High Speed Intelligent Communication for Tele-Care Early Warning System—A Survey

FU Xiang, LIN Wen-biao, LIN Wen-yan, JIN Guo-sheng, QIU Xian-qin, GAO Xuan-ling, and ZHANG Yong-hua

(Health Aging Research Center, Chang Gung University　Taoyuan, Taiwan China　333)

Abstract　Aging problem is a crucial issue nowadays. The population of old persons of age more than 65 will achieve 20% in Asia area in 2020. To care these aged persons, one of the important things is to provide early warning of the physical improper situations before it is too late to be warned by themselves. The intelligent high speed tele-care system could be a solution. It includes design, and implementation of low profile, short distance, high speed intelligent sensor network with high data rate communication, and modern signal processing techniques. The technologies behind is to promote high speed chip designs and to enhance the smart system command and control capability. A novel intelligent communication topology with smart-suit for body kinematics, blood pressure, heart beat rate and breath monitoring is presented. The prominent characteristic of the structure is that data source for every communicating unit can be determined by its current sensing state. Propagation delay is reduced and transmitting speed is improved. The topology fits to be adopted in a complex communication system, contributing to threshold control and integrated management for the early warning. Modern technologies and experimental waveforms are presented.

Key words　accelerometer-based inertial sensing(ABIS);　millimeter wave;　multiband orthogonal frequency division multiplexing(MB-OFDM);　tele-care

远距医护高速智能通信之建构

傅　祥，林炆标，林文彦，金国生，邱显钦，高瑄苓，张永华

(长庚大学健康老化研究中心　中国台湾　桃园　333)

【摘要】亚洲地区65岁以上高龄人口将于2020年突破总人口20%，健康老化问题日趋严重，老人紧急状况预警系统之建构势在必然，远距医护高速智能通信可供作通信平台。该平台包含低剖面、高速传输、传感网络及信号处理等理论，能通过高速芯片及智能型指挥控制等技术来完成。该文透过人体动态等现象，集结预警临界点设定，研究驱动无线收发机达到预警效果，并作实验型建构叙述。未来结合人体智能及有线网络将更能发挥远距医护功效。

关　键　词　加速规惯性感测;　毫米波;　多信道正交频分多任务;　远距医护

中图分类号　TN92　　**文献标识码**　A　　doi:10.3969/j.issn.1001-0548.2011.06.001

In recent years, lower birth rates and increased aging population make the elderly care services to be the trend of the times. Tele-care is one approach to develop a healthy-aging environment in the future. Tele-care means telemedicine application at home, also known as home-based e-health, including monitor or diagnose elderly or chronic patients remotely by using the information and communication technologies (ICTs) to improve the quality of health care[1-3].

In the United States, more than 5.9 million Americans received home healthcare services valued at more than $USD 25 billion in 1996[4]. Home tele-care

Received date：2011－10－15
收稿日期：2011－10－15
Foundation item：Supported by the Chang Gung Fund (EMRPD1A0891)
基金项目：长庚基金(EMRPD1A0891)
Biography：Jeffrey S. Fu is professor of Chang Gung University, his research interests include microwave circuits and antennas.
作者简介：傅　祥(1947－2011)，男，博士，教授，博士生导师，主要从事微波电路及天线方面的研究.

equipment not only implies 24-hour-a-day access to a nurse but also has the potential to reduce health care costs. Its widespread implementation is powerful forces for shifting the focus of care from hospital to home.

1 Introduction of Some Tele-Care Systems

RFID is widespread popular in today's world of smart labels for military, logistics, education, production, security, and health applications due to its low cost and portability.

Tag stores individual information of its attached object and reader communicates with the tag in radio frequencies to identify the object. RFID system establishes communication between devices within the system without any physical contact. The tele-care using RFID system can be created a probable information and RFID application to monitor and diagnose elderly/patient [5]. The tele-care RFID system supports wireless mobile communication between tags and readers. Each elderly/patient wears a bracelet or vest integrated with a tag can be move inherently in the system and the readers are mobile devices, e. g. PDA, laptops, and other mobile devices, each including a wireless RFID reader card. Mobile devices can reach the server and transfer the healthy information e.g. blood pressure, heart beat rate, blood glucose, oxygen concentration or other vital signs at the remote location using wireless technology. Doctors can have fast and automatic access elderly/patient information via by tele-care RFID system especially while elderly/patient is not able to establish healthy communication as shown in Fig. 1. Table 1 summaries frequency intervals, tag reading distances, and data transfer rates in communication for major RFID communication types[1]. With RFID for tele-care application, elderly or homecare patient can increase their independence, convenience, freedom, and enjoy a better life. And the cost of health will be cut by maximizing the efficiencies.

Table 1　RFID Communication Features[1]

Frequency	Distance/m	Data rate/kb·s^{-1}
125～134 kHz	<0.5	<1
13.56 MHz	<1.5	<25
433 MHz, 865～956 MHz, 2.4 GHz	<100	<100

With the increasing technology of devices in millimeter wave short range application, integration of individual sensors onto a smart suit as shown in Fig. 2, upgrades the communication chips to millimeter waves using GaN, GaAs or Si and low-temperature co-fired ceramic (LTCC) technologies, and using millimeter wave-over-fiber system to constitute the indoor and distant communication as shown in Fig. 3, become a new generation tele-care system structure.

