Implementation of Radiated emission and Radiated susceptibility of pressure sensor.

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***Abstract*- The measurement of emi/emc of equipments and devices has become a prime importance in the field of Communication due to the radio frequency interference. Radiations are classified as radiated, conducted emissions and radiated, conducted susceptibility. In this paper we would like to give prime importance to measure the radiated emission and radiated susceptibility of pressure sensor, an simple measuring mathematical model with some ideal assumptions, electric fields and magnetic fields are measured, for different Frequencies and for different currents. The radiations due to differential-mode current and due to common-mode currents of pressure sensor are measured. The analysis are implemented using MATLAB.**

***Keywords*- EMI/EMC, RFI, OATS, Common-mode, Radiated emission, Radiated susceptibility, Differential-mode current, Dipole, Loop, Gain, Power spectral density**

I. Introduction

The Importance of testing the Electronic devices and Electronic equipments for Radiation Emission and Radiated Susceptibility [3] is to ascertain compliance with regulations and standards [1]. For the effective performance of the pressure sensor one has to minimize the RE and RS of the device. RE is the electromagnetic energy propagated through space, measure is used to test the ability to operate in the presence of internal interference and RS is to test the ability of the device to operate in the presence of external interference. There are many techniques available like Open-Area Test Site (OATS), Semi-Anechoic Chamber (SAC), Gigahertz Transverse Electromagnetic cell (GTEM), Mode Stirred Chamber (MSC).When the Device is susceptible to electromagnetic interference , it can cause the device to operate in an undesired manner.

II. OATS

The OATS[2][8] technique is opted due to the presence of electromagnetic ambient environment, The pressure sensor is placed and measurements are made at a distance of 3m, the height of the antenna[7] ranges between 1 to 4 m, with these we can record maximum emissions, Due to worn, broken connectors, cables ,antenna factor and poor ground planes the emissions were ranging between 20 to 30 dB were major factors and some minor factors are involved that is atmospheric conditions ,termination of the ground screen. An Dipole antenna is used with a 3-meter separation, mutual impedance terms are added to account for lower frequency near-field effects between the antennas. We know that, Friis Transmission formulae[4].

$$P_r / p_t = (\lambda / 4\pi R)^2 G_{ot} G_{or}$$

Where,
Pr = Received Power ,
Pt = Transmitted power,
λ = Wave length,
R = Distance between transmitting and receiving antenna,
G_{ot} = Gain of transmitting antenna,
G_{or} = Gain of receiving antenna.

Since the Radiated power is directly proportional to the square of the field strength, the received electric field is proportional to the wavelength or inversely proportional to the frequency f according to -20log10f.

III. GENERAL BLOCK DIAGRAM

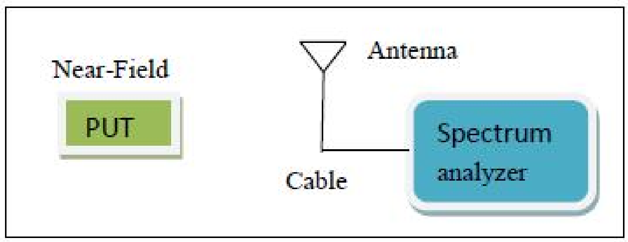

Figure 01: Block Diagram.

It is permissible to take measurements at a different distance, Here we have performed standard measurements at 10m away from PUT and referenced to 3m or separate the antenna and PUT by 3m, Note that antenna is not placed in the Near-Field which is $\lambda/2\pi$ away from PUT[3].

IV. ASSUMPTIONS

- Measurements are made in the far fields that allows the PUT to be modeled as a resonant dipole.
- All dipole are to be in phase.
- Conductor lengths L are short and those of the measurement points are parallel
- Current distribution is constant

V. PROCEDURE AND DESIGN

Performing radiated emissions measurements is not simple, there is complexity of the ambient environment (TV, FM, Cellular radio), which could interfere with the emissions from the PUT. Electromagnetic measurement system are used to measure power densities or power spectral densities (mW/m2 or μW/m2), plane waves, power densities, electric field intensity (E), magnetic field intensity(H) are related with respect to free space[9].

$$E = \sqrt{120\,\pi\,P}$$

Where,
E = rms value of field strength v/m,
P = power density w/m2,
120 = impedance of free space Ω.

Power density (PD) is related to the electric field intensity and magnetic field intensity is,

$$P_D = (E^2 / 377\,\Omega) \text{ [or] } (377\,\Omega\,H^2)$$

The power density equation is given by

$$P_D = P_T / 4\,\pi\,R^2$$

Where, P_T = transmitted power in watts.

