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Design & Modelling of Comb Generator for EMI/EMC Test Chamber Validation

[1]Laxmi Kc, [2]P. Siva Kumar, [3]Dr.S.Aruna

[1]Lecturer, Dept. of Electronics and Computer Engineering, Advanced College of Engineering and Management, Tribhuvan University, Kupondole, Lalitpur, Nepal

[2]Scientist - C, SAMEER Electromagnetics Environmental Effects (E3), Vishakhapatnam, Andhra Pradesh, India

[3]Associate Professor, Dept. of Electronics and Communication Engineering, Andhra University, College of Engineering (A), Visakhapatnam, Andhra Pradesh, India

***Abstract* - Comb generator circuit is a broadband signal source for quick EMI radiated emissions test site verifications. Its output spans the frequency range of 30 MHz to 1 GHz in 30 MHz steps. The Comb generator produces spectra at frequency based on crystal's oscillatory frequency. An electronic circuit which produces a train of impulses is fed to the dipole antenna for radiating the energy. In a typical Radiated emission test environment, the receiving antenna picks up these spectra to check the RF level emitted by the Comb generator to verify the RF setup and also to ensure the repeatability of the testing over a period of time, carried inside the test chamber. In this paper, the electronic circuit which produces the train of impulses is designed in a Multisim software tool and its pulse train is imported to the FEKO 3D EM modeling tool and fed to a dipole antenna so as to observe the spectra at a distance governed by the standards.**

Keywords: EMI (Electromagnetic Interference), EMC (Electromagnetic Compatibility).

I. INTRODUCTION

Comb generator is used as a reference signal source before commencing each emissions test. It is used to test and verify the radiated emission test as well as to verify the test chamber.

Comb generator circuit is designed which generates a very short, fast pulse with sharp rise time and sharp fall time. This signal is imported to 3D electromagnetic modelling software FEKO and fed to a radiating dipole antenna and corresponding nearfield response is observed [1]. The resulting near field response was further imported to the MATLAB software and the Fast Fourier transform was computed so as to observe spikes which ensure that the designed Comb Generator model works properly if modeled in real life environment. Various Comb generators are available commercially these days.

Some of them are taken as basis of this research. Those are listed below:

- Comb Generator Emitters (CGEs) are designed and manufactured by York EMC Services and sold globally for the verification of test and measurement setups and to ensure validity of EMC and RF laboratory tests. [2]
- A low-cost Comb generator from applied electromagnetic technology (AET) for approximately $350. These Generators are available in various fundamental comb frequencies from 1.8MHz to 200MHz and have useful harmonic frequencies well into the GHz. For general purpose use their 10 MHz model works well and produces harmonics from 10 to over 1000 MHz .A Small USB port is used for power. [3]
- EMC test laboratories calibrate their entire radiated emissions testing sites and instruments every year. Calibrating of testing sites is complex and involves tedious procedures. Although calibrating is done every year, it does not prevent failure of the used testing instrumentation and accessories in between calibration periods. To perform the full calibration procedure each time is not practical. Malfunctioning equipment used during EMC testing results in bad readings and faulty data. A Comb generator can avoid these situations by monitoring a few frequencies on its broadband radiated output regularly. [4]

a) Comb Generator design

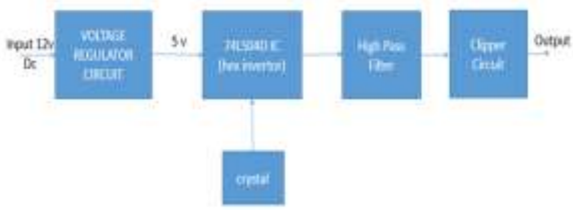

Figure 1: Block diagram representation of Comb generator circuit

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The corresponding model of Comb generator was designed in Multisim software as shown below: [5]

