André E. Jardini (State Bar No. 71335)
aej@kpclegal.com
KNAPP, PETERSEN & CLARKE
500 North Brand Boulevard, 20th Floor
Glendale, California 91203-1904
Telephone: (818) 547-5000
Facsimile: (818) 547-5329

Attorneys for Plaintiff
RESONANCE TECHNOLOGY, INC.

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BY ____________

UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

RESONANCE TECHNOLOGY, INC.,

Plaintiff,

v.

NORDICNEUROLAB AS, a Norwegian corporation,

Defendant.

NO. CV08-06772 SVW (Ex)

COMPLAINT FOR PATENT INFRINGEMENT AND MISAPPROPRIATION OF TRADE SECRETS

DEMAND FOR JURY TRIAL

PRELIMINARY ALLEGATIONS

1. Plaintiff Resonance Technology, Inc., is a corporation in good standing existing under and by virtue of the laws of the State of California, with its principal place of business in Los Angeles County, California.

2. Plaintiff is in the business of designing and manufacturing video and audio services for use with magnetic resonance imaging ("MRI") systems. In particular, plaintiff designs and manufactures devices for the purpose of displaying LCD images and delivering audio signals in the magnet room of MRI systems.

3. Plaintiff alleges that defendant NodicNeuroLab AS is a Norwegian corporation with its principal place of business in Bergen, Norway ("NNL"). NNL does substantial and continuous business in California and Los Angeles County,

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including the sale of MRI equipment, including equipment that infringes the patents herein.

JURISDICTION AND VENUE

4. This court has subject matter jurisdiction over this action pursuant to 28 U.S.C. § 1331, federal question jurisdiction, 28 U.S.C. § 1332, diversity jurisdiction, 28 U.S.C. § 1338(a), patent action jurisdiction, and 1338(b), unfair competition (patent) jurisdiction.

5. Venue is proper in this court pursuant to 28 U.S.C. § 1391(b) because defendant NNL resides in this judicial district for venue purposes, and defendant NNL is subject to personal jurisdiction in this district, and 28 U.S.C. § 1400(b) providing for venue in this judicial district because defendant NNL resides herein and has committed acts of infringement herein, and has a regular and established place of business herein.

BACKGROUND ALLEGATIONS

A. The Patents

6. On May 2, 1995, the United States Patent Office issued to Mokhtar Ziarati patent number 5,412,419 (the "'419 patent"). A true and correct copy of the 5,412,419 patent is attached hereto as exhibit 1.

7. Among other things, the '419 patent permits audio and video LCD display to function in an MRI magnetic room.

8. On July 11, 1995, the United States Patent Office issued to Mokhtar Ziarati patent number 5,432,544 (the "'544 patent"). A true and correct copy of 5,432,544 patent is attached hereto as exhibit 2.

9. Among other things, the '544 patent concerns visual display on LCD devices in the magnet room of MRI systems. The '544 patent permits the display of MRI signals, ultrasonic signals, patient vital signs, and any other LCD visual imagery within a magnetic room of an MRI system. This is breakthrough technology. It permits a surgeon to view images from the MRI and other LCD

displays at the same time the surgeon is conducting surgical procedures. The technology also permits the patient to view LCD images for the purpose of patient comfort. Also, the technology permits the display of visual images at the same time the MRI device is recording images of patient brain activity for the purpose of important medical study known as functional MRI ("fMRI"). Prior to the development of plaintiff's technology, none of these displays would be possible in the magnet room due to interference by the visual and audio display devices with the MRI signals and interference by the MRI signal with the visual and audio devices.

10. On March 2, 1999, the United States Patent Office issued to Mokhtar Ziarati patent number 5,877,732 (the "'732 patent"). A true and correct copy of the 5,877,732 patent is attached hereto as exhibit 3. The '732 patent relates to video and audio systems. The invention relates to methods and apparatus for a combined video and audio system that provide three dimensional, high resolution video images and corresponding audible sound over the full frequency range to a patient positioned in an MRI electromagnetic environment.

11. The '419, '544 and '732 patents are valid and enforceable patents and belong to plaintiff. The patents have been assigned by the inventor to plaintiff Resonance Technology, Inc.

12. The Patent Office has reexamined the '419 patent and found it to be valid and enforceable. A true and correct copy of the Patent Office reexamination of the '419 patent is attached hereto as exhibit 4.

13. The '544 patent has been reexamined by the Patent Office and found to be valid and enforceable. A true and correct copy of the reexamination of the '544 patent is attached hereto as exhibit 5.

14. Defendant NNL has been given notice of its infringing activity.

15. Defendant NNL makes and sells MRI-compatible products, including an fMRI product known as "VisualSystem" integrating the NNL "EyeTracking Camera."

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16. The VisualSystem product practices the claims of the '419. '544 and '732 patents.

17. Defendant sells other products/devices which similarly infringe upon the '419, '544 and '732 patents.

18. Resonance Technology has never licensed NNL to make, use, sell or offer to sell products covered by the '419. '544 or '732 patents.

B. Infringement

19. Plaintiff is informed and believes, and based on that information and belief, alleges that defendant NNL has infringed the '419, '544 and '732 patents by using the patented technology in defendants' MRI systems, which defendant markets and sells in this district, in the State of California, and elsewhere. Defendant NNL has demonstrated and advertised its MRI system, which includes the '419, '544 and '732 patent technology, at product conferences and shows, marketing these infringing devices throughout the United States, including California and in this district.

20. Plaintiff is informed and believes and, based on that information and belief, alleges that defendant NNL is presently manufacturing and/or marketing MRI systems containing plaintiff's patented audio and LCD display technology in this district, in the State of California, and throughout the United States.

C. Notice of Infringement

21. After the patentability of the '419, '544 and '732 patents were determined by the patent office, plaintiff, through its counsel, contacted defendant NNL and gave notice concerning the apparent infringing activity, including the use of the technology in the "VisualSystem" product.

22. Despite this notice, defendant NNL based on information and belief, continues to actively manufacture and market its MRI systems, infringing the '419 '544 and '732 patents.

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First Claim

Infringement on the '419 Patent

23. Plaintiff refers to and incorporates herein by this reference each and every averment contained in paragraphs 1 through 22, inclusive, as set forth above.

24. Plaintiff is informed and believes and, based upon that information and belief, alleges that defendant NNL is infringing the '419 patent by making, selling, and using technology embodying the patent and invention and will continue to do so unless enjoined by this court.

25. Plaintiff has placed the required statutory notice on its products, including technology for audio and LCD display in the MRI magnetic room manufactured and sold by plaintiff under the '419 patent, and has given written notice to defendant NNL of its said infringement.

26. Plaintiff is informed and believes and, based upon that information and belief, alleges that defendant's MRI system and equipment has increased in value through the use of plaintiff's patented technology. Plaintiff, accordingly, seeks recovery of compensatory damages, which include, but are not limited to, the increased value of defendant's MRI system and equipment attributable to plaintiff's technology, royalties, and any other allowable damages.

27. Defendant NNL is infringing the '419 patent with full knowledge thereof, and the infringement is, therefore, in willful and wanton disregard of the rights of plaintiff. Accordingly, plaintiff seeks an award of treble damages and an award of its attorneys' fees incurred in bringing this action.

Second Claim

Infringement of the '544 Patent

28. Plaintiff refers to and incorporates herein by this reference each and every averment contained in paragraphs 1 through 22, inclusive, as set forth above.

29. Defendant NNL is infringing the '544 patent by making, selling, and using technology embodying the patented invention and will continue to do so unless

enjoined by this court.

30. Plaintiff has placed the required statutory notice on all LCD visual display devices and technology manufactured and sold by plaintiff under the '544 patent and has given written notice to defendant NNL of its said infringement.

31. Plaintiff is informed and believes and, based upon that information and belief, alleges that defendant's MRI system and equipment has increased in value through the use of plaintiff's patented technology. Plaintiff, accordingly, seeks recovery of compensatory damages, which include, but are not limited to, the increased value of defendant's MRI system and equipment attributable to plaintiff's technology, royalties, and any other allowable damages.

32. Defendant NNL is infringing the '544 patent with full knowledge thereof, and the infringement is, therefore, in willful and wanton disregard of the rights of plaintiff. Accordingly, plaintiff seeks an award of treble damages and an award of its attorneys' fees incurred in bringing this action.

Third Claim

Infringement of the '732 Patent

33. Plaintiff refers to and incorporates herein by this reference each and every averment contained in paragraphs 1 through 22, inclusive, as set forth above.

34. Defendants are infringing the '732 patent by making, selling and using technology embodying the patented invention and will continue to do so unless enjoined by this court.

35. Plaintiff has placed the required statutory notice on all LCD visual display devices and technology manufactured and sold by plaintiff under the '732 patent and has given written notice to defendants of its said infringement.

36. Plaintiff is informed and believes and, based upon that information and belief, alleges that defendants' MRI system and equipment has increased in value through the use of plaintiff's patented technology. Plaintiff, accordingly, seeks recovery of compensatory damages, which include, but are not limited to, the

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increased value of defendants' MRI system and equipment attributable to plaintiff's technology, royalties, and any other allowable damages.

Defendants are infringing the '732 patent with full knowledge thereof, and the infringement is, therefore, in willful and wanton disregard of the rights of plaintiff. Accordingly, plaintiff seeks an award of treble damages and an award of its attorneys' fees incurred in bringing this action.

WHEREFORE, plaintiff prays for the following relief:

First, Second and Third Claims:

1. An injunction, both preliminary and permanent, enjoining and restraining defendant NNL, its officers, agents, servants, employees, attorneys, and those in active concert and participation with it from further infringing said United States patent numbers 5,412,419, 5,432,544 and 5,877,732;

2. An accounting of defendant's profits and an award of damages sustained by plaintiff, trebled;

3. An award to plaintiff of its costs of this action and its reasonable attorneys' fees;

4. Damages for the actual loss caused by the misappropriation, unjust enrichment, royalty, or other damages necessary to compensate plaintiff; and

5. An award of reasonable attorneys' fees as authorized by Civil Code section 3426.4.

Dated: October 14, 2008

KNAPP, PETERSEN & CLARKE

By: [signature]
André E. Jardini
Attorneys for Plaintiff
RESONANCE TECHNOLOGY, INC.

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DEMAND FOR JURY TRIAL

Plaintiff, RESONANCE TECHNOLOGY, INC., hereby demands a trial by jury in the above-entitled matter.

Dated: October 14, 2008

KNAPP, PETERSEN & CLARKE

By: ______________________

André E. Jardini
Attorneys for Plaintiff
RESONANCE TECHNOLOGY, INC.

EXHIBIT 1

US005412419A

United States Patent [19]

Ziarati

[11] Patent Number: 5,412,419

[45] Date of Patent: May 2, 1995

[54] MAGNETIC RESONANCE IMAGING COMPATIBLE AUDIO AND VIDEO SYSTEM

[75] Inventor: Mokhtar Ziarati, Calabasas, Calif.

[73] Assignee: Susana Ziarati, North Hollywood, Calif.

[21] Appl. No.: 653,711

[22] Filed: Feb. 11, 1991

[51] Int. Cl.^{6} H04N 7/18

[52] U.S. Cl. 348/61; 348/77; 324/318; 128/653.2

[58] Field of Search .... 358/93, 901, 102, 110, 358/112; H04N 7/18; 128/653 R, 653 A, 653 AF, 653 CA, 653 SC; 381/94, 88, 90, 154, 159; 348/61, 77, 162

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AAPM report No. 20, "Site planning for Magnetic Resonance Imaging Systems," published in 1986 by the American Association of Physicists in Medicine.

Primary Examiner—Victor R. Kostak

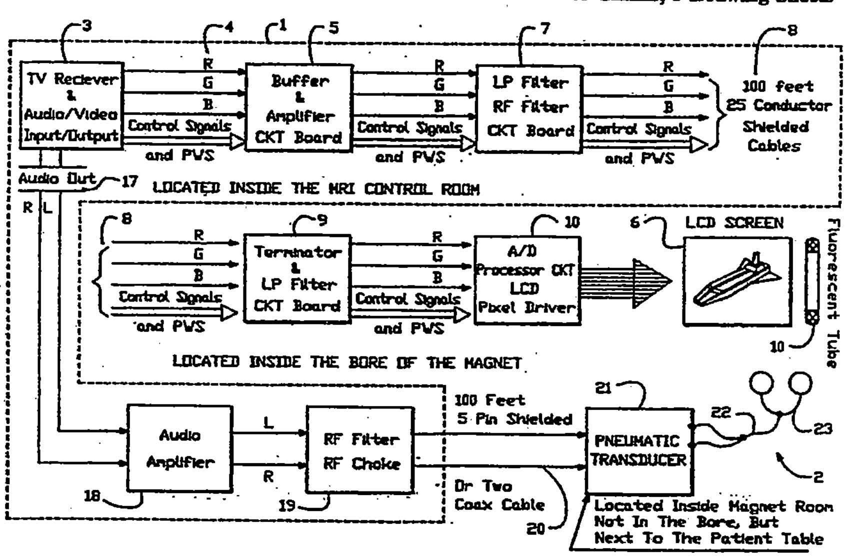
Assistant Examiner—Michael H. Lee

Attorney, Agent, or Firm—Wilson, Sonsini, Goodrich & Rosati

[57] ABSTRACT

An audio and video system that is compatible with the strong magnetic fields generated by Magnetic Resonance Imaging equipment (wherein the MRI equipment is separated by a penetration panel into a control room and a magnet room). The system receives an incoming RF signal through a television or video cassette recorder, and then separates the RF signal into a video section signal and an audio section signal. The video section signal passes through appropriate buffering, amplifying, low pass (for the procession frequency) and RF filtering circuits, and is next conducted through the penetration panel into the magnet room where it is terminated and filtered again for spurious noise. A processor and LCD pixel driver then process the video section signal and send it to an LCD display screen. A mushroom shaped hook is mounted to the screen and a catch is mounted to a bore of a main magnet inside the magnet room so that the LCD screen can be attached to the bore. The audio section signal is separated into two channels, passed through an amplifier and appropriate RF filters and chokes, and fed into a pneumatic transducer inside the magnet room. A headset having an inner set connects the output of the pneumatic transducer to the patient's ear, while an outer set covers the patient's ear to block out gradient knocking noises. In an alternate embodiment, a CCD camera is mounted inside the control room along with a microphone so that pictures and sounds from the MRI technologist can be broadcast through the present system to allow the patient to see and hear the technologist speaking. Fiber optics technology may also be incorporated into the signal conducted cables provided under this invention.

46 Claims, 3 Drawing Sheets



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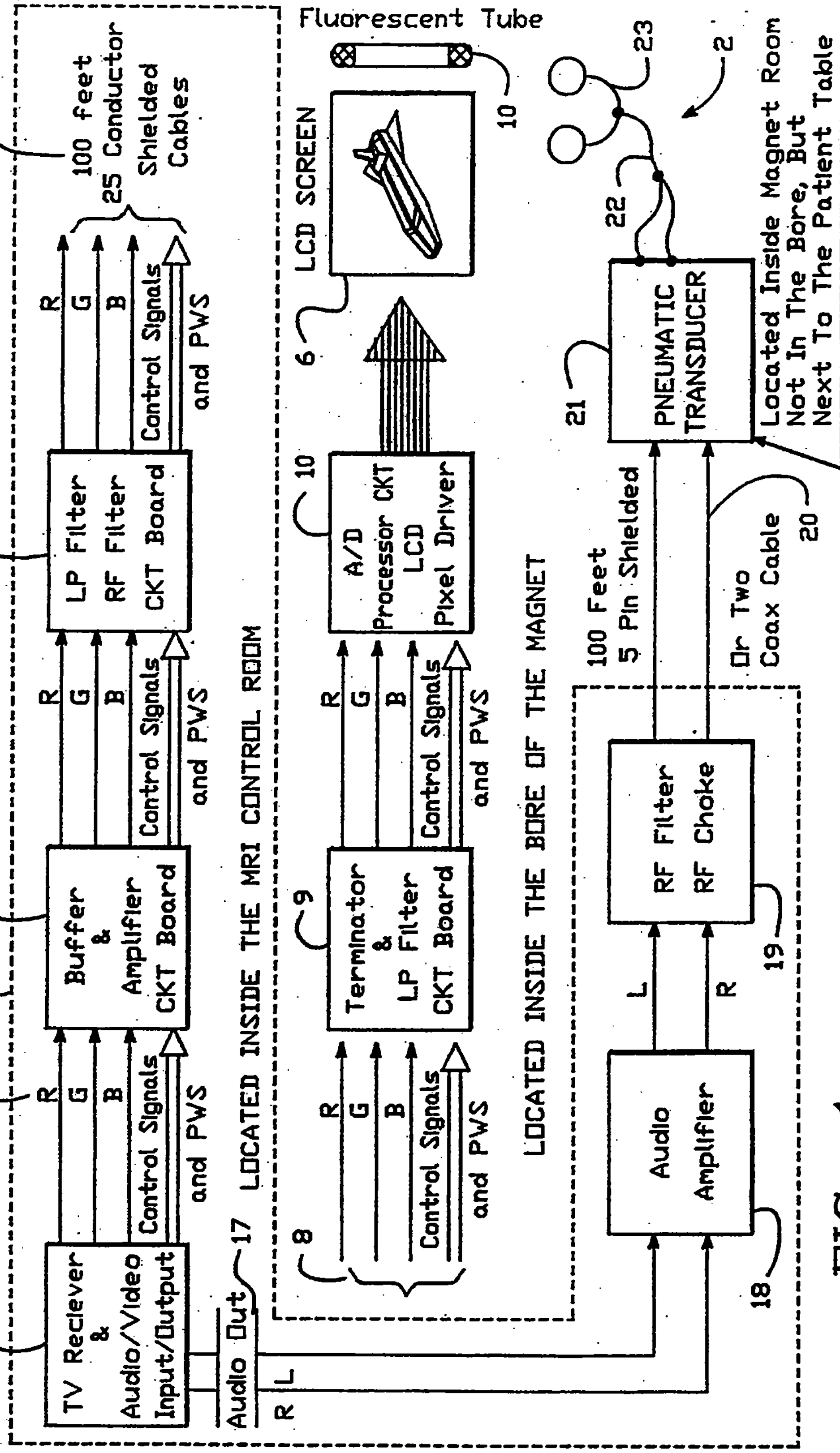
TV Reciever & Audio/Video Input/Output
Audio Out
R
L
Buffer & Amplifier CKT Board
LP Filter RF Filter CKT Board
R G B Control Signals and PWS
100 feet 25 Conductor Shielded Cables
LOCATED INSIDE THE MRI CONTROL ROOM
Terminator & LP Filter CKT Board
A/D Processor CKT LCD Pixel Driver
LCD SCREEN
Fluorescent Tube
LOCATED INSIDE THE BORE OF THE MAGNET
Audio Amplifier
RF Filter RF Choke
100 Feet 5 Pin Shielded
Or Two Coax Cable
PNEUMATIC TRANSDUCER
Located Inside Magnet Room Not In The Bore, But Next To The Patient Table
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FIG. — 1

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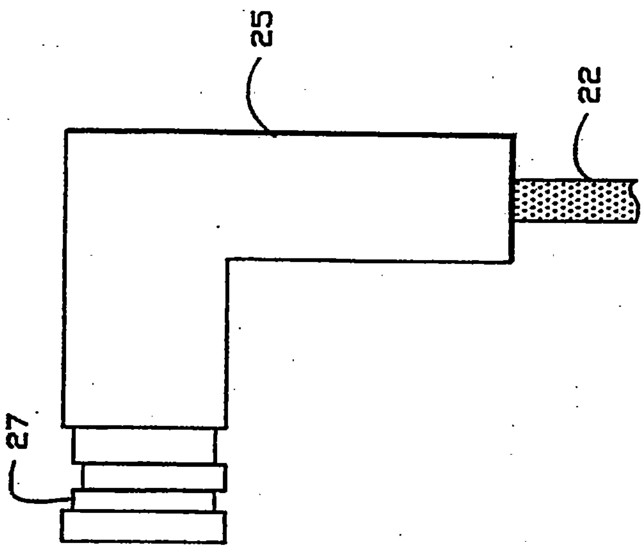

FIG.—3

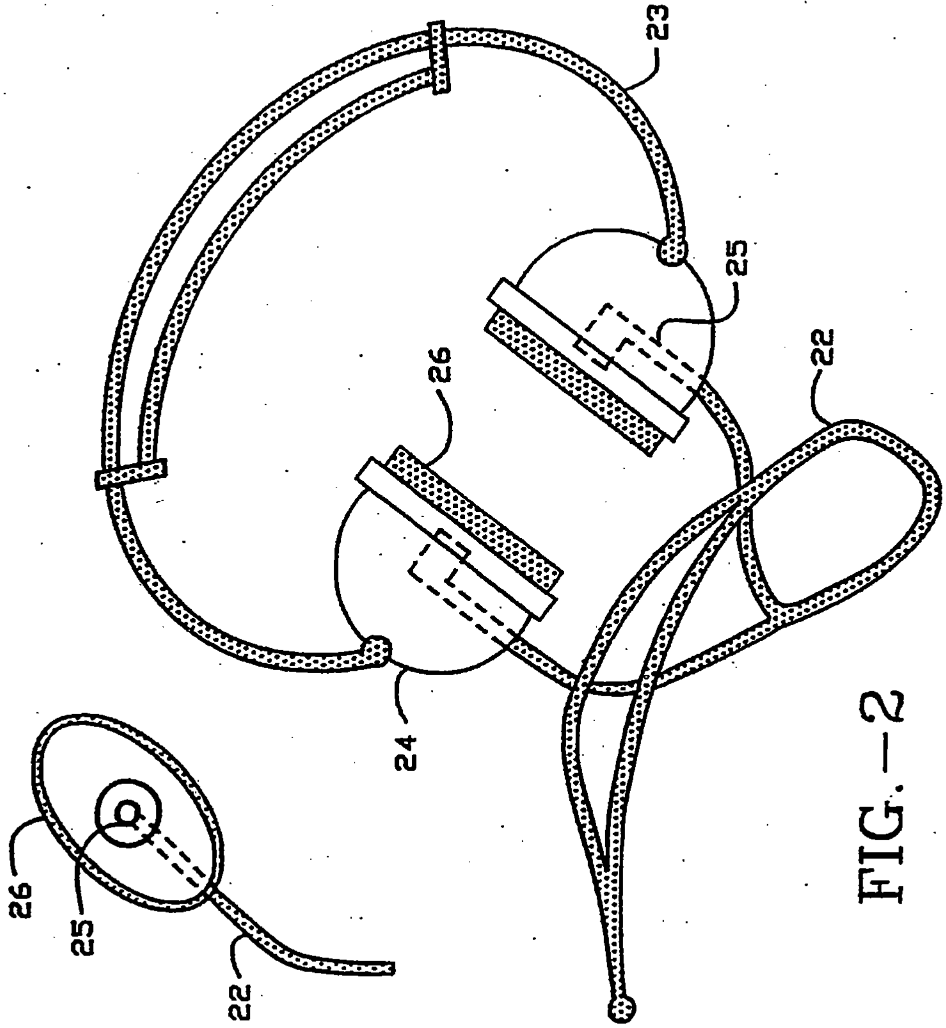

FIG.—2

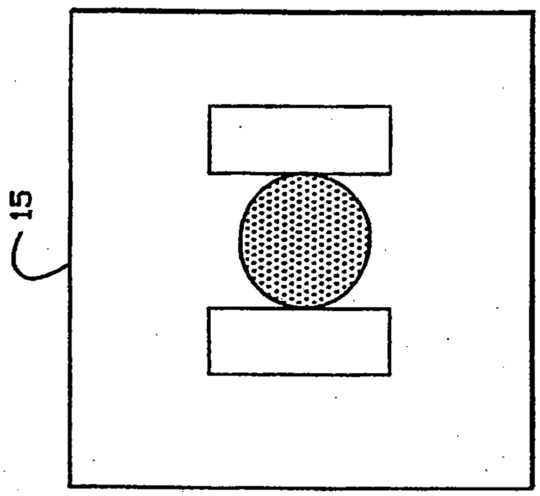

FIG.—6B

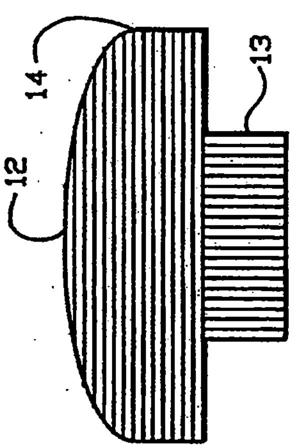

FIG.—5

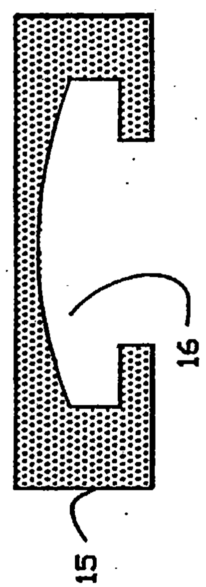

FIG.—6A

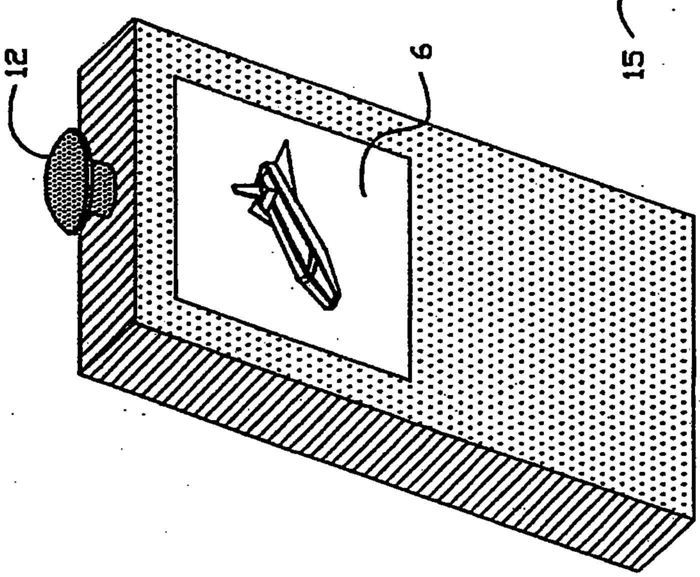

FIG.—4

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MAGNETIC RESONANCE IMAGING COMPATIBLE AUDIO AND VIDEO SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of magnetic resonance imaging equipment. More precisely, the present invention relates to an audio and video system including a liquid crystal display that is not disrupted by strong magnetic fields created by Magnetic Resonance Imaging devices.