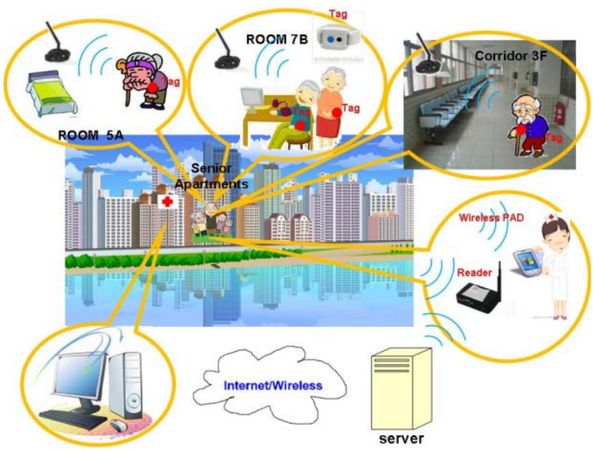


Fig. 1　Communication infrastructure of conventional tele-care RFID system

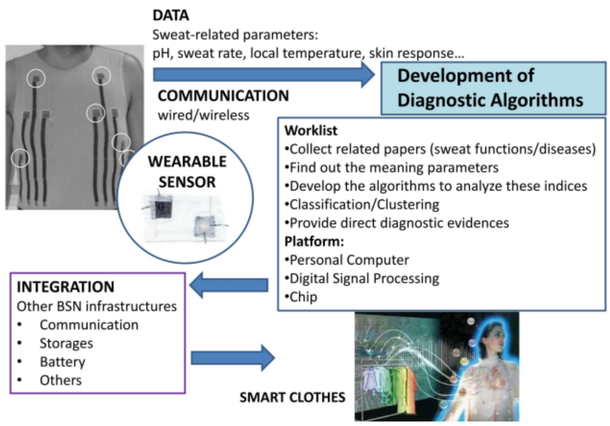


Fig. 2　A proposed smart suit by Chang Gung University

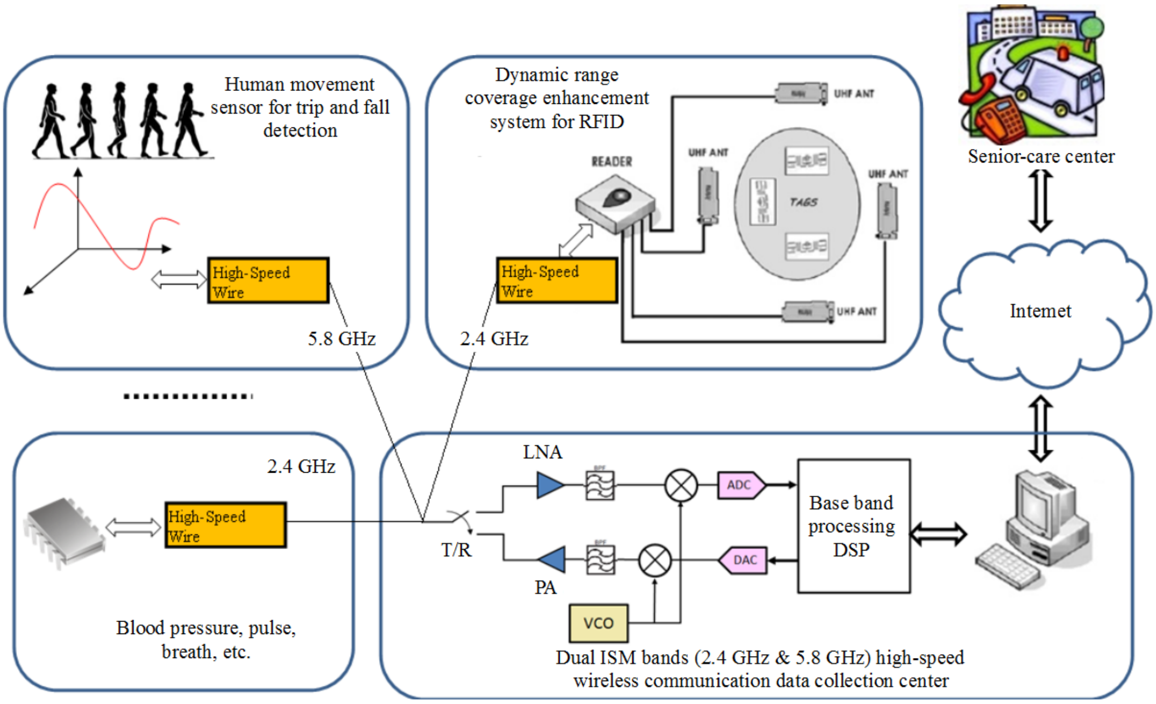


Fig. 3 Conventional ISM bands tele-care system can be upgraded to millimeter wave-over-fiber system

2 Survey of High Speed Millimeter Wave-over-Fiber Systems

Ultra wide-band (UWB) wireless system has fixed everyone's eyes in the field of wireless communication[6-7]. Not only it provides high data rate in mobile communication, but also is applied in electrical fitting, which could be employed in communication and message delivered such as high-speed wireless LAN (WLAN), global positioning system (GPS), sensing network and wireless video transmission. Nowadays, in order to provide high resolution network TV and dynamic video streaming, the transmitting quality is the most important challenge.

For multiuser and different signals using, we can not satisfy with the purposes under such bandwidths in today. Moreover, with the increasing demands of bandwidths, we can reach higher data transmitting rates and provide more bandwidths with extending the transmitting center frequency to the millimeter wave frequency band. In general, the millimeter wave frequency band has 270 GHz bandwidths to use. Since the federal communications commission (FFC) allocated 57～64 GHz band for unlicensed use in 2001. It has motivated the interesting of many people to research the 60 GHz millimeter wave band. There are some standards formulated under 60 GHz system, such as ECMA-387, wireless HD/HDMI, IEEE 802.15.3c/ 802.11 VHT, and WiGig[8]. Owing to the requirement of upconverting to millimeter wave band, it is so expensive to use the high frequency electronic components. For the sake of reducing the costs at the electronic components, it needs some optical tuning techniques to raise the frequency to millimeter wave band. Recently, there are some optical tuning techniques such as two-mode beating, four-wave mixing, TSSB modulation, optical frequency multiplication, and so on. These techniques can reduce our costs[9-10].

Recently, it is required to decrease the system costs under the ROF system techniques. It is easy for us to reach the millimeter frequency wave band when we use the optical tuning techniques. The transmission of the millimeter wave is more directive property which is related to the higher frequency. But the receiving area is much narrow. Hence it requires antenna techniques to be under the applications of the millimeter wave, which is one of the most important core technologies. It can be more integrative with the popularization of WiMAX and LTE-A and it provides higher transmission rates, more available bandwidths and the qualities of transmission. Since the lost of the

60 GHz millimeter wave to transmit 10m distances under indoor circumstances is about 80～85 dB, it requires lots of base stations (BSs) to connect to the wireless network. In the interior of every building, it needs to set up a central base station. The radio frequency (RF) signals transmit from the central station to base stations in every floor by means of optical fiber transmissions[11].

