بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Engineering

Biomedical Engineering Department

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Review of CT and MRI Maintenance

مراجعة صيانة جهازي الرنين المغناطيسي والأشعة المقطعية

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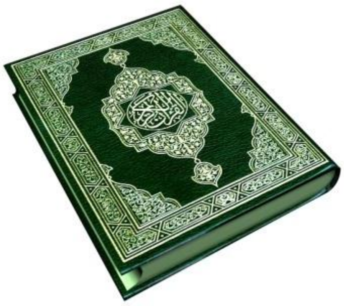

قال تعالى:

﴿ وَعَلَّمَ آدَمَ الأَسْمَاء كُلَّهَا ثُمَّ عَرَضَهُمْ عَلَى الْمَلاَئِكَةِ فَقَالَ أَنبِئُونِي
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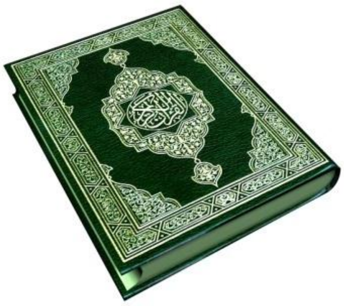

Dedication

I dedicate this humble work to the soul of my dear father

Acknowledgement

Firstly Thanks to Almighty ALLAH for giving me strength and ability to learn and complete this research.

And I would like to express my very profound gratitude to my supervisor DR. Elias siddig for providing indispensable advice, information, and support, he steered me in the right direction whenever he thought I need, without him this work would not have been possible.

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Finally, I also would like to thank my great mum that praying for me and give me the opportunity for education.

Abstract

CT scan and MRI machines are very essential for the advance diagnostic, more complicated and high cost equipment in the radiology department that its failure can cause a detrimental effect on its financial income and the ability to provide proper healthcare to the patient.

This study was done in Khartoum state hospitals, centers, and a number of private hospitals which are about 15 hospitals and centers in the period from March 2016 to February 2017 .Empirical field , observation and field level data collection through inventory meetings, survey and interviews with the technicians, biomedical engineers of hospitals, biomedical engineers of companies and managers of hospitals and administrators were done to identify the most frequent failures that have been happened in these devicesusing questionnaire. Moreover, the benefits on how to prevent these faults to repeat again and powerful recommendation was investigated to maintain and give a sustainable healthcare.

المستخلص:

اجهزة الرنسن المغناطيسى والاشعة المقطعية ضرورية جدا للتشخيص المتطور،وهى من اكثر اجهزة التصوير تعقيدا وارتفاعا للتكلفه بحيث ان فشلها يمكن ان يسبب تأثيرا ضارا على دخل المؤسسة الصحية والقدرة على توفير الرعاية الصحية المناسبة للمريض.وقد أجريت هذه الدراسة في مستشفيات ولاية الخرطوم_عدد من المستشفيات الخاصة والحكومية والمراكز الصحية_والتى عددها 15 مستشفى ومركزا صحيا فى الفتره من مارس 2016 الى فبراير 2017 .تم اجراء جمع البيانات عن طريق الاستبيانات والمسح الميدانى والمقابلات مع المهندسين والفنيين العاملين بالمستشفيات الطبية والشركات الطبية ومدراء المستشفيات لتحديد اكثر الاعطال شيوعا فى هذه الاجهزة بإستخدام طرق الاستبيان.علاوة على ذلك ، تم التحقيق فى كيفيه منع تكرار هذة الاخطاء وتم الوصول الى توصيات قوية للحفاظ عليها واعطاء الرعاية الصحية المستدامة.

Table of contents

Chapter One Introduction

Chapter Two Theoretical Fundamentals

List of Tables:

List of Figures:

Abbreviations:

CT	Computed tomography
MR	Magnetic resonance
GA	Gradient amplifier
GC	Gradient coil
RF amplifier	Radio frequency amplifier
Nb-Ti	Niobium-Titanium
PSS	Patient support system
SNR	Signal\Noise Ratio
HV generator	High voltage generator.
LED	Light Emitting Diode
SRAM	Static RAM
VAC	AC voltage
VDC	DC voltage
PIU	Power Inverter Unit.
TCU	Tank Control Unit.
DMS	Data Measurement System
T/R coil	Transmit/receive (T/R) coil
FDA	Food and Drug Administration
GE company	General Electric Company

CHAPTER ONE
INTRODUCTION

1.1General view:

There are many medical imaging devices used in hospitals, medical centers, where many problems occur either by misuse of the device or by a malfunction in the program and these failures are often common.

To improve the safety and quality of the care that radiologists provide, and to allow radiologists and radiology personnel to remain competitive in an increasingly complex environment, it is essential that all imaging departments establish and maintain managed, comprehensive, and effective performance improvement programs.

Although the structure and focus of these programs can vary, a number of common components exist, many of which are now widely mandated by organizations that regulate the field of radiology. Basic components include patient safety, process improvement, customer service, professional staff assessment, and education, each of which requires strategies for implementing continuous programs to monitor performance, analyzing and depicting data, implementing change, and meeting regulatory requirements.

All of these components are part of a comprehensive quality management system in a large academic radiology department. For smaller departments or practices, the gradual introduction of one or more of these components is useful in ensuring the safety and quality of their services.

Medical imaging devices are considered modern medicine revolution ,which is characterized by clearly high in the image as in the device of the CT which gives bones details in a high precision unlike magnetic resonance which depicts the soft tissue at high resolution imaging Therefore, we find these devices are expensive compared with other devices such as ultrasound

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1.2Problem statement and solution:

Applying maintenance management of (CT,MRI) because of the importance of these medical imaging devices in terms of use in medical diagnosis , most complex ,high cost and it's defects relate to human life.

1.3 Objectives:

1.3.1 General objective:

Applying maintenance management of (CT, MRI).

1.4.1 Specific objectives:

- To know if the medical equipment is calibrated regularly.
- Provide optimum health care service.
- Reduce health care cost.
- Reduce patient dose.
- Provide accurate diagnosis.
- Training staff.
- Explain the importance of the log book..
- Provide data base of faults.
- Raising awareness in the healthcare community.
- The proposed database system will help engineers and technicians recent graduates working on these devices to identify the most common fault with a range of potential solutions proposed for each of them as well as the speed and ease of maintenance operations.
- The use of this data in future studies and research.

1.4 Methodology:

Observation and field level data collection through inventory meetings, survey, text book, paper, internet and interviews with the technicians, biomedical engineers of hospitals, biomedical engineers of companies and managers of hospitals and administrators were done to identify the most frequent failures that have been happened in these devices(CT, MRI) what its causes, how to treat these errors ,how it is being calibrated to maintain the quality of the device and reduce the cost using questionnaire method. Moreover, the benefits on how to prevent these faults to repeat again and powerful recommendation was investigated to maintain and give a sustainable healthcare.

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1.5 Thesis lay out:

This thesis consists of seven chapters, chapter one illustrate a brief introduction and general view about the project. Chapter tow containing theoretical fundamental, when chapter three presents the back ground studies of the common faults of these two devices and its causes. In chapter four the methodology was discussed and data were collect to get the result. Chapter five show the analysis of faults of these two devices and a strong discussion about these problems illustrated in chapter six. Chapter seven include conclusion and recommendation. Finally the reference illustrated flowed by the appendices.

CHAPTER TWO

THEORETICAL FUNDAMENTAL

2.1 Medical imaging:

Medical imaging is an essential part of the diagnosis of many diseases and has an important role in the improvement of public health in all population groups. The procedures used often involve the use of powerful and potentially damaging ionizing radiation. Poorly controlled medical imaging equipment, techniques and facilities can cause serious harm to both the operators of the equipment and the patient.

While all clinicians and health administrators are familiar with medical imaging— radiography (X-rays), sonography (ultrasound), scintigraphy/radionuclide, computerized tomography (CT) and magnetic resonance (MR) scanning—because it is an integral part of medical education, few are familiar with the details of quality control which are necessary to produce a high quality image. Even radiologists and radiographers are often unaware of the many details which should be routinely checked and rechecked if a high standard is to be maintained. Particularly in need of guidance are the imaging staff of small, relatively isolated hospitals and clinics and those in small private practices. Busy with their daily work, they become oblivious to slow deterioration in their complex equipment and their own techniques. Their training seldom provides the systematic checks which must be applied if an imaging service is to run smoothly, efficiently and at a consistently high standard.

The staffs of ministries of health and many hospital administrators also need the guidance of this manual. No program of quality control can be satisfactorily organized and performed without the expenditure of time and, equally important, money. However, it is easy to waste both on inappropriate schemes which have a poor yield and do not improve patient care.

All medical imaging services use expensive and complex equipment. The proper control and management of this huge investment in capital and skill requires that the equipment be properly calibrated, maintained and regularly serviced. Detailed records must be kept not only of routine servicing but any breakdown which may occur. The hours not available for patient care, the reasons for the interruption in service and the difficulties experienced by the staff are as important as the quality of images when the equipment is functioning properly. A graphic representation frequently makes it easier to realize that equipment is wearing out or has developed a recurring fault which requires a significant overhaul. Equally, when equipment is very highly rated, this too should be note4

The procedures for purchasing new equipment must be documented and agreed by not only the administrative staff but by the radiologists, radiographers, the physicists and those who undertake care and maintenance. This applies not only to obviously expensive equipment such as MR and CT scanners, but even to smaller items such as reception computers.

Good management also requires that every item of equipment is available when needed, ranging from catheters to syringes to wound dressings and including drugs for routine and emergency procedures. Again, documentation and the allocation of responsibility is the essence of good management, so that there is someone who will ensure that equipment of every sort is available when or if required. Advice and help from other specialized services, such as anesthesia and pharmacology should always be welcomed. There is an immense range and amount of equipment in any imaging department but even one small missing item may make the difference between life and death for a patient [1].

2.2 general overview of MRI:

MRI (magnetic resonance imaging) is a noninvasive diagnostic test that takes detailed images of the soft tissues of the body. Unlike X - rays or CT, images are created by using a magnetic field, radio waves, and a computer. It allows your doctor to view your spine or brain in slices, as if it were sliced layer-by-layer and a p picture taken of each slice. An MRI scan works by using a powerful magnet, radio waves, and a computer to create detailed images [2].

Your body is made up of millions of hydrogen atoms (the human body is 80% water), which are magnetic. When your body is placed in the magnetic field, these atoms align with the field, much like a compass points to the North Pole. A radio wave "knocks down" the atoms and disrupts their polarity. The sensor detects the time it takes for the atoms to return to their original alignment. In essence, MRI measures the water content (or fluid characteristics) of different tissues, which is processed by the computer to create a black and white image. The image is highly detailed and can show even the smallest an abnormality [2].

2.2.1 Three types of magnets are distinguished:

–Resistive magnets are conventional electromagnets that depend on a high and constant power supply to create a magnetic field. The maximum field strength generated by resistive magnets is about 0.3T. Their major disadvantages are the high operating costs due to the large amounts of power required and a field homogeneity that is often poor. An advantage is the safety of the system as the field can be turned off instantly in an emergency.

–Permanent magnets: consist of ferromagnetic substances and create a magnetic field that is maintained without an external power supply. However, permanent magnets are very heavy, can generate a field with a maximum strength of only 0.5T, and rely on a constant external temperature.

–Superconducting magnets: consist of a coil made of a niobium-titanium (Nb-Ti) alloy whose resistance to current flow is virtually eliminated when cooled to near absolute zero (about 4°Kelvin or –269°C). In this superconducting state, which is achieved using coolants known as cryogens (usually liquid helium), a current once induced flows practically forever. Once the magnetic field has been established, it is maintained without additional power input. Very strong and highly homogeneous magnetic fields of up to 18T can be generated using superconducting magnets. However, liquid helium evaporates and must be resupplied regularly [3].

.About 95% of all MR systems used today have superconducting magnets that here we talk about this type.