2. Description of the Prior Art and Related Information

Magnetic Resonance Imaging (i.e., "MRI") is a relatively new scanning procedure being used in the medical community extensively. MRI is a valued technique for assisting doctors diagnose numerous medical ailments. The scanning procedure requires that a patient lie still inside a tunnel shaped enclosure called the bore. The MRI device uses a strong magnetic field that is generated around the patient's body. Disturbances in the field due to the presence of the body can be detected and translated into images displayed on a viewing screen.

MRI technology involves very sophisticated hardware. The most prominent piece of hardware is a large magnet that induces a strong, uniform, and static magnetic field. Generally, the magnetic field ranges from 0.5 Tesla to 2.0 Tesla inside the bore. Gradient coils disposed around the bore induce spatially variant magnetic fields (i.e., gradients) that modify the existing uniform magnetic field. To induce nuclear resonance, a transmitter emits radio waves through a coil, which coil couples the radio wave energy with the resonating nuclei inside the magnetic field. A receiver, also connected to the coil, receives the disrupted electromagnetic waves. The waves are filtered, amplified, and processed into visual data for viewing by an MRI technologist attending to the procedure. More detailed information regarding MRI equipment is available in a book entitled *Nuclear Magnetic Resonance*, pp. 53–66 (1st ed. 1981), the contents of which are incorporated by reference.

As useful as an MRI scanning procedure is, it exacts a toll on the patient. For example, on many occasions patients cannot complete the exam due to claustrophobia caused by having to lie prone inside the bore for a long time while the procedure takes place. To be sure, the procedure is rather long in duration, lasting about half an hour up to two hours. Or, the patient simply gets bored or restless from being in a tight area.

Another discomforting factor is that during the MRI exam there is a harsh and loud knocking noise generated by the MRI gradient amplifier. This noise is commonly called gradient pulse, which naturally is very annoying to the patient who must endure the drone for a long period of time.

Accordingly, there is a great demand for some method of comforting the patient to keep his mind off the MRI scanning procedure. He should be entertained in some way without having the entertainment aspect detracting from the quality of the images that are being taken by the MRI technologist. Indeed, the patient should be relaxed somehow since the MRI device is formidable-looking and the patient is most likely already nervous from having to undergo such an examination.

A quick and simple solution to the entertainment problem is to provide the patient with a television to view, or a radio to listen to. But by virtue of the operating principles behind MRI technology, the exam room where the main magnet is located is permeated with very strong magnetic fields. So it is nearly impossible for a typical television, video cassette recorder (VCR), stereo, cassette player, or any electronic device to function properly in those conditions. In short, the effect of the strong magnetic field and the sensitivity of the MRI hardware to high frequency RF leakage (mainly from 10 MHz to 70 MHz) do not allow an ordinary television or audio system to function inside the magnet room (i.e., exam room).

Therefore, a need presently exists for an electronic device that can operate in the environment of an MRI magnet room to entertain a nervous patient while he or she undergoes the scanning procedure. The electronic device should also not interfere with the MRI process.

SUMMARY OF THE INVENTION

The present invention relates to an electronic entertainment device suitable for operation within strong magnetic fields. In a preferred embodiment, the present invention provides an audio and video system with properly filtered and shielded circuitry so that the system can be operated in a strong magnetic field created by MRI equipment. For the patient's benefit, the system also provides a liquid crystal display (LCD) screen for watching and a headset for listening.

The audio and video system provided by the present invention is divided between two rooms occupied by the MRI equipment. Although not part of the present invention, description of the rooms is given as background information. One room is called the control room and is where the MRI technologist controls the MRI process. The other room is the magnet or exam room, which is separated from the control room by a penetration panel, and contains the main magnet of the MRI device.

According to the present invention, the system receives an incoming RF signal through a television receiver or video cassette recorder, which then separates the RF signal into a video section signal and an audio section signal. The video section signal passes through appropriate buffering, amplifying, low pass and RF filtering circuits. The low pass filter is necessary to block out high frequency noise around the procession frequency of a hydrogen proton, which resonates during the MRI process. Next, the video section signal is conducted through the penetration panel into the magnet room where it is terminated and filtered again for noise.

Inside the magnet room, a processing circuit and LCD pixel driver then process the video section signal and send it to an LCD display screen. An optional magnifying lens system may be adapted to the LCD display screen to project the pictures on to a large reflective screen (as in a big screen TV). A patient lying prone inside the magnet bore can then watch the television pictures on the reflective screen through a pair of prism glasses worn by him.

But without the lens system, the patient views the LCD display screen directly. To facilitate viewing, a mushroom shaped hook is mounted to the LCD screen and a catch is mounted to the bore so that the LCD screen can be attached to the bore.

The audio section signal is separated into two channels, passed through an amplifier and appropriate RF filters and chokes, and fed through the penetration panel and into a pneumatic transducer inside the magnet room. The pneumatic transducer converts the electrical impulses of the audio section signal into audible sound waves.

Also provided by the present invention is a headset designed to fit the skull of the patient undergoing the MRI procedure. The headset comprises an inner set and an outer set. The inner set connects the output of the pneumatic transducer to the patient's ear, thereby bringing sounds of the television or VCR to the patient. By contrast, the outer set is circumaurel in construction so that each ear cup covers the patient's ears to block out gradient knocking noises.

Another feature of the preferred embodiment system is for the patient to be able to see and hear the MRI technologist speaking to him from the control room via the LCD display screen and headset. This is achieved by mounting a CCD (charge coupled device) camera with a microphone in the control room and using a television signal interrupt switch to turn the CCD camera and microphone on, and then patching into the television receiver. The receiver then functions as before to direct the pictures and sounds to the patient. Hence, this feature allows the patient to see and hear the technologist.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a preferred embodiment of the present invention illustrating the entire audio and video system separated between a control room and a magnet room.

FIG. 2 illustrates a headset provided by the present invention and a supplemental side view of an ear cup of the headset.

FIG. 3 provides a magnified view of an ear tip component of the inner set.

FIG. 4 is a view of a preferred embodiment LCD video display screen.

FIG. 5 is an enlarged view of the hook mounted to the LCD display screen.

FIGS. 6A and 6B provide side and bottom views, respectively, of the catch mechanism designed to engage the hook shown in FIG. 5.

DETAILED DESCRIPTION OF THE INVENTION

The following detailed description outlines an MRI compatible audio and video system having an LCD display screen. In the following description, numerous details such as specific materials and configurations are set forth in order to provide a more complete understanding of the present invention. But it is understood by those skilled in the art that the present invention can be practiced without these specific details. In other instances, well known elements are not described in detail so as not to obscure the present invention. In any event, the scope of the invention is best determined by reference to the appended claims.

GENERAL ARRANGEMENT

In a preferred embodiment, the present invention provides an MRI compatible audio and video system. FIG. 1 gives a general overview of how the present invention system is set up in relation to the MRI equipment, which is disposed partly in a magnet room and partly in a control room.

One portion of the present invention system is located inside the MRI control room 1. That portion of the system includes a receiver and associated electronic filters and circuitry. Dashed lines in FIG. 1 circumscribe the borders of that room. Everything outside the dashed lines represents the examination or magnet room 2. The other portion of the system that includes an LCD screen and its circuitry are located within the magnet room 2. As the name implies, the magnet room 2 contains a main magnet of the MRI device (not shown) that generates a strong magnetic field.

Continuing with the general overview, FIG. 1 shows that the system contained in the magnet room 2 is again divided such that certain parts of the system are mounted inside the bore of the main magnet (so labeled in FIG. 1) and other parts remain outside the bore. The parts inside the bore include a terminator, filter circuits, an LCD pixel driver, and an LCD screen. Of course the patient (not shown) undergoing the scanning process is positioned inside the bore, too. Outside the bore but still within the magnet room 2 is a pneumatic transducer 21 for generating sound, which is connected to a headset 23 worn by the patient.

Aside from being physically divided into two portions, the system in a preferred embodiment is separated in terms of electronics into two major sections; namely, a video section and an audio section. Each section is explained in detail below.

THE VIDEO SECTION (CONTROL ROOM)

The video section is located partially in the control room 1 and partially in the magnet room 2, as illustrated in FIG. 1. In the control room 1, a television receiver 3 picks up an incoming RF signal through an antenna or from a video source like a video cassette recorder (VCR) player. The receiver 3 processes the incoming RF signal and separates out the sound or audio section signal 17 from the picture or video section signal 4. Since a television receiver and VCR are devices well known in the art, no detailed discussion is required here.

In the video section, the video section signal 4 is processed from the incoming RF signal in the television receiver 3 to obtain red, green, and blue chroma video signals (labeled R, G, and B in FIG. 1), and a control signal. The red, green and blue chroma signals along with the control signal, collectively labeled the video section signal 4, are sent to a buffer board 5. A power supply, well known in the art, delivers as part of the video section signal 4 a power signal (labeled PWS in FIG. 1) to the buffer circuit board 5.

At this point all the signals necessary to drive the LCD display screen 6 are present, but since the LCD screen 6 is located a distance away from the television receiver 3 (in a preferred embodiment, about 100 feet away from the television unit) the video section signal 4 needs to be amplified and buffered. Hence the need for a buffer and amplifier board 5. For some types of signals, only a unity-gain, current driver amplifier is sufficient. In this preferred embodiment, a high gain bandwidth operational amplifier is used as a buffer to drive the video section signal 4 through the approximately 100 feet. In some signals, amplification along with a driver are necessary.

A typical MRI signal is very sensitive to the electrical noise around the procession frequency of a hydrogen proton, wherein this frequency varies from 12 MHz to 80 MHz depending on the field strength of the magnet. This relationship is generally expressed as:

$$f=(42.5)\times(B)$$

wherein B is the field strength in Tesla and f is the frequency in Megahertz.

Mindful of the foregoing relationship, a filter board 7 is included to block out all other frequencies above the video frequency range, typically above 4.5 MHz. To do that, a LP filter and an RF filter are required for the filter board 7. All of the signals from the buffer board 5 have to pass through the filter board 7 before entering the magnet room 2.

As alluded to above, after leaving the filter board 7, the video section signal 4 can travel up about 100 feet before interfacing with the LCD screen 6. Thus, a 25-conductor shielded cable 8 is used to carry the video section signal 4 for that distance.

In an alternate embodiment (not shown), a fiber optic cable may be used in place of the shielded cable 8. Further, a fiber optic generator is added to the filter board 7 to convert the electrical video section signal 4 to optical impulses to be carried by the fiber optic cable. In this embodiment, the terminator board 9 is not required. In its place is a fiber optic receiver to decode and convert the optical impulses into electrical signals.

THE VIDEO SECTION (MAGNET ROOM)

The 25-conductor shielded cable 8 is fed into the magnet room 2 where the other part of the video section is located. But first, the cable 8 must pass through a penetration panel (not shown) separating the magnet room 2 from the control room 1. In the magnet room 2, the incoming video section signal 4 from the 25-conductor shielded cable 8 is terminated with the proper load resistor 9 known in the art. Appropriate filters are also provided on that same circuit board 9 to eliminate the effects of RF signals and gradient noise from the MRI equipment upon the video section signal 4, and vice versa.

The video section signal 4 next proceeds to circuit board 10. Here, the incoming analog and digitized signal 4 from the terminator and filter board 9 is processed and fed into an LCD pixel driver circuit 10. The output of the processor circuit and pixel driver 10 is sent to the LCD display screen 6. As seen in FIG. 1, located just behind the LCD screen 6 is a light source 10 such as a fluorescent tube to supply backlighting for the picture on the LCD screen 6. Naturally, other means of backlighting known in the art are possible. FIG. 4 provides a more detailed view of the LCD display screen 6.

MOUNTING THE LCD DISPLAY SCREEN

According to the present invention, placement of the LCD display screen 6 is important. There are basically two different ways of positioning a patient inside the main magnet bore for an MRI exam; he can be positioned inside the bore either with his head in first or with his feet in first. Needless to say, this complicates the way the LCD display screen 6 can be oriented. For instance, the LCD display screen 6 cannot be mounted in a horizontal plane if the patient goes into the bore feet first because the picture on the LCD display screen 6 would appear upside down to him. Of course the screen 6 would then have to be rotated 180° along a vertical axis of rotation to obtain an upright image.

Fortunately, most of the MRI devices on the market already have a built-in reflection mirror inside the magnet bore. With this mirror, the patient can see outside of the bore along a horizontal axis as he lies on his back on a patient carriage oriented head first in the magnet bore. To take advantage of the orientation of the patient, the present invention provides that the LCD display screen 6 be mounted vertically a quarter of the distance inside the magnet bore. When the patient is placed inside the magnet head first, he can see the LCD display screen 6 through its reflection in the mirror. If the patient enters the magnet bore feet first, he has a direct view of the LCD display screen 6 if the screen 6 is pivoted around a vertical axis.

FIGS. 4, 5, 6A and 6B illustrate the means by which the LCD display screen 6 is held in position inside the magnet bore. In this preferred embodiment, a mushroom shaped hook 12 extends from the top of the LCD display screen 6 as depicted in FIG. 4. The display screen 6 in FIG. 4 is tilted slightly to reveal the placement of the hook 12. FIG. 5 shows an enlarged view of the mushroom-shape hook 12. As the name implies, the hook 12 has a round shaft 13 capped at one end by a circular dome 14. A catch 15, shown in FIGS. 6A and 6B, mounted to the bore is designed to receive the hook 12 of the LCD screen 6, holding the screen 6 up in the bore. It can be seen that the large dome 14 of the hook 12 slides into the dovetail opening 16 of the catch 15. Moreover, the hook 12 is designed to rotate, slide or disengage if the LCD display screen 6 is accidentally knocked along a horizontal direction, thus avoiding any damage to the LCD screen 6. Alternatively, the LCD screen 6 can be mounted to the bore with something as simple as a hook and pile fastener (i.e., Velcro).

THE AUDIO SECTION

The next part of the system as provided in the preferred embodiment of the present invention is an audio section that enables the patient to hear the signal from the television receiver 3. Going back to FIG. 1, the television receiver 3 separates out the audio section signal 17 from the received RF signal in a manner known in the art. Next, the audio output from the receiver 3 is separated into two channels for left and right stereo imaging (labeled L and R in FIG. 1), then amplified through a dedicated audio amplifier 18 with a volume control.

The output of the audio section signal 17 from the audio amplifier 18 needs to be filtered to block out electromagnetic interference having a frequency above 20 kHz. Therefore, the present invention provides an appropriate RF filter and RF choke 19 to block out the unwanted electrical noise, obtaining approximately −50 dbA attenuation for all frequencies above 5 MHz. The outputted audio section signal 17 is then conducted into the magnet room 2 through an audio cable 20 that passes through the penetration panel. In a preferred embodiment, the audio cable 20 can be about 100 feet in length of either a five-pin shielded conductor, or two separate coaxial cables. Optical fiber technology may also be incorporated herein to conduct the audio section signal 17 too.

The magnet room 2 where the patients undergo the MRI procedure is completely shielded for RF signals. As mentioned above, the magnet room 2 features a penetration panel that helps shield out unwanted RF signals. Any cable that goes into the magnet room 2 must pass through the penetration panel. As a result, all of the audio and video signals have to be RF shielded and passed through a low pass filter before going through the penetration panel and into the magnet room 2.

Inside the magnet room 2, the audio cable 20 is connected to a box containing a pneumatic transducer 21 to convert electrical impulses of the audio section signal 17 into audible sound waves (i.e., pneumatic impulses). The pneumatic transducer 21 can be made in several different ways. In the preferred embodiment, piezoelectric speakers known in the art are ideal since they utilize the piezoelectric effect and are non-magnetic. Thus, the function of the speaker is not affected by the main magnet.

The sound waves generated by the transducer 21 are conveyed through a hollow tube 22 connected at one end to a headset 23 worn by the patient. In the preferred embodiment, the tubing 22 is made from a flexible polymer material, has a ⅛th inch inside diameter, and extends about 36 inches long. Clearly, there are many other possible methods known in the art of conducting audible sound from the transducer to the headset, of which plastic tubing is only one.

Another acceptable pneumatic transducer is a small, full-range speaker packaged in a manner such that its cone driver faces and abuts the plastic tubing to transfer the sound to the headset. Yet another type of pneumatic transducer is a 4" mid-range driver, model LM1824, manufactured by Electro Voice. This type of driver is configured into a horn where the sound is emitted out of a one-inch diameter opening. The opening can be adapted to a one-half inch diameter plastic tubing which conducts the sound waves to the patient. With this specific horn speaker design, however, the speaker has to be mounted outside of the magnet room because this particular horn driver has a large magnet that might be disrupted by the main magnet of the MRI imager.

THE HEADSET

The audible sound waves from the pneumatic transducer 21 propagate through the hollow tube 22 and into a headset 23. As mentioned above, during the MRI procedure, data is usually collected by a high current RF signal called a gradient pulse. Gradient pulse causes an audible and loud knocking noise that tends to be very annoying to the patient. To overcome this problem, the present invention provides a specially designed headset 23 to block the gradient noise by 21 decibels or approximately 92% attenuation from its original level.

According to the present invention, the diagram in FIG. 2 shows a preferred embodiment headset 23. The two major parts of the headset 23 are an outer set 24 and an inner set 25. The outer set 24 is similar to the ear muff type headsets used at gun ranges. That particular design is intended to muffle the loud crack or sound impulse generated by a discharging gun. The outer set 24 as provided by this preferred embodiment has ear cups 26 (shown in a supplemental side view in FIG. 2) that are circumaural, meaning that the ear cups 26 completely enclose each ear. The ear cups 26 are all plastic and have very soft and comfortable cushions that conform to the side of the patient's head while sealing out external sounds. Also, the headpiece is adjustable and the ear cups 26 are hinged to ensure a proper fit around the patient's skull. In sum, the outer set 24 by virtue of its circumaural design blocks out the gradient knocking noise.

Disposed inside the outer set 24 is the inner set 25, to which the tubing 22 conducting the sound waves is connected. As shown in FIG. 3, the inner set 25 is configured somewhat like the headsets rented out to passengers by airlines on long distance flights. The basic inner set 25 has an L shape so that its eartip 27 easily hooks into the patient's ear canal while its base connects with the tubing 22. Operating together, the outer set 24 blocks out any gradient knocking noise while the inner set 25 supplies to the patient soothing sounds broadcast from the receiver 3.

In an alternate embodiment, the present invention is modified with an array of magnifying lenses (not shown) disposed adjacent to the LCD display screen. A reflective screen is set up a distance away from the lenses but aligned therewith. In this manner, the pictures on the LCD display screen are projected through the lenses onto the larger reflective screen. In effect, a big screen TV effect can be obtained for easier viewing by the patient.

Many other modifications are possible. For example, a volume control, VCR controls, along with a television channel control could be accessed remotely from the patient's end through a means known in the art. In the same vein, even a panic switch for the patient could be adapted to the system. This way, if the patient has an emergency, he can immediately signal the MRI technologist through a remote controller. One such controller is a handheld infra-red remote controller well known in the art that could be easily adapted by one having ordinary skill in the art to incorporate all of the above-mentioned functions.

In another alternate embodiment, the system may be modified for the patient to be able to see and hear the MRI technologist in the control room via the LCD display screen and headset as the technologist talks to him. This is achieved by mounting a CCD (charge coupled device) camera and a microphone in the control room and using an RF signal interrupt switch in the television, known in the art, to turn the CCD camera and microphone on. The pictures and sounds are then supplied to the patient's LCD display screen and headset in the same manner as described for the preferred embodiment audio and video section signals.

In yet another alternate embodiment, the present invention provides that one cable from the television receiver or VCR located outside the magnet room be passed through the penetration panel. Along with video signal, the cable could carry the power source signal for the television processor/pixel driver circuit and the buffer circuit board. The buffer board and the television processor circuit are both kept in the magnet room inside an RF shielded enclosure, which connects with the incoming cable. An outgoing cable from the shielded enclosure then conducts the signals to the LCD display screen.

An advantage of the foregoing alternate embodiment is that only one filter is required for the video section signal and one filter for the power supply. By contrast, the preferred embodiment requires about twenty filters. Also, it is much easier to install since this embodiment can be adapted to use the RG 58 coaxial cable typically already connected to the penetration panel. No opening has to be cut into the panel to provide access for other cables.

Unfortunately, the buffer board and associated filters for this alternate embodiment might create spurious RF signals that adversely affect the ongoing MRI imaging

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scan. Indeed, the quality of the patient scan image may be adversely affected by such RF signal leaks.

What is claimed is:

1. An audio and video system compatible with a magnetic resonance imager disposed in a control room and a magnet room separated by a penetration panel, wherein the magnet room contains a main magnet having a bore, the system comprising:

means for receiving an incoming signal and dividing the incoming signal into a video section signal and an audio section signal, located in the control room;

means for buffering and amplifying the video section signal, located in the control room, and connected to the means for receiving;

means for filtering the video section signal for RF and high frequencies, located in the control room, and connected to the means for buffering and amplifying;

a first means for conducting the video section signal, connected to the means for filtering and passing through the penetration panel into the magnet room;

means for terminating and filtering the video section signal, located in the main magnet bore, connected to the first means for conducting;

means for processing and converting the video section signal into a display driving signal, located in the main magnet bore, connected to the means for terminating;

means for displaying the display driving signal, connected to the means for processing, and secured to the main magnet bore by an attachment means;

means for amplifying the audio section signal, located in the control room, connected to the means for receiving;

means for RF filtering and RF choking the audio section signal, located in the control room, connected to the means for amplifying;

a second means for conducting the audio section signal, connected to the means for RF filtering and passing through the penetration panel into the magnet room;

means for converting the audio section signal into audible sound waves, located in the magnet room, connected to the second means for conducting;

a hollow tube, located in the magnet room, connected to the means for converting; and

a headset connected to the hollow tube, located in the magnet room, providing an inner set adapted to engage a human ear to conduct audible sound waves thereto and disposed inside an outer set, wherein the outer set is adapted to cover the human ear to block out audible sound.

2. The audio and video system according to claim 1, wherein the means for displaying further comprises means for focussing and projecting an image from the means for displaying onto a projection screen.

3. The audio and video system according to claim 2, wherein the video section signal includes a chroma signal, a control signal and a power source signal.

4. The audio and video system according to claim 3, wherein the means for converting is a pneumatic transducer.

5. The audio and video system according to claim 4, wherein the means for displaying is a liquid crystal display screen.

6. The audio and video system according to claim 5, wherein the pneumatic transducer is a piezoelectric driver.

7. The audio and video system according to claim 6, wherein the first means for conducting is a 25-conductor shielded cable.

8. The audio and video system according to claim 7, wherein the second means for conducting is a 5-pin shielded cable.

9. The audio and video system according to claim 7, wherein the second means for conducting is a coaxial cable.

10. The audio and video system according to claim 7, wherein the liquid crystal display further comprises a fluorescent tube.

11. The audio and video system according to claim 10, wherein the system further comprises means for remotely controlling the means for receiving for volume and channel selection.

