International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064, Impact Factor (2013): 4.438
www.ijsr.net

A New Generation of Ultrasonic Techniques Applied In Medical Imaging by Using Cell Phones

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Abstract: ***In the field of medical application of ultrasound imaging, the probe- smartphone concept has been integrated. Imagine that these smartphones in ambulances and emergency rooms. In the case of larger scale, these kinds of cellphones will act as a complete computer that runs windows. It could become the essential computer of the Developing World, where trained medical personnel are scarce, but most of the population, as much as 90 percent, has access to a cell phone tower. Developments took place elsewhere such as the world's first mobile- phone ultrasound instrument using a low- cost ultrasound probe and a windows mobile phone; Stethoscope of the 21st century will be described in this paper. Steps to be taken for commercializing this ultrasound technology are suggested.***

Keywords: Ultrasound imaging, smartphones, cell phones, Stethoscopes, Ultrasound technology

1. Introduction

The ultrasound imaging technique is a rapidly changing subject, whose almost frenetic activity is attested by the number of research papers appearing in established new journals and proliferation of monographs and reviews on all aspect of the field. These expansions of knowledge in this field possess pedagogical problems. It is difficult for a single researcher to be cognizant of developments over the whole field and probably no one can honestly claim expertise or even competence in all the important areas of subjects. Yet, the earlier studies done in ultrasonic imaging provide a remarkable opportunity for the research students to continue the invention as it really an active field of research. The continuous enhance in this field demand of further improvement in this technique and also reduce the cost of equipment used. Hence in this present study, the various technique adopted in different instruments are explain in detail.

Medical Imaging is defined as the twenty-first century medicine. Among 80% of world's population has not aware of medical imaging. It's is very important for cancer patients to take an MRI or CT scan. It is impossible and also very hard to take this in rural community without power. Basics of biomedical ultrasound for engineers composed in a book [1] covering a wide range of topics within biomedical ultrasound, from conceptual definitions of waves to the intricacies of focusing devices, transducers and acoustic fields.

Ultrasound imaging is a safe medical imaging modality that uses sound waves to allow the observation of internal anatomical structures such as tissues and organs. Ultrasound imaging works by emitting pulses of sound energy along thin acoustic beams into the human body and reconstructing the echoes of the original sound waves into a viewable image. Compared to other medical imaging technologies such as CAT scans, MRI and X-Ray, ultrasound imaging can most easily be adapted to a portable environment due to relatively low power and size constraints [2]. A mobile ultrasound system was developed [3] that can be housed in anumber of different configurations such as vest or a small handheld bag.

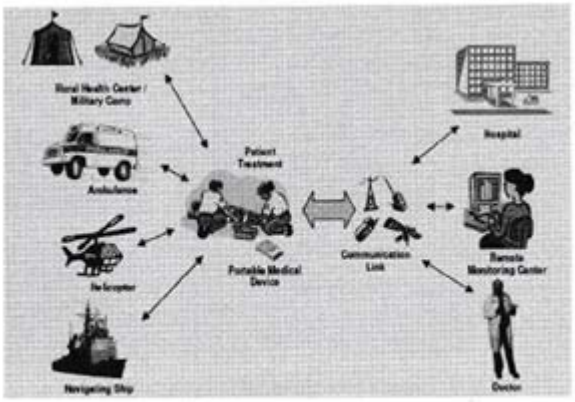

Fig. 1. Possible Environmental settings in telemedicine

The reconfigurable unit allows imaging to take place in environments lacking suitable power sources where ultrasound technology has not previously been possibility. Some of these environments include ambulances, disaster sites, war zones and rural medicine.Fig.1 shows the possible environment settings in telemedicine. In most of these settings , it may be necessary to transmit image data from the mobile ultrasound unit to some base station, either for long term storage or to be viewed by a more and highly experienced physician. Because ultrasound is an interactive imaging method that requires training and experience on the part of the ultra-sonographer, guidance from experienced medical personnel will greatly benefit the remote sonographer who may not sufficiently skilled in ultrasound.