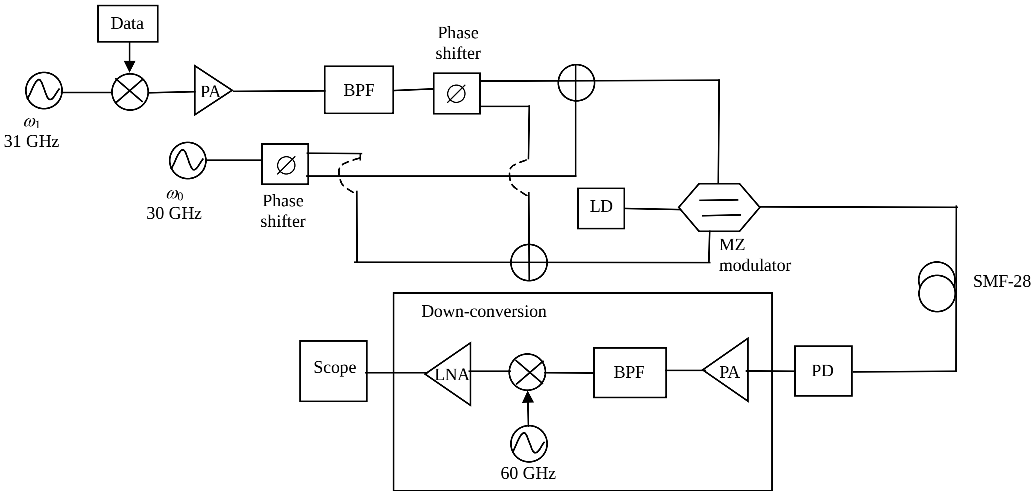


Fig. 4　The architecture of millimeterwave-over-fiber system

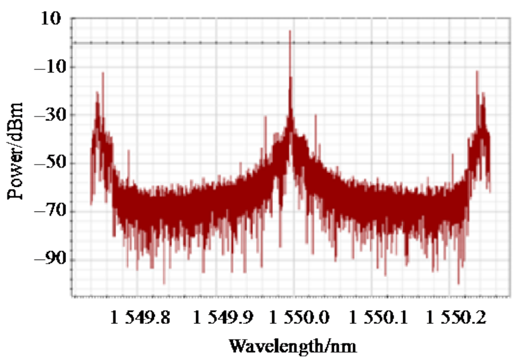


Fig. 5　Optical spectrum at the output of MZ modulator

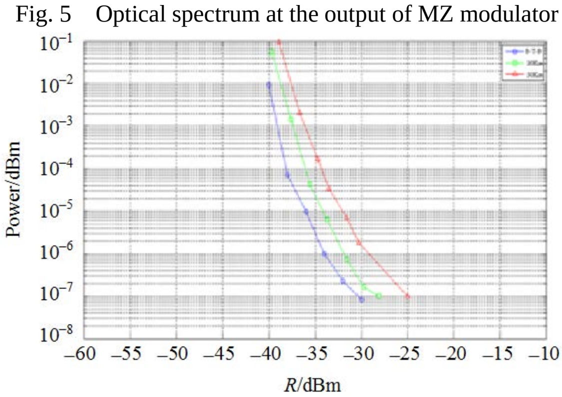


Fig. 6　The simulaasedted curves of BER

Because of the high price of the high frequency components, we apply some optical tuning techniques to reach the frequency multiplication and reduce the component cost. We mainly use a dual port dual drive mach-zender modulator (MZM) to modulate the single sideband (SSB) or optical central carriers suppressed (OCS) to generate 60 GHz millimeter wave signals as shown in Fig. 4[12] and Fig. 5. But it can still produce the unwanted optical carriers through the optical transmission. In this moment, we need some filters to go filtering. In addition to filters, we can also use the interleaver but its price is much expensive[13]. Some people used wavelength division multiplexer (WDM) to replace the optical filter[14]. However, its selection to wavelength is important. It needs calculation before hand to avoid the filtering of distorted optical carriers or unwanted carriers. We use the fiber brag grating (FBG) to reach the filtering effect to reduce the system costs and complete the frequency multiplication[15]. Finally, we demodulate by the photo detector (PD) for transmitting and receiving signals via 60 GHz antennas. And the 60 GHz wireless signal is converted to the baseband signal by a downconverter. There are lots of selections for the downconverters, such as the second order and the third order which are designed to prevent the harmonic interference generated from the local oscillator (LO), direct current (DC) offset and the volume of production from the high frequency down convert to baseband. Finally, we process and analyze the baseband signals after downconvertion. Our transmission signal is multiband orthogonal frequency division multiplexing (MB-OFDM) which is inevitable for integrations and applications in LTE-A wireless communications. Except for more users available under the same bandwidths, MB-OFDM can not only use frequency hopping to avoid bad channels and noise effects but also can provide much better transmission rates and qualities in wireless communications. Fig. 6 shows the simulated curves of BER.

3 Accelerometer-B Inertial Sensing (ABIS) for Medical Applications

Nowadays, the inertial sensing has been widely used in many fields of applications[16]. Indeed, the 4 out of 5 modes of motion sensing: acceleration, vibration, shock, tilt, but only not rotation, are actually different manifestations of acceleration over different periods of time. As a result, the accelerometer-based inertial sensing (ABIS) is used in areas that include consumer electronics, such as gaming (Nintendo Wii), horizon detection in digital cameras, screen rotation in PDA phones and tablet PCs, industrial applications, such as detecting the heading of a device, automotive electronics, and especially medical applications driven by the increasing demands of tele-care due to the aging of the societies and lifestyle changes. A broadened survey of the ABIS in medical applications has been conducted and summarized in this article with special focusing on communications, controls, and commands.

3.1 ABIS: Communications for Medical Applications

Communication is the activity of meaningful information exchange. The communications of ABIS for medical applications will be discussed in two levels: the explicit behaviors and the implicit meanings.

1) The explicit behaviors of communications

The explicit behaviors of communications are basically to define how the information can be exchanged by specifying the interfaces, formats, and protocols. In this level, it covers two phases. The first phase is to retrieve information from accelerometer itself. The output formats evolved from analog voltage outputs for single-, dual-, or tri-axis acceleration data into digital output in two's complement formats accessed through I2C or SPI digital interfaces in the latest state of the arts accelerometers. The second phase covers how to deliver the information from the ABIS systems to interested parties , such as the health care agencies, doctors, and families. Wireless communications have been widely adopted in this phase. However, to fulfill the special requirements, such as real time, low power, fast response time, and flexibility, etc., in medical applications, most of the related work proposes their own communication protocols to construct their own wireless sensor networks based on either proprietary or standard physical network layers. For example, in Ref. [17], a contention-free MAC protocol was implemented in a sensor node which transmits data to a gateway node through a RF transceiver operating at 868 MHz within the wireless body area sensor network for posture monitoring. This gateway node then could interchange information with outside world through RS232, Bluetooth or Ethernet. In Ref. [18], the LPRT (Low-Power Real-Time) protocol was proposed and implemented in a smart-suit network. The smart-suit is for body kinematics monitoring and posture analysis in hidrocinesiotherapy sessions and the network is based on IEEE 802.15.4 WPAN physical layer standard. The LPRT protocol proposed for loss intolerant real-time applications is to replace the standard IEEE 802.15.4 MAC protocol which uses a contention based CDMA/CA algorithm and it is unable to provide the quality of service required by medical applications.

2) The implicit meanings of communications in ABIS

Besides to correctly retrieve and deliver information from accelerometers and to the outside world, what information is embedded in the accelerometer data is also very important. The implicit meanings of communications in ABIS can be categorized into three types: acceleration, distance, and orientation.

(1) Acceleration. This is the direct meaning of the raw data carried. The magnitude of the data represents the acceleration. Fast magnitude back-and forth changes within a time period show vibrations. A significant change in magnitude within a short period will be a shock. After further processing and analysis, the information retrieved from ABIS can be applied in many medical applications, such as biomedical parameter measurements: heart rate, respiratory rate,

snoring rate, etc., for sleep apnea diagnosis[19], heart rate (HR) and HR trend in real time for physical activity assessment [20], falls-risk estimation[21], wearable automatic fall detectors[22-24], and accelerometer-based non-wearable fall detection of elderly people using floor vibrations and sound[25].

(2) Distance. The distance of a linear movement can be computed by a direct double integration of the acceleration, as in 1). The ABIS system can be calibrated when it starts with a still position by setting its initial distance, d_0, to zero and then the moving distance can be calculated. This implicit meaning of information carried by the ABIS was applied on some medical applications, such as compression depth estimation for CPR quality assessment[26], posture analysis for Parkinson's disease[27-28], and walking distance estimation complimented with gyroscope sensor as in Ref. [29-31].

$$\mathrm{d}(t)=\iint_0^{\tau} a(\tau)\mathrm{d}\tau+\mathrm{d}_0 \tag{1}$$

(3) Orientation. When the net acceleration or force on the system overtime is gravity, the projections of the gravity vector on the axes of the accelerometer can determine the static inclination or tilt angles of the system. The tilt and inclination angles of the accelerometer can be calculated by mathematical trigonometric functions from the projected gravity vector on the 3 axes of the accelerometer. Hence, the orientation information of the ABIS system can be determined. This implicit meaning carried by the ABIS is typically utilized in the posture monitoring applications, as in Ref. [32], and some position monitoring applications, such as head's angle position monitoring after vitreoretinal surgery[33].