2.2.2 Composition of System:

The system consists of several subsystems shown in figure (2.1) That together full the task of making MRI scans .The main subsystems that are used in the scanner are the magnet, patient Support System with posterior coil, gradient system (amplifier with Gradient coil), RF system (RF amplifier, RF transmit coil, RF receive coil, and pre-amplifier): and magnet with Cry cooler and chiller.

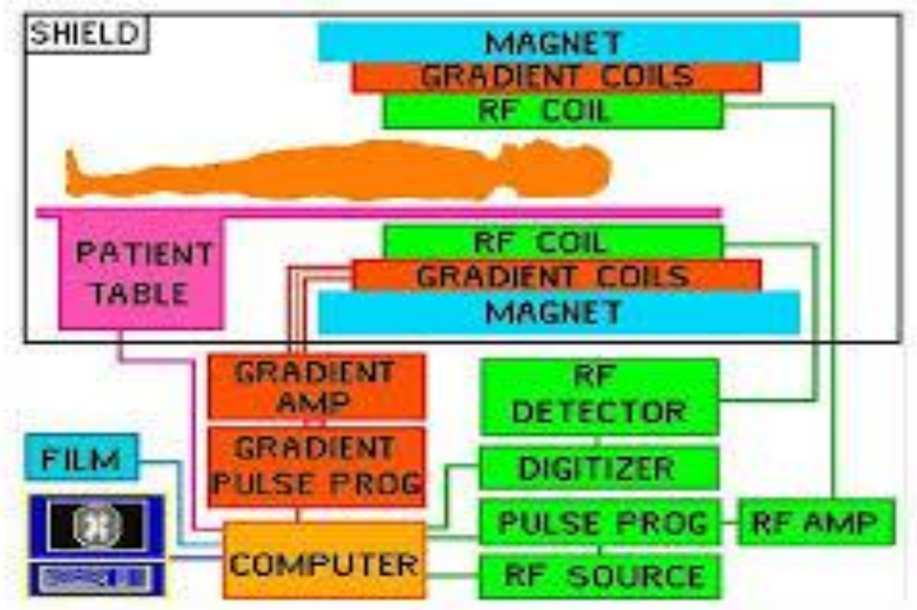


Figure (2.1): MRI composition

2.2.2.1Magnet:

One of the main components of the MRI scanner is the superconducting magnet. The purpose of the magnet is to produce a homogeneous, stationary magnetic field over a certain imaging volume s[4].it consist of a coil made of a niobium-titanium (Nb-Ti) alloy whose resistance to current flow is virtually eliminated when cooled to near absolute zero (about 4°Kelvin or –269°C)[3].

2.2.2.2 Gradient system (amplifier and coil):

Gradient system consists of gradient amplifier and the X, Y, Z gradient coils. Gradient amplifier is settled in gradient cabinet, and coils are fixed on magnet. Gradient amplifier involves three power amplifiers fixed in the upper part of the cabinet separately and one power supply unit fixed in the lower part of the cabinet. Gradient system generates a gradient magnetic field in imaging area. This field endues MRI signal with special information. [5].n

The purpose of the Gradient amplifier (GA) [depicted in Figure (2.2), is to produce an electrical current for the Gradient coil (GC) to produce three orthogonal magnetic field gradients within the powerful main magnetic field of the scanner s [4].

Figure (2.2): Gradient amplifier

2.2.2.3 RF system:

RF system is consist of RF amplifier, RF transmit coil, RF receive coil, and pre-amplifier. Which are describe below:

2.2.2.3.1 RF amplifier:

RF amplifier transmits the amplified RF excitation signal to RF transmit coil.

2.2.2.3.2 RF transmit coil and RF receive coil:

Coils include RF transmit coil and RF receive coils. RF transmit coil transmits powerful RF pulse to excite hydrogen nuclei. RF receive coil receives MRI returned from human body. The MRI signal is transferred to the low noise pre-amplifier through 50Ω.matching network. The MRI signal is acquired after being amplified by pre-amplifier and then reconstructed into image. There are many kinds of RF receive coil, depending on the body parts to be examined, such as head coil, body coil, neck coil, and knee coil, but all receive coils have the same principle and the connecting method[4].

2.2.2.3.3 Pre-amplifier:

The pre-amplifier of the system shown in figure (2.3) is used to amplify MRI signal received by receive coil.

Figure (2.3): RF Amplifier

2.2.2.4 Patient Support System:

The Patient Support System (PSS), despite in Figure (2.4), is used to support the patient and position the patient inside the bore. The system consists of three main parts, the table support (pedestal), which supplies the vertical movement, the carrier, which supplies the horizontal movement and the tabletop on which the patient is placed and which is removable from the carrier. To control both the movement of the pedestal and the carrier the PSS is equipped with a user interface. The pedestal is capable of moving in a vertical direction by a motor and the tabletop that is placed on top of the carrier is capable of moving in a horizontal direction by a motor [5].

Figure (2.4): Patient Support System

2.2.2.5 Magnet with Cryocooler and chiller:

One of the main components of the MRI scanner is the superconducting magnet. The purpose of the magnet is to produce a homogeneous, stationary magnetic field over a certain imaging volume. At Philips, the field strength of these magnets can be 1.0, 1.5, 3.0 or 7.0 Tesla. To maintain a magnet with a certain field strength in a superconducting state it needs to be in 4K (-269c). The cooling system for the magnet, uses helium to reach the low temperature of 4K. The cooling system, Cryo cooler depicted in Figure (2.5), is coupled via a plate heat exchanger to the same chiller or cold-water system as the LCC. The main components of the Cryo cooler are the compressor unit and the cold head. The function of the compressor unit is to supply high pressure helium gas to the cold head and re-compress the returned helium gas from the cold head. The compressed helium gas flows first through the heat exchanger, where it disposes heat into the coolant before it reaches the cold head. The function of the cold head is to produce continuous closed-cycle refrigeration at temperatures, depending upon the heat load imposed [4].

Cryogens are cooling agents, typically liquid helium or liquid nitrogen that are used to reduce the temperature of the magnet windings in a superconducting magnet. Cryogenic liquids are gases at normal temperatures and pressures. Different cryogens become liquids under different conditions of temperature and pressure. All Have two properties in common: They are extremely cold Small amounts of liquid can expand into very large volumes of gasy The Boiling points of cryogens are commonly below -150°C(-238°F)y Transported in Dewarcy cylinders Cryogens [6].

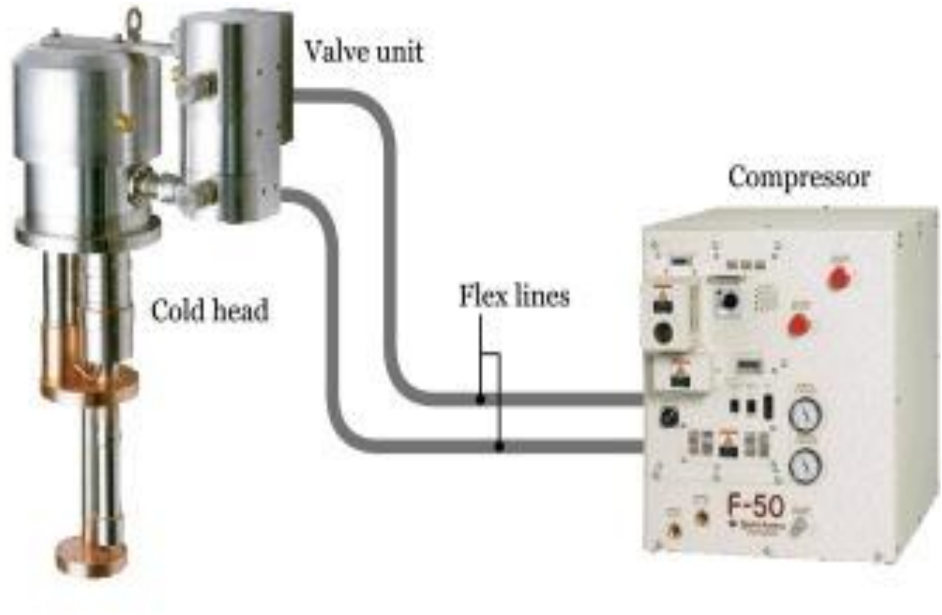


Figure (2.5): cro cooler system.

2.2.2.6 Chiller:

The another very important issue is a chiller .Chiller shown in figure (2.6) is a refrigeration unit That supplies cold water to cool MRI components .it is very essential for superconducting magnets. To reduce the boil-off of Helium and/or Nitrogen depending on the system configuration chillers are used to cool shield coolers, coils and sometimes the air conditioning [6].

Figure (2.6); chiller

2.2.3 Most common problems in MRI machine:

There are more malfunctions in MRI, the common problems illustrated below:

2.2.3.1 Cooling system:

Which is composed of chiller, and cryocooler system (cold head and Compressor). The problem happen in one of these parts.

2.2.3.2. Image artifacts:

Artifact are caused by a variety of factors that may be patient related such as voluntary and physiologic motion, metallic implants or foreign bodies. Finite sampling, and Fourier transformation may cause aliasing and Gibbs artifact.

2.2.3.2.1 Patient motion:

Motion artifacts despite n figure (2.7) typically show up as blurring or ghosting, especially in the phase-encoding direction. Recognizing that these ghost images are due to motion can help radiologists diagnose patients more accurately.

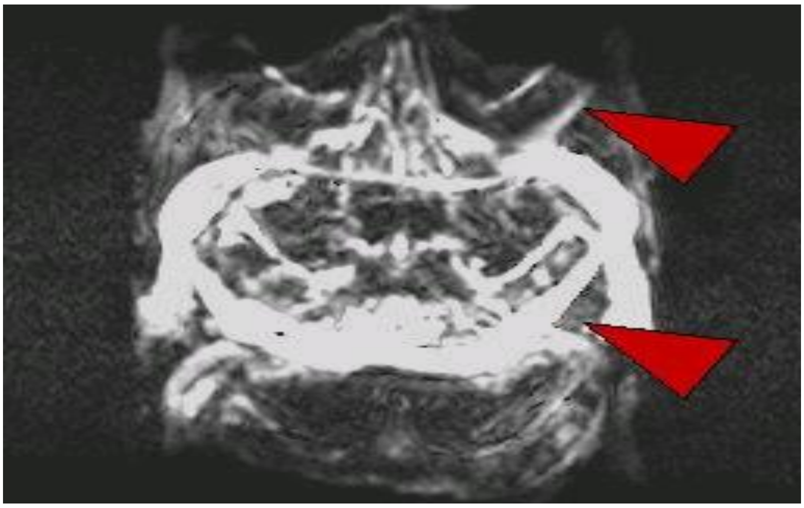


Figure (2.7): motion artifact

2.2.3.2.2 Chemical-shift artifacts:

Chemical-shift shown in figure (2.8) artifacts occur during the frequency encoding of the MRI process. Fat and water molecules oscillate differently within the magnetic field, causing them to show up differently during the encoding. This causes a black or bright band at the edge of the anatomy, and can sometimes be misinterpreted as pathology.

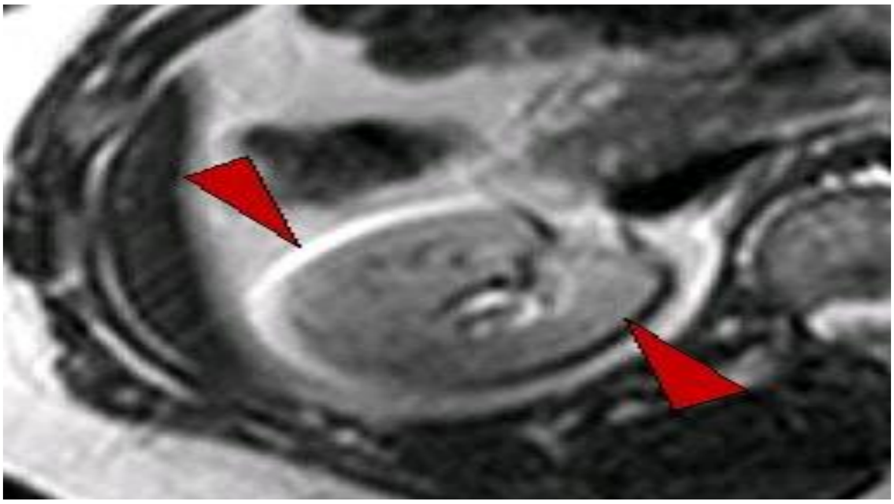


Figure (2.8): Chemical-shift artifact

2.2.3.2.3 Zipper artifacts:

Zipper artifacts shown in figure (2.9) can cause noise on the image, making it difficult to read. These occur when something in the environment interferes with the MRI unit, such as devices in the MR room, blinking light bulbs, the door not being securely shut, or nearby construction. This here due to (RF leakage).