The sources of RF interference are many such as broadcast stations, automobile ignition system, galactic noise and lightning. To calculate the radiation above the ground plane the concept of radiation resistance is used.

$$I = (2K+1)\lambda/4$$

Where, k=0,1,2,3,4,……

For open or short circuited, radiation resistance is $30\beta^2 b^2$ where b is twice the height of the cable above a ground plane, and radiated power is $30\beta^2 b^2 I^2$ where I is current flow either measured or calculated.

The magnetic field and electric field

$$H = \sqrt{PK}\;/\;4\,\pi\,R^2\,Z_W$$

and

$$E = \sqrt{Z_w PK}\;/\;4\,\pi\,R^2$$

Where,
P = radiated power,
Z_w= wave impedance,
k= directivity (1.5),
R= distance in meters, with respect to free space Z_w=377 Ω
.
E field radiated may be obtained from $E = H \times Z_w$

A Radiated emission due to Differential-mode current

The Differential mode currents[3][6] are equal in magnitude and in opposite direction, the differential-mode current and common mode current are capable to produce significant radiated emission, model as dipole , We will determine the radiated fields at a point that is perpendicular to the line conductors and in the plane containing them

$I_2 = -I_1$, $I_1 = I_D$, $I_2 = -I_D$.

Maximum will occur at $\varphi = 0^0, 180^0$. The measurement point is at a distance d from the midpoint of the line, and is in the far-field of the line of 1m length , 100 μV/m at 30MHz differential-mode current, for waveform of clock(50% duty cycle) then with a loop area A.

We know that,

$$M = jI\beta_0\,\eta_0 / 4\pi$$
$$M = j\,2\pi \times 10^{-7} f\,L$$
$$\beta_0 = 2\pi / \lambda$$
$$f / v_0 = 1 / \lambda_0$$
$$E_\theta = M\,e^{-jr\beta 0}\left(I_1 e^{js\beta 0/2cos\phi} + I_2 e^{-js\beta 0/2cos\phi}\right) / r$$

On substitution,

$$E_{D,max} = j\,2\pi 10^{-7} f\,I_D\,L\;\; e^{-jd\beta 0}\left(e^{js\beta 0/2} - e^{-js\beta 0/2}\right) / d$$
$$E_{D,max} = -4\pi 10^{-7} f\,I_D\,L\;\; e^{-jd\beta 0}\sin(0.5\beta_0\,s\,)\;/\;d$$
$$\sin(0.5\beta_0\,s\,) = 0.5\beta_0\,s = 1.05 \times 10^{-8}\,s\,f$$

Therefore,

$$E_{D,max} = 1.316 \times 10^{-14} f^2\,I_D\,L\,S / d$$

Loop area A = L S,

Then,

$$E_{D,max} / I_D = K\,f^2\,A$$

For d=3m, $K = 4.39 \times 10^{-15}$

Maximum radiated fields vary with square of the frequency, loop area, current level, thus to minimize the radiation we required to reduce current level and loop area.

B Radiated emission due to Common-mode current

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The common mode currents[5][6] are equal in magnitude and in same direction, the differential-mode current and common-mode current are capable to produce significant radiated emission, model as dipole , We will determine the radiated fields at a point that is perpendicular to the line conductors and in the plane containing them.

$I_2 = I_1$, $I_1 = I_C$, $I_2 = I_C$.

Thus,

$E_{C,max} = j\,2\pi 10^{-7} f\, I_C\, L\ e^{-jd\beta 0}\left(e^{js\beta 0/2} + e^{-js\beta 0/2}\right) / d$

$E_{C,max} = 4\pi 10^{-7} f\, I_C\, L\ e^{-jd\beta 0} \cos(0.5\beta_0\, s) / d$

$\cos(0.5\beta_0\, s) = 1$

$E_{C,max} = 1.257 \times 10^{-6} f\, I_C\, L / d$

Replace N wires carrying current I_C with one wire carrying current NI_C, the current in the probe measures the total current as I_P

Thus,

$E_{C,max} = 1.257 \times 10^{-6} f\, I_P\, L / d$

Loop area $A = L\,S$

Then,

$E_{C,max} / I_C = K\,f\,L$

For d=3m, $K = 4.19 \times 10^{-7}$

Maximum radiated fields vary with the frequency, length, current level, thus to minimize the radiation we required to reduce current level and length.

