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Evaluation of Electric and Magnetic Fields Distribution and SAR with the Help of Intensity of Time Averaged Electromagnetic Wave

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Abstract: ***Potential Risk From Exposure to EMF have been explored for a long time .Different research endeavours have tended to security rules to Protect the Human body from EM penetration. The study of Electromagnetic fields and non-ionizing effects on human body is a very useful due to possible health effects that these many electromagnetic field can cause in humans. At the point when an Electric or Magnetic field Penetrates into body ,it is weakened and some portion of is assimilated inside the body tissue. Impact of EM on Human body relies upon force of Electromagnetic field and distance of EM source to human body.Specific Absorption Rate (SAR) is a parameter used to estimate amount of energy absorbed by a human body.SAR Is depends on Frequency and Intensity of Electromagnetic wave. Broad Research is already done on Reduction of SAR in the case over usage of Mobile phones units but SAR minimization in Medical Application like MRI is always a challenge to Researchers. The advantages of Magnetic Resonance imaging (MRI) have made it the Radiological Method of Choice for an extraordinary Number of analytic Procedures,but the drawback is options are limited in the case of patients who are having implantable devices,The SAR Value is increased due to implantable devices because of temperature Rise. Leakage Magnetic field from the diagnosis instruments leads to hazardous to medical Personnel. this Paper is a initiated work on Study of SAR considering the intensity of electromagnetic wave and assessment of SAR in case of leakage of Magnetic field leakage.***

Index Terms-EMF,MRI, Leakage Magnetic Field, Specific Absorption Rate (SAR)

I. INTRODUCTION

The impact of non ionizing Radiation on human health has turned out to be one of the Common territory of enthusiasm for both Technical and clinical Researcher because of Rapid development in the utilization of biomedical imaging devices all through the world. A human body is a homogeneous, lossy dielectric, whose naturally visible electrical Properties are depicted by its unpredictable Permittivity. At the point when an electric or attractive field enters in to the body, it is constricted by and part of it is ingested inside the body.

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The power of interior fields relies upon the Parameters of the outside fields. The Dose rate at which RF electromagnetic vitality bestowed into human body parts is Measured as far as SAR.Weak fields could affect human health. The WHO expert agency for Research on cancer has classified both it is characterized as rate at which an individual assimilates EM vitality per unit mass.SAR is utilized to evaluate Biological Adverse impacts. Low frequency and radio frequency fields as possible Carcinogenic to human.

II. SAR

SAR is a Vital Parameter for safety concerns to human exposure analysis.SAR Measures Rate of the amount of absorption of energy when there is an exposure of the human body to the radio frequency.

$$SAR=\frac{\sigma|E|^2}{\rho}\ldots\ldots\ldots\ldots(1)$$

|E|=Magnitude of Electric field
σ= Conductivity of tissue
ρ=Mass density of tissue
It is important to decide RF energy absorbed by the body as far as explicit assimilation Rate(SAR).it Provides a proportion of Electromagnetic radiation that is absorbed by any organic article. As indicated by global Electro specialized Commission (IEC),The SAR Value ought to be restricted to 3.2w/kg for head and 4.0w/kg for body applications for length of 6 minutes. So also The Food and Drug Administration of the United states necessitates that the SAR ought to be under 4w/kg when arrived at the midpoint of over whole body for 15 minutes and 3 w/kg for the head for 10 minutes..SAR is calculated by using three Parameters. absorbed power by coil and total incident RF Power and body weight

$$SAR=\frac{1}{Weight}(P_{total}-P_{coil})\ldots\ldots\ldots\ldots(2)$$

P_{total}= Total Incident Power
P_{COIL} =Power Received by Coil
Specific Absorption Rate Can also be defined as the Energy absorbed by Patient Tissue per second per kg.it is calculated based on the power absorbed by a patient divided by Patient Weight.