2. Medical Ultrasound Imaging Principle

Ultrasound technology is well established in medicine both as a diagnostic tool and as a therapeutic agent, and its major use is in diagnostics because it provides the clinician with anatomical and physiologic information both non –

invasively and without the use of ionizing radiation. An ultrasound transducer generates acoustic waves by converting electrical energy into mechanical energy. The most efficient technique for medical ultrasound uses the piezoelectric effect which can convert an oscillating electric signal into an acoustic wave, and vice versa.

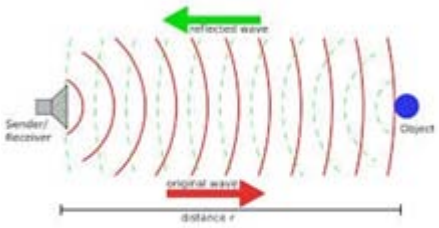

Fig.2. Principles of Ultrasonic Imaging

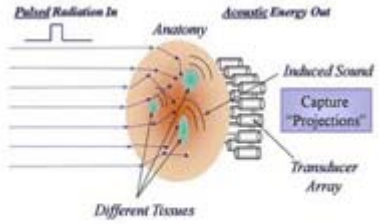

Fig.3. Generic Acoustic Imaging Instrumentation

This sound pulse is generally created [and transmitted as shown in Fig.2] electronically using a system consisting of a signal generator, power amplifier and electro acoustic-transducers/array, possibly with a beam former. Modern array transducers with electronic scanning involve no moving parts and the focal point can be changed dynamically to any location in the scanned plane. The reflected energy can be received and processed into an image of the reflecting structure[as shown in Fig.3] Because different body tissues have slightly different structural characteristics, leading to differences in acoustical properties . This is the basic principle of pulse – echo imaging devices.

3. Development of Biomedical Ultrasound Device

In a recent paper the author described [4] the current developments of ultrasonic imaging by a mobile phone. Design of portable electronic devices and subsequent miniaturization is made possible through the improved technology over the years. For instance, number of transistors per IC: Scales every 4 -5 [5] as presented in Fig.4 and also memory capacity of the chip increased manifold [5] as displayed in Fig.5. Zar [6] utilized the miniaturization techniques and began working on ultrasound

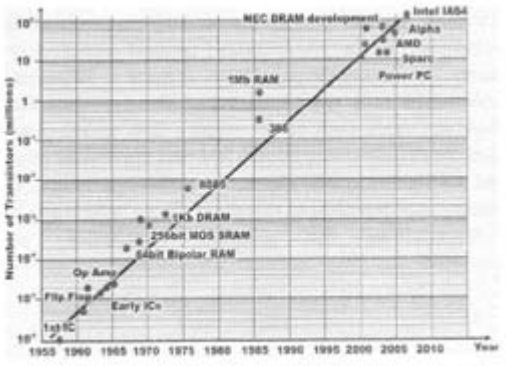

Fig. 4. Number of transistors per IC : Scales every 4-5 years

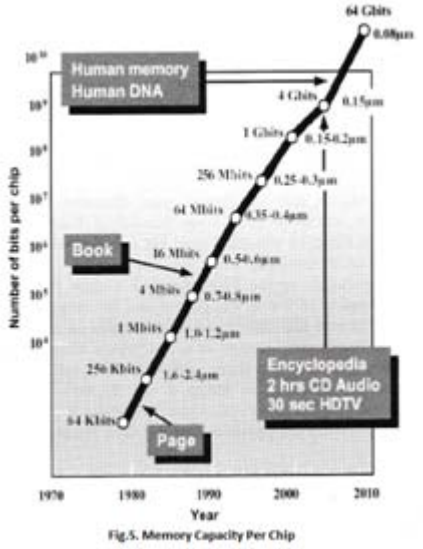

Fig.5. Memory Capacity Per Chip

system designs 25 years ago and in that span he has shrunk the electronics from cabinet – sized to a tiny circuit board one inch by three inches. A typical, portable ultrasound device may cost as much as $30,000. Some of these USB-based probes sell for less than $2,000 with the goal of a price tag as low as $400.