12. The audio and video system according to claim 11, wherein the hollow tube is made from a flexible polymer.

13. The audio and video system according to claim 12, wherein the attachment means further comprises a mushroom shaped hook affixed to the liquid crystal display screen, and a catch, mounted to the main magnet bore and adapted to engage the hook.

14. The audio and video system according to claim 13, wherein the means for receiving is a television.

15. The audio and video system according to claim 13, wherein the means for receiving is a video cassette recorder.

16. The audio and video system according to claim 1, wherein the system further comprises a charge coupled device camera and a microphone mounted inside the control room, wherein a video output of the camera and an audio output of the microphone are connected to the means for receiving.

17. An audio and video system compatible with a magnetic resonance imager disposed in a control room and a magnet room separated by a penetration panel, wherein the magnet room contains a main magnet having a bore, the system comprising:

means for receiving an incoming signal and dividing the incoming signal into a video section signal and an audio section signal, located in the control room;

means for buffering and amplifying the video section signal, located in the magnet room and contained within a RF shielded enclosure, and connected to the means for receiving;

means for processing and converting the video section signal into a display driving signal, located in the main magnet bore, connected to the means for buffering;

means for displaying the display driving signal, connected to the means for processing, and secured to the main magnet bore by an attachment means;

means for amplifying the audio section signal, located in the control room, connected to the means for receiving;

means for RF filtering and RF choking the audio section signal, located in the control room, connected to the means for amplifying;

a means for conducting the audio section signal, connected to the means for RF filtering and passing through the penetration panel into the magnet room;

means for converting the audio section signal into audible sound waves, located in the magnet room, connected to the means for conducting;

a hollow tube, located in the magnet room, connected to the means for converting; and

a headset connected to the hollow tube, located in the magnet room, providing an inner set adapted to engage a human ear to conduct audible sound waves thereto and disposed inside an outer set, wherein the outer set is adapted to cover the human ear to block out audible sound.

18. A method of producing audio and video signals compatible with a magnetic resonance imager disposed in a control room and a magnet room separated by a penetration panel, wherein the magnet room contains a main magnet having a bore, the method comprising the steps of:

receiving an incoming signal inside the control room;
separating the incoming signal into a video section signal and an audio section signal;
buffering and amplifying the video section signal;
filtering the video section signal;
shielding the video section signal;
passing the video section signal through the penetration panel into the magnet room;
terminating and filtering the video section signal;
processing the video section signal to drive an LCD display screen;
attaching the LCD display screen to the bore;
amplifying the audio section signal;
filtering and choking the audio section signal;
shielding the audio section signal;
passing the audio section signal through the penetration panel into the magnet room;
transducing the audio section signal into an audible sound wave;
conducting the audible sound wave to a headset; and
blocking out noise external to the headset.

19. An audio and video system compatible with a magnetic resonance imager disposed in a control room and a magnet room separated by a penetration panel, wherein the magnet room contains a main magnet having a bore, the system comprising:

means for receiving an incoming signal and dividing the incoming signal into a video section signal and an audio section signal, located in the control room;

means for buffering and amplifying the video section signal, connected to the means for receiving;

means for filtering out signals above a first high frequency of the video section signal, connected to the means for buffering;

means for displaying the video section signal, connected to the means for filtering out signals above a first high frequency, located in the magnet room;

means for attaching the means for displaying to the bore;

means for amplifying the audio section signal, connected to the means for receiving, located in the control room;

means for filtering out signals above a second high frequency of the audio section signal, connected to the means for amplifying;

means for converting the audio section signal into an audible sound wave, connected to the means for filtering out signals above a second high frequency, located in the magnet room; and

means for conveying the audible sound wave to a patient in the magnet room and for blocking out external noise, connected to the means for converting.

20. The audio and video system according to claim 19, wherein the first high frequency is above 4.5 MHz.

21. The audio and video system according to claim 20, wherein the second high frequency is above 20 kHz.

22. The audio and video system according to claim 21, wherein the system further comprises:

a fiber optics generator, connected to the means for filtering out signals above a first high frequency, located in the control room;

a fiber optics cable connected to the fiber optics generator to conduct the video section signal;

a fiber optics receiver connected to the fiber optics cable, located in the magnet room; and wherein

the means for displaying the video section signal is connected to the fiber optics receiver.

23. A video display system for a patient disposed within a magnetic resonance imaging device having a magnetic field, said magnetic resonance imaging device comprising a control room and a magnet room separated by a penetration panel, said magnet room comprising a main magnet having a bore, said video display system comprising:

a magnetically inert display comprising a liquid crystal display (LCD) screen;

said magnetically inert display positioned within the magnetic field of said magnetic resonance imaging device; and

a filter preventing electrical signals generated by said magnetically inert display from interfering with said magnetic resonance imaging device.

24. The system of claim 23, further comprising means for preventing electrical signals generated by said magnetic resonance imaging device from interfering with said magnetically inert display.

25. The system of claim 23 or 24, wherein said filter comprises a low pass filter.

26. The system of claim 25, further comprising means for attaching said magnetically inert display to the main magnet bore, said means comprising a mushroom-shaped hook affixed to the LCD screen, and a catch mounted to the main magnet bore and adapted to engage the hook.

27. A video display system for a patient disposed within a magnetic resonance imaging device having a magnetic field, said magnetic resonance imaging device comprising a control room and a magnet room separated by a penetration panel, said magnet room comprising a main magnet having a bore, said video display system comprising:

a magnetically inert display comprising a liquid crystal display (LCD) screen;

said magnetically inert display positioned within the magnetic field of said magnetic resonance imaging device; and

means for preventing electrical signals generated by said magnetically inert display from interfering with said magnetic resonance imaging device.

28. The system of claim 27, further comprising means for preventing electrical signals generated by said magnetic resonance imaging device from interfering with said magnetically inert display.

29. The system of claim 27 or 28, wherein at least one of said means for preventing comprises a low pass filter.

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30. The system of claim 29, further comprising means for attaching said magnetically inert display to the main magnet bore, said means comprising a mushroom-shaped hook affixed to the LCD screen, and a catch mounted to the main magnet bore and adapted to engage the hook.

31. A video display system for a patient disposed within a magnetic resonance imaging device having a magnetic field, said magnetic resonance imaging device comprising a control room and a magnet room separated by a penetration panel, said magnet room comprising a main magnet having a bore, said video display system comprising:

a video signal;

a magnetically inert display comprising a liquid crystal display (LCD) screen;

said magnetically inert display positioned within the magnetic field of said magnetic resonance imaging device; and

means for preventing electrical signals generated by said video signal from interfering with said magnetic resonance imaging device.

32. The system of claim 31, further comprising means for preventing electrical signals generated by said magnetic resonance imaging device from interfering with said video signal.

33. The system of claim 32, wherein at least one of said means for preventing comprises a low pass filter.

34. The system of claim 31, 32 or 33, wherein said video signal is supplied to said magnetically inert display through a shielded cable.

35. The system of claim 31, 32 or 33, wherein said video signal is supplied to said magnetically inert display through a fiber optic cable.

36. The system of claim 33, further comprising an amplifier located in the control room, for amplifying the video signal before the video signal is filtered by said filter.

37. The system of claim 36, further comprising means for attaching said magnetically inert display to the main magnet bore, said means comprising a mushroom-shaped hook affixed to the LCD screen, and a catch mounted to the main magnet bore and adapted to engage the hook.

38. The system of claim 32, further comprising a charge coupled device camera and a microphone mounted inside the control room, wherein a video output of the camera supplies said video signal.

39. A video and audio display system for a patient disposed within a magnetic resonance imaging device having a magnetic field, said magnetic resonance imaging device comprising a control room and a magnet room separated by a penetration panel, said magnet room comprising a main magnet having a bore, said video and audio display system comprising:

an incoming signal comprising a video signal portion and an audio signal portion;

a video and audio receiver, wherein said receiver divides said incoming signal into a video signal portion and an audio signal portion;

a magnetically inert display comprising a liquid crystal display (LCD) screen;

said magnetically inert display positioned within the magnetic field of said magnetic resonance imaging device; and

means for preventing electrical signals generated by said video signal portion from interfering with said magnetic resonance imaging device.

40. The system of claim 39, further comprising means for preventing electrical signals generated by said magnetic resonance imaging device from interfering with said video signal portion.

41. The system of claim 39, further comprising a filter preventing said audio signal portion from interfering with the magnetic resonance imaging device.

42. The system of claim 41, wherein said filter comprises a low pass filter.

43. The system of claim 39, 40 or 41, wherein said video signal portion is supplied to said magnetically inert display through a shielded cable.

44. The system of claim 39, 40 or 41, wherein said video signal portion is supplied to said magnetically inert display through a fiber optic cable.

45. The system of claim 39, 40 or 41, further comprising a piezoelectric transducer for converting said audio signal portion into audio sound waves.

46. The system of claim 45, further comprising a hollow tube connected to said piezoelectric transducer, and a headset connected to said hollow tube, said headset comprising an inner set portion adapted to engage a human ear to conduct audible sound waves thereto and disposed inside an outer set portion, wherein the outer set portion is adapted to cover the human ear to block out audible sound.

* * * * *

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EXHIBIT 2

US005432544A

United States Patent [19]

Ziarati

[11] Patent Number: 5,432,544

[45] Date of Patent: * Jul. 11, 1995

[54] MAGNET ROOM DISPLAY OF MRI AND ULTRASOUND IMAGES

[75] Inventor: Mokhtar Ziarati, North Hollywood, Calif.

[73] Assignee: Susana Ziarati, North Hollywood, Calif.

[*] Notice: The portion of the term of this patent subsequent to May 2, 2012 has been disclaimed.

[21] Appl. No.: 997,957

[22] Filed: Dec. 21, 1992

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 653,711, Feb. 11, 1991.

[51] Int. Cl.[6] H04N 7/18

[52] U.S. Cl. 348/61; 348/77; 324/318; 128/653.2

[58] Field of Search 358/93, 22, 901, 108, 358/110, 112; H04N 7/18; 324/300, 307, 308, 309, 318, 319; 128/653.2, 653.3; 348/61, 77, 162

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Primary Examiner—James J. Groody
Assistant Examiner—Michael H. Lee
Attorney, Agent, or Firm—Roberts and Quiogue

[57] ABSTRACT

A display system for display of MRI, ultrasonic, patient vital sign or other imagery within a magnet room of an MRI system. An MRI compatible video display is disposed with the magnet room, and is connected to the MRI image processor to provide MRI images to medical personnel working in the magnet room. The display can be an MRI compatible LCD projection display, a wired LCD screen display, a reflective LCD screen display or a plasma display. The display within the magnet room is made MRI compatible by appropriate shielding and filtering. The display may also display patient vital sign data or imagery from an MRI compatible ultrasound apparatus.

35 Claims, 3 Drawing Sheets

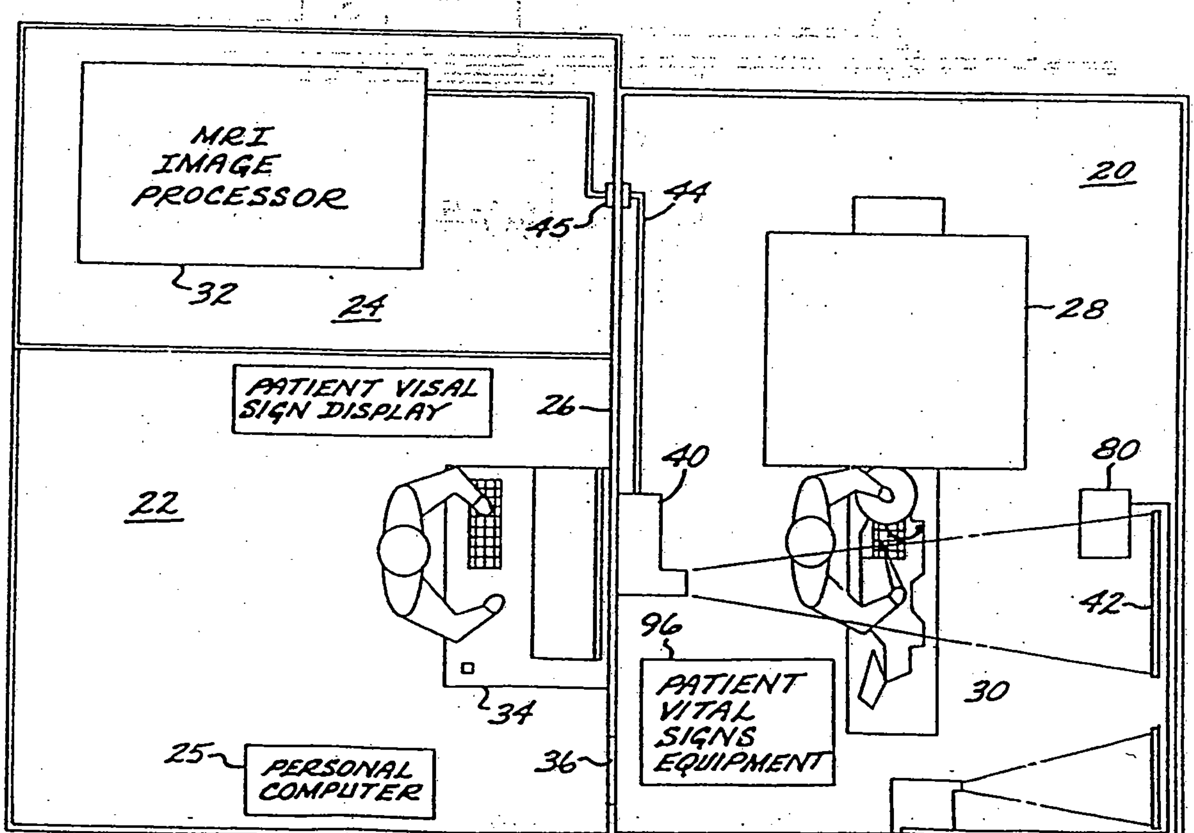

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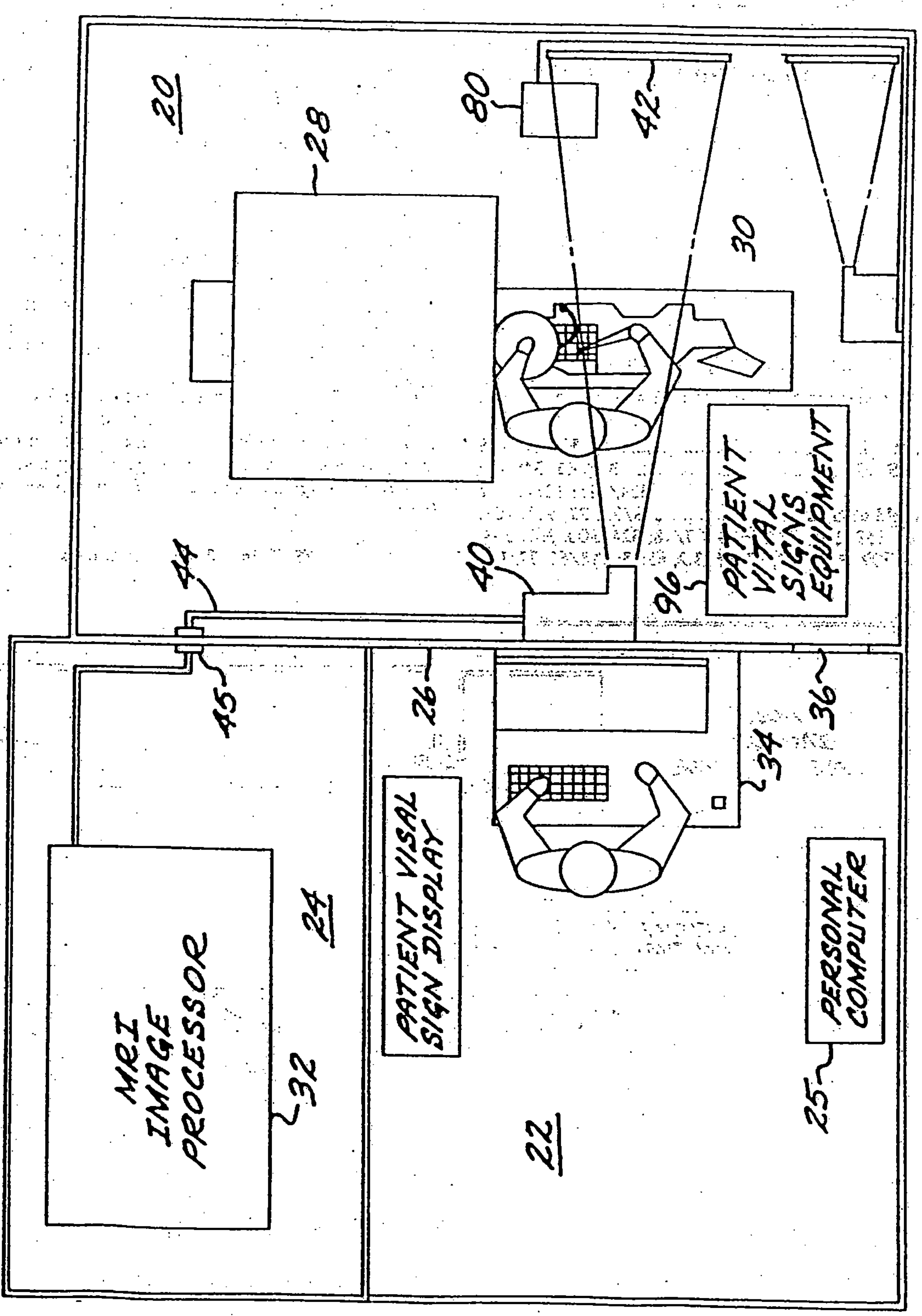
FIG. 1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28
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44
40
96
PATIENT VITAL SIGNS EQUIPMENT
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MRI IMAGE PROCESSOR
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24
PATIENT VISAL SIGN DISPLAY
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PERSONAL COMPUTER
25

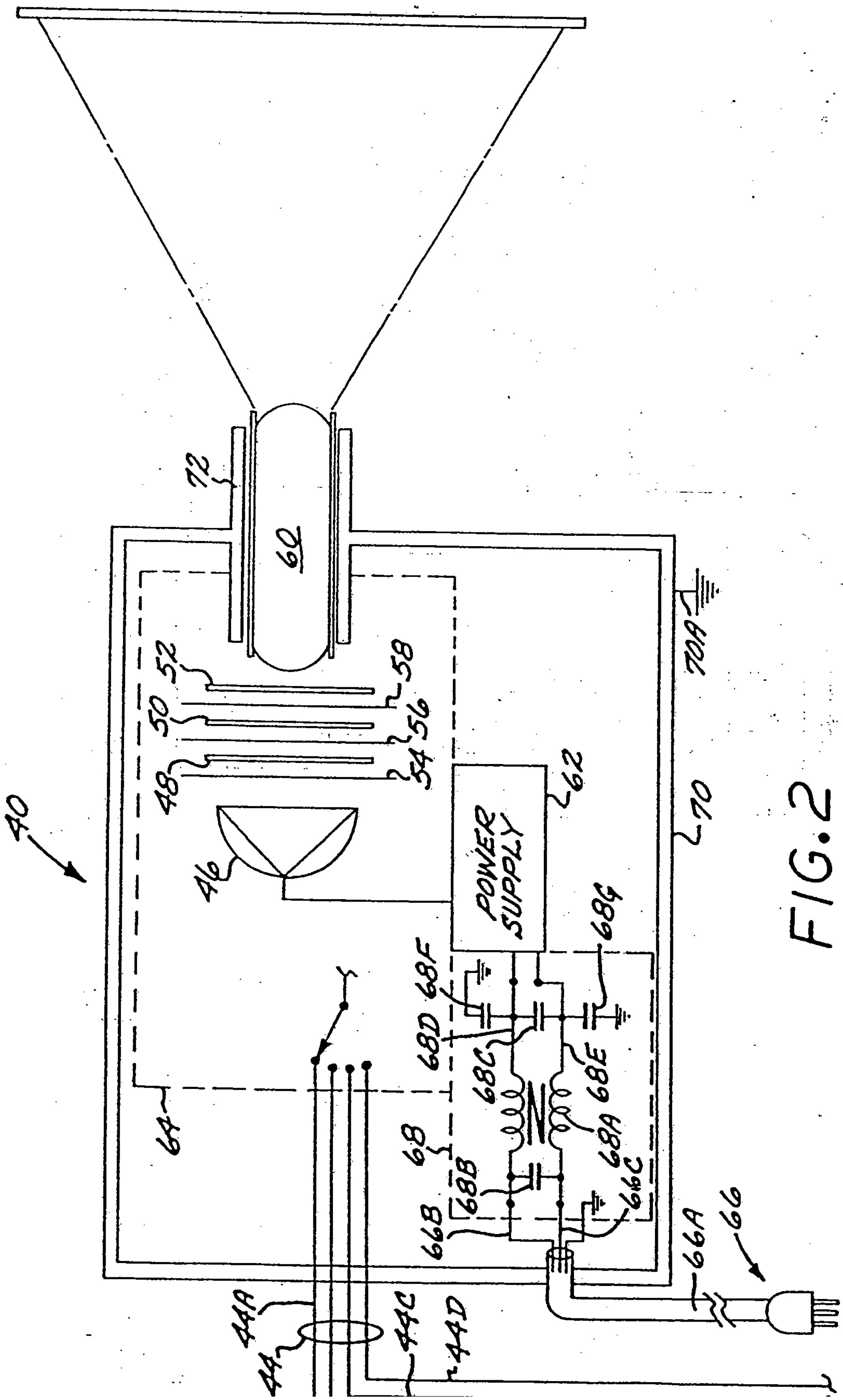
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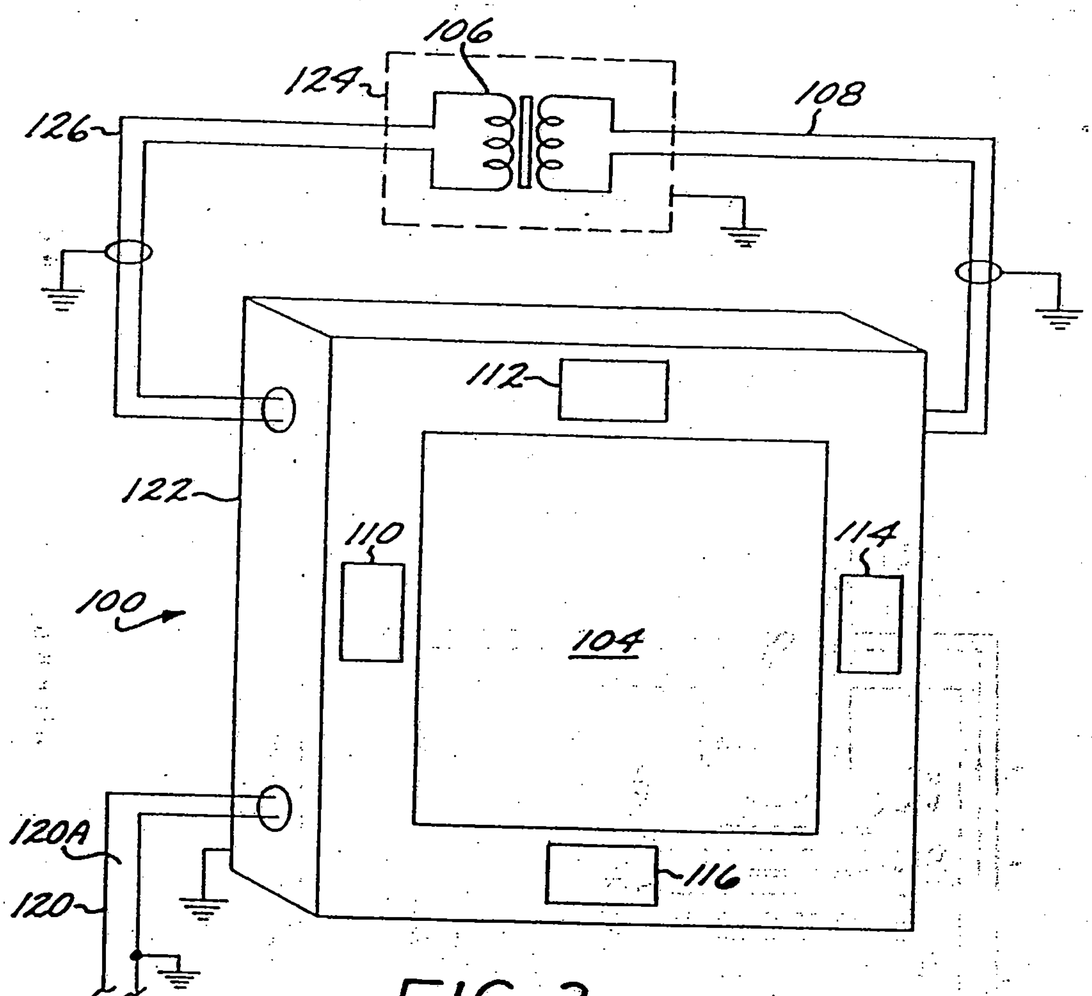
FIG. 2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120
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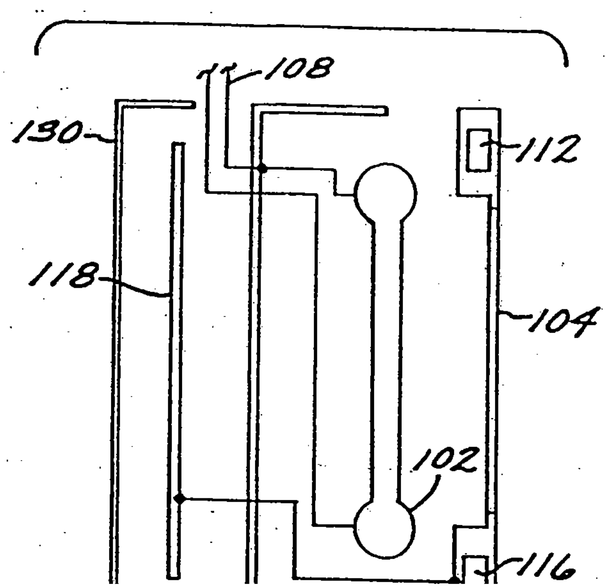
FIG.3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104
102
116

FIG.4

MAGNET ROOM DISPLAY OF MRI AND ULTRASOUND IMAGES

This is a continuation-in-part of applicant's pending application, Ser. No. 07/653,711, filed Feb. 11, 1991, for MAGNETIC RESONANCE IMAGING COMPATIBLE AUDIO AND VIDEO SYSTEM, the entire contents of which are incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates to the field of magnetic resonance imaging (MRI) equipment, and more particularly to a video system including a display for displaying MRI images and patient vital sign data within a magnet room.