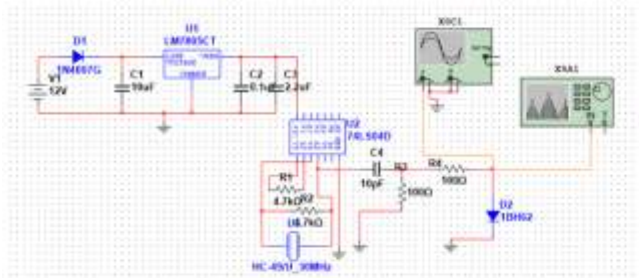

Figure 2: Comb generator circuit design in Multisim software

b) Dipole Antenna Design

The design of dipole antenna is done in CADFEKO, a 3D Electromagnetic simulation software.[6]The antenna model specifications are as follows:

Operating frequency (f):150 MHz

Wavelength (λ): C_0/f

Length: λ/2

Range of frequency: 30 MHz to 1GHz

Voltage source: 6V

II. SIMUALTION

a) Simulation of Comb Generator model

Following figures illustrate the simulation Output as observed from output of Hex inverter, high pass filter and Clipper circuit.

The later one represents the simulation output of the Comb generator observed in the Spectrum analyzer.

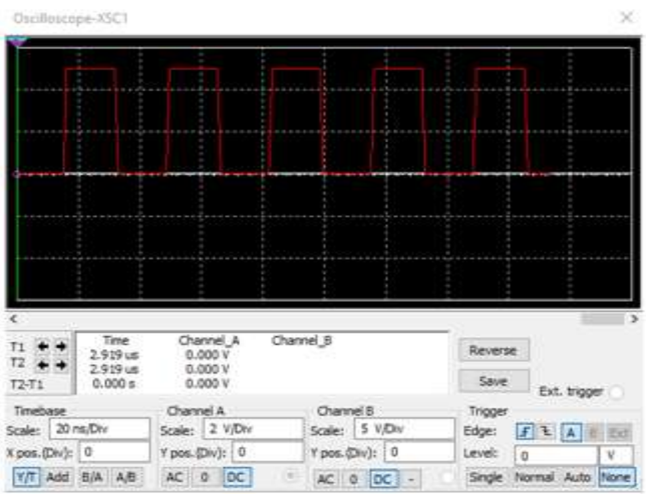