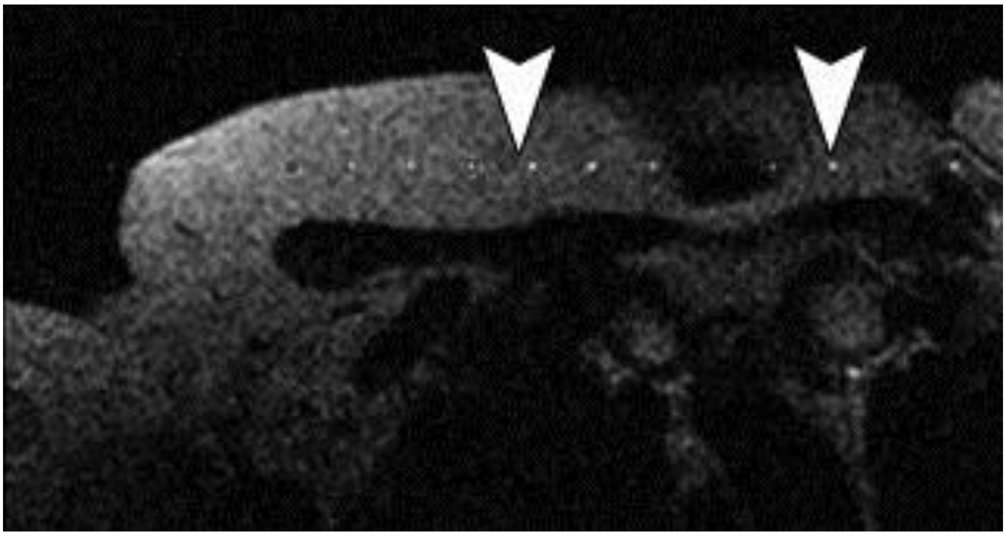


Figure (2.9): Zipper artifacts

2.2.3.2.4 Metal Artifact:

Magnetic resonance imaging relies on a homogenous magnetic field. When we introduce magnetic field variations across the patient with magnetic field gradients, the magnetic field strength relates to position, and is used to encode the MR signal. Susceptibility effects of introducing metals shown in figure (2.10) not only cause signal loss and distortion in-plane, they also cause slice profiles which deviate from the expected planar sheet. As a result, thicker slices can result in partial volume effects through-plane, which can cause SNR loss. So, contrary to expectation, thinner slices might actually increase SNR around a metal implant. However, SNR will decrease in the rest of the image as normal.

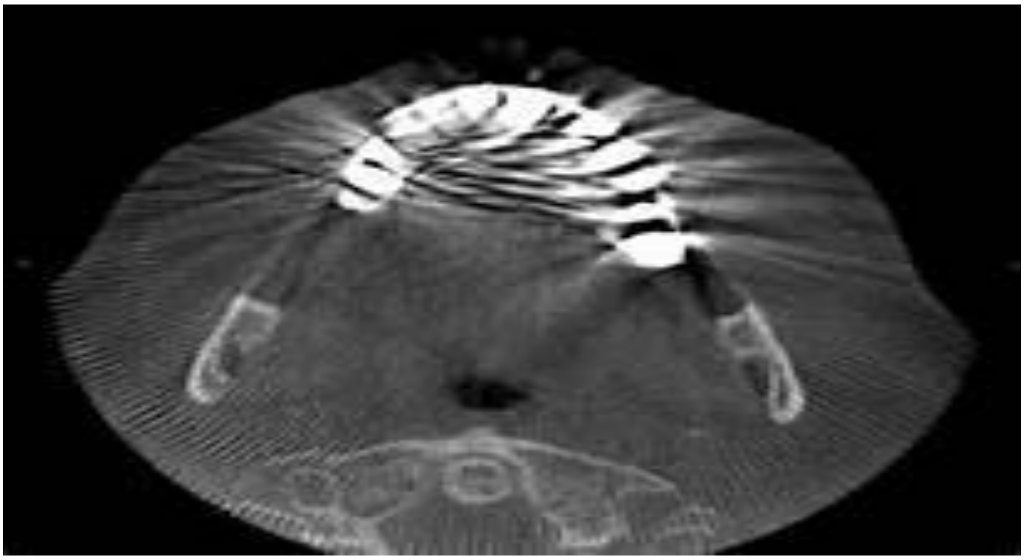


Figure (2.10): Metal Artifact

2.2.3.3 RF receive coils used in clinical routine:

RF receive coil are critical part in MRI Which have send radio and receive the signal type like Surface coils(smaller and larger), volume coils ,phased array coils.

2.2.3.4 Shimming:

Is a Correction of inhomogeneity of the magnetic field produced by the main magnet of a MRI system due to imperfections in the magnet or to the presence of external ferromagnetic objects. May involve changing the configuration of the magnet or the using of shim coils (active shimming) or adding or removing steel from the magnets poles (passive shimming) to fine-tune the magnetic field[7] .Broad classifications of shimming techniques passive and active:

In **passive shimming** small pieces of sheet metal or ferromagnetic pellets are affixed at various locations within the scanner bore to improve homogeneity. Conversely, **active shimming** uses currents directed through specialized coils to generate a "corrective" magnetic field [8].

2.3 CT device:

CT is a radiological method which has been used since 1974 to visualize certain regions of your body slice by slice. Today, CT technology is an indispensable tool in medicine. It is used for routine examinations of the entire body. For example, CT can assist your physician in: Detecting strokes, head injuries, herniated discs, a abscesses’. Locating fractures .Determining the extent of bone and soft tissue damage in trauma patients; in such cases it is especially helpful to have an imaging procedure which allows a fast first diagnosis. Diagnosing changes in various organs. Diagnosing or excluding diseases [9].

2.3.1 System components and their functions:

CT scan is composed of three parts:

2.3.1.1Gantry

The scanner is composed of the gantry and the patient couch. The scanner shown in figure (2.11) uses a continuous X-ray beam to scan the region to be examined. Transmitted X-rays are detected and converted into electrical signals by the area detector. The gantry includes the main body and its support mechanism. The X-ray tube and the area detector are mounted facing each other on either side of the gantry aperture, and the X-ray tube and detectors rotate continuously around the aperture of the gantry. A slip ring is employed to transmit power between the gantry and the rotating X-ray high voltage generator assembly. The X-ray high-voltage generator is built into the gantry, and the system employs a high-frequency inverter for generating and stabilizing the high voltage supplied to the X-ray tube. The generator includes electronic circuits for controlling the speed of the rotating anode in the X-ray tube [11].

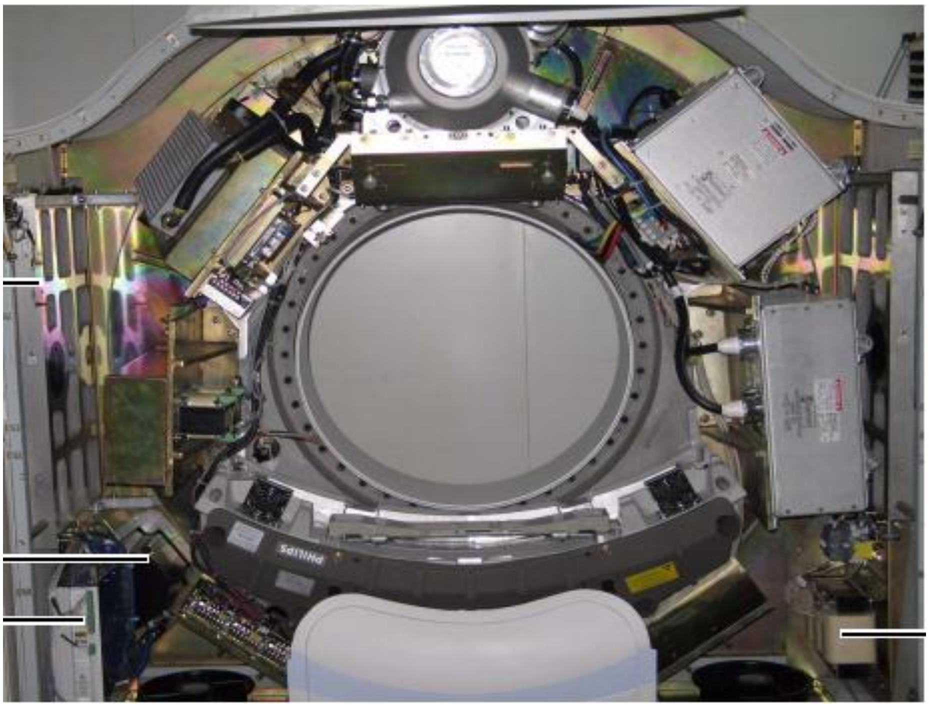


Figure (2.11): gantry

2.3.1.2Patient couch:

The patient couch is positioned in front of the gantry and supports the patient. The entire unit moves vertically and the top moves longitudinally. In an emergency, the couch top can be pulled out manually with very little effort. The couch top can also be lowered to a minimum height of 330 mm from the floor, facilitating transfer of the patient from a low bed or stretcher [11].

2.3.1.3 Console:

The console is provided with a hybrid keyboard, a monitor, and a mouse.
Functions of the console for scanning is Selection of scan parameters, Scan control, Remote control of couch-top movement, and remote control of gantry tilt [11].

2.3.2 CT scan troubleshooting:

There are frequent problems occure in CT illustrated beliw:

2.3.2.1 Gantry rotation:

Computed tomography (CT) gantry rotation shown in figure time (2.12) is one factor influencing image quality. Until now, there has been no report investigating the influence of gantry rotation time on chest CT image quality. Faster CT gantry rotation reduces scan time and motion artifacts. However, accelerating rotation time increases image noise and streak artifacts. Therefore, a slower CT gantry rotation speed is still recommended for higher image quality in some cases.

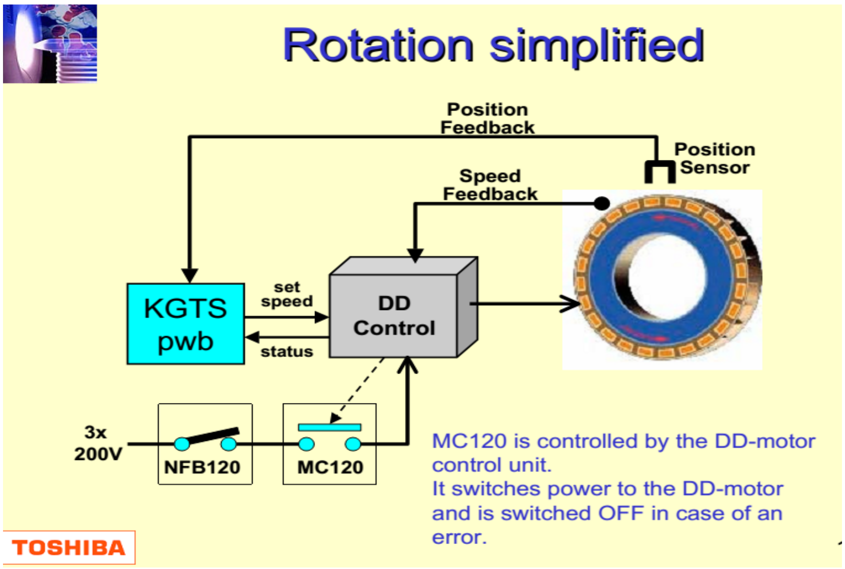


Figure (2.12): rotation of gantry.