MRI is a relatively new scanning procedure being used in the medical community to assist doctors in various diagnostic and other procedures. The scanning procedure requires that a patient lie still inside a tunnel shaped enclosure called the bore. The MRI device uses a strong magnetic field that is generated around the patient's body. Disturbances in the field due to the presence of the body can be detected and translated into images displayed on a viewing screen.

The MRI device includes a large magnet that induces a strong, uniform, and static magnetic field. Generally, the magnetic field ranges from 0.5 Telsa to 2.0 Telsa inside the bore. Gradient coils disposed around the bore induce spatially variant magnetic fields (i.e. gradients) that modify the existing uniform magnetic field. To induce nuclear resonance, a transmitter emits radio waves through a coil, which couples the radio wave energy with the resonating nuclei inside the magnetic field. A receiver, also connected to the coil, receives the disrupted electromagnetic waves. The waves are filtered, amplified, and processed into visual data for viewing by an MRI techologist attending to the procedure. More detailed information regarding MRI equipment is available in a book entitled *Nuclear Magnetic Resonance*, pp. 53-66 (1st ed. 1981), the contents of which are incorporated by reference.

Typically, the MRI magnet is set up in a magnet room. The patient typically is supine on a table which fits into the magnet bore. In an adjacent room, typically known as the control room, shielded from the magnet room by a penetration panel, an MRI technologist controls the operation of the MRI equipment by a control console. The MRI image processor is set up in an adjacent computer room.

One procedure for which MRI equipment is now being used is non-invasive surgery, typically using a laser fiber device to burn tissue or cancer tumors while at the same time using the MRI device to provide images of the patient to view the effect of the laser operation on the tissue or tumor. A disadvantage is that the doctor conducting the procedure cannot view the MRI images of the patient while inside the MRI magnet room. The reason is that it is nearly impossible for a typical television, video cassette recorder or the like to operate properly in the presence of the strong magnetic fields in the magnet room, and the MRI equipment is very sensitive to high frequency RF leakage from cathode ray tube and other electronic equipment. Therefore, presently the surgeon performing the surgery has to localize the area of interest outside the magnet room [illegible] moved in and out of the magnet room each time the ultrasound equipment must be used. During the actual surgery when the MRI imagery is being generated, the surgeon must leave the magnet room and go to the operator console area located outside the magnet room to view the MRI images through the operator console monitor. This is also not conducive to good practice and can lengthen the operation.

For similar reasons, a conventional CRT type display for the patient's vital signs or EKG monitoring cannot be used within the MRI magnet room.

Therefore, a need presently exists for a display system permitting MRI images to be displayed to a surgeon or other medical personnel working within the MRI magnet room.

SUMMARY OF THE INVENTION

An image display system compatible with an MRI apparatus disposed within a magnet room is described, wherein MRI video image signals are provided by an MRI image processor connected to the MRI apparatus in the magnet room. An MRI compatible display responsive to the video signals is disposed within the magnet room for providing a display within the magnet room. The display includes RF and electromagnetic interference filtering to prevent noise from the display from propagating within the magnet room and affecting the quality of the MRI images. In one preferred form, the display comprises an LCD projector. Alternatively, the display may comprise a wired LCD screen, a reflective LCD screen display or a plasma display.

In accordance with another aspect of the invention, the display within the magnet room may display alternate types of imagery from alternate image sources, such as from an MRI compatible ultrasonic imaging apparatus located within the magnet room, apparatus for providing patient vital sign data and the like.

BRIEF DESCRIPTION OF THE DRAWING

These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIG. 1 is a diagrammatic schematic diagram of an MRI facility employing a display system in accordance with this invention.

FIG. 2 is a schematic diagram of an LCD projector employed in the display system of FIG. 1.

FIG. 3 is a schematic diagram of a wired LCD screen for use in the display system of FIG. 1.

FIG. 4 is a diagrammatic side view illustrative of the components of the LCD screen of FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates in schematic form an exemplary MRI apparatus embodying the invention. Physically the magnet room 20 is separated from the control room 22 and the computer room 24 by a penetration panel 26, which provides shielding for RF and magnetic signals emanating from the equipment in the respective rooms. The control and computer rooms are shown as separate rooms, although the equipment in the two rooms may alternately be combined in a single room.

The MRI magnet 28 is located in the magnet room 20, [illegible]

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image processor 32 is in the computer room 24, and is connected to the MRI apparatus in the magnet room via connection made through the penetration panel, omitted from FIG. 1 for clarity. Connections are also made from the image processor 32 to the MRI operator console 34 in the control room 22, to allow the MRI technologist at the control console to control the operation of the MRI apparatus, and to view the MRI images generated by the image processor 32. A door 36 through the penetration panel permits egress between the control room and the magnet room.

The foregoing is descriptive of conventional MRI apparatus. To perform procedures such as non-invasive surgery on a patient with the aid of the MRI apparatus, it has been necessary in the past for the surgeon to move back and forth between the control room and the magnet room to alternatively view the MRI images on the control console display and to perform the procedure while attending the patient on the table 30.

The present invention solves this problem by providing an MRI compatible video display comprising, in this exemplary embodiment, a video projector 40 and screen 42 within the magnet room 20, permitting the surgeon to perform the procedure and view MRI images without leaving the magnet room.

A typical MRI signal is very sensitive to the electrical noise around the procession frequency of a hydrogen proton, wherein this frequency varies from 12 Mhz to 80 Mhz depending on the field strength of the magnet. Accordingly, steps are taken to block frequencies above the video frequency range, about 4.5 Mhz, in order that the video display components do not affect the MRI image quality.

The projector 40 is connected to the MRI image processor 32 by a multi-conductor cable 44 which passes through a low pass RF filter 45 disposed in the penetration panel 26 to prevent RF noise from the computer room 24 from propagating into the magnet room to adversely affect the MRI image quality. In a preferred embodiment, the filter 45 3 dB rolloff point is at 10 Mhz.

In other embodiments, the display 40 could comprise, for example, an MRI compatible reflective LCD screen display, a plasma display or other type of display which is compatible with the MRI apparatus.

The projector 40 is shown in further detail in the schematic diagram of FIG. 2. The projector 40 comprises a commercially available, conventional LCD projector assembly which has been modified in accordance with the invention to make the projector MRI compatible. The projector 40 includes a projector lamp assembly 46 comprising an incandescent lamp and a reflector, respective red, green and blue LCD panels 48, 50 and 52, and optical filtering and mirror optics 54, 56 and 58, and a projector zoom lens assembly 60. Element 62 represents the main power supply for the projector, and 64 indicates the outline of the projector main processor board. Each of the forgoing elements is present in the conventional LCD projector assembly. The manner in which the conventional projector is modified to make it MRI compatible will now be described.

The AC power cable 66 is encased within a braided metal RF shield 66A. An electromagnetic interference (EMI) filter 68 is provided between the shielded cable 66 and the power supply 62, to eliminate any electromagnetic noise from propagating from the project-

choke 68A, across which are connected 0.0047 farad capacitors 68B and 68C. The output lines 68D and 68E are respectively capacitively coupled to ground by 0.0022 microfarad capacitors 68F and 68G.

The entire projector assembly is shielded by an RF shielding housing 70 made, e.g. of copper, with feed-throughs provided for the cables 42 and 66. The shielding housing is grounded by ground connection 70A.

A round elongated metallic waveguide 72 is placed about the zoom lens assembly 60 to operate as a filter to prevent high frequency energy above about 10 MHz from propagating from the projector electronics into the magnet room. In an exemplary embodiment, the waveguide 72 has a diameter of 3.5 inches and a length of about 9 inches.

The projector 40 projects imagery onto the non-magnetic screen 42, placed in a suitable location for the doctor to view while in the magnet room.

In accordance with the invention, various video input signals are provided to the projector 40 via multi-conductor cable 44. Conductor 44A provides MRI image signals from the MRI image processor 32, permitting the projector 40 to project the MRI imagery onto the screen 42. Conductor 44B provides ultrasound imagery signals from an MRI compatible ultrasound apparatus 80 located within the magnet room 20. Conductor 44C provides input signals from the computer monitor comprising console 34, to allow the doctor to view images available on the console 34, or images generated by the personal computer 25 located in the control room, which may provide images for research or diagnostic purposes, or in aid of the surgical procedure. Conductor 44D provides data to display patient vital signs, e.g. breathing, EKG, from equipment within the magnet room monitoring the condition of the patient's vital signs. A switch 76 is provided to select the desired video input to be processed and displayed by the projector 40. The switch may be positioned so that it may be operated from within the magnet room, or remotely via the control console 34.

In some instances, it may be preferable to display images within the magnet room via a direct viewing display, rather than, or in addition to, images projected onto a screen. There may be strong lighting which interferes with the images projected onto a display screen, for example. FIGS. 3 and 4 illustrate a wired LCD display 100 which is modified to be MRI compatible. As in the case of the projector 40, the display 100 is a conventional, commercially available device which has been modified to be MRI compatible. This type of display requires a high biasing voltage, e.g. on the order of 300-500 volts. FIG. 4 is a diagrammatic side view of the major components of the display 100. Power and input video signals are provided to the unit via cable 120. A fluorescent lamp 102 provides the backlighting for an active matrix LCD screen 104. The lamp 102 requires the high biasing voltage, and is connected to a high voltage power supply via cabling 108. The display is controlled by four LCD driver integrated circuit chips 110, 112, 114 and 116 located along each side of the rectangular screen 104, as shown diagrammatically in FIG. 3. The driver circuits are connected to a main processor board 118, and are controlled by the processor board in response to externally provided image

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modified to make it MRI compatible will now be described.

The power and video input signal cable 120 is shielded by a braided metallic shield, which is grounded, to eliminate any interference with the MRI image quality.

The device 100 is enclosed within a shielded housing 122 made of copper or the like, with an opening for the LCD screen 104. The housing is grounded.

The power supply 106 is removed from within the housing of the device, as in the conventional display device, and located some distance away, so that it is not within the strong magnetic field adjacent the magnet 28. The power supply includes a transformer which if subjected to powerful magnetic fields could be damaged. The power supply 106 is placed within a shielded housing or box 124, and shielded cables 126 and 108 run from the main processor board 118 and the lamp 102 to the power supply 106. The shielding on both cables 126 and 108 is grounded. The power supply 106 includes a transformer for converting the low voltage power operating the main processor board 118 to the relatively high voltage required to operate the lamp 102. Typically, the power supply 106 will be located some twenty or thirty feet away from the strong magnetic field of the MRI apparatus to avoid interference. Typically, the power supply can be placed in a corner of the magnet room where the magnetic fields are not strong, or alternatively the power supply may be moved into the computer room by use of RF shielding in the manner of the cable 44.

The main processor board 118 is further shielded by shielding 130 which extends about the sides of the board 118 and along the surface of the board facing away from the LCD panel 104. The shielding may be fabricated of copper sheeting. The shielding 130 is grounded.

Additional shielding 132, e.g. copper sheeting, is provided for the lamp 102 and the driver circuits, and extends between the lamp 104 and the board 118, and along the sides. The shielding 132 is also grounded. The circuits 110, 112, 114 and 116 are virtually enclosed by additional copper sheeting 134 which is grounded. This sheeting 134 is to prevent RF leakage from leaking out into the magnet room to adversely affect the image quality.

The system further includes an MRI compatible ultrasonic apparatus 80, connected to the display 40, or alternatively to a second video display located within the magnet room, for example, a second projector 90 for viewing of ultrasonic images on a second screen 92. The second projector 90 can also be used to provide a display of imagery for the patient, e.g. entertainment imagery, in the manner described in the referenced patent application. MRI compatible ultrasonic apparatus are commercially available from the General Electric Company.

The system further includes apparatus 96 located within the magnet room for monitoring the patient's vital signs, such as breathing, EKG, and the like. Such equipment provide data signals which can be provided either directly to the display 40 or 90, or through conventional video processing equipment to the projector, to provide one of the inputs to the projector. One such commercially available patient vital sign monitoring equipment is the Hewlett-Packard Company model HP 78351A EKG equipment. Other types of monitoring equipment include peripheral gating devices, wherein a

pensation monitoring devices and the like. Some apparatus monitor several patient vital signs simultaneously. These apparatus provide data which may be processed for display on the display 40 or 90, for example.

The invention permits the surgeon to perform such procedures as non-invasive laser surgeries with the aid of MRI ultrasonic imaging without having to move to and from the patient in the magnet room and the display in the control room. In a typical procedure, the surgeon localizes the area of the patient's body which is to be the subject of the procedure, i.e. which part of the patient's anatomy is to be burned with a laser/optical fiber tool, with the patient's body outside the magnet bore. The ultrasound images are displayed on the display 40 or 150. The operating end of the optical fiber is then inserted into the localized area by the surgeon with the aid of the ultrasound images displayed within the magnet room. The patient's body can then be moved into the magnet bore in position for the MRI processing. With the MRI images of the localized area being displayed on the display screen 42 and observed by the surgeon, the laser can be pulsed or activated, and the results of the procedure can be observed on the display screen 42. The laser procedure can be adjusted or terminated with the aid of the MRI images, without the surgeon having to periodically go to and from the control room to see the display there. The time required for the procedure can therefore be reduced.

Another use for the display described above is in employing MRI techniques to visualize the propagation of neural activation in the brain (or accompanying physiological changes). In order to stimulate the brain, there is a need for visual stimulation that can be used in the magnetic field, and which fills up all the field of view for the patient. An LCD display can be used, by placing an LCD display such as an MRI compatible LCD TV screen, at the end of the patent table 30, and by using mirrors within the magnet bore with proper optics to direct the images inside the magnet bore for viewing by the patient within the bore. The LCD TV display can be easily interfaced to a computer or any video source to send different graphs or image patterns to the magnet room for viewing by the patient. The MRI apparatus can then be used to provide MRI images of the brain to visualize neural activation of the brain in response to the viewed visual stimulation.

It is understood that the above-described embodiments are merely illustrative of the possible specific embodiments which may represent principles of the present invention. Other arrangements may readily be devised in accordance with these principles by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A display system compatible with a magnetic resonance imaging (MRI) apparatus disposed in a magnet room, the system comprising:

means for providing MRI image video signals;

an MRI-compatible display means responsive to said video signals and disposed within said magnet room for providing a display within said magnet room, said display means including RF and electromagnetic interference filtering means to prevent noise from said display means from affecting the quality of the images produced by said MRI apparatus.

2. The display system of claim 1

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tor and a non-magnetic display screen located within said magnet room.

3. The display of claim 2 wherein said projector comprises a housing shield for containing the electronic components of said display and shielding against the propagation of RF noise from components within said housing shield to said magnet room.

4. The display of claim 3 wherein said projector comprises an optical lens for focussing light projected by said projector, and further including a metallic waveguide within which said lens is disposed, said waveguide extending from within said projector housing over the extent of said lens and comprising filter means for shielding against propagation of RF energy above about 10 MHz in frequency out said housing through said lens.

5. The display of claim 2 wherein said projector further comprises an ac power cable, said cable being provided with grounded RF shielding.

6. The display of claim 2 wherein said projector comprises a power supply connected to a source of electrical energy, said projector further comprising an electromagnetic filter connected between said source and said power supply.

7. The display of claim 1 wherein said display is further responsive to an alternate source of video image signals illustrative of an alternate image type, and said display further includes a means for selecting whether the display means is displaying said MRI images or said alternate image.

8. The display of claim 7 wherein said selecting means comprises a switch.

9. The display of claim 7 wherein said alternate source of video image signals is apparatus for providing patient vital sign data.

10. The display of claim 9 wherein said patient vital sign apparatus comprises EKG apparatus.

11. The display of claim 9 wherein said patient vital sign apparatus comprises apparatus for monitoring patient breathing signs.

12. The display of claim 7 wherein said alternate source of video image signals comprises MRI compatible ultrasonic imaging apparatus located within said magnet room.

13. The display of claim 1 wherein said display means comprises an LCD screen display device.

14. The display of claim 13 wherein said screen display device comprises a wired LCD screen.

15. The display of claim 13 wherein said screen display device includes a fluorescent light source powered by a high voltage power supply.

16. The display of claim 14 wherein said screen display device further includes a display housing shield and a high voltage power supply means located physically outside said shield but within said magnet room in a location where there is no strong magnetic field.

17. The display of claim 16 further comprising RF shielded cabling connecting said housing shield and said power supply means.

18. The display of claim 13 wherein said LCD screen display comprises LCD driver circuitry, and RF shielding means enclosing said driver circuitry for preventing unwanted propagation of RF noise into said magnet room.

19. An image display system compatible with ...

tration panel, wherein the magnet room contains a main magnet having a bore, the system comprising:

means for providing MRI image video signals, located within said control room;

an MRI-compatible display means disposed within said magnet room for providing a display within said magnet room, said display means including RF and electromagnetic interference filtering means to prevent noise from said display means from affecting the quality of the images produced by said MRI apparatus; and

means for conducting said image video signals through said penetration panel to said MRI-compatible display means located within said magnet room, said means including means for filtering said image display video signals for RF and high frequency energy.

20. The display system of claim 19 wherein said display means comprises a liquid crystal display (LCD) projector and a non-magnetic display screen located within said magnet room.

21. The display of claim 20 wherein said projector comprises a housing shield for containing the electronic components of said display.

22. The display of claim 20 wherein said projector comprises an ac power cable passed through said penetration panel to a source of ac power, a power supply operating on ac power, and an electromagnetic interference filter for coupling said ac power to said power supply, said filter for preventing electromagnetic noise energy from passing from said projector outwardly into said magnet room and thereby affecting said image quality.

23. A display system compatible with a magnetic resonance imaging (MRI) apparatus disposed in a magnet room, the system comprising:

means for providing data signals representative of a vital sign of a patient located within said magnet room;

an MRI-compatible display means responsive to said data signals and disposed within said magnet room for providing a visual display within said magnet room illustrative of said patient vital sign, said display means including RF and electromagnetic interference filtering means to prevent noise from said display means from adversely affecting the quality of images produced by said MRI apparatus.

24. The system of claim 23 wherein said means for providing data signals comprises an electrocardiogram sensing means.

25. The system of claim 23 wherein said means for providing data signals comprises means for providing patient breathing data.

26. The system of claim 23 wherein said means for providing data signals comprises peripheral gating means coupled to the patient.

27. The system of claim 23 wherein said display means comprises LCD projection means.

28. The system of claim 23 wherein said display comprises a plasma display apparatus.

29. The system of claim 23 wherein said display comprises a wired LCD display system.

30. The system of claim 23 wherein said display comprises a reflective LCD display system.

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an MRI compatible ultrasonic imaging system disposed within said magnet room for providing ultrasonic image signals of a patient within said magnet room;

an MRI-compatible display means responsive to said ultrasonic image signals and disposed within said magnet room for providing an ultrasonic image display within said magnet room, said display means including RF and electromagnetic interference filtering means to prevent noise from said display means from affecting the quality of the images produced by said MRI apparatus.

32. The display of claim 31 wherein said display means comprises an LCD projector for projecting images onto a non-magnetic screen disposed within said room.

33. The display of claim 3 wherein said display means comprises a wired LCD screen display.

34. The display of claim 31 wherein said display means comprises a plasma display means.

35. The display of claim 3 wherein said display means comprises a reflective LCD display means.

* * * * *

EXHIBIT 3

US005412419C1

(12) EX PARTE REEXAMINATION CERTIFICATE (4900th)

United States Patent
Ziarati

(10) Number: **US 5,412,419 C1**
(45) Certificate Issued: **Feb. 3, 2004**

(54) **MAGNETIC RESONANCE IMAGING COMPATIBLE AUDIO AND VIDEO SYSTEM**

(75) Inventor: **Mokhtar Ziarati**, Calabasas, CA (US)

(73) Assignee: **Resonance Technology, Inc.**, Van Nuys, CA (US)

Reexamination Request:
No. 90/004,833, Nov. 12, 1997

Reexamination Certificate for:
Patent No.: **5,412,419**
Issued: **May 2, 1995**
Appl. No.: **07/653,711**
Filed: **Feb. 11, 1991**

(51) **Int. Cl.**[7] **H04N 7/18**
(52) **U.S. Cl.** **348/61**; 348/77; 324/318; 600/418
(58) **Field of Search** 348/61, 77, 162; 324/318, 300, 307, 308, 309, 319; 128/653.3, 653.2; H04N 7/18

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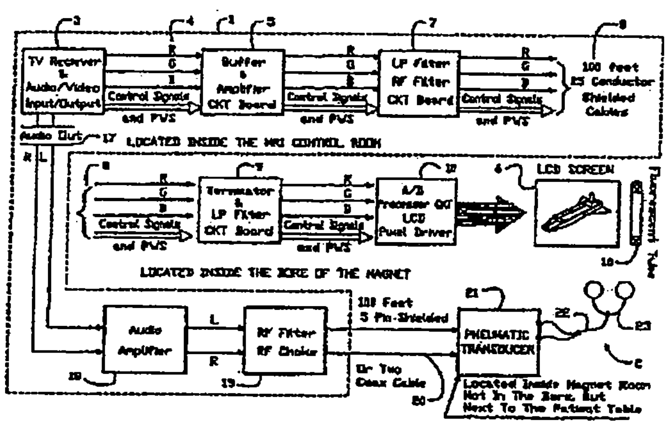
(List continued on next page.)

Primary Examiner—M. Lee

(57) **ABSTRACT**

An audio and video system that is compatible with the strong magnetic fields generated by Magnetic Resonance Imaging equipment (wherein the MRI equipment is separated by a penetration panel into a control room and a magnet room). The system receives an incoming RF signal through a television or video cassette recorder, and then separates the RF signal into a video section signal and an audio section signal. The video section signal passes through appropriate buffering, amplifying, low pass (for the procession frequency) and RF filtering circuits, and is next conducted through the penetration panel into the magnet room where it is terminated and filtered again for spurious noise. A processor and LCD pixel driver then process the video section signal and send it to an LCD display screen. A mushroom shaped hook is mounted to the screen and a catch is mounted to a bore of a main magnet inside the magnet room so that the LCD screen can be attached to the bore. The audio section signal is separated into two channels, passed through an amplifier and appropriate RF filters and chokes, and fed into a pneumatic transducer inside the magnet room. A headset having an inner set connects the output of the pneumatic transducer to the patient's ear, while an outer set covers the patient's ear to block out gradient knocking noises. In an alternate embodiment, a CCD camera is mounted inside the control room along with a microphone so that pictures and sounds from the MRI technologist can be broadcast through the present system to allow the patient to see and hear the technologist speaking. Fiber optics technology may also be incorporated into the signal conducted cables provided under this invention.



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EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims 1–22, 26, 30, 34, 37 and 39–46 is confirmed.

Claims 23–25, 27–29, 31–33, 35, 36 and 38 are cancelled.

* * * * *

EXHIBIT 4

US005877732A

United States Patent [19]

Ziarati

[11] Patent Number: 5,877,732

[45] Date of Patent: Mar. 2, 1999

[54] THREE-DIMENSIONAL HIGH RESOLUTION MRI VIDEO AND AUDIO SYSTEM AND METHOD

[75] Inventor: Mokhtar Ziarati, No. Hollywood, Calif.