The small probes are connected to a phone with a USB cord that have been typically, connected to a laptop for displaying the images. But it is not an option in many clinics in developing countriesfor lack of consistent electricity, heat and lack of internet access. Mobile phones areubiquitous, easy to use and they have the mobile network to transmit images. Further, Zar wrote the phone software and firmware for the probes; Richard came up with the low –power probe electronics design [6]. Since, all that is needed is actual probe, a USB cable and the imaging platform connected with a USB cord –such as Windows mobile phone. The researches [6] modified probes to work with smart phone and developed a software developments kit (SDK) to allow developers to build fully custom applications for various mobile platforms.USB- based ultrasound probes have been around since 2005, offering a much cheaper and portable alternative to larger ultrasound machines.

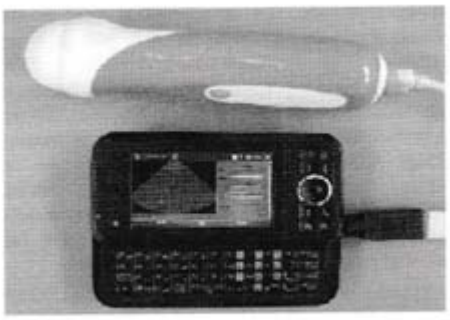

Fig. 6. Ultrasound on a mobile [Toshoba G900] – Inexpensive, Pervasive and the future.

Probes provide increasingly high – quality imaging for a tenth of the cost. A typical portable ultrasound device costs around $20,000, while USB probes sell for around $1000 right now- and the price is declining. Probes are ideally suited for first – responders and for primary care in developing countries , for example. Thus, Zar and Richard [6] have recently developed world's first mobile –phone ultrasound instrument using a low – cost ultrasound probe and a Windows mobile phone. This can be plugged into a standard Microsoft Windows mobile – based smartphone, as shown in Fig.6 and the operator can immediately image the kidney, the liver, the bladder and the eyes using the screen on the smartphone. It is also possible to use ultrasound endocavity probes for prostrate and uterine screenings and biopsies and vascular probes for imaging veins and arteries for starting IVs and central lines. If ergonomics is the issueMySonoU6 enables us to work quickly and efficiently through its automated image optimization functions and extended measurement functions; to image archiving systems called SonoView.It is the image management software offers the possibility of seamless integration with image archive systems or hospital PACS. MySonoU6 supports DICOM Store and DICOM Storage Commit, to store ultrasound studies safely into an image archive. Wired and wireless LAN support and it can receive and send DICOM study data through wired and wireless connections and allows complete operation within seconds.

4. Ultrasound Imaging Communication – Present Trends

[i] A small handheld ultrasound probe used in conjunction with a Windows – based mobile phone as shown in Fig.6 may provide proof of concept for what amounts to a 'tricoder' like those seen in the 1960's era Star Trek television show. Recently Zar et al [6] have tweaked every aspect of ultrasound probe design and operation-from power consumption and data transfer rate to image formation algorithms."You can carry around a probe and cell phone and image on the fly now," said Richard. The result is a smartphone - compatible USB ultrasound probe. Workflow that enhances MySono U6 is a smart and lightweight ultrasound system with minimal Power consumption that can be easily transported, operated, stored and equipped with front and back handles for mobility. At the bedside, in the operating room, or near the sports field, MySono U6 is always ready for use. Ergonomic design Major key functions are grouped under the palm of your hand for maximum Efficiency and applied ergonomics. The special and innovative structure of this device is

- High resolution 15" LED monitor - delivers superb image quality.
- Backlit keyboard and control panel

Imaging having these smartphones in ambulances and emergency rooms. On a larger scale, this kind of cell phone is a complete computer that runs Windows. It could become the essential computer of the Developing World, where trained medical personnel are scarce, but most of the population as much as 90 percent, have access to a cell phone tower.one example of how the device might be used is given below.