There are many other applications utilizing two or more implicit meanings of ABIS. For example, the wearable automatic fall detectors are typically combining the shock sensing with tilt information to improve accuracy as in Ref. [22-24], and Ref. [34]. Rissanen et al. Ref. [35] combined acceleration and the distance information for the analysis of dynamic voluntary muscle contractions in Parkinson's disease, and Khan et al. Ref. [36] proposed an approach for the physical activity recognition with combination of acceleration data and tilt information.

3.2 ABIS: Controls for Medical Applications

The purposes of controls in ABIS systems for medical applications is to make sure that accurate information can be gathered from the accelerometer as well as defining how the information that the ABIS system is interested is can be retrieved efficiently. Most of the ABIS systems for medical applications assume and ideal accelerometer are used. This means a device with no 0g offset and with perfect-matched sensitivity. However, since the accelerometer is still a mechanical device, even the devices are calibrated in manufacturing; the system may still be affected by any static stress on the part after assembly. If the application requires precise results which would beyond the allowable limits, the user calibration of the accelerometer is desired. Ref. [3] proposed a calibration method using a mathematical model of six calibration parameters: three gain factors and three biases. The proposed method is confirmed to be able to calibrate the accelerometer in extreme cases.

There are also some efforts on developing algorithms, i.e. the ways to control accelerometers, for retrieving meaningful information from the raw data of accelerometer efficiently. Curone et al. Ref. [38] developed an algorithm for the detection of human posture and activity independent, of the sensor orientation with respect to the body which opposed to conventional algorithms requring the sensors mounted on the human body with known orientation. Ref. [39] presented a robust DSP integrator for distance calculation of accelerometer signals. Lin et al. at Chang-Gung University also presented a CORDIC-based algorithm for inclination and tilt angle calculations which can be efficiently implemented in a low-cost and low-power microcontroller.

3.3 ABIS: Commands for Medical Applications

After the meaningful information are communicated through the ABIS system and the desired information, activity patters and critical behaviors are interpreted. It is now important to see what actions that the ABIS system can inform interested parties to take, that is, to command the people.

Fig. 7 shows a platform of a posture monitoring and fall detection alarm system proposed by Chang-Gung University. In this platform, as an emergent situation detected, e.g. elderly fall, an alarm signal will trigger the subject's cell phone through Bluetooth and have it send out text message through 3G/GSM/GPRS network to some pre-defined phone numbers, such as doctors and families. So that the doctor may take action to send an ambulance to the subject's location or the families can rush back to the subject's place and check on his/her conditions. In the meantime, once the alarm triggers, the continuous bio-parameters, such as activities (accelerations), will be transmitted through the home WiFi gateway to remote care center, such as hospitals, over internet. The remote care agent can monitor on the subject's activity in realtime to evaluate how bad the subject's condition is and to judge what actions to take. The system could also save long-term monitored data into onboard storage devices, such as SD card. The subject could bring the logged data to his doctor for the review and diagnosis, and his doctor can check on if there are any potential risks. In this scenario, typically the subject is still healthy and the real-time monitoring is not necessary to avoid excessive data transmitted wirelessly.

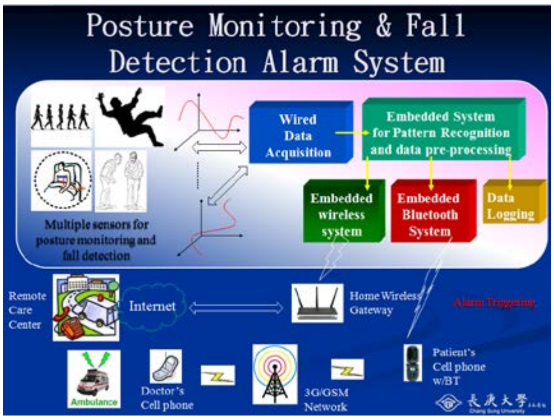


Fig. 7 Posture monitoring and fall detection alarm system (CGU)

3.4 Conclusion Remarks

A complete ABIS system targeting for medical applications typically consists of its communications, controls, and commands. Putting all these features together could enhance the tele-care capabilities for the coming healthy aging lifestyle changes. Hence, the government and society can afford a complete health-care system for the people. The ABIS system plays a very important role on the whole system and we still expect to see more and more researchers devoting themselves to more sophisticated accelerometer-based inertial sensing (ABIS) systems for medical applications.

4 LTCC Three Dimensional Milli-meter-Wave Circuits with Vertical Interconnection Structures

4.1 Introduction

Modern communication systems require circuits with light, thin, short, and small features. Low-temperature co-fired ceramic (LTCC) technology is a popularly choice for microwave circuit design because of its advantageous three-dimensional scheme, high integrity, high quality factor, low thermal expansion, and compact size[40-43]. Several commercial LTCC tape systems, such as DuPont 951, DuPont 943, Ferro A6-S, and Heraeus CT 2000, are available for high-frequency applications. LTCC technology can also be used in system-in-package (SiP) solutions, integrating the separated transceiver circuits into a single module. Most of the approaches were presented in low-frequency bands (<10 GHz), and less are in millimeter-wave (mm-wave) bands due to the difficulty of achieving high frequency. A major concern with LTCC mm-wave circuit design is the vertical interconnection structures, such as how to realize low insertion-loss and high return-loss of interconnections. Inadequate interconnections and transitions may induce parasitic inductances and capacitances, and distort the circuit performance [43-46]. Accordingly, this work briefly introduces the recent developments of LTCC vertical interconnection structures with an emphasis on mm-wave filter and antenna designs.

4.2 Vertical Interconnection Structures

Fig. 8 shows the cross view of a LTCC transceiver SiP module, which embeds and integrates various passive circuits for packaging. A good vertical interconnection with the cross-layer scheme is necessary between circuit connections, and is also important for input/output port design to allow good signal transmission. Feeding a cross-layer signal into and out of a circuit without disturbing its performance is difficult, especially at high frequency [47]. Signal vias are often used in interconnection structures, though vias can potentially cause serious parasitic inductance, behaving similarly to low-pass filters and attenuating high-frequency components. Possible improvement approaches include one that introduces more capacitances to compensate for parasitic inductance effects and the other uses smooth transition structures for field continuity. In Ref. [43], the study proposes a ball grid array-via a transition structure using large plastic- core solder balls having a broadband performance up to K-band. Panther et al. developed three vertical transitions: stripline to CPW, CPW to CPW, and CPW to microstrip using an artful via layout[44]. The shielded vertical transition[45] has a coaxial- like structure to smooth the field transformation. Stark and Jacob presented a broadband vertical three wire line with defected ground structure[46], for use in microstrip to microstrip interconnection.