C Radiated susceptibility

The Pressure sensor under test is placed in a TEM cell to provide an accurate and uniform field The wires are separated by a distance S , Load resistance R_s and R_L, located at x = 0 and x = L respectively. We have to determine the V_s and V_L for a given incident electric field E_i, The electric field is transverse [3] and that of the magnetic field is normal.

i.e., $E_t^i = E_y^i$

and $H_t^i = H_z^i$

Thus the inductance and capacitance is given by

$L_{inductance} = (\mu_0 / \pi) \ln(S/r)$

$C_{capacitance} = \pi \epsilon_0 \epsilon_r / \ln(S/r)$

From faraday's law

The magnetic field component $\boldsymbol{H_n^i}$ induces emf

i.e., emf $= j\omega \int_s^0 B_n^i\, ds$

emf $= j\omega\mu_0 \int_s^0 H_n^i\, ds$

emf $= j\omega\mu_0 \Delta x \int_{y=0}^{s} H_n^i\, dy$

For Δx section

$V_s(x) = j\omega\mu_0 \int_{y=0}^{s} H_n^i\, dy$

And

$I_s(x) = j\omega c \int_{y=0}^{s} E_t^i\, dy$

For the radiated power located at a distance d away and of gain G then

$E^i = \sqrt{60 P_T}\, G / d$

And

$H^i = E^i / \eta_0$

For d=3 to 3000m and power is 1mw to 1kW respectively and absolute gain 1.64, $\eta_0 = 120\pi$, E_{max}^i and H_{max}^i are calculated.

VI. RESULTS

A Radiations due to differential-mode current

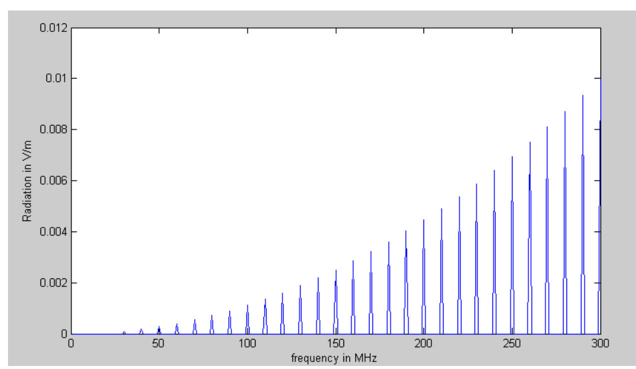

Figure 02: Radiation of Electric field intensity due to dipole(20mA)

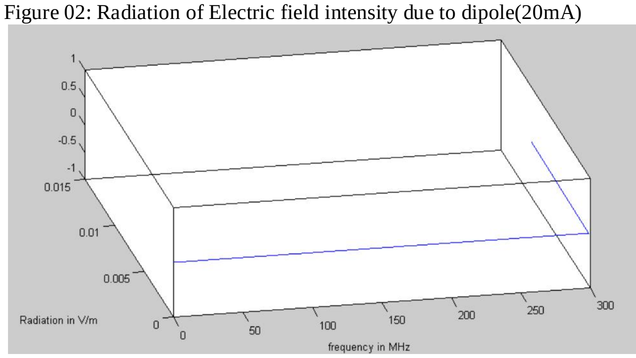

Figure 03: Radiation of Electric field intensity due to loop(20mA)

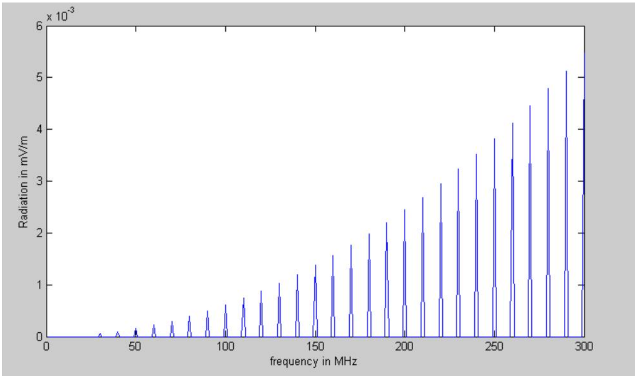

Figure 04: Radiation of Electric field intensity due to dipole (10mA)

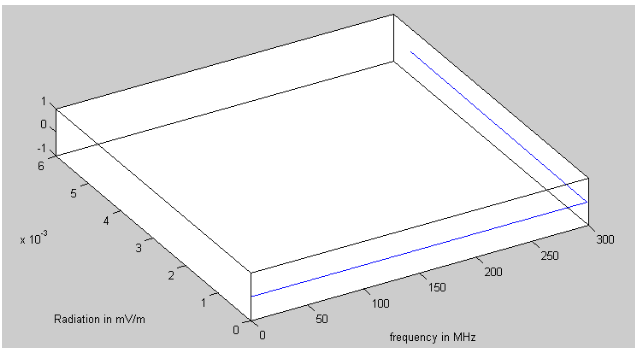

Figure 05: Radiation of Electric field intensity due to loop(10mA)