[ii] General Electric showed off a forthcoming hand – held ultrasound device called Vscan. It is a low –cost and very portable device called Vscan and calling itas "the stethoscope of the 21st century". It's about the same size as a BlackBerry, "One can hold up a white device [7] that appeared to fold in the middle like a flip – phone as shown in Fig.8.The top of the device showed an ultrasound image (depicting of a patient's liver) while the bottom showed control keys. The device which features a clam – shell design, with a small screen on one side and a circular input padon the other, aspects a cable terminated in an ultrasound sensor. It could easily be mistaken for a cell phone.

Fig. 7. Portable cell phone imaging - Credit David Kilper/ WUSTL Photo

Fig. 8. Vscan ultrasound scanner develope by GE

Vscan will improve cost device. This is Moore's law and the device had the same power as a console ultrasound from two to three years ago that would cost $250,000. The price of the device could be cheap as these devices going to Africa and other developing countries like India and helping health care providers, there determine, if a baby is breech.Vscan will improve the quality of healthcare by allowing physicians to more quickly and accurately diagnose patients. It should help primary care doctors gauge the necessity of more thorough testing and give critical care workers an additional tool to diagnose patients in the field. Efforts are on integrating their probe-smart phone concept into a suite of field trials for medical applications in developing countries.

Portable remote imaging by ultrasound carried out in India is shown in Fig.9.

Fig.9. Portable Remote Imaging by ultasound in India

The Vscan was demonstrated to show an enhanced online medical records system, in which patient data is combined with clinical outcome data and research to help caregivers apply effective and current treatment to patients. Medical records can give patients portable electronic files, but rather, "it's about making better clinical decisions faster".

5. Recent Innovative Approach of Iphone and smartphone

The creation and widespread use of the iPhone and Smartphone has impacted many industries, and now has affected Medicine profoundly in many ways. In many cases the iPhone empowers and smartphones enhances the efficiency of the device to which it is attached by its optic or computing power. These are the miracle Medical Uses that will have a deep, continuing impact on the practice of healthcare.

- **iPhone app and Smartphone to detect toxins, bacteria & viruses**
  Another promising application is of patients with Duchene's Muscular Dystrophy. A degenerative disease that often strikes young boys and robs them of their live by their late 20's, DMD is a degenerative disease for which there is no cure. This leading treatment to slow its progression is a daily dose of steroids. Patients often experience some side effects from steroids, which are close related in the field of cancer. These side effects include behavioral problems and weight again. Researchers now know that physical changes in muscle tissue can indicate the efficacy of the steroids. Measuring these changes in muscle can be accomplished with ultrasound and may allow researchers to optimize steroid dosing to maximize efficacy while minimizing side effects. The idea is that caregivers, who otherwise have to transport a young person, often wheel chair bound, to a hospital or clinic on a regular basis for examination, can be trained to do ultrasound to track muscle condition. This could lower the dosage of least effective amount to further increase quality of life of the patient and the caregiver and hopefully extend life. This application is really exciting. The caregiver would only have to do a one- minute scan; transfer the data captured to clinic and the results would come back to the caregiver. A group at the WUSTL Medical School studying Duchene's Muscular Dystrophy is proposing to incorporate this ultrasound device into their research plans.

- **The iPhone as Otoscope**
  The Otoscope using the iPhone is also called the Remotoscope, and sometimes Cellscope. The versatile old iPhone is used to, not only view the inner ear with magnification, but also take pictures, to send to doctors, or specialists, from home or remote areas. It is approved by the FDA. This is yet another use of the iPhone as a peripheral device useful in Internet Medicine.