2.3.2.2 High voltage (HV) Generator:

The high voltage Generator is placed inside the gantry and has two module,Spellman Chassis X3815 and Fironia-50**.** Its functions aregenerate working voltage and current for tube,Monitor working status of tube, and offer protection for the system,Control of tube filament and tube rotating anode, Set tube voltage and current.

2.3.2.2.1Spellman Chassis X3815:

The HV generator shown in figure (2.13) contains two parts: AC/INV CHASSIS ASSY X3815 and HV CHASSIS ASSY X3815. The main input power supply 320~440VAC is connected to AC/INV module. The AC/INV CHASSIS ASSY X3815 is connected to the HV CHASSIS ASSY X3815 via 20-cores cable, and commands from system-control board in HV CHASSIS ASSY X3815 are transferred to the AC/INV CHASSIS ASSY X3815 via this cable.

In the AC/INV CHASSIS ASSY X3815, AC/DC converter/filter changes 380VAC 3phase input to 540VDC, then Inverters convert 540VDC to High Frequency AC(25KHz), Step-up transformers convert the High Frequency AC to mid voltage, ~7kV. The mid-voltage is output to the HV CHASSIS ASSY X3815 via cable. In the HV CHASSIS ASSY X3815, the Multiplier/rectifier assembly to converts ~7kV to Positive or Negative High voltage output (30-70kVDC). The AC/INV CHASSIS ASSY X3815 also offers 24VDC output to the Low Voltage Power Supplies of HV CHASSIS ASSY X3815 via cable so that the HV CHASSIS ASSY X3815 can supply power to the filament board and system control board [12].

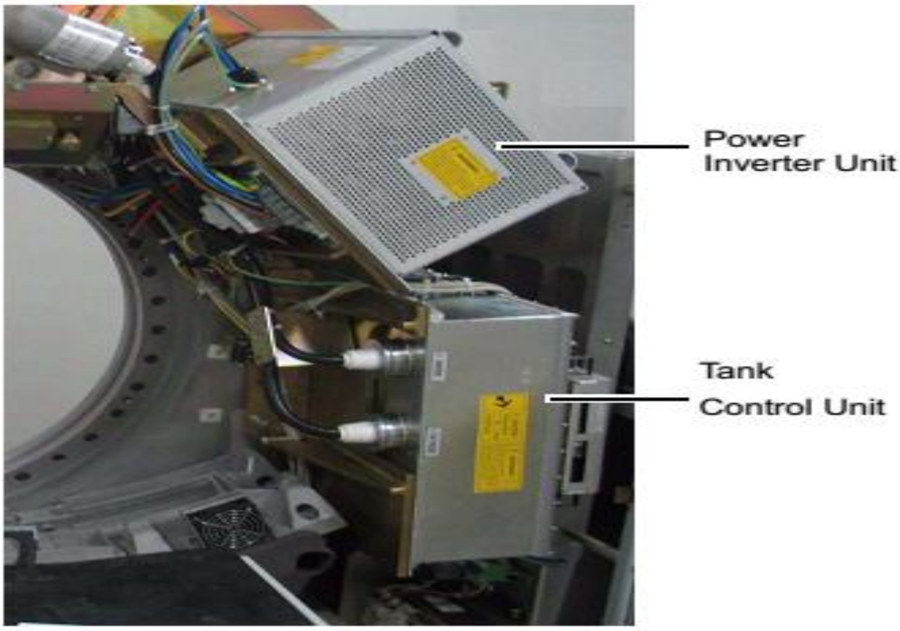
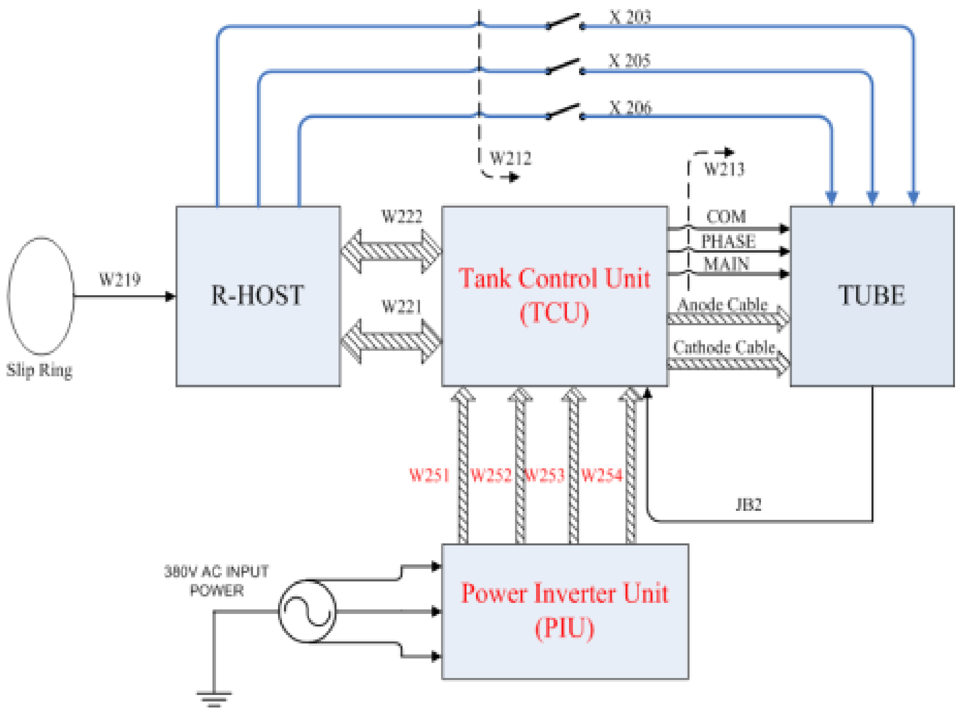


Figure (2.13): Spellman Chassis X3815.

2.3.2.2.2 Fironia-50:

The HV generator shown in figure (2.14) contains two parts: PIU (Power Inverter Unit) and TCU (Tank Control Unit).The PIU consists with Power Control Board, Inverter Drive Board, IGBT module, Resonant circuit and Cooling Unit.

The TCU include System Control Board, filament board, Anode Control Board. Grid Module is in Tank oil box [12].



Figure(2.14): Fironia-50 system Connections.

HV system theory shown in figure (2.15) consists of the following three parts:

- PIU (Power Inverter Unit):

The PIU consist of full bridge inverter, rectifier & filter, power control board, drive protection board, resonant capacitors, resonant inductors, cooling fans and mechanical parts etc. Rectifier & Filter Parts consist of power filter, rectified bridge and rectifier capacitors etc., The functions serve to implement rectification and filtering of the mains input, and to supply DC voltage for inverter parts.. The power control part consist of a switched-mode power supply, power control board, contactors etc., The functions serve to supply low DC voltage and to implement the pre-charging of capacitors and to provide power supply forcooling fan. The Inverter Resonant includes the full bridge inverter, heat sinks, resonant inductors and resonant capacitors. ,The main functions is to provide the high frequency AC voltage for the high voltage generator (transformer, cascade etc.). The Drive protection part is realized by the inverter drive board and provides the drive and the protection of IGBT modules [12].

- **TCU (Tank Control Unit):**

The TCU consists of the Tank module, Grid modular, Filament board, System Control Board, Anode drive board cable and mechanical parts. The Filament board provides filament current for the tubes filament. System control board is mostly controlling all modules in the generator, interfacing with CT system, exchange data. The Anode Drive control board provides boosts voltage and operational voltage for the tube, controls the speed- up the tubes plate and keep it spinning

- HV control sub system (Rotor control board)

HV control sub system is controlled by the Rotor control board inside the RHOST. The function of the HV control sub system is to set up kV, mA, filament current and grid voltage, control tube anode boost, run and brake function, and HV X-ray exposure in response to the command of software [12].

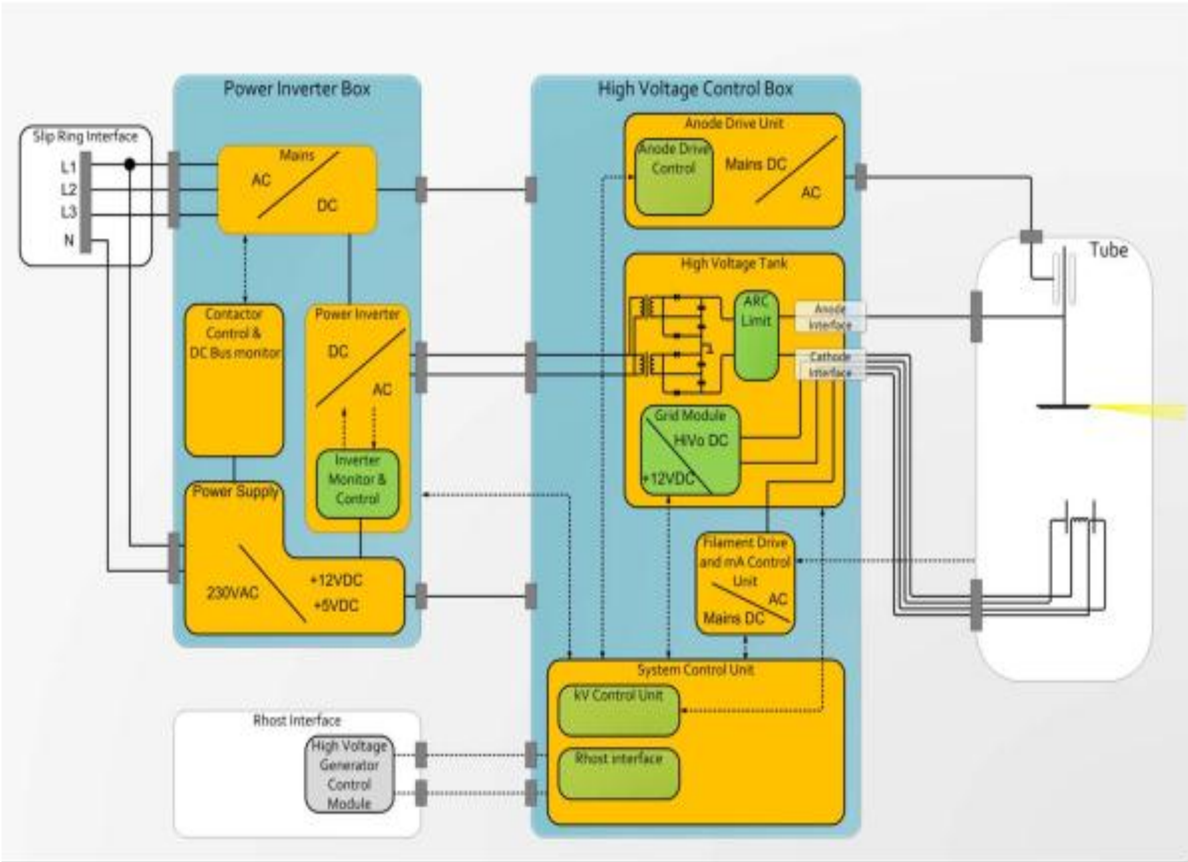


Fig (2.15):Fironia Theory

2.3.2.3 X-Ray tube faults:

X-ray tube is a vacuum tube which convert electrical input power into X ray. Environmental Specifications in Operating Limits Ambient Air Temp.5° C to 40° C. to prevent tube failure the tube filament current should switch to STANDBY in 100s after its last exposure, Filament boost time should include 1 sec before, 3 sec after end of scan. And the temperature of tube should be store and Transportation in ambient Air Temp.-30° C to 70° C , and the Operating Limits ambient Air Temp should be in the range of .5° C to 40° C. The X-ray generated by the Tube passes through a mechanical collimator and the object. Once the X-ray has passed through an object, the attenuated X-ray will be collected by the DMS and converted to a digital signal. There is an A-plane.A-plane is located on the Tube side and controlled by the Rotor Control

Board. The main purpose of the A-plane is to limit the X-ray exposed surface area of the DMS resulting in better image quality [12].