B Radiations due to Common-mode current

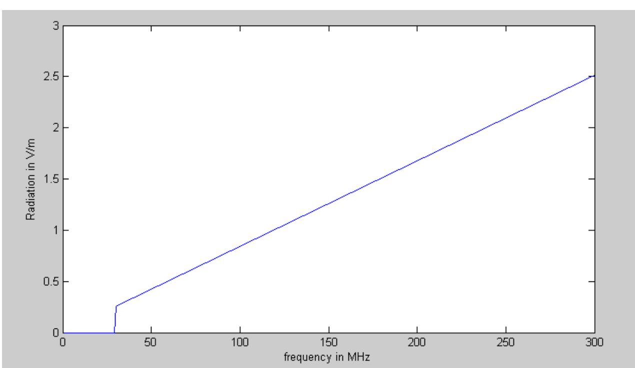

Figure 06 Radiation of Electric field intensity due to dipole(20mA)

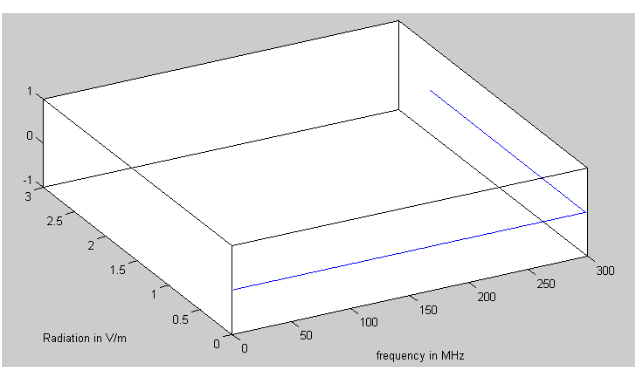

Figure 07: Radiation of Electric field intensity due to loop (20mA)

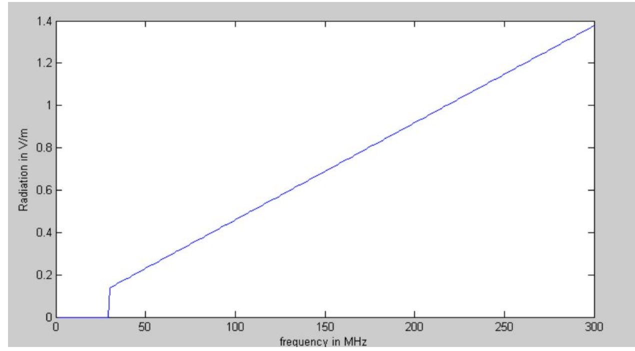

Figure 08: Radiation of Electric field intensity due to dipole(10mA)

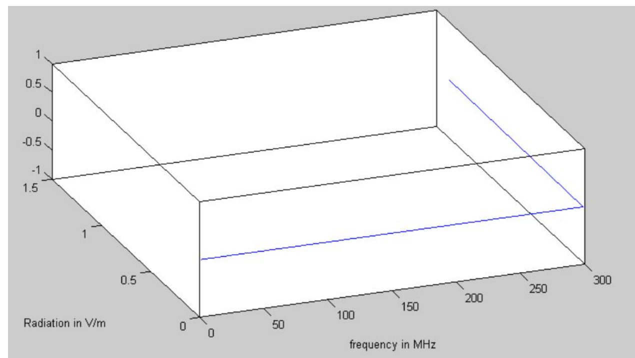

Figure 09: Radiation of Electric field intensity due to dipole(10mA)