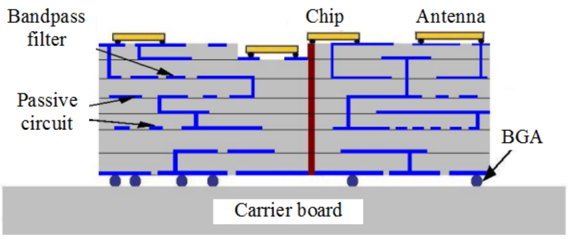
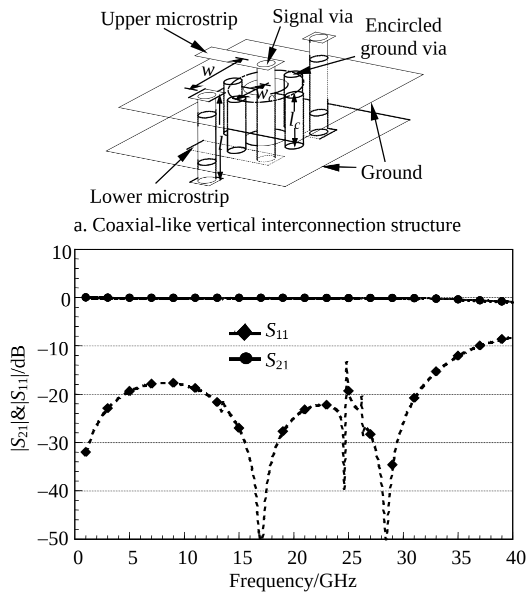


Fig. 8　Cross view of an LTCC transceiver SiP module

A good vertical interconnection structure should have a lower insertion loss ($|S_{21}|$) and a higher return loss ($|S_{11}|$). Fig. 9a schematically depicts three dimensions of the coaxial-like vertical interconnection structure, in which four encircled ground vias are added around the signal via to perform a coaxial-like structure for better performance at high frequency. Fig. 9b shows the simulated S parameters of the interconnection structure in Fig. 9a, which has good performance of $|S_{11}| > 10$ dB and $|S_{21}| < 0.9$ dB up to 37 GHz.

Generally, flip chip and wire bonding are two major connections used for chip connections. Since the wire bonding also may induce parasitic inductance and cause a discontinuity problem, flip chip recently gains more and more attention for circuit connections. Flip chip uses ball grid array (BGA) to connect circuits. Bumps of BGA have shorter length and larger radius than the wire bonding, leading to smaller parasitic inductance. The development of accurate equivalent circuit model for BGA becomes a hot issue. Fig 10 shows the photograph of bumps of BGA. For further reduction of parasitic capacitance, it is possible to cave bumps to form an air-cavity.



a. Coaxial-like vertical interconnection structure

b. Simulated S-parameter responses of the interconnection structure

Fig. 9　Interconnection structure

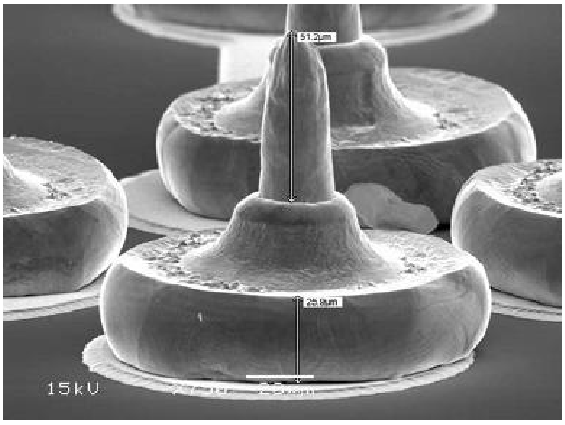
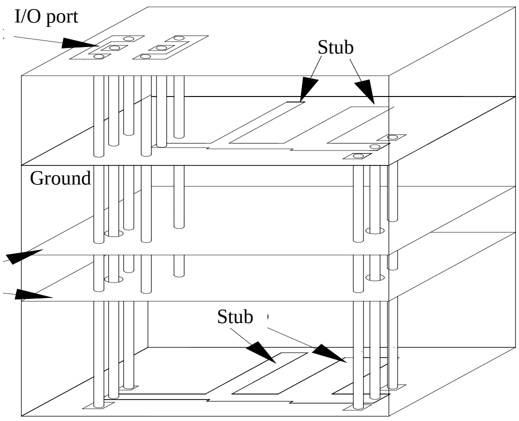


Fig. 10　Photograph of bumps of BGA

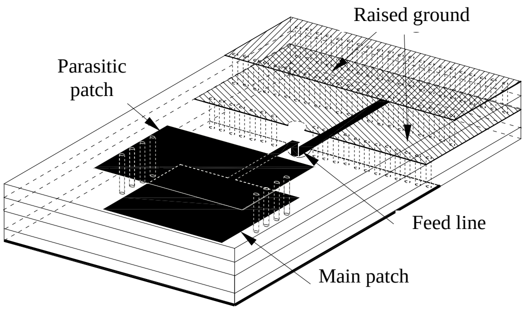
4.3　Interconnection Structures Used in LTCC Millimeter-Wave Filter and Antenna Design

For illustration, an mm-wave bandpass filter and two patch antennas with interconnection structures are reported. Fig. 11a shows the LTCC embedded stub-type Chebyshev bandpass filter synthesized at 28

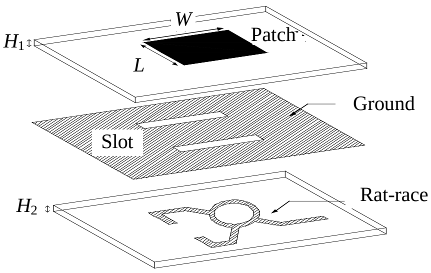
GHz with excellent performance[48]. The stubs on Metal 2 and 5 connect through a vertical interconnection. Fig. 11b depicts a wideband antenna consisting of stacked patches and via-wall structures in LTCC for operated at 28 GHz[49-51], which the opposite-side feeding structure is designed with a shorter vertical interconnection, reducing the parasitic via inductance. Fig. 11c shows a 40 GHz LTCC differential-fed patch antenna with low cross-polarization. Here, two coupled slots are designed instead of using signal vias for patch feeding. Fig.12 shows the photograph of the LTCC mm-wave circuits presented in Fig. 11.



a. 28 GHz stub-type Chebyshev bandpass filter



b. 28 GHz via-wall wideband stacked patch antenna



c. 40 GHz differential-fed slot coupled patch antenna

Fig. 11 LTCC 3D schematic structures

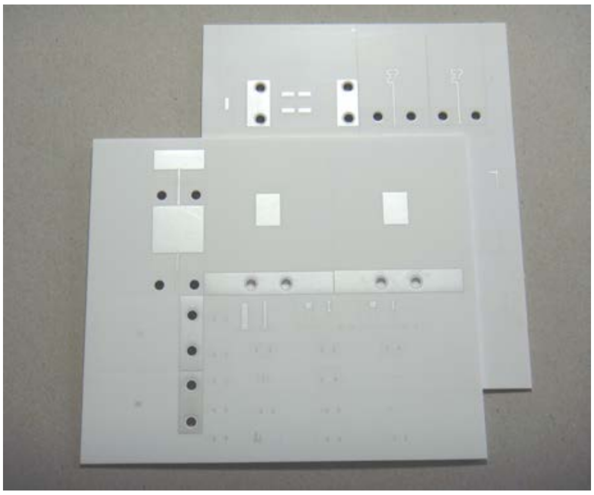


Fig. 12 Photograph of LTCC mm-wave circuits

4.4 Conclusions

LTCC three dimensional millimeter-wave circuits have associated challenges such as how to realize low-loss vertical interconnections for circuit connections and packages. This work briefly introduces the recent developments of vertical interconnection structures for LTCC mm-wave circuit design. A bandpass filter and two patch antennas are presented for illustration.