Fig. 11.Ostoscope or Remotoscope

- **AliveCor as Portable EKG**
  It is just recently approved by the FDA (December 2012). The iPhone ECG is a single-lead electrocardiogram reader that attaches to the back of an iPhone and displays heart rate info via an app. (An Android version is in the works.) The creator, Dr. David Albert, is an Oklahoma Cardiologist recently compiled data in June 2012.Basically, a peripheral device, projected to be around $100, is attached to any Smartphone, and a real time a high quality lead EKG can be done anywhere and allows for rapid, quick assessment of some cardiac problems in the field, including rhythm disturbances.

Fig. 12. AliveCor EKG

Additionally, its' low cost also allows for mass screening in developing countries. The AliveCor's ECG devicebasically enables medical professionals and regular consumers to monitor a person heart health. Its cardiac monitoring technology is designed to work with the iPhone, iPad and also in all Android devices.

- **The Smartphone Ultrasound**
  It is "Inexpensive, Mobile, Wireless, Portable Ultrasound". This ultrasound is sure to find widespread use in all medical settings across America, and the world. it is inexpensive,especially in rural and third-world areas. This device will find widespread use in Emergency

Rooms, and in the surgical and medical wards, as well as in office practice. Of course, there will be times when a higher grade ultrasound will be needed, but this Smartphone Ultrasound is a great start for diagnosing all types of medical problems, as a screening device, for medical conditions such as vascular problems, gallstones, kidney stones, abdominal masses, and other problems. This invention will be brought to areas that could not afford it, or live in inaccessible areas.

Fig. 12. Smartphone- Ultrasound Mobisante

The above model is a_Mobisante, which is the world's first Smartphone-based ultrasound imaging system, the MobiUS SP1 ultrasound system. This device has been approved by the FDA is made to order to reduce healthcare costs and improve diagnostics in areas that cannot access imaging centers.Mobius fuses the power and wireless connectivity of a Smartphone with the Internet into a game-changing diagnostic solution that is personal and accessible makes the system easy to use and to share information with remote providers."

- **SMARTPHONE AS A BRAIN SCANNER**

At the University of Demark, research is being conducted on using the Smartphone, along with specially programmed software, and a specialized headset, to do portable, mobile brain scans. Of course, it is just in the beta stage, but goes to show the potential of this powerful little computer, known as a Smartphone. (SOURCE: *milab, at University of Denmark*)

The system is a mobile, wireless, real-time brain scanner, and the software allows for wireless transmission to the Smartphone program, which receives the EEG-like transmissions from the various electrodes on the head, and like anything recorded on the Smartphone, can be sent to a consulting physician, anywhere in the world. In their words: "Our system provides a fully portable EEG based real-time functional brain scanner including stimulus delivery, data acquisition, logging, brain state decoding and 3D activity visualization. The frame rate of the visualization is around 30fps."

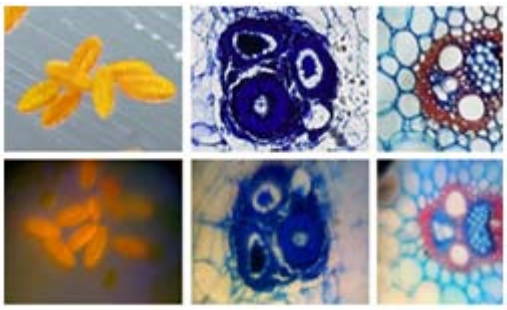

Fig. 14. Picture taken by smartphone by using Ultrasound Technique

- **IPhone - Blood Pressure Monitor and BREATHALYZER**

This device allows a truer measure of blood pressure, avoiding "white-coat hypertension" or having falsely high readings at a doctor's office andalso allows you to send your record to wherever you wish, including to your doctor. The important part of a device will make the patient more conscious of the trends of the blood pressure. There is also the option of using Microsoft® HealthVault™ , which keeps all your health records in one place.Another use of the iPhone is used with a peripheral used as a breathalyzer, to detect alcohol levels, from your expiration. "Most people keep their phones on them at all times (including drinking), which is why the iPega Alcohol Breathalyzer is so convenient. This portable breathalyzer plugs right into the bottom of the iOS device and displays the 2 digit BAC (blood alcohol content) on the LCD screen.It could help in avoiding drunk driving.