2.3.2.4 Image Artifacts:

Artifacts are commonly encountered in clinical computed tomography (CT), and may obscure or simulate pathology. There are many different types of CT artifacts, including noise, beam hardening, scatter, pseudo enhancement, motion, cone beam, helical, ring, and metal artifacts.

Noise can be reduced using iterative reconstruction or by combining data from multiple scans. This enables lower radiation dose and higher resolution scans. Metal artifacts can also be reduced using iterative reconstruction, resulting in more accurate diagnosis. Dual and multi-energy (photon counting) CT can reduce beam hardening and provide better tissue contrast. Methods for reducing noise and out-of-field artifacts may enable ultra-high resolution limitd-field-of-view imaging of tumors and other structures [13].

2.3.2.4.1Ring artifact:

Ring artifact shown in figure (2.16)is caused by a miss calibrated or defective detector element, which results in rings centered on the center of rotation. This can often be fixed by recalibrating the detector [13].

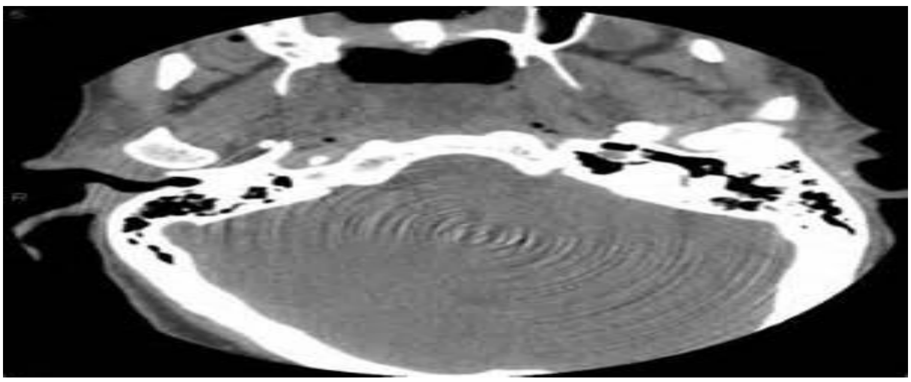


Figure (2.16); ring artifact

2.3.2.4.2 Cupping Artifacts:

Is the first type of Beam Hardening artifact shown in figure (2.17) in which in it: an x-ray beam is composed of individual photons with a range of energies. As the beam passes through an object, it becomes “harder,” that is to say its mean energy increases, because the lower-energy photons are absorbed more rapidly than the higher-energy photons. Two types of artifact can result from this effect: so-called cupping artifacts and the appearance of dark bands or streaks between dense objects in the image.X rays passing through the middle portion of a uniform cylindrical phantom are hardened more than those passing though the edges because they are passing though more material. As the beam becomes harder, the rate at which it is attenuated decreases, so the beam is more intense when it reaches the detectors than would be expected if it had not been hardened. Therefore, the resultant attenuation profile differs from the ideal profile that would be obtained without beam hardening.

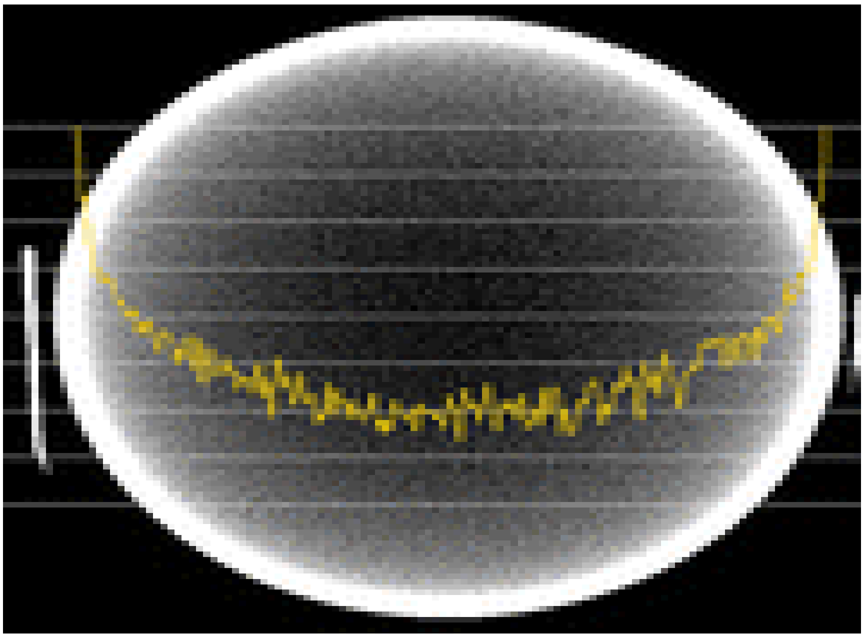


Figure (2.17) Cupping Artifacts

2.3.2.4.3Streaks and Dark Bands:

Is the second type of Beam Hardening artifact shown in figure (2.18) in which a very heterogeneous cross sections, dark bands or streaks can appear between two dense objects in an image. They occur because the portion of the beam that passes through one of the objects at certain tube positions is hardened less than when it passes through both objects at other tube positions. This type of artifact can occur both in bony regions of the body and in scans where a contrast medium has been used.

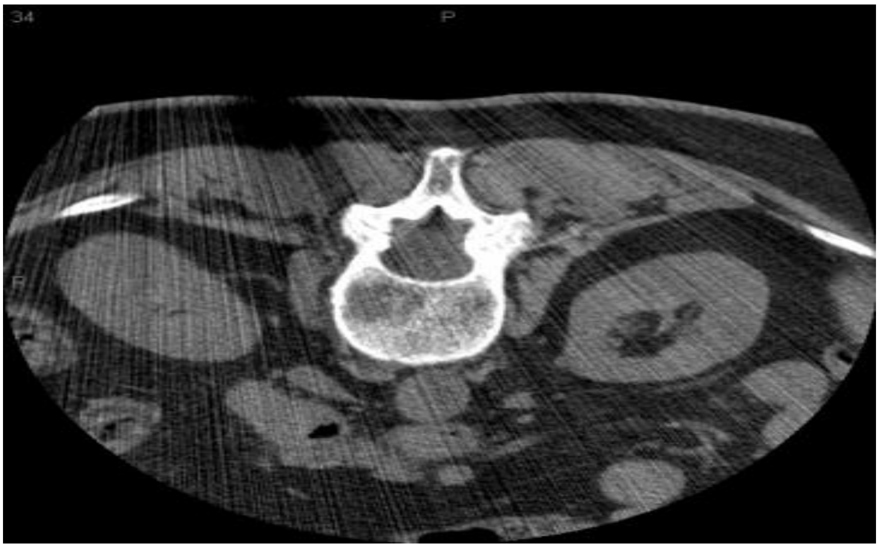


Figure (2.18): Streaks and Dark Bands

2.3.2.4.4Metallic artifacts:

The presence of metal objects shown in figure (2.19)in the scan field can lead to severe streaking artifacts. They occur because the density of the metal is beyond the normal range that can be handled by the computer, resulting in incomplete attenuation profiles.

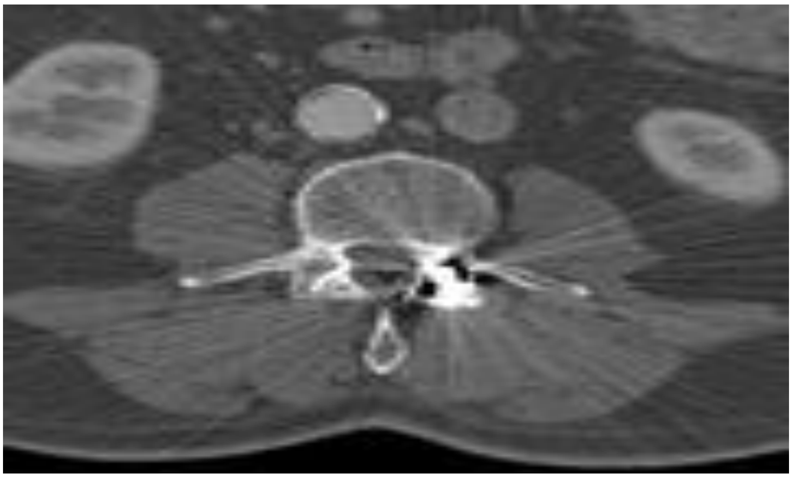


Figure (2.19)Metal artifact

2.3.2.4.5Patient Motion:

Patient motion shown in figure (2.20) can cause missregistration artifacts, which usually appear as shading or streaking in the reconstructed image.

Figure (2.20) Patient Motion

2.3.2.5Isocenter:

Isocentershown in figure (2.21)is the convergence of the three axes of rotation in radiation therapy; the intersecting point of the axis of rotation of the gantry, the collimator, and the treatment couch.

Figure (2.21): Ct Isocenter

2.3.2.6CT number:

CT numbersshown in table (2.3)is a normalized value of the calculated X-ray absorption coefficient of a pixel (picture element) in computed tomography, express in a Hounsfield number.

Table (2.3): CT number

2.3.2.7 Table:

Table shown in figure (2.22)is the place where the patient is place to do the scan**.**

Tissue	CT Number (HU)
Bone	+1000
Liver	40-60
White mater	-20 to -30
Grey mater	-37 to -45
Blood	40
Muscle	10-40
Kidney	30
CSF	15
Water	0
Fat	-50 to -100
Air	-1000

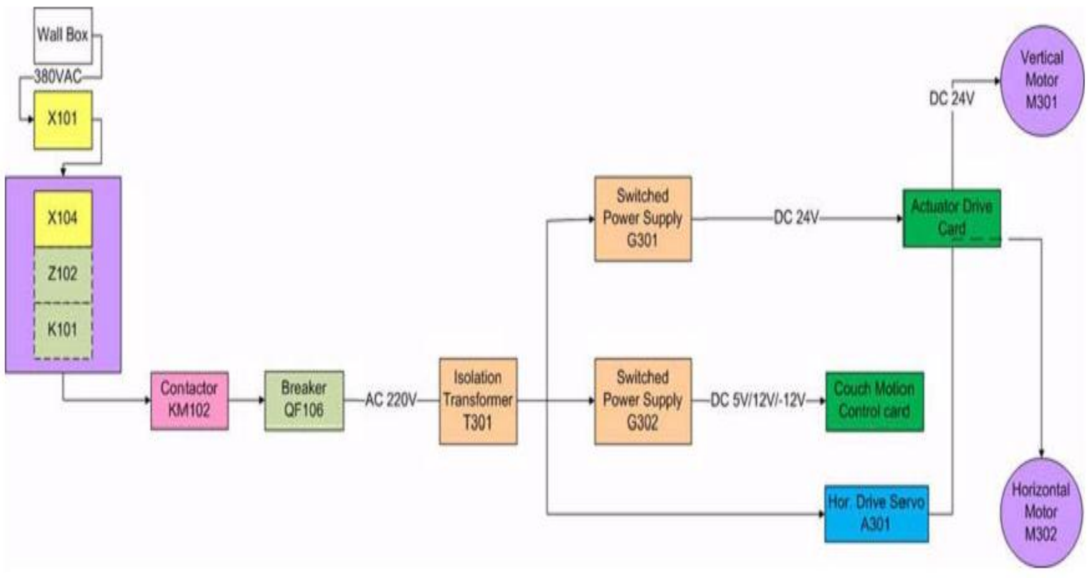


Figure (2.22): CT table

2.3.2.7.1 Standard specification:

Horizontal Speed: 0.5 to 100mm/Sec.

• Vertical Range: 430 to 980mm

• Vertical Speed: 2.5 to 50mm/Sec.

• Table Load Capacity: 200 kg with full accuracy

2.3.2.7.2Table main functions:

Positioning the Patient Table in the Gantry for the scan (in Z direction).