$$P_{object}=P_{total}-P_{COIL}\ldots\ldots\ldots\ldots(3)$$

III. MRI

A MRI Scanner depends on a large electromagnet which Produces The Main static field. The Magnet is the Main factor in deciding the expense and abilities of the MRI System. X-ray Differs from other imaging methods utilizes non ionizing

Radiation depending on static and gradually changing magnetic field and electromagnetic energy to Provide delicate The Main Characteristic of the magnet is the quality of the magnetic field delivered with in the Patient. magnetic field is created either by utilizing a ferro attractive material or by passing an electrical flow through wire. Most MRI machines utilized the electrical current and flow as a wellspring of magnetic field.MRI produces pictures for Medical analyses of illnesses utilizing a static magnetic field and time changing electromagnetic field created by a radio recurrence transmit loop, these time-variation electromagnetic fields initiate electric flows and voltages in the conductive human body when situated inside a MRI scanner .RF Pulses applied during MR Scan Transfer energy into human body.to ensure Patient safety, The Maximum Rise in tissue needs to be limited .How ever ,The Temperature increases with in human body is difficult to measure and even more Challenging to predict due to variety of unknown Physiological Parameters .Three Kinds of Magnetic Fields are produced in a MRI Device, Which are utilized to Capture the Image of Internal Body Parts. Three Types incorporate the Main Magnetic Field(B0),Radio Frequency Field(B1)and Gradient field(B2).The Main Magnet is the Most Crucial in planning of n MRI Device. The Accuracy of the picture relies upon the quality of fundamental Magnetic field. A Strong and uniform Magnetic Field (B0) is required to Capture the great pictures. Some Studies demonstrated genetic effects in cells after exposure to an MRI Scan.

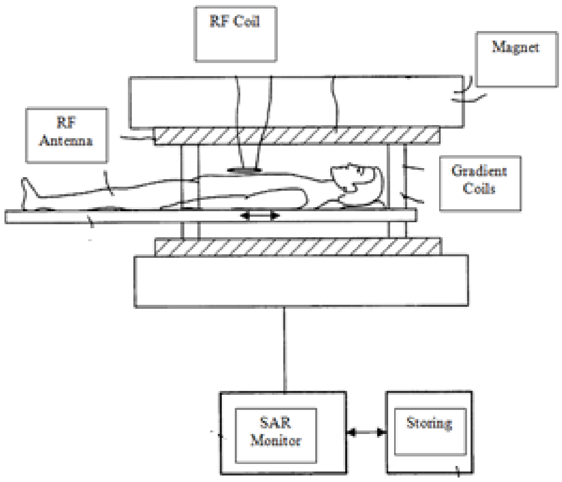


Figure1: MRI Scanning System

IV. FRAMEWORK

The Thing Makes the MRI Different from other Diagnostic Devices is it is mixture of static low frequency and radio frequency Magnetic field. The Range of Static Magnetic field is 3 T. Low Frequency Range is Several milli Tesla and Radio Frequency field has Micro Tesla range. Extremely high static Magnetic Fields above 2T may cause Various Biological effects .The SMF is always ON regardless of whether the scanner is active or not, it is known that Strong Static Magnetic Field can cause un pleasant sensations. These have been associated with induced electric fields inside the body due to movement in the SMF. The static field is designed to be constant. A typical MRI exam includes several imaging sequences of varying length and intensity to Produce several different type of images. The SAR Value depends on length of the exam.For Patients with Implantable devices, There is a significant Clinical need to undergo an MRI Scan. How ever, due to safety concern, patients having Metallic Implant device may Potentially be denied an MRI Scan. The other Choices Available to Patients with implantable devices is CT Scan or X-Ray i.e. instead of MRI, These Patients can Experience a CT Scan. How ever, This is not an Perfect option, as it Forces ionizing radiation.