5 High Efficiency Radio Frequency Battery Charger for Inner Body Electronics Chips

The GaAs and Si based microwave VCOs, LNAs and PAs have been studied extensively in past decades. Fig. 13 shows some MMIC chips developed by Chang Gung University. Recently, the wireless power transmission attracted tremendous attention owing to the rapid development of green power technology. A novel high efficiency RF battery charger for inner body electronics chips using GaN MMIC technology was proposed. The wide bandgap GaN transistor exhibites a high electronic mobility together with a high breakdown voltage. In addition, GaN-on-Si technology could realize a RF power transmitter with high power-added efficiency (PAE) and long-term reliability, which were two key factors to demonstrate a high performance wireless rechargeable inner body electronics chips.

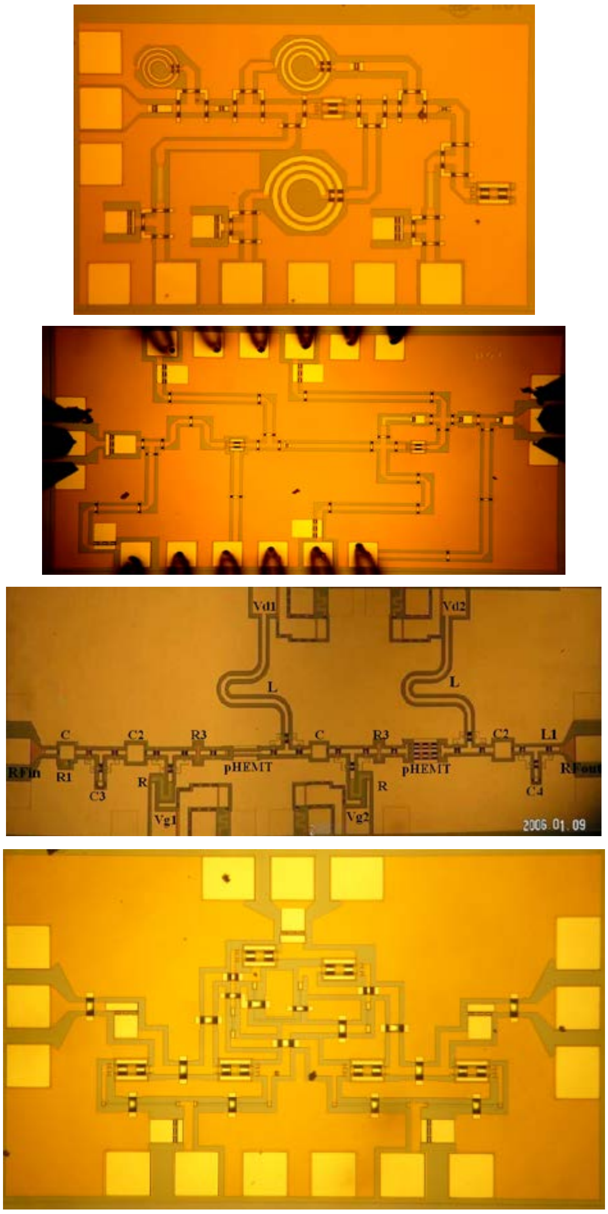


Fig. 13　Tele-care transceiver chips developed by Chang Gung University

Fig. 14 shows the system topology of an inner body electronics chip with a RF rechargeable battery. The RF power transmitter is composed of voltage controlled oscillator (VCO), driving amplifier (DA), power amplifier (PA), and these sub-circuits are integrated into a single GaN MMIC. The VCO is designed to deliver a 2.45 GHz RF power and this 2.45 GHz operation band is an unlicensed ISM band. The VCO frequency should be locked by a Si-based phase locked loop (PLL) for avoiding the adjacent signals of ISM band, Which are were influenced by the 30 dBm output power of this transmitter. The output power of VCO is –5～0 dBm which is too low to drive the 30 dBm power of PA. Therefore, a 15 dB-gain driving amplifier is needed. For wireless power transmitter, the PAE performance was a critical issue of power amplifier, therefore, high efficiency class-F PA architecture is preferred. A Class-F amplifier performs a theoretical 100% drain efficiency by shaping the drain voltage and current waveforms to square-like waveform[52]. The voltage and the current waveforms were designed not to overlap to minimize the power dissipation. In this study, the drain voltage of PA was 28 V and the PAE was designed to exceed 70%. Two identical loop antennas were simulated by HFSS and realized on a low loss print circuit board (PCB) to achieve a –1.5 dB antenna gain. For inner body application, the size of loop antenna was a challenge issue and the antenna size in this study is 2 cm×2 cm. The inner body antenna received 25～27 dBm power from the RF power transmitter and power loss was dominated by the skin thickness and the adhesion of the antenna. By inserting a matching circuit between the antenna and waveform rectifier, the received power delivered to rectifier and the energy stored into Cout and Rout for DC output thus the battery could be charged.

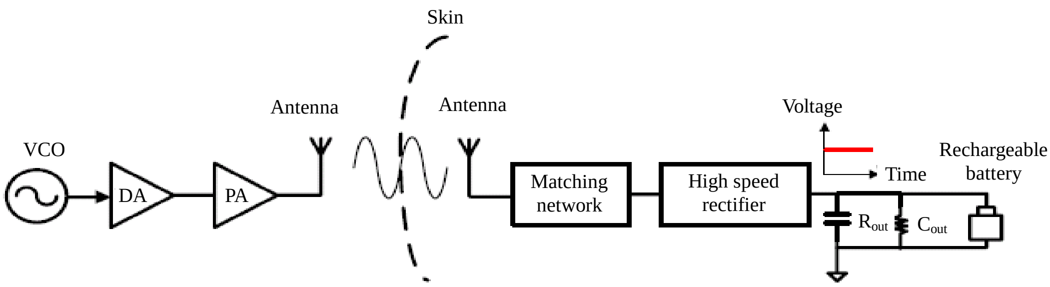


Fig. 14　The system architecture of rechargeable inner body electronics chips

In this research topic, high PAE, high output power, and reliable MMICs were the key technology which cannot be realized by traditional Si-based chips. However, although GaAs power amplifier could drive enough power in this project, the comparatively low breakdown voltage (20 V) limited its PAE performance. In this study, we demonstrated 0.5 μm gate-length GaN HEMT on Si substrate for power transmitter MMIC and the device cross section plot was shown in Fig. 15. The breakdown voltage is more than 200 V and the maximum current can exceed 500 mA/mm. Therefore, the drain voltage can be enlarged to 60 V to effectively improve PAE of PA. In addition, GaN on Si substrate also provides a highly potential for low cost and high performance MMIC technology[53]. Based on the device characteristics in Chang Gung University as shown in Fig. 16, the GaN MMIC on Si substrate can demonstrate a high efficiency, high output power, and low cost wireless power transmitter MMIC for high performance rechargeable inner body electronics chips.

