of the horn antenna and simulation results. The simulation results show that antenna gain is approximately 14 dBi, also at least about 10 dB return loss (S11 and S22) separately for each port providing horizontal and vertical polarization and the interference of the ports is more than 25dB.

Index Terms — Antenna, EMC, Quad-Ridged Horn

I. INTRODUCTION

Electromagnetic Compatibility (EMC) is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. EMC studies the unintentional generation, propagation and reception of electromagnetic energy [1]. In order to achieve this, EMC is separated into two main issues. Emission issues are related to reduce the unwanted generation of electromagnetic signal from designed products, which can involve proper working of the other products. Immunity or susceptibility issues, in contrast, examine the correct operation of electrical devices, referred to as the victim, in electromagnetic disturbances.

The using of wideband horn antenna technologies is being common for EMC testing by the day. In order to cover the whole frequency range (1 GHz-6 GHz) in EMC testing, several narrowband antennas are used in general. To overcome the disadvantage of using narrowband antennas, development of an efficient and accurate broad-band antenna is necessary [2]. Some class wideband antennas are researched, such as; biconical antenna, log-periodical antenna, helical antenna and ridged horn antenna. For EMC test system, high gain, antenna factor, return loss (S11 and S22) are very important, so the ridged horn antenna is proper for this application. Also, 3 dB beam width is important parameter for radiated, radio-frequency, electromagnetic field immunity test because of creating constant field area. Log-periodical antennas have a problem about illuminating sixteen points field uniformity as described in EN 61000-4-3, Annex D.

Therefore, the antenna designed in this paper is suitable for practical EMC testing that requires high gain and wideband. Horn antenna manufacturers made several double-ridged horn antennas but quad-ridged horn is new for EMC testing.

II. METHODOLOGY

The high gain ridged horn antenna has accomplishment of widening the bandwidth, which is based on the design theory of the horn antenna. By loaded with metal ridges symmetrically, it can restrain the transmission of higher harmonic mode TE20, so ridged horn can widen the bandwidth in great degree [5]. Dual ridged antenna can achieve wideband performance, and the quad-ridged horn antenna can employ the dual polarization characteristics.

For aperture antennas such as horns, it is well known that maintaining constant beam width as a function of frequency implies that aperture fields must be tapered at the aperture edges with increasing frequency [6]. When the dimension of aperture enlarges some degree, the side lobe lever will rise and electricity performance else will be worse severely, as the field phase difference between edge and center of the aperture. So, usually the field phase difference is not greater than π/8. But, it depletes the gain performance.

Most of the prior works on quadruple-ridge horn antennas are designed by using exponential or elliptical for both ridges
and sidewall. On the other hand, many more profiles have previously been considered in the literature within the context of corrugated or smooth-wall horn designs [7]. There are four most promising functions for quad-ridge horns: exponential, elliptical, $x^p$, and $\tan^p$. The exponential profile is used for both the ridge and sidewall tapers of the horn antenna presented in this paper. It is defined as

$$x = A \left( c_1 e^{R_L z} + c_2 \right) + (1-A)(a_i + (a_0 - a_i) \frac{z}{L})$$

(1)

where:

$$c_1 = \frac{a_0 - a_i}{e^{R_L L} - 1}$$

(2)

$$c_2 = \frac{a_i e^{R_L} - a_0}{e^{R_L L} - 1}$$

(3)

III. DESIGN AND SIMULATION RESULTS

Once the design was completed, the designed horn antenna, which is depicted in Fig. 1, is simulated on CST Microwave Studio. The horn antenna length is 60.3 cm, and the radius of the horn antenna is 28.0 cm.

The simulation results are analyzed in terms of return loss ($S_{11}$ and $S_{22}$), mutual coupling ($S_{12}$), voltage standing wave ratio (VSWR), gain and radiation pattern.

The Fig. 2 refers to the $S_{11}$, $S_{22}$ and $S_{12}$ parameters which mean that $S_{11}$ and $S_{22}$ are return loss of the horn antenna and $S_{12}$ is the interference (mutual coupling) of the input ports. The return loss from 1 GHz to 6 GHz is below -10 dB, and it indicates almost 90% of signal transmitted through the antenna had been received with minimum loss. Interference of the ports ($S_{12}$) is maximum -27 dB, and two ports can be used simultaneously while testing. This is verified by the VSWR calculated during the simulation.

The Fig. 3 showed above that the amount of Voltage Standing Wave Ratio (VSWR) which is calculated by using the simulation program. The maximum value of VSWRs is 1.92, which is found to be less than 2. Consequently, it is considered fairly well for the signal transmission with lower attenuation.
Antenna gain is one of the most important properties for an EMC antenna because good matching cannot be used if the antenna does not radiate. Antenna gain refers to how good an antenna radiates or receives power. According to the simulation results, the gain of the designed antenna varies from 13.72 dB to 18.26 dB, which is sufficient for 3 meter EMC tests. As an example, the gain is 14.63 dB at 2 GHz for both ports of the horn antenna through simulation, as can be observed from the results in Fig 4. Besides, the efficiency of the designed antenna is sufficiently high, which is above 99 percent.

Finally, Fig. 5 shows the radiation patterns at 2 GHz for both ports of the horn antenna. Radiation pattern is the graphical representation of the electromagnetic power distribution in free space. As can be seen from above figure, magnitude of main lobe is 14.5 dBi while the side lobe is -24.9 dB. This difference means that much more power radiates through main lobe direction compared to other directions. Also, angular width of the horn antenna, which can be called as 3 dB beamwidth, is 33.5 degrees. This amount of beamwidth is useful and sufficient for EMC testing.
IV. CONCLUSIONS

According to the results above, the designed wideband quad-ridged horn antenna is suitable for EMC testing within given range 1-6 GHz. Return losses, interference of ports and VSWR ensure that the radiated signal is almost in equilibrium state that means transmitted signal or received signal of the horn antenna is almost perfect with lower attenuation. Also, higher gain shows that antenna radiates in the desired direction with higher radiated power. Antenna gain range changes from 13.72 dB to 18.26 dB within the overall antenna operation frequency band. That refers the gain target is achieved. Radiation pattern shows main lobe is larger than side lobes and back lobe. 3 dB beamwidth is greater than 30 degrees, and designed quad-ridged horn antenna is suitable for using Emission and Immunity testing.

REFERENCES