Figure 3: Simulation output of the 74LS04D IC

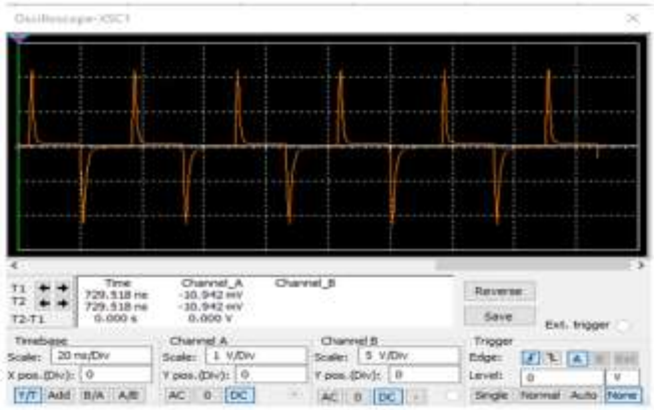

Figure 4: Simulation output of the HPF connected with 74LS04D IC

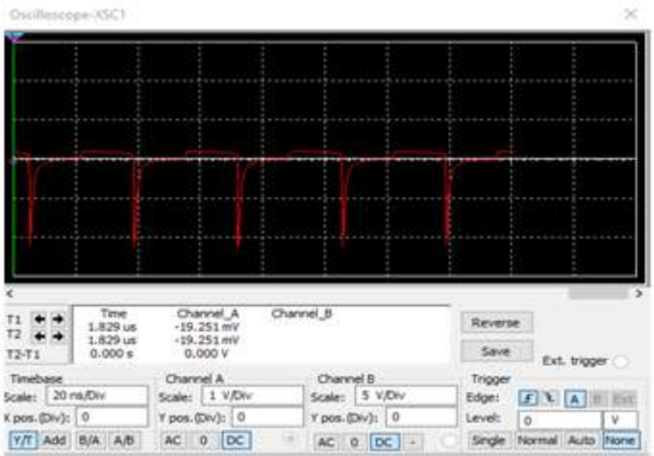

Figure 5: Simulation output from the clipper circuit

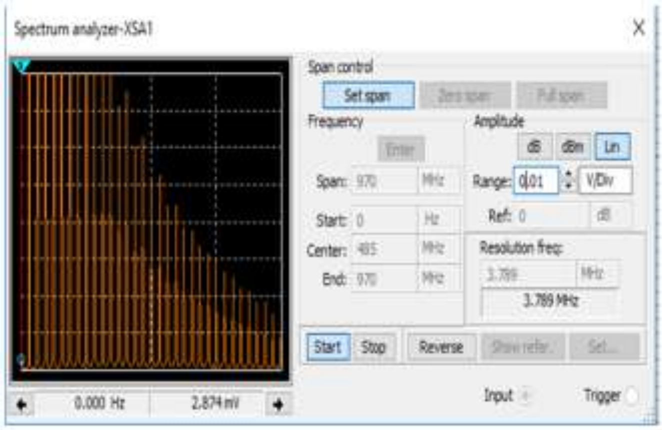

Figure 1: Simulation output as observe from Spectrum Analyzer

b) Simulation of dipole antenna model

Various output characteristics of the designed dipole antenna model as observed from POSTFEKO, 3D Electromagnetic simulation software.

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S-Parameters:

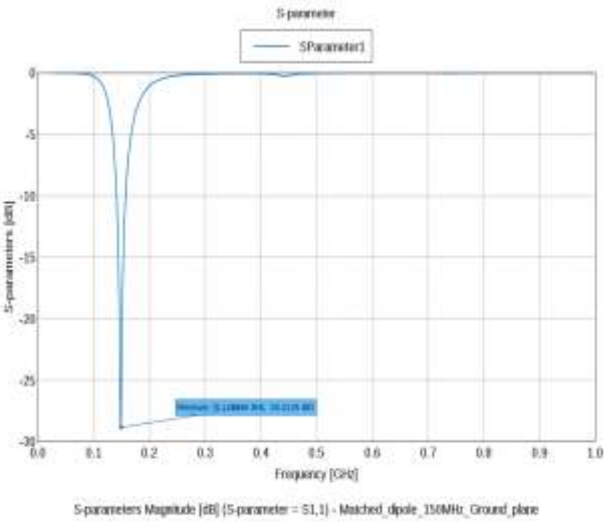

Figure 2: S11-parameter response of dipole antenna

Near field:

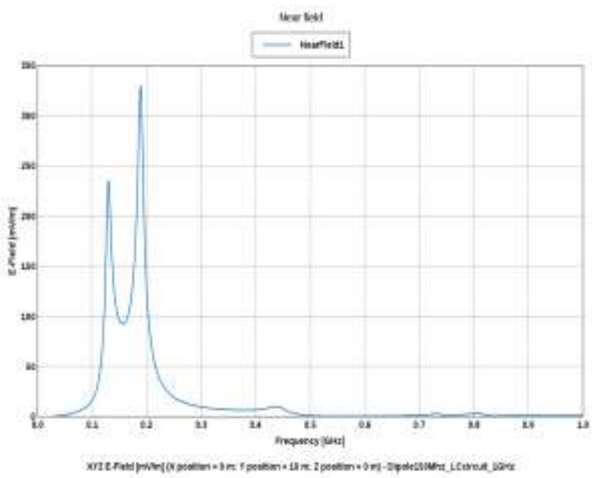

Figure 3: Near field response of dipole antenna

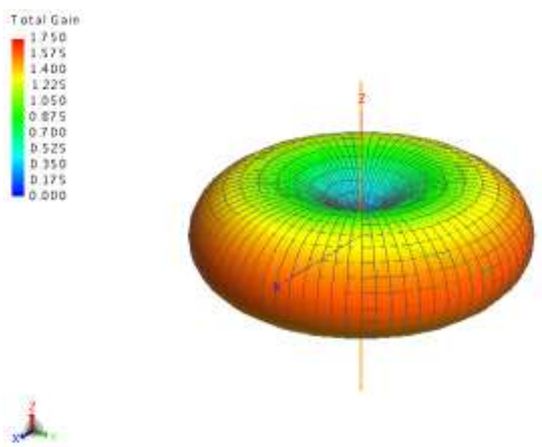

Figure 4: 3D view of radiation pattern

III. RESULTS

Theoretical calculations:

Theoretical calculation to compute E-field at 10m as per CISPER 11 requirement:

As per our project requirement we have taken:

Power supply (V) = 6V

Resistance (R) = 50Ω

Transmitted power (P_t) = V*I

$P = V^2/R$

$= 6^2/50\Omega$

= 0.72W = 720mW

P_t (dBm) = 10*log (720mW) = +28.57 dBm

For Radiated Power calculation we have from equation 1.

$$\mathbf{P_R} = \frac{P_T G_T G_R C^2}{(4\pi R f)^2} \text{...........equation 1}$$

Here we take receiver antenna gain (G_R) as 1 and Receiver antenna distance as 10m. For continuous values of frequency and transmitter antenna gain and corresponding Radiated Power, the frequency vs. gain plot was extracted from the Post Feko analysis of far field in .dat file and converted to .txt file which was then imported to MATLAB so as to calculate the radiated power accordingly as per the formula given above. [7]

The electric field intensity is given by,

$$E0 = \frac{\sqrt{30 * P_T * G_T}}{R}\,[V/m] \text{.........equation 2}$$

Where R = 10m

E0 (dBμV) = 20* log (E0*1*10^6)

Time Domain Analysis

For time domain analysis sample spikes of Comb generator from Multisim simulations (nearly 4 to 10 spikes) is imported to CADFEKO and then is fed to the designed antenna port. The Near field response and the spectrum distribution is observed.

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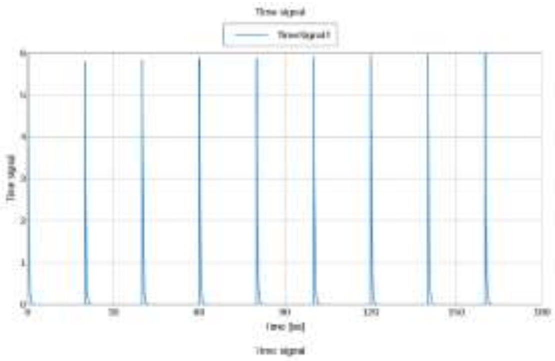

Figure 5: Spikes signal from Comb generator simulation imported to CADFEKO

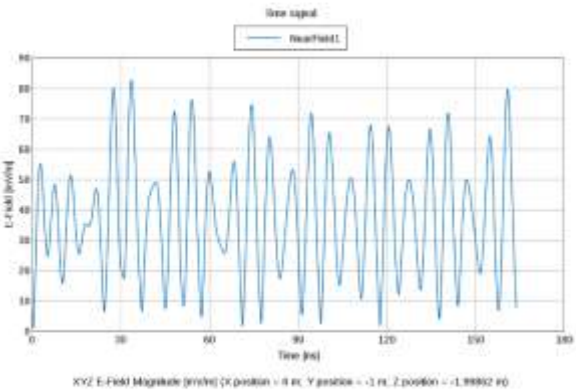

Figure 6: Near field response of train of pulses

FFT computation is done using MATLAB software and following output is observed where we can view the spike response. This gives the reasonable assurance that our designed Comb generator model performs well, when developed in real life environment.

