A Wireless Network Scheme of Fetal Monitoring

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***Abstract*— This paper describes a new scheme of wireless fetal monitoring from which the difficulty of having uninterrupted monitoring when patients on move can be solved. This wireless network monitoring scheme provides features of low power consumption, high consistency, low cost, and high accuracy of signal transmitting.**

Keywords- Wireless Network Monitoring; Uninterrupted Monitoring; Monitor

I. INTRODUCTION

Patient monitoring is a type of uninterrupted monitoring; it must be a 24-hour continuous monitoring for the physiological parameters of patients, and it has to quickly react or respond in order for the doctors and nurses to take proper actions. Nevertheless, due to the lack of enough doctors and nurses, together with the increasing number of medical equipment, it becomes nearly impossible to continuously observe every single monitor at all times. The result of being out of monitoring can be serious. This is of same importance when it comes to fetal monitoring, especially for pregnant women whose expected dates of delivery are close enough. It is well known that lack of care, especially when the parameter of a fetus is unusual, can result in abnormality of the fetus. Moreover, it could even be seriously fatal to the life of the fetus or the mother. Therefore, the idea of network monitoring is widely spread for the reason of achieving uninterrupted monitoring.

The traditional wired network, mainly used as LAN network, is limited in terms of function because it cannot monitor pregnant women when they are on move. Besides, the complicated structure makes it usually difficult in case of any maintenance work. Therefore, wireless technology is coming to use in order to practically achieve uninterrupted monitoring for the fetus and the mother.

The application of wireless network has been developed vastly with its mobility, easy-to-install feature, and high efficiency. There are a set of protocols and standards from IEEE to make it become more popular, e.g. 802.11a, 802.11b, 802.11g, Bluetooth, etc. However, as the standards may differ in countries, the schemes implemented are different accordingly, e.g. WMTS, WLAN, ISM, BLUETOOTH, etc. Because of its special requirements, limited radiation power for instance, some of the above schemes are not suitable for fetal monitoring [1] [2] [3].

Fetal monitoring network is designed for both fetal monitoring and maternal monitoring, and the application of wireless technology in this field is supposed to meet the requirements of signal transmitting capacity of real time signal transmission. Since signals transmitted during fetal monitoring contain only Fetal Heart Rate, Pressure of Uterus Contraction and Fetal Movement, the requirement for the transmitting speed of the network is relatively low. Transmitting signals of parameters of the mother, on the other side, requires higher speed as many parameters are transmitted at the same time, e.g. waveforms of ECG, Heart Rate, waveforms of SpO_2, Pulse Rate, Blood Pressure and Temperature [4] [5]. In addition, the Radio Frequency power of fetal monitoring network must be low enough in order to meet relevant requirements of medical equipment like EMC and EMI. The wireless network system must not be interfered by any electromagnetic signals, and it should not have any interference on other medical devices when it is running. Finally, it must be absolutely secure to protect the private information of all patients.

Actually, some of wireless networks provided by other organizations have been applied to medical monitoring equipment, but in general not ideal enough for the reasons of small coverage on low radiation power, or lack of the ability to achieve uninterrupted monitoring. In the following sections, a wireless network scheme of fetal monitoring will be introduced to meet the requirements of low power consumption, low cost and high quality of performance.

II. THEORY AND DESIGN

A. System Design

A wireless network of fetal monitoring consists of central workstation, wireless communications nodes, wireless repeaters, and wireless network card. The system design is as follows:

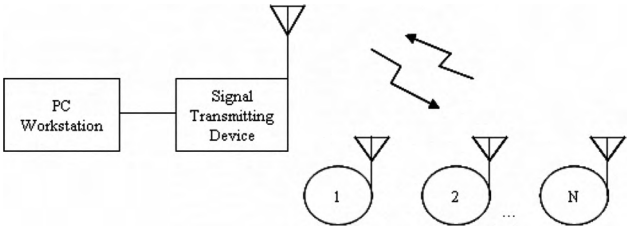

Figure 1. Wireless Fetal Monitoring Network System Design

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In Figure 1, Circles marked 1, 2 ... and N are Fetal Monitors or Fetal & Maternal Monitors with transceivers, namely Slave Modules. The tempo in between Slave Modules and the Master Module is in Figure 2 below:

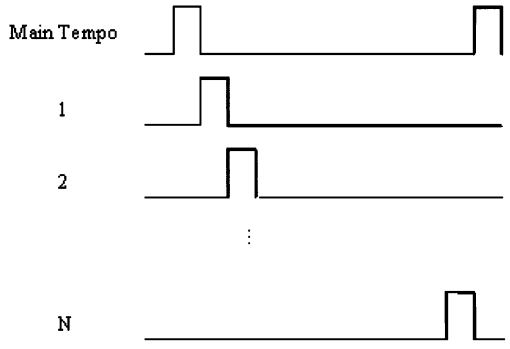

Figure 2. System Tempo

B. *Design of Hardware*

The design of the Master Module and Slave Module is in Figure 3:

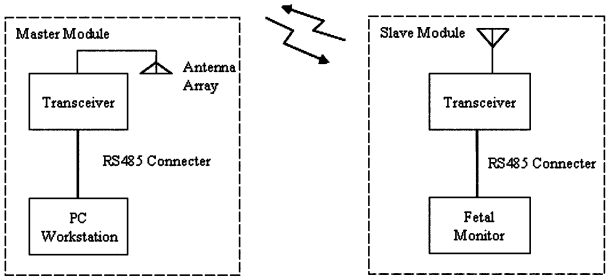

Figure 3. Design of Master and Slave Module

Fetal Monitors or Fetal & Maternal Monitors transmit signals to Slave Modules through Serial Ports. The transceivers in Slave Modules transmit signals to that in Master Module when they receive the data. The transceiver in Master Module then communicates with PC through Serial Port. The transceiver in both Master Module and Slave Module functions the same (refer to Figure 3), but the software is different. The software in the Master Module is to let it transmit synchronous signal and command frame, which picks up the correct Slave Module. The software in Slave Module, on the other hand, is to receive the command from the Master Module and transmit the signal information. The detailed design of software is presented in the next section.

It can be seen from Figure 3 that the design of these two types of Modules are similar to each other. It should be pointed out here that antennas in Master Module are in the array to obtain the balance of signal coverage.

The transceiver, undoubtedly, is the core part in both Master Module and Slave Module. The design of a transceiver is in Figure 4 below:

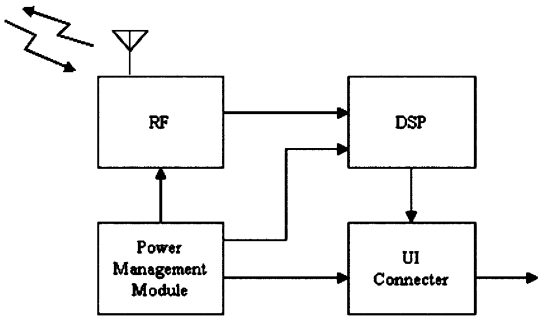

Figure 4. Design of Transceiver

The RF Module in Figure 4 is to transmit and receive RF signal, and the DSP Module is used for the coding and decoding of the transmitting data, together with its verification and buffering. The communication is through RS 485 UI connector. The power management module is the power supply for the whole module of a transceiver.

Obviously, the design of hardware makes it low in cost, compact in size and light in weight. The transmitting frequency is between 406 – 424 MH_Z. The transmitting power is only 5mW with a RS 485 connector [6] [7].

C. *Design of Software*

The design of software in this system contains three parts: system software, communications protocols and coding.

System software manages and monitors the whole system with TDMA technology (Figure 2), through which every single Slave Module can only transmit the signal to the Master Module in a certain time slot per frame, and the Master Module receives signals from different Slave Modules in the certain order. Therefore, the efficiency of signal transmitting is enhanced.

Communications protocols are divided in two parts - uplink communications protocol and downlink communications protocol [8]. Uplink communication means the synchronous signal and command frame coming from the PC to a Fetal Monitor, which ask the Fetal Monitor to transmit all the error signals again. Downlink communication is to verify and buffer the packed and coded data, and to resend the error signals, if there are any, again. Technology of CRC verification and control of resending error signals are applied here in order to improve the accuracy of received signal.

The coding in this system contains forward error correcting technology with checker self-convolution. In addition, the redundant error correcting code is added into the codes of parameters that need to be transmitted. This is to automatically correct the transmitted error signals on certain occasions when coding, thus accuracy of information transmitted is guaranteed.