C Radiations due to Susceptibility

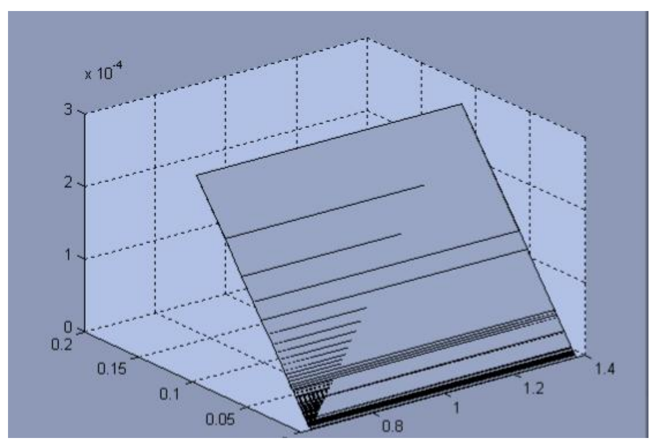

Figure 10: Radiation of Electric field and Current

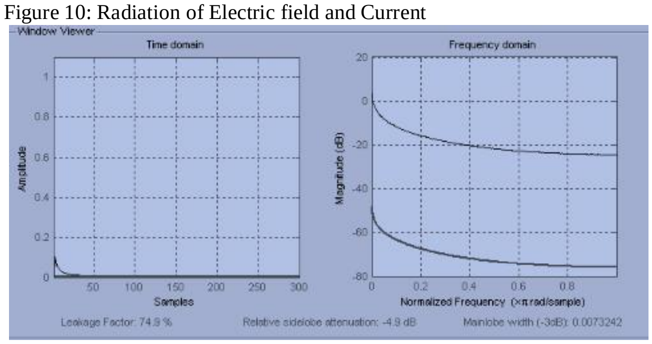

Figure 11: Time and Frequency analysis of Electric field and Current

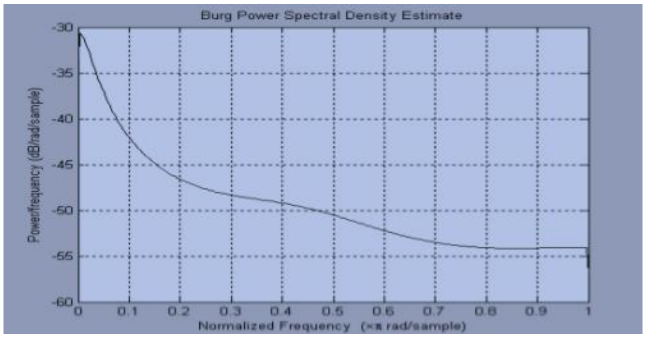

Figure 12: PSD of Electric field

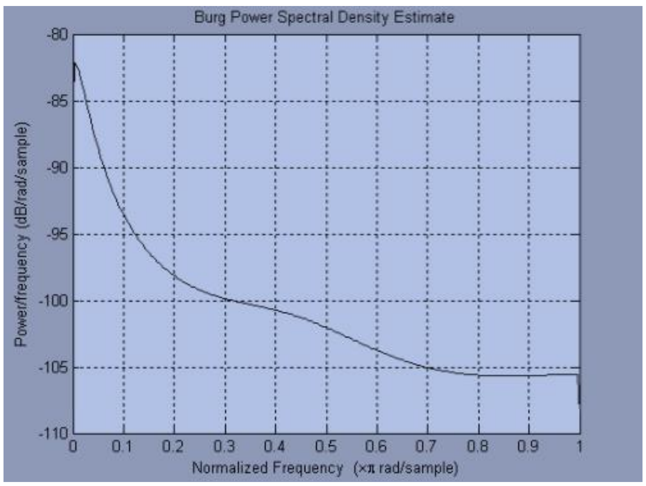

Figure 13: PSD of Current

VII. CONCLUSION

Based on the results obtained we can see that as the frequency increases the radiations are increasing , to limit the radiations we required to design and HPF as per our requirements.

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Reference

[1] Federal Communications Commission. FCC Rules and Regulations part 15.Washington DC,FCC,2003

[2] Montrose, Mark and Nakauchi , Edward. Testing for EMC Compliance Approaches and Techniques. New York, IEEE press/john wiley and sons,Inc.,2004

[3] Paul, Clayton. Introduction to Electromagnetic Compatibility. New York john wiley and sons,Inc.,1992

[4] C R Paul and S A Nasar. Introduction to Electromagnetic Fields, 2nd ed., McGrawHill, New York, 1987.

[5] C R Paul and D R Bush, Radiated emissions from common-mode currents, Proc.1987 IEEE Int.Symp. Electromagnetic Compatibility, Atlanta,1987

[6] C R Paul , A comparison of the common-mode and differential-mode currents in Radiated emissions, IEEE Transactions Electromagnetic Compatibility. 31,189-193, 1989.

[7] Dola Sanjay S, S Varadarajan. AMSA as EMI/EMC sensor, Journal of innovation in electronics and communication, Vol.2(2),Jan-2012, 126-129 @ ISSN 2249-9946.Guru Nanak Publications

[8] T J Dvorak, Fields at a radiation measuring site, Proc.1988 IEEE Int.Symp. Electromagnetic Compatibility, Seattle, WA,1988.

[9] Dola Sanjay S, S Varadarajan. A Moment Method Solution for Spherical Structures used in Shielding Electronic Components, Applied mathematical sciences, Vol.6, 2012, no 7,333-341, Hikari Ltd, ISSN 1312-885X.