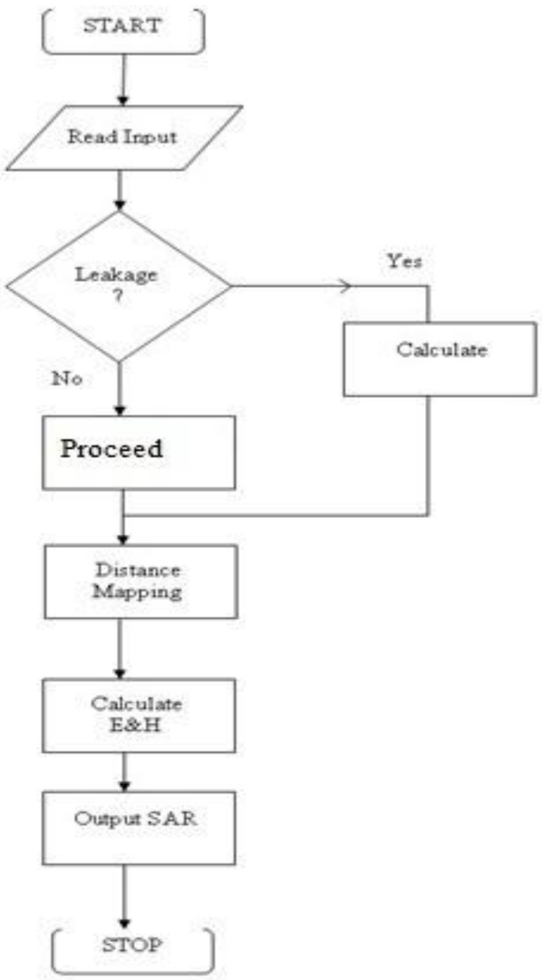


Figure 2:Flow Chart for SAR Measurement

Many Researchers have researched through this area for Measuring SAR For MRI .Jihong Wang,Joshua Yung et al[3] Proposed a new methodology for Assessment of Leakage and Scattered Radiation of integrated MR-LINAC systems, and as per as the assessment when magnetic field was on at 1.5 T, The maximum head leakage at 1m was 0.192R/1000 MU. This is Corresponds to approximately 0.01% of the Primary beam intensity. The Scattered Radiation at 1m from the centre was 1.091 R/1000 MU(0.08%),when Magnetic field was off(B=0) the measured head leakage was 0.199R/1000 MU. The Scattered Radiation at 1m was 1.153 R/1000 MU.The Magnetic field leakage is controlled by Defining a Maximum boundary field on the contour of the boundary.

The Openings at Middle section shield will Un avoidably cause some magnetic field leakage into shield. the impact of these opening was wasted as follows, homogeneity is provided for better imaging ,we should increase the shield length to reduce the Leakage of Magnetic Field.

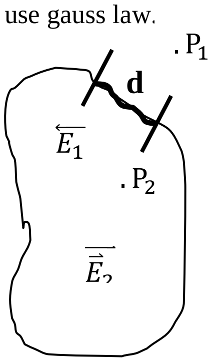
V. INTENSITY (I) OF INSTANTANEOUS WAVE

Generally intensity is defined as Power per area (energy per area per time).for an electromagnetic wave, you can find its intensity by computing the Magnitude of Poynting Vector.

Consider a conductor with 2 charges P1&P2 lying outside and inside of the conductor. Consider a small element 'dS' area and let that area emit electric field $\overline{E_1}$ and now the Remaining Field is $\overline{E_2}$

$\overline{E_T}$=$\overline{E_1}$ +$\overline{E_2}$ (Total E_T be superposition of E_1 &E_2)

To get the Electric field E_1&E_2 we use gauss law.



$$\oint_s E.dS=\frac{q}{\varepsilon 0}$$

$$E.S=\frac{q}{\varepsilon 0}$$

$$E=\frac{q}{S\varepsilon_0}$$

$$\sigma=\frac{dq}{ds} \quad \text{.................................} \quad 3(a)$$

[σ=surface charge density]

$$E=\frac{dq}{ds}.\frac{1}{\varepsilon 0}$$

$$E=\frac{\sigma}{\varepsilon 0} \quad \text{.............. ....} \quad 3(b)$$

This E=$\frac{\sigma}{\varepsilon 0}$ is at P_1 outside the conductor, E=0 at P_2 inside the conductor (Electric field inside the conductor is 0).