[73] Assignee: Resonance Technology Co., Northridge, Calif.

[21] Appl. No.: 644,841

[22] Filed: May 8, 1996

Related U.S. Application Data

[63] Continuation of Ser. No. 226,995, Apr. 13, 1994.

[51] Int. Cl.[6] G09G 5/00

[52] U.S. Cl. 345/8; 128/653.2; 348/77

[58] Field of Search 345/7, 8, 9, 87, 345/32; 324/318; 128/653.1, 653.2; 348/46, 47, 48, 51, 52, 53, 77, 61

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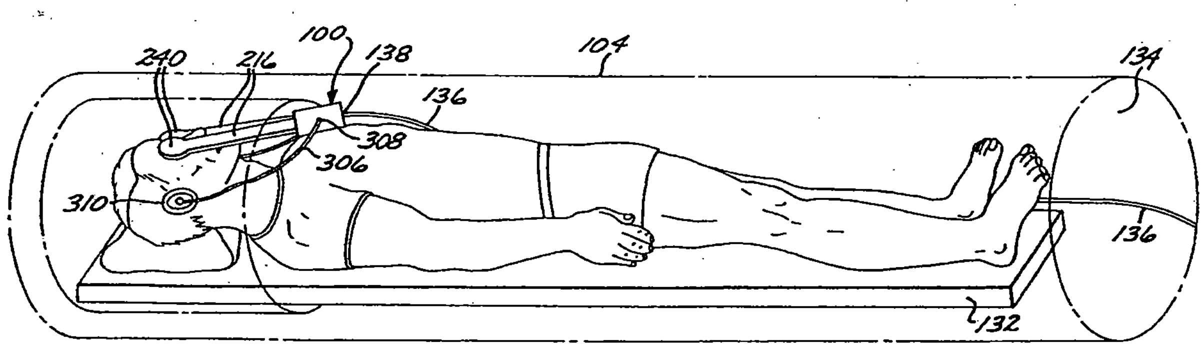
Primary Examiner—Dennis-Doon Chow
Attorney, Agent, or Firm—Larry K. Roberts

[57] **ABSTRACT**

A three-dimensional high resolution magnetic resonance imaging (MRI) video and audio system employed within the magnetic field of a bore of an MRI scanner to provide video images via a relay lens system and corresponding audible sound via a non-magnetic path to an MRI patient. The invention provides non-magnetic video sources and audio speakers for generating the images and sound, respectively, and includes a first non-magnetic shielded generating mechanism positioned within the magnetic field of the bore for providing a video image. A first optical mechanism captures and transmits the generated video image to provide a high resolution video image. A second optical mechanism magnifies and redirects the high resolution video image for viewing by the patient. A second non-magnetic shielded generating mechanism is positioned within the magnetic field of the bore for providing audible sound over the full frequency range. In a preferred embodiment, twin optical systems each receive a video signal supplied by a video source to a liquid crystal display (LCD) panel for providing a video image. The video image is impressed upon and travels across a relay lens system to a multi-element eyepiece prism and lens assembly. Each eyepiece assembly utilizes a combination of lenses to magnify the image and a prism to refract the image into the eye of the viewer in the scanner tunnel. Likewise, twin audio systems each receive audio signals supplied by an audio source to a non-magnetic shielded transducer. The audio signals are converted to audible sound over the full frequency range and transmitted to a noise canceling headset via a short non-magnetic path.

39 Claims, 6 Drawing Sheets



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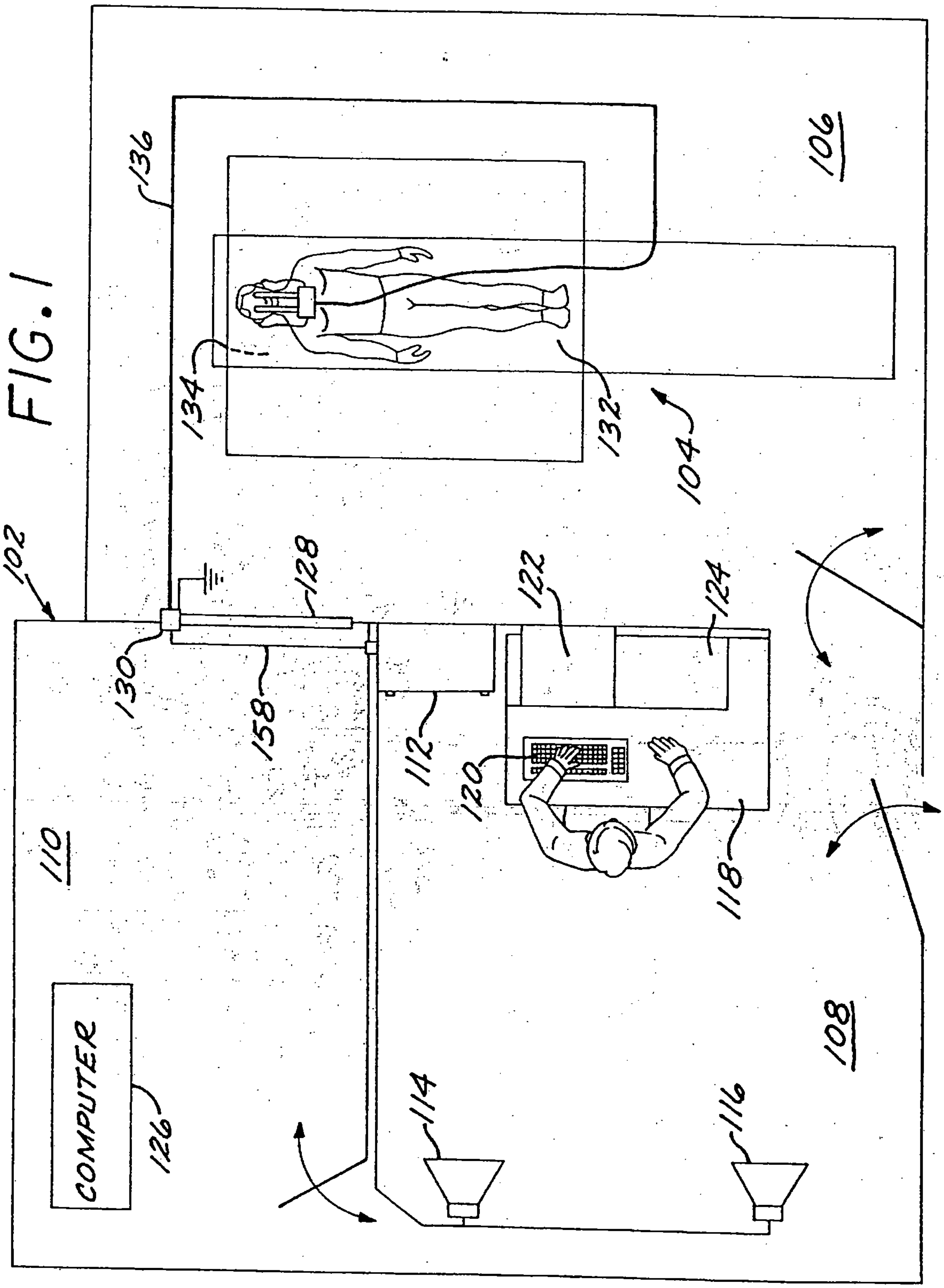

102
104
106
108
110
112
114
116
118
120
122
124
COMPUTER
126
128
130
132
134
136
158

FIG. 1

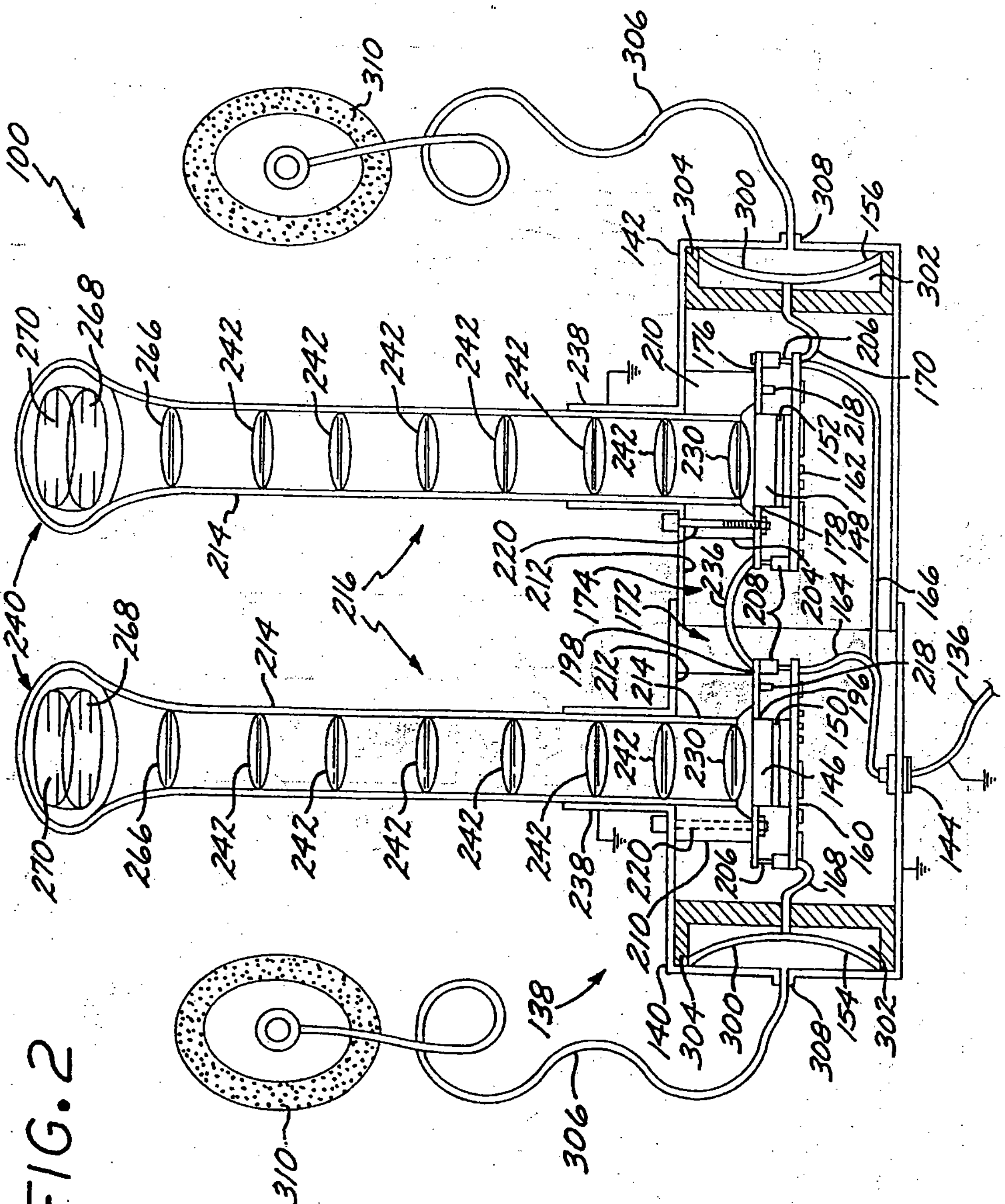
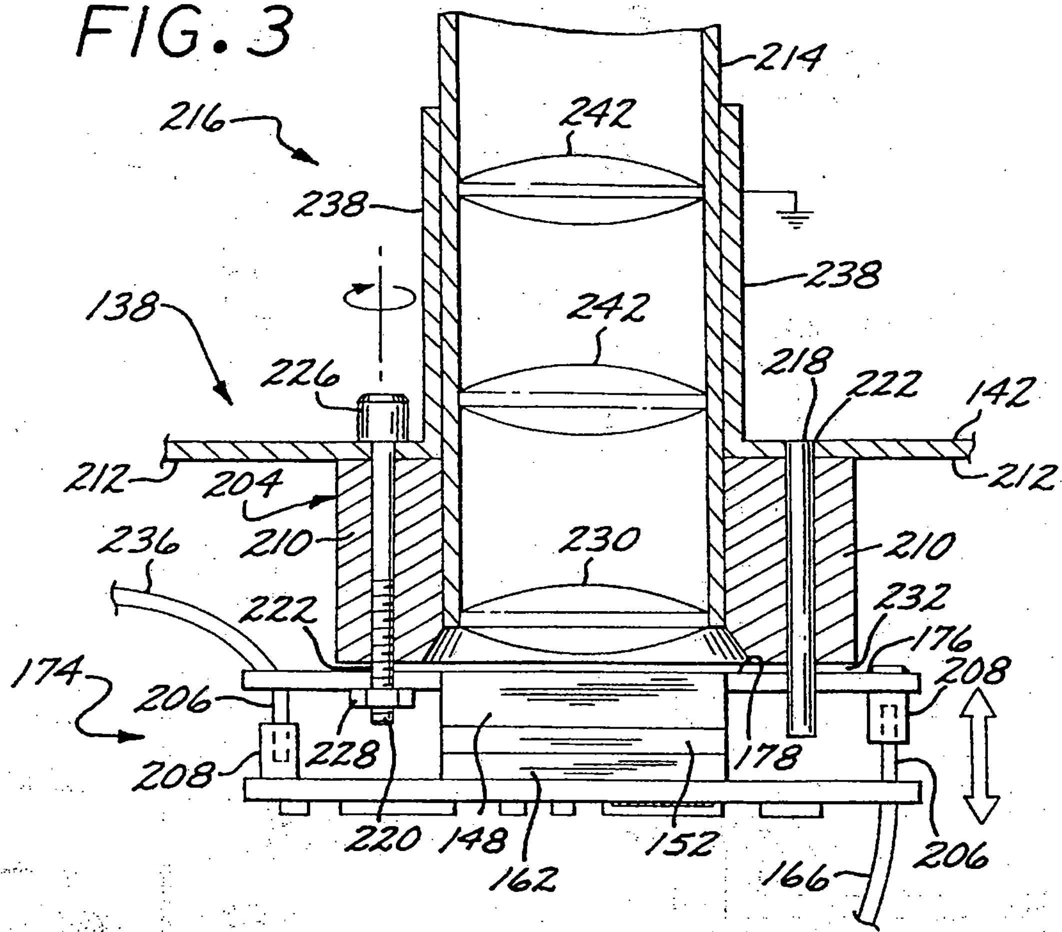

100
310
306
304
300
308
156
142
302
270
268
266
242
238
210
176
206
170
230
152
218
162
148
178
214
216
220
212
236
174
172
208
204
164
166
198
196
150
146
160
168
144
136
240
138
140
154

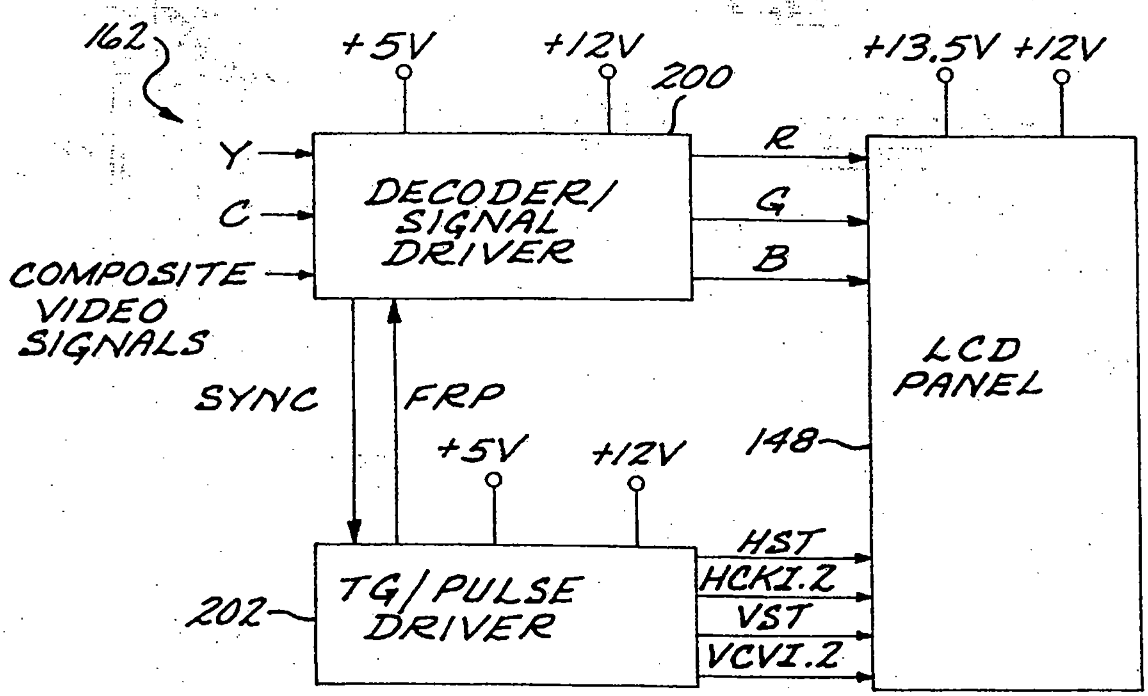
FIG. 2

FIG. 3



214
216
242
238
238
138
242
226
218
222
142
212
204
212
236
210
230
210
222
232
174
176
206
208
208
228
178
220
148
152
206
162
166

FIG. 7



162
+5V
+12V
200
+13.5V
+12V
Y
C
COMPOSITE VIDEO SIGNALS
DECODER/ SIGNAL DRIVER
R
G
B
LCD PANEL
SYNC
FRP
+5V
+12V
148
HST
HCK1.2
VST
VCV1.2
202
TG/PULSE DRIVER

FIG.4

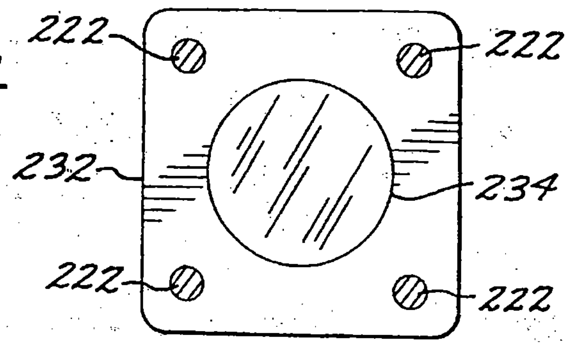


FIG.8a

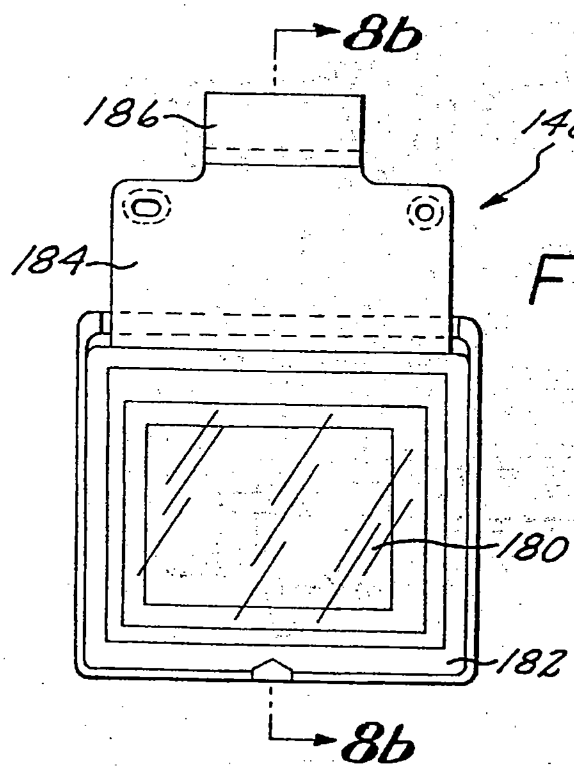


FIG.8b

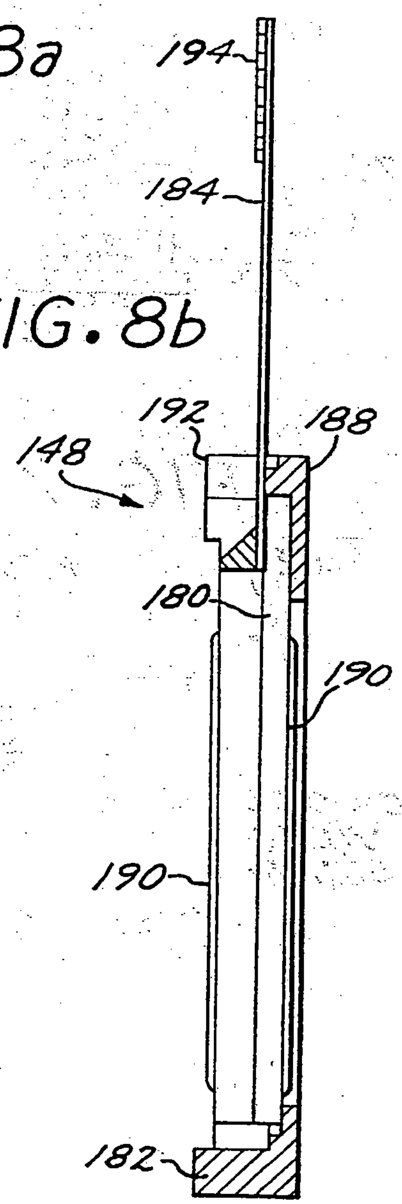
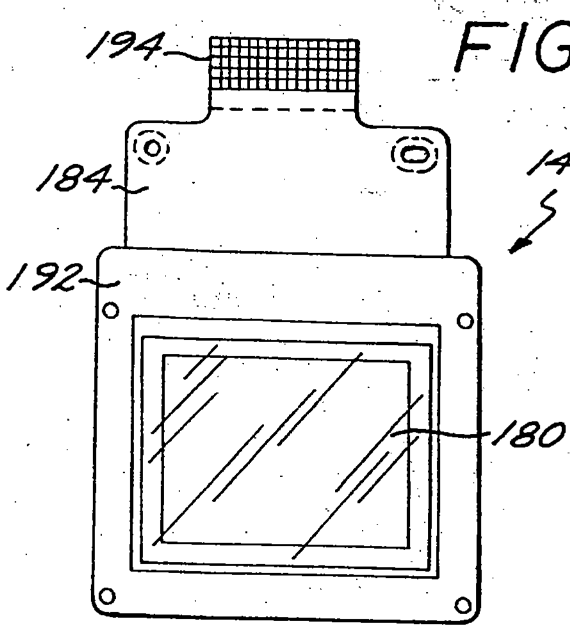