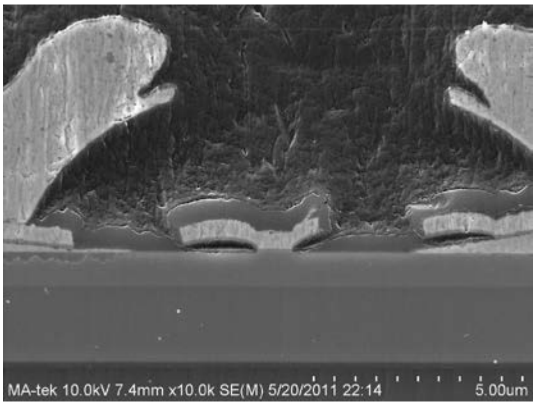


Fig. 15 The cross-sectional photograpgy of 0.5 μm gate-length GaN HEMT on Si substrate

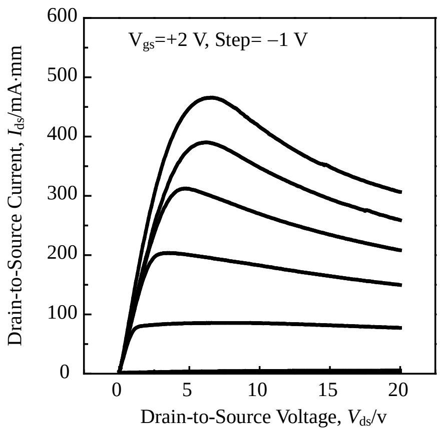


Fig. 16 The I_{ds}-V_{ds} characteristics of proposed GaN HEMT

6 Conclusions

Using emerging technologies of GaAs, GaN and Si based microwave chips, LTCC integration technique, millimeter wave-over-fiber, and accelerometer-based inertial sensing, a high speed tele-care warning system is proposed. Some experimental waveforms are also presented. By use of smart suit as the warning source, the improper situations of elderly can be warned effectively through the proposed high speed intelligent platform.

Acknowledgments

The authors would like to thank the support of National Science Council under contract number NSC99-2632- E-182-001-MY3 and Chang Gung Fund under contract number EMRPD1A0891 and the facilities support of high speed intelligent communication (HSIC) research center of chang Gung University, all in Taiwan.

References

[1] KORKMAZ I, ATAY C, KYPARISIS G. A mobile patient monitoring system using RFID[C]//ICCOMP. [S.l.]: [s.n.], 2010: 726-732.

[2] MATERNAGHAN C, TURNER K J. A component framework for telecare and home automation[C]//CCNC. [S.l.]: [s.n.], 2010.

[3] BOTSIS T G, PEDERSEN S, HARTVIGSEN G. Home telecare technologies for the elderly[J]. Telemedicine and Telecare, 2008, 14: 333-337.

[4] BRANKO G C, NIGEL H L, DANIEL K Y. The potential impact of home telecare on clinical practice[EB/OL]. [2011-08-06].http://mja.com.au/public/issues/171_10_151199/celler/ celler.html.

[5] CHOWDHARY B, KHOSLA R. RFID-based hospital real-time patient management system[C]//ICIS. [S.l]: [s.n.], 2007: 363-368.

[6] KATO S, HARADA H, FUNADA R, et al. Single carrier transmission for multi-gigabit 60-GHz WPAN systems[J]. Selected Areas in Communications, 2009, 7: 1466-1478.

[7] SHIH P T, CHEN J, LIN C T, et al. Optical millimeter-wave signal generation via frequency 12-tupling[J]. Lightwave Technology, 2010, 28: 71-78.

[8] DONG Z, CAO Z, LU J, et al. All-optical up-conversion of millimeter-wave signals for ROF system using optical carrier suppression-based dual-pump FWM in an SOA[C]// Optical Fiber Communication. San Diego, CA: IEEE, 2009: 1-3.

[9] CHOWDHURY A, CHIEN H C, CHANG G K. Demonstration of simultaneous all-optical up-conversion of gigabit wireless services at 60-GHz and 64-GHz in