Now since, Electric field at P1 is E=$\frac{\sigma}{\varepsilon 0}$

$$E_T = E_1 + E_2$$

$$E_1=E_2=\frac{\sigma}{2eo} \quad \text{.................................} \quad (4)$$

Now force experienced by surface (elemental area) 'ds' due to charge on rest of surface

F= (dq) E2

From equation 1(a)

F= (σds). $\frac{\sigma}{2eo}$ (From equation 4)

$$F=\frac{\sigma^2 ds}{2\varepsilon_0}$$

Now Electrical Pressure =$\frac{F}{A}$= $\frac{\sigma 2}{2\varepsilon 0}$ .... (5)

It is known that energy per unit Area i.e. energy density has same physical unit as electrical Pressure.

Electrical energy density=$\frac{1}{2}$ $\varepsilon_0 E^2$

E= CB and C= $\frac{1}{\sqrt{\mu_0 \varepsilon 0}}$

$$U_E=\frac{1}{2}\varepsilon_0 C^2 B^2$$

$$U_E=\frac{B2}{2\mu 0} \text{.................................} \quad (6)$$

U_E=Electric Field Energy

$$U_B=\frac{B2}{2\mu 0}$$

U_B=Magnetic Field Energy

From U_E we are obtaining the U_B. Therefore we can say that U_E=U_B

Therefore The total energy density U_T=U_E+U_B

$$=\frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\varepsilon_0 E^2$$

$$U_T=\varepsilon_0 E^2 \text{...} (7)$$

Now intensity (I) =C [.$\frac{Energy}{Volume/area}$]

I=U_T.C

I=C $\varepsilon_0 E^2$...... .... (8)

C=VelocityofLight

Above equation (8) is the intensity for instantaneous electromagnetic wave.

VI. INTENSITY OF TIME AVERAGED ELECTROMAGNETIC WAVE

Time Varying Magnetic fields induce Electric fields and currents in living tissues in accordance with Faraday's law of induction. such fields an currents may also be induced by movement in a static magnetic field. Once propagated EM wave doesn't depend on source once propagated. it will vary sinusoidal in the medium(in general air: a non conducting medium) so, Now we have to consider time average of the EM wave. Poynting Vector is a quantity that describes the magnitude and direction of energy flow in Electromagnetic Wave. we can obtain the intensity of EM wave by poynting vector or by obtaining the average energy density of EM wave multiplied by the velocity of light. let us represent the Electric field in the direction of propagation as $E_x(z)e^{jwt}$. Now let $E_x(z)$ be the field containing both the propagated and the reflected waves.

$$E_x(z)=E_x^+ e^{jwt} + E_x^- e^{-jwt} \text{......................................} (9)$$

E_x^+=Electric Field in the direction of Propagation

E_x^- = Electric Field towards the source /Reflected Electric field

Neglecting Reflected wave part in the expression (9).Now it becomes

$$E_x(z)= E_x^+ e^{jwt} \text{...} 10(a)$$

Now we consider the real part of equation (10) as only the real power contributes the work to be done and reactive power which is imaginary just helps in propagation. Therefore the expression (10 a) becomes

$$E_x(z)= E_x^+ \ coswt\text{------------------------------} \quad 10(b)$$

The Average of above expression 10(b) results in

$$= \frac{E_x^{+2}\epsilon_0}{4} \quad \text{..} \quad (11)$$

since the time average electrical energy density=time average magnetic energy density[U_E=U_B] Total energy density of EM wave is U_T=$\frac{1}{2}$ $\varepsilon_0 E^2$ Therefore the total time averaged energy density is half of the instantaneous energy density of EM wave. Now we can find intensity of EM wave directly by using the I=U_T.C which results in

$$I= C\frac{1}{2}\varepsilon_0 E^2$$

but in order to get the intrinsic impedance and to get to know the power in harmonics of EM wave, we use poynting vector. In instantaneous poynting vector : S=E(t) X H(t) Time Average instantaneous Poynting Vector is given as

$$S=\frac{1}{2} Re\,[E(t) X H(t)] \text{.................................} \quad (12)$$