- **IPhone - Skin Scanner: THE DERMATOSCOPE**

From Germany, we have the development of the "Handyscope", or Dermatoscope, which is a case that fits snugly over an iPhone, and takes up top 20x magnification. It also has accompanying polarized light to better show the skin lesion. Easily save the picture, send it to a colleague by email, or send it to the desktop

- **The iPhone as a Microscope**

Never think that the iPhone, Android, Blackberry as a phone, when dealing with its place in Internet Medicine. It rather makes our thought as a powerful mini-computer, with state-of-the-art photo equipment. It can be converted to a powerful, picture-taking camera, to act as a supremely useful peripheral device.Of course, this would not be needed in most labs, but in rural area, in underdeveloped countries, it would have unlimited potential. No phone connection is needed, simply the peripheral and the Smartphone without an internet connection. Of course, a connection would be needed if the image is sent to other parts of the world to be interpreted.

Basically, there is a combination of finding the right economical lens, and developing software to work with the image. The aim in underdeveloped countries is the diagnosis of infectious diseases, TB, malaria, and other microbes. Above, in the top row, are images of pollen seen under a normal microscope.The miraculous thing about Smartphone and the use of the microphone, is that is shows the unlimited, fantastic potential of using portable computers for use in the field. The device

will prove to be invaluable in underdeveloped countries where cost and distance are now problems to diagnose the common infectious disease in the Third World.

- **The iPhone - GLUCOMETER: IBGStar**
  "Killer App" will be the creation of a non-invasive way to measure serum glucose. That day has not arrived yet, at least none has been approved by the FDA. ALTAPURE says they will be the first. Until then, we have peripheral devices as on this page.IBGStar is a blood glucose meter plug-in for the iPhone there is an IBGStar Diabetes Manager App that tracks blood glucose, carbohydrate intake, and insulin dose.The benefit of this peripheral is to manage your regimen of care of the diabetes, by posting alerts, keeping log, etc.Finger sticks with the lancet are still required. There are other devices on the horizon of the digital revolution that will avoid being stuck to check glucose.

Fig. 15. Glucometer

- **SPECTROMETER: Smartphone - Measure Oxygen and Diagnose Disease**
  Currently in medicine today, the spectrometer is used to measure blood sugar and pulse oximetry as well as to measure drug levels in blood in forensics, measuring chemicals as well. Besides application in science class, there are innumerable applications in medicine, for a portable, cheap, wireless, mobile device to identify substances in blood, and other bodily fluids. A team of researchers from the University of California, Davis has done much work in this optic medical diagnosis via a smartphone. It would certainly be useful in rural areas as well as third-world countries. Since it will be more likely to be explored as a tool to identify substances, the technology will be more fully explored.iPhone being researched as Spirometer to investigate Lung Function

- **The "BioAssembler System" iPhone Measures Drug Toxicity, and Speeds up Culture Growth:**
  A company from Houston, Texas, n3D Biosciencesis harnessing both the computing power of the iPhone, as well as its powerful optical properties to essentially record and interpret the movement of cell cultures, when exposed to various drug toxic environments, thereby testing drug potency, or toxicity. By utilizing a device called a "Bio-Assembler" they utilize magnetic levitation to speed the process of cell movement, in a more realistic 3d environment than the 2D Petri dish. The iPhone takes time sequence photos and the company's program interprets the movement data.