D. *Antenna System*

The antenna system acts as a great role in this scheme and therefore the application of both single half-wave balanced dipole and antenna array with multiple half-wave balanced dipoles are employed. Single half-wave balanced dipole is generally used in ceiling-mounted antennas (indoors), and the

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antenna array with multiple half-wave balanced dipoles can achieve the large relatively coverage with low power as it can limit the radiation and let signals focus on the horizon. It can be demonstrate in the Figure 5 and Figure 6 as follows:

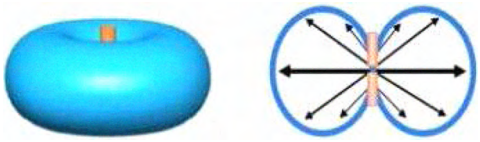

Figure 5 Single half-wave balanced dipole

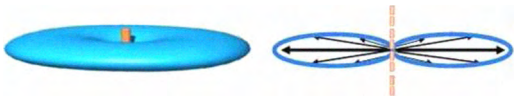

Figure 6 Four half-wave balanced dipoles

From the system design illustrated above, it can be learnt that the signal transmission in this system is safe and secure, and low in power and cost are other features.

III. HOSPITAL APPLICATION

We come to a real application in a hospital of this wireless fetal monitoring network after several sections explaining the system theory.

The central PC workstation is located on the 3rd floor of the in-patient building in a hospital. The requirement of the hospital of the fetal monitoring network is to cover the whole floor, together with operation rooms on the 4th floor and the out-patient department in the out-patient building, which are 15 meters away from in-patient building.

The floor plan of the hospital is as follows:

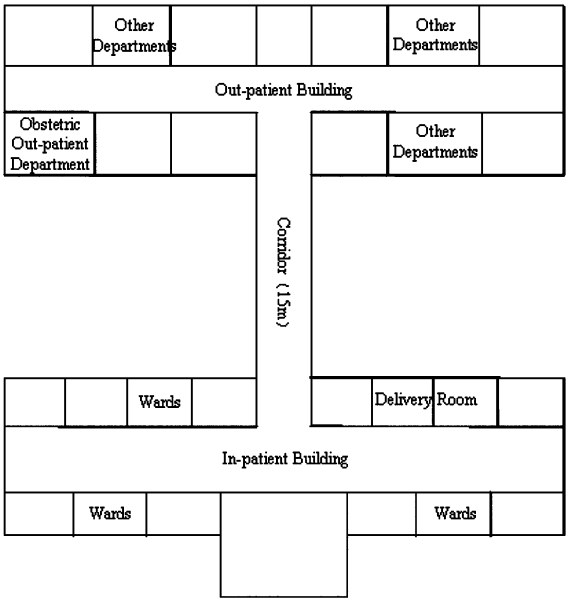

Figure 7. Hospital Floor Plan

It can be viewed from Figure 7 that the coverage requested is really large and areas need to be covered are quite separated.

In order to achieve the target, various antennas are used in this case to guarantee the high quality signal transmitting in the coverage area. The scheme of wireless network in this hospital is shown in Figure 8 below:

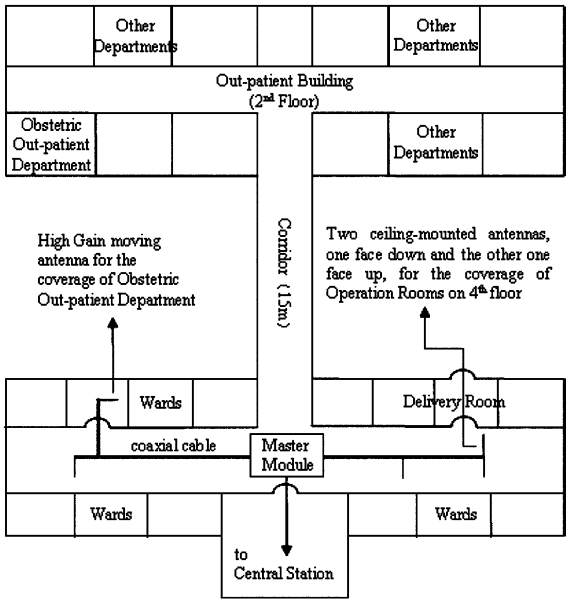

Figure 8. Wireless Network Scheme

Figure 8 shows the real solution of the wireless fetal monitoring network applied in this hospital. This case is the typical application of wireless fetal monitoring network, which provides flexible solution in order to cover separate areas with low power and low cost system.

IV. CONCLUSIONS

The system design and its application of the wireless fetal monitoring network have been discussed. It has been investigated that this scheme of wireless network is capable and practical.

The scheme has been applied in several hospitals in China. The applications of various technologies make the wireless fetal monitoring network a low cost and low error code ratio scheme. The low RF power is the guarantee for the wireless network to be a people harm-free system.

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