2.3.2.8 Output devices:

Output device display information in the way that you can see and understand .the most common output device is printer and hard disk. Due to bad sectors or too small free volume on hard disk some undesired situations occur such as loss of files, system hanging and abnormal filming.

2.3.2.9 DMS (Data Measurement System):

Located on the Gantry Rotor, its function is Converts X-ray radiation passed through the patient's body into digital data, Preprocesses the digital data (compress the data), Transfers preprocessed data to the Operating Console via the Optical Link,

Transfers RAW data to the Host Computer (Data Receiving Card) for the reconstruction process.

CHAPTER THREE
THEORETICAL BACK GROUND

Springer Berlin Heidelberg (2014), in this century, medical imaging is at the heart of medical practice. Besides providing fast and accurate diagnosis, advances in radiology equipment offer new and previously non-existing options for treatment guidance with quite low morbidity, resulting in the improvement of health outcomes and quality of life for the patients. Although rapid technological development created new medical imaging modalities and methods, the same progress speed resulted in accelerated technical and functional obsolescence of the same medical imaging equipment, consequently creating a need for renewal. Older equipment has a high risk of failures and breakdowns, which might cause delays in diagnosis and treatment of the patient, and safety problems both for the patient and the medical staff. The European Society of Radiology is promoting the use of up-to-date equipment, especially in the context of the EuroSafe Imaging Campaign, as the use of up-to-date equipment will improve quality and safety in medical imaging. Every healthcare institution or authority should have a plan for medical imaging equipment upgrade or renewal. This plan should look forward a minimum of 5 years, with annual updates [14].

Adrian Brady (Jan 2012),Errors are inevitable, in medicine as in life, and the concept of necessary fallibility must be accepted. Equally a threshold of competency is required of all professionals involved in the delivery of medical services. In this paper, we explore the concepts of error and discrepancy in radiology, discuss some of the factors which may contribute to errors and discrepancies, and outline a graduated approach to the management of perceived or identified errors or discrepancies in radiological practice, which, with appropriate adaptation, may be applicable to similar scenarios in other specialties[15].

AlineGarcia Pereira (Sept./Oct. 2015), The present study was aimed at reviewing the literature to identify solutions for problems observed in radiology services .Basic, qualitative, exploratory literature review at Scopus and SciELO databases, utilizing the Mendeley and Illustrator CC Adobe software's. In the databases, 565 papers – 120 out of them, pdf free – were identified. Problems observed in the radiology sector are related to procedures scheduling, humanization, lack of training, poor knowledge and use of management techniques, and interaction with users. The design management provides the services with interesting solutions such as Benchmarking, CRM, Lean Approach, Service Blueprinting, and continued education, among others. Literature review is an important tool to identify problems and respective solutions. However, considering the small number of studies approaching management of radiology services, this is a great field of research for the development of deeper studies [16].

ECRI (Jan 1989) continues to receive and review numerous reports of mechanical failures in radiologic equipment that either resulted in or had the potential to cause serious patient injury or death. After examining many other malfunctions that occur with radiologic equipment and assessing how these malfunctions are detected, we have concluded that mechanical components are not being properly inspected during routine inspection and preventive maintenance.They investigated information on malfunctions discovered in the Nordic countries (Finland, Norway, Sweden) compiled by STUK and reviewed incidents cited in ECRI's Health Devices Alerts database (1976-present), as well as the FDA's Device Experience Network (DEN) and Medical Device Reporting (MDR) databases (1984-present). Our investigation revealed that malfunctions of radiologic devices were discovered during acceptance testing, periodic inspections, and use. Malfunctions discovered during use were most likely to cause serious injury; however, it is also clear that when acceptance testing and periodic inspections are performed consistently and properly, failures during clinical use are reduced significantly. Malfunctions related to improper design or manufacturing errors (e.g., incorrect or improper radiation filtration) were usually identified during acceptance testing. Malfunctions discovered at this stage often result in manufacturer recalls, thereby benefiting other customers [17].

Srinivasan Kathiravan a,JagannathanKanakaraj,29 October 2013, Magnetic resonance imaging is a noninvasive technique that has been developed for its excellent depiction of soft tissue contrasts. Instruments capable of ultra-high field strengths, ≥7 Tesla, were recently engineered and have resulted in higher signal-to-noise and higher resolution images. This paper presents various subsystems of the MR imaging systems like the magnet subsystem, gradient subsystem, and also various issues which arise due to the magnet. Further, it also portrays finer details about the RF coils and transceiver and also various limitations of the RF coils and transceiver. Moreover, the concept behind the data processing system and the challenges related to it were also depicted. Finally, the various artifacts associated with the MR imaging were clearly pointed out. It also presents a brief overview about all the challenges related to MR imaging system [18].

CHAPTER FOUR
METHODOLOGY

4.1 Methodology:

The methodology for this research includes empirical field observation and field level data collection through inventory meetings, survey and interviews.

The collected data with interviews survey and observation were analyzed properly.

4.1.1 Study Duration:

A period of nine months (from March to December).

4.1.2 Study population:

Personal interviews with the technicians, biomedical engineers of hospitals, biomedical engineers of medical companies and manager of hospitals and administrators.

4.1.3 Data collection technologies and tools:

Observation and field level data collection through inventory meetings, survey, text book, paper, internet and interviews with the technicians, biomedical engineers of hospitals, biomedical engineers of companies and managers of hospitals and administrators were done to identify the most frequent failures that have been happened in these devices(CT, MRI) what its causes, how to treat these errors ,how it is being calibrated to maintain the quality of the device and reduce the cost using questionnaire method. Moreover, the benefits on how to prevent these faults to repeat again and powerful recommendation was investigated to maintain and give a sustainable healthcare.

CHAPTER FIVE

RESULTS AND DISCUSSION

5. Results and discussion:

This chapter show the result and discussion of the result.

5.1 Results:

Table (5.1) represent a summary of the results obtained through the survey.

The problem	**Percentage**
Cooling system problems	95% (MRI)
Others	5% (MRI)
X-ray Tube	45%(CT)
Mechanical part(spare parts)	40% (CT)
Others	15% (CT)
The hospital provides training course only when the device is bought.	95% (CT and MRI)
The percentage of applying quality control (QC) of these devices.	5% (CT and MRI)
Does the hospital constrain about life span of these devices?	10%(CT and MRI)
The percentage of hospital follow maintenance program with spare parts	35% (CT and MRI)
The percentage of logging device faults into the log book	15% (CT and MRI)
Availability of spare parts in storage	30% (CT and MRI)

5.2. Discussion:

The most common faults in CT is happen in X-ray tube and this is happen due to overheating, gasy and oily tube evacuating, filament damage, mirror surface, Stator winding or tube arcing. The proposed solution that should take is replacement of tube.

Also in High voltage (HV) Generator it is stop working due to failure in its coil or it's due to phase shifting in the power supply. The suggested solution that should take is to replacement of generator and calibration, or adjustment and calibration of power supply.

Moreover the main causes of faults in Gantry rotation is come from Servo Motor defect, tiltation Pump (motor) failure or due to un balance base (Vibration) .The proposed solution is to replace the defected motor or check rotation balance (Check rotation balance when changing tube or other large parts. Check the force needed to get the system moving at 0^{o} , 90^{o} , 180^{o} and 270^{o} with a push/pull gauge (limit = differences within 1 kg).

On the other hand the detectors failure come from dust, foreign body, environment factors (heat, cold), power, one or more Channel damage. The suggested solution consequently is to maintenance according to the type of error (miss connection, environmental problems), adjustment of the output power, detector replacement or applying preventive maintenance.

The main causes of faults in isocenter problem is happen when changing the Lamp size, light source orifice, low voltage supply or alignment. The proposed solution that should take is calibration and adjustment (move the cover, adjust the position of the position lamps on the support and re-fix them ,Fix the position lamp cover; lighten the laser position lamps to check if the point of the beam intersection is located at the center of the magnet. Repeat the above steps until the requirement is met).

The first type of artifact is "ring artifact", it come from miss calibrated or defective detector element. The proposed solution that should take is usually, recalibrating the detector is sufficient to fix this artifact or the detector itself needs to be replaced.

Another type of artifact is called "beam hardening artifact" (cupping artifacts) and is happen when X _rays passing through the middle portion of a uniform cylindrical phantom are hardened more than those passing though the edges because they are passing though more material. The suggested solution is filtration, calibration correction, and beam hardening correction software.

Also in" Dark streaks bands" artifact is happen when the portion of the beam that passes through one of the objects at certain tube positions is hardened less than when it passes through both objects at other tube positions. The proposed solution is filtration, calibration correction, and beam hardening correction software.

The third one is the artifact that happen due to present of metallic materials. The proposed solution is that Patients should asked to take off removable metal objects such as jewelry before scanning commences, Software corrections for metal artifacts such as interpolation techniques, For non-removable items, such as dental fillings, prosthetic devices, and surgical clips, it is sometimes possible to use gantry angulation to exclude the metal inserts from scans of nearby anatomy.

Fourthly, patient motion artifact come from motion of patient itself. The suggested solution is use of positioning aids is sufficient to prevent voluntary movement in most patients, However, in some cases (eg, pediatric patients), it may be necessary to immobilize the patient by means of sedation. Using as short a scan time as possible helps minimize artifacts when scanning regions prone to movement. And in respiratory motion, motion can be minimized if patients are able to hold their breath for the duration of the scan.

CT number failure come from absent of preventive maintenance and calibration or the life span of X_ ray tube expired. The proposed solution is calibration and constrain with life span of the x ray tube.

Moreover Table failure is come from absence of preventive maintenance ,power supply, motor defect, overweight or un cleaning (vomiting).The proposed solutions is apply the preventive maintenance and calibration. When special situation happen when patients undergo examination, such as vomiting or bleeding, the countermeasure should be taken immediately to prevent the spew, blood, or excrement from entering inside patient couch and the bloodstain should be wiped away with hydrogen peroxide. Also adjustment of output power and replace the motor, consequently.

Output devices such as hard disk and printer are failure due to the absence of preventive maintenance or when there are small free volume on hard disk. The proposed solution is calibration, normal maintenance of hard disk includes the following procedures (delete some image files to increase free volume on hard disk (at least 50M) when the free volume is too small .also Run SCANDISK option under DOS environment regularly (e.g. every 1 or 2 months) to regulate status of hard disk and take record of the bad sectors as well, consequently.

Message like (F06 messagemotor temperature) means that the motor thermostat has been activated or feedback connector is loose or break in feedback cable. The Solution that should take is wait until motor has cooled down, then check why it became so hot. Or use new feedback cable.

Another message such as (F01messageheat sink temperature) means that permissible heat sink temperature exceeded. The solution is to improve ventilation of room.

This is all problems related to CT scan,the problems according to MRI is classified as hardware problems, software problems, power problems and environmental problems.

According to power supply faults there are some cases like when the alarm is on and the power stabilizer is switched on by the bypass, that mean is there is a problem in driver board, the fuse is broken, or the surge absorberis failed, the proposed solution is to replace the driver board, replace the fuse, or replace the surge absorber.

Furthermore when the voltage meter indicates that the power supply system is lack of phase(s), that mean is there is a problem in power board or the CPU board is failed.The proposed solution is to replace the power board or to replace the CPU board.

When circuit breaker is overload tripped,that mean there is a short circuit within the transformer of the main loop or there is short circuit within external load. The proposed solution is to replace the corresponding transformer or check on the external load.

On the other hand when the output voltage exceeds the precision of power stabilizerthat mean there is a difference between the local power network and the factory-test-environment.The proposed solution is adjusting the VR1 potentiometer on the CPU board.

When the voltage meter display wrongly.The proposed cause of this problem is refer to deviation during transportation, the proposed solution is adjusting the VR3 potentiometer on the CPU board.

Hardware problems include cooling system, Coils failure, Gradient coil faults, Gradient amplifier faults, RF amplifier faults, shimming (zero field).