This factor $\frac{1}{2}$ is a result of time averaging..[in finding of time average, as the highest electric field magnitude is $\frac{E_x^+}{2}$ and the lowest magnitude is zero.

$$=\frac{1}{2} Re(E_x e^{jwt}) \ X \ Re(H_x e^{jwt})$$

$$= \frac{1}{2}Re\ (\ E_x^+ \ e^{jwt}$$

$$+E_x^- e^{-jwt}) \ X \ \frac{1}{2}(H_x^+ e^{jwt}+H_x^- e^{jwt})$$

$$= \frac{1}{2}\,\mathrm{Re}(\ E_x^+\ \ X\ \ H_x^-\ ) + \frac{1}{2}\ \mathrm{Re}(E_x\ \ X\ \ \ H_x e^{2jwt})$$

(since even harmonics power is 0)

$$=\frac{1}{2}\mathrm{Re}(E_x^+\ X\ H_x^-)..\quad(13)$$

From Maxwell time Varying equation

$$\nabla\, X\, E = -\frac{\partial B}{\partial t}$$

$$\frac{\partial Ex}{\partial z} = \frac{-\mu Hy}{\partial z}$$

$$\frac{\partial Ex}{\partial z} = -j\omega\mu Hy$$

$$[E_x(z)=E_x^+ e^{-\gamma z}+E_x^- e^{\gamma z}]$$

$$H_y=-\frac{1}{j\omega\mu}\frac{\partial Ex}{\partial x}$$

$$H_y(z)=(\frac{\gamma}{j\omega\mu}E_x^+ e^{-\gamma z}-\frac{\gamma}{j\omega\mu}E_x^- e^{\gamma z})......................(14)$$

$$H_y^+ = \frac{\gamma}{j\omega\mu}E_x^+$$

$$\frac{E_x^+}{H_y^+} = \frac{j\omega\mu}{\gamma} = \sqrt{\frac{\mu}{\varepsilon}}=\eta$$

$$H_y^+ = \frac{E_x^+}{\eta}$$

$$[\mathrm{since}\,\gamma = \alpha + j\beta]$$

$$E_x(z)=E_x^+ e^{-\gamma z}$$

$$=E_x^+ e^{-\alpha z}e^{-j\beta z}$$

since the medium is non- conducting (air) medium conductivity is zero. $\sigma = 0$ the attenuation 'α' will also be zero. E_x and H_y are fields along the Respective Planes and Cross Product of the them gives Magnitude and Direction of EM wave in the Direction of Propagation

$$E_x(z)=E_x^+ e^{-j\beta z}..............................\quad(15)$$

$$H_y(z)=\frac{E_x^+}{|\eta|}e^{-j\beta z}...............................\quad(16)$$

$$P=\frac{1}{2}\mathrm{Re}[E^*H^*]$$

$$=\frac{1}{2}\mathrm{Re}[\hat{z}\,\frac{{E_x^+}^2}{|\eta|}.e^{-2\alpha z}]$$

$$\sigma=0 \text{ so } \alpha=0$$

$$|P|=\frac{|E|^2}{2\eta}..\ (17)$$

From equation 11(a) and 17

$$\mathbf{I=C\frac{1}{2}\,\varepsilon_0 E^2=\frac{|E|^2}{2\eta}}$$

VII. CONCLUSION

It is clear from above discussion that all the mathematical approach is having significant impact on Finding the Intensities of instantaneous and time averaged electromagnetic waves are Advantageous from different aspects. The Novel Approach present in finding the Intensity of Instantaneous Electromagnetic wave gives Specific absorption value on a subject as a good conductor, further work is necessary to give a comprehensive description of SAR and find the Change in the SAR due to medical implant Compare the Theoretical Values with Clinical Results

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