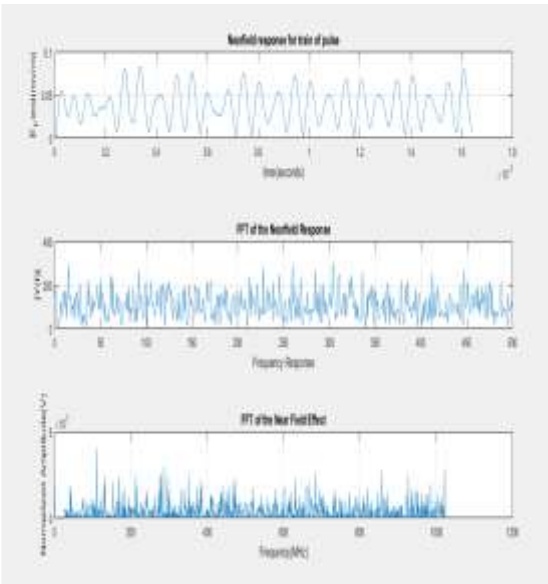

Figure 7: FFT analysis of the near field response of the pulse train

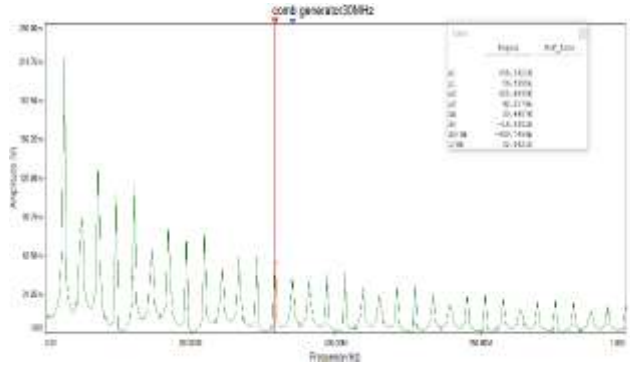

Figure 8: Output of Comb generator model

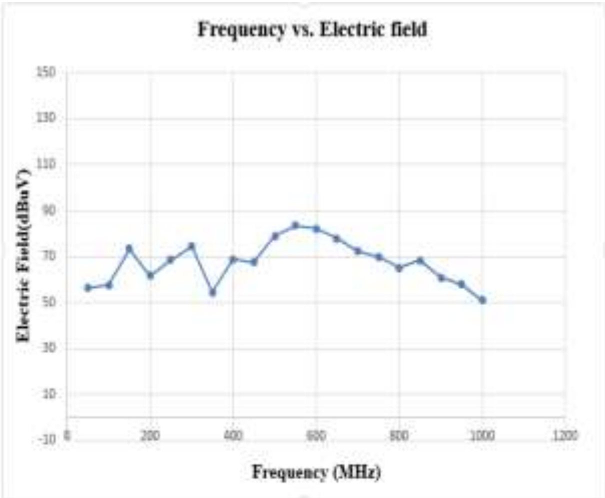

Figure 9: Frequency Vs Electric field plot of designed Comb generator

IV. CONCLUSION

Here radiating antenna was designed and its radiation pattern, near field response, far field and S-parameters was observed. In order to carry out time signal analysis of the designed antenna the spikes from Comb generator circuit in NI Multisim was extracted to the FEKO Electromagnetic simulation software and corresponding near field response was observed. The near field response was further exported to MATLAB so as to compute Fast Fourier Transform to view the spectral output. Finally the spectral output was compared with commercially available Comb generator model.

The comparison assures that the designed Comb generator model and the commercial ones are well matched. It also confirms that if the designed model along with radiating antenna is placed in the test site before commencing any radiated emission test can resemble similar output as that of the commercial ones. Thus, it can verify the equipment in the test chamber are in proper working order and insures the radiated emissions test carried out the test chamber are also correct.

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Further, the Comb generator model designed is simple one and probably the least expensive too. It is more accurate as it uses the digital IC 74LS04D to get the square wave output which follows the simple logic of Not gate only.

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