Chiller failed due to reduce level of helium, cold head failure, slow flow of water, compressor failure, dust, defected components, contamination. The proposed solution is to provide back up of chiller, filling helium, replace cold head with another one, apply preventive maintenance, replace compressor, applying Ideal environment of chiller, consequently.

Most MRI coil (Body coils) failures occur due to one of three reasons.firstly frequent use (over load), as with any electronic device frequent use of a product can cause failure over time. Electronic components break down, poor solder connections fail, flexible components experience metal fatigue and become brittle, and system transients (nonstandard operating currents/voltages) expose design limitations. The second reasons is failure due to impact, Failures due to impact, such as when the coil is dropped or roughly handled, are the second most frequent cause of coil replacement or repair. The third reason is improper use, finally, improper use of MRI coils also drives failures. One example of improper use is trying to use a transmit /receive (T/R) coil in conjunction with a large body coil. This will cause the electronics in the T/R coil to break down due to an increase of focused energy levels from the body coil. Additionally, coil connectors usually fail when forcefully pulled from the system connection port. The proposed solution is to proper handling of the coils Preventive maintenance, or Operators should use extreme care when disconnecting a surface coil from the scanner port because MRI coil connections usually cannot be repaired onsite, consequently. Appropriate use and care of the equipment will greatly reduce the occurrence of failures.

When there is no output from gradient coils that mean the Gradient coil failure .This mean there is abnormality of power module. The proposed solution is measure the output voltage, replaces the relevant module if the output voltage is higher than the rated by 1.2.

According to gradient amplifier faults there are some cases , firstly when LEDs on front panel are dimly flashing the possible cause is that Gradient power board is not starting or Incorrect setting of ‘Master' and "Slave"in gradientamplifier module, so the proposed solution is to check setting of "Master" and "Slave". If the setting is correct and system isn't working, replace the gradient amplifier module. If not adjust the connection interface properly.

In the case when "power" LED is green and "OPERATION LED" is red, this mean the button" ON/OFF" is off, the proposed solution is to check the button ON/OFF. If button is correct and system isn’t working, replace the gradient amplifier module, if not replace the button "ON/OFF" and calibrate the newer one.

When" OPERATION LED" is red and "OVER CURRENT"LED is also red that mean current output is too large, so press button "RESET". If it isn’twork, check the input signal. If input signal is correct and system isn’t working, replace the gradient amplifier module. If not adjust the input signal to solve this problem.

When "POWER" LED is red, and "OPERATION" LED is red this mean the inner power or external power fault. You should better to check the input voltage of module. If it the voltage is between 130V and 160V, and system isn’t working, replace the gradient amplifier module, if not adjust the input power.

When "OPERATION" LED is red, and "HOT" LED is red that mean the bare radiator is too hot, so switch device off and wait for 10 minutes. If fault still exists, replace the gradient amplifier module to solve this problem.

When OPERATION LED is red,"FAULT" LED is red that mean power output board failure, so replace the gradient amplifier module with another one to solve this problem.

According to RF amplifier faults there are some cases , firstly when power ready and there is a fault indicator LEDs are off that mean there is no AC power supply for amplifier or error with main circuit of RF amplifier, so it is better to check whether the power supply is correct or not. If yes, there should be error with main circuit of RF amplifier so replace RFamplifier.if not adjust the power supply.

In case FAULT indicator LED is On that mean reflecting power, peak power or averaged power is too high, so adjust VSWR of RF coils or adjust transmission attenuation.

When energizing," FAULT indicator LED is ON", that mean there are troubles with fuses or capacitances, so replace fuses, capacitances or RF amplifier accordingly.

On the other hand Shimming problem (zero field) happen when there is low level of helium(less than 20%), absent of preventive maintenance, bad shimming during configuration, have an accident that enforce the technician to press the quench key for safety (quench for safety), during filling the helium especially when the level of the helium is under 50% and when the filling is increase and reach 100% (the acceptance level is till 98%), failure of cold head or the compressor stop working, or iron constructions in walls and floor of the examination room become magnetized and disturb the field of the scanner. The proposed solution is filling helium, Calibration and adjustment of cold head and compressor, apply shimming test, concentrated on MRI safety guidelines, consequently.

Software problems include Image artifacts(vertical strips appeared on image, points over image in vertical direction appears ,on image there is only a longitudinal or horizontal bright line, motion artifact, chemical-shift artifacts, zipper artifacts, metal Artifact), frequency drift, mouse failed, keyboard failed, no signal, images cannot be transferred, environmental problems (size, cleaning, temperature)).

When there are vertical strips appeared on image that mean there is error with buffer circuit of Interface panel. The proposed solution is to replace chip IC15 on Interface panel.

When there are points over image in vertical direction appears that mean there is an error with 8500 memory circuit. The proposed Solution is to replace memory chip(s).

When there is only a longitudinal or horizontal bright line on image that mean there is abnormality of encoding process in gradient magnet. Probably, it is due to the abnormal function of gradient amplifier in one or two channels of X, Y, and Z three channels, which causes no current to be outputted, therefore no required gradient magnetic field to be created, thus encoding fails. The proposed solution is to check whether gradient amplifiers are powered on, check the LEDs of gradient amplifiers and press RESET button if any one of them is red, Carry on scanning while no LED is red. Otherwise, turn off gradient amplifier and wait for 10 minutes. If any LED is still red after the above procedures, contact us for advice and service.

Motion artifact happen due to Patient motion, so the proposed solution is that patients should be advised to hold their breathing during the exam or using faster sequences and respiratory-ordered phase encoding in case of involuntary motion like heartbeats, and blood flow.

Chemical-shift artifacts happen because fat and water molecules oscillate differently within the magnetic field, causing them to show up differently during the encoding. The proposed solution is increasing the bandwidth, reducing the matrix size, or suppressing the fat-frequency signal can all minimize this artifact.

Zipper artifactsoccur when something in the environment interferes with the MRI unit, such as devices in the MR room, blinking light bulbs, the door not being securely shut, or nearby construction. The proposed Solution is removing the source of interference should eliminate the artifact, MRI room are typically isolated and strictly controlled to minimize the chance of interference.

Metal Artifact occur due to the presence of metal. The proposed solution is remove the metal or acquire Thinner Slices.

Frequency drift happen when operating frequency changes with the magnetic field intensity which is changes with the temperature of scan room and magnet temperature. Frequency drift would happen when the difference between the operating frequency and the set central frequency of spectrometer is more than 20 kHz. The proposed solution is check air conditioner and magnet thermostat, users can adjust central frequency of system for the time being according to the change of temperature, i.e. decrease central frequency when temperature goes up or increase central frequency when temperature goes down. By this manner, system may work properly temporally, Be sure to reset central frequency to default value after air conditioner and magnet thermostat functions properly. Check temperature thermostat so that the temperature regime is 32℃± 0.2℃.

Mouse is failed if it is spoiled or mouse is disconnected. The Solution is test the connector of the switch line or the switch line itself and repair it .Otherwise, it indicates that the mouse is spoiled, so replace the mouse.

Keyboard is failed if it is spoiled or keyboard is disconnected. The proposed Solution is test the connector of the switch line or the switch line itself and repair it. otherwise, it indicates that the keyboard is spoiled. Replace the keyboard.

There are many reasons when there is" NO signal" is detected .This problem mean that there is an error in one of these components , RF waveform generator, RF power amplifier, RF coils or Pre-amplifier. The proposed Solution is (Necessary examination instrument: oscillograph, millimeter) First of all, check all the junctions on the components to make sure that they are not loose or improperly connected and measure the output by millimeter if necessary. Secondly, check working status of each component. In RF waveform generator check the output of RF waveform generator on the back panel of spectrometer, and observe the output with oscilloscope. RF waveform generator can function properly if waveform is shown on oscilloscope screen.

In RF power amplifier check LEDs on RF power amplifier panel. Turn off RF power amplifier first if any FAULT LED is ON and make sure that RF power amplifier is properly connected with filter and filter is properly connected with Tx coils. Turn on RF power amplifier. If any FAULT LED is ON, take note of the fault of LED.

In RF coil replace RF coil with another. For instance, if there is no signal while scanning with a head coil, then replace the head coil with a body coil and tune frequency. It indicates that the head coil has problem if signal is detected. Otherwise, check other components.

Finally, in Pre-amplifier generally, preamplifier is not liable to be damaged because it is housed in the magnet enclosure. If it is necessary to check preamplifier when all the other components function normally like the output of filter panel that should be +15V and all the connection is perfect, contact with company. The test should only be done when qualified engineers are present on the field.

When Images cannot be transferred and If the start-up sequence is not so, or the connection of Ethernet cables is loose, system would be incapable of transferring images. The proposed solution is to check whether any connection is loose or disconnected and replace the Ethernet cables if necessary.

Finally Environmental problems (size, cleaning, temperature),The problem According to the size is that hospitals order equipment's after the building is finish (incorrect layout), don't considered MRI safety guidelines and absence of preventive maintenance. The proposed solution is all site construction should be completed before equipment is delivered and installation starts. Attempting to install the system while construction is under way will impact installation efficiency and further delay the completion of site completion. Making sure that all pre-installation and construction work is completed before equipment is delivered will usually result in an earlier turnover date. According to Cleaning, floor should be cleaned by vacuum cleaner to avoid raising a dust. Be careful not let water or liquid detergent enter inside the equipment if the former is necessary in cleaning. Magnet enclosure, patient couch and Rx coils should be Clean with mild detergent instead of strong alkali or strong acidic detergent and wipe away stain with a piece of cloth. Be careful not to let water or liquid enter inside Rx coils, laser localizer panel sand the sockets of Rx coils. Otherwise, short circuit may be caused to charged components and the serious damage may be incurred. Finally temperature should be in the range (23±3).

Another issue is there are many devices stop working due to in availability of spare parts. This study show that the main causes of failure of this devices is due to it take a long time getting these spare parts. Failure cases are caused by deterioration of consumable components including accessories. This deterioration can be predicted, and the designated lifespan of general consumable components can achieve from the experience and good knowledge of medical equipment. If the frequency of equipment usage should be analyzed well, then questions such as what, when and how many consumable components are required can be predicted. Estimation on procurement, and stock and use of the consumable components should be done every fiscal year. .but unfortunately this do not happen in most hospitals .Consequently the purchase process for such component should be easy enough to replace them quickly when needed. And for parts that are highly critical and predicted to fail frequently, it should be held in stock to avoid the possibility of stock out situation in case of failure. But sometimes they could not make all of these spare parts available even they know them, for example X-ray tube part that deteriorate frequently in CT scan. It is difficult to keep this part available in stock because of its very high cost which is between $30,000 and $45,000. So in this case hospitals should find a way to purchase these parts quickly as required by the maintenance department to avoid any delay in repairing the device, and should be supplied by making a deal with the suppliers to deliver them in a short time when necessary.