FIG.8c



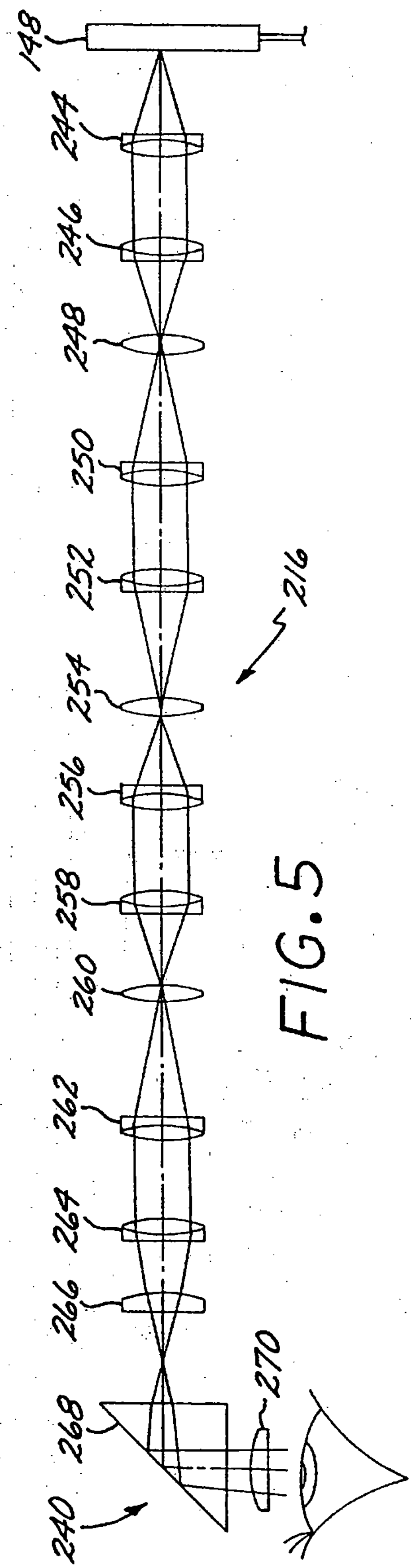

148
244
246
248
250
252
216
254
256
258
260
262
264
266
270
268
240

FIG. 5

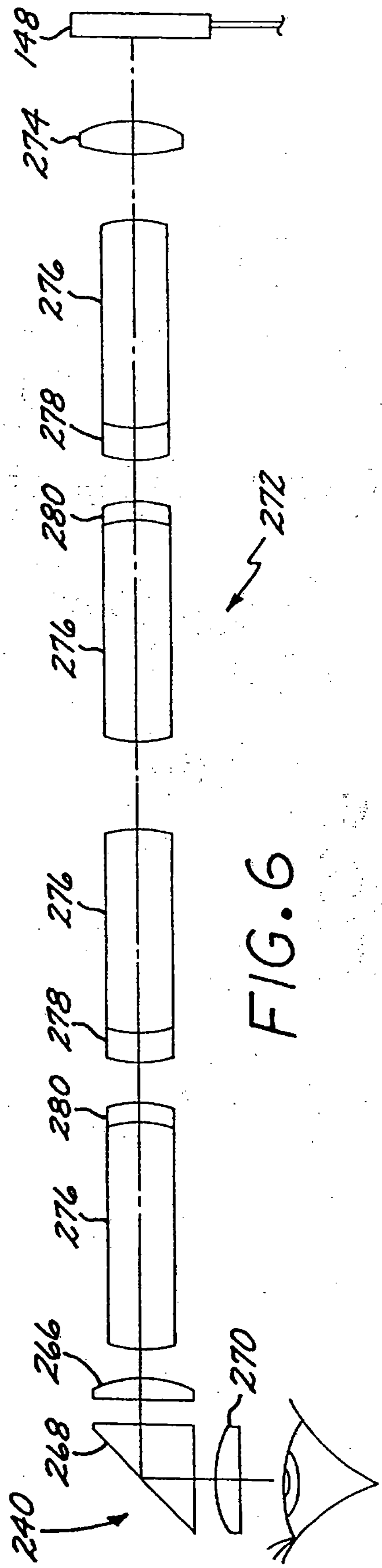

148
274
276
278
280
272
276
276
278
280
276
266
270
268
240

FIG. 6

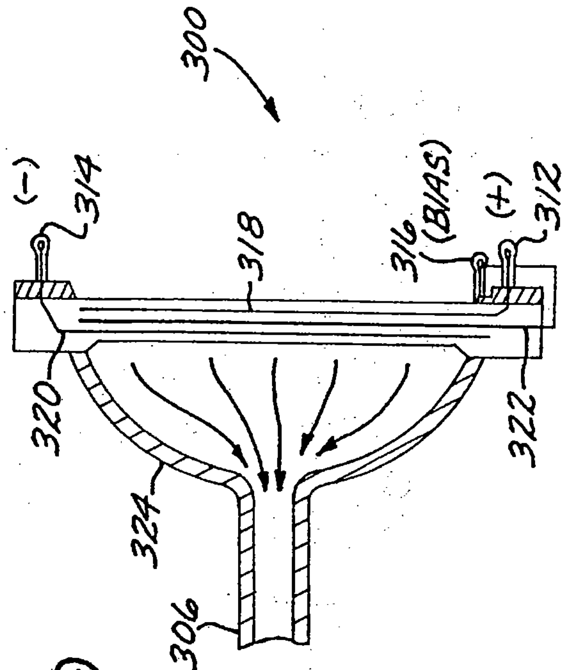

300
(−)
314
318
316
(BIAS)
(+)
312
320
322
324
306

FIG. 9

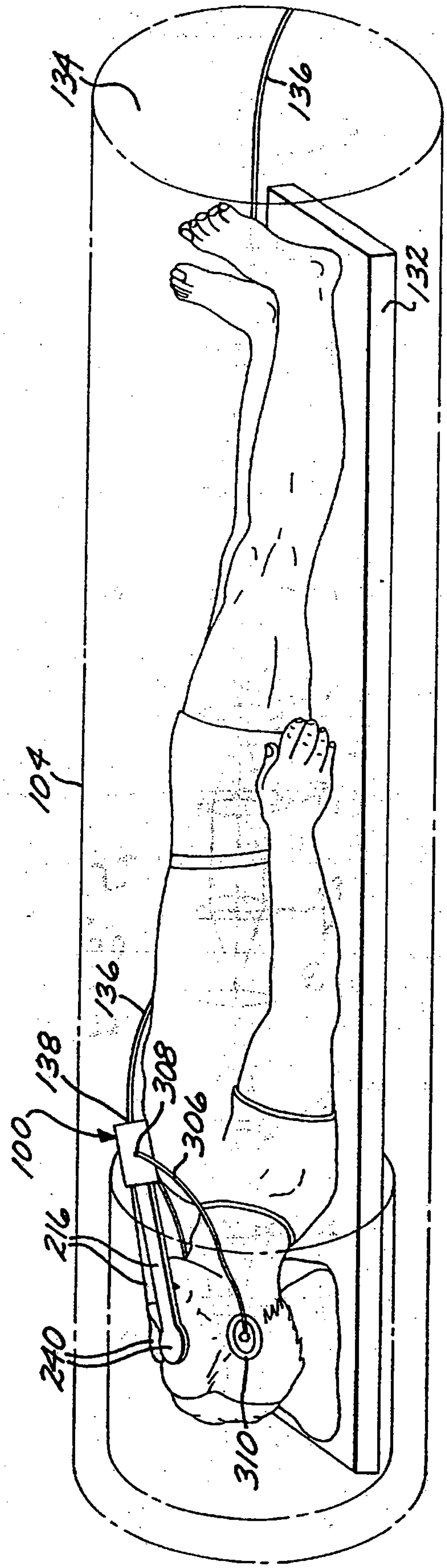

134
136
132
104
136
138
308
306
100
216
240
310

FIG. 10

THREE-DIMENSIONAL HIGH RESOLUTION MRI VIDEO AND AUDIO SYSTEM AND METHOD

"This application is a continuation of copending application Ser. No. 08/226,995 filed on Apr. 13, 1994".

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to video and audio systems. More specifically, the present invention relates to methods and apparatus for a combined video and audio system that provides three-dimensional, high resolution video images and corresponding audible sound over the full frequency range to a patient positioned in an MRI electromagnetic environment.

2. Description of the Related Art

A magnetic resonance imaging (MRI) scanner is a medical diagnostic apparatus employed to generate images of soft tissue of the human body which are not otherwise visible, for example, by the use of x-rays. In general, the MRI scanner includes a tunnel area which accommodates a patient lying, for example, in the supine position. The tunnel area is surrounded by a plurality of magnetic pickup coils. Radio frequency (RF) pulses generated by the MRI scanner enable the pickup coils to sense the changes in the energy state of the hydrogen atom protons of the human body. The changes in the energy state of the hydrogen atom protons are then captured, for example, on video images which are subsequently used for diagnostic purposes.

Generally, with respect to the use of MRI scanners, video and audio systems are employed for both (a) clinical and (b) research applications. In clinical applications, the concern is directed to anxious or claustrophobic patients who resist entering the tunnel of the MRI scanner. The capability to adequately display visual information for viewing and to efficiently transmit audio information responsive to the full frequency range of the human ear for listening pleasure are important factors for relief for the anxious or claustrophobic patient. The existing method to achieve patient comfort through visual entertainment is dependent upon the use of liquid crystal display (LCD) projection screens for display of visual information. The existing method to achieve patient comfort through audio entertainment is dependent upon the use of inefficient apparatus that provides poor sound quality and frequency response, is heavy and requires a voltage of approximately (30–50) volts RMS of a received audio signal to generate sufficient sound amplitude to enable the patient to hear the music entertainment over MRI gradient noise.

In one visual entertainment method, the LCD screen contents are viewed by the patient with the assistance of reflecting mirrors. The reflecting mirror method suffers from certain limitations. Initially, the LCD projection screen is located outside the bore of the scanner tunnel. Thus, the position of the patient within the scanner tunnel can interfere with the line of sight to the LCD screen. Further, the level of ambient light within the MRI magnet room and the need for repeated adjustments of the overhead reflecting mirrors result in limited use of this method. Since the overhead reflecting mirrors extend the field of view and the LCD projection screen is outside the tunnel, the patient is aware of her surroundings. Thus, the possibility of being distracted by the external surroundings in addition to the interior of the tunnel further limits the usefulness of this technique for the reduction of anxiety and claustrophobia in patients.

In another visual entertainment method, an MRI video system provides video images in a magnetic field through a fiber optic medium and includes a non-magnetic video source for generating a video image. A composite reduction lens is employed for capturing and compacting the generated video image and a fiber optic bundle receives and transmits the compacted video image. A magnification lens intercepts the compacted video image from the fiber optic bundle and then magnifies and focuses the intercepted video image in a magnetic field. In this application, the LCD image is transmitted to the inside of the scanner tunnel to a set of goggles so that the total field of view of the patient is limited by the goggles.

Current MRI fiber optic systems that position the LCD screen within the scanner room (but outside the bore of the MRI scanner) are extremely useful and provide a definite advance in the art. Notwithstanding, certain features of this design could be improved. In particular, the length of the fiber optic bundle employed to carry the video images from the LCD screen to the eyepiece for viewing by the patient is of concern. As with all transmission systems, a portion of the transmitted parameter is lost during transmission and the longer the transmission path, the greater the loss. For long fiber optic bundles, it is known that the loss of as much as forty percent (40%) of the transmitted video image can occur. This loss affects the resolution and brightness of the transmitted video image. Therefore, the resolution and brightness of the transmitted video image is limited by the length of the fiber optic bundle. Additionally, the longer the fiber optic bundle, the more cumbersome it is to carry the bundle and associated fiber optic equipment into and out of the MRI scanner tunnel.

A fiber optic bundle is comprised of a plurality of optical fibers. When an optical fiber is interrupted, the pixels of light of the transmitted image carried by the interrupted fiber are blocked. This situation results in dead pixels, e.g., black spots that appear on the video display. As the length of the fiber optic bundle is increased, the probability that individual fibers will be broken increases. Further, as the fiber optic bundle is bent and manipulated over a period of time, the number of broken fibers increases. An increasing number of broken fibers results in a greater number of black spots appearing on the video display. Eventually, the transmitted image becomes inadequate and distorted. Thus, long fiber optic bundles are not cost effective.

During an MRI examination, the patient is positioned upon an examination table which can be moved into and out of the MRI scanner tunnel. When lying upon the examination table within the scanner tunnel, the patient's head is positioned within a head coil. The head coil is arranged to surround the patient's head and to provide MRI images thereof. Advanced designs of MRI scanner head coils minimizes the distance between the patient's eyes and the top of the head coil. The limited distance between the patient's head and the head coil would be inadequate to accommodate the goggles employed by known MRI fiber optic systems that (a) position the image from the LCD display within the scanner tunnel or (b) employ a reflecting mirror over the patient's eyes.

The second use of video systems in MRI scanners is directed to research applications. In particular, video systems have been utilized to generate visual activation in MRI scanner studies of the visual cortex in the human brain. The visual activation, also known as functional imaging, typically includes audio or video brain stimulation utilizing computer generated images during an MRI scan of the brain. When, for example, a video image is displayed before the patient during the MRI scans, different sections of the brain will induce energy. The change in the energy level of the brain can be identified on the MRI images. These research activities are typically conducted by universities and research facilities. However, functional imaging is also useful to map specific areas around a tumor in the brain to determine, for example, the boundaries for surgical removal thereof.

The current state of video image display within the MRI magnet room in research applications consists of projection of the image onto a screen mounted on a wall or placed at the end of the imaging table. The projection is achieved within the magnetic environment by employing an MRI-compatible LCD screen. The video information is viewed by the patient with the aid of adjustable light reflecting mirrors. The utility of this method of visual activation is limited by the position of the patient within the scanner tunnel. Further, the level of ambient light in the MRI magnet room will effect the quality of the image that the patient sees on the screen. A high level of ambient light will cause the screen image to be washed out. Also, the time required to adjust the light reflecting mirrors with respect to the LCD screen is determined by the position of the patient inside the scanner tunnel. For functional magnetic resonance imaging, it is ideal to cover the entire patient field-of-view with the MRI screen or display.

The effectiveness of this method of visual activation is further reduced by an open field of view (e.g., the LCD screen is outside of the tunnel) which enables the patient to be aware of her surroundings. During functional imaging, the best results are achieved when the visual stimulus is controlled which is inconsistent with an open field of view. Further, this method of visual activation does not include the ability to generate three-dimensional (3D) images for patient viewing since the image is projected onto a single screen. The inability to create a condition is which the eye and brain perceive a 3D effect prevents virtual reality from being achieved.

It is known that the only reproducible and standard method for visual activation studies has been with the use of goggles fitted with single or multiple light emitting diodes (LEDs). Although this method has been effective in performing feasibility type functional MRI studies of visual activation, it is limited in that it represents a simple two-state photic stimulation paradigm (e.g., a two-state visual stimula). Advanced studies of the visual cortex will require the capability for implementation of visual activation paradigms more sophisticated than simple flashing lights. Further, the limited distance between the patient's head and modern head coil designs would be inadequate to accommodate the goggles employed in visual activation studies.

Typically there are two methods in which audio information can be transmitted to the patient. These methods include the use of (a) a magnetic transducer and (b) a non-magnetic transducer. A magnetic transducer or speaker incorporates a ferrous core in the construction thereof for transducing an electrical signal into sound energy by operating a diaphragm. Because of the ferrous core, the magnetic speaker must be located (20'–50') away from the patient positioned within the tunnel of the MRI scanner. This requirement is necessary so that the static magnetic field of the MRI magnet will not saturate the speaker magnetic core within the transducer and generate heat resulting in damage thereto. The entire magnetic speaker could be attracted and placed in motion by the MRI magnetic field and cause injury to the patient. Positioned at the output of the magnetic speaker is a non-magnetic transmitting medium such as a plastic tube which is employed to deliver the audio signals to a set of headphones used by the MRI patient as is known in the art.

The medium (e.g., plastic tube) utilized to transmit the audio signals from the magnetic speaker to the headphones must also be non-magnetic to avoid generating stray signals that interfere with the MRI magnetic field. Therefore, the plastic tube must be (20'–50') in length extending from the magnetic speaker to the headphones. One of the characteristics of the plastic material used to form the tube is that it tends to absorb the high frequency components of the audio signal. Thus, the frequency response is poor and the sound quality is muffled, unclear and annoying to the MRI patient.

The second method of transmitting audio signals to an MRI patient utilizes a non-magnetic speaker. An example of a non-magnetic speaker includes (a) an electret element or (b) a piezo ceramic (piezoelectric) transducer as is known in the art. These two non-magnetic speakers each serve as a transducer to convert electrical signals to sound energy, do not include a magnetic core and thus do not interfere with the MRI generated magnetic field. The electret element has a plurality of disk-shaped plates and three electrical terminals. The terminals include a positive, negative and biasing terminal. The positive terminal is connected to a first copper plate and the negative terminal is connected to a second copper plate in juxtaposition to the first copper plate. The biasing terminal is connected to a third copper plate positioned between the first and second copper plates. In operation, the positive and negative plates are energized at several hundred volts. A biasing voltage is applied to the third copper plate via the biasing terminal which causes the transducer to oscillate at a frequency within the range of 15 Hz to 30 KHz. The biasing voltage provides the amplification of the audio signal applied to the electret element as is known in the art.

The piezo speaker includes an element shaped in the form of a disk and comprised of, for example, ceramic material. When an audio signal is impressed across a piezo element, the transducer generates sound energy as is known in the art. Further, when a diaphragm is mounted over and communicates with the piezo element, the sound energy is amplified. Each of these transducer structures provides an audio speaker that can be employed to provide audio signals to the MRI patient within the scanner tunnel.

Thus, there is a need in the art for an improvement in combined video and audio systems for use with MRI scanners which provide high resolution video images with a three-dimensional effect, shortens the transmission paths that the video image and audio signals must travel, eliminates the problems associated with fiber optic bundles, is sized to fit within the limited space of modern head coil designs, is light weight and economical to produce, provides audio signals over the full frequency range and can be mounted and operated within the MRI magnetic field.

SUMMARY OF THE INVENTION

The need in the art is addressed by the three-dimensional high resolution magnetic resonance imaging (MRI) video and audio system and method of the present invention. The invention is employed within the magnetic field of a bore of an MRI scanner to provide video images through a relay lens system and corresponding audible sound via a non-magnetic path to an MRI patient and includes non-magnetic video sources and audio speakers for generating the images and sound, respectively. A first non-magnetic shielded generating mechanism is positioned within the magnetic field of the bore for providing a video image. A first optical mechanism captures and transmits the generated video image to provide a high resolution video image. A second optical mechanism magnifies and redirects the high resolution video image for viewing by the patient. A second non-magnetic shielded generating mechanism is positioned within the magnetic field of the bore for providing audible sound over the full frequency range.

In a preferred embodiment, twin optical systems each receive a video signal supplied by a video source to a liquid crystal display (LCD) panel for providing a video image. The video image is impressed upon and travels across a relay lens system to a multi-element eyepiece prism and lens assembly. Each eyepiece assembly utilizes a combination of lenses to magnify the image and a prism to refract the image into the eye of the viewer in the scanner tunnel. Likewise, twin audio systems each receive audio signals supplied by an audio source to a non-magnetic transducer. The audio signals are converted to audible sound over the full frequency range and transmitted to a noise canceling headset via a short non-magnetic path.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top planar view of an MRI facility including control and computer rooms and an adjoining magnet room housing an MRI scanner.

FIG. 2 is a front elevational view partially in cross-section of the three-dimensional high resolution MRI video and audio system of the present invention.

FIG. 3 is a front elevational view partially in cross-section of a focusing adjustment mechanism for use with the three-dimensional high resolution MRI video and audio system of FIG. 2.

FIG. 4 is a top planar view of an alignment plate for use with the focusing adjustment mechanism of FIG. 3.

FIG. 5 is a schematic diagram of an optical relay lens system for use with the three-dimensional high resolution MRI video and audio system of FIG. 2.

FIG. 6 is a schematic diagram of a rod lens relay system for use with the three-dimensional high resolution MRI video and audio system of FIG. 2.

FIG. 7 is a block diagram of the color display system of the three-dimensional high resolution MRI video and audio system of FIG. 2.

FIGS. 8*a*, 8*b* and 8*c* are front, side and rear elevational views, respectively, of a liquid crystal display (LCD) panel used with the three-dimensional high resolution MRI video and audio system of FIG. 2.

FIG. 9 is a cross-sectional view of the audio section of the three-dimensional high resolution MRI video and audio system of FIG. 2 showing a non-magnetic transducer and sound collection hood.

FIG. 10 is a perspective view of a patient positioned within the body coil of an MRI scanner tunnel showing the three-dimensional high resolution MRI video and audio system of FIG. 2 positioned on the chest of the patient.

DESCRIPTION OF THE INVENTION

The present invention is a three-dimensional high resolution magnetic resonance imaging (MRI) video and audio system **100** and method as shown in FIG. 2. The MRI video and audio system **100** is utilized to provide a patient undergoing an MRI examination with three-dimensional (3D) high resolution video images and corresponding sound over the full frequency range of the human ear. The patient examination is conducted within an MRI facility **102** which houses an MRI scanner **104** as shown in FIG. 1. The MRI facility **102** includes a magnet room **106**, a control room **108** and a computer room **110**.

The control room **108** houses an MRI audio/video unit **112** which generates audio and video signals for transmission into the magnet room **106**. In electrical communication with the audio/video unit **112** is a pair of loudspeakers **114** and **116** used for receiving voice communications from the patient during the MRI examination. Also included within the control room **108** is a desk **118** for supporting a keyboard **120** and monitor **122** mounted on a shelf **124** for use by an operator during the MRI examination. The computer room **110** houses a computer **126** used in conjunction with the operation of the MRI scanner **104**.

The MRI scanner **104** is located within the magnet room **106**. Because of the sensitivity of the signals generated by the MRI scanner **104** to electromagnetic interference (EMI) noise, the magnet room **106** must be radio frequency (RF) shielded from the control room **108** and the computer room **110** to prevent the entry of stray RF signals therein. Such shielding is known in the art and prevents interference with the imaging process. Likewise, all electrical and signal facilities entering the magnet room **106** must pass through a penetration panel **128**. The penetration panel **128** is electrically grounded to the magnet room **106** and mounted within the wall between the computer room **110** and the magnet room **106** as shown in FIG. 1. Each of the electrical and signal facilities entering the magnet room **106** must also be RF shielded to prevent interference with the imaging process. An adapter **130** is mounted on the penetration panel **128**. The adapter **130** is employed to couple the various signal and power conductors that form a shielded cable **136** through the penetration panel **128** and into the magnet room **106**. In order to ensure that the magnet room **106** is RF shielded, each of the shielded components of the MRI video and audio system **100** must be interconnected. Thus, the shield of the penetration panel **128** must be connected to the shield of the cable **136**.

The magnet room **106** houses the MRI scanner **104** which includes an imaging table **132** on which the patient is placed prior to being moved into a scanner tunnel **134** for the MRI examination. The MRI video and audio system **100** of the present invention is shown conveniently mounted on the chest and head of the patient lying on the imaging table **132** and is connected to the RF shielded cable **136**. The shielded cable **136** contains a plurality of conductors including video signal, audio signal and power supply conductors. The audio and video signal conductors of the shielded cable **136** are routed from the MRI audio/video unit **112** within the control room **108** which provides the audio and video signals to the MRI video and audio system **100** as shown in FIG. 1. The power supply conductors which include low voltage direct current and high voltage alternating current (not shown) are routed from the respective power panels (not shown) within the MRI facility **102**. Each of the video, audio and power conductors enclosed within the shielded cable **136** are then passed through the penetration panel **128** via the adapter **130**.

The video image and sound generating portions of the MRI video and audio system **100** of the present invention are enclosed within a liquid crystal display (LCD) housing **138** as is shown in FIG. 2. The LCD housing **138** is comprised of a pair of adjustable sliding boxes **140** and **142** in which box **142** can be moved into and out of box **140** by applying the appropriate force. Each of the boxes **140** and **142** can be fashioned from, for example, plastic and is coated with a layer of non-ferrous conductive material such as copper or silver. Thus, the LCD housing **138** functions as a Faraday cage. The Faraday cage (e.g., LCD housing **138**) isolates (e.g., shields) the electronic components of the MRI video and audio system **100** from the MRI RF pickup coils (not shown) positioned within the bore of the scanner tunnel **134**.

The construction of the boxes **140** and **142** is such that the two boxes always remain in physical contact to ensure continuity in the shielding or grounding of the Faraday cage. Further, the layer of non-ferrous conductive material can be positioned over the inner surface or the outer surface or both surfaces of the LCD housing **138**. In this manner, any electromagnetic interference (EMI) generated within the LCD housing **138** is intercepted and routed to electrical ground via any of the several shielded ground conductors connected to the LCD housing **138** as shown in FIG. **2**. This design prevents the EMI from affecting the quality of the MRI images of the patient and interfering with the video image and sound generating portions of the present invention. Therefore, to ensure the continuity of the RF shield for the magnet room **106**, the non-ferrous coating of the Faraday cage (e.g., LCD housing **138**) is connected to the shield of the cable **136** which in turn is connected to the shield of the penetration panel **128**.

The LCD housing **138** which is utilized in the magnetic field within the bore of the MRI scanner tunnel **134** serves to enclose and protect the video image and sound generating portions of the MRI video and audio system **100**. Further, the sliding feature exhibited by boxes **140** and **142** enables the optical and video components of the present invention as described more fully hereinbelow to be adjusted for accommodating the inter-pupil spacing of different users. Additionally, boxes **140** and **142** of the LCD housing **138** can be completely separated to facilitate maintenance to the circuitry contained therein as described hereinbelow.

The shielded cable **136** terminates in the external side of a terminal board connector **144** mounted in the bottom of the LCD housing **138**. The terminal board connector **144** is RF shielded by virtue of being connected to the LCD housing **138** (e.g., Faraday cage) and grounded as shown in FIG. **2**. The terminated shielded cable **136** includes conductors carrying video signals, audio signals, low voltage d.c. power and high voltage a.c. power. The video conductors can be, for example, standard 75 ohm coaxial video cable while the audio conductors can be standard size 28 AWG wire. The low voltage d.c. power (e.g., 24 vdc) is utilized to energize the video electronic circuitry of a pair of non-magnetic liquid crystal display (LCD) panels **146** and **148** shown in FIGS. **2**, **3** and **8**. The high voltage a.c. power (e.g., 600 vac) is used to energize a corresponding set of backlights **150** and **152** used in conjunction with the LCD panels **146** and **148**, each located within the LCD housing **138**.