converged optical wireless system carried by single wavelength lightwave[C]//Optical Fiber Communication. San Diego, CA: IEEE, 2010: 1-3.
[10] ZHANG Q, LIN R, XIU M. Research on wireless indoor channel in 60GHz radio over fiber system[C]//Optical Fiber Communication. San Diego, CA: IEEE, 2006: 1-5.
[11] SHI Y, YANG H, OKONKWO C M, et al. Multimode fiber transmission of up-converted MB-OFDM UWB employing optical frequency multiplication[C]//IEEE Microwave Photonics. San Diego, CA: IEEE, 2010: 343-345.
[12] JIA Z, YU J, HSUEH Y T, et al. Multiband signal generation and dispersion-tolerant transmission based on photonic frequency tripling technology for 60-GHz radio-over-fiber systems[J]. Photonics Technology Letters, 2008, 20: 1470-1472.
[13] HSUEH Y T, JIA Z, CHIEN H C, et al. A novel bidirectional 60-GHz radio-over-fiber scheme with multiband signal generation using a single intensity modulator[J]. IEEE Photonics Technology Letters, 2009, 21: 1338-1340.
[14] KIM H S, WON Y Y, SON Y H, et al. Full colorless WDM-RoF system with simultaneous transmission of 63-GHz and baseband 1.25-Gbps data by sideband separation[C]//Optical Fiber Communication. San Diego, CA: IEEE, 2010: 1-3.
[15] YIN F, CHEN M, LI M, et al. A dual-peak optical demultiplexer in 60GHz-band radio over fiber systems [C]//Optical Fiber Communication. San Diego, CA: IEEE, 2010: 1-3.
[16] O’REILLY R, WEINBERG H. The five motion senses: MEMS inertial sensing to transform applications[J]. Analog Devices, Inc, White Papers, 2010.
[17] FARELLA E, PIERACCI A, BENINI L, et al. A wireless body area sensor network for posture detection[C]// Proceedings of 11th IEEE Symposium on Computers and Communications (ISCC’06). San Diego, CA: IEEE, 2006: 454-459.
[18] SILVA H R, AFONSO J A, MORIM P C, et al. Wireless hydrotherapy smart-suit network for posture monitoring [C]//IEEE International Symposium on Industrial Electronics (ISIE). San Diego, CA: IEEE, 2007: 2713-2717.
[19] MORILLO D, OJEDA J, FOIX L, et al. An accelerometer-based device for sleep apnea screening[J]. IEEE Trans Inf Technol Biomed, 2010, 14(2): 491-499.
[20] CURONE D, TOGNETTI A, SECCO E L, et al. Heart rate and accelerometer data fusion for activity assessment of rescuers during emergency interventions[J]. IEEE Trans Inf Technol Biomed, 2010, 14(3): 702-710.
[21] NARAYANAN M R, REDMOND S J, SCALZI M E, et al. Longitudinal falls-risk estimation using triaxial accelerometry[J]. IEEE Trans Biomed Eng, 2010, 57(3): 534-541.
[22] DIAZ A, PRADO M, ROA L M, et al. Preliminary evaluation of a full-time falling monitoring for the elderly[C]//Proc 26th Annu Int Conf Eng Med Biol Soc. [S.l.]: [s.n.], 2004, 1: 2180-2183.
[23] BOURKE A K, O’BRIEN J V, LYONS G M. Evaluation of a threshold-based tri-axial accelerometer fall detection algorithm[J]//Gait Posture, 2007, 26(2): 194-199.
[24] WILLIAMS G, DOUGHTY K, CAMERON K, et al. A smart fall and activity monitor for telecare applications [C]//Proc 20th Annu Int Conf IEEE Eng Med Biol Soc. [S.l.]: [s.n.], 1998, 3:1151-1154.
[25] ZIGEL Y, LITVAK D, GANNOT I. A method for atuomatic fall detection of elderly people using floor vibrations and sound – Proof of concept on human mimicking doll falls[J]. IEEE Trans Biomed Eng, 2009, 56(12): 2858-2867.
[26] AASE S, MYKLEBUST H. Compression depth estimation for CPR quality assessment using DSP on accelerometer signals[J]. IEEE Trans Biomed Eng, 2002, 49(3): 263-268.
[27] PALMERINI L, ROCCHI L, MELLONE S, et al. Feature selection for accelerometer-based posture analysis in Parkinson’s disease[J]. IEEE Trans Inf Technol Biomed, 2011, 15(3): 481-490.
[28] MELLONE S, PALMERINI L, CAPPELLO A, et al. Hilbert-Huang-based tremor removal to assess postural properties from accelerometers[J]. IEEE Trans Biomed Eng, 2011, 58(6): 1752-1761.
[29] SABATINI A, MARTELLONI C, SCAPELLATO S, et al. Assessment of walking features from foot inertial sensing[J]. IEEE Trans Biomed Eng, 2005, 52(3): 486-494.
[30] SAGAWA K, SATOH Y, INOOKA H. Non-restricted measurement of walking distance[C]//IEEE Int Con on Systems, Man, and Cybernetics. [S.l.]: [s.n.], 2000: 1847-1852.
[31] ALVAREZ J C, GONZALEZ R, ALVAREZ D, et al. Multisensor approach to walking distance estimation with foot inertial sensing[C]//Proc 29th Annu Int Conf IEEE Eng Med Biol Soc. Lyon, France: IEEE, 2007.
[32] NEVINS R, DURDLE N G, RASO V J. A posture monitoring system using accelerometers[C]//Proceedings of the 2002 IEEE Canadian Conference on Electrical & Computer Engineering (CCECE 2002). Canadian: IEEE, 2002, 2: 1087-1092.
[33] CECH P, DLOUHY J, CIZEK M et al. Head position monitoring system design[C]//2010 20th International Conference on Radioelektronika. Brno: [s.n.], 2010.
[34] LI Q, STANKOVIC J A, HANSON M A, et al. Accurate, fast fall detection using gyroscopes and accelerometer-derived posture information[C]//6th International Workshop on Wearable and Implantable Body Sensor Network (BSN 2009). [S.l.]: [s.n.], 2009: 138-143.
[35] RISSANEN S, KANKAANPAA M, TARVAINEN M, et al. Analysis of dynamic voluntary muscle contractions in Parkinson’s disease[J]. IEEE Trans Biomed Eng, 2009, 56(9): 2280-2288.
[36] KHAN A, LEE Y K, LEE S Y, et al. A triaxial accelerometer-based physical-activity recognition via augmented-signal features and a hierarchical recognizer[J]. IEEE Trans Inf Technol Biomed, 2010, 14(5): 1166-1172.
[37] WON S H, GOLNARAGHI F. A triaxial accelerometer calibration method using a mathematical model[J]. IEEE

Trans Instrumentation and Measurement, 2010, 59(8): 2144-2153.

[38] CURONE D, BERTOLOTTI G M, CRISTIANI A, et al. A real-time and self-calibrating algorithm base on triaxial accelerometer signals for the detection of human posture and activity[J]. IEEE Trans Inf Technol Biomed, 2010, 14(4): 1098-1105.

[39] WU Y, MUGLER D H. A robust DSP integrator for accelerometer signals[J]. IEEE Trans Biomed Eng, 2004, 51(2): 385-389.

[40] PERGOLA L, GINDERA R, JAGER D, et al. An LTCC-based wireless transceiver for radio-over-fiber applications[J]. IEEE Trans Microwave Theory Tech, 2007, 55: 579-587.

[41] LEE J H, KIDERA N, PINEL S, et al. Fully integrated passive front-end solutions for a V-band LTCC wireless system[J]. IEEE Antennas Wireless Propag Lett, 2007, 6: 285-288.

[42] PINEL S. Advanced 3D integrated and low cost RF wireless system using system-on-package (SOP) architectures[C]//Asia-Pacific Microwave Conference. [S.l]: [s.n.], 2003.

[43] KANGASVIERI T, HALME J, VÄHÄKANGAS J, et al. Broadband BGA-via transitions for reliable RF/microwave LTCC-SiP module packaging[J]. IEEE Microwave Wireless Compon Let, 2008, 18: 34-36.

[44] PANTHER A, GLASER C, STUBBS M G, et al. Vertical transitions in low temperature co-fired ceramics for LMDS applications[C]//IEEE MTT-S Int Microwave Symp Dig 3. [S.l]: [s.n.], 2001: 1907-1910.

[45] VALOIS R, BAILLARGEAT D, VERDEYME S, et al. High performance of shielded LTCC vertical transitions from DC up to 50 GHz[C]//IEEE Trans Microwave Theory Tech. [S.l]: [s.n.], 2005, 53: 2026-2032.

[46] STARK A, JACOB A F. A broadband vertical transition for millimeter-wave applications[C]//Proceedings of the 38th European Microwave Conference. San Diego, CA: IEEE, 2008: 476-479.

[47] CHIN Kuo-sheng, HUNG Jian-luen, HUANG Chun-wei, et al. LTCC dual-band stepped-impedance- stub filter constructed with vertically folded structure[J]. Electronics Letters, 2010, 46(23): 1554-1556.

[48] CHIN Kuo-sheng, HUNG Jian-luen, HUANG Chun-wei, et al. Compact LTCC bandpass filter with vertically folded structure[J]. Microw Optical Tech Lett, 2011, 53(6): 1389-1394.

[49] CHIN Kuo-sheng, CHANG Ho-ting, LIU Jia-an. Design of LTCC wideband patch antenna for LMDS band applications[J]. IEEE Antennas and Wireless Propagation Letters, 2010, 9: 1111-1114.

[50] CHIN Kuo-sheng, CHANG Ho-ting, LIU Jia-an, et al. Stacked patch antenna array on LTCC substrate operated at 28 GHz[J]. Journal of Electromagnetic Waves and Applications, 2011, 25(4): 527-538.

[51] ZHANG Y P, LIU D. Antenna-on-chip and antenna-in-package solutions to highly integrated millimeter-wave devices for wireless communications[J]. IEEE Trans Antennas Propag, 2009, 57(10): 2830-2841.

[52] RAAB F H. Class-F power amplifiers with maximally flat waveforms[J]. IEEE Trans Microwave Theory Tech, 1997, 45: 2007-2012.

[53] DUMKA D C, SAUNIER P. GaN on Si HEMT with 65% power added efficiency at 10 GHz[J]. Electron Lett, 2010, 46(13): 946-947.

编 辑 蒋 晓