Overall, the company hopes to use the iPhone to "To apply this breakthrough technology in the fields of toxicology screening, drug discovery, and regenerative medicine: especially, to apply the technology for cancer and stem cell research". As we contend in other parts of this website, cancers days are numbered. Between fantastic devices like this as well as advances in microscopy, and radiology, cancer cells can be more accurately isolated, manipulated and evaluated.

6. Future Scope

To enable low- cost development of new and customized application based on these probes, work is underway at Washington University in St. Louis to create an open – source imaging application. This development is based on the software development kit [SDK] that works with all of the available low- cost, USB – based ultrasound probes. The SDK works with Microsoft Visual Studio 2008 and includes a fully – functioning laptop/ desktop – based Windows XP/Vista application for testing and determining optimal imaging settings. Additionally,a fully functioning Windows Mobile sample application in C# with full source code is included. The cell phone SDK will be made available for a nominal cost to developers.

Fig. 15. Ultrasound Scan In Dolphin

In order to make commercial USB ultrasound probes work with smartphones, the researchers had to optimize every aspect of probe design and operation, from power consumption and data transfer rate to image formation algorithms. As a result, it is now possible to build smartphone – compatible USB ultrasound probes for imaging the kidney, liver, bladder and eyes, endocavity probes for prostrate and uterine screenings and biopsies and vascular probes for imaging veins and arteries for starting IVs and central lines. Both medicine and global computer use will never be the same. It is interesting to note that portable ultrasonic scanning even applied to dolphin as shown in fig.16.

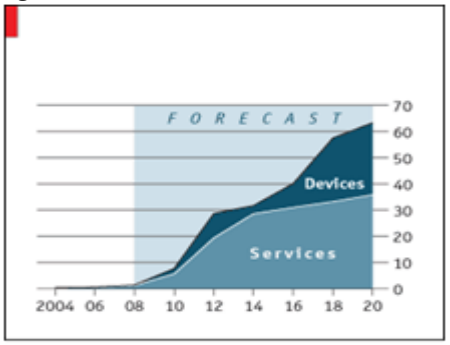

Fig.16. Graph drawn between year and percentage of sales and service

Several applications could find its way to the military. Medics could quickly diagnose wounded soldiers with the small, portable probe and phone to detect quickly the site of shrapnel wounds in order to make the decision of transporting the soldier or treating him elsewhere on the field. The vision of the new system is to train people in remote areas of the developing world on the basics of gathering data with the phones and sending it to a centralized unit many miles, or half a world away where specialists can analyze the image and make a diagnosis.

7. Summary

Details of a wireless communication technology that could be integrated into the ultrasound system for possible utilization in remote data applications where medical information can be transmitted from the mobile unit to some centralized base station, such as emergency room or field hospital has been presented. By incorporating wireless telecommunication technology into the design, on site medical personnel can be assisted in diagnostic decisions by remote medical experts. Recently, Microsoft and General Electric [GE] have independently initiated research activity on development of a cell phone ultrasound device for communicating images. Funded by Microsoft Zar and Richard investigated the world's first mobile – phone ultrasound instrument. It is small, portable smart phone connected to the probe by a USB driver. On the other hand, GE has developed a hand held ultrasound device called Vscan calling the "the stethoscope of the 21st century". In spite of developments in medical imaging, many world's population has no access to medical imaging. It's hard to take an MRI or CT scanner to a rural community without power. The developed ultrasound device is a low cost and finds application to diagnose wounded soldiers in military, probe patients in rural areas of developing countries etc.

The above graph has shown that there are plenty of devices available. But the service percentage is very low compared to the ultrasound device amount. A mobile ultrasound system make medical examinations possible in harsh environments without reliable power sources, such as ambulances, helicopters, war zones and disaster sites. In order to make this technology commercially viable, an ultra – low- cost probes to bring down the probe cost down to $100. Application of specific probes needs development through collaborative research. Open source USB probe imaging suite software need to be produced.

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