Both the video and audio signals carried by the shielded cable **136** are supplied by the MRI audio/video unit **112** shown in FIG. **1**. The audio portion of the MRI audio/video unit **112** can be supplied by, for example, a stereophonic sound apparatus or other suitable device capable of transmitting appropriate sound signals to a set of non-magnetic audio transducers **154** and **156** located and shielded within the LCD housing **138**. The video portion of the MRI audio/video unit **112** can be supplied by, for example, a VCR or other suitable device capable of providing video signals to the pair of LCD panels **146** and **148**. It is known that a device that provides a true three-dimensional signal for both the right and left eye is available in the art. The known device is capable of interfacing with an ordinary VCR or personal computer to provide the three-dimensional output signal. The audio and video signals provided by the MRI audio/video unit **112** are carried by a shielded conductor **158** to the adapter **130** mounted on the penetration panel **128** as shown in FIG. **1**. Thereafter the audio and video conductors of the shielded conductor **158** pass through the RF shielded adapter **130** and merge with the power supply conductors (not shown) to form the shielded cable **136**.

The internal side of the terminal board connector **144** distributes the conductors carrying the video signals, audio signals, a.c. and d.c. power to a pair of main printed circuit boards **160** and **162** via paralleled distribution cables **164** and **166**, respectively. Likewise, a pair of audio distribution wires **168** and **170** are shown connecting the main printed circuit boards **160** and **162** to the non-magnetic audio transducers **154** and **156**, respectively.

The MRI video and audio system **100** of the present invention is comprised of a pair of LCD assemblies **172** and **174** each enclosed and shielded within the LCD housing **138**. The function of the LCD assemblies **172** and **174** is to generate a pair of stereo video images that are viewed by the patient during the MRI examination. The LCD assemblies **172** and **174** are duplicate and thus only LCD assembly **174** will be described in detail with the understanding that LCD assembly **172** is comprised of the same components which operate in the same manner. Thus, LCD assembly **174** is comprised of the non-magnetic LCD panel **148**, backlight **152**, main printed circuit board **162** and a display panel **176**.

The LCD panel **148** is the element of the LCD assembly **174** that generates the video image. The LCD panel **148** is positioned within a penetration **178** formed in the display panel **176** immediately above the backlight **152** as shown in FIGS. **2** and **3**. The LCD panel **148** of choice is known in the art and is manufactured and sold under the Part No. LCX003BK by Sony Component Products Company located at 10833 Valley View Street, Cypress, Calif. The LCD panel **148** is a 0.7" diagonal active matrix panel of super thin film polycrystal silicon transistors with built-in drivers. The LCD panel **148** can provide a full color, high resolution display in the NTSC mode (applied in the United States, Canada and Japan). Further, the LCD panel **148** has a density of 103,114 effective pixels and has a typical power consumption of 4 milliwatts. The red, green, blue (R.G.B.) pixels are arranged in a delta pattern to provide high picture quality without the fixed color pattern inherent in vertical strip and mosaic pattern arrangements.

An illustration of a suitable LCD panel **148** is shown in FIGS. **8***a*, **8***b* and **8***c*. A front elevational view of the LCD panel **148** is shown in FIG. **8***a* which clearly shows a display area **180** surrounded by molding material **182**. A flux printed circuit board (FPC) area **184** is shown positioned between the molding material **182** and a reinforcing material **186**. A side elevational view of the LCD panel **148** taken along line **8***b*–**8***b* of FIG. **8***a* is shown in FIG. **8***b*. Additional components of the LCD panel **148** shown in FIG. **8***b* include reinforcing material **188** and a pair of polarizing plates **190**. FIG. **8***c* shows a back elevational view of the LCD panel **148** and further illustrates an outside frame **192** and a pin connection pad **194**. Each of the components illustrated in FIGS. **8***a*, **8***b* and **8***c* are known in the art and available in Sony Part No. LCX003BK. It is noted that LCD panel **146** shown in FIG. **2** is mounted within a penetration **196** of a display panel **198** and functions in the same manner as LCD panel **148**.

Mounted immediately beneath the LCD panel **148** is the backlight **152**. The backlight **152** is a high voltage, cold cathode florescent (CCF) lamp which is an integral part of the LCD panel 148. The operating parameters of the backlight 152 include an operating terminal voltage of approximately 600 volts a.c. and a line amperage of 15 milliamps that operates at a frequency in the kilohertz range. The power supply (not shown) of the backlight 152 utilizes a step-up transformer that includes a core comprised of ferrous material. Ferrous material will not operate properly when positioned within the MRI magnetic field. Therefore, the power supply for the backlight 152 must be located remote from the MRI scanner tunnel 134. Further, the magnetic field associated with the power supply of the backlight 152 must have a field strength of less than thirty Gauss. In addition, there can be no ferrous material located within any components of the MRI video and audio system 100 including the main printed circuit boards 160 and 162 as shown in FIGS. 2 and 3. The description of backlight 152 applies equally to backlight 150 associated with the LCD panel 146.

Mounted directly beneath the backlight 152 is the main printed circuit board (PCB) 162 as shown in FIG. 2. The main PCB 162 includes all of the electronic circuitry associated with the LCD panel 148 and is utilized in conjunction with the display panel 176 to sandwich the LCD panel 148 and the backlight 152. The main PCB 162 is more clearly shown in FIG. 7 which is a block diagram of the three major components each of which are known in the art. The three major components include a decoder/signal driver 200, a timing generator/pulse driver 202 and the LCD panel 148.

The decoder/signal driver 200 is an integrated circuit designed to drive the LCD panel 148 and which receives both a +5 volt and +12 volt input. The decoder portion converts the composite video signals into red, green, blue (R.G.B.) signals for the LCD panel 148. The signal driver portion delivers the R.G.B. signals to the LCD panel 148. The timing generator/pulse driver 202 also receives both a +5 volt and +12 volt input. The timing signal generator portion develops a timing signal or pulse to drive the pixels of the LCD panel 148 while the pulse driver portion delivers the (horizontal and vertical) timing signals (HST, HCKL2, VST, VCKL2) to the LCD panel 148. Further, the decoder/signal driver 200 and the timing generator/pulse driver 202 exchange input signals (e.g., sync and FRP signals) as shown in FIG. 7.

The LCD panel 148 receives the R.B.G. signals from the decoder/signal driver 200 and the horizontal and vertical timing signals from the timing generator/pulse driver 202 to display the video image within the magnetic field without affecting the MRI image quality. The LCD panel 148 also receives +13.5 volt and +12 volt inputs. Examples of suitable devices for use in the design of the main PCB 162 are as follows. Sony Part No. CXA1785R is a decoder and signal driver which converts composite video signals into R.G.B. signals before they are transmitted to the LCD panel 148. Sony Part No. CXD2403R is a timing generator and pulse driver that synchronizes the timing of the color signals and generates horizontal and vertical signals. The LCD panel 148 can be comprised of Sony Part No. LCX003BK for use with NTSC video signals. The entire circuit for the main PCB 162 is disclosed in a Sony drawing having reference number LCD005-1. The design and operation of each of the components of the main PCB 160 are duplicate to those described above for the main PCB 162.

The display panel 176 serves to interface with the LCD panel 148, act as a mounting platform for certain of the electronic components of the main PCB 162 and to interface with a focusing adjustment mechanism 204. The penetration 178 formed within the display panel 176 as shown in FIG. 2 serves as a window in which the display area 180 of the LCD panel 148 can be viewed. The LCD panel 148 must be mounted within the penetration 178 so that when the image is viewed through an optical subsystem, the image will appear in the upright position. Also, by utilizing the display panel 176 to mount components associated with the main PCB 162, the LCD assembly 174 can be miniaturized.

It is noted that the LCD panel 148 and the backlight 152 are sandwiched between the main PCB 162 and the display panel 176. In particular, FIGS. 2 and 3 show that the main PCB 162, the backlight 152, the LCD panel 148 and the display panel 176 are connected as a single unit within the LCD housing 138. This is accomplished by utilizing eight pin PC mount male-female connectors to join or jump the main PCB 162 with the display panel 176. The male-female connectors comprise male connectors 206 and female connectors 208 as best shown in FIG. 3. This design provides mechanical support to each of the four components enabling the LCD assembly 174 to move in unison. Further, mounting of the main PCB 162, the backlight 152, the LCD panel 148 and the display panel 176 as a single unit provides the added benefits of keeping the LCD assembly 174 dark and free of any contamination in case the LCD housing 138 is opened for maintenance.

By inspection of FIGS. 2 and 3, it can be seen that the focusing adjustment mechanism 204 includes a non-ferrous mounting bracket 210 which butts against the top inside surface 212 of the LCD housing 138 and surrounds a lens housing 214. The mounting bracket 210 is fixedly connected to the top inside surface 212 and the lens housing 214 by either being integrally molded thereto as by being comprised of plastic or by being adhered with an adhesive.

The focusing adjustment mechanism 204 is designed to permit the position of the LCD assembly 174 to be moved slightly with respect to the LCD housing 138 to adjust the focal point of an optical relay lens system 216 for different users. The focusing adjustment mechanism 204 includes a set of four shafts of which three shafts 218 have a smooth outer surface and one shaft 220 is threaded as is shown in FIG. 3. Each of the shafts 218 and 220 fit into a smooth bore 222 formed in the mounting bracket 210 as shown in FIG. 4. At the top of the threaded shaft 220 is a knob 226 which enables the threaded shaft 220 to be manually rotated within the corresponding bore 222. Each of the shafts 218 and 220 extend through the mounting bracket 210 and the display panel 176. The threaded shaft 220 is received by a threaded nut 228 which can be physically attached to the bottom of the display panel 176 as with an adhesive.

Each of the shafts 218 and 220 extends through the corresponding bore 222 of the mounting bracket 210 and the top inside surface 212 of the LCD housing 138. The non-threaded shafts 218 are employed for alignment purposes and prevent the image on the LCD panel 148 from rotating in the horizontal plane. The focusing knob 226 is mounted to the top of the threaded shaft 220 and is large enough to avoid passing through the bore 222 as shown in FIG. 3. Mounted beneath the optical relay lens system 216 and a focus lens 230 but above the display panel 176 is an alignment bracket 232 as shown in FIG. 4. The alignment bracket 232 shows the four bores 222 which receive the shafts 218 and 220, respectively. The smooth bores 222 ride on the non-threaded shafts 218 and on the threaded shaft 220. A center penetration 234 is formed at the center of the alignment bracket 232 which is aligned with the penetration 178 formed in the display panel 176. The pair of penetrations 178 and 234 enable the focus lens 230 to capture the entire video image appearing on the LCD panel 148 mounted directly beneath and to focus the image through the optical lens relay system 216.

When the knob 226 is manually rotated, the threaded shaft 220 rotates within the smooth bore 222. The threaded shaft 220 does not advance or retract within the smooth bore 222 because there are no threads within the smooth bore 222. However, the threads of the shaft 220 do turn in the corresponding threads of the stationary threaded nut 228. Thus, the threaded nut 228 does advance and retract along the threads of the shaft 220 when the threaded shaft 220 is manually rotated. The direction of movement of the threaded shaft 220 and the threaded nut 228 depends upon the direction of rotation of the knob 226. Movement of the threaded nut 228 along the threaded shaft 220 carries with it the entire LCD assembly 174 and thus permits the distance between the LCD panel 148 and the focus lens 230 to be adjusted. The adjusted distance is sufficient to alter the focal point of the optical relay lens system 216.

In order to obtain a 3D effect with the MRI video and audio system 100, each video signal delivered to the respective LCD panels 146 and 148 must originate from a separate video source such as a VCR, computer or the like. In the alternative, any suitable video source can be interfaced with known devices that provide a three-dimensional signal for both eyes of the patient. If a condition should arise that a 3D stereo effect is not required, the signals can be provided by a single video source to provide mono-operation. Under these conditions, the main PCB 162 of LCD assembly 174 is sufficient to provide the video and audio signals and power supply to both LCD panels 146 and 148. In practice, this is accomplished by using a parallel ribbon cable 236 to link the display panel 176 of LCD assembly 174 to display panel 198 of LCD assembly 172. In this manner, the audio and video signals and the power supply are shared to provide a mono effect.

The LCD housing 138 includes an upward extension 238 which lies in the same plane as the mounting bracket 210 of the focusing adjustment mechanism 204 best shown in FIG. 3. The upward extension 238 is attached to the lens housing 214 as with an adhesive for providing support to the optical relay lens system 216. The upward extension 238 is part of the Faraday cage and is thus shielded by being connected to electrical ground.

The function of the optical relay lens system 216 is to transfer the video image generated by the LCD panel 148 to an eyepiece 240 for viewing by the patient. It is noted that the optical relay lens system 216 such as the one utilized in the present invention is known in the art. In FIG. 2, the optical relay lens system 216 is illustrated by a general diagram that shows the lens housing 214 enclosing a plurality of lenses 242. The number of lenses 242 can vary depending upon the length of the lens housing 214 and the correction required for the aberration which is the distortion of the image through the lenses 242. The more lenses 242 included in the lens housing 214, the more the distortion of the image can be minimized.

A more detailed diagram of the optical relay lens system 216 is shown in FIG. 5. The number of lens combinations shown in FIG. 5 of the optical relay lens system 216 is equal to the number of lenses 242 shown enclosed within the lens housing 214 of FIG. 2. The LCD panel 148 is shown located at the entry of the optical relay lens system 216 in FIG. 5. The first combination of two lenses 244 and 246 is equivalent to the focus lens 230 shown in FIG. 2. The combination of lenses 244 and 246 serve to maintain the light from the LCD image in a collimated condition, e.g., maintain the light rays in a parallel state so that a particular pixel appearing on the LCD screen at a first position also appears at the first position on the transmitted image in the eyepiece 240 as perceived by the patient.

The next lens 248 shown on FIG. 5 is equivalent to the next lens 242 as shown on FIG. 2. Lens 248 serves to reverse the image and couple the collimated light rays exiting lens 246 to the next combination of lenses 250 and 252. Lenses 250 and 252 serve the same function as lenses 244 and 246. Thereafter, a lens 254 serves the same function as the coupler lens 248 and so on with each stage functioning as an optical relay using combinations of lenses equivalent to lens 242 shown in FIG. 2. Likewise, lenses 256 and 258 and lens 262 and 264 each serve as optical relays collimating the light rays of the LCD image and lens 260 serves as an optical coupler as with lenses 254 and 248. The final lens in the optical relay lens system 216 is a magnification lens 266 used to magnify and focus the video image received from the LCD panel 148.

The combination of lenses used in the optical relay lens system 216 has been commonly used in related fields of industrial technology including but not limited to laparoscopy (viewing stomach interior during surgery), endoscopy (viewing joint interior during surgery) and borescopy (viewing interior of gun barrel). The optical relay lens system 216 can be custom designed for a particular application. In the alternative, off-the-shelf designs are available from COMEG U.S.A. located at 1200 South Parker in Denver, Colo. and from Edmund Scientific Company located at 101 E. Gloucester Pike in Barrington, N.J. 08007-1380.

The optical relay lens system 216 terminates in a right angle prism 268 which receives the magnified video image from magnification lens 266. The size of the video image depends upon the magnification factor of the lens 266. The function of the right angle prism 268 is to refract the light orthogonally (e.g., at a right angle) into the eyepiece 240 to enable the patient to see a virtual image as if the image were projected onto a large screen. A second magnification lens 270 receives the refracted light rays from the prism 268 and magnifies and focuses the video image prior to perception by the eye of the patient. Both of the magnification lenses 266 and 270 are normally attached to the right angle prism 268 as with an adhesive. The right angle prism 268 and the associated lenses 266 and 270 are also available from Edmund Scientific Company. The optical relay lens system as disclosed in FIG. 5 is suitable for use in the manufacture of small quantities as a prototype to carry the video image from the LCD panel 148 to the eyepiece 240.

An alternative optical relay system for use in transmitting the video image to the eyepiece 240 and suitable for mass production is disclosed in FIG. 6 and comprises a rod lens relay system 272. The video image which is provided by the LCD panel 148 is projected onto an objective lens 274. The objective lens 274 serves as a focus lens and operates in conjunction with the focusing adjustment mechanism 204. The rod lens relay system 272 is comprised of a plurality of optical unit rods 276 each including a doublet achromatic lens 278 (e.g., two lenses) and a single lens 280 on the opposing side. Use of the doublet achromatic lens 278 and the single lens 280 is known in the art. As with the optical relay lens system 216, the combination of lenses of the rod lens relay system 272 is utilized to collimate the light of the video image (e.g., to make the light rays parallel). This design corrects for achromatic aberration (where the edges of the image are distorted) as is known in the art.

The number of optical unit rods 276 (e.g., doublets 278 and single lens 280) required in the design of the rod lens relay system 272 in a particular application is determined by the distance between the LCD panel 148 and the optical eyepiece 240. The rod lens relay system 272 is also available from COMEG U.S.A. in Denver, Colo. An expensive precision design mold is required to develop the rod lens relay system 272. However, subsequent mass production of the rod lens relay system 272 is more economical than for the optical relay lens system 216. The eyepiece 240 comprised of the right angle prism 268 and the first and second magnifying lens 266 and 270 are exactly duplicate to and operate the same as those described in conjunction with the optical relay lens system 216.

Several advantages are derived from employing either the optical relay lens system 216 or the rod lens relay system 272 to transmit the video image from the LCD panel 148 to the eyepiece 240 as opposed to a fiber optic bundle. There are no dead pixels and thus the video images are very clear as with a camera lens. The lens relay system is many times more economical than a fiber optic bundle or rod. The relay lens system is lighter in weight which is important since the MRI video and audio system 100 is mounted over the patient's face. Additionally, the relay lens system is compatible with advance technology in that it will still be viable as a circuit element when the resolution of the LCD panel 148 increases. Notwithstanding these advantages, it is to be understood that either the optical relay lens system 216 or the rod lens relay system 272 can be replaced by a fiber optic rod (not shown). However, the fiber optic rod is expensive, heavy and exhibits limited resolution and thus either of the two lens relay systems are preferred.

A description of the audio portion of the MRI video and audio system 100 will now be presented. The audio portion is comprised of a high efficiency, full frequency response MRI non-magnetic transducer which converts audio signals into sound energy. A non-magnetic transducer 300 is shown mounted and shielded within each end of the LCD housing 138 in FIG. 2. Both non-magnetic shielded transducers 300 are duplicate copies and thus only one will be described in detail. The non-magnetic shielded transducer 300 does not have a magnetic core and thus can be successfully operated within the MRI magnetic field. In order to direct the generated sound energy to the patient, the transducer 300 is enclosed in a pocket 302 comprised of noise absorbing material 304 which isolates the transducer 300 from the video section of the MRI video and audio system 100. The sound absorbing material 304 can be, for example, any lightweight material suitable for trapping sound such as paper particles, fiberglass or the like.

The audio distribution wires 168 and 170 are shown in FIG. 2 transporting audio signals from the parallel distribution cables 164 and 166 via the main PCBs 160 and 162, respectively. The audio signals are transmitted to the non-magnetic shielded transducer 300 for conversion to sound energy. The sound energy is amplified by the transducer 300 and thereafter transmitted to a non-magnetic tube 306 which serves as a conduit. The non-magnetic tube 306 is approximately 8' in length and ¼" in diameter and can be comprised of plastic as is known in the art. It is noted that the short length of plastic tube 306 minimizes the loss of high frequencies (e.g., provides a high frequency response) and providing a clear sound having high fidelity characteristics.

The respective ends of the LCD housing 138 each include a nipple formation 308 which receives the end of the plastic tube 306. This connection provides a direct pathway for the sound energy to travel from the transducer 300 to the plastic tube 306. The plastic tube 306 transports the sound energy to a noise canceling headset 310 as is shown in FIG. 1. A suitable noise canceling headset for use in the present invention is shown and described in copending patent application having Ser. No. 07/653,711 and filed on Feb. 11, 1991 by the present applicant. The copending application is entitled Magnetic Resonance Imaging Compatible Audio and Video System.

Several non-magnetic transducers known in the art are suitable for use as the non-magnetic shielded transducer 300 of the present invention. For example, a piezoelectric transducer would be appropriate for the present application. An example of a suitable piezoelectric transducer is shown and described in a copending patent application having Ser. No. 08/221,852 and filed on Apr. 1, 1994 by the present applicant. The title of the copending application relating to piezoelectric transducers is High Efficiency Full Frequency Response MRI Audio Transducer System and Method.

Another non-magnetic transducer suitable for use in the present invention is the electret element shown in FIG. 9. The non-magnetic electret element 300 serves to convert electrical signals to sound energy, does not include a magnetic core and thus does not interfere with the MRI generated magnetic field. The electret element 300 has a plurality of disk-shaped plates and three electrical terminals. The electret element 300 includes a positive terminal 312, a negative terminal 314 and a biasing terminal 316. The positive terminal 312 is connected to a first copper plate 318 and the negative terminal 314 is connected to a second copper plate 320 in juxtaposition to the first copper plate 318. The biasing terminal 316 is connected to a third copper plate 322 positioned between the first and second copper plates 318 and 320, respectively.

In operation, the first (+) and second (–) copper plates 318 and 320 are energized at several hundred volts. A biasing voltage of 150–200 volts is applied to the third copper plate 322 via the biasing terminal 316 which causes the transducer 300 to oscillate at a frequency within the range of 15 Hz to 30 KHz. The biasing voltage provides the amplification of the audio signal applied to the electret element 300 as is known in the art. The amplified sound energy provided by the transducer 300 shown in FIG. 9 is collected by a sound collection hood 324 and routed into the non-magnetic tube 306 for transmission to the headset 310. The electret element serving as the transducer 300 is available from STAX Kogyo, Inc. located at 16920 Halldale Avenue, Gardena, Calif. 90247 under the Part No. SR-5N.

The patient is shown in the supine position during an MRI examination in FIG. 10 with the LCD housing 138 of the three-dimension high resolution MRI video and audio system 100 mounted on his chest. The eyepiece 240 is positioned over the eyes of the patient and the headset 310 is mounted over his ears. The shielded cable 136 is shown running through the scanner tunnel 134 from the penetration panel 128 (shown in FIG. 1) to the LCD housing 138. An additional feature includes installing a mercury on-off switch (not shown) within the LCD housing 138 to facilitate energizing the video portion of the MRI video and audio system 100. The mercury switch (not shown) can be strategically placed and wired so that the video portion would be energized only when the LCD housing 138 was in the horizontal position.

It is noted that a novel feature of the present invention is that all of the components of the MRI video and audio system 100 are utilized in the magnetic field of the bore of the MRI scanner 104. It is emphasized that the present invention operates properly while positioned in the bore of the MRI scanner because the LCD housing 138 is a Faraday cage which shields each of the electronic components contained therein, the components of the main PCBs **160** and **162** are of non-ferrous construction, and all components containing ferrous construction are located remote from the magnetic field of the MRI scanner **104**. However, it should be emphasized that the main PCBs **160** and **162** can be located outside of the magnetic field of the scanner tunnel **134** with the optics and the LCD panel **148** located within the magnetic field and the invention would operate in a manner equivalent to that described hereinabove.

The present invention provides novel advantages over other video and audio systems known in the art. The invention is a combined video and audio system, the set-up time of the invention is reduced, the set-up mirror is eliminated, the field of view from inside the scanner tunnel **134** is limited, all system components are located within the bore of the MRI scanner tunnel, the video and audio transmission paths are shorter, the fiber optic bundle/rod is eliminated, the new video and audio system fits inside the headcoil within the scanner tunnel **134**, the use of the Faraday cage eliminates the need for a low pass filter, and installation is simple and economical.

While the present invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those having ordinary skill in the art and access to the teachings provided herein will recognize additional modifications, applications and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

It is therefore intended by the appended claims to cover any and all such modifications, applications and embodiments within the scope of the present invention. Accordingly,

What is claimed is:

1. An image generating system for use within a magnetic field of a scanner tunnel of a magnetic resonance imaging scanner, comprising:

a first non-magnetic image generator disposed within said scanner tunnel for generating a visible image in response to first electronic image-defining signals, said first image generator comprising a first electronic display device responsive to said first image-defining signals;

a non-magnetic, non-ferrous shield enclosure for housing said first non-magnetic image generator within said scanner tunnel and within a strong magnetic field generated within said scanner tunnel during imaging operation of said imaging scanner, said shield enclosure adapted to shield said image generator from RF pulses generated by said imaging scanner during imaging operation such that said RF pulses do not appreciably affect operation of said first image generator, said shield enclosure further adapted to shield said imaging scanner from any electromagnetic interference generated by said first image generator such that said first image generator does not appreciably affect operation of said imaging scanner; and

first optical apparatus connected to said shield enclosure for directing said visible image from a penetration in said shield enclosure to a person's eye for viewing by a person disposed within said scanner tunnel.

2. The system of claim **1** wherein said shield enclosure is adapted to perform the function of a Faraday cage.

3. The system of claim **1** wherein said first electronic display device comprises a liquid crystal display.

4. The system of claim **3** wherein said liquid crystal display (LCD) comprises a display panel having a penetration formed therein, and a non-magnetic LCD panel for generating a video image positioned within said penetration, and wherein said shield enclosure further includes a supporting bracket for supporting said first optical apparatus in alignment with said penetration.