Another very essential issue is the maintenance that manages the reliability and safety of medical equipment through maintenance and inspection. Use of unsafe and unreliable equipment can cause fatal medical accidents. The medical equipment has a vital role to take care of the life of the patient, directly or indirectly. Carrying out regular inspection is, therefore, essential to prevent breakdowns, to maintain accurate and hazard-free functioning of equipment, to attain the expected lifespan of equipment; and to maintain and manage equipment rationally and economically. So by applying effectively preventative maintenance and repairs will help to ensure that medical devices are being properly maintained. But unfortunately there are a few hospitals that apply this issue and the discussion for this point is based on cost. The engineers said that if you have money why not! .So the administrators and managers of hospital must know the benefit of applying this issue and consider the future subsequences if they don’t apply it. A maintenance strategy includes procedures for inspection, as well as preventive and corrective maintenance. Performance inspections ensure that equipment is operating correctly, safety for both patients and operators, and preventive maintenance (PM) aims to extend the life of the equipment and reduce failure rates. Additionally, some hidden problems may be discovered during a scheduled inspection. However, performing inspections of equipment only ensures that the device is in good operating condition at the time of inspection and cannot eliminate the possibility of failure during future use; the nature of most electrical and mechanical components is that they can potentially fail at any time. Corrective maintenance (CM) restores the function of a failed device and allows it to be put back into service. An effective medical equipment maintenance program consists of adequate planning, management and implementation. Planning considers the financial, physical and human resources required to adequately implement the maintenance activities. Once the program has been defined, financial, personnel and operational aspects are continually examined and managed to ensure the program continues uninterrupted and improves as necessary. Ultimately, proper implementation of the program is key to ensuring optimal equipment functionality .Therefore when medical devices are routinely inspected and maintained, potential issues can be identified and resolved prior to the device malfunctioning or failing to work altogether, allow your facility to operate much more efficiently. By taking a proactive approach to medical equipment repair and maintenance, you can plan for the times when a certain device will be out of service. This can allow you to schedule your equipment repair, without having to compromise when it comes to actually serving the needs of your patients, Saving money because Complete replacement of a medical device or emergency repairs are often much more expensive than routine maintenance. So performing PPM was beneficial in detecting the fault before it exaggerates, reducing the downtime of the equipment, extends equipment life, improves equipment availability and retains equipment in proper condition, and provide a safe working environment for patient and operator. Also there are many malfunction happen when mechanical component are not being properly inspected during routine inspection and preventive maintenance .Malfunctions of radiologic devices were discovered during acceptance testing, periodic inspections, and use. Malfunctions discovered during use were most likely to cause serious injury; however, it is also clear that when acceptance testing and periodic inspections are performed consistently and properly, failures during clinical use are reduced significantly. Malfunctions related to improper design or manufacturing errors (e.g., incorrect or improper radiation filtration) were usually identified during acceptance testing. Malfunctions discovered at this stage often result in manufacturer recalls. Here the problem is that although outside services perform inspections and preventive maintenance procedures; yet, mechanical malfunctions still occur. Therefore, hospitals must check that manufacturers and third parties perform sufficiently thorough mechanical inspections by Ensure that all mechanical components are examined during periodic inspections of radiologic devices and that worn or faulty parts are replaced immediately, exercise all moving components and structures

Training staff is one of the important point that don’t consider and this study show that the engineers only go for training when the hospital got the device, The maintenance of the machine is limited to the engineers of companies and in each company only one or two engineers are responsible for the maintenance work. There are many devices inside and outside the state, the failure of two devices at the same time may lead to the loss of time waiting for the engineer in charge of the specific model, thus wasting time and increasing cost .Through the study I spent a long time to find the engineer that is specialized in these devices to discuss the failure of these two devices, their causes, how to treat them and how to avoid them if possible. Therefore, getting this information together was so difficult, and this is a real problem for these two devices that I have faced. So it must ensure that training needs of staff have been identified in the system of the hospital as one of the basic rule, and that staff are competent on the medical devices in their area and that training records are well documented. This responsibility will extend to the induction of new staff .The training courses must be up to date and should continuously develop standards of courses.When staff is either not fully trained or experienced, more time is needed for support and/or supervision to assure the defined outcomes are met. The lack of experienced staff means there are not the role models, preceptors or mentors needed to assist the newer staff as they work to become oriented to the role and/or facility, and this is very real problem that I have noticed from this survey is that the maintenance is reserved for certain people, for this reason there are many CT and MRI devices stop working waiting expert one to solve their problem, because the majority of them are not found in the city travelling to solve another problem in these devices, so a lot of time waste, and this is very sensitive problem specially threaten in MRI. Also this impacts the length of time it takes for beginner to gain confidence in their ability to complete the expected work in a safe and quality manner. For most of us, the shortage of staff resources has the most impact on our ability to provide the level of service we want to provide and is the second highest factor determining whether or not we are satisfied with our jobs and work environment.

A log book is a record used to save all the activities carried out on equipment, it should contain data such as model, preventive maintenance that have done, all spare parts that have used and replaced, the corrective maintenance that have done. So all maintenance process should be reported and documented in the logbook, but this study show that some hospitals haven’t got log book which delay the maintenance process.

One of the main reasons for stopping the devices is the absence of calibration and this is what is done in the quality control where the calibration of devices is applied to ensure accuracy in test results by carefully monitoring test procedures. The quality control is very essential task and become indispensable issue especially in complicated devices such as CT and MRI.it reduce hazard of radiation by specify the amount of radiation that is adequate to produce a diagnostic image , comfort of the patient in reduce patient waiting time, check the components of the device if it perform its functions correctly and calibrate it to ensure the quality of the image using phantoms and all these things comes back positively to prolong the life of the device and ensure its safety. But unfortunately all the engineers and administrators of hospitals said that they do not apply quality control because theydid not allocate a special budget to it. Their thinking is limited to the present time not according to the consequences at the long term .This is what makes most of the devices stand-off and lead to complex problems that could have been avoided. So manufacturers must establish and follow quality systems to help ensure that their products consistently meet applicable requirements and specifications.

Another issue that have shown in this study is that is that most of the service contracts written by doctors, whom don't have the knowledge about the devices. They should be aware of these medical devices and all the services and spare parts that the machine needs should be written in the contract to decrease the time of maintenance at the end.

On the other hand One of the important issue that we have consider is the Life Cycle of medical devices, this cycle is begins with a process of acquisition

, planning, and continues into installation, acceptance testing, usage, monitoring, maintenance and decommissioning, And the lifespan of medical equipment is generally set between five and seven years. Although this is very important point that we should consider, there are many hospitals do not constrain about this issue of devices and the life cycle doesn't begin and end correctly because part of this medical devices were enter to our country as a second hand or a donation, and the life span for this devices are almost expired, especially in developing countries the purchase load of new equipment is a heavy financial burden, and uses this old model can make the maintenance too complicated, difficult and high cost. Although the life span of a biomedical devices can be longer or shorter depends on a number of factors frequency of use, nature of use, environment of use , the personnel do not exploit this issue for elongate the life time of devices and minimize the opportunity of malfunction, but there are overload in the work like what happen in X-ray of CT scan ,it almost stop working because the technician do not constrain about the number of pictures that should take per day, and these unfortunately the most common problem in CT scan. So the engineers or technician must comply with the life span of medical devices to prevent future problems and minimize cost

CHAPTER SIX

CONCLUSION AND DISCUSSION

6.1 Conclusion:

Failures in CT scan and MRI equipment, cases are caused by a lot of factors. Preventable factors (inappropriate handling (misuse) and inadequate maintenance (deterioration of consumable parts)). Most failures arise from deterioration of accessories and consumable components. The deterioration time of the accessories and consumable components can, however, be predicted by carrying out maintenance and inspection. Therefore failures can be prevented by replacing such 'consumable parts' on a regular basis, or replacing them immediately when the equipment becomes defective. These are not real breakdowns of the equipment. In addition to this, failures due to inappropriate handling, environmental stress and wear-out can also be prevented by carrying out appropriate measures based on preventive maintenance. Through the discussion It can be said that the majority of error, preventable.

6.2Recommendations:

- An ideal design and proper installation, continuous quality program should be applied.
- The operation and service manual for each device must be provide.

- Consider the climate of Sudan when designing a suitable environment for the devices.
- Address the problem of electricity in respect of spike and find solutions for it.

- Document the faults of the device in log book to estimate the consumable spare parts annually in order to reduce the time required for maintenance and facilitate the maintenance process at the end.
- Service contract must be written in a proper way by an engineer to ensure its conformity with the required specifications, its availability of spare parts and complete its life cycle of the device correctly.

- Discrepancy meetings must be applied as a method of learning process.

- Training courses should be applied for all staff and must be up to date to improve the effectiveness of the workforce.

- Availability of trained and certified engineer within the department.
- Hospitals must check that manufacturers and third parties perform sufficiently thorough mechanical inspections.
- Hospital should find a way to purchase spare parts that deteriorate frequently like X- ray tube in CT scan quickly as required by the maintenance department to avoid any delay in repairing the device. And

if spare parts that their prices are relatively high and the customers are not willing to hold them in stock therefore they should make a deal with the suppliers to deliver them in a short time when necessary.

- Proper storage and transportation should be done.

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Appendix:

Logbook example of Al Salaam hospital for CT scan (GE Company)

SERVICE CALL						
FAULT DESCRIPTION	WORK DESCRIPTION	SPARE PARTS	ORDER /DATE	REPARATION NOTES	TECHNICIAN	LOCATION
Cradle Error Code 12-1030-02, The table doesn't move IN-OUT position	Press the two Yellow bottoms in the two side at the end of the table.				Fabio, Sana	CT Scan
Stopped when working	wait for Antonio's availability			Problem solved by Scooter	Fabio	CT Scan
Phantom Calibration					Fabrizio, Dejan	CT Scan
	Checked all system files and errors logs,performed air and phantom calibration,performed image quality analysis				Scooter	CT Scan
Phantom Calibration					Amal, Zoba	CT Scan
Phantom Calibration					Sana, Zoba	CT Scan
Phantom Calibration					Beppe, Amal,Muhammad, Zoba	CT Scan
Phantom Calibration					Beppe, Amal,Abeer, Zoba	CT Scan
Phantom Calibration					Beppe, Amal,Abeer, Zoba	CT Scan
Phantom Calibration					Amal,Abeer, Zoba	CT Scan

A white scanning during sauté (preview) scan (Right one in the screen)	Restarted the machine and tested with phantom				Amal, Beppe	CT Scan
Doesn't switched on , Alarm on UPS "Changed battery"	Replaced the exhaust battery with new one (12V 7Ah)			Worked done by AROS technician	Amal, Lorenzo, Carlo	CT Scan
Alarm on UPS "Changed battery"	Need replaced the exhaust battery with one (12V 7Ah) , Carlo know the problem , for now reset acoustic alarm. Changed by new battery			By electrician	Lorenzo	CT Scan
Code error : 11-1010-02 , 11-1002-0F	Change the gantry, check all cables, switches(one switch was off) and board.			Need to change the switch on /off board , work done by the GE tech	Amal, Abeer, Lorenzo	CT Scan
Code error 30-1010-01	Cleaned all boards of the collimator				Lorenzo	CT Scan
PM	Warm-up and daily calibration, general condition ok.				Lorenzo	CT Scan
SD data error, does not pass daily calibration.	GE technician came and checked, the error is due to a fault in one of three hardware parts either the detector or the Bow filter or the CAM boards. The			Waiting GE Technician.	Stefano, Lorenzo, Eyman	CT Scan

	first two were clear to him but his doubts were on one of the CAM boards. Then, on 03/02/16 the local GE technicians came and done the following: Started by the current system backup to save all the parameters before altering it during testing. Next started the Service calibration=> Air calibration test, the test always stops at the final slides and display SD Data error. On the log book the error is more explained as "Error 189022 error channel 99" when repeating the calibration almost 10 times the same error appears but the number of the error channel changes; 66, 95, 89, 83, 118 and 112. When compared the number of these channels it was all					

	found in the range of CAM boards 4 and 5 only. Advised to change if possible.					
The central positioning light was not working; all the display, buttons and the light emitter were off.	The safety/lock button on the patient table was pressed. Unpressed the button to unlock the functions.				Enrico, Aseel	CT Scan
Yearly preventive maintenance by GE technician.	As a start he checked the error log for calibration problem, then he shoot on a film and found that the x-ray beam is not centered, started to allign beam by adjusting two screws near the filter after he got the centered beam and waited tube to cool down he did automated alignment following procedure, checked the filter of collimator was clean and good not cracked, Cleaned miler ring, inspect the fans were all running without problem,				Stefano, Lorenzo, Eyman	CT Scan

	checked x-ray tube oil level was good, inspect for leakage, cleaned the brushes using brush and hoover, cleaned the slip ring, adjusted light by moving screws situated below the camera from both left and right side after using grease gun and refilled the channel of the bearings about 5 times each after a complete circulation(360 C°), checked image quality by performing air, water and QC phantom all were good and within range. After checked system unnecessary raw data following procedure found in CD and erase them to improve system speed and performance.					