5. The system of claim **4** wherein said first optical apparatus comprises an optical lens relay system including a focal lens.

6. The system of claim **4** wherein said LCD includes a printed circuit board disposed within said shield enclosure, and wherein said image generator is free of any ferrous material.

7. The system of claim **4** wherein said LCD further includes a high voltage backlight disposed beneath said display panel and within said shield enclosure.

8. The system of claim **7** wherein said backlight includes a cold cathode fluorescent lamp, and further comprising a step-up transformer located remote from the MRI scanner tunnel.

9. The system of claim **1** wherein said first optical apparatus comprises an optical relay lens system.

10. The system of claim **1** wherein said first optical apparatus comprises a rod lens relay system.

11. The system of claim **1** wherein said first optical apparatus comprises an eyepiece including at least one magnifying lens for magnifying said image.

12. The system of claim **11** wherein said eyepiece comprises a prism for orthogonally redirecting said image.

13. The system of claim **1** wherein said shield enclosure comprises apparatus for adjusting to accommodate interpupil spacing variations of different persons within the scanner tunnel.

14. The system of claim **1** wherein said first optical apparatus includes a focus lens for focusing said generated image.

15. The system of claim **14** further including a focusing adjustment mechanism for changing the distance between said focusing lens and said image generator.

16. The system of claim **15** wherein said focusing adjustment mechanism includes an alignment plate for preventing lateral movement of said image generator.

17. The system of claim **1** wherein said first image generator comprises a video image generator and said first electronic image-defining signals include video image signals.

18. The system of claim **1** wherein said shield enclosure comprises first and second non-magnetic sliding boxes comprising electrically conductive surfaces, said first box adapted for movement into and out of said second box.

19. The system of claim **1** further comprising a second non-magnetic image generator disposed within said scanner tunnel for generating a second visible image in response to second electronic image-defining signals, said second image generator comprising a second electronic display device responsive to said second image-defining signals, said second display device disposed within said shield enclosure, and a second optical apparatus for directing said second visible image for viewing by said person, and wherein said first image generator and said first optical apparatus cooperate to direct said first image for viewing by the right eye of said person, and said second image generator and said second optical apparatus cooperate to direct said second image for viewing by the left eye of said person, thereby providing a binocular image generating system.

20. The system of claim **1** wherein said first electronic image-defining signals are carried via a non-magnetic, RF-shielded cable extending into said scanner tunnel and connected into said shield enclosure.

21. The system of claim 1 wherein said first display device comprises a liquid crystal display, and a backlight powered by a remote source located outside said scanner tunnel, said remote source connected to said shield enclosure via a non-magnetic, RF-shielded cable.

22. The system of claim 1 further comprising a non-magnetic audio generator responsive to electrical audio-defining signals for generating audio signals, said audio generator disposed within said shield enclosure.

23. The system of claim 22 wherein said audio generator comprises a non-magnetic transducer.

24. The system of claim 22 wherein said audio generator comprises a non-magnetic tube for transmitting said audio signals to a headset.

25. An image generating system for use within a magnetic field of a scanner tunnel of a magnetic resonance imaging scanner, comprising:

a first non-magnetic image generator disposed within said scanner tunnel for generating a visible image in response to first electronic image-defining signals, said first image generator comprising a first electronic display device responsive to said first image-defining signals;

a second non-magnetic image generator disposed within said scanner tunnel for generating a second visible image in response to second electronic image-defining signals, said second image generator comprising a second electronic display device responsive to said second image-defining signals;

a non-magnetic, non-ferrous shield enclosure for housing said first and second non-magnetic image generators within said scanner tunnel and within a strong magnetic field generated within said scanner tunnel during imaging operation of said imaging scanner, said shield enclosure for shielding said image generators from RF pulses generated by said imaging scanner during imaging operation such that said RF pulses do not appreciably affect operation of said image generators, and for shielding said imaging scanner from any electromagnetic interference generated by said image generators such that said image generators do not appreciably affect operation of said imaging scanner;

first optical apparatus for directing said first visible image for viewing by a person disposed within said scanner tunnel;

second optical apparatus for directing said second visible image for viewing by said person; and

wherein said first image generator and said first optical apparatus cooperate to direct said first image for viewing by the right eye of said person, and said second image generator and said second optical apparatus cooperate to direct said second image for viewing by the left eye of said person; and

wherein said shield enclosure comprises first and second non-magnetic sliding boxes, said first box adapted for movement into and out of said second box so as to accommodate inter-pupil spacing variations of different persons within the scanner tunnel.

26. The system of claim 25 wherein said first and second boxes are fabricated of plastic coated with a metallic layer, the respective layers of each box in electrical contact with each other.

27. The system of claim 26 further comprising a shielded ground conductor for electrically grounding said metallic layers, such that any electromagnetic interference generated within said shield enclosure is intercepted and routed to electrical ground, thereby preventing said interference from affecting the quality of MRI images of the patient.

28. The system of claim 27 further comprising a non-magnetic audio generator responsive to electrical audio-defining signals for generating audio signals, said audio generator disposed within said shield enclosure.

29. The system of claim 28 wherein said audio generator comprises a non-magnetic transducer.

30. The system of claim 28 wherein said audio generator comprises a non-magnetic tube for transmitting said audio signals to a headset.

31. An image generating system for display of images to a patient within the magnetic field of a scanner tunnel of a magnetic resonance imaging scanner, comprising:

a first non-magnetic image generator disposed within said scanner tunnel for generating a visible image in response to first electronic image-defining signals, said first image generator comprising a first electronic liquid crystal display (LCD) panel responsive to said first image-defining signals;

a non-magnetic, non-ferrous shield enclosure for housing said first non-magnetic image generator within said scanner tunnel and within a magnetic field generated within said scanner tunnel during imaging operation of said imaging scanner, said shield enclosure adapted to shield said image generator from RF pulses generated by said imaging scanner during imaging operation such that said RF pulses do not appreciably affect operation of said first image generator, said shield enclosure further adapted to shield said imaging scanner from any electromagnetic interference generated by said first image generator such that said first image generator does not appreciably affect operation of said imaging scanner;

first optical apparatus connected to said shield enclosure for directing said visible image from a penetration in said shield enclosure to a person's eye for viewing by said patient disposed within said scanner tunnel; and

an LCD driver circuit mounted on a circuit board and located outside said scanner tunnel and connected to said first image generator via an RF-shielded cable to provide said first electronic image-defining signals.

32. The system of claim 31 wherein said shield enclosure is adapted to perform the function of a Faraday cage.

33. An image generating system for use within a magnetic field of a scanner tunnel of a magnetic resonance imaging scanner, comprising:

a first non-magnetic image generator disposed within said scanner tunnel for generating a visible image in response to first electronic image-defining signals, said first image generator comprising a first electronic display device responsive to said first image-defining signals;

a non-magnetic, non-ferrous shield enclosure for housing said first non-magnetic image generator within said scanner tunnel and within a magnetic field generated within said scanner tunnel during imaging operation of said imaging scanner, said shield enclosure sure for shielding said image generator from RF pulses generated by said imaging scanner during imaging operation such that said RF pulses do not appreciably affect operation of said first image generator, and for shielding said imaging scanner from any electro-magnetic interference generated by said first image generator such that said first image generator does not appreciably affect operation of said imaging scanner, said shield enclosure comprising first and second non-magnetic sliding boxes comprising electrically conductive surfaces, said first box adapted for movement into and out of said second box; and

first optical apparatus for directing said visible image for viewing by a person disposed within said scanner tunnel.

34. An image generating system for use within a magnetic field of a scanner tunnel of a magnetic resonance imaging scanner, comprising:

a first non-magnetic image generator disposed within said scanner tunnel for generating a first visible image in response to first electronic image-defining signals, said first image generator comprising a first electronic display device responsive to said first image-defining signals;

a second non-magnetic image generator disposed within said scanner tunnel for generating a second visible image in response to second electronic image-defining signals, said second image generator comprising a second electronic display device responsive to said second image-defining signals;

a non-magnetic, non-ferrous shield enclosure for housing said first and second non-magnetic image generators within said scanner tunnel and within a strong magnetic field generated within said scanner tunnel during imaging operation of said imaging scanner, said shield enclosure adapted to shield said image generators from RF pulses generated by said imaging scanner during imaging operation such that said RF pulses do not appreciably affect operation of said image generators, said shield enclosure further adapted to shield said imaging scanner from any electromagnetic interference generated by said image generators such that said image generators do not appreciably affect operation of said imaging scanner;

first optical apparatus connected to said shield apparatus for directing said first visible image for viewing by a person disposed within said scanner tunnel;

second optical apparatus connected to said shield apparatus for directing said second visible image for viewing by said person; and

wherein said first image generator and said first optical apparatus cooperate to direct said first image for viewing by the right eye of said person, and said second image generator and said second optical apparatus cooperate to direct said second image for viewing by the left eye of said person.

35. The system of claim 34 further including apparatus for generating said first and second electronic image-defining signals, said apparatus located outside said scanner tunnel, wherein said first and second electronic image-defining signals are different from each other so as to produce first and second images which are different from each other.

36. The system of claim 35 wherein said generating apparatus is adapted to generate first and second electronic image-generating signals to produce stereoscopic images at the viewer's eyes.

37. The system of claim 34 further comprising a shielded ground conductor for electrically grounding said metallic layers, such that any electromagnetic interference generated within said shield enclosure is intercepted and routed to electrical ground, thereby preventing said interference from affecting the quality of MRI images of the patient.

38. The system of claim 34 further comprising a non-magnetic audio generator responsive to electrical audio-defining signals for generating audio signals, said audio generator disposed within said shield enclosure.

39. The system of claim 38 wherein said audio generator comprises a non-magnetic transducer.

* * * * *

EXHIBIT 5

(12) EX PARTE REEXAMINATION CERTIFICATE (5496th)

United States Patent

Ziarati

(10) Number: US 5,432,544 C1

(45) Certificate Issued: *Sep. 12, 2006

(54) MAGNET ROOM DISPLAY OF MRI AND ULTRASOUND IMAGES

(75) Inventor: Mokhtar Ziarati, North Hollywood, CA (US)

(73) Assignee: Resonance Technology, Inc., Van Nuys, CA (US)

Reexamination Request:
No. 90/004,834, Nov. 12, 1997

Reexamination Certificate for:
Patent No.: 5,432,544
Issued: Jul. 11, 1995
Appl. No.: 07/997,957
Filed: Dec. 21, 1992

(*) Notice: This patent is subject to a terminal disclaimer.

Related U.S. Application Data

(63) Continuation-in-part of application No. 07/653,711, filed on Feb. 11, 1991, now Pat. No. 5,412,419.

(51) Int. Cl.
H04N 7/18 (2006.01)

(52) U.S. Cl. 600/410; 600/425; 324/318; 348/77

(58) Field of Classification Search 348/77, 348/61, 82, 552, 739, 744; 600/410, 425; 324/318
See application file for complete search history.

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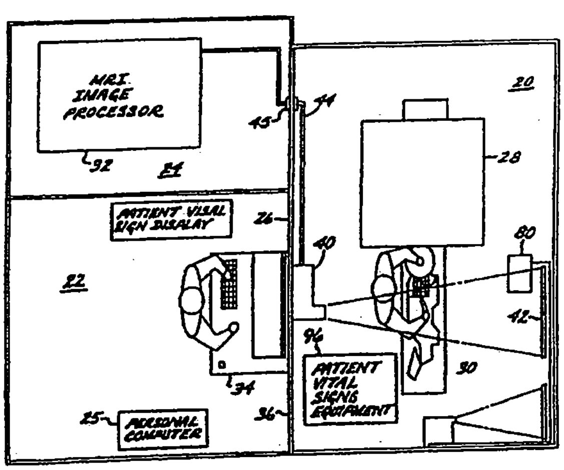
(Continued)

Primary Examiner—Michael H. Lee

(57) ABSTRACT

A display system for display of MRI, ultrasonic, patient vital sign or other imagery within a magnet room of an MRI system. An MRI compatible video display is disposed with the magnet room, and is connected to the MRI image processor to provide MRI images to medical personnel working in the magnet room. The display can be an MRI compatible LCD projection display, a wired LCD screen display, a reflective LCD screen display or a plasma display. The display within the magnet room is made MRI compatible by appropriate shielding and filtering. The display may also display patient vital sign data or imagery from an MRI compatible ultrasound apparatus.



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Declaration of Mokhtar Ziarati filed in Case No. C–93–1052–JSL (Ex).

Declaration of John Villasenor, dated Apr. 10, 1997, filed in Case No. CV–97–0788–GHK (Ctx).

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34/51

1

EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

2

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims 7–12, 15, 31, 32 and 34 is confirmed.

Claims 1–6, 13, 14, 16–30, 33 and 35 are cancelled.

* * * * *

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UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

NOTICE OF ASSIGNMENT TO UNITED STATES MAGISTRATE JUDGE FOR DISCOVERY

This case has been assigned to District Judge Stephen V. Wilson and the assigned discovery Magistrate Judge is Charles Eick.

The case number on all documents filed with the Court should read as follows:

CV08- 6772 SVW (Ex)

Pursuant to General Order 05-07 of the United States District Court for the Central District of California, the Magistrate Judge has been designated to hear discovery related motions.

All discovery related motions should be noticed on the calendar of the Magistrate Judge

NOTICE TO COUNSEL

A copy of this notice must be served with the summons and complaint on all defendants (if a removal action is filed, a copy of this notice must be served on all plaintiffs).

Subsequent documents must be filed at the following location:

[X] Western Division
312 N. Spring St., Rm. G-8
Los Angeles, CA 90012

[ ] Southern Division
411 West Fourth St., Rm. 1-053
Santa Ana, CA 92701-4516

[ ] Eastern Division
3470 Twelfth St., Rm. 134
Riverside, CA 92501

Failure to file at the proper location will result in your documents being returned to you.

Andre E. Jardini (State Bar No. 71335)
KNAPP, PETESEN & CLARKE
500 North Brand Boulevard, 20th Floor
Glendale, CA 91203
(818) 547-5000
Facsimile: (818) 547-5329

UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

RESONANCE TECHNOLOGY, INC. PLAINTIFF(S) v. NORDICNEUROLAB AS, a Norwegian corporation, DEFENDANT(S).	CASE NUMBER **CV08-06772 SVW(Ex)** **SUMMONS**

TO: DEFENDANT(S): NORDICNEUROLAB AS, a Norwegian corporation

A lawsuit has been filed against you.

Within 20 days after service of this summons on you (not counting the day you received it), you must serve on the plaintiff an answer to the attached ☑ complaint ☐ ____________ amended complaint ☐ counterclaim ☐ cross-claim or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff's attorney, Andre E. Jardini, whose address is Knapp, Petersen & Clarke, 500 N. Brand Blvd., 20th Fl., Glendale, CA 91203. If you fail to do so, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

Clerk, U.S. District Court

Dated: ____________________ By: ____________________
Deputy Clerk

(Seal of the Court)

[Use 60 days if the defendant is the United States or a United States agency, or is an officer or employee of the United States. Allowed 60 days by Rule 12(a)(3)].

UNITED STATES DISTRICT COURT, CENTRAL DISTRICT OF CALIFORNIA
CIVIL COVER SHEET

I (a) PLAINTIFFS (Check box if you are representing yourself ☐)
RESONANCE TECHNOLOGY, INC.

DEFENDANTS
NORDICNEUROLAB AS, a Norwegian corporation,

(b) Attorneys (Firm Name, Address and Telephone Number. If you are representing yourself, provide same.)
Andre E. Jardini, Esq.
KNAPP, PETERSEN & CLARKE, 500 North Brand Boulevard, 20th Floor, Glendale, CA 91203; Tel: (818) 547-5000/Fax: (818) 547-5329

Attorneys (If Known)

II. BASIS OF JURISDICTION (Place an X in one box only.)

☐ 1 U.S. Government Plaintiff
☑ 3 Federal Question (U.S. Government Not a Party)
☐ 2 U.S. Government Defendant
☐ 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES - For Diversity Cases Only (Place an X in one box for plaintiff and one for defendant.)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated or Principal Place of Business in this State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated and Principal Place of Business in Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. ORIGIN (Place an X in one box only.)

☑ 1 Original Proceeding ☐ 2 Removed from State Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from another district (specify): ☐ 6 Multi-District Litigation ☐ 7 Appeal to District Judge from Magistrate Judge

V. REQUESTED IN COMPLAINT: JURY DEMAND: ☑ Yes ☐ No (Check 'Yes' only if demanded in complaint.)

CLASS ACTION under F.R.C.P. 23: ☐ Yes ☑ No ☐ **MONEY DEMANDED IN COMPLAINT: $** Undetermined

VI. CAUSE OF ACTION (Cite the U.S. Civil Statute under which you are filing and write a brief statement of cause. Do not cite jurisdictional statutes unless diversity.)
Patent Infringement (28 U.S.C. section 1338(a) and (b))

VII. NATURE OF SUIT (Place an X in one box only.)

OTHER STATUTES
☐ 400 State Reapportionment
☐ 410 Antitrust
☐ 430 Banks and Banking
☐ 450 Commerce/ICC Rates/etc.
☐ 460 Deportation
☐ 470 Racketeer Influenced and Corrupt Organizations
☐ 480 Consumer Credit
☐ 490 Cable/Sat TV
☐ 810 Selective Service
☐ 850 Securities/Commodities/ Exchange
☐ 875 Customer Challenge 12 USC 3410
☐ 890 Other Statutory Actions
☐ 891 Agricultural Act
☐ 892 Economic Stabilization Act
☐ 893 Environmental Matters
☐ 894 Energy Allocation Act
☐ 895 Freedom of Info. Act
☐ 900 Appeal of Fee Determination Under Equal Access to Justice
☐ 950 Constitutionality of State Statutes

CONTRACT
☐ 110 Insurance
☐ 120 Marine
☐ 130 Miller Act
☐ 140 Negotiable Instrument
☐ 150 Recovery of Overpayment & Enforcement of Judgment
☐ 151 Medicare Act
☐ 152 Recovery of Defaulted Student Loan (Excl. Veterans)
☐ 153 Recovery of Overpayment of Veteran's Benefits
☐ 160 Stockholders' Suits
☐ 190 Other Contract
☐ 195 Contract Product Liability
☐ 196 Franchise

REAL PROPERTY
☐ 210 Land Condemnation
☐ 220 Foreclosure
☐ 230 Rent Lease & Ejectment
☐ 240 Torts to Land
☐ 245 Tort Product Liability
☐ 290 All Other Real Property

TORTS PERSONAL INJURY
☐ 310 Airplane
☐ 315 Airplane Product Liability
☐ 320 Assault, Libel & Slander
☐ 330 Fed. Employers' Liability
☐ 340 Marine
☐ 345 Marine Product Liability
☐ 350 Motor Vehicle
☐ 355 Motor Vehicle Product Liability
☐ 360 Other Personal Injury
☐ 362 Personal Injury- Med Malpractice
☐ 365 Personal Injury- Product Liability
☐ 368 Asbestos Personal Injury Product Liability

IMMIGRATION
☐ 462 Naturalization Application
☐ 463 Habeas Corpus- Alien Detainee
☐ 465 Other Immigration Actions

TORTS PERSONAL PROPERTY
☐ 370 Other Fraud
☐ 371 Truth in Lending
☐ 380 Other Personal Property Damage
☐ 385 Property Damage Product Liability

BANKRUPTCY
☐ 422 Appeal 28 USC 158
☐ 423 Withdrawal 28 USC 157

CIVIL RIGHTS
☐ 441 Voting
☐ 442 Employment
☐ 443 Housing/Accommodations
☐ 444 Welfare
☐ 445 American with Disabilities - Employment
☐ 446 American with Disabilities - Other
☐ 440 Other Civil Rights

PRISONER PETITIONS
☐ 510 Motions to Vacate Sentence Habeas Corpus
☐ 530 General
☐ 535 Death Penalty
☐ 540 Mandamus/ Other
☐ 550 Civil Rights
☐ 555 Prison Condition

FORFEITURE / PENALTY
☐ 610 Agriculture
☐ 620 Other Food & Drug
☐ 625 Drug Related Seizure of Property 21 USC 881
☐ 630 Liquor Laws
☐ 640 R.R. & Truck
☐ 650 Airline Regs
☐ 660 Occupational Safety /Health
☐ 690 Other

LABOR
☐ 710 Fair Labor Standards Act
☐ 720 Labor/Mgmt. Relations
☐ 730 Labor/Mgmt. Reporting & Disclosure Act
☐ 740 Railway Labor Act
☐ 790 Other Labor Litigation
☐ 791 Empl. Ret. Inc. Security Act

PROPERTY RIGHTS
☐ 820 Copyrights
☑ 830 Patent
☐ 840 Trademark

SOCIAL SECURITY
☐ 861 HIA (1395ff)
☐ 862 Black Lung (923)
☐ 863 DIWC/DIWW (405(g))
☐ 864 SSID Title XVI
☐ 865 RSI (405(g))

FEDERAL TAX SUITS
☐ 870 Taxes (U.S. Plaintiff or Defendant)
☐ 871 IRS-Third Party 26 USC 7609

FOR OFFICE USE ONLY: Case Number: CV08-06772

AFTER COMPLETING THE FRONT SIDE OF FORM CV-71, COMPLETE THE INFORMATION REQUESTED BELOW.

UNITED STATES DISTRICT COURT, CENTRAL DISTRICT OF CALIFORNIA
CIVIL COVER SHEET

VIII(a). IDENTICAL CASES: Has this action been previously filed in this court and dismissed, remanded or closed? ☑ No ☐ Yes
If yes, list case number(s):

VIII(b). RELATED CASES: Have any cases been previously filed in this court that are related to the present case? ☐ No ☑ Yes
If yes, list case number(s): CV 08-2580 PSG (PLAx)

Civil cases are deemed related if a previously filed case and the present case:
(Check all boxes that apply)
☐ A. Arise from the same or closely related transactions, happenings, or events; or
☑ B. Call for determination of the same or substantially related or similar questions of law and fact; or
☐ C. For other reasons would entail substantial duplication of labor if heard by different judges; or
☑ D. Involve the same patent, trademark or copyright, and one of the factors identified above in a, b or c also is present.

IX. VENUE: (When completing the following information, use an additional sheet if necessary.)

(a) List the County in this District; California County outside of this District; State if other than California; or Foreign Country, in which **EACH** named plaintiff resides.
☐ Check here if the government, its agencies or employees is a named plaintiff. If this box is checked, go to item (b).

County in this District:*	California County outside of this District; State, if other than California; or Foreign Country
Los Angeles County	

(b) List the County in this District; California County outside of this District; State if other than California; or Foreign Country, in which **EACH** named defendant resides.
☐ Check here if the government, its agencies or employees is a named defendant. If this box is checked, go to item (c).

County in this District:*	California County outside of this District; State, if other than California; or Foreign Country
Los Angeles County	

(c) List the County in this District; California County outside of this District; State if other than California; or Foreign Country, in which **EACH** claim arose.
Note: In land condemnation cases, use the location of the tract of land involved.

County in this District:*	California County outside of this District; State, if other than California; or Foreign Country
Los Angeles County	

*** Los Angeles, Orange, San Bernardino, Riverside, Ventura, Santa Barbara, or San Luis Obispo Counties**
Note: In land condemnation cases, use the location of the tract of land involved

X. SIGNATURE OF ATTORNEY (OR PRO PER): [signature] **Date** October 8, 2008

Notice to Counsel/Parties: The CV-71 (JS-44) Civil Cover Sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law. This form, approved by the Judicial Conference of the United States in September 1974, is required pursuant to Local Rule 3-1 is not filed but is used by the Clerk of the Court for the purpose of statistics, venue and initiating the civil docket sheet. (For more detailed instructions, see separate instructions sheet.)

Key to Statistical codes relating to Social Security Cases:

Nature of Suit Code	Abbreviation	Substantive Statement of Cause of Action
861	HIA	All claims for health insurance benefits (Medicare) under Title 18, Part A, of the Social Security Act, as amended. Also, include claims by hospitals, skilled nursing facilities, etc., for certification as providers of services under the program. (42 U.S.C. 1935FF(b))
862	BL	All claims for "Black Lung" benefits under Title 4, Part B, of the Federal Coal Mine Health and Safety Act of 1969. (30 U.S.C. 923)
863	DIWC	All claims filed by insured workers for disability insurance benefits under Title 2 of the Social Security Act, as amended; plus all claims filed for child's insurance benefits based on disability. (42 U.S.C. 405(g))
863	DIWW	All claims filed for widows or widowers insurance benefits based on disability under Title 2 of the Social Security Act, as amended. (42 U.S.C. 405(g))
864	SSID	All claims for supplemental security income payments based upon disability filed under Title 16 of the Social Security Act, as amended.
865	RSI	All claims for retirement (old age) and survivors benefits under Title 2 of the Social Security Act, as amended. (42 U